NUREG–1437
Vol. 2

Generic Environmental Impact Statement for License Renewal of Nuclear Plants

Appendices

Final Report

U.S. Nuclear Regulatory Commission

Office of Nuclear Regulatory Research

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Division of Regulatory Applications
Office of Nuclear Regulatory Research
U.S. Nuclear Regulatory Commission
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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®

APPENDIX A

GENERAL CHARACTERISTICS AND ENVIRONMENTAL SETTINGS OF DOMESTIC NUCLEAR POWER PLANTS

General Characteristics and Environmental Settings of Domestic Nuclear Power Plants

This section contains brief descriptions of each nuclear power plant site in the United States. The information was compiled from: (1) the plant safety analysis reports (SARs), (2) the Nuclear Regulatory Commission "Gray Book" (NUREG-0020), (3) site environmental reports, (4) environmental impact statements, (5) environmental assessments used to check data for cooling water system and site information, and (6) WASH-1319 used for selected data. Specific data that could not be found in these six sources were obtained from ORNL-NSIC-55.

Specific data sources are listed on the following page.

Source for General Information

Plant Name: SAR

Location: County and distance and direction from nearest town
or city: NUREG-0020
Latitude and longitude: List provided by R. Rush, ORNL
Licensee: Utility as listed in NUREG-0020

Source for Information on Unit

Docket Number: NUREG-0020
Construction Permit: *Nuclear Safety Journal*, Power Reactor Licensing Activity
Operating License: Table A.1 of SECY-90-160 (NUREG-0020)
Commercial Operation: NUREG-0020
License Expiration: Table A.1 of SECY-90-160 (NUREG-0020)
Licensed Thermal Power [MW(t)]: NUREG-0020
Design Electrical Rating [net MW(e)]: NUREG-0020
Type of Reactor: NUREG-0020
Nuclear Steam Supply System Vendor: NUREG-0020

Source for Information on Cooling Water System

Type: SAR, NUREG-0020
Source: NUREG-0020
Source Temperature Range: SAR, ORNL-NSIC-55
Condenser Flow Rate: SAR, ORNL-NSIC-55
Design Condenser Temperature Rise: SAR, ORNL-NSIC-55
Intake Structure: SAR
Discharge Structure: SAR

Source for Information on Site

Total Area: SAR, WASH-1319
Exclusion Distance: SAR
Low Population Zone: SAR
Nearest City: SAR; 1980 population:*
Site Topography: SAR
Surrounding Area Topography: SAR
Land Use within 8 km (5 miles): SAR
Nearby Features: SAR
Area of Transmission Line Corridor: WASH-1319
Population within an 80-km (50-mile) radius:*

*Population data are taken from population projections developed for NRC by MITRE Corporation and made available to GEIS project.

ARKANSAS NUCLEAR ONE

Location: Pope County, Arkansas
10 km (6 miles) WNW of Russellville
latitude 35.3100°N; longitude 93.2308°W
Licensee: Arkansas Power and Light Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-313	50-368
Construction Permit	1968	1972
Operating License	1974	1978
Commercial Operation	1974	1980
License Expiration	2014	2018
Licensed Thermal Power [MW(t)]	2568	2815
Design Electrical Rating [net MW(e)]	850	912
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	B&W	CE

Cooling Water System

Type: Unit 1, once through
Source: Dardanelle Reservoir Unit 2, natural draft cooling tower
Source Temperature Range: 4-28°C (40-83°F)
Condenser Flow Rate: 48.3 m^3/s (765,000 gal/min) for Unit 1
26.6 m^3/s (422,000 gal/min) for Unit 2
Design Condenser Temperature Rise: 8.3°C (15°F) for Unit 1
17.1°C (30.7°F) for Unit 2
Intake Structure: 981-m (3220-ft) canal
Discharge Structure: 160-m (520-ft) canal

Site Information

Total Area: 469 ha (1160 acres)
Exclusion Distance: 1.05-km (0.65-mile) radius
Low Population Zone: 6.44-km (4.00-mile) radius
Nearest City: Little Rock; 1980 population: 159,159
Site Topography: flat
Surrounding Area Topography: hilly to mountainous
Land Use within 8 km (5 miles): wooded
Nearby Features: The nearest town is Mill Creek 3 km (2 miles) NE. The size of the Dardanelle Reservoir is 15,000 ha (37,000 acres). The reservoir is part of the Arkansas River. The Missouri Pacific Railroad and U.S. Highway I-40 are just N of the site.
Area of Transmission Line Corridor: 1500 ha (3700 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
200,000	210,000	220,000	250,000	270,000

BEAVER VALLEY POWER STATION

Location: Beaver County, Pennsylvania
40 km (25 miles) NW of Pittsburgh
latitude 40.6219°N; longitude 80.4339°W

Licensee: Duquesne Light Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-334	50-412
Construction Permit	1970	1974
Operating License	1976	1987
Commercial Operation	1976	1987
License Expiration	2016	2027
Licensed Thermal Power [MW(t)]	2652	2652
Design Electrical Rating [net MW(e)]	835	836
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: natural draft cooling towers
Source: Ohio River
Source Temperature Range: 1.1-28°C (34-83°F)
Condenser Flow Rate: 30.31 m^3/s (480,400 gal/min) each unit
Design Condenser Temperature Rise: 14°C (26°F)
Intake Structure: concrete structure at river edge
Discharge Structure: at river edge

Site Information

Total Area: 203 ha (501 acres)
Exclusion Distance: 0.45 km (0.28 mile)
Low Population Zone: 5.79 km (3.60 miles)
Nearest City: Pittsburgh; 1980 population: 423,959
Site Topography: flat
Surrounding Area Topography: hilly
Land Use within 8 km (5 miles): industrial and residential
Nearby Features: The nearest town is Midland 1.6 km (1 mile) NW. A large industrial area is about 1.6 km (1 mile) WNW. The Penn Central Railroad is adjacent to the site. Beaver Creek and Raccoon Creek State Parks are within 16 km (10 miles).
Area of Transmission Line Corridor: uses existing corridor
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
3,740,000	3,840,000	3,910,000	4,040,000	4,170,000

BELLEFONTE NUCLEAR PLANT

Location: Jackson County, Alabama
11 km (7 miles) ENE of Scottsboro
latitude 34.7089°N; longitude 85.9275°W

Licensee: Tennessee Valley Authority

Unit Information	Unit 1	Unit 2
Docket Number	50-438	50-439
Construction Permit	1974	1974
Operating License	--	--
Commercial Operation	--	--
License Expiration	--	--
Design Thermal Power [MW(t)]	3760	3760
Design Electrical Rating [net MW(e)]	1213	1213
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	B&W	B&W

Cooling Water System

Type: natural draft cooling towers
Source: Guntersville Lake
Source Temperature Range: 5-27°C (41-81°F)
Condenser Flow Rate: 26 m^3/s (410,000 gal/min) each unit
Design Condenser Temperature Rise: 20°C (36°F)
Intake Structure: intake channel
Discharge Structure: submerged multi-port diffuser

Site Information

Total Area: 610 ha (1500 acres)
Exclusion Distance: 0.92-km (0.57-mile) minimum
Low Population Zone: 3.22 km (2.00 miles)
Nearest City: Huntsville; 1980 population: 142,513
Site Topography: flat valley
Surrounding Area Topography: hilly out of valley
Land Use within 8 km (5 miles): agricultural and wooded
Nearby Features: The nearest town is Hollywood 5 km (3 miles) WNW. The Widows Creek coal-fired plant is 24 km (15 miles) NE. Guntersville Lake is on the Tennessee River.
Area of Transmission Line Corridor: 1200 ha (2900 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
1,070,000	1,150,000	1,230,000	1,340,000	1,470,000

BIG ROCK POINT NUCLEAR PLANT

Location: Charlevoix County, Michigan
6 km (4 miles) NE of Charlevoix
latitude 45.3592°N; longitude 85.1947°W
Licensee: Consumers Power Co.

Unit Information	Unit 1
Docket Number	50-155
Construction Permit	1960
Operating License	1962
Commercial Operation	1963
License Expiration	2002
Licensed Thermal Power [MW(t)]	240
Design Electrical Rating [net MW(e)]	72
Type of Reactor	BWR
Nuclear Steam Supply System Vendor	GE

Cooling Water System

Type: once through
Source: Lake Michigan
Source Temperature Range: 3-20°C (38-68°F)
Condenser Flow Rate: 3.1 m^3/s (49,000 gal/min)
Design Condenser Temperature Rise: 11°C (20°F)
Intake Structure: underwater crib
Discharge Structure: open discharge canal

Site Information

Total Area: 240 ha (600 acres)
Exclusion Distance: 0.82 km (0.51 mile)
Low Population Zone: 4.02 km (2.50 miles)
Nearest City: Sault Ste. Marie, Canada; 1980 population: 81,048
Site Topography: gently sloping
Surrounding Area Topography: gently sloping
Land Use within 8 km (5 miles): commercial and industrial
Nearby Features: The nearest town is Charlevoix 6 km (4 miles) SW. The C&O Railroad is about 1.6 km (1 mile) SE. Lake Charlevoix is 5 km (3 miles) S.
Area of Transmission Line Corridor:
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
200,000	210,000	210,000	230,000	240,000

BRAIDWOOD STATION

Location: Will County, Illinois
39 km (24 miles) SSW of Joliet
latitude 41.2436°N; longitude 88.2297°W

Licensee: Commonwealth Edison Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-456	50-457
Construction Permit	1975	1975
Operating License	1987	1988
Commercial Operation	1988	1988
License Expiration	2027	2028
Licensed Thermal Power [MW(t)]	3411	3411
Design Electrical Rating [net MW(e)]	1120	1120
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: closed cycle cooling pond
Source: Kankakee River
Source Temperature Range: 0-31°C (32-87°F)
Condenser Flow Rate: 46.05 m^3/s (729,800 gal/min) each unit
Design Condenser Temperature Rise: 12°C (21°F)
Intake Structure: concrete structure at lake shore
Discharge Structure: surface discharge flume to lake

Site Information

Total Area: 1804 ha (4457 acres)
Exclusion Distance: 0.48-km (0.30-mile) minimum
Low Population Zone: 1.810 km (1.125 mile) radius
Nearest City: Joliet; 1980 population: 77,956
Site Topography: flat to rolling
Surrounding Area Topography: flat to rolling
Land Use within 8 km (5 miles): agricultural
Nearby Features: The nearest town is Godley 0.8 km (0.5 mile) SW. There are 4 state parks within 16 km (10 miles). Joliet Arsenal is about 13 km (8 miles) NE. Dresden Nuclear Power Station is about 16 km (10 miles) N and La Salle County Station (nuclear) is about 32 km (20 miles) WSW. The Illinois Central Gulf Railroad is just NW. U.S. Highway I-55 is about 3 km (2 miles) NW.
Area of Transmission Line Corridor: 961.5 ha (2376 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
4,510,000	4,650,000	4,750,000	4,920,000	5,090,000

BROWNS FERRY NUCLEAR POWER STATION

Location: Limestone County, Alabama
16 km (10 miles) NW of Decatur
latitude 34.7042°N; longitude 87.1186°W
Licensee: Tennessee Valley Authority

Unit Information	Unit 1	Unit 2	Unit 3
Docket Number	50-259	50-260	50-296
Construction Permit	1967	1967	1968
Operating License	1973	1974	1976
Commercial Operation	1974	1975	1977
License Expiration	2013	2014	2016
Licensed Thermal Power [MW(t)]	3293	3293	3293
Design Electrical Rating [net MW(e)]	1065	1065	1065
Type of Reactor	BWR	BWR	BWR
Nuclear Steam Supply System Vendor	GE	GE	GE

Cooling Water System

Type: once through and helper towers
Source: Tennessee River
Source Temperature Range: 4-32°C (40-90°F)
Condenser Flow Rate: 40 m^3/s (630,000 gal/min) each unit
Design Condenser Temperature Rise: 14°C (25°F)
Intake Structure: concrete structure in small inlet
Discharge Structure: diffuser pipes

Site Information

Total Area: 340 ha (840 acres)
Exclusion Distance: 1.22-km (0.76-mile) radius
Low Population Zone: 11.3 km (7.00 miles)
Nearest City: Huntsville; 1980 population: 142,513
Site Topography: flat
Surrounding Area Topography: flat to rolling
Land Use within 8 km (5 miles): agricultural
Nearby Features: The nearest town is Lawngate 1.6 km (1 mile) NE. The Redstone Arsenal is 40 km (25 miles) E. The Southern Railroad is 10 km (6 miles) S and the Louisville and Nashville Railroad is 10 km (6 miles) E.
Area of Transmission Line Corridor: 546 ha (1350 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
760,000	810,000	850,000	930,000	1,010,000

BRUNSWICK STEAM ELECTRIC PLANT

Location: Brunswick County, North Carolina
26 km (16 miles) S of Wilmington
latitude 33.9583°N; longitude 78.0106°W

Licensee: Carolina Power and Light Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-325	50-324
Construction Permit	1967	1968
Operating License	1976	1974
Commercial Operation	1977	1975
License Expiration	2016	2014
Licensed Thermal Power [MW(t)]	2436	2436
Design Electrical Rating [net MW(e)]	821	821
Type of Reactor	BWR	BWR
Nuclear Steam Supply System Vendor	GE	GE

Cooling Water System

Type: once through
Source: Cape Fear River
Source Temperature Range: 4-30°C (40-86°F)
Condenser Flow Rate: 42.6 m^3/s (675,000 gal/min) each unit
Design Condenser Temperature Rise: 9°C (17°F)
Intake Structure: 5-km (3-mile) canal from Cape Fear River
Discharge Structure: 10-km (6-mile) canal to Atlantic Ocean

Site Information

Total Area: 490 ha (1200 acres)
Exclusion Distance: 0.92 km (0.57 mile)
Low Population Zone: 3.22 km (2.00 miles)
Nearest City: Wilmington; 1980 population: 44,000
Site Topography: flat
Surrounding Area Topography: flat
Land Use within 8 km (5 miles): less than one-half agricultural, remainder swamps or wooded
Nearby Features: Nearest town is Southport 5 km (3 miles) S. Sunny Point Military Ocean Terminal is about 8 km (5 miles) N.
Area of Transmission Line Corridor: 1400 ha (3500 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
230,000	250,000	270,000	300,000	340,000

BYRON STATION

Location: Ogle County, Illinois
27 km (17 miles) SW of Rockford
latitude 42.0750°N; longitude 89.2811°W
Licensee: Commonwealth Edison Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-454	50-455
Construction Permit	1975	1975
Operating License	1985	1987
Commercial Operation	1985	1987
License Expiration	2025	2027
Licensed Thermal Power [MW(t)]	3411	3411
Design Electrical Rating [net MW(e)]	1120	1120
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: natural draft cooling towers
Source: Rock River
Source Temperature Range:
Condenser Flow Rate: 39.9 m^3/s (632,000 gal/min) each unit
Design Condenser Temperature Rise: 13°C (24°F)
Intake Structure: concrete structure on river bank
Discharge Structure: discharged to river

Site Information

Total Area: 565.8 ha (1398 acres)
Exclusion Distance: 0.42-km (0.26-mile) minimum
Low Population Zone: 4.83 km (3.00 miles)
Nearest City: Rockford; 1980 population: 139,712
Site Topography: rolling
Surrounding Area Topography: rolling
Land Use within 8 km (5 miles): agricultural
Nearby Features: The nearest town is Byron about 5 km (3 miles) NNE. The Chicago Milwaukee and the St. Paul and Pacific Railroads are about 6 km (4 miles) NNE. White Pines State Park is about 18 km (11 miles) WSW.
Area of Transmission Line Corridor: 800 ha (2000 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
1,000,000	1,030,000	1,060,000	1,100,000	1,140,000

CALLAWAY PLANT

Location: Callaway County, Missouri
16 km (10 miles) SE of Fulton
latitude 38.7622°N; longitude 91.7817°W
Licensee: Union Electric Co.

Unit Information	Unit 1
Docket Number	50-483
Construction Permit	1976
Operating License	1984
Commercial Operation	1984
License Expiration	2024
Licensed Thermal Power [MW(t)]	3565
Design Electrical Rating [net MW(e)]	1171
Type of Reactor	PWR
Nuclear Steam Supply System Vendor	WEST

Cooling Water System

Type: natural draft cooling tower
Source: Missouri River
Source Temperature Range:
Condenser Flow Rate: 33 m^3/s (530,000 gal/min)
Design Condenser Temperature Rise: 17°C (30°F)
Intake Structure: intake from river
Discharge Structure: discharged to river

Site Information

Total Area: 1290 ha (3188 acres)
Exclusion Distance: 1.21-km (0.75-mile) radius
Low Population Zone: 4.02 ha (2.50 miles)
Nearest City: Columbia; 1980 population: 62,061
Site Topography: flat, on a small plateau
Surrounding Area Topography: rolling to hilly
Land Use within 8 km (5 miles): wooded, agricultural, and pasture
Nearby Features: The nearest town is Portland 8 km (5 miles) SE. The Missouri River is about 8 km (5 miles) S. The Missouri, Kansas, and Texas Railroad is about 5 km (3 miles) S and the Missouri Pacific Railroad is about 10 km (6 miles) S. U.S. Highway I-70 is about 16 km (10 miles) N.
Area of Transmission Line Corridor: 461 ha (1140 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
400,000	420,000	430,000	460,000	500,000

CALVERT CLIFFS NUCLEAR POWER PLANT

Location: Calvert County, Maryland
56 km (35 miles) S of Annapolis
latitude 38.4347°N; longitude 76.4419°W

Licensee: Baltimore Gas and Electric Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-317	50-318
Construction Permit	1969	1969
Operating License	1974	1976
Commercial Operation	1975	1977
License Expiration	2014	2016
Licensed Thermal Power [MW(t)]	2700	2700
Design Electrical Rating [net MW(e)]	845	845
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	CE	CE

Cooling Water System

Type: once through
Source: Chesapeake Bay
Source Temperature Range: 1-31°C (34-87°F)
Condenser Flow Rate: 76 m^3/s (1,200,000 gal/min) each unit
Design Condenser Temperature Rise: 6°C (10°F)
Intake Structure: about 170 m (560 ft) from shore
Discharge Structure: about 260 m (850 ft) from shore

Site Information

Total Area: 459 ha (1135 acres)
Exclusion Distance: 1.08-km (0.67-mile) radius
Low Population Zone:
Nearest City: Washington, D.C.; 1980 population: 638,432
Site Topography: rolling
Surrounding Area Topography: rolling
Land Use within 8 km (5 miles): agricultural and wooded
Nearby Features: The nearest town is Long Beach 1.6 km (1 mile) NNW. Calvert Cliffs State Park is about 6 km (4 miles) SSE. A naval ordnance facility is 11 km (7 miles) SSW. Washington, D.C., is 72 km (45 miles) NW.
Area of Transmission Line Corridor: 805 ha (1990 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
3,030,000	3,140,000	3,260,000	3,480,000	3,720,000

CATAWBA NUCLEAR STATION

Location: York County, South Carolina
10 km (6 miles) NNW of Rock Hill
latitude 35.0514°N; longitude 81.0708°W

Licensee: Duke Power Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-413	50-414
Construction Permit	1975	1975
Operating License	1985	1986
Commercial Operation	1985	1986
License Expiration	2025	2026
Licensed Thermal Power [MW(t)]	3411	3411
Design Electrical Rating [net MW(e)]	1145	1145
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: mechanical draft cooling towers
Source: Lake Wylie
Source Temperature Range: 6-28°C (43-83°F)
Condenser Flow Rate: 42 m^3/s (660,000 gal/min) each unit
Design Condenser Temperature Rise: 13°C (24°F)
Intake Structure: skimmer wall on cove of the lake
Discharge Structure: on another cove of the lake

Site Information

Total Area: 158 ha (391 acres)
Exclusion Distance: 0.76-km (0.47-mile) radius
Low Population Zone: 6.12-km (3.80-mile) radius
Nearest City: Charlotte, North Carolina; 1980 population: 315,474
Site Topography: rolling
Surrounding Area Topography: rolling
Land Use within 8 km (5 miles): wooded with recreational and permanent homes along the lake
Nearby Features: The nearest town is Rock Hill 10 km (6 miles) SSE. U.S. Highway I-77 is about 10 km (6 miles) E and I-85 is about 27 km (17 miles) N. The Southern Railway is 8 km (5 miles) S.
Area of Transmission Line Corridor: 236 ha (584 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
1,590,000	1,730,000	1,860,000	2,090,000	2,340,000

CLINTON POWER STATION

Location: De Witt County, Illinois
10 km (6 miles) E of Clinton
latitude 40.1731°N; longitude 88.8342°W

Licensee: Illinois Power Co.

Unit Information	Unit 1
Docket Number	50-461
Construction Permit	1976
Operating License	1987
Commercial Operation	1987
License Expiration	2027
Licensed Thermal Power [MW(t)]	2894
Design Electrical Rating [net MW(e)]	933
Type of Reactor	BWR
Nuclear Steam Supply System Vendor	GE

Cooling Water System

Type: once through
Source: Salt Creek
Source Temperature Range: 0-28°C (32-83°F)
Condenser Flow Rate: 35.8850 m^3/s (568,701 gal/min)
Design Condenser Temperature Rise: 13°C (23°F)
Intake Structure: concrete structure at shoreline of North Fork Salt Creek
Discharge Structure: 5-km (3-mile) flume discharging to Salt Creek

Site Information

Total Area: 5702 ha (14,090 acres)
Exclusion Distance: 0.97-km (0.60-mile) radius
Low Population Zone: 4.02-km (2.50-mile) radius
Nearest City: Decatur; 1980 population: 93,939
Site Topography: flat
Surrounding Area Topography: flat
Land Use within 8 km (5 miles): agricultural
Nearby Features: The nearest town is De Witt 3 km (2 miles) ENE. Weldon Springs State Park is 10 km (6 miles) SW. The Illinois Central Gulf Railroad crosses the site. U.S. Highway I-74 is 18 km (11 miles) NE. A dam on Salt Creek near the site creates the reservoir for the cooling water system.
Area of Transmission Line Corridor: 367 ha (906 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
730,000	770,000	790,000	830,000	870,000

COMANCHE PEAK STEAM ELECTRIC STATION

Location: Somervell County, Texas
64 km (40 miles) SW of Fort Worth
latitude 32.2983°N; longitude 97.7856°W

Licensee: Texas Utilities Electric Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-445	50-446
Construction Permit	1974	1974
Operating License	1990	1993
Commercial Operation	1990	1993
License Expiration	2030	2033
Design Thermal Power [MW(t)]	3411	3411
Design Electrical Rating [net MW(e)]	1150	1150
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: once through
Source: Squaw Creek Reservoir
Source Temperature Range:
Condenser Flow Rate: 65 m^3/s (1,030,000 gal/min) each unit
Design Condenser Temperature Rise: 8°C (15°F)
Intake Structure: on shore of reservoir
Discharge Structure: canal to reservoir

Site Information

Total Area: 3104 ha (7669 acres)
Exclusion Distance: 1.54-km (0.96-mile) minimum
Low Population Zone: 6.44-km (4.00-mile) radius
Nearest City: Fort Worth; 1980 population: 385,164
Site Topography: flat with hills rising from the reservoir
Surrounding Area Topography: rolling to hilly
Land Use within 8 km (5 miles): agricultural, farm/ranch land, and range land
Nearby Features: The nearest town is Glen Rose 8 km (5 miles) SSE. Dinosaur Valley State Park is 8 km (5 miles) SW. A 66-cm (26-inch) oil pipeline is very near the site and a 91-cm (36-inch) natural gas line is about 3 km (2 miles) from the site.
Area of Transmission Line Corridor: 185 ha (458 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
1,130,000	1,310,000	1,460,000	1,650,000	1,880,000

DONALD C. COOK NUCLEAR POWER PLANT

Location: Berrien County, Michigan
16 km (10 miles) S of St. Joseph
latitude 41.9761°N; longitude 86.5664°W
Licensee: Indiana and Michigan Electric Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-315	50-316
Construction Permit	1969	1969
Operating License	1974	1977
Commercial Operation	1975	1978
License Expiration	2014	2017
Licensed Thermal Power [MW(t)]	3250	3411
Design Electrical Rating [net MW(e)]	1030	1100
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: once through
Source: Lake Michigan
Source Temperature Range: 1-23°C (34-74°F)
Condenser Flow Rate: 50 m^3/s (800,000 gal/min) each unit
Design Condenser Temperature Rise: 12°C (21°F)
Intake Structure: intake cribs 686 m (2250 ft) from shore
Discharge Structure: 381 m (1250 ft) from shore

Site Information

Total Area: 260 ha (650 acres)
Exclusion Distance: 0.61 km (0.38 mile)
Low Population Zone: 3.22 km (2.00 miles)
Nearest City: South Bend, Indiana; 1980 population: 109,727
Site Topography: rolling
Surrounding Area Topography: flat to rolling
Land Use within 8 km (5 miles): agricultural and wooded
Nearby Features: The nearest town is Livingston 1.6 km (1 mile) SW. The Chesapeake and Ohio Railroad and U.S. Highway I-94 are just E of the site. Warren Dunes State Park is about 8 km (5 miles) SSW.
Area of Transmission Line Corridor: 1340 ha (3300 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
1,250,000	1,310,000	1,350,000	1,440,000	1,530,000

COOPER NUCLEAR STATION

Location:	Nemaha County, Nebraska 37 km (23 miles) S of Nebraska City latitude 40.3619°N; longitude 95.6411°W
Licensee:	Nebraska Public Power District

Unit Information

Docket Number	50-298
Construction Permit	1968
Operating License	1974
Commercial Operation	1974
License Expiration	2014
Licensed Thermal Power [MW(t)]	2381
Design Electrical Rating [net MW(e)]	778
Type of Reactor	BWR
Nuclear Steam Supply System Vendor	GE

Cooling Water System

Type: once through
Source: Missouri River
Source Temperature Range: 1-23°C (34-73°F)
Condenser Flow Rate: 39.8 m^3/s (631,000 gal/min)
Design Condenser Temperature Rise: 10°C (18°F)
Intake Structure: at shoreline
Discharge Structure: at shoreline

Site Information

Total Area: 441 ha (1090 acres)
Exclusion Distance: 1.09 (0.68 mile)
Low Population Zone: 1.61-km (1.00-mile) radius
Nearest City: Lincoln; 1980 population: 171,932
Site Topography: flat
Surrounding Area Topography: flat
Land Use within 8 km (5 miles): agricultural
Nearby Features: The nearest town is Nemaha about 1.6 km (1 mile) S. A railroad runs just W of the site. Indian Cave State Park is about 13 km (8 miles) SSE.
Area of Transmission Line Corridor: 2777 ha (6862 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
180,000	190,000	200,000	220,000	230,000

CRYSTAL RIVER NUCLEAR PLANT

Location: Citrus County, Florida
11 km (7 miles) NW of Crystal River
latitude 28.9572°N; longitude 82.6989°W
Licensee: Florida Power Corp.

Unit Information	Unit 3
Docket Number	50-302
Construction Permit	1968
Operating License	1977
Commercial Operation	1977
License Expiration	2017
Licensed Thermal Power [MW(t)]	2544
Design Electrical Rating [net MW(e)]	825
Type of Reactor	PWR
Nuclear Steam Supply System Vendor	B&W

Cooling Water System

Type: once through
Source: Gulf of Mexico
Source Temperature Range: 31°C (87°F) maximum
Condenser Flow Rate: 43 m^3/s (680,000 gal/min)
Design Condenser Temperature Rise: 9.5°C (17.1°F)
Intake Structure: 4900 m (16,000 ft) from shoreline
Discharge Structure: 4000-m (13,000-ft) canal

Site Information

Total Area: 1917 ha (4738 acres)
Exclusion Distance: 1.34-km (0.83-mile) radius
Low Population Zone: 8.05 km (5.00 miles)
Nearest City: Gainesville; 1980 population: 81,371
Site Topography: swamps and marshland
Surrounding Area Topography: flat
Land Use within 8 km (5 miles): wooded and pasture land
Nearby Features: The nearest town is Crystal River about 11 km (7 miles) SE. Units 1 and 2 are coal-fired plants and share a common intake and discharge with the nuclear unit.
Area of Transmission Line Corridor: 866 ha (2140 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
440,000	490,000	550,000	660,000	790,000

DAVIS-BESSE NUCLEAR POWER STATION

Location: Ottawa County, Ohio
34 km (21 miles) E of Toledo
latitude 41.5972°N; longitude 83.0864°W
Licensee: Toledo Edison Co.

Unit Information	Unit 1
Docket Number	50-346
Construction Permit	1971
Operating License	1977
Commercial Operation	1978
License Expiration	2017
Licensed Thermal Power [MW(t)]	2772
Design Electrical Rating [net MW(e)]	906
Type of Reactor	PWR
Nuclear Steam Supply System Vendor	B&W

Cooling Water System

Type: natural draft cooling tower
Source: Lake Erie
Source Temperature Range: 1-23°C (34-74°F)
Condenser Flow Rate: 30 m^3/s (480,000 gal/min)
Design Condenser Temperature Rise: 14°C (26°F)
Intake Structure: submerged intake about 900 m (3000 ft) offshore
Discharge Structure: submerged discharge about 280 m (930 ft) offshore

Site Information

Total Area: 386 ha (954 acres)
Exclusion Distance: 0.72-km (0.45-mile) radius
Low Population Zone: 3.22 km (2.00 miles)
Nearest City: Toledo; 1980 population: 354,635
Site Topography: flat
Surrounding Area Topography: flat
Land Use within 8 km (5 miles): agricultural with marshland around site
Nearby Features: The nearest town is Oak Harbor about 10 km (6 miles) SW. Several wildlife refuge areas are within 8 km (5 miles) of the site.
Area of Transmission Line Corridor: 730 ha (1800 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
1,920,000	1,990,000	2,050,000	2,170,000	2,290,000

DIABLO CANYON NUCLEAR POWER PLANT

Location: San Luis Obispo County, California
19 km (12 miles) W of San Luis Obispo
latitude 35.2117°N; longitude 120.8544°W
Licensee: Pacific Gas and Electric Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-275	50-323
Construction Permit	1968	1970
Operating License	1984	1985
Commercial Operation	1985	1986
License Expiration	2024	2025
Licensed Thermal Power [MW(t)]	3338	3411
Design Electrical Rating [net MW(e)]	1086	1119
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: once through
Source: Pacific Ocean
Source Temperature Range: 10-17°C (50-63°F)
Condenser Flow Rate: 54.5 m^3/s (863,000 gal/min) each unit
Design Condenser Temperature Rise: 10°C (18°F)
Intake Structure: reinforced-concrete structure located at shore line in a cove with artificial breakwater wall
Discharge Structure: reinforced-concrete structure drops water in stair step type weir overflow from elevation 21 m (70 ft) to the ocean and discharges on the surface at the shore line

Site Information

Total Area: 300 ha (750 acres)
Exclusion Distance: 0.80 km (0.50 mile)
Low Population Zone: 9.66 km (6.00 miles)
Nearest City: Santa Barbara; 1980 population: 74,542
Site Topography: hilly
Surrounding Area Topography: hilly to mountainous
Land Use within 8 km (5 miles): undeveloped and wooded
Nearby Features: Site is remote, the nearest town being San Luis Obispo 19 km (12 miles) E. Beaches 11-24 km (7-15 miles) ESE have an influx of summer visitors. Pismo Beach State Park and Morro Bay State Park are within 24 km (15 miles). Vandenberg Air Base is 56 km (35 miles) ESE.
Area of Transmission Line Corridor: 2400 ha (6000 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
300,000	330,000	350,000	380,000	420,000

DRESDEN NUCLEAR POWER STATION

Location: Grundy County, Illinois
14 km (9 miles) E of Morris
latitude 41.3897°N; longitude 88.2711°W

Licensee: Commonwealth Edison Co.

Unit Information	Unit 2	Unit 3
Docket Number	50-237	50-249
Construction Permit	1966	1966
Operating License	1969	1971
Commercial Operation	1970	1971
License Expiration	2010	2011
Licensed Thermal Power [MW(t)]	2527	2527
Design Electrical Rating [net MW(e)]	794	794
Type of Reactor	BWR	BWR
Nuclear Steam Supply System Vendor	GE	GE

Cooling Water System

Type: cooling lake & spray canal
Source: Kankakee River
Source Temperature Range: 4-29°C (40-85°F)
Condenser Flow Rate: 29.7 m^3/s (471,000 gal/min) each unit
Design Condenser Temperature Rise:
Intake Structure: canal from Kankakee River to a crib house
Discharge Structure: A canal carries water to a cooling lake of about 520 ha (1275 acres) with a hold-up time of about 3 days. The water then divides, some going to the Illinois River and some returns to the plant. Spray modules are floated in the canals.

Site Information

Total Area: 386 ha (953 acres) plus 516-ha (1275-acre) cooling lake
Exclusion Distance: 0.80-km (0.50-mile) radius
Low Population Zone: 8.00 km (4.97 miles)
Nearest City: Joliet; 1980 population: 77,956
Site Topography: flat
Surrounding Area Topography: rolling prairie
Land Use within 8 km (5 miles): agriculture
Nearby Features: The nearest town is Channahon 5 km (3 miles) NNE. The General Electric Nuclear Power Plant Training Center is S of the site. A large abandoned strip mine is located in the area. Braidwood Station nuclear plant is about 16 km (10 miles) S and La Salle County Station nuclear plant is about 35 km (22 miles) SW. An army ammunition plant is about 11 km (7 miles) E.
Area of Transmission Line Corridor: 911 ha (2250 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
6,820,000	7,050,000	7,200,000	7,450,000	7,710,000

DUANE ARNOLD ENERGY CENTER

Location: Linn County, Iowa
13 km (8 miles) NW of Cedar Rapids
latitude 42.1006°N; longitude 91.7772°W
Licensee: Iowa Electric Light and Power Co.

Unit Information	Unit 1
Docket Number	50-331
Construction Permit	1970
Operating License	1974
Commercial Operation	1975
License Expiration	2014
Licensed Thermal Power [MW(t)]	1658
Design Electrical Rating [net MW(e)]	538
Type of Reactor	BWR
Nuclear Steam Supply System Vendor	GE

Cooling Water System

Type: mechanical draft cooling towers
Source: Cedar River
Source Temperature Range: 0-32°C (32-89°F)
Condenser Flow Rate: 18 m^3/s (290,000 gal/min)
Design Condenser Temperature Rise: 14°C (25°F)
Intake Structure: structure on river shoreline
Discharge Structure: canal to shoreline

Site Information

Total Area: 200 ha (500 acres)
Exclusion Distance: 0.43 km (0.27 mile)
Low Population Zone: 9.66 km (6.00 miles)
Nearest City: Cedar Rapids; 1980 population: 110,243
Site Topography: flat
Surrounding Area Topography: rolling and hilly
Land Use within 8 km (5 miles): agricultural
Nearby Features: The nearest town is Palo about 3 km (2 miles) SW. Several wildlife refuge areas are within 16 km (10 miles) of the site.
Area of Transmission Line Corridor: 469 ha (1160 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
620,000	660,000	690,000	750,000	820,000

JOSEPH M. FARLEY NUCLEAR PLANT

Location: Houston County, Alabama
26 km (16 miles) E of Dothan
latitude 31.2228°N; longitude 85.1125°W
Licensee: Alabama Power Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-348	50-364
Construction Permit	1972	1972
Operating License	1977	1981
Commercial Operation	1977	1981
License Expiration	2017	2021
Licensed Thermal Power [MW(t)]	2652	2652
Design Electrical Rating [net MW(e)]	829	829
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: mechanical draft cooling towers
Source: Chattahoochee River
Source Temperature Range: 30°C (86°F) maximum
Condenser Flow Rate: 40.1 m^3/s (635,000 gal/min) each unit
Design Condenser Temperature Rise: 11°C (20°F)
Intake Structure: intake from river bank via a storage pond
Discharge Structure: at river bank

Site Information

Total Area: 749 ha (1850 acres)
Exclusion Distance: 1.26 km (0.78 mile)
Low Population Zone: 3.22 km (2.00 miles)
Nearest City: Columbus, Georgia; 1980 population: 169,441
Site Topography: flat to rolling
Surrounding Area Topography: rolling
Land Use within 8 km (5 miles): agricultural and wooded
Nearby Features: The nearest town is Columbia about 6 km (4 miles) N. Chattahoochee State Park is about 19 km (12 miles) S.
Area of Transmission Line Corridor: 2140 ha (5300 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
390,000	410,000	440,000	490,000	540,000

ENRICO FERMI ATOMIC POWER PLANT

Location: Monroe County, Michigan
48 km (30 miles) SW of Detroit
latitude 41.9631°N; longitude 83.2578°W
Licensee: Detroit Edison Co.

Unit Information	Unit 2
Docket Number	50-341
Construction Permit	1972
Operating License	1985
Commercial Operation	1988
License Expiration	2025
Licensed Thermal Power [MW(t)]	3292
Design Electrical Rating [net MW(e)]	1093
Type of Reactor	BWR
Nuclear Steam Supply System Vendor	GE

Cooling Water System

Type: natural draft cooling towers
Source: Lake Erie
Source Temperature Range: 1-24°C (34-76°F)
Condenser Flow Rate: 52.80 m^3/s (836,700 gal/min)
Design Condenser Temperature Rise: 10°C (18°F)
Intake Structure: at edge of lake
Discharge Structure: to the lake via a 20-ha (50-acre) pond

Site Information

Total Area: 453 ha (1120 acres)
Exclusion Distance: 0.92 km (0.57 mile)
Low Population Zone: 4.83 km (3.00 miles)
Nearest City: Detroit; 1980 population: 1,203,368
Site Topography: flat
Surrounding Area Topography: flat to rolling
Land Use within 8 km (5 miles): mostly agricultural
Nearby Features: The town of Stony Point is adjacent to the site to the S. Sterling State Park and General Custer Historical Site are about 8 km (5 miles) SW.
Area of Transmission Line Corridor: 73 ha (180 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
5,370,000	5,630,000	5,840,000	6,230,000	6,650,000

JAMES A. FITZPATRICK NUCLEAR POWER PLANT

Location: Oswego County, New York
10 km (6 miles) NE of Oswego
latitude 43.5239°N; longitude 76.3983°W
Licensee: Power Authority of the State Of New York

Unit Information

Docket Number	50-333
Construction Permit	1970
Operating License	1974
Commercial Operation	1975
License Expiration	2014
Licensed Thermal Power [MW(t)]	2436
Design Electrical Rating [net MW(e)]	816
Type of Reactor	BWR
Nuclear Steam Supply System Vendor	GE

Cooling Water System

Type: once through
Source: Lake Ontario
Source Temperature Range: 3-19°C (37-67°F)
Condenser Flow Rate: 22.25 m^3/s (352,600 gal/min)
Design Condenser Temperature Rise: 18°C (32°F)
Intake Structure: intake from the lake
Discharge Structure: discharge to the lake

Site Information

Total Area: 284 ha (702 acres)
Exclusion Distance: 0.92 km (0.57 mile)
Low Population Zone: 5.47 km (3.40 miles)
Nearest City: Syracuse; 1980 population: 170,105
Site Topography: flat to rolling
Surrounding Area Topography: rolling
Land Use within 8 km (5 miles): agricultural, industrial, residential, and recreational
Nearby Features: The nearest town is Lakeview about 1.6 km (1 mile) WSW. Fort Ontario is about 8 km (5 miles) SW. Nine Mile Point Nuclear Station is about 0.8 km (0.5 mile) W.
Area of Transmission Line Corridor: 400 ha (1000 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
820,000	810,000	800,000	800,000	810,000

FORT CALHOUN STATION

Location: Washington County, Nebraska
31 km (19 miles) N of Omaha
latitude 41.5208°N; longitude 96.0767°W
Licensee: Omaha Public Power District

Unit Information	Unit 1
Docket Number	50-285
Construction Permit	1968
Operating License	1973
Commercial Operation	1974
License Expiration	2013
Licensed Thermal Power [MW(t)]	1500
Design Electrical Rating [net MW(e)]	478
Type of Reactor	PWR
Nuclear Steam Supply System Vendor	CE

Cooling Water System

Type: once through
Source: Missouri River
Source Temperature Range: 0-27°C (32-80°F)
Condenser Flow Rate: 23 m^3/s (360,000 gal/min)
Design Condenser Temperature Rise: 9.94°C (17.9°F)
Intake Structure: concrete structure at river shore
Discharge Structure: at river shore

Site Information

Total Area: 270 ha (660 acres)
Exclusion Distance: 0.92-km (0.57-mile) minimum
Low Population Zone: 8.05 km (5.00 miles)
Nearest City: Omaha; 1980 population: 313,939
Site Topography: flat to rolling
Surrounding Area Topography: flat and rolling
Land Use within 8 km (5 miles): agricultural
Nearby Features: The nearest town is De Soto 3 km (2 miles) SSE. De Soto National Wildlife Refuge is about 1.6 km (1 mile) E. Wilson Island State Park is about 6 km (4 miles) SE.
Area of Transmission Line Corridor: 75.3 ha (186 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
770,000	800,000	830,000	890,000	950,000

ROBERT EMMETT GINNA NUCLEAR POWER PLANT

Location: Wayne County, New York
32 km (20 miles) NE of Rochester
latitude 43.2778°N; longitude 77.3089°W
Licensee: Rochester Gas and Electric Corp.

Unit Information	Unit 1
Docket Number	50-244
Construction Permit	1966
Operating License	1969
Commercial Operation	1970
License Expiration	2009
Licensed Thermal Power [MW(t)]	1520
Design Electrical Rating [net MW(e)]	470
Type of Reactor	PWR
Nuclear Steam Supply System Vendor	WEST

Cooling Water System

Type: once through
Source: Lake Ontario
Source Temperature Range: 0-27°C (32-80°F)
Condenser Flow Rate: 22.5 m^3/s (356,000 gal/min)
Design Condenser Temperature Rise: 10.9°C (19.6°F)
Intake Structure: Structure is located on lake bottom 940 m (3100 ft) from shore. Water flows to screenhouse via a 3-m (10-ft) diameter tunnel in bedrock.
Discharge Structure: open canal to Lake Ontario

Site Information

Total Area: 137 ha (338 acres)
Exclusion Distance: 0.47-1.38 km (0.29-0.85 mile)
Low Population Zone: 4.83 km (3.00 miles)
Nearest City: Rochester; 1980 population: 241,741
Site Topography: gently rolling to flat
Surrounding Area Topography: sloping
Land Use within 8 km (5 miles): agricultural, orchards
Nearby Features: The nearest town is Lakeside 3 km (2 miles) SW. The N.Y. Central Railroad is about 5 km (3 miles) S.
Area of Transmission Line Corridor: 110 ha (280 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
1,140,000	1,120,000	1,100,000	1,110,000	1,120,000

GRAND GULF NUCLEAR STATION

Location: Claiborne County, Mississippi
40 km (25 miles) S of Vicksburg
latitude 32.0075°N; longitude 91.0475°W
Licensee: System Energy Resources, Inc.

Unit Information	Unit 1
Docket Number	50-416
Construction Permit	1974
Operating License	1984
Commercial Operation	1985
License Expiration	2024
Licensed Thermal Power [MW(t)]	3833
Design Electrical Rating [net MW(e)]	1250
Type of Reactor	BWR
Nuclear Steam Supply System Vendor	GE

Cooling Water System

Type: natural draft cooling towers
Source: Mississippi River
Source Temperature Range: 1-28°C (33-82°F)
Condenser Flow Rate: 36.1 m^3/s (572,000 gal/min)
Design Condenser Temperature Rise: 17°C (30°F)
Intake Structure: a series of radial-collector wells along the shoreline
Discharge Structure: discharge to river via a barge slip

Site Information

Total Area: 850 ha (2100 acres)
Exclusion Distance: 0.69-km (0.43-mile) radius
Low Population Zone: 3.22 km (2.00 miles)
Nearest City: Jackson; 1980 population: 202,895
Site Topography: flat to rolling
Surrounding Area Topography: flat and rolling
Land Use within 8 km (5 miles): wooded and recreational
Nearby Features: The nearest town is Grand Gulf 3 km (2 miles) N. The Natchez Trace Parkway is about 10 km (6 miles) SE. The Grand Gulf Military Park is just N of the site. There are numerous hunting lodges near the site.
Area of Transmission Line Corridor: 930 ha (2300 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
350,000	380,000	410,000	450,000	500,000

HADDAM NECK PLANT (CONNECTICUT YANKEE)

Location: Middlesex County, Connecticut
21 km (13 miles) E of Meriden
latitude 41.4819°N; longitude 72.4992°W
Licensee: Connecticut Yankee Atomic Power Co.

Unit Information

Docket Number	50-213
Construction Permit	1964
Operating License	1967
Commercial Operation	1968
License Expiration	2007
Licensed Thermal Power [MW(t)]	1825
Design Electrical Rating [net MW(e)]	582
Type of Reactor	PWR
Nuclear Steam Supply System Vendor	WEST

Cooling Water System

Type: once through
Source: Connecticut River
Source Temperature Range: 1-29°C (34-85°F)
Condenser Flow Rate: 23.5 m^3/s (372,000 gal/min)
Design Condenser Temperature Rise: 12.4°C (22.4°F)
Intake Structure: at shoreline
Discharge Structure: discharge canal to Connecticut River about 1.6 km (1 mile) downriver

Site Information

Total Area: 212 ha (525 acres)
Exclusion Distance: 0.53 km (0.33 mile)
Low Population Zone: 4.35 km (2.70 miles)
Nearest City: Meriden; 1980 population: 57,118
Site Topography: level with steep slopes up from river
Surrounding Area Topography: mostly hilly
Land Use within 8 km (5 miles): wooded
Nearby Features: The nearest town is Haddam 1.6 km (1 mile) WSW. Haddam Meadows State Park is within 1.6 km (1 mile). The New York, New Haven, and Hartford Railroad runs along the opposite river bank. The Millstone Nuclear Power Station is 32 km (20 miles) SE.
Area of Transmission Line Corridor: 399 ha (985 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
3,630,000	3,770,000	3,910,000	4,140,000	4,380,000

SHEARON HARRIS NUCLEAR POWER PLANT

Location:	Wake County, North Carolina 32 km (20 miles) SW Raleigh latitude 35.6336°N; longitude 78.9564°W
Licensee:	Carolina Power and Light Co.

Unit Information	Unit 1
Docket Number	50-400
Construction Permit	1978
Operating License	1987
Commercial Operation	1987
License Expiration	2027
Licensed Thermal Power [MW(t)]	2775
Design Electrical Rating [net MW(e)]	900
Type of Reactor	PWR
Nuclear Steam Supply System Vendor	WEST

Cooling Water System

Type: natural draft cooling tower
Source: Buckhorn Creek
Source Temperature Range: 5-27°C (41-81°F)
Condenser Flow Rate: 30.5 m^3/s (483,000 gal/min)
Design Condenser Temperature Rise: 14.3°C (25.7°F)
Intake Structure: at shoreline of reservoir on Buckhorn Creek
Discharge Structure: discharged to reservoir

Site Information

Total Area: 4348 ha (10,744 acres)
Exclusion Distance: 2.03-km (1.26-miles) minimum
Low Population Zone: 4.83 km (3.00 miles)
Nearest City: Raleigh; 1980 population: 149,771
Site Topography: rolling
Surrounding Area Topography: rolling
Land Use within 8 km (5 miles): mostly wooded with some agricultural Nearby Features: The nearest town is Bonsal 3 km (2 miles) NW. The Seaboard Coast Line Railroad is 3 km (2 miles) NW. Buckhorn Creek feeds into the Cape Fear River.
Area of Transmission Line Corridor: 1400 ha (3500 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
1,430,000	1,570,000	1,690,000	1,890,000	2,120,000

EDWIN I. HATCH NUCLEAR PLANT

Location: Appling County Georgia
18 km (11 miles) N of Baxley
latitude 31.9342°N; longitude 82.3444°W
Licensee: Georgia Power Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-321	50-366
Construction Permit	1969	1972
Operating License	1974	1978
Commercial Operation	1975	1979
License Expiration	2014	2018
Licensed Thermal Power [MW(t)]	2436	2436
Design Electrical Rating [net MW(e)]	776	784
Type of Reactor	BWR	BWR
Nuclear Steam Supply System Vendor	GE	GE

Cooling Water System

Type: mechanical draft cooling towers
Source: Altamaha River
Source Temperature Range: 6-32°C (43-90°F)
Condenser Flow Rate: 35.1 m^3/s (556,000 gal/min) each unit
Design Condenser Temperature Rise: 11°C (20°F)
Intake Structure: at edge of river
Discharge Structure: 37 m (120 ft) from shore

Site Information

Total Area: 908 ha (2244 acres)
Exclusion Distance: 1.26 km (0.78 mile)
Low Population Zone: 1.26 km (0.78 mile)
Nearest City: Savannah; 1980 population: 141,654
Site Topography: flat to rolling
Surrounding Area Topography: flat to rolling
Land Use within 8 km (5 miles): mostly wooded
Nearby Features: The nearest town is Cedar Crossing about 11 km (7 miles) NNW. U.S. Highway 1 is just west of the site.
Area of Transmission Line Corridor: 1898 ha (4691 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
330,000	360,000	380,000	420,000	460,000

HOPE CREEK GENERATING STATION

Location: Salem County, New Jersey
13 km (8 miles) SW of Salem
latitude 39.4678°N; longitude 75.5381°W
Licensee: Public Service Electric and Gas Co.

Unit Information	Unit 1
Docket Number	50-354
Construction Permit	1974
Operating License	1986
Commercial Operation	1986
License Expiration	2026
Licensed Thermal Power [MW(t)]	3293
Design Electrical Rating [net MW(e)]	1067
Type of Reactor	BWR
Nuclear Steam Supply System Vendor	GE

Cooling Water System

Type: natural draft cooling tower
Source: Delaware River
Source Temperature Range: 1-27°C (34-81°F)
Condenser Flow Rate: 34.8 m^3/s (552,000 gal/min)
Design Condenser Temperature Rise: 16°C (28°F)
Intake Structure: at edge of river
Discharge Structure: pipe 3 m (10 ft) offshore

Site Information

Total Area: 300 ha (740 acres)
Exclusion Distance: 0.90-km (0.56-mile) radius
Low Population Zone: 8.05-km (5.00-mile) radius
Nearest City: Wilmington, Delaware; 1980 population: 70,195
Site Topography: flat
Surrounding Area Topography: flat
Land Use within 8 km (5 miles): tidal marshes and grasslands
Nearby Features: The nearest town is Port Penn about 6 km (4 miles) NW in Delaware. The nearest railroad is 13 km (8 miles) NE. The plant is on the same site as the Salem Nuclear Generating Station.
Area of Transmission Line Corridor: 369 ha (912 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
4,850,000	4,960,000	5,050,000	5,230,000	5,420,000

INDIAN POINT STATION

Location: Westchester County, New York
39 km (24 miles) N of New York City
latitude 41.2714°N; longitude 73.9525°W

Licensee: Consolidated Edison Co. of New York, Inc. (Unit 2)
Power Authority of the State of New York (Unit 3)

Unit Information	Unit 2	Unit 3
Docket Number	50-247	50-286
Construction Permit	1966	1969
Operating License	1973	1976
Commercial Operation	1974	1976
License Expiration	2013	2016
Licensed Thermal Power [MW(t)]	2758	3025
Design Electrical Rating [net MW(e)]	873	965
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: once through
Source: Hudson River
Source Temperature Range: 0-26°C (32-78°F)
Condenser Flow Rate: 53 m^3/s (840,000 gal/min) each unit
Design Condenser Temperature Rise: 9.2°C (16.6°F)
Intake Structure: concrete structure at river bank
Discharge Structure: discharge channel to river exiting through 12 ports

Site Information

Total Area: 96.7 ha (239 acres)
Exclusion Distance: 0.32-km (0.20-mile) radius
Low Population Zone: 1.05-km (0.65-mile) radius
Nearest City: White Plains; 1980 population: 46,999
Site Topography: hilly
Surrounding Area Topography: hilly to mountainous
Land Use within 8 km (5 miles): residential, parks, military reservations
Nearby Features: The nearest town is Buchannan 3 km (2 miles) ESE. Camp Smith (military) is 1.6 km (1 mile) N and West Point is 13 km (8 miles) N.
Area of Transmission Line Corridor: 4 ha (10 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
15,190,000	15,000,000	14,890,000	15,200,000	15,520,000

KEWAUNEE NUCLEAR POWER PLANT

Location: Kewaunee County, Wisconsin
43 km (27 miles) E of Green Bay
latitude 44.3431°N; longitude 87.5361°W
Licensee: Wisconsin Public Service Corp.

Unit Information

Docket Number	50-305
Construction Permit	1968
Operating License	1973
Commercial Operation	1974
License Expiration	2013
Licensed Thermal Power [MW(t)]	1650
Design Electrical Rating [net MW(e)]	535
Type of Reactor	PWR
Nuclear Steam Supply System Vendor	WEST

Cooling Water System

Type: once through
Source: Lake Michigan
Source Temperature Range: 1-19°C (34-67°F)
Condenser Flow Rate: 27 m^3/s (420,000 gal/min)
Design Condenser Temperature Rise: 11°C (19°F)
Intake Structure: intake crib 4.6 km (15 ft) deep 533 m (1750 ft) from shore
Discharge Structure: at shoreline

Site Information

Total Area: 367 ha (908 acres)
Exclusion Distance: 1.21 km (0.75 mile)
Low Population Zone: 4.83-km (3.00-mile) radius
Nearest City: Green Bay; 1980 population: 87,899
Site Topography: flat to rolling
Surrounding Area Topography: flat to rolling
Land Use within 8 km (5 miles): agricultural and dairy farming
Nearby Features: The nearest town is Two Creeks about 5 km (3 miles) S. Point Beach Nuclear Plant is about 8 km (5 miles) S.
Area of Transmission Line Corridor: 431.4 ha (1066 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
640,000	670,000	690,000	730,000	780,000

LA SALLE COUNTY STATION

Location: La Salle County, Illinois
18 km (11 miles) SE of Ottawa
latitude 41.2439°N; longitude 88.6708°W
Licensee: Commonwealth Edison Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-373	50-374
Construction Permit	1973	1973
Operating License	1982	1984
Commercial Operation	1984	1984
License Expiration	2022	2024
Licensed Thermal Power [MW(t)]	3323	3323
Design Electrical Rating [net MW(e)]	1078	1078
Type of Reactor	BWR	BWR
Nuclear Steam Supply System Vendor	GE	GE

Cooling Water System

Type: cooling pond
Source: Illinois River
Source Temperature Range: 8-29°C (47-85°F)
Condenser Flow Rate: 40.7 m^3/s (645,000 gal/min) each unit
Design Condenser Temperature Rise: 13°C (24°F)
Intake Structure: intake from 832.8-ha (2058-acre) cooling pond, makeup from river
Discharge Structure: discharge to cooling pond

Site Information

Total Area: 1240 ha (3060 acres)
Exclusion Distance: 0.51 km (0.32 mile)
Low Population Zone: 6.41 km (3.98 miles)
Nearest City: Joliet; 1980 population: 77,956
Site Topography: flat
Surrounding Area Topography: flat with hills along river
Land Use within 8 km (5 miles): agricultural
Nearby Features: The nearest town is Seneca about 8 km (5 miles) NNE. Braidwood Station (nuclear plant) is about 32 km (20 miles) ENE and Dresden Nuclear Power Station is about 35 km (22 miles) NE.
Area of Transmission Line Corridor: 921.9 ha (2278 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
1,160,000	1,220,000	1,260,000	1,310,000	1,370,000

LIMERICK GENERATING STATION

Location: Montgomery County, Pennsylvania
34 km (21 miles) NW of Philadelphia
latitude 40.2200°N; longitude 75.5900°W

Licensee: Philadelphia Electric Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-352	50-353
Construction Permit	1974	1974
Operating License	1985	1990
Commercial Operation	1986	1990
License Expiration	2025	2020
Licensed Thermal Power [MW(t)]	3293	3293
Design Electrical Rating [net MW(e)]	1055	1055
Type of Reactor	BWR	BWR
Nuclear Steam Supply System Vendor	GE	GE

Cooling Water System

Type: natural draft cooling towers
Source: Schuylkill River
Source Temperature Range: 6-28°C (42-82°F)
Condenser Flow Rate: 28 m^3/s (450,000 gal/min) each unit
Design Condenser Temperature Rise: 17°C (30°F)
Intake Structure: intake from river
Discharge Structure: discharge to river

Site Information

Total Area: 241 ha (595 acres)
Exclusion Distance: 0.76 km (0.47 mile)
Low Population Zone: 2.09-km (1.30-mile) radius
Nearest City: Reading; 1980 population: 78,686
Site Topography: rolling
Surrounding Area Topography: rolling
Land Use within 8 km (5 miles): agricultural and undeveloped
Nearby Features: The nearest town is Linfield about 1.6 km (1 mile) SE. Valley Forge State Park is 16 km (10 miles) SSE. U.S. Highway I-76 is about 16 km (10 miles) S.
Area of Transmission Line Corridor: 3 ha (7 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
6,970,000	7,070,000	7,170,000	7,390,000	7,620,000

MAINE YANKEE ATOMIC POWER PLANT

Location: Lincoln County, Maine
16 km (10 miles) NE of Bath
latitude 43.9506°N; longitude 69.6961°W

Licensee: Maine Yankee Atomic Power Co.

Unit Information

Docket Number	50-309
Construction Permit	1968
Operating License	1973
Commercial Operation	1972
License Expiration	2013
Licensed Thermal Power [MW(t)	2700
Design Electrical Rating [net MW(e)]	825
Type of Reactor	PWR
Nuclear Steam Supply System Vendor	CE

Cooling Water System

Type: once through
Source: Back River
Source Temperature Range: 3-14°C (37-57°F)
Condenser Flow Rate: 26.9 m^3/s (426,000 gal/min)
Design Condenser Temperature Rise: 14.2°C (25.6°F)
Intake Structure: at river bank
Discharge Structure: to Montsweag Bay on Back River

Site Information

Total Area: 300 ha (740 acres)
Exclusion Distance: 0.61-km (0.38-mile) radius
Low Population Zone: 9.66-km (6.00-mile) radius
Nearest City: Portland; 1980 population: 61,572
Site Topography: flat to rolling
Surrounding Area Topography: rolling
Land Use within 8 km (5 miles): wooded and some idle farm land
Nearby Features: The nearest town is Edgecomb about 5 km (3 miles) E. U.S. Highway 1 and the Maine Central Railroad are about 1.6 km (1 mile) NE.
Area of Transmission Line Corridor: 89 ha (220 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
640,000	700,000	750,000	830,000	920,000

WILLIAM B. MCGUIRE NUCLEAR STATION

Location: Mecklenburg County, North Carolina
27 km (17 miles) NNW of Charlotte
latitude 35.4322°N; longitude 80.9483°W

Licensee: Duke Power Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-369	50-370
Construction Permit	1973	1973
Operating License	1981	1983
Commercial Operation	1981	1984
License Expiration	2021	2023
Licensed Thermal Power [MW(t)]	3411	3411
Design Electrical Rating [net MW(e)]	1180	1180
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: once through
Source: Lake Norman
Source Temperature Range: 3-32°C (38-89°F)
Condenser Flow Rate: 42.6 m^3/s (675,000 gal/min) each unit
Design Condenser Temperature Rise: 12.3°C (22.1°F)
Intake Structure: submerged and surface intakes at shoreline
Discharge Structure: 610-m (2000-ft) discharge canal

Site Information

Total Area: 12,100 ha (30,000 acres)
Exclusion Distance: 0.76-km (0.47-mile) radius
Low Population Zone: 8.85 km (5.50 miles)
Nearest City: Charlotte; 1980 population: 315,474
Site Topography: rolling
Surrounding Area Topography: hilly
Land Use within 8 km (5 miles): agricultural and wooded
Nearby Features: The nearest town is Lowesville about 5 km (3 miles) W. The dam forming Lake Norman and a hydro powerplant are adjacent to the site.
Area of Transmission Line Corridor: 25 ha (62 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
1,750,000	1,900,000	2,040,000	2,280,000	2,540,000

MILLSTONE NUCLEAR POWER STATION

Location: New London County, Connecticut
5 km (3 miles) WSW of New London
latitude 41.3086°N; longitude 72.1681°W

Licensee: Northeast Utilities

Unit Information	Unit 1	Unit 2	Unit 3
Docket Number	50-245	50-336	50-423
Construction Permit	1966	1970	1974
Operating License	1970	1975	1986
Commercial Operation	1971	1975	1986
License Expiration	2010	2015	2026
Licensed Thermal Power [MW(t)]	2011	2700	3411
Design Electrical Rating [net MW(e)]	660	870	1154
Type of Reactor	BWR	PWR	PWR
Nuclear Steam Supply System Vendor	GE	CE	WEST

Cooling Water System

Type: once through
Source: Long Island Sound
Source Temperature Range: 2-22°C (36-72°F)
Condenser Flow Rate: 27 m^3/s (420,000 gal/min) for Unit 1
32.97 m^3/s (522,500 gal/min) for Unit 2
57.2108 m^3/s (906,668 gal/min) for Unit 3
Design Condenser Temperature Rise: 12°C (21°F) for Unit 1
13°C (24°F) for Unit 2
9.7°C (17.5°F) for Unit 3
Intake Structure: on shore of Niantic Bay off Long Island Sound
Discharge Structure: discharge to Niantic Bay via holding pond

Site Information

Total Area: 200 ha (500 acres)
Exclusion Distance: 0.55-km (0.34-mile) minimum
Low Population Zone: 3.86-km (2.40-mile) radius
Nearest City: New Haven; 1980 population: 126,089
Site Topography: flat
Surrounding Area Topography: flat to rolling
Land Use within 8 km (5 miles): mostly undeveloped with some recreational, agricultural, and residential
Nearby Features: The nearest town is Niantic 3 km (2 miles) NW. U.S. Highway I-95 is about 6 km (4 miles) NNE. Stone Ranch Military Reservation is about 10 km (6 miles) NW. Harkness Memorial State Park, Bluff Point State Park, and Rocky Neck State Park are within 8 km (5 miles) of the site. The U.S. Dept. of Agriculture Plum Island facility is 16 km (10 miles) S

in Long Island Sound. The Haddam Neck Plant (nuclear) is 32 km (20 miles) NW.

Area of Transmission Line Corridor: 375 ha (927 acres)

Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
2,760,000	2,860,000	2,960,000	3,140,000	3,330,000

MONTICELLO NUCLEAR GENERATING PLANT

Location: Wright County, Minnesota
56 km (35 miles) NW of Minneapolis
latitude 45.3333°N; longitude 93.8483°W

Licensee: Northern States Power Co.

Unit Information

Docket Number	50-263
Construction Permit	1967
Operating License	1970
Commercial Operation	1971
License Expiration	2010
Licensed Thermal Power [MW(t)]	1670
Design Electrical Rating [net MW(e)]	545
Type of Reactor	BWR
Nuclear Steam Supply System Vendor	GE

Cooling Water System

Type: once through and helper towers
Source: Mississippi River
Source Temperature Range: 0-29°C (32-85°F)
Condenser Flow Rate: 18 m^3/s (280,000 gal/min)
Design Condenser Temperature Rise: 14.9°C (26.8°F)
Intake Structure: canal
Discharge Structure: canal

Site Information

Total Area: 860 ha (2150 acres)
Exclusion Distance: 0.48 km (0.30 mile)
Low Population Zone: 1.61 km (1.00 mile)
Nearest City: Minneapolis; 1980 population: 370,951
Site Topography: flat terraces
Surrounding Area Topography: flat to gently sloping
Land Use within 8 km (5 miles): agricultural and dairy farming
Nearby Features: The business district of Monticello is about 3.2 km (2 miles) SE. Sherburne National Wildlife Refuge is about 14 km (9 miles) N. Lake Maria State Park is about 10 km (6 miles) WSW and Sand Dunes State Forest and campground are 14 km (9 miles) NE.
Area of Transmission Line Corridor: 588.4 ha (1454 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
2,170,000	2,360,000	2,520,000	2,820,000	3,150,000

NORTH ANNA POWER STATION

Location: Louisa County, Virginia
64 km (40 miles) NW of Richmond
latitude 38.0608°N; longitude 77.7906°W
Licensee: Virginia Electric and Power Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-338	50-339
Construction Permit	1971	1971
Operating License	1978	1980
Commercial Operation	1978	1980
License Expiration	2018	2020
Licensed Thermal Power [MW(t)]	2893	2893
Design Electrical Rating [net MW(e)]	907	907
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: once through
Source: Lake Anna
Source Temperature Range: 9-28°C (48-83°F)
Condenser Flow Rate: 59.33 m^3/s (940,300 gal/min) each unit
Design Condenser Temperature Rise: 8°C (14°F)
Intake Structure: intake on lake shore
Discharge Structure: discharged to lake via a 1400-ha (3400-acre) cooling pond.

Site Information

Total Area: 7545 ha (18,643 acres)
Exclusion Distance: 1.35 km (0.84 mile)
Low Population Zone: 9.66 km (6.00 miles)
Nearest City: Richmond; 1980 population: 219,214
Site Topography: rolling
Surrounding Area Topography: rolling
Land Use within 8 km (5 miles): agricultural and wooded
Nearby Features: The nearest town is Centreville 1.6 km (1 mile) SW. Fredericksburg and Spotsylvania National Military Park is about 24 km (15 miles) NE.
Area of Transmission Line Corridor: 1428 ha (3528 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
1,150,000	1,250,000	1,340,000	1,480,000	1,630,000

NINE MILE POINT NUCLEAR STATION

Location: Oswego County, New York
10 km (6 miles) NE of Oswego
latitude 43.5222°N; longitude 76.4100°W

Licensee: Niagra Mohawk Power Corp.

Unit Information	Unit 1	Unit 2
Docket Number	50-220	50-410
Construction Permit	1965	1974
Operating License	1968	1987
Commercial Operation	1969	1988
License Expiration	2008	2027
Licensed Thermal Power [MW(t)]	1850	3323
Design Electrical Rating [net MW(e)]	620	1080
Type of Reactor	BWR	BWR
Nuclear Steam Supply System Vendor	GE	GE

Cooling Water System

Type: Unit 1 - once through
Unit 2 - natural draft cooling tower

Source: Lake Ontario

Source Temperature Range: 1-25°C (33-77°F)

Condenser Flow Rate: 16 m^3/s (250,000 gal/min) for Unit 1
37 m^3/s (580,000 gal/min) for Unit 2

Design Condenser Temperature Rise: 18°C (32°F) for Unit 1
15°C (27°F) for Unit 2

Intake Structure: separate submerged pipelines about 300 m (1000 ft) offshore

Discharge Structure: diffuser pipe 169 m (555 ft) long serving both units

Site Information

Total Area: 360 ha (900 acres)

Exclusion Distance: 1.19 km (0.74 mile) minimum

Low Population Zone: 6.44 km (4.00 mile) radius

Nearest City: Syracuse; 1980 population: 170,105

Site Topography: flat to rolling

Surrounding Area Topography: rolling

Land Use within 8 km (5 miles): agricultural, industrial, residential, and recreational

Nearby Features: The nearest town is Lakeview about 1.6 km (1 mile) WSW. Fort Ontario is about 10 km (6 miles) SW. James A. FitzPatrick Nuclear Power Plant is 0.8 km (0.5 mile) E.

Area of Transmission Line Corridor: 664 ha (1640 acres)

Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
820,000	810,000	790,000	800,000	810,000

OCONEE NUCLEAR STATION

Location: Oconee County, South Carolina
42 km (26 miles) W of Greenville
latitude 34.7917°N; longitude 82.8986°W
Licensee: Duke Power Co.

Unit Information	Unit 1	Unit 2	Unit 3
Docket Number	50-269	50-270	50-287
Construction Permit	1967	1967	1967
Operating License	1973	1973	1974
Commercial Operation	1973	1974	1974
License Expiration	2013	2013	2014
Licensed Thermal Power [MW(t)]	2568	2568	2568
Design Electrical Rating [net MW(e)]	887	887	887
Type of Reactor	PWR	PWR	PWR
Nuclear Steam Supply System Vendor	B&W	B&W	B&W

Cooling Water System

Type: once through
Source: Lake Keowee
Source Temperature Range: 7-25°C (44-77°F)
Condenser Flow Rate: 43 m^3/s (680,000 gal/min) for each unit
Design Condenser Temperature Rise: 9.6°C (17.2°F)
Intake Structure: A skimmer wall draws water from depths of 216-223 m (710-733 ft) at a velocity of 0.2 m/s (0.6 ft/s).
Discharge Structure: All three units discharge through one structure near Keowee dam. Discharge is underwater at a depth of 233 m (765 ft).

Site Information

Total Area: 210 ha (510 acres)
Exclusion Distance: 1.61-km (1.00-mile) radius
Low Population Zone: 9.66 km (6.00 miles)
Nearest City: Greenville; 1980 population: 58,242
Site Topography: flat to rolling
Surrounding Area Topography: hilly
Land Use within 8 km (5 miles): wooded
Nearby Features: The nearest town is Six Mile 6 km (4 miles) ENE. Keowee dam is close to the plant. Chattahoochee National Forest is about 24 km (15 miles) W.
Area of Transmission Line Corridor: 3160 ha (7800 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
990,000	1,080,000	1,170,000	1,310,000	1,470,000

OYSTER CREEK NUCLEAR GENERATING STATION

Location: Ocean County, New Jersey
14 km (9 miles) S of Toms River
latitude 39.8142°N; longitude 74.2064°W
Licensee: GPU Nuclear Corp.

Unit Information	Unit 1
Docket Number	50-219
Construction Permit	1964
Operating License	1969
Commercial Operation	1969
License Expiration	2009
Licensed Thermal Power [MW(t)]	1930
Design Electrical Rating [net MW(e)]	650
Type of Reactor	BWR
Nuclear Steam Supply System Vendor	GE

Cooling Water System

Type: once through
Source: Barnegat Bay
Source Temperature Range: 2-28°C (35-83°F)
Condenser Flow Rate: 29 m^3/s (460,000 gal/min)
Design Condenser Temperature Rise: 8°C (14°F)
Intake Structure: Forked River serves as a canal for intake and discharge to Barnegat Bay.
Discharge Structure: Forked River serves as a canal for intake and discharge to Barnegat Bay.

Site Information

Total Area: 573 ha (1416 acres)
Exclusion Distance: 0.40 km (0.25 mile)
Low Population Zone: 3.22 km (2.00 miles)
Nearest City: Atlantic City; 1980 population: 40,199
Site Topography: flat
Surrounding Area Topography: rolling plains to flat lowlands
Land Use within 8 km (5 miles): mostly undeveloped
Nearby Features: The nearest town is Forked River about 3 km (2 miles) N. The Garden State Parkway is 1.6 km (1 mile) W. There is a large influx of people seeking recreation in the summer.
Area of Transmission Line Corridor: 130 ha (322 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
4,030,000	4,190,000	4,300,000	4,560,000	4,840,000

PALISADES NUCLEAR PLANT

Location: Van Buren County, Michigan
56 km (35 miles) W of Kalamazoo
latitude 42.3222°N; longitude 86.3153°W
Licensee: Consumers Power Co.

Unit Information	Unit 1
Docket Number	50-255
Construction Permit	1967
Operating License	1972
Commercial Operation	1973
License Expiration	2012
Licensed Thermal Power [MW(t)]	2530
Design Electrical Rating [net MW(e)]	805
Type of Reactor	PWR
Nuclear Steam Supply System Vendor	CE

Cooling Water System

Type: mechanical draft cooling towers
Source: Lake Michigan
Source Temperature Range: 2-24°C (35-75°F)
Condenser Flow Rate: 25.6 m^3/s (405,000 gal/min)
Design Condenser Temperature Rise: 14°C (25°F)
Intake Structure: intake crib 1000 m (3300 ft) from shore
Discharge Structure: canal 33 m (108 ft) long

Site Information

Total Area: 197 ha (487 acres)
Exclusion Distance: 0.71-km (0.44-mile) radius
Low Population Zone:
Nearest City: Kalamazoo; 1980 population: 79,722
Site Topography: flat to rolling
Surrounding Area Topography: rolling
Land Use within 8 km (5 miles): agricultural, wooded, berry farms, and orchards
Nearby Features: The nearest town is South Haven about 6 km (4 miles) N. Van Buren State Park joins the plant on the north. Many tourists come to the beaches in the summer. The C&O Railway is about 3 km (2 miles) E. Highway I-196 is about 1.6 km (1 mile) E.
Area of Transmission Line Corridor: 910 ha (2250 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
1,170,000	1,220,000	1,260,000	1,340,000	1,420,000

PALO VERDE NUCLEAR GENERATING STATION

Location: Maricopa County, Arizona
55 km (34 miles) W of Phoenix
latitude 33.3881°N; longitude 112.8644°W

Licensee: Arizona Public Service Co.

Unit Information	Unit 1	Unit 2	Unit 3
Docket Number	50-528	50-529	50-530
Construction Permit	1976	1976	1976
Operating License	1985	1986	1987
Commercial Operation	1986	1986	1988
License Expiration	2025	2026	2027
Licensed Thermal Power [MW(t)]	3800	3800	3800
Design Electrical Rating [net MW(e)]	1270	1270	1270
Type of Reactor	PWR	PWR	PWR
Nuclear Steam Supply System Vendor	CE	CE	CE

Cooling Water System

Type: mechanical draft cooling towers treatment plant
Source: Phoenix city sewage
Source Temperature Range:
Condenser Flow Rate: 35 m^3/s (560,000 gal/min) each unit
Design Condenser Temperature Rise: 17.8°C (32.1°F)
Intake Structure: 56-km (35-mile) underground pipeline from Phoenix 91st Avenue Sewage Treatment Plant
Discharge Structure: blowdown from the circulating water system is directed to on-site evaporation ponds without requiring any off-site discharge

Site Information

Total Area: 1640 ha (4050 acres)
Exclusion Distance: 0.87-km (0.54-mile) minimum
Low Population Zone: 6.44-km (4.00-mile) radius
Nearest City: Phoenix; 1980 population: 789,704
Site Topography: flat with hills
Surrounding Area Topography: flat with hills
Land Use within 8 km (5 miles): open desert with some agriculture
Nearby Features: The nearest town is Wintersburg about 5 km (3 miles) N. U.S. Highway I-10 is about 11 km (7 miles) N. The Southern Pacific Railroad is about 8 km (5 miles) SE.
Area of Transmission Line Corridor: 6720 ha (16,600 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
1,180,000	1,330,000	1,450,000	1,690,000	1,970,000

PEACH BOTTOM ATOMIC POWER STATION

Location: York County, Pennsylvania
29 km (18 miles) S of Lancaster
latitude 39.7589°N; longitude 76.2692°W

Licensee: Philadelphia Electric Co.

Unit Information	Unit 2	Unit 3
Docket Number	50-277	50-278
Construction Permit	1968	1968
Operating License	1973	1974
Commercial Operation	1974	1974
License Expiration	2013	2014
Licensed Thermal Power [MW(t)]	3293	3293
Design Electrical Rating [net MW(e)]	1065	1065
Type of Reactor	BWR	BWR
Nuclear Steam Supply System Vendor	GE	GE

Cooling Water System

Type: once through with helper towers
Source: Conowingo Pond
Source Temperature Range: 1-27°C (34-80°F)
Condenser Flow Rate: 47 m^3/s (750,000 gal/min) each unit
Design Condenser Temperature Rise: 11.6°C (20.8°F)
Intake Structure: intake from Conowingo Pond through a small intake pond
Discharge Structure: 1520-m (5000-ft) canal to Conowingo Pond

Site Information

Total Area: 250 ha (620 acres)
Exclusion Distance: 0.82-km (0.51-mile) minimum
Low Population Zone: 2.22 km (1.38 miles)
Nearest City: Lancaster; 1980 population: 54,725
Site Topography: rolling to hilly
Surrounding Area Topography: rolling to hilly
Land Use within 8 km (5 miles): agricultural and wooded
Nearby Features: The nearest town is Slate Hill 3 km (2 miles) SW. Susquehanna State Park is about 5 km (3 miles) N. U.S. Highway I-95 is about 24 km (15 miles) SE. Conowingo Dam, about 13 km (8 miles) SE on the Susquehanna River, forms Conowingo Pond. Unit 1 is a 40 Mwe nuclear plant on the same site and was retired from service in 1974. Three Mile Island Nuclear Station is 56 km (35 miles) upstream on the Susquehanna River.
Area of Transmission Line Corridor: 417 ha (1030 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
4,660,000	4,850,000	5,010,000	5,280,000	5,570,000

PERRY NUCLEAR POWER PLANT

Location: Lake County, Ohio
11 km (7 miles) NE of Painesville
latitude 41.8008°N; longitude 81.1442°W
Licensee: Cleveland Electric Illuminating Co.

Unit Information	Unit 1
Docket Number	50-440
Construction Permit	1977
Operating License	1986
Commercial Operation	1987
License Expiration	2026
Licensed Thermal Power [MW(t)]	3579
Design Electrical Rating [net MW(e)]	1205
Type of Reactor	BWR
Nuclear Steam Supply System Vendor	GE

Cooling Water System

Type: natural draft cooling tower
Source: Lake Erie
Source Temperature Range: 0-26°C (32-79°F)
Condenser Flow Rate: 34.41 m^3/s (545,400 gal/min)
Design Condenser Temperature Rise: 18°C (32°F)
Intake Structure: submerged multiport structure 777 m (2550 ft) offshore
Discharge Structure: submerged diffuser 503 m (1650 ft) offshore

Site Information

Total Area: 450 ha (1100 acres)
Exclusion Distance: 0.89-km (0.55-mile) radius
Low Population Zone: 4.02 km (2.50 miles)
Nearest City: Euclid; 1980 population: 59,999
Site Topography: flat
Surrounding Area Topography: rolling
Land Use within 8 km (5 miles): forest land, agricultural (horticulture), residential, industrial, and some recreational
Nearby Features: The nearest town is North Perry 1.6 km (1 mile) SW. The Penn Central Railroad is about 5 km (3 miles) S. U.S. Highway I-90 is about 8 km (5 miles) S.
Area of Transmission Line Corridor: 610 ha (1500 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
2,480,000	2,530,000	2,570,000	2,670,000	2,770,000

PILGRIM NUCLEAR POWER STATION

Location: Plymouth County, Massachusetts
6 km (4 miles) SE of Plymouth
latitude 41.9444°N; longitude 70.5794°W
Licensee: Boston Edison Co.

Unit Information	Unit 1
Docket Number	50-293
Construction Permit	1968
Operating License	1972
Commercial Operation	1972
License Expiration	2012
Licensed Thermal Power [MW(t)]	1998
Design Electrical Rating [net MW(e)]	655
Type of Reactor	BWR
Nuclear Steam Supply System Vendor	GE

Cooling Water System

Type: once through
Source: Cape Cod Bay
Source Temperature Range: 0-28°C (32-83°F)
Condenser Flow Rate: 19.6 m^3/s (311,000 gal/min)
Design Condenser Temperature Rise: 16°C (29°F)
Intake Structure: concrete structure at edge of bay protected by a breakwater
Discharge Structure: canal about 260 m (850 ft) long

Site Information

Total Area: 209 ha (517 acres)
Exclusion Distance: 0.53 km (0.33 mile)
Low Population Zone: 6.76 km (4.20 miles)
Nearest City: Brockton; 1980 population: 95,172
Site Topography: flat to rolling
Surrounding Area Topography: rolling to hilly
Land Use within 8 km (5 miles): mostly undeveloped
Nearby Features: The nearest town is Plymouth about 6 km (4 miles) NW. Miles Standish State Forest is about 10 km (6 miles) SW. Plymouth Rock and Plimoth Plantation historical sites are about 8 km (5 miles) W.
Area of Transmission Line Corridor: 70 ha (174 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
4,440,000	4,590,000	4,690,000	4,880,000	5,080,000

POINT BEACH NUCLEAR PLANT

Location: Manitowoc County, Wisconsin
21 km (13 miles) NNW of Manitowoc
latitude 44.2808°N; longitude 87.5361°W

Licensee: Wisconsin Electric Power Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-266	50-301
Construction Permit	1967	1968
Operating License	1970	1972
Commercial Operation	1970	1972
License Expiration	2010	2012
Licensed Thermal Power [MW(t)]	1519	1519
Design Electrical Rating [net MW(e)]	497	497
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: once through
Source: Lake Michigan
Source Temperature Range:
Condenser Flow Rate: 22 m^3/s (350,000 gal/min) each unit
Design Condenser Temperature Rise: 10.7°C (19.3°F)
Intake Structure: Structure is 533 m (1750 ft) from shore in 7-m (22-ft) deep water. Top elevation is 2.4 m (8 ft) above normal lake level. Intake to plant is through 38 pipes located 1.5 m (5 ft) above lake bed.
Discharge Structure: 2 flumes projecting about 46 m (150 ft) from shore

Site Information

Total Area: 836 ha (2065 acres)
Exclusion Distance: 1.19-km (0.74-mile) radius
Low Population Zone: 9.01 km (5.60 miles)
Nearest City: Green Bay; 1980 population: 87,899
Site Topography: flat to rolling
Surrounding Area Topography: rolling
Land Use within 8 km (5 miles): agricultural, dairy farming, vegetable canning
Nearby Features: The nearest town is Two Creeks 1.6 km (1 mile) NNW. Point Beach State Forest is just S of site. The Kewaunee Nuclear Power Plant is about 8 km (5 miles) N.
Area of Transmission Line Corridor: 1344 ha (3321 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
610,000	640,000	660,000	700,000	740,000

PRAIRIE ISLAND NUCLEAR GENERATING PLANT

Location: Goodhue County, Minnesota
45 km (28 miles) SE of Minneapolis
latitude 44.6219°N; longitude 92.6331°W

Licensee: Northern States Power Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-282	50-306
Construction Permit	1968	1968
Operating License	1973	1974
Commercial Operation	1973	1974
License Expiration	2013	2014
Licensed Thermal Power [MW(t)]	1650	1650
Design Electrical Rating [net MW(e)]	530	530
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: mechanical draft and/or once cooling towers
Source: Mississippi River
Source Temperature Range: 0-28°C (32-82°F)
Condenser Flow Rate: 18.6 m^3/s (294,000 gal/min) each unit
Design Condenser Temperature Rise: 15°C (27°F)
Intake Structure: short canal
Discharge Structure: Discharges to a basin then to towers and/or river.

Site Information

Total Area: 230 ha (560 acres)
Exclusion Distance: 0.69-km (0.43-mile) radius
Low Population Zone: 2.41 km (1.50 miles)
Nearest City: Minneapolis; 1980 population: 370,951
Site Topography: flat to rolling
Surrounding Area Topography: rolling
Land Use within 8 km (5 miles): dairy farming and agricultural
Nearby Features: The business district of the town of Red Wing is 9.6 km (6 miles) SE. A railroad line is just SW of the site.
Area of Transmission Line Corridor: 394 ha (973 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
2,290,000	2,490,000	2,650,000	2,960,000	3,310,000

QUAD-CITIES STATION

Location: Rock Island County, Illinois
32 km (20 miles) NE of Moline
latitude 41.7261°N; longitude 90.3100°W
Licensee: Commonwealth Edison Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-254	50-265
Construction Permit	1967	1967
Operating License	1972	1972
Commercial Operation	1973	1973
License Expiration	2012	2012
Licensed Thermal Power [MW(t)]	2511	2511
Design Electrical Rating [net MW(e)]	789	789
Type of Reactor	BWR	BWR
Nuclear Steam Supply System Vendor	GE	GE

Cooling Water System

Type: once through
Source: Mississippi River
Source Temperature Range: 0-29°C (32-85°F)
Condenser Flow Rate: 29.7 m^3/s (471,000 gal/min) each unit
Design Condenser Temperature Rise: 13°C (24°F)
Intake Structure: crib house at edge of river
Discharge Structure: 4300-m (14,000-ft) spray canal

Site Information

Total Area: 317 ha (784 acres)
Exclusion Distance: 0.80 km (0.50 mile)
Low Population Zone: 4.83 km (3.00 miles)
Nearest City: Davenport, Iowa; 1980 population: 103,264
Site Topography: flat
Surrounding Area Topography: flat
Land Use within 8 km (5 miles): agricultural and small industrial park
Nearby Features: The nearest town is Folletts 5 km (3 miles) NW. The Rock Island Railroad is 3 km (2 miles) W and the Chicago, Milwaukee, and St. Paul Railroad is 1.6 km (1 mile) E. The Rock Island Arsenal is about 24 km (15 miles) SW.
Area of Transmission Line Corridor: 570 ha (1400 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
740,000	760,000	780,000	810,000	850,000

RANCHO SECO NUCLEAR GENERATING STATION

Location:	Sacramento County, California 40 km (25 miles) SE of Sacramento latitude 38.3444°N; longitude 121.1200°W
Licensee:	Sacramento Municipal Utility District

Unit Information	Unit 1
Docket Number	50-312
Construction Permit	1968
Operating License	1974
Commercial Operation	1975
License Expiration	2014
Licensed Thermal Power [MW(t)]	2772
Design Electrical Rating [net MW(e)]	918
Type of Reactor	PWR
Nuclear Steam Supply System Vendor	B&W

Cooling Water System

Type: natural draft cooling
Source: Folsom Canal towers
Source Temperature Range: 10-21°C (50-70°F)
Condenser Flow Rate: 28.1 m^3/s (446,000 gal/min)
Design Condenser Temperature Rise: 16°C (28°F)
Intake Structure: 5.6-km (3.5-mile) pipeline from Folsom Canal
Discharge Structure: 2.4-km (1.5-mile) pipeline to reservoir

Site Information

Total Area: 1000 ha (2480 acres)
Exclusion Distance: 0.64-km (0.40-mile) radius
Low Population Zone: 8.05 km (5.00 miles)
Nearest City: Sacramento; 1980 population: 275,741
Site Topography: flat to rolling
Surrounding Area Topography: rolling
Land Use within 8 km (5 miles): agricultural and grazing land
Nearby Features: The nearest town is Clay 3 km (2 miles) WSW. The Southern Pacific Railroad is about 1.6 km (1 mile) N.
Area of Transmission Line Corridor: 350 ha (870 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
2,010,000	2,200,000	2,360,000	2,590,000	2,850,000

Note: This plant was shut down as the result of a public referendum in June 1989.

RIVER BEND STATION

Location:	West Feliciana County, Louisiana 39 km (24 miles) NNW of Baton Rouge latitude 30.7569°N; longitude 91.3314°W
Licensee:	Gulf States Utility Co.

Unit Information	Unit 1
Docket Number	50-458
Construction Permit	1977
Operating License	1985
Commercial Operation	1986
License Expiration	2025
Licensed Thermal Power [MW(t)]	2894
Design Electrical Rating [net MW(e)]	936
Type of Reactor	BWR
Nuclear Steam Supply System Vendor	GE

Cooling Water System

Type: mechanical draft cooling towers
Source: Mississippi River
Source Temperature Range:
Condenser Flow Rate: 32.084 m^3/s (508,470 gal/min)
Design Condenser Temperature Rise: 15°C (27°F)
Intake Structure: at river bank
Discharge Structure: pipe extending into the river

Site Information

Total Area: 1352 ha (3342 acres)
Exclusion Distance: 0.92-km (0.57-mile) radius
Low Population Zone: 4.02-km (2.50-mile) radius
Nearest City: Baton Rouge; 1980 population: 220,394
Site Topography: flat
Surrounding Area Topography: flat to rolling
Land Use within 8 km (5 miles): agricultural and forest
Nearby Features: The nearest town is St. Francisville 5 km (3 miles) NW. Audubon Memorial State Park is about 5 km (3 miles) NNE. The Illinois Central Railroad crosses the site.
Area of Transmission Line Corridor: 410 ha (1014 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
800,000	860,000	920,000	1,010,000	1,110,000

H. B. ROBINSON PLANT

Location: Darlington County, South Carolina
42 km (26 miles) NE of Florence
latitude 34.4025°N; longitude 80.1586°W
Licensee: Carolina Power and Light Co.

Unit Information	Unit 2
Docket Number	50-261
Construction Permit	1967
Operating License	1970
Commercial Operation	1971
License Expiration	2010
Licensed Thermal Power [MW(t)]	2300
Design Electrical Rating [net MW(e)]	700
Type of Reactor	PWR
Nuclear Steam Supply System Vendor	WEST

Cooling Water System

Type: once through
Source: Lake Robinson
Source Temperature Range: 8-29°C (46-85°F)
Condenser Flow Rate: 30.42 m^3/s (482,100 gal/min)
Design Condenser Temperature Rise: 10°C (18°F)
Intake Structure: concrete structure on edge of lake
Discharge Structure: 6.8-km (4.2-mile) canal discharging about 6 km (4 miles) upstream from intake

Site Information

Total Area: 2000 ha (5000 acres)
Exclusion Distance: 0.43-km (0.27-mile) radius
Low Population Zone: 7.24 km (4.50 miles)
Nearest City: Columbia; 1980 population: 101,229
Site Topography: rolling
Surrounding Area Topography: rolling
Land Use within 8 km (5 miles): agricultural and wooded, some recreational
Nearby Features: The nearest town is Hartsville 8 km (5 miles) SE. Unit 1 is an adjacent 185 MW(e) capacity coal-fired plant. Sand Hills State Forest is about 6 km (4 miles) N. The Carolina Sandhills National Wildlife Refuge is about 8 km (5 miles) NNW.
Area of Transmission Line Corridor: 414 ha (1024 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
740,000	810,000	880,000	990,000	1,120,000

SALEM NUCLEAR GENERATING STATION

Location: Salem County, New Jersey
13 km (8 miles) SW of Salem
latitude 39.4628°N; longitude 75.5358°W
Licensee: Public Service Electric and Gas Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-272	50-311
Construction Permit	1968	1968
Operating License	1976	1981
Commercial Operation	1977	1981
License Expiration	2016	2021
Licensed Thermal Power [MW(t)]	3411	3411
Design Electrical Rating [net MW(e)]	1115	1115
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: once through
Source: Delaware River
Source Temperature Range: 1-26°C (33-79°F)
Condenser Flow Rate: 69 m^3/s (1,100,000 gal/min) each unit
Design Condenser Temperature Rise: 7.6°C (13.6°F)
Intake Structure: 12 bay structure on edge of river
Discharge Structure: submerged pipes extending 150 m (500 ft) into the river

Site Information

Total Area: 280 ha (700 acres)
Exclusion Distance: 1.29 km (0.80 mile)
Low Population Zone: 8.05 km (5.00 miles)
Nearest City: Wilmington, Delaware; 1980 population: 70,195
Site Topography: flat
Surrounding Area Topography: flat
Land Use within 8 km (5 miles): tidal marshes and grasslands
Nearby Features: The nearest town is Port Penn about 6 km (4 miles) NW in Delaware. The nearest railroad is 13 km (8 miles) NE. The plant is on the same site as the Hope Creek Generating Station (nuclear).
Area of Transmission Line Corridor: 1600 ha (3900 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
4,810,000	4,910,000	5,000,000	5,180,000	5,370,000

SAN ONOFRE NUCLEAR GENERATING STATION

Location: San Diego County, California
8 km (5 miles) SE of San Clemente
latitude 33.3703°N; longitude 117.5569°W

Licensee: Southern California Edison Co.

Unit Information	Unit 1	Unit 2	Unit 3
Docket Number	50-206	50-361	50-362
Construction Permit	1964	1973	1973
Operating License	1967	1982	1983
Commercial Operation	1968	1983	1984
License Expiration	2007	2022	2023
Licensed Thermal Power [MW(t)]	1347	3390	3390
Design Electrical Rating [net MW(e)]	436	1070	1080
Type of Reactor	PWR	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	CE	CE

Cooling Water System

Type: once through
Source: Pacific Ocean
Source Temperature Range: 12-23°C (54-73°F)
Condenser Flow Rate: 21.51 m^3/s (340,900 gal/min) for Unit 1
50.3 m^3/s (797,000 gal/min) each for Units 2 & 3
Design Condenser Temperature Rise: 11°C (19°F) for Unit 1
11°C (20°F) For Units 2 & 3
Intake Structure: Unit 1—intake 980 m (3200 ft) from shore; Units 2 & 3—velocity-cap structure about 1040 m (3400 ft) from shore in water 9 m (30 ft) deep
Discharge Structure: Unit 1-discharged 790 m (2600 ft) from shore in water 7.3 m (24 ft) deep; Units 2 & 3-diffuser port systems extending 1160 m to 2590 m (3800 to 8500 ft) from shore

Site Information

Total Area: 34 ha (84 acres)
Exclusion Distance: 0.60 (0.37 mile)
Low Population Zone: 3.14 km (1.95 miles)
Nearest City: Oceanside; 1980 population: 76,698
Site Topography: narrow sloping coastal plain and sea cliffs
Surrounding Area Topography: hilly
Land Use within 8 km (5 miles): military reservation
Nearby Features: The nearest town is San Clemente 8 km (5 miles) NW. The site is surrounded by Camp Pendleton Marine Base. Camps on the base are 2.4 km (1.5 miles) or more from the site. U.S. Highway I-5 and the Atchison, Topeka, and Santa Fe Railroad are adjacent to the site to the east.

Area of Transmission Line Corridor: 450 ha (1100 acres)

Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
5,430,000	5,950,000	6,400,000	7,050,000	7,760,000

SEABROOK STATION

Location:	Rockingham County, New Hampshire 21 km (13 miles) SSW of Portsmouth latitude 42.8983°N; longitude 70.8497°W
Licensee:	Public Service Company of New Hampshire

Unit Information	Unit 1
Docket Number	50-443
Construction Permit	1976
Operating License	1990
Commercial Operation	--
License Expiration	2032
Design Thermal Power [MW(t)]	3411
Design Electrical Rating [net MW(e)]	1198
Type of Reactor	PWR
Nuclear Steam Supply System Vendor	WEST

Cooling Water System

Type: once through
Source: Atlantic Ocean
Source Temperature Range: 3-13°C (37-55°F)
Condenser Flow Rate: 25.2 m^3/s (399,000 gal/min)
Design Condenser Temperature Rise: 21°C (38°F)
Intake Structure: 3 structures 15 m (50 ft) below sea level with pipeline submerged about 50 m (175 ft) below mean sea level and extending about 2100 m (7000 ft) offshore
Discharge Structure: submerged pipeline ending in a diffuser located about 1675 m (5500 ft) offshore and about 1525 m (5000 ft) S of intake

Site Information

Total Area: 363 ha (896 acres)
Exclusion Distance: 0.92-km (0.57-mile) minimum
Low Population Zone: 2.01 km (1.25 miles)
Nearest City: Lawrence, Massachusetts; 1980 population: 63,175
Site Topography: flat
Surrounding Area Topography: flat to rolling
Land Use within 8 km (5 miles): undeveloped salt-water marshes with some industrial, residential, and recreational
Nearby Features: The nearest town is Seabrook 1.6 km (1 mile) W. U.S. Highway I-95 is about 1.6 km (1 mile) W. The Boston and Maine Railroad is adjacent to the site. Hampton Beach State Park is 3 km (2 miles) E.
Area of Transmission Line Corridor: 625 ha (1545 acres)

Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
3,760,000	3,900,000	4,010,000	4,220,000	4,450,000

SEQUOYAH NUCLEAR PLANT

Location: Hamilton County, Tennessee
16 km (10 miles) NE of Chattanooga
latitude 35.2233°N; longitude 85.0878°W

Licensee: Tennessee Valley Authority

Unit Information	Unit 1	Unit 2
Docket Number	50-327	50-328
Construction Permit	1970	1970
Operating License	1980	1981
Commercial Operation	1981	1982
License Expiration	2020	2021
Licensed Thermal Power [MW(t)]	3411	3411
Design Electrical Rating [net MW(e)]	1148	1148
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: once through and/or natural draft cooling towers
Source: Chickamauga Lake
Source Temperature Range: 6-28°C (42-83°F)
Condenser Flow Rate: 32.9 m^3/s (522,000 gal/min) each unit
Design Condenser Temperature Rise: 17°C (30°F)
Intake Structure: intake from lake
Discharge Structure: discharge to lake

Site Information

Total Area: 212 ha (525 acres)
Exclusion Distance: 0.56 km (0.35 mile)
Low Population Zone: 4.83 km (3.00 miles)
Nearest City: Chattanooga; 1980 population: 169,514
Site Topography: rolling
Surrounding Area Topography: hilly
Land Use within 8 km (5 miles): some residential and recreational
Nearby Features: The nearest town is Shady Grove about 3 km (2 miles) NW. Harrison Bay State Park is 5 km (3 miles) S. The Volunteer Ordnance Works is about 15 km (9 miles) S. Chickamauga Lake is part of the Tennessee River.
Area of Transmission Line Corridor: 510 ha (1260 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
930,000	1,020,000	1,090,000	1,210,000	1,330,000

SHOREHAM NUCLEAR POWER STATION

Location: Suffolk County, New York
19 km (12 miles) NW of Riverhead
latitude 40.9583°N; longitude 72.8667°W
Licensee: Long Island Lighting Co.

Unit Information

Docket Number	50-322
Construction Permit	1973
Operating License	1989
Commercial Operation	--
License Expiration	2013
Design Thermal Power [MW(t)]	2436
Design Electrical Rating [net MW(e)]	819
Type of Reactor	BWR
Nuclear Steam Supply System Vendor	GE

Cooling Water System

Type: once through
Source: Long Island Sound
Source Temperature Range: 2-23°C (36-74°F)
Condenser Flow Rate: 36.19 m^3/s (573,600 gal/min)
Design Condenser Temperature Rise: 11°C (20°F)
Intake Structure: intake canal
Discharge Structure: diffuser system

Site Information

Total Area: 202 ha (499 acres)
Exclusion Distance: 0.31 km (0.19 mile)
Low Population Zone: 3.22 km (2.00 miles)
Nearest City: New Haven, Connecticut; 1980 population: 126,089
Site Topography: flat to rolling
Surrounding Area Topography: rolling to hilly
Land Use within 8 km (5 miles): some residential and recreational
Nearby Features: The nearest town is Shoreham 3 km (2 miles) W. Brookhaven State Park is about 3 km (2 miles) S. Brookhaven National Laboratory is about 11 km (7 miles) S. Grumman Peconic River Airport is about 10 km (6 miles) SE. Wildwood State Park is about 6 km (4 miles) E.
Area of Transmission Line Corridor: 16 ha (39 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
5,390,000	5,400,000	5,420,000	5,550,000	5,690,000

Note: This plant has not been allowed to operate due to litigation concerning emergency response.

SOUTH TEXAS PROJECT

Location: Matagorda County, Texas
19 km (12 miles) SSW of Bay City
latitude 28.7950°N; longitude 96.0481°W

Licensee: Houston Lighting and Power Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-498	50-499
Construction Permit	1975	1975
Operating License	1988	1989
Commercial Operation	1988	1989
License Expiration	2028	2029
Licensed Thermal Power [MW(t)]	3800	3800
Design Electrical Rating [net MW(e)]	1250	1250
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: closed cycle cooling reservoir
Source: Colorado River
Source Temperature Range: 14-29°C (58-84°F)
Condenser Flow Rate: 57.26 m^3/s (907,400 gal/min) each unit
Design Condenser Temperature Rise: 11°C (19°F)
Intake Structure: on bank of Colorado River
Discharge Structure: on bank of Colorado River

Site Information

Total Area: 4998 ha (12,350 acres)
Exclusion Distance: 1.43-km (0.89-mile) minimum
Low Population Zone: 4.83 km (3.00 miles)
Nearest City: Galveston; 1980 population: 61,902
Site Topography: flat
Surrounding Area Topography: flat
Land Use within 8 km (5 miles): agricultural
Nearby Features: The nearest town is Matagorda 13 km (8 miles) SE. The Missouri Pacific Railroad is about 8 km (5 miles) NNE. A 40-cm (16-inch) natural gas pipeline is about 3 km (2 miles) NW.
Area of Transmission Line Corridor: 1932 ha (4773 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
270,000	300,000	320,000	350,000	380,000

ST. LUCIE PLANT

Location: St. Lucie County, Florida
11 km (7 miles) SE of Fort Pierce
latitude 27.3486°N; longitude 80.2464°W
Licensee: Florida Power and Light Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-335	50-389
Construction Permit	1970	1977
Operating License	1976	1983
Commercial Operation	1976	1983
License Expiration	2016	2023
Licensed Thermal Power [MW(t)]	2700	2700
Design Electrical Rating [net MW(e)]	830	830
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	CE	CE

Cooling Water System

Type: once through
Source: Atlantic Ocean
Source Temperature Range: 31°C (87°F) maximum
Condenser Flow Rate: 30.96 m^3/s (490,600 gal/min) each unit
Design Condenser Temperature Rise: 14°C (25°F)
Intake Structure: 370 m (1200 ft) offshore
Discharge Structure: Unit 1 is 370 m (1200 ft) offshore; Unit 2 is a multiport discharge 900 m (3000 ft) offshore; both structures are 730 (2400 ft) from the intake structures.

Site Information

Total Area: 458 ha (1132 acres)
Exclusion Distance: 1.56-km (0.97-mile) radius
Low Population Zone: 1.61 km (1.00 mile)
Nearest City: West Palm Beach; 1980 population: 62,530
Site Topography: flat land and water
Surrounding Area Topography: flat
Land Use within 8 km (5 miles): expanding residential and some recreational
Nearby Features: The nearest town is Ankona 3 km (2 miles) W. The Florida East Coast Railroad is about 3 km (2 miles) W. The plant is on Hutchinson Island which is separated from the mainland by the Indian River which is part of the intercoastal waterway. A causeway to the mainland is about 10 km (6 miles) SSE.
Area of Transmission Line Corridor: 310 ha (760 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
690,000	780,000	860,000	1,040,000	1,250,000

VIRGIL C. SUMMER NUCLEAR STATION

Location: Fairfield County, South Carolina
42 km (26 miles) NW of Columbia
latitude 34.2958°N; longitude 81.3203°W
Licensee: South Carolina Electric and Gas Co.

Unit Information	Unit 1
Docket Number	50-395
Construction Permit	1973
Operating License	1982
Commercial Operation	1984
License Expiration	2022
Licensed Thermal Power [MW(t)]	2775
Design Electrical Rating [net MW(e)]	900
Type of Reactor	PWR
Nuclear Steam Supply System Vendor	WEST

Cooling Water System

Type: once through
Source: Lake Monticello
Source Temperature Range: 11-33°C (52-91°F)
Condenser Flow Rate: 30.6 m^3/s (485,000 gal/min)
Design Condenser Temperature Rise: 14°C (25°F)
Intake Structure: intake at shoreline
Discharge Structure: discharge to lake via a discharge pond

Site Information

Total Area: 890 ha (2200 acres)
Exclusion Distance: 1.63-km (1.01-mile) radius
Low Population Zone: 4.83 (3.00 miles)
Nearest City: Columbia; 1980 population: 101,229
Site Topography: rolling
Surrounding Area Topography: rolling to hilly
Land Use within 8 km (5 miles): mostly wooded with some agricultural
Nearby Features: The nearest town is Jenkinsville 5 km (3 miles) SE. U.S. Highway I-26 is 11 km (7 miles) SSW. The Southern Railroad is 1.6 km (1 mile) W. The Fairfield pumped storage hydrostation is about 1.6 km (1 mile) NW and uses Lake Monticello as well as the Parr Reservoir.
Area of Transmission Line Corridor: 638 ha (1576 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
910,000	990,000	1,080,000	1,220,000	1,390,000

SURRY POWER STATION

Location: Surry County, Virginia
27 km (17 miles) NW of Newport News
latitude 37.1656°N; longitude 76.6983°W

Licensee: Virginia Electric and Power Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-280	50-281
Construction Permit	1968	1968
Operating License	1972	1973
Commercial Operation	1972	1973
License Expiration	2012	2013
Licensed Thermal Power [MW(t)]	2441	2441
Design Electrical Rating [net MW(e)]	788	788
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: once through
Source: James River
Source Temperature Range: 2-29°C (35-84°F)
Condenser Flow Rate: 53 m^3/s (840,000 gal/min) each unit
Design Condenser Temperature Rise: 8°C (14°F)
Intake Structure: 2.7-km (1.7-mile) concrete canal
Discharge Structure: 880-m (2900-ft) canal

Site Information

Total Area: 340 ha (840 acres)
Exclusion Distance: 0.50 km (0.31 mile)
Low Population Zone: 4.83 km (3.00 miles)
Nearest City: Newport News; 1980 population: 144,903
Site Topography: flat
Surrounding Area Topography: flat
Land Use within 8 km (5 miles): agriculture, military reservations, recreation
Nearby Features: The nearest town is Scotland 8 km (5 miles) W. Jamestown Island, a Federal park, is 6 km (4 miles) NW. Chippokes Plantation, a state park, is 5 km (3 miles) WSW. Jamestown National Historical Park is 8 km (5 miles) WNW. Colonial Williamsburg is 11 km (7 miles) NNW. These numerous attractions bring many visitors to the area. Adjacent to the site on the north is Hog Island, a waterfowl refuge. U.S. Highway I-64 is 19 km (12 miles) NW.
Area of Transmission Line Corridor: 1790 ha (4420 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
1,900,000	2,080,000	2,240,000	2,510,000	2,800,000

SUSQUEHANNA STEAM ELECTRIC STATION

Location: Luzerne County, Pennsylvania
11 km (7 miles) NE of Berwick
latitude 41.0922°N; longitude 76.1467°W

Licensee: Pennsylvania Power and Light Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-387	50-388
Construction Permit	1973	1973
Operating License	1982	1984
Commercial Operation	1983	1985
License Expiration	2022	2024
Licensed Thermal Power [MW(t)]	3293	3293
Design Electrical Rating [net MW(e)]	1050	1050
Type of Reactor	BWR	BWR
Nuclear Steam Supply System Vendor	GE	GE

Cooling Water System

Type: natural draft cooling towers
Source: Susquehanna River
Source Temperature Range:
Condenser Flow Rate: 28.3 m^3/s (448,000 gal/min) each unit
Design Condenser Temperature Rise: 8°C (14°F)
Intake Structure: at river bank
Discharge Structure: diffuser pipe 73 m (240 ft) from river bank

Site Information

Total Area: 435 ha (1075 acres)
Exclusion Distance: 0.55-km (0.34-mile) radius
Low Population Zone: 4.83 km (3.00 miles)
Nearest City: Wilkes-Barre; 1980 population 51,551
Site Topography: rolling
Surrounding Area Topography: hilly with flat river valley
Land Use within 8 km (5 miles): wooded and agricultural
Nearby Features: The nearest town is Beach Haven about 1.6 km (1 mile) SW. U.S. Highway I-80 is 8 km (5 miles) S. The ConRail Railroad is 0.8 km (0.5) mile E and the Delaware and Hudson Railroad is 1.6 km (1 mile) E.
Area of Transmission Line Corridor: 730 ha (1800 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
1,500,000	1,510,000	1,530,000	1,550,000	1,580,000

THREE MILE ISLAND NUCLEAR STATION

Location: Dauphin County, Pennsylvania
16 km (10 miles) SE of Harrisburg
latitude 40.1531°N; longitude 76.7250°W

Licensee: Metropolitan Edison Co.

Unit Information	Unit 1
Docket Number	50-289
Construction Permit	1968
Operating License	1974
Commercial Operation	1974
License Expiration	2014
Licensed Thermal Power [MW(t)]	2568
Design Electrical Rating [net MW(e)]	819
Type of Reactor	PWR
Nuclear Steam Supply System Vendor	B&W

Cooling Water System

Type: natural draft cooling towers
Source: Susquehanna River
Source Temperature Range: 1-29°C (33-85°F)
Condenser Flow Rate: 27 m^3/s (430,000 gal/min)
Design Condenser Temperature Rise:
Intake Structure: concrete structure on river bank
Discharge Structure: discharged at the shoreline

Site Information

Total Area: 191 ha (472 acres)
Exclusion Distance: 0.61-km (0.38-mile) radius
Low Population Zone: 3.22 km (2.00 miles)
Nearest City: Harrisburg; 1980 population: 53,264
Site Topography: flat
Surrounding Area Topography: rolling to hilly
Land Use within 8 km (5 miles): agricultural
Nearby Features: The nearest town is Middletown 6 km (4 miles) N. Harrisburg-York airport is 13 km (8 miles) WNW. Unit 2 ceased operation after an accident in 1979. Peach Bottom Atomic Power Station is 56 km (35 miles) downstream.
Area of Transmission Line Corridor: 725 ha (1790 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
2,170,000	2,210,000	2,240,000	2,290,000	2,350,000

TROJAN NUCLEAR PLANT

Location: Columbia County, Oregon
51 km (32 miles) N of Portland
latitude 46.0408°N; longitude 122.8844°W
Licensee: Portland General Electric Co.

Unit Information	Unit 1
Docket Number	50-344
Construction Permit	1971
Operating License	1975
Commercial Operation	1976
License Expiration	2015
Licensed Thermal Power [MW(t)]	3411
Design Electrical Rating [net MW(e)]	1130
Type of Reactor	PWR
Nuclear Steam Supply System Vendor	WEST

Cooling Water System

Type: natural draft cooling tower
Source: Columbia River
Source Temperature Range:
Condenser Flow Rate: 27.04 m^3/s (428,600 gal/min)
Design Condenser Temperature Rise: 25°C (45°F)
Intake Structure: at river bank
Discharge Structure: submerged pipe extending 110 m (350 ft) from river bank

Site Information

Total Area: 257 ha (635 acres)
Exclusion Distance: 0.66-km (0.41-mile) minimum
Low Population Zone: 4.02-km (2.50-mile) radius
Nearest City: Portland; 1980 population: 368,148
Site Topography: flat to rolling
Surrounding Area Topography: hilly to mountainous
Land Use within 8 km (5 miles): wooded
Nearby Features: The nearest town is Prescott 0.8 km (0.5 mile) N. The Burlington Northern Railroad is just W of the site. Gifford Pinchot National Forest and Mount St. Helens National Monument are about 48 km (30 miles) ENE.
Area of Transmission Line Corridor: 510 ha (1260 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
1,850,000	2,160,000	2,430,000	2,820,000	3,780,000

TURKEY POINT PLANT

Location: Dade County, Florida
40 km (25 miles) S of Miami
latitude 25.4350°N; longitude 80.3314°W
Licensee: Florida Power and Light Co.

Unit Information	Unit 3	Unit 4
Docket Number	50-250	50-251
Construction Permit	1967	1967
Operating License	1972	1973
Commercial Operation	1972	1973
License Expiration	2012	2013
Licensed Thermal Power [MW(t)]	2200	2200
Design Electrical Rating [net MW(e)]	693	693
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: closed cycle canal
Source: Biscayne Bay
Source Temperature Range: 12-32°C (54-90°F)
Condenser Flow Rate: 39.4 m^3/s (624,000 gal/min) each unit
Design Condenser Temperature Rise: 9°C (16°F)
Intake Structure: intake canal and barge canal
Discharge Structure: canal system covering about 1600 ha (4000 acres)

Site Information

Total Area: 9700 ha (24,000 acres)
Exclusion Distance: 1.27 km (0.79 mile)
Low Population Zone: 8.05 km (5.00 miles)
Nearest City: Miami; 1980 population: 346,681
Site Topography: flat
Surrounding Area Topography: flat
Land Use within 8 km (5 miles): mostly undeveloped
Nearby Features: The nearest town is Florida City about 14 km (9 miles) W. Hawk Missile Base is 1.6 km (1 mile) NW. Homestead recreation park is about 3 km (2 miles) NNW. The Florida East Coast Railroad is about 14 km (9 miles) NW. Units 1 and 2 are coal fired and adjacent to the site.
Area of Transmission Line Corridor: 331 ha (817 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
2,700,000	3,070,000	3,420,000	4,160,000	5,050,000

VERMONT YANKEE NUCLEAR POWER STATION

Location: Windham County, Vermont
8 km (5 miles) S of Brattleboro
latitude 42.7803°N; longitude 72.5158°W

Licensee: Vermont Yankee Nuclear Power Corp.

Unit Information	Unit 1
Docket Number	50-271
Construction Permit	1967
Operating License	1973
Commercial Operation	1972
License Expiration	2013
Licensed Thermal Power [MW(t)]	1593
Design Electrical Rating [net MW(e)]	540
Type of Reactor	BWR
Nuclear Steam Supply System Vendor	GE

Cooling Water System

Type: once through & helper towers
Source: Connecticut River
Source Temperature Range: 0-23°C (32-74°F)
Condenser Flow Rate: 23.1 m^3/s (366,000 gal/min)
Design Condenser Temperature Rise: 11°C (20°F)
Intake Structure: concrete structure at edge of river
Discharge Structure: aerating structure discharging at edge of river

Site Information

Total Area: 50.6 ha (125 acres)
Exclusion Distance: 0.27 km (0.17 mile)
Low Population Zone: 8.05 km (95.00 miles)
Nearest City: Holyoke, Massachusetts: 1980 population: 44,678
Site Topography: flat
Surrounding Area Topography: rolling to hilly
Land Use within 8 km (5 miles): mostly wooded, some agricultural and industrial
Nearby Features: The nearest town is Vernon about 1.6 km (1 mile) W. Vernon Dam is 1 km (0.7 mile) downstream from the site. The Yankee Nuclear Power Station is about 32 km (20 miles) WSW.
Area of Transmission Line Corridor: 627 ha (1550 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
1,510,000	1,580,000	1,620,000	1,710,000	1,800,000

VOGTLE ELECTRIC GENERATING PLANT

Location: Burke County, Georgia
42 km (26 miles) SE of Augusta
latitude 33.1414°N; longitude 81.7625°W

Licensee: Georgia Power Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-424	50-425
Construction Permit	1974	1974
Operating License	1987	1989
Commercial Operation	1987	1989
License Expiration	2027	2029
Licensed Thermal Power [MW(t)]	3411	3411
Design Electrical Rating [net MW(e)]	1101	1160
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: natural draft cooling towers
Source: Savannah River
Source Temperature Range: 4-30°C (39-86°F)
Condenser Flow Rate: 32.16 m^3/s (509,600 gal/min) each unit
Design Condenser Temperature Rise: 18°C (33°F)
Intake Structure: at river bank
Discharge Structure: single-point discharge pipe near the shoreline

Site Information

Total Area: 1282 ha (3169 acres)
Exclusion Distance: 1.09-km (0.68-mile) minimum
Low Population Zone: 3.22-km (2.00-mile) radius
Nearest City: Augusta; 1980 population: 47,532
Site Topography: rolling
Surrounding Area Topography: rolling, river flood plain
Land Use within 8 km (5 miles): Department of Energy Savannah River Plant, some farming and wooded
Nearby Features: The nearest town is Shell Bluff about 11 km (7 miles) W. The Seaboard Coast Line Railroad is about 6 km (4 miles) NE. The Department of Energy Savannah River Plant is about 16 km (10 miles) NNE.
Area of Transmission Line Corridor:
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
630,000	690,000	750,000	840,000	930,000

WASHINGTON NUCLEAR PROJECT 2
(WNP-2)

Location: Benton County, Washington
19 km (12 miles) NW of Richland
latitude 46.4714°N; longitude 119.3331°W
Licensee: Washington Public Power Supply System

Unit Information	Unit 2
Docket Number	50-397
Construction Permit	1973
Operating License	1984
Commercial Operation	1984
License Expiration	2024
Licensed Thermal Power [MW(t)]	3323
Design Electrical Rating [net MW(e)]	1100
Type of Reactor	BWR
Nuclear Steam Supply System Vendor	GE

Cooling Water System

Type: mechanical draft cooling towers
Source: Columbia River
Source Temperature Range: 3-18°C (38-64°F)
Condenser Flow Rate: 35 m^3/s (550,000 gal/min)
Design Condenser Temperature Rise: 15.9°C (28.7°F)
Intake Structure: 2 perforated pipe inlets supported offshore above the river bed 270 m (900 ft) from pump structure on river bank
Discharge Structure: buried 5-km (3-mile) pipeline terminating at the river bed 53 m (175 ft) from the shoreline

Site Information

Total Area: on Department of Energy Hanford Reservation
Exclusion Distance: 1.95-km (1.21-mile) radius
Low Population Zone: 4.83 km (3.00 miles)
Nearest City: Spokane; 1980 population: 171,300
Site Topography: flat
Surrounding Area Topography: flat
Land Use within 8 km (5 miles): Hanford Reservation and agricultural
Nearby Features: The nearest town is Richland 14 km (9 miles) S. The site is in the SE part of the Hanford Reservation.
Area of Transmission Line Corridor: on Hanford Reservation
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
280,000	310,000	330,000	370,000	410,000

WATERFORD STEAM ELECTRIC STATION

Location: St. Charles County, Louisiana
32 km (20 miles) W of New Orleans
latitude 29.9947°N; longitude 90.4711°W

Licensee: Louisiana Power and Light Co.

Unit Information	Unit 3
Docket Number	50-382
Construction Permit	1974
Operating License	1985
Commercial Operation	1985
License Expiration	2025
Licensed Thermal Power [MW(t)]	3390
Design Electrical Rating [net MW(e)]	1104
Type of Reactor	PWR
Nuclear Steam Supply System Vendor	CE

Cooling Water System

Type: once through
Source: Mississippi River
Source Temperature Range: 8-28°C (46-82°F)
Condenser Flow Rate: 61.53 m^3/s (975,100 gal/min)
Design Condenser Temperature Rise: 9°C (16°F)
Intake Structure: at river bank
Discharge Structure: at river bank

Site Information

Total Area: 1441 ha (3561 acres)
Exclusion Distance: 0.92-km (90.57-mile) radius
Low Population Zone: 3.22 km (2.00 miles)
Nearest City: New Orleans; 1980 population: 557,927
Site Topography: flat
Surrounding Area Topography: flat
Land Use within 8 km (5 miles): industrial, agricultural, recreational, and residential
Nearby Features: The nearest town is Killona 1.6 km (1 mile) WNW. U.S. Highway I-10 is about 11 km (7 miles) NE and I-90 about 11 km (7 miles) SE. Several active and abandoned gas and oil fields are with in 16 km (10 miles). Lake Pontchartrain is about 11 km (7 miles) NE. The Missouri Pacific Railroad is just S of the site and the Southern Pacific Railroad is about 13 km (8 miles) SE.
Area of Transmission Line Corridor: 110 ha (280 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
1,970,000	2,130,000	2,290,000	2,520,000	2,780,000

WATTS BAR NUCLEAR PLANT

Location: Rhea County, Tennessee
11 km (7 miles) SSE of Spring City
latitude 35.6022°N; longitude 84.7894°W
Licensee: Tennessee Valley Authority

Unit Information	Unit 1	Unit 2
Docket Number	50-390	50-391
Construction Permit	1973	1973
Operating License	--	--
Commercial Operation	--	--
License Expiration	--	--
Design Thermal Power [MW(t)]	3411	3411
Design Electrical Rating [net MW(e)]	1170	1170
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: natural draft cooling towers
Source: Chickamauga Lake
Source Temperature Range: 6-28°C (43-82°F)
Condenser Flow Rate: 26 m^3/s (410,000 gal/min) each unit
Design Condenser Temperature Rise: 21°C (38°F)
Intake Structure: at lake bank
Discharge Structure: to lake via a holding pond

Site Information

Total Area: 716 ha (1770 acres)
Exclusion Distance: 1.21 km (0.75 mile) radius
Low Population Zone: 4.83 km (3.00 miles)
Nearest City: Chattanooga; 1980 population: 169,514
Site Topography: flat to rolling
Surrounding Area Topography: rolling to hilly
Land Use within 8 km (5 miles): wooded with some agricultural
Nearby Features: The nearest town is Peakland 3 km (2 miles) NE. Watts Bar Dam is 1.6 km (1 mile) N. A fossil-fired steam plant is just N of the site. U. S. Highway I-75 is about 18 km (11 miles) SE. The New Orleans and Texas Pacific Railroad is 11 km (7 miles) NW. Chickamauga Lake is on the Tennessee River.
Area of Transmission Line Corridor: 1281 ha (3165 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
950,000	1,040,000	1,120,000	1,240,000	1,370,000

WOLF CREEK GENERATING STATION

Location: Coffey County, Kansas
6 km (4 miles) NE of Burlington
latitude 38.2386°N; longitude 95.6894°W
Licensee: Wolf Creek Nuclear Operating Corp.

Unit Information	Unit 1
Docket Number	50-482
Construction Permit	1977
Operating License	1985
Commercial Operation	1985
License Expiration	2025
Licensed Thermal Power [MW(t)]	3411
Design Electrical Rating [net MW(e)]	1170
Type of Reactor	PWR
Nuclear Steam Supply System Vendor	WEST

Cooling Water System

Type: closed cycle cooling lake
Source: Wolf Creek
Source Temperature Range: 0-31°C (32-87°F)
Condenser Flow Rate: 30 m^3/s (500,000 gal/min)
Design Condenser Temperature Rise: 17.5°C (31.5°F)
Intake Structure: structure on shore of cooling lake
Discharge Structure: discharged to 2060-ha (5090-acre) cooling lake into an embayment separated from the intake

Site Information

Total Area: 3973 ha (9818 acres)
Exclusion Distance: 1.21-km (0.75-mile) radius
Low Population Zone: 4.02-km (2.50-mile) radius
Nearest City: Topeka; 1980 population: 118,690
Site Topography: flat to rolling
Surrounding Area Topography: flat to rolling
Land Use within 8 km (5 miles): agricultural and range land
Nearby Features: The nearest town is Sharpe about 3 km (2 miles) N. The Flint Hills National Wildlife Refuge is about 11 km (7 miles) W. The John Redmond Reservoir is about 6 km (4 miles) W. U.S. Highway I-35 is 23 km (14 miles) N. The cooling lake is formed by a dam on Wolf Creek.
Area of Transmission Line Corridor: 1200 ha (2900 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
200,000	210,000	220,000	250,000	270,000

YANKEE NUCLEAR POWER STATION

Location: Franklin County, Massachusetts
34 km (21 miles) NE of Pittsfield
latitude 42.7281°N; longitude 72.9289°W
Licensee: Yankee Atomic Electric Co.

Unit Information	Unit 1
Docket Number	50-029
Construction Permit	1957
Operating License	1960
Commercial Operation	1961
License Expiration	2000
Licensed Thermal Power [MW(t)]	600
Design Electrical Rating [net MW(e)]	175
Type of Reactor	PWR
Nuclear Steam Supply System Vendor	WEST

Cooling Water System

Type: once through
Source: Deerfield River
Source Temperature Range: 2-20°C (35-68°F)
Condenser Flow Rate: 8.8 m^3/s (140,000 gal/min)
Design Condenser Temperature Rise: 13°C (24°F)
Intake Structure: intake from Sherman Pond about 27 m (90 ft) below normal pond level.
Discharge Structure: discharge to Sherman Pond

Site Information

Total Area: 800 ha (2000 acres)
Exclusion Distance: 0.95 km (0.59 mile)
Low Population Zone: 8.05 km (95.00 miles)
Nearest City: Pittsfield; 1980 population: 51,974
Site Topography: hilly
Surrounding Area Topography: very hilly
Land Use within 8 km (5 miles): some maple syrup production
Nearby Features: The nearest town is Monroe Bridge 1.6 km (1 mile) WSW. Sherman Pond is adjacent to the site and discharges to the Deerfield River. A hydro station is just below the dam. Vermont Yankee Nuclear Power Station is about 32 km (20 miles) ENE. There are many ski resorts in the area.
Area of Transmission Line Corridor:
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
1,720,000	1,760,000	1,800,000	1,870,000	1,950,000

ZION NUCLEAR PLANT

Location: Lake County, Illinois
10 km (6 miles) N of Waukegan
latitude 42.4456°N; longitude 87.8022°W
Licensee: Commonwealth Edison Co.

Unit Information	Unit 1	Unit 2
Docket Number	50-295	50-304
Construction Permit	1968	1968
Operating License	1973	1973
Commercial Operation	1973	1974
License Expiration	2013	2013
Licensed Thermal Power [MW(t)]	3250	3250
Design Electrical Rating [net MW(e)]	1040	1040
Type of Reactor	PWR	PWR
Nuclear Steam Supply System Vendor	WEST	WEST

Cooling Water System

Type: once through
Source: Lake Michigan
Source Temperature Range: 0-19°C (32-66°F)
Condenser Flow Rate: 46.4 m^3/s (735,000 gal/min) each unit
Design Condenser Temperature Rise: 11°C (20°F)
Intake Structure: Intake is located 790 m (2600 ft) offshore in water 6.7 m (22 ft) deep. Intake cap is 3 m (10 ft) below normal lake surface.
Discharge Structure: Each unit has a separate discharge structure 230 m (760 ft) from shoreline.

Site Information

Total Area: 100 ha (250 acres)
Exclusion Distance: 0.40-km (0.25-mile) radius
Low Population Zone: 1.61-km (1.00-mile) radius
Nearest City: Waukegan; 1980 population: 67,653
Site Topography: flat
Surrounding Area Topography: flat
Land Use within 8 km (5 miles): residential, industrial, agricultural, and recreational
Nearby Features: Site is bounded by the Illinois Beach State Park on the south, a city park on the north, the town of Zion on the west, and Lake Michigan on the east. A railroad runs along the western site boundary. U.S. Highway I-94 is 10 km (6 miles) W.
Area of Transmission Line Corridor: 58.7 ha (145 acres)
Population within an 80-km (50-mile) radius:

1990	2000	2010	2030	2050
7,480,000	7,720,000	7,900,000	8,200,000	8,520,000

REFERENCES

Nuclear Safety Journal, various issues 1957—1979.

NUREG-0020, Vol. 9, *Licensed Operating Reactors, Summary Status Report: Data as of 8-31-85,* U.S. Nuclear Regulatory Commission, Office of Resource Management, Division of Budget and Analysis, October 1985.

ORNL-NSIC-55, Vols. 1 and 2, F. A. Heddleson, *Design Data and Safety Features of Commercial Nuclear Power Plants,* Oak Ridge National Laboratory, Oak Ridge, Tennessee, November 1973.

WASH-1319, W. Ramsay and P. R. Reed, *Land Use and Nuclear Power Plants: Case Studies of Siting Problems,* U.S. Atomic Energy Commission, October 1974.

APPENDIX B

DEFINITION OF IMPACT INITIATORS FOR NUCLEAR PLANT LICENSE RENEWAL GENERIC ENVIRONMENTAL IMPACT STUDY

DEFINITION OF IMPACT INITIATORS FOR NUCLEAR PLANT LICENSE RENEWAL GENERIC ENVIRONMENTAL IMPACT STUDY

B.1 INTRODUCTION

Chapter 2 described the nuclear plant programs characterized for the purpose of assessing possible environmental impacts associated with license renewal. Both typical and conservative programs for both boiling-water reactors (BWRs) and pressurized-water reactors (PWRs) were described, together with the underlying assumptions and bases used in the development of these programs. Chapter 2 also presented estimates of the incremental environmental impact initiators associated with nuclear power plant license renewal.

This appendix provides additional discussion of impact initiator estimates. Additional factors and details are discussed, and comparisons are provided with license renewal-related impact initiator estimates derived from other sources. This appendix also compares the differences in impact initiators between the typical and conservative programs.

As noted in Chapter 2, license renewal for a particular plant will be based on ensuring compliance by the licensee with the current licensing basis for that plant (i.e., the original plant licensing basis as amended during the initial license term). In addition, the licensees will be required to demonstrate for certain important systems, structures, and components (SSC) that the effects of aging will be managed in the renewal period in a manner such 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 as readily monitorable performance or condition characteristics and include most passive, long-lived plant SSCs. Therefore, the Nuclear Regulatory Commission's (NRC's) license renewal rule requires a systematic review of, as a minimum, passive, long-lived SSCs that support safety or other critical functions of a nuclear power facility. To make these determinations regarding these SSCs, it is expected that licensees will implement aging management activities for SSCs for which current programs are not adequate to ensure continued functionality in the renewal term. These aging management activities are expected to include surveillance, on-line monitoring, inspections, testing, trending, and recordkeeping (SMITTR) as appropriate. This enhanced activity, together with updated aging assessments, is intended to ensure that aging-related degradation of important SSCs is detected and mitigated in a timely manner. The satisfactory fulfillment of NRC requirements for license renewal may necessitate repairs or modifications to the facility or its operations which are incremental to corresponding actions being performed during the term of the current license. Note that the license renewal rule does not require any specific modifications to a facility.

In addition to those actions required by 10 CFR Part 54 or other licensing requirements, licensees may undertake various refurbishment and upgrade activities at nuclear plants to better ensure economic and reliable power generation from these facilities. These activities performed for safety and/or economic reasons can result in environmental initiators which are different from those incurred in the original licensing term.

B.1.1 Purpose

The primary objective of the effort discussed here was the development of quantitative estimates of selected license renewal-related environmental impact initiators. The term "impact initiators" was defined in Chapter 2. The resulting impact initiator estimates were used in developing the Generic Environmental Impact Statement (GEIS) to support nuclear plant license renewal rulemaking. All initiators characterized in this appendix are incremental relative to those already experienced with current nuclear plant operation. The incremental environmental impact initiators expected to result from license renewal-related activities are as follows:

- labor hours and work force size;
- labor costs;
- occupational radiation exposure;
- capital costs; and
- radioactive waste types, volumes, and disposal costs.

As noted in Chapter 2, the impact initiators cited above are those which result from nuclear plant incremental aging management activities. These are the incremental activities performed to support license renewal and extended plant operation. 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). The impact initiators assessed herein form a sufficient set from which to assess most license renewal-related environmental impacts.

Two types of license renewal program estimates are developed herein. The first applies to "typical" license renewal programs and is intended to be representative of the type of programs that most plants seeking license renewal might implement. The second is more encompassing and is intended to be an upper bound as to the impacts likely to be generated at any particular plant.

Both types of estimates are useful. The typical scenarios are useful for estimating impacts from an "average" license renewal program and for estimating total nuclear plant population impacts on the nation as a whole. The typical programs are intended to be representative of plants that have been reasonably well maintained and that have already undertaken most major refurbishment activities that might have been necessary. The conservative scenario estimates, on the other hand, are useful for estimating the maximum impacts likely to result from any individual plant's license renewal program.

B.1.2 Scope and Organization

This appendix presents estimates of potential environmental impact initiators that may result from nuclear plant license renewal. These quantitative estimates apply to an assumed approach to aging management for two specific reactor plant types, BWRs and PWRs. Postulated sets of license renewal activities, with separate implementation schedules, have been defined for each reactor type and for both the typical and conservative scenarios. This appendix also presents the bases and assumptions used in developing the information.

More specifically, the results include the following:

- definition of reasonable license renewal programs, which include specific activities for specific SSCs, developed separately for a generic BWR and a generic PWR;
- estimates of the labor hours, work force size, labor cost, capital cost, occupational radiation exposure, and radioactive waste associated with each activity;
- summary estimates of impact initiators associated with the conduct of an entire license renewal program; and
- definition of the rates at which impacts are accrued for each program.

This appendix presents and describes all of these results. In addition, estimates are provided of the impact initiators attributable to satisfying the proposed revision to the license renewal rule [FR 59, no. 174, 46574 (September 9, 1994)]. Possible off-site labor costs are also quantified, as are replacement energy costs for the incremental downtime needed to perform aging management activities.

To encompass the full range of individual plant license renewal actions, additional candidate programs could have been defined and characterized. These could have been developed based on other approaches to plant aging management. For example, the programs used in this analysis are characterized by extensive refurbishment and replacement of SSCs as a means of managing aging. An alternative program might be one with reliance on more extensive SMITTR activities and less reliance on refurbishment. The approach followed in this evaluation is more conservative because it results in higher estimates of impact quantities. Alternative approaches to license renewal will likely be proposed by some nuclear utilities. However, the staff believes the programs characterized here are reasonably comprehensive and provide reasonable estimates of both typical program impacts characteristic of the reactor population as a whole, and upper bound impacts associated with what might be required by a few outlier plants seeking license renewal.

Section B.2 discusses the technical approach and bases used in the development of environmental impact initiator estimates. The specific SMITTR and major refurbishment activities included in the typical and conservative license renewal programs are reviewed in Section B.3, as are additional details of the data and information development. The results of the analysis are presented in Section B.4. That section also compares the results and estimates of license renewal-related costs developed here with similar information developed by industry.

B.2 TECHNICAL APPROACH AND BASES

The overall plan for support of the GEIS was to develop, by plant category, expert estimates for the various environmental impact initiators associated with nuclear plant license renewal. Plant categories were defined based on the characteristics deemed important in determining environmental impacts. The environmental impact initiators for the two basic plant categories of interest were estimated by first defining a representative set of activities to be pursued to achieve license renewal and extended plant operation. Impact initiators (labor, radiation exposure, radioactive wastes, etc.) were then identified and quantified for each activity. These activity impacts were summed to provide an estimate of overall environmental impacts associated with each plant type and each program type.

B.2.1 Technical Approach

The work undertaken to define and characterize impact initiators in support of the GEIS development was divided into three primary technical areas. These are briefly discussed below.

B.2.1.1 Definition of Information Requirements

This effort addressed two key aspects to ensure complete support for the GEIS: (1) development of candidate lists of activities with potential environmental consequences and (2) identification of environmental attributes (impact initiators) associated with those 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 (i.e., 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 range from enhanced inspection programs to component replacement, and they include the list of activities originally developed for the License Renewal Rule Regulatory Analysis (NUREG-1362). The list of activities developed for that regulatory analysis was modified to reflect the proposed changes to the license renewal rule (10 CFR Part 54). In turn, the potential environmental impact initiators of each identified activity were examined and analyzed. Typical attributes included labor force requirements, low-level waste generation, capital costs, and worker radiation exposure.

B.2.1.2 Design of Database Extension and Application

Work performed in support of the 10 CFR Part 54 License Renewal Regulatory Analysis had initiated the development of a database of aging management and aging mitigation activities. To maintain control over the quality of the data and the effort required, the data were managed with a state-of-the-art relational database program on a microcomputer. This database application incorporated models of SMITTR effectiveness, permitting assessment of proposed aging management programs. The relational database facilitated the organization, archiving, and retrieval of the generic SMITTR data. The microcomputer database design was expanded to cover the more comprehensive information requirements related to assessing license renewal environmental impacts.

B.2.1.3 Review and Development of Data

Estimates of the potential incremental environmental attributes or challenges (i.e., impact initiators) created by license renewal-related activities were prepared for a generic BWR and a generic PWR. The plant features utilized were based on representative 1000-MW(e) plant designs. The plant designs were briefly discussed in Chapter 2. All attributes were quantified using actual data, industry estimates, or NRC's generic estimating methods. In addition, schedules were developed for implementing each activity of each program. Many activities carried out in support of license renewal and extended plant life are repeated at given intervals. For these types of activities, the repetition frequency and implementation schedule were also established.

The Part 54 Regulatory Analysis was reviewed for applicability and updated with more recent or more accurate information if available. New data requirements were evaluated and information sources identified.

All information was reviewed in detail to ascertain its accuracy and entered into a database system. The database was then sorted into the requisite plant categories and the information provided for performance of the environmental impact assessment.

B.2.1.4 Accounting for the Effects of Other NRC Regulations

All activities were reviewed for possible overlap with actions that may be undertaken to satisfy other licensee requirements, such as those imposed by the Maintenance Rule. For the typical license renewal programs, any activity potentially required by regulations other than the license renewal rule was deleted from the programs. In certain cases, activities which met this criterion were retained to encompass what licensees might do to better ensure reliable and economical plant performance, and thus to account for enhanced or additional actions performed on non-safety-related SSCs. Whenever such activities were retained, the numbers of SSCs to which these activities applied were reduced to reflect that fraction of the time that the actions would be performed in response to Maintenance Rule or other rule requirements.

Note that this type of review was performed for the typical scenarios only. For the conservative scenarios, this type of refinement to the programs would have had a negligible effect on the overall estimates of impact initiator quantities.

B.2.2 Assumptions and Bases

B.2.2.1 Bases for Reference License Renewal Programs

Most of the assumptions and bases used in developing the license renewal program environmental impact initiator estimates were discussed in Chapter 2. Additional aspects are presented here.

The typical and conservative license renewal programs characterize actions a licensee may take to ensure both safe and economic operation of its plant beyond the current 40-year license period. In reality, each plant's program and the specific refurbishment or repairs made for extended life will depend on many factors, including the original plant design, repairs already undertaken in the original license period, operating conditions and unusual occurrences, and plant management philosophy. The set of actions actually undertaken for license renewal, therefore, are expected to vary by plant because of specific plant designs, vintages, and classes. The staff believes the range of estimates developed here reasonably bound the impacts likely to actually accrue at any individual plant site.

The typical programs are intended to be representative of the typical or "average" plant's activities in support of license renewal. However, as noted in Chapter 2, the typical programs are still somewhat conservative.

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 programs are quite comprehensive, they encompass impacts from more typical programs. The primary bases and assumptions used were discussed in Chapter 2.

The typical programs for both BWRs and PWRs are similar, except for the differences caused by reactor design and technology. This is also the case for the conservative programs.

B.2.2.2 Aging Management Programs: Descriptions, Assumptions, and Bases

Key aspects of the license renewal environmental impact assessments were discussed in Chapter 2. Additional factors and considerations are presented in the following discussions.

B.2.2.2.1 Sources of Information

Activities assumed to occur under each plant operational or outage mode were based on information available in industry lead and pilot plant life extension studies (EPRI NP-5181SP and NP-5181M; EPRI NP-5289P; EPRI NP-5002), NRC's Nuclear Plant Aging Research program results (NUREG/CR-5284; NUREG/CR-4731), previous and ongoing NRC license renewal regulatory analysis efforts (Sciacca 1989; MITRE 1988; Sciacca January 25, 1990; Sciacca February 20, 1990), discussions of major repair activities undertaken at operating nuclear power plants as reported in technical literature (Forest 1988; Katz 1988; Miselis 1988), and discussions with industry and nuclear equipment suppliers. Discussions were also held with lead plant personnel to further ascertain the results of their life extension and license renewal evaluations (Sciacca January 3, 1993; Attachment 1). Estimates of labor and routine occupational exposure incurred in the performance of these activities were largely based on information provided in those sources. Where such estimates were not available, they were derived using the generic estimating methods developed by the NRC (NUREG/CR-4627; NUREG/CR-5236; NUREG/CR-5035; NUREG/CR-4555). The assessment of available information included an extensive literature search of actual industry data of relevant SMITTR and refurbishment/replacement activities. The information found, and the sources investigated, are discussed in Attachment 1 to this appendix. The Maintenance Rule (10 CFR 50.65) was also reviewed to assess the effects of this requirement relative to detecting and mitigating aging degradation of important SSCs.

B.2.2.2.2 Major Refurbishment Schedules

Impact initiators were initially developed for two different schedules for major refurbishment or replacement activities (Sciacca 1990). The reference schedule assumes that major refurbishment activities associated with 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. A second schedule was explored which was based on the assumption that all major activities of this type occur at the end of the current 40-year license period, either by preference or because the license renewal is not expected in time to schedule activities earlier during the current period. This major refurbishment outage would necessitate a longer duration than that called for by the reference schedule. Because of the complexity of accomplishing all of the major refurbishment activities called for in the example aging management programs at a single outage, this latter scenario was dropped from consideration.

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, 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 typical programs was reduced compared with that deemed necessary for the conservative case scenarios.

B.2.2.2.3 Outage Types and Durations

Chapter 2 noted that 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; they are referred to as normal refueling, 5-year in-service inspection (ISI) refueling, 10-year ISI refueling, current term refurbishment outages, and major refurbishment outages.

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. Of greatest concern from this standpoint are the projections of the number of temporary workers needed to accomplish license renewal activities. The number of workers required at a site for a given outage depends 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.

Certain aging management activities were assumed to be performed during full power operation. These activities will add to the plant full-time staff requirements.

In the reference BWR and PWR programs, the initial period of the renewed license was characterized by the major refurbishment outage as well as by several shorter outages referred to as current-term outages. The duration of the major refurbishment outage for the conservative case scenarios was set at 9 months for both reactor types. This duration was established based on the most limiting activity taking place during that period. For the PWRs, the most limiting activity was steam generator replacement. The limiting activity for the BWRs was the replacement of reactor recirculation piping. Recent experience indicates that both of these major activities can be accomplished in 9 months or less.

For the conservative scenarios, the 10-year ISI was given a duration of 4 months, with other 5-year ISIs lasting 3 months. Most other refuelings were assumed to be 2-month outages. Current-term outages were assumed to have a duration of 4 months each.

For the typical scenarios, the duration of the major refurbishment outage was set at 4 months. This duration was adequate to accomplish the limited number of major refurbishment activities included in these programs. For these scenarios the 10-year and 5-year ISIs, as well as current-term outages, were given a duration of 3 months each.

Assignments of outage duration were based on experience prevalent in the nuclear industry.

In reality, all outage durations will be established based on both economic considerations (e.g., cost of replacement power) and what can practically be accomplished during each outage. The short outages in which many major activities (including refueling, ISIs, major component replacement, etc.) are assumed to be undertaken simultaneously may require very large (possibly unreasonably so) labor forces. No attempt was made in this limited effort to optimize outage schedules or durations. However, preliminary work schedules were developed for the conservative scenario major refurbishment outages for both BWRs and PWRs to assess whether the major activities slated for this period could reasonably be accomplished in the allotted time. This assessment indicated it is feasible to accomplish the example refurbishment during the 9-month duration assumed.

B.2.2.2.4 Labor Categories

Labor necessary to accomplish the inspection, surveillance, testing, maintenance (ISTM), and major refurbishment/ replacement activities associated with license renewal and plant life extension (PLEX) were estimated separately for each activity. Labor was subdivided into the categories of engineering, administrative, skilled crafts, and laborers. Each labor category's hours in different radiation fields were estimated by activity. In addition, health physics-related support service labor was separately estimated for all activities performed in a radioactive environment.

B.2.2.2.5 Activity Repetitions

The number of times a given activity was performed was determined based on the intervals between the times when a given activity (such as a particular inspection or refurbishment) would be performed on a given component and the number of such components in the plant subject to those actions. Quantities of similar components were determined from reviews of representative plant piping and instrumentation diagrams, key system schematics, plant descriptions, and detailed material take-offs available for various plants. Frequencies for activities such as major refurbishment or replacements might occur only once in the plant's lifetime (e.g., BWR recirculation pipe replacement), or they might occur several times (e.g., valve refurbishment or replacement). Only incremental aging management activities, those which are in addition to those currently performed, were included here. Lead plant program information was also used in establishing activity repetitions and frequencies.

B.2.2.2.6 Radioactive Waste Generation

Volumes and types of waste generated were estimated on an activity-by-activity basis. For refurbishment, overhaul, or replacement activities, estimates of noncompactible wastes were based on the size of the items involved (i.e., the physical dimensions of the target items). Associated compactible wastes were estimated based on typical ratios of compactible-to-noncompactible volumes. In addition, compactible and noncompactible waste volumes were derived from information found in published reports of major repairs undertaken at nuclear power plants. Fluid volumes generated as a result of decontamination activities were estimated based on typical volumes generated for similar activities. All fluids used in these processes were assumed to be processed through filters or resin beds to remove contamination so that no radioactive liquids needed to be disposed of. The resulting resins or filters are disposed of as dry wastes.

All inspection, surveillance, and test activities conducted on radioactive systems or in radiation areas were also assumed to generate radioactive wastes. For such activities, compactible dry active wastes (DAW) were assumed to be generated at the rate of 0.012 m^3 (0.4 ft^3) per craft labor hour (as-generated volume). These result from the laundering and disposal of anti-contamination clothing and other protective equipment.

B.2.2.2.7 Waste Disposal Costs

Costs associated with the disposal of low-level radioactive wastes generated from license renewal-related activities were estimated separately for BWRs and PWRs. These estimates took into account the projected volumes of noncompactible and compactible DAW generated by each reactor type in the conduct of license renewal-related activities. The disposal costs were calculated using the NRC's generic estimating methodology (NUREG/CR-4555), but the bases were updated to reflect the rapid escalation in burial costs arising from the formation of regional compacts and the likely closure or limited availability of the existing low-level waste disposal sites. The basis for estimating waste disposal costs is discussed more fully in Section B.3.2.4.

B.2.2.3 Approach to Estimating Impact Initiators

The estimation of impact initiators first required that the generic license renewal programs be defined in terms of the specific activities and activity repetitions making up each program. Next, the median value of each impact for each individual SMITTR or refurbishment activity was estimated for that activity taken over the full range of plants and potential circumstances. For major refurbishment activities, however, surveys were performed of pertinent, recent industry experience. Experience has shown that strong learning curve effects exist (i.e., subsequent work benefits from the experience of prior similar activities), even when the activities of interest are performed by different nuclear plant licensees. These learning curve effects suggest that, especially for major repair/refurbishment activities, it is appropriate to use information reflecting recent experience rather than median or average experience. Impact estimates for activities of this type were based on recent experience. Once values were established for each activity included in a license renewal program, the values were summed for all activities making up the program.

The particular aging management approach assumed for assessing environmental impact initiators relies more heavily on refurbishment, replacement, and monitoring than on extensive inspection, surveillance, and testing. The approach taken for these example programs tends to concentrate the impact initiators during initial refurbishment periods. For the conservative case outages, they represent an envelope that captures the activities that might be performed at essentially any U.S. nuclear power plant in support of license renewal and extended plant life. They are intended to present fairly robust scenarios in terms of environmental impacts incurred during the refurbishment outages.

B.3 DATA DEVELOPMENT

The primary objective of this effort was to provide quantitative estimates for license renewal-related initiators which could produce incremental environmental hazards or impacts because of extended operation of nuclear power plants beyond the original 40-year term. That objective was accomplished using the following basic approach. First, candidate lists of plant SSCs susceptible to aging degradation were identified. Next, prototypic license renewal and aging management programs were defined in terms of the activities which could be carried out to manage the aging of these SSCs. These were the incremental activities carried out to support license renewal and extended plant life but not required or impacted by other NRC requirements. Each activity performed on each SSC was evaluated to estimate the potential impact initiators resulting from the conduct of that activity. Finally, total program impacts were estimated by summing the impacts from the individual activities making up a license renewal program. As noted previously, these programs of activities were defined and evaluated separately for BWRs and PWRs, each with both a typical and a conservative scenario. This section discusses the methods and bases used to establish the quantitative estimates of impact initiators.

As indicated in Section B.2.2.2.1, many different sources of information were drawn upon to establish the characteristics and content of the prototypic license renewal aging management programs and to estimate the impacts associated with each. These sources helped, in particular, to characterize the types of aging management programs that might be needed to support extended plant life during the license renewal term. The activities carried out under these programs will be needed to maintain the current licensing basis of the plants and to provide for their economical operation, as well as to satisfy the aging management requirements stipulated in the license renewal rule.

In the discussions which follow, Section B.3.1 describes the key aging management programs used to assess potential environmental impacts, and Section B.3.2 presents the specific impact initiators and describes the quantification of each initiator.

B.3.1 Aging Management Activities

The SSCs of interest for the example license renewal programs were presented in Chapter 2. The following discussions elaborate on representative aging management activities likely to be carried out on these SSCs.

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. These two categories of activities are (1) SMITTR actions, most of which are repeated at regular intervals, and (2) major refurbishment or replacement actions that usually occur fairly infrequently, or possibly only once, in the life of the plant for any given item.

B.3.1.1 SMITTR Aging Management Activities

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

Table B.1 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. The table also indicates the actions included in the typical scenarios, as well as those in the conservative case scenarios.

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.

B.3.1.2 Major Refurbishment Aging Management Activities

The list of major replacement and refurbishment activities included here was derived largely from areas of concern identified in the industry pilot and lead plant life extension studies, 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 that, as a minimum, 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 well be other plants which would undertake such tasks only to allow for extended plant operation. Inclusion of these activities in the conservative case scenario evaluations provides for a conservative estimate of what at least a few plants may require.

Table B.2 lists the major refurbishment or replacement activities used to estimate environmental impacts. Both typical and conservative case activities are indicated. 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 (EPRI NP-5181SP;

Table B.1 Incremental SMITTR[a] enhancement activities

SMITTR action	Conservative/typical program
BWR[b] SMITTR Enhancements	
Bellows	
Inspect one refueling and dry well bellows assembly	Both
Control Rod Drive Mechanism	
Discharge and vent value tests of one mechanism	Both
Recirculation Pump and Motor	
Conduct detailed inspection (disassembly/reassembly) of one pump and motor	Both
Metal Containment Including Suppression Chamber	
Inspect suppression pool and vent system exterior	Both
Renew protective coating on containment structure	C
RPV[c] Internals	
Conduct underwater inspection of core plate for IGSCC,[d] jet pump brace and safe ends, shroud-to-shroud flange and access hold cover, bolt inspection method, and ultrasonic testing of top guide.	Both
Conduct ultrasonic testing of top guide in central core region for IGSCC, shroud-shroud support cylinder welds, core spray inlet tee attachment, jet pump riser elbow to thermal sleeve weld region, and jet pump diffuser-to-adapter weld joint	Both
PWR[e] SMITTR Enhancements	
Critical Concrete Structure—Containment	
Renew all concrete protective coating on containment structure	Both
Reactor Coolant pump	
Conduct detailed inspection (disassembly, reassembly) of PWR coolant pump, shaft, and motor	Both

See footnotes at end of table

Table B.1 (continued)

SMITTR action	Conservative/typical program
RPV Internals	
Inspect core support plate, core shroud, top guide using visual and ultrasonic testing or similar methods, and welds and critical areas	Both
Enhancements to Components of Both PWRs and BWRs	
AC or DC Bus	
Inspect one medium-voltage breaker per manufacturer's recommendations	Both
Actuation and Instrumentation Channel	
Inspect connectors and penetrations for one channel	Both
Building Crane	
Perform load lift program on one crane, comprehensive SMITTR of crane or hoist	Both
Check Valve	
Re-grind one valve seat; replace moving parts mechanisms	Both
Compressed Air System	
Perform frequent inspection of compressed air system elements, including filter ΔP and leakage checks	Both
Containment	
Examine fabrication welds (ultrasonic testing and visual) and base and concrete core sample (remove and replace a 6-in. square of concrete)	Both
Emergency Diesel Generator	
Inspect main bearings for wear and connecting rods for fatigue damage; also check for gear fatigue and wear	Both
Conduct turbocharger drive gearing surveillance for one emergency diesel generator	Both

See footnotes at end of table

Table B.1 (continued)

SMITTR action	Conservative/typical program
Fan Cooler	
Inspect one fan motor for break down during run (megger); perform visual check of fan running, vibration	Both
Fuel Pool	
Conduct visual inspection of liner	Both
Heat Exchanger	
Conduct comprehensive efficiency test on one heat exchanger	Both
Heating, Ventilation, and Air Conditioning (HVAC)	
Inspect ducting, fans and motors, flex-joints, and dampers for degradation	Both
Conduct SMITTR of HVAC of one building	Both
Hydraulic or Air-Operated Valve	
Refurbish operator on one valve; regrind valve seat	Both
Main Condenser	
Inspect wall thickness of condenser	Both
Main Generator	
Inspect rotor of one main generator	Both
Main Turbine	
Conduct ultrasonic test of casing for one turbine	C
Motor Operated Valve	
Refurbish one valve, replacing internals	Both
Motor-Driven Pump and Motor	
Conduct detailed disassembly-inspection-reassembly for one pump and motor internals	Both

See footnotes at end of table

Table B.1 (continued)

SMITTR action	Conservative/typical program
Nuclear Steam Supply System Supports	
Torque statistical sample of component support anchor bolts	Both
RPV	
Visually assess condition of entire vessel exterior; inspect/evaluate one specimen for fracture toughness and tensile strength	Both
Inspect condition of dry lubricants in sliding foot area	Both
Turbine-Driven Pump and Turbine	
Conduct detailed disassembly-inspection-reassembly of one pump and turbine internals	Both

[a]SMITTR = Surveillance, On-Line Monitoring, Inspections, Testing, Trending, and Recordkeeping
[b]BWR = boiling-water reactor
[c]RPV = reactor pressure vessel
[d]IGSCC = intergranular stress-cracking corrosion
[e]PWR = pressurized-water reactor

Table B.2 Major refurbishment/replacement activities

Refurbishment/replacement action	Conservative/typical program
Activities Common to Both BWRs[a] and PWRs[b]	
• General refurbishment and repair of turbine building, primary auxiliary building, waste processing building, fuel storage building, and feedwater pipe enclosures	C
• Major overhaul and upgrade for buildings	C
• Major repair/refurbishment of main generator	Both
• Overhaul one crane	C
• Refurbish 25 percent of liquid rad waste system	C
• Refurbish coating of one condensate storage tanks	C
• Refurbish main station switchgear	C
• Refurbish main steam valves	C
• Renew protective coating on containment structure	Both
• Repair/refurbish 5 percent of reactor containment building interior concrete (or equivalent repairs)	C
• Repair/refurbish turbine pedestal	C
• Repair/replace major concrete imbedments in reactor containment building	C
• Repair/replace portions of nuclear steam supply system major piping and component supports	C
• Repair ultimate heat sink structure	C
• Repair/replace 20 percent of main steam, feedwater, condensate, and circulating water system piping	C
• Replace approximately half of the feedwater heaters	C
• Replace closure stud bolts	Both
• Replace containment electrical penetrations	Both
• Replace containment sensors and instrumentation	C
• Replace diesel generators	C
• Replace turbine rotor	Both

Table B.2 (continued)

Refurbishment/replacement action	Conservative/typical program
• Replace portions of electrical cabling both inside and outside of containment	C
• Replace/repair electrical raceways and supports	C
Activities Unique to BWRs	
• Replace all shroud head bolts in reactor vessel	C
• Replace recirculation pump shaft and impeller, refurbish casing—of each pump	C
• Replace entire BWR recirculation piping system and safe-ends	C
• Replace one-half of the jet pump assemblies in the reactor vessel	C
• Replace upper and lower core structure	Both
Activities Unique to PWRs	
• Anneal the reactor vessel	C
• Replace approximately half of reactor pressure vessel lower internal structures	Both
• Replace steam generators	C
• Replace pressurizer	C
• Replace reactor coolant pump internals and refurbish pump	C

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

EPRI NP-5181M) and from reported existing industry experience on major refurbishment (Forest 1988; Katz 1988; Miselis 1988; North Anna-1 1993; Rippon 1990). In other cases, engineering judgment provided the basis for the portions of the systems or structures being replaced or refurbished. The actual industry experience to date with similar activities indicates that theactions listed and quantities represented in Table B.2 for the conservative case scenarios are quite conservative in that no individual plant has had to undertake the comprehensive set of actions shown. An even more conservative approach could have been taken whereby the list of activities could have been expanded and/or the portions of the SSCs involved could have been increased (e.g., replace 100 percent of feedwater heaters rather than 50 percent). However, such an approach was judged to be highly unrealistic and would have resulted in unrealistically high estimates of license renewal environmental impacts.

Table B.2 indicates that relatively few major refurbishment activities have been included in the typical license renewal programs. The activities of this type that were retained were based in part on a review of the lead plant license renewal program plans. The typical programs are based on the assumption that most plants will be maintained and operated in a manner that reduces the need for all but a few major refurbishment activities that must be undertaken sometime during the term of the renewed license. In reality, many plants will have undertaken various major refurbishment activities during the term of the current license.

B.3.1.3 Outage and Operational Modes

The bulk of the incremental activities making up the example license renewal programs must be performed when the plants are shut down. As indicated in Section B.2.2.2.3, five different types of outages were used for defining the schedule for conducting these activities. These modes are referred to as current-term outages, refurbishment outages, 5-year ISI outages, 10-year ISI outages, and normal refueling outages. In addition, certain incremental inspection and surveillance activities were assumed to be conducted during power operation. This is referred to as the full power mode. The five outage modes are characterized in the following sections.

Figure 2.3 in Chapter 2 indicated the points in a representative license renewal schedule at which these various outage modes were assumed to occur.

B.3.1.3.1 Current Term Outages

Many of the major refurbishment and replacement activities undertaken to support license renewal can be performed in stages and need not be accomplished in a single outage. This would apply, for example, to activities such as electrical cable replacement and structural upgrades. For the example programs used herein, such activities are assumed to commence shortly after the renewed license is granted by the NRC. The current analysis assumes that four current-term outages occurring within the first 10 years under the new license will be used to accomplish the bulk of the major upgrades that can be spread out in time. These outages had an assumed duration of 4 months each for the conservative case scenarios and 3 months each for the typical scenarios.

B.3.1.3.2 5-Year In-service Inspections

Two 5-year ISIs will be performed during the renewal term, corresponding to years 5 and 15 of the extended period. Certain incremental activities are assumed to be performed in addition to the 5-year ISI actions currently required of nuclear plant licensees. The incremental SMITTR activities performed during the normal refueling outages of the extended term are also carried out for the 5-year ISI outages. These outages have durations of 3 months each for all programs.

B.3.1.3.3 10-Year In-service Inspection

A single 10-year ISI is assumed to be performed midway through the extended license period. The activities assumed to occur at this outage are incremental to current 10-year ISI requirements, and also include all actions undertaken during normal outages of the extended term of plant operation. A 4-month outage duration is assumed for the conservative case scenarios, and 3 months each for the typical scenarios.

B.3.1.3.4 Refueling Outages

In addition to the 5- and 10-year ISI outages, the 20-year renewal term is assumed to be characterized by eight normal refueling outages with a duration of 2 months each for each license renewal program. Incremental SMITTR activities are performed at each of these outages.

B.3.1.3.5 Refurbishment Outage

Certain major plant upgrades, replacements, and refurbishment must realistically be accomplished during a single outage period. Replacement of steam generators in a PWR and recirculation piping in a BWR fall into this category. To accommodate major activities such as these, a single extended outage is assumed to occur at the end of the 40-year current term of operation for the conservative scenarios. For both BWRs and PWRs this conservative case outage was assumed to have a duration of 9 months. The refurbishment activities in the typical license renewal scenarios are modest compared to those in the conservative case scenarios and can be accomplished in less time. A 4-month duration was judged to be adequate for this outage for the typical scenario. Other major activities that were initiated during the current-term outages are assumed to be completed at this refurbishment outage.

A preliminary check was performed as to the reasonableness of the 9-month duration for the major refurbishment outages of both the BWR and the PWR conservative case license renewal programs. This check entailed identifying the critical path activities slated for accomplishment at this outage, assessing the time required to perform each activity, and developing an overall schedule. Figures B.1 and B.2 display the results of this evaluation. Figure B.1 shows a possible schedule for the PWR for completing the critical path activities. The comparable information for the BWR is displayed in Figure B.2. Recent industry experience, where available, was used to estimate the duration requirements for each critical path activity. These assessments also focused primarily on in-containment activities, and the assumption was made that outside-containment work was less limiting and allowed greater scheduling flexibility than the in-containment work. Both schedules allow for complete defueling of the reactor before initiating major refurbishment activities in the containment buildings. These assessments, although preliminary, suggest that the assumed 9-month duration for the conservative case major refurbishment outages is feasible.

Note that recent industry experience with major refurbishment activities such as steam generator replacement indicates that these large efforts can be accomplished in periods ranging from about 3 to 5 months, rather than the 9 months assumed for the current conservative program evaluations (North Anna-1 1993; Rippon 1990). The 9-month major refurbishment outage duration was retained to more realistically accommodate the large number of refurbishment activities assumed to proceed simultaneously during this outage.

For the typical license renewal scenarios, the most limiting activities undertaken during the major refurbishment outage were replacement of certain reactor vessel internal components and repairs to the main turbine-generator. A 4-month outage duration was judged to be sufficient to accomplish these activities.

Table B.3 summarizes the different outage types and durations for both reactor types

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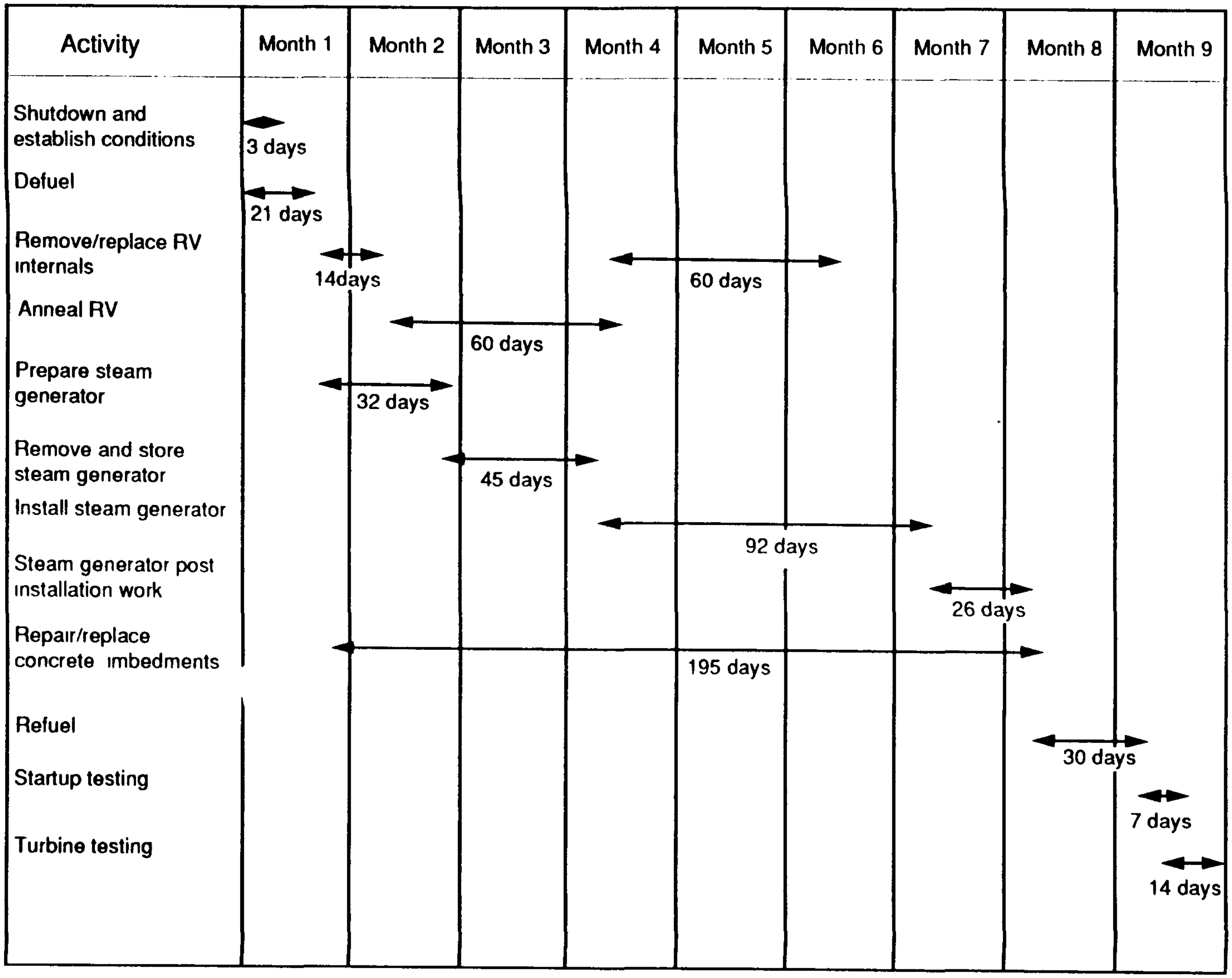


Figure B.1 PWR major refurbishment outage schedule.

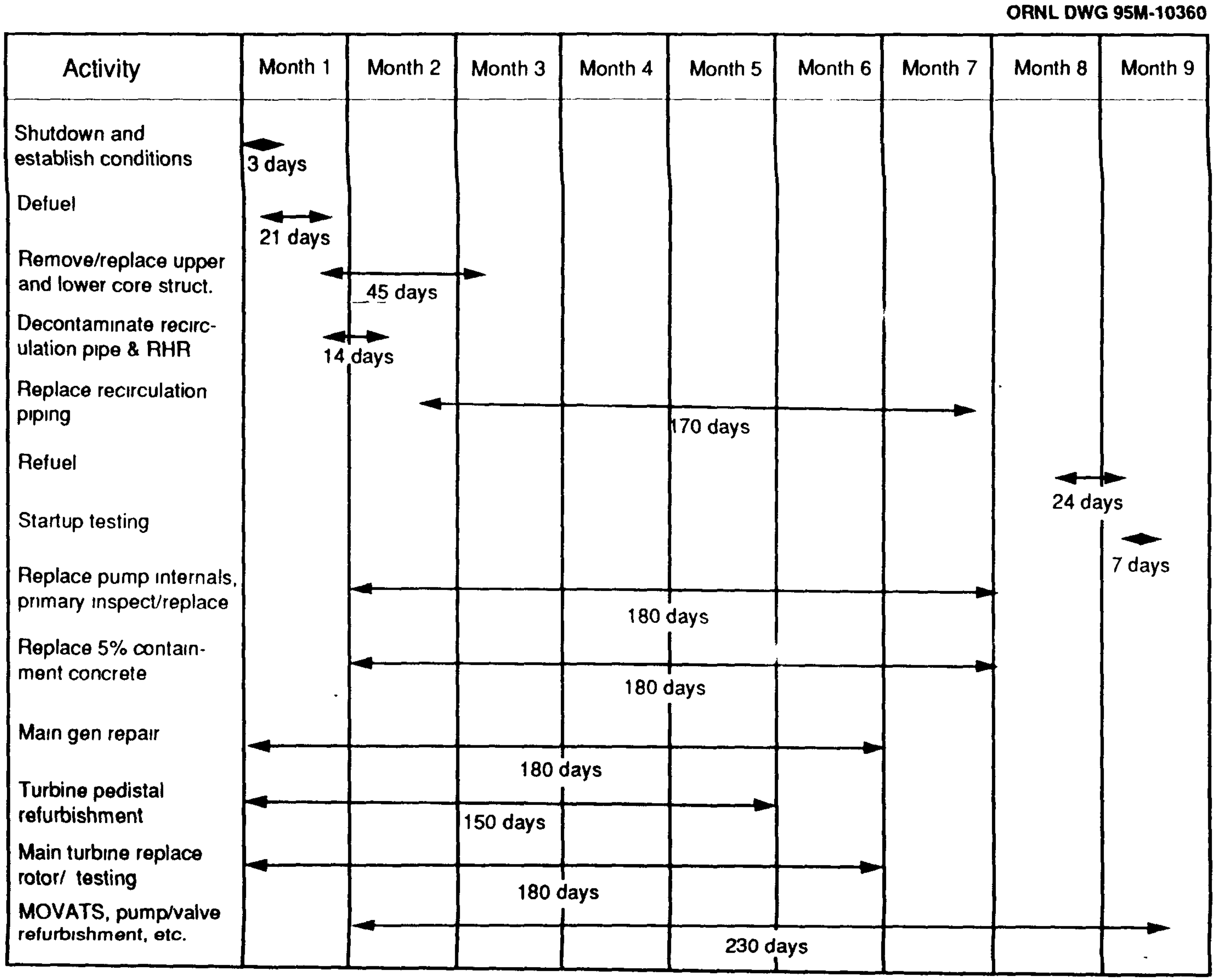


Figure B.2 BWR major refurbishment schedule.

Table B.3 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

and for both the typical and conservative license renewal scenarios.

In addition to the aging assessment and management activities performed during plant shutdown, certain incremental SMITTR activities can also be performed during full power operation. The current assessment identified only a limited number of activities of this type. This activity mode is referred to as the full power mode.

B.3.2 Quantification of Impact Initiators

Three primary types of impact initiators related to license renewal activities were quantified in this assessment: on-site labor, occupational radiation exposure, and radioactive waste generation. Other possible contributors to socioeconomic and/or environmental impacts were also assessed: capital costs, radioactive waste disposal costs, additional off-site labor requirements, and plant down time and replacement energy costs. The following sections discuss the basis for the impact quantification associated with conducting the license renewal-related activities.

B.3.2.1 Labor

This assessment developed three aspects of labor required to carry out aging management activities in support of license renewal. These aspects include labor hours, labor costs, and the number of individuals needed during a given period to perform the activities. In addition, the five labor categories of administrative personnel, engineering, craft workers, unskilled laborers, and health physics support staffing were treated.

This labor quantification effort first defined the number of craft and/or unskilled labor hours needed to perform each specific activity encompassed by any of the aging management programs. The labor estimates associated with the conduct of the SMITTR activities were taken largely from the license renewal regulatory analysis developed previously (Sciacca January 25, 1990; Sciacca February 20, 1990). The labor estimates for each activity were reviewed. Changes to the original estimates were made if new information indicated the need for revision. In many cases, the number of times a given activity was carried out was increased relative to the estimates used in the regulatory analysis. This approach was taken because the current effort encompasses actions undertaken to address both plant safety and economics, whereas the regulatory analysis dealt strictly with safety-related activities. This is particularly true for the conservative scenarios. Also, the broader scope of the current effort required the inclusion of many balance-of-plant SSCs that need to be addressed to provide economical and reliable electrical power generation over the extended term of operation.

The labor estimates required to accomplish major refurbishment or replacements were derived in two ways. If the activity of concern had already been performed in U.S. nuclear plants, and if the actual labor expenditures were reported in available documentation, this actual experience was used as a basis. Adjustments were made in certain cases to reflect learning curve effects where future repetitions of that activity could benefit from the earlier examples. However, many major refurbishment/replacement activities postulated in the current assessment have not been performed previously, or if they have, the labor required to accomplish these actions is not available. For activities in this category, NRC's generic cost estimation methods were used (NUREG/CR-4627; NUREG/CR-5236). This method uses "greenfield" or new construction labor estimates as a starting point. Labor to remove and replace given SSCs is then estimated by factoring in operating plant constraints which affect labor productivity. These constraints include factors such as access restrictions, congestion, interference with non-target systems and structures, radiation impacts, and manageability aspects. For those activities for which this method was used, the present estimates of labor requirements to accomplish major refurbishment and replacement activities took into account the specific environment under which the work would be performed. This included area-specific radiation dose rates if the work had to be performed in a radioactive environment (NUREG/CR-5035).

Distinctions between craft and unskilled workers were also developed on an activity-by-activity basis. Most of the SMITTR activities are assumed to be performed by trained technicians, who were treated as being the equivalent of skilled craftsmen. Unskilled labor was assumed to be used for some of the major replacement/refurbishment work. The ratio of craft to unskilled labor was estimated based on engineering experience. This ratio was determined separately for each activity for which some mix of both craft and unskilled labor could realistically be assumed.

Estimates of on-site administrative and engineering labor requirements for each activity were derived from the estimates of craft and unskilled labor hours. For most activities, engineering labor was assumed to be 15 percent of the craft and unskilled labor hours, and administrative efforts were taken to be 5 percent. However, engineering labor for certain activities was based on estimates presented in the industry pilot and lead plant studies on plant life extension.

Health physics (HP) support labor efforts were estimated based on the occupational radiation exposure incurred in the conduct of activities performed in a radiation environment. Previous studies (NUREG/CR-5236) indicated that typical nuclear plant expenditures for radiation protection services are in excess of $10,500 per person-rem[1] of radiation exposure incurred. Of this amount, about 85 percent is labor expenditures, and the balance is attributable to materials, equipment, etc. The hourly cost of providing HP support was assumed to be $63.00 (NUREG/CR-4627). Using these figures, an estimate of 127 person-hours per person-rem of exposure was established and used in estimating HP labor hours.

All labor estimates reflect incremental on-site personnel requirements only. Additional engineering and administrative support would very likely be required for some activities, especially for major refurbishment and replacement efforts. These efforts are assumed to take place at locations remote from the reactor plant sites and would not contribute to local environmental or socioeconomic impacts. However, these off-site costs are separately accounted for to make the estimates of license renewal costs more comprehensive.

Labor costs were derived once the labor hour estimates were established. The hourly rates used for each labor category were as follows:

Administrative	$40.80
Craft	$41.30
Engineering	$45.80
Health Physics	$63.00

These hourly rates are fully burdened to reflect fringe benefits and indirect or overhead costs. They are based on electric utility wage surveys conducted by the Bureau of Labor Statistics and reflect 1994 dollars. The rates used are U.S. averages; higher or lower rates may prevail in specific geographic regions.

B.3.2.2 Occupational Radiation Exposure

Occupational radiation exposures were estimated for all activities involving radioactive systems or work in radioactive areas. Three equivalent average dose rates were assumed for the activities considered in this assessment. These rates were 0.015 rem/h for high radiation zone activities, 0.0075 rem/h for average or medium conditions, and 0.0025 rem/h for low radiation zones. These dose rate ranges were derived from a review of actual experience for both major replacement/refurbishment activities and routine surveillance and inspection activities. The rates as derived are based on the total labor hours taken to accomplish a task and the total exposure recorded for that task. As such, they take into account both the time spent in radiation zones and that spent in nonradioactive areas associated with the conduct of a particular activity. They also reflect actions taken to reduce exposures, such as application of shielding and decontamination. Exposures were determined by multiplying the total labor hours for craft and unskilled workers for a given activity by the high, medium, or low dose rates.

Estimates of occupational radiation exposure for most of the SMITTR activities included in the present assessment used the foregoing average exposure rates. Particular dose rates were assigned to a given activity based on the location and relative radiation levels of the SSC addressed by the SMITTR action.

Exposure estimates for major refurbishment/replacement actions were typically handled on an activity-by-activity basis. Estimates for activities for which data from actual experience were available used that actual experience. Steam generator replacement and recirculation piping replacement provide examples of activities for which actual radiation exposure data are available. For such cases, the total labor hours were spread among the three standard dose rates in a manner which resulted in total job exposures matching those from actual experience.

Major activities for which no actual exposure data were available employed a slightly different approach for exposure estimates. For most of these activities total labor estimates were derived using NRC's generic cost estimation methods (NUREG/CR-4627; NUREG/CR-5236). Job-specific radiation dose rates prevalent for each activity were assessed based on surveys of typical conditions for both BWRs and PWRs (NUREG/CR-5035). These estimates took into account the likelihood of decontamination or other dose-reduction measures being applied, and the raw dose rate data were adjusted accordingly. Similarly, these cases took into account the time actually spent in the radiation field.

B.3.2.3 Radioactive Waste Generation

This effort initially sought to define radioactive waste generation according to classical designations of dry wastes, Class A, B, or C; dry mixed wastes (radioactive wastes mixed with hazardous chemicals); wet wastes, Class A, B, or C; or wet mixed wastes. A review of current practices for the nuclear industry indicated that essentially none of the radioactive wastes presently shipped from nuclear plants for burial are wet wastes. Radioactive liquids are decontaminated or solidified on-site or at contractor facilities, eliminating the need for burial of the liquids. A review of the types of dry wastes likely to be generated by the activities carried out in support of license renewal and plant life extension indicated that most of these could be considered as dry Class A waste. No Class B or C wastes were identified. However, certain activities are expected to produce some greater-than-Class C (GTCC) dry wastes. This waste will result from the removal of neutron-activated materials from the reactor vessel or from the removal of materials located sufficiently close to the reactor core that activation is a problem.

The assessment of the volumes of radioactive waste to be disposed of, and the estimation of labor requirements associated with the in-plant handling of the waste, requires that DAW be defined or classified as compactible or noncompactible. Compactible DAW is amenable to significant volume reduction by compaction, incineration, or other processes. The as-shipped or as-processed volume of this waste is typically factors of 5 to 100 less than the as-generated volume. Noncompactible DAW, on the other hand, typically has an as-packaged volume which is greater than the as-generated volume because of the difficulty of achieving high packing factors with the noncompactible materials involved. The extent of volume reduction achieved is typically referred to as the volume reduction factor (VRF). This factor is defined as:

$$VRF = \frac{\text{untreated (as-generated) waste volume}}{\text{packaged (as-shipped) volume}}$$

The current assessment used a VRF of 10 for compactible DAW to estimate as-shipped volumes from the as-generated values. This VRF is reasonably representative of current industry experience, and it assumes a modest amount of improvement in waste processing in the future for the industry as a whole. A VRF of 0.8 (i.e., a volume increase) was used for estimating the as-shipped volume of noncompactible DAW requiring disposal. This factor also assumes the use of state-of-the-art technology in the packaging of the noncompactible wastes.

Volumes and types of waste generated were estimated on an activity-by-activity basis. For refurbishment, overhaul, or replacement activities, estimates of noncompactible wastes were based on the size of the items involved (i.e., the physical dimensions of the target items). Associated compactible wastes were estimated based on typical ratios of compactible-to-noncompactible volumes. In addition, compactible and noncompactible waste volumes were derived from information found in published reports for major repairs undertaken at nuclear power plants.

Fluid volumes generated as a result of decontamination activities were estimated based on typical volumes generated for similar activities. All fluids used in these processes were assumed to be processed through filters or resin beds to remove contamination, with the result that no radioactive liquids needed to be disposed of. The resulting resins or filters are solidified and disposed of as dry wastes.

All inspection, surveillance, and test activities conducted on radioactive systems or in radiation areas were also assumed to generate radioactive wastes. For such activities, compactible DAW was assumed to be generated at the rate of 0.0113 m^3 (0.4 ft^3) per craft or unskilled worker labor hour (as-generated volume). This generation rate represents a rough average of waste production based on experience with both major replacement activities and with more routine SMITTR activities. These wastes result from the laundering and disposal of anti-contamination clothing and other protective equipment, from plastic sheeting used to restrict the spread of airborne contamination, and from the use of other such materials.

Some site labor must be expended in handling and processing the wastes generated by the activities performed in support of license renewal. In addition, some incremental radiation exposure will be incurred by those workers handling these wastes. The current assessment estimated the labor using the following rates:

Noncompactible DAW	10.6 h/m^3 (0.3 h/ft^3)
Compactible DAW	17.7 h/m^3 (0.5 h/ft^3)

These rates apply to the as-generated volumes of wastes. Similarly, radiation exposure incurred in the in-plant handling of radioactive wastes was estimated using a rate of 0.0012 person-rem per cubic foot of waste in the as-shipped form, and this rate applies to both compactible and noncompactible types of waste. (These rates were obtained from NUREG/CR-4627).

At least some of the waste processing activities can occur during reactor operating periods rather than being completed during the outage times when the wastes are generated. Such processing will reduce (or at least not add to) the labor burden on-site during the outages when large work forces are needed. However, the current estimates assume that the waste handling efforts occur during the same periods that the wastes are generated. This approach adds somewhat to the conservatism of the impact production rates presented here.

B.3.2.4 Waste Disposal Cost

Costs associated with the disposal of low-level radioactive wastes generated as a result of license renewal-related activities were estimated separately for BWRs and PWRs, taking into account the projected volumes of noncompactible and compactible DAW generated by each reactor type for each license renewal program. The estimates utilized the base information developed in NUREG/CR-4555, Rev. 1. However, the costs were modified to reflect the rapid escalation in burial costs resulting from the formation of regional compacts and the likely closure or limited availability of the existing low-level waste disposal sites. The analysis performed indicated that burial costs at the regional compact sites are projected to be in the range of $7,000 to $16,000/m^3 ($200 to $450/ft^3). The current estimates used $12,000/m^3 ($340/ft^3) for burial. The costs associated with handling, on-site temporary storage, and transportation of the DAW were added to the burial costs. These generic estimates were based on an assumed plant-to-burial-site distance of 1,600 km (1000 miles) and the wastes were assumed to have relatively high activity levels for the purpose of estimating costs.

Steam generators replaced as part of the PWR conservative case license renewal program are contaminated and could be disposed of as low-level radioactive waste. Their volume is quite large (approximately 1,130 m^3 or 40,000 ft^3), however, and the spent units are typically stored on-site rather than buried at an approved waste disposal site. Special storage buildings have been constructed at the affected reactor sites to house the spent steam generators. The cost of the storage buildings is estimated to be about $1 million and is included in the overall waste disposal cost estimates.

B.3.2.5 Capital Costs

Capital costs were estimated for those activities involving the application or installation of new equipment, materials, and hardware. Wherever available, the estimates were established based on recent industry experience for the addition or replacement of the items of concern. Where such cost information was not available, two other approaches were used. The first relied on NRC's generic cost estimation methods and databases (NUREG/CR-4627). This methodology draws on the Energy Economic Data Base (EEDB) developed by the U.S. Department of Energy (DOE/NE-0051/1; DOE/CR-5764). The EEDB provides estimates of both labor and material/equipment quantities and cost. This information has been developed for modern, large PWR and BWR plant designs. The EEDB presents reasonably detailed information which covers most areas of the plant, including both the nuclear steam supply system (NSSS) and the balance of plant. However, this cost base does not include any detail of the NSSS equipment or hardware capital costs. The second alternative approach to estimating capital cost where no recent industry experience was available was based on the use of detailed, actual construction cost breakdowns from a U.S. nuclear plant constructed several years ago. This cost base provided sufficient breakdown of the entire plant, including detail on the NSSS component and subcomponent cost. Where this base was used, the costs reported were escalated to 1994 dollars, and, where appropriate, the costs were adjusted to reflect size differences between this base plant and the 1000-MW(e) reference size adopted for the current estimates.

B.3.2.6 Other Costs

Two other cost elements were considered to define license renewal-related costs in a more comprehensive manner: home office costs and replacement energy costs. The home office costs account for off-site engineering and quality assurance (QA) expenditures. This category of costs accounts for the design, analysis, safety review, and documentation efforts typically associated with modifications at nuclear power plants.

Home office costs also allow for QA functions and activities carried on to support these modifications. Home office engineering and QA efforts were estimated using NRC's generic cost estimation methodology (NUREG/CR-4921). Based on surveys of a wide range of actual physical modifications made to operating nuclear power plants, this methodology has established that, on average, the engineering and QA functions typically amount to about 25 percent of the direct modification costs. This basis accounts for both on-site and off-site engineering and QA functions. The direct costs include direct (unburdened) labor as well as the cost of materials, equipment, and hardware associated with a particular modification. Because the on-site efforts were separately accounted for as described in Section B.3.2.1, estimates of the off-site work were developed using the 25 percent of direct costs approach and subtracting from this the estimate of on-site engineering costs.

Replacement energy costs can be a major contributor to overall project cost if plants remain out of service for extended periods. An assessment was made of replacement energy costs as they relate to the example license renewal programs. This evaluation reviewed the replacement energy costs per day of plant downtime (NUREG/CR-4012 1992) separately for BWRs and PWRs. Weighted averages were taken for several plants whose electrical generating capacity was nearest to 1000 MW(e). For PWRs, the daily replacement energy cost estimated on this basis was $342,000 (1994 dollars). For BWRs, this figure was estimated to be $287,000 (1994 dollars) per day. Replacement energy cost depends on several factors, including plant size, location and load pool, season, and cost fluctuations in non-nuclear alternative energy sources. However, the estimates cited here are representative of U.S. plants in the 1000-MW(e) size range.

B.4 RESULTS

This section summarizes the quantitative results developed in this evaluation. All key impact initiators are discussed, including labor, occupational radiation exposures, capital costs, radioactive waste generation, and waste disposal costs associated with the conduct of activities carried out in support of license renewal and extended plant life. This section also discusses elements of license renewal which do not necessarily contribute to environmental or socioeconomic impacts but which play important roles in assessing the overall economic viability of license renewal. These are the elements of off-site costs and replacement energy costs. Finally, this section provides a comparison of industry-developed license renewal cost estimates with those developed in this assessment. Both typical and conservative case scenario results are discussed.

B.4.1 BWR and PWR License Renewal Program Impact Initiators

As noted previously, the typical license renewal program scenarios presented herein are intended to be representative of those the majority of nuclear plants seeking license renewal might experience regarding major refurbishment and enhanced SMITTR activities needed to satisfy NRC requirements and better ensure reliable and economical plant life extension. The conservative case scenarios, on the other hand, are intended to reflect what might occur at a few outlier plants requiring much more extensive refurbishment/replacement activities than are typical of the reactor population as a whole. As such, the typical programs are estimated to have rather modest environmental impacts compared with those expected for the conservative case scenarios.

Tables B.4 and B.5 present summaries of the license renewal program impact initiator quantities for the typical and conservative case license renewal scenarios, respectively. Each table shows the quantities separately for BWRs and PWRs. Similarly, each table shows the impact quantities generated during the different plant modes. Note that the impact quantities are presented on a per-occurrence basis for refueling outages, current-term outages, and the 5-year ISI outage, each of which occurs more than once. The totals, however, reflect the summation over all occurrences of all activities performed in support of license renewal. Tables B.4 and B.5 also show the labor and costs associated with incremental activities performed during full-power plant operation. The labor hours and costs for this category represent the totals accrued over the entire period of the renewed licenses. All values shown are intended to capture only incremental effects associated with license renewal, and they exclude baseline activities which represent a continuation or evolution of current practices related to the operation and maintenance of nuclear power plants.

The types and extent of activities included in the conservative case programs, especially the extensive major replacement/refurbishment activities included and their resulting impact initiator estimates as reflected in Table B.5, are thought to reasonably bound what might be needed for any individual nuclear plant site in pursuit of license renewal and plant life extension.

The values in Tables B.4 and B.5 indicate that most of the environmental impact initiators accrue during the major refurbishment outages. For the conservative scenarios, the current-term outages also result in considerably higher levels of impact quantities being generated compared with the more routine outages. The current-term and major refurbishment outages are the periods when major replacement and refurbishment activities performed in support of license renewal and extended plant life are assumed to occur. For the conservative case scenarios, the impacts produced are primarily from activities performed to ensure that current safety and licensing bases are maintained, as well as to help ensure that plant economic and availability/reliability goals are met. Relatively few of the conservative case impacts are attributable to the enhanced aging management of SSCs important to license renewal called for by the License Renewal Rule. The rule requirements have a relatively greater impact on the typical programs, because these programs have fewer major refurbishments compared with the conservative case scenarios. The specific effects of the 10 CFR 54 rulemaking on the impact quantities are discussed in Section B.4.3.

A comparison of the figures in Tables B.4 and B.5 shows that the typical license renewal program impact initiators are on the order of 15 to 25 percent of the quantities estimated for the conservative case scenarios. Figure B.3 graphically illustrates the overall fraction of the total impacts for the typical programs relative to the conservative case scenario totals. The values shown represent a linear, composite average of the various impact category totals listed in Table B.4 relative to the totals presented in Table B.5. Thus, the conservative case scenarios are estimated to have five to six times the impact quantities of typical license renewal programs. This result is to be

Table B.4 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-sievert)	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]	68,208	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	345,000	1,715,040	578,360	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

[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, 3-month duration
[f]4 occurrences, 3-month duration each
[g]1 occurrence, 4-month duration
Note: Multiply $m^3 \times 35.32$ to find ft^3 Multiply person-sievert × 100 to find person-rem.

Table B.5 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-sievert)	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	0.78	290,508	2,258,137	712,251	3,269,896	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 (22 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	1,294,224	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	3,889,204	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	6,550,006	—	2,500	23.74	36,919,300	269,000,000	154,700,000	460,700,000	38,300,000	499,000,000

[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

Note: Multiply m^3 x 35.32 to find ft^3 Multiply person-sievert x 100 to find person-rem.

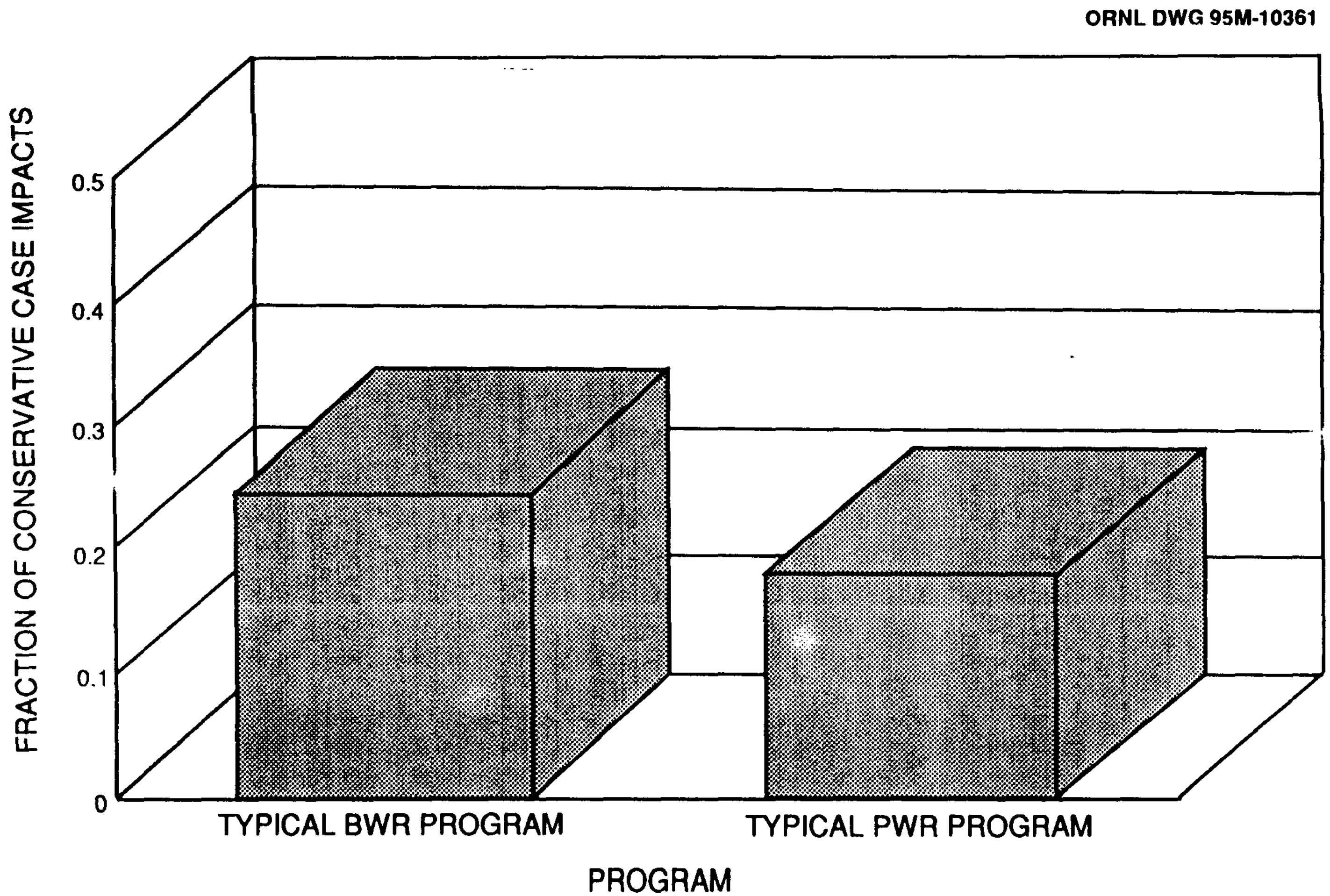


Figure B.3 Typical program impacts relative to corresponding conservative case impacts.

expected because of the extensive major refurbishment activities assumed to be undertaken by a few outlier plants represented by the conservative case scenarios.

Note that the additional on-site personnel figures cited in Tables B.4 and B.5 represent the average incremental work force sizes needed to accomplish license renewal-related activities assuming this work is uniformly spread over the entire duration of each separate outage. Peak work force sizes for each outage will be higher, as discussed in Section B.4.1.1.

B.4.1.1 Labor Hours and On-Site Staffing

The estimates of incremental labor shown in Tables B.4 and B.5 indicate that roughly 0.5 to 0.8 million labor hours could be expended for typical license renewal activities for both BWRs and PWRs, whereas the corresponding labor hour estimates for the conservative case scenarios are on the order of 5 to 7 million. These estimates include administrative, engineering, health physics, craft, and nonskilled labor. For the conservative case scenarios of Table B.5, about 95 percent of the labor hours for both BWRs and PWRs are attributable to the major activities that occur during the current-term outages and the major refurbishment outage. Thus, for the conservative case scenarios, these major activities tend to dominate the impact quantities compared with the more routine activities occurring at normal refueling and at the 5- and 10-year ISI outages. The labor values shown are greater for the conservative case PWR than for the corresponding BWR primarily because of the large amount of labor associated with the replacement of all four steam generators assumed in the reference PWR plant design.

Table B.4 indicates that the typical case BWR labor hours are about 30 percent greater than the corresponding PWR estimates. The differences here are primarily the result of a few additional SMITTR activities being performed for the BWR over the remaining life of the plant, as well as a greater number of components that are subject to these activities.

The labor hour estimates for the different license renewal scenarios are illustrated in Figure B.4.

The additional on-site personnel estimates reflect both the labor estimates and the assumed outage durations. The conservative case license renewal programs assumed that the major refurbishment outage would be 9 months long. As discussed in Section B.3.1.3, this duration appears to be reasonable. The conservative case major refurbishment outage would require about 870 additional on-site staff for the BWR and about 1700 incremental on-site personnel for the PWR to accomplish the example program aging management activities in the allotted time. As previously noted, the larger work force required for the PWR primarily results from the large effort associated with steam generator replacement. These estimates address personnel needed over and above those who would be on-site to perform normal refueling and maintenance tasks. Most of the other outages require roughly the same number of incremental on-site personnel for both reactor types. Note that for each type of outage, the staffing indicated is in all cases incremental to the staff needed to carry out current practices. Also, these estimates reflect average incremental staff assuming the work is spread uniformly over the entire outage duration.

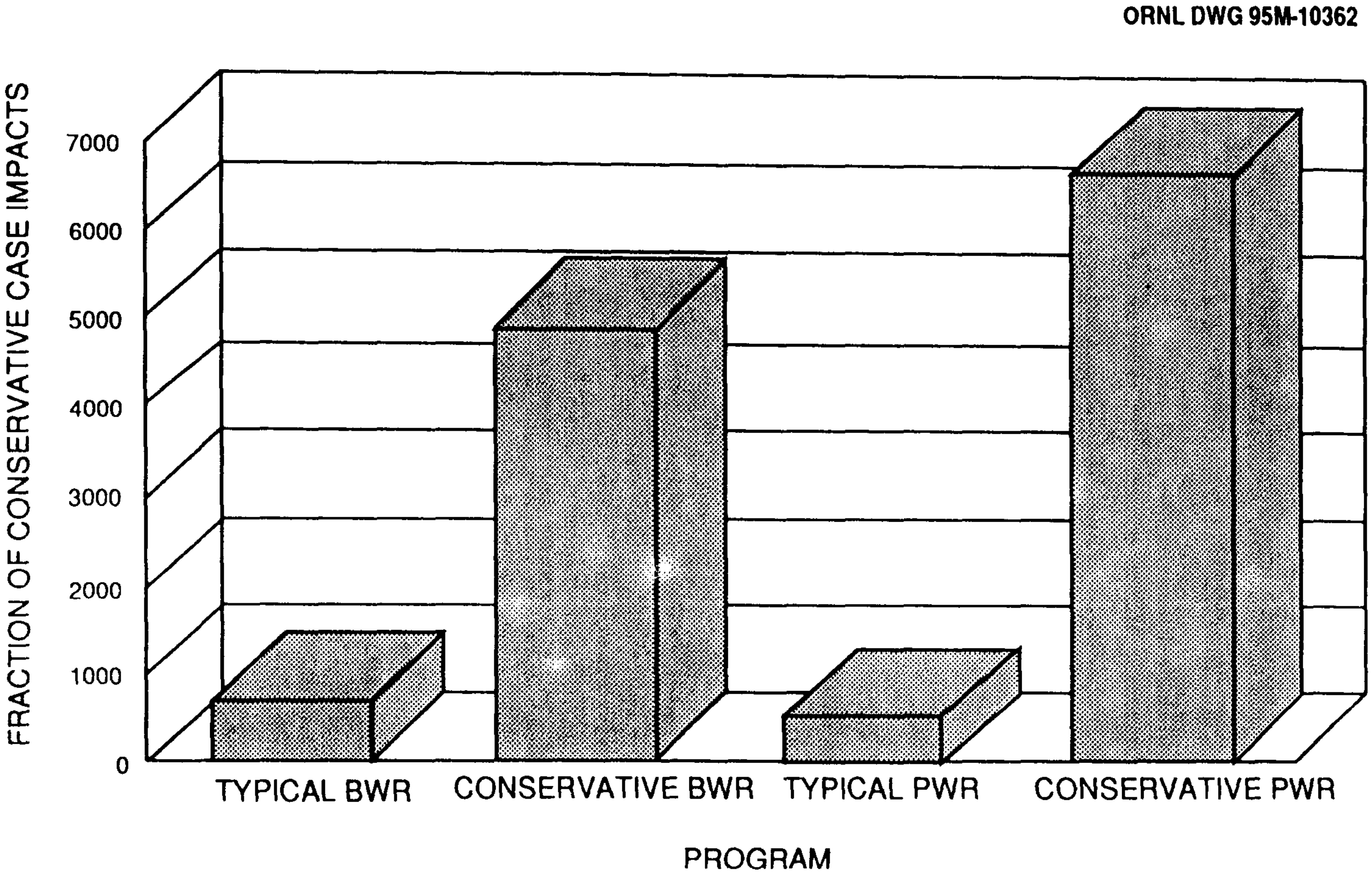


Figure B.4 Incremental labor hours.

For the typical scenarios, the incremental on-site staffing requirements are relatively modest. The largest staff increment is required for the major refurbishment outage, as this is the time when the few major refurbishment or replacement activities in these programs are assumed to be carried out.

The number of on-site personnel estimated in Tables B.4 and B.5 is not strictly proportional to the outage duration and the total labor hours expended during a given outage. This is because a 50-hour work week was assumed for craft, health physics, and nonskilled workers, whereas the engineering and administrative personnel were assumed to have a 40-hour work week. Also, the ratio of engineering and administrative hours to craft, health physics, and nonskilled worker hours varied from activity to activity.

Figure B.5 graphically indicates the highest average number of temporary workers needed to carry out license renewal-related activities for each of the four license renewal scenarios. This figure shows the largest requirement for each scenario as identified in Tables B.4 and B.5. Note that all estimates of incremental on-site personnel displayed in Tables B.4 and B.5, and in Figure B.5, were arrived at assuming level staffing for the entire duration of a given outage.

The extent of certain socioeconomic impacts such as housing will depend on peak numbers of personnel on-site rather than on the average numbers employed over a given outage. Therefore, additional analyses were performed to define probable staffing profiles throughout the major outages. Because the outages of interest would also include defueling/refueling and work typically conducted during present-day outages (e.g., ISIs, routine maintenance), the temporary workers needed to accomplish these routine activities must also be considered in estimating peak work force sizes. Table 2.4 of Chapter 2 noted that, based on a recent industry survey, there are typically 750 to 800 additional workers on-site at a nuclear plant during routine planned outages. The assumption was made that these workers are needed for a period of 2 months per outage. Therefore, these more routine efforts performed by temporary workers add up to a total of about 1600 person-months of effort. This effort needed to accomplish more routine outage activities was added to the license renewal-related labor efforts identified in Tables B.4 and B.5 to arrive at estimates of peak work force sizes.

Figures B.6 through B.9 present monthly projections of temporary worker staffing needed to carry out both license renewal activities and routine refueling, and ISTM activities. The most limiting cases are shown for each license renewal scenario. Figure B.6 shows the projected number of temporary personnel needed during the major refurbishment outage for the conservative PWR license renewal scenario. This outage was assumed to require 9 months. The monthly staffing needs were arrived at by developing a schedule for carrying out each of the different activities to be accomplished during this outage. These schedules were similar to those presented in Figures B.1 and B.2, but they were more complete in that all activities slated for the outage of interest were included. An effort was made to average out the work force over the entire outage duration to the extent possible. However, considerable peaking does occur because not all activities can proceed simultaneously. Figure B.6 separately identifies temporary personnel needed to accomplish license renewal activities versus those needed for more routine outage

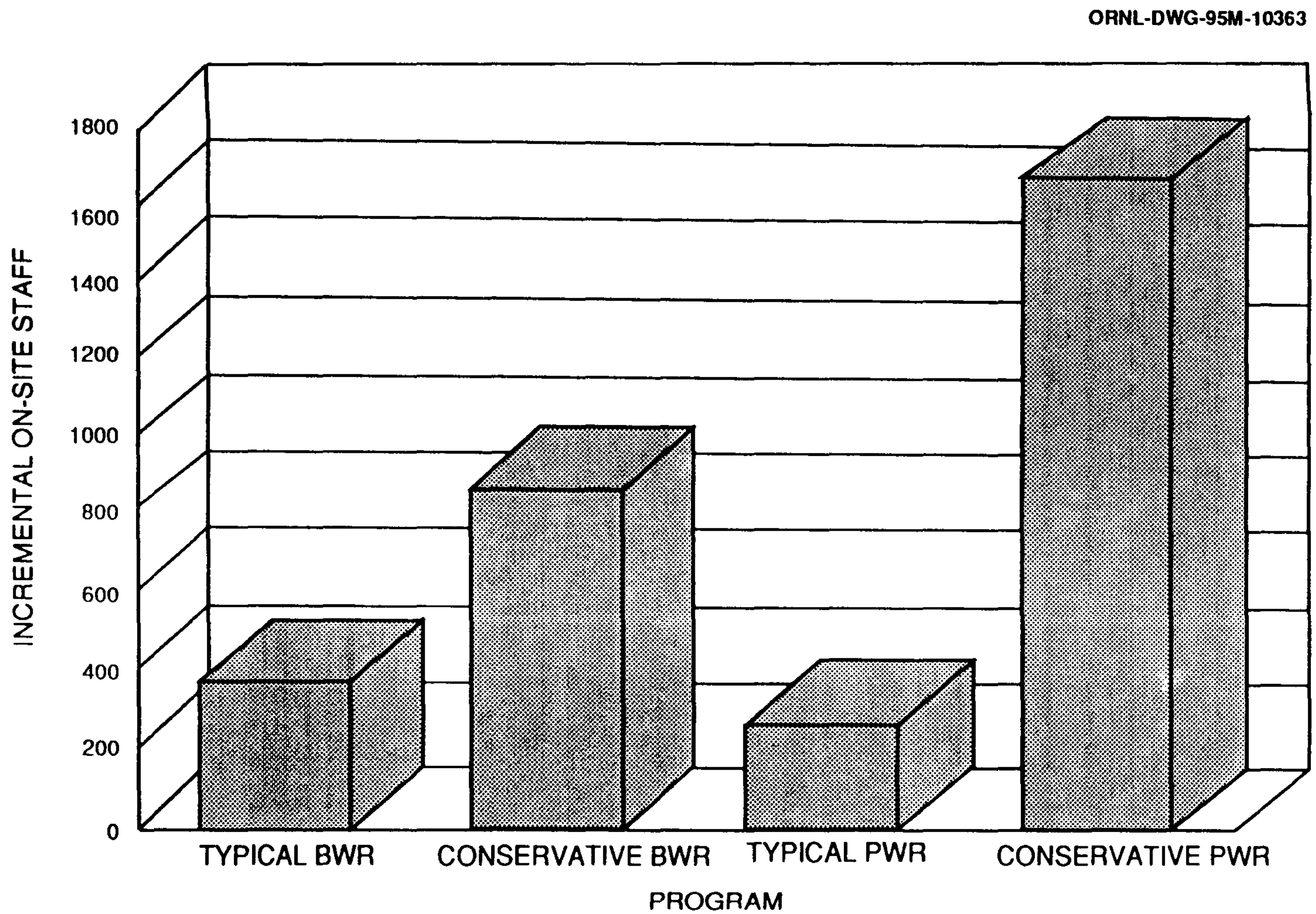
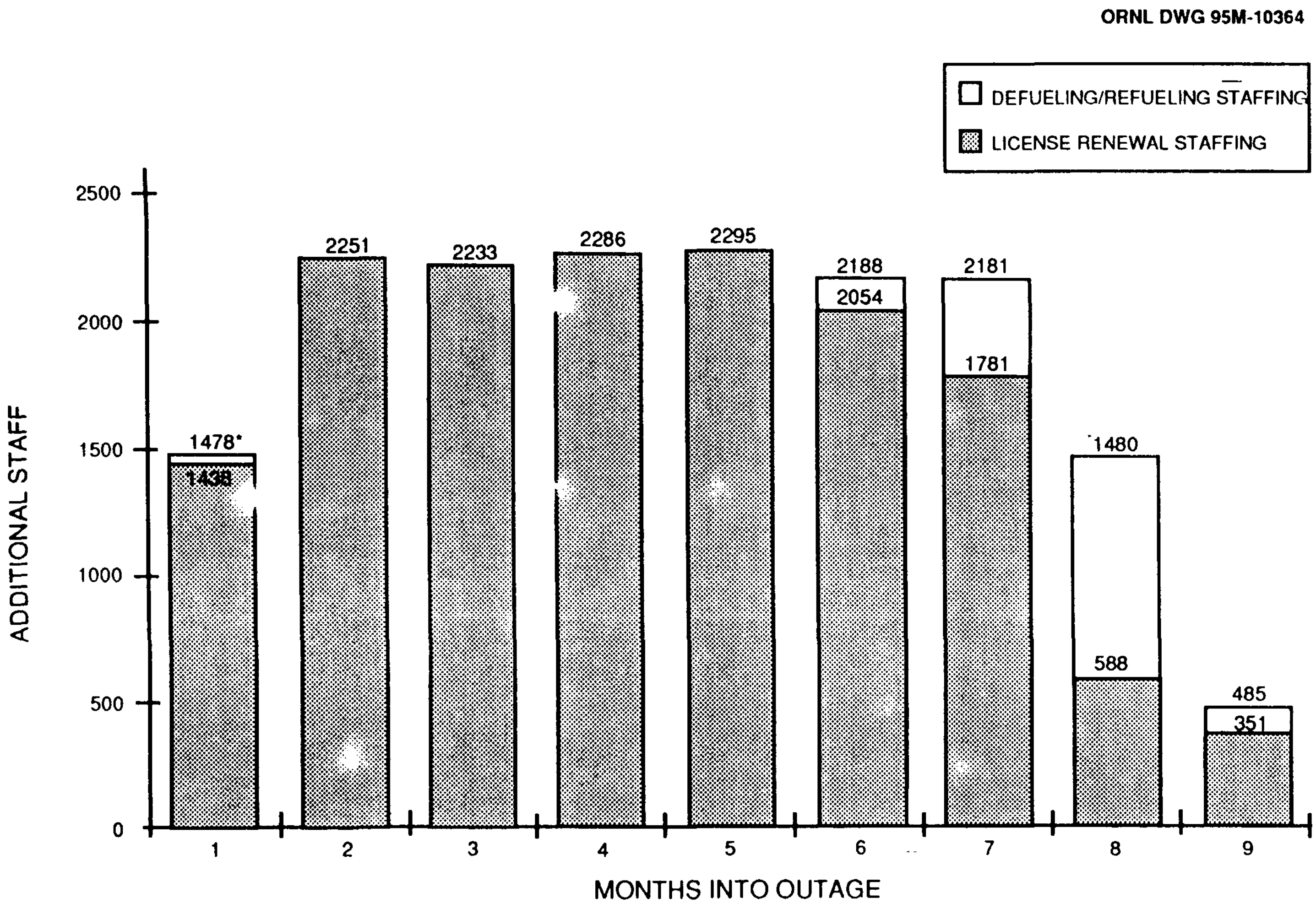
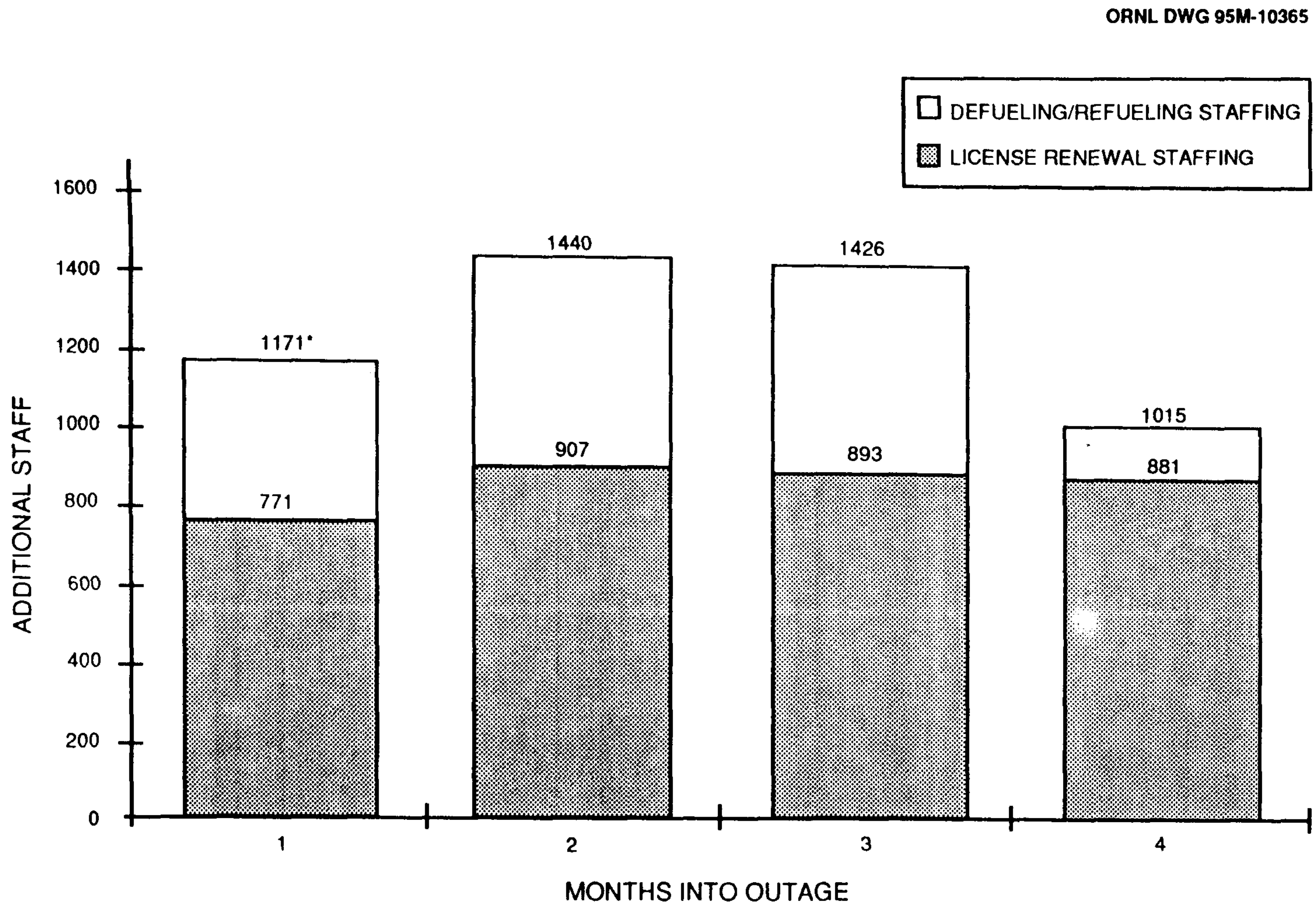


Figure B.5 Outage average incremental on-site staff.



* The upper number is the sum of both defueling/refueling and license renewal staffing.

Figure B.6 Additional personnel required to perform conservative case pressurized-water reactor license renewal major refurbishment outage activities.



* The upper number is the sum of both defueling/refueling and license renewal staffing.

Figure B.7 Additional personnel required to perform conservative case boiling-water reactor license renewal current-term outage activities.

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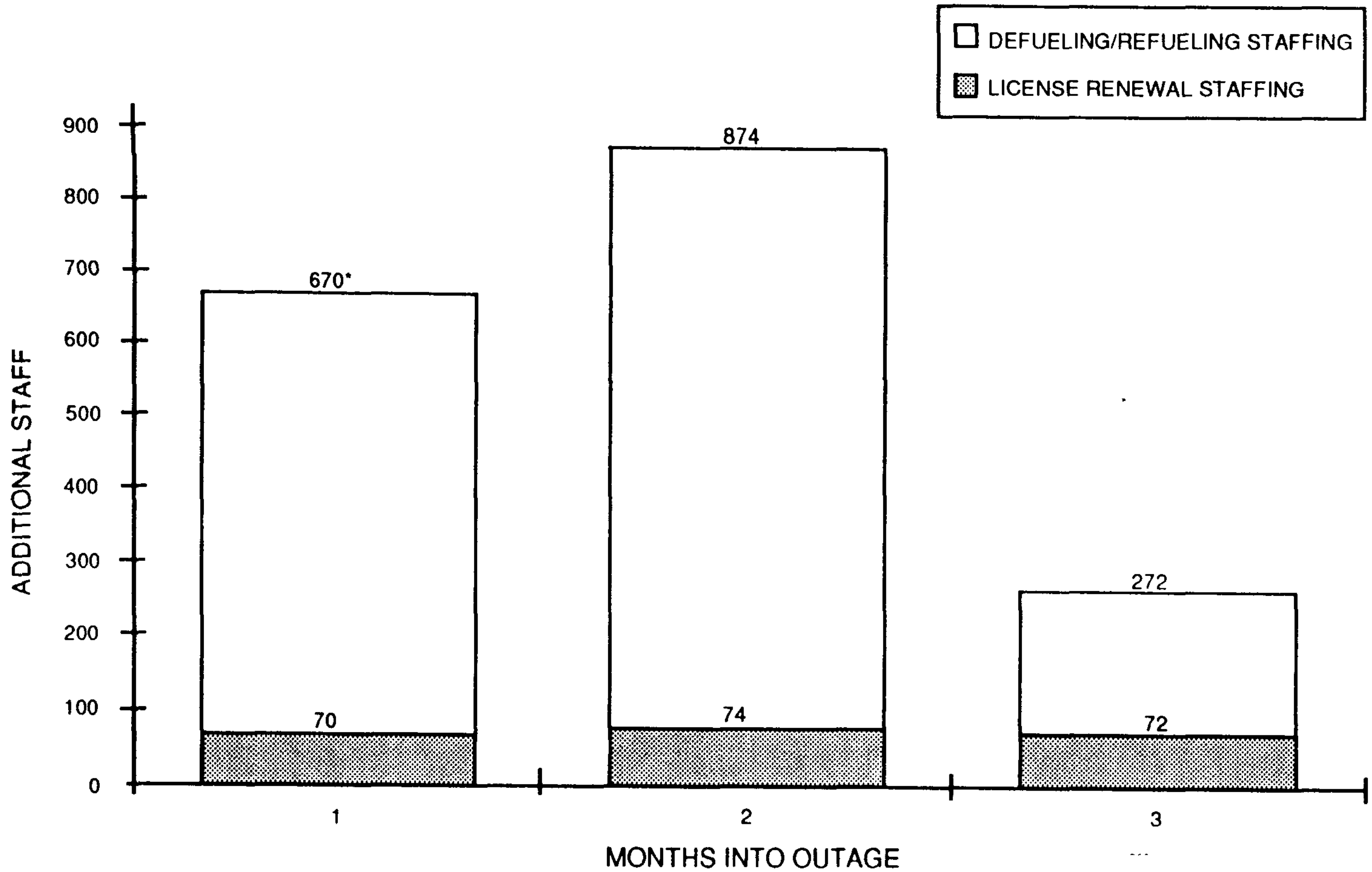

* The upper number is the sum of both defueling/refueling and license renewal staffing.

Figure B.8 Additional personnel required to perform typical case pressurized-water reactor license renewal current-term outage activities.

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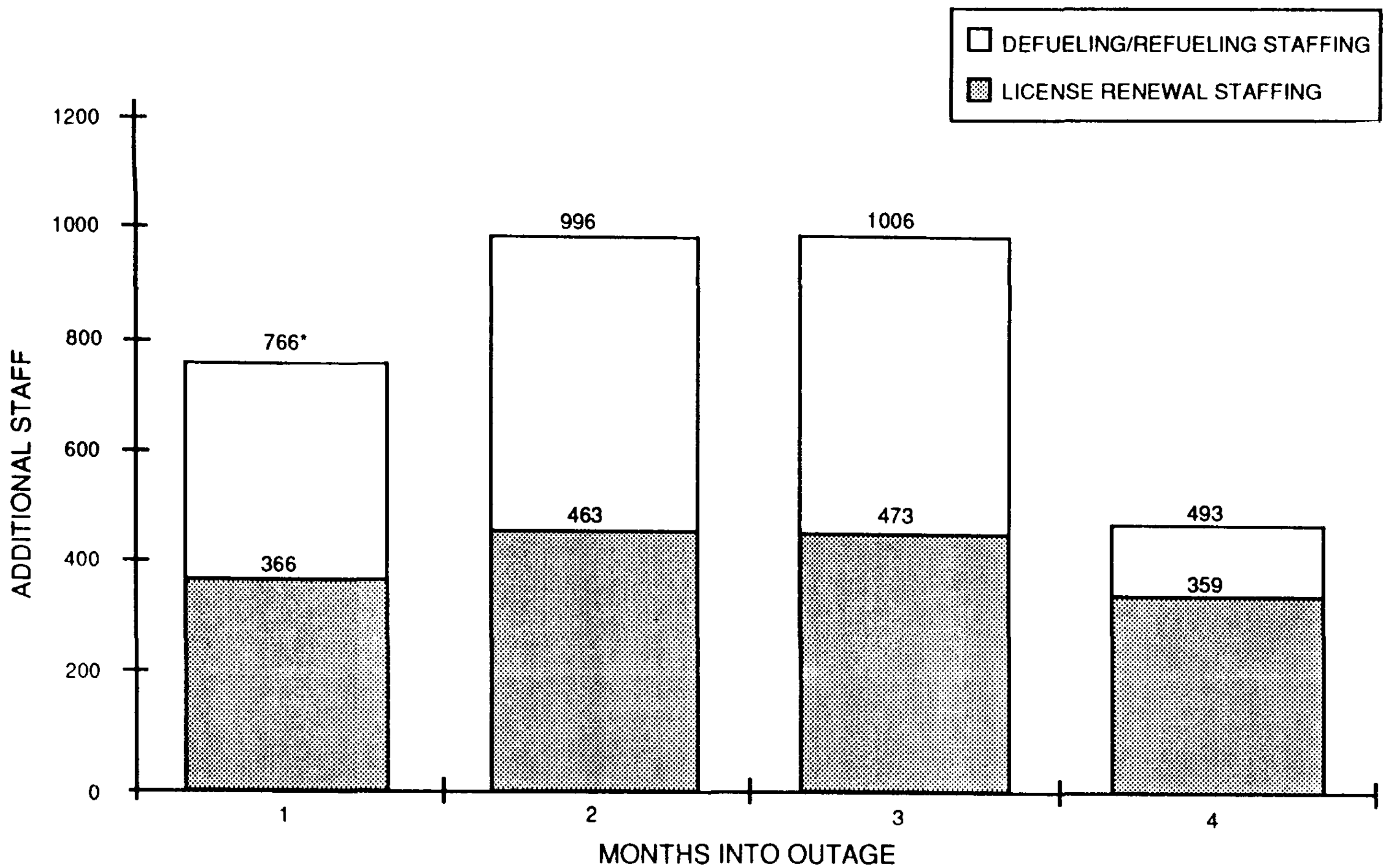

* The upper number is the sum of both defueling/refueling and license renewal staffing.

Figure B.9 Additional personnel required to perform typical case boiling-water reactor license renewal major refurbishment activities.

activities. The upper figures on the bars in Figure B.6 represent the total number of temporary workers needed during each particular month of the outage; the lower figure, where present, is the number needed to accomplish the incremental license renewal-related activities only. Based on this projection, the temporary work force needed during the major refurbishment outage for the conservative PWR license renewal scenario is estimated to be about 2300. This contrasts with the 1700 additional workers averaged over the entire outage as identified in Table B.5, which excluded consideration of the work force needed to carry out refueling and other routine activities. The month-to-month temporary staffing needs presented in Figure B.6 are by no means optimized, but they do indicate that the peak numbers of workers considerably exceeds estimates based on averages over the entire outage duration.

Figure B.7 presents estimates of peak temporary worker staffing needs for the BWR conservative license renewal scenario. In this case, the highest staffing needs are projected to occur during the current-term outages rather than during the major refurbishment outage. This is the most limiting BWR outage, because although the number of temporary workers on-site needed to accomplish incremental license renewal-related activities was about equal for both the current-term outage and the major refurbishment outage (see Table B.5), the 1600 person-months of effort needed for refueling and routine outage tasks must be accomplished in a 4-month period rather than a 9-month period, giving a greater overall total for the current-term outages. The projections in Figure B.7 indicate that the peak temporary work force needed for this BWR license renewal scenario is 1440 personnel.

Temporary worker needs for the typical license renewal scenarios are shown in Figures B.8 and B.9 for PWRs and BWRs, respectively. The peak staffing needs for the PWR occur during the 3-month current-term outage. In this scenario, the number of temporary workers needed during this outage to accomplish incremental license renewal-related activities is very modest, and the majority of the temporary staff would be needed to carry out refueling and more routine outage activities. The peak staffing needs are only about one-third of those needed for the conservative PWR license renewal scenario. Figure B.9 for the typical BWR license renewal scenario indicates that slightly more than 1000 temporary workers would be needed during the peak period of the major refurbishment outage. This is the most limiting outage staffing need for the typical BWR case.

B.4.1.2 Radioactive Waste Volumes

The waste volumes shown in Tables B.4 and B.5 include all types of low-level radioactive waste generated as a result of incremental license renewal and plant life extension activities. The volumes are those which remain after the wastes have been processed for storage or burial, and they include the volume of the burial or storage containers. The compactible waste items are assumed to undergo volume reduction. An average VRF of about 10 was used. This VRF is consistent with the use of currently available supercompactor technology. Even higher VRFs are achievable with incineration techniques, but these were not assumed here to preserve the conservative nature of the overall estimates. The noncompactible items of waste, on the other hand, are assumed to require a burial or storage volume which is about 20 percent greater than the initial volume of the solid article resulting from less-than-perfect packing factors associated with this type of waste.

Table B.4 indicates that the typical case BWR scenario is estimated to produce about 226 m^3 (8000 ft^3) of low-level radioactive waste as a result of license renewal-related activities. The corresponding volume for the PWR is about 170 m^3 (6000 ft^3). The greater volume for the BWR is because of the slightly greater number of SMITTR activities and the greater number of SSCs subject to these activities compared with the PWR. In addition, activities on turbine plant equipment for the BWR generate radioactive waste, whereas similar activities for the PWR do not.

The considerably larger volume of waste noted in Table B.5 for the PWR conservative case compared to the BWR conservative case is almost solely due to the effects of steam generator replacement in the PWR. These very large items contribute about 1,130 m^3 (40,000 ft^3) to the total PWR waste volume, and there are no comparable items in the BWR. The steam generators that have been removed to date from operating reactors have typically been stored on-site in special facilities constructed for that purpose rather than being disposed of at licensed burial facilities.

Total waste generation quantities are illustrated in Figure B.10 for both the typical and conservative case scenarios for each plant type. The example license renewal programs generated small amounts of GTCC wastes. These wastes are neutron-activated materials removed from the reactor vessels and/or reactor internals. The estimated amounts for the typical scenarios are 28 m^3 (1000 ft^3) for BWRs and 14 m^3 (500 ft^3) for PWRs, and for the conservative case scenarios about 44 m^3 (1540 ft^3) for BWRs and 14 m^3 (500 ft^3) for PWRs. These GTCC wastes were not included in the volumes cited in Tables B.4 or B.5. They are assumed to be retained on-site rather than shipped off-site for burial.

B.4.1.3 Occupational Radiation Exposure

Figure B.11 displays the estimates of incremental occupational radiation exposure incurred in carrying out license renewal activities. As shown in Figure B.11 and as indicated in Tables B.4 and B.5, incremental radiation exposure is projected to be on the order of 250 to 450 person-rem for the typical case scenarios and about 2500 person-rem for both reactor types for the conservative case scenarios. Because current average annual exposures for U. S. nuclear power plants are about 500 person-rem, the license renewal-related incremental occupational exposure for the typical scenarios represents the equivalent of about one additional year of operation. Given a 20-year incremental operating period, the license renewal-related activities appear to add about 5 percent to the cumulative exposure that would otherwise be expected over that period of extended plant life. For the conservative case scenarios of Table B.5, the estimated incremental exposure of roughly 2500 person-rem represents about five times the currently experienced annual exposure. However, the estimates from the conservative case license renewal programs are highly conservative because they encompass a greater variety and extent of activities than is expected from most plants pursuing license renewal. The largest fraction of the radiation exposure is expected to accrue from the major refurbishment activities for both reactor types. The bulk of the exposure is estimated to occur during the major refurbishment outage, and to a lesser extent during the current-term outages. The BWRs are expected to incur somewhat greater

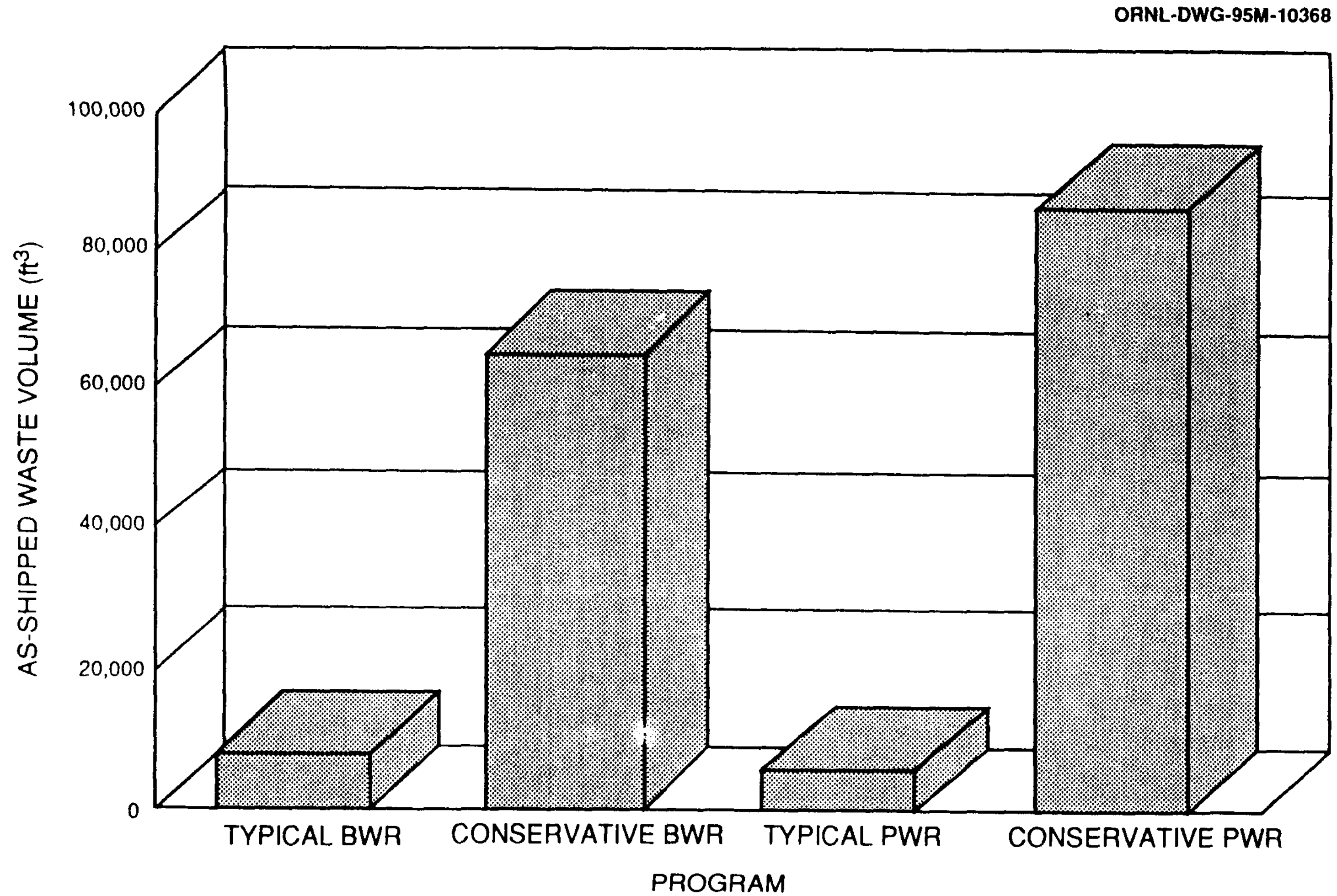

Figure B.10 Incremental low-level waste generated.

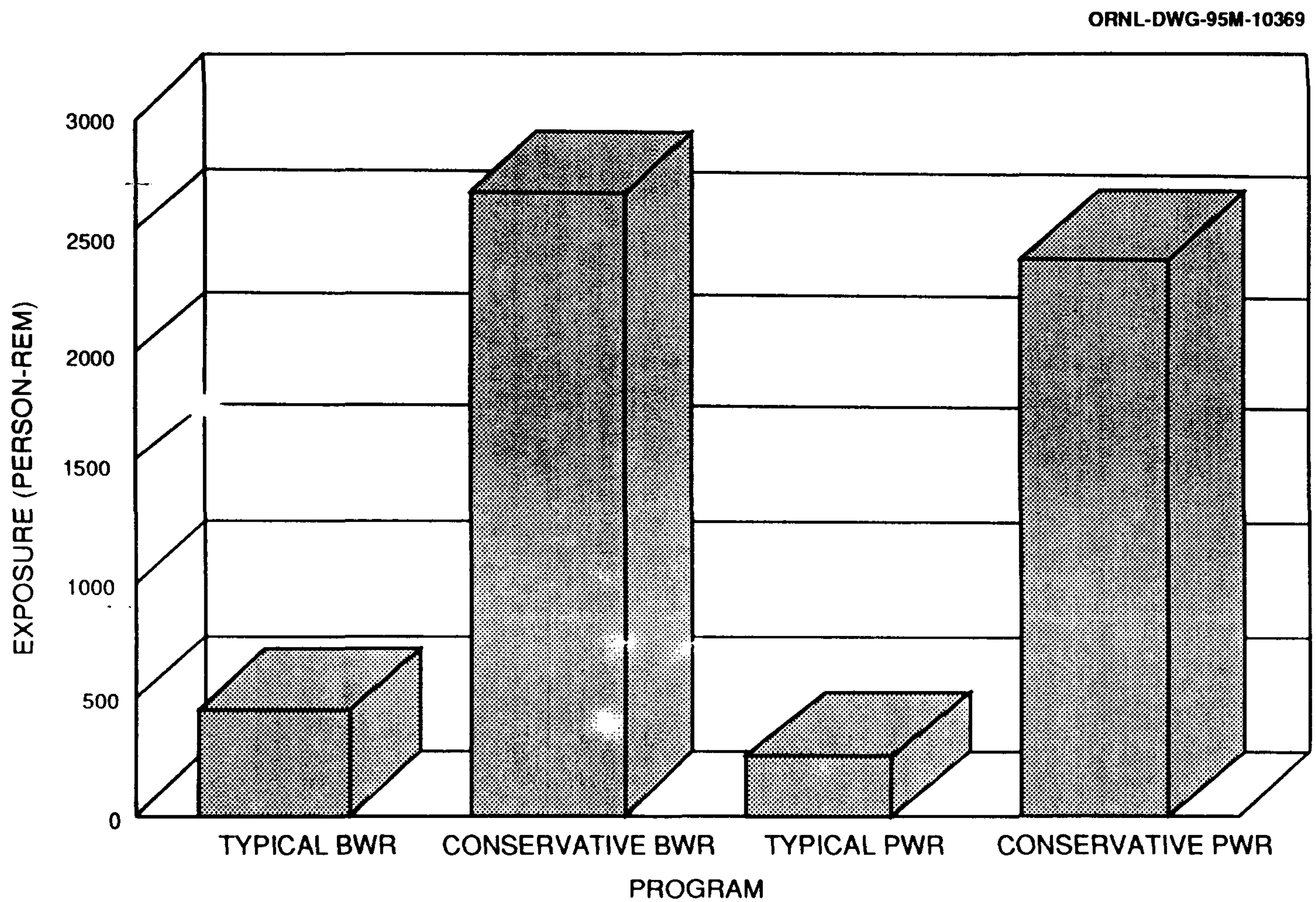

Figure B.11 Incremental occupational radiation exposure.

occupational radiation exposures than are the PWRs.

B.4.1.4 Waste Disposal Costs

The costs for disposing of low-level radioactive wastes generated as a result of license renewal-related activities are estimated to be about $3 million for the typical case scenarios and about $26 million to $37 million for the conservative case scenarios. Relative to the total costs associated with license renewal activities, these costs represent about 3 to 4 percent of the totals. As noted in Section B.3.2.4, waste disposal costs include charges for waste handling and packaging, short-term on-site storage, transportation, and burial. For the PWR conservative case scenario, the spent steam generators are assumed to be stored on-site rather than sent to an approved burial site for permanent disposal.

A cost of roughly $1 million has been assumed for the on-site steam generator storage facility, and this cost has been added to the overall waste disposal cost for the conservative case PWR. Waste disposal costs are graphically displayed in Figure B.12.

B.4.1.5 Capital Costs and On-Site Labor Costs

In addition to waste disposal costs, Tables B.4 and B.5 display labor costs and capital costs (costs associated with the purchase of materials, equipment, and hardware). The labor costs include those attributable to all categories of on-site labor, including administrative, engineering, craft, unskilled, and health physics. The costs are based on wage rates appropriate to each labor category and the labor mix as discussed in previous sections.

The values in Table B.4 indicate that, for the typical cases, capital costs are roughly twice the labor costs. Total on-site (labor plus capital) costs are estimated to be about $90 million for the typical BWR and about $80 million for the typical PWR. The higher costs for the BWR are consistent with the greater number of incremental SMITTR activities and greater number of SSCs included in the BWR program.

For the conservative case results displayed in Table B.5, the trends of capital versus labor costs are essentially reversed. That is, labor costs are higher than the capital costs for both reactor types. This relatively higher labor cost is attributable to the fact that many of the major refurbishment/replacement activities of the conservative cases involve radioactive SSCs and work in radiation zones. Work in radiation zones is less productive than work in nonradiation zones, and relatively more labor hours must be expended to accomplish a given activity. Capital costs, on the other hand, are essentially independent of whether the equipment or materials involved are in radiation zones. The combined labor and capital costs for the conservative case are estimated to be about $400 million for the BWR and about $460 million for the PWR. The higher costs for the PWR are primarily due to the large labor cost associated with steam generator replacement.

Labor and capital costs for both the typical and conservative case license renewal scenarios are illustrated in Figure B.13.

B.4.1.6 Off-Site Labor Costs

Off-site engineering and QA work are estimated to cost about $13 million–$15 million for the typical cases and about $38 million–$42 million for the conservative case scenarios. These are the off-site costs in this

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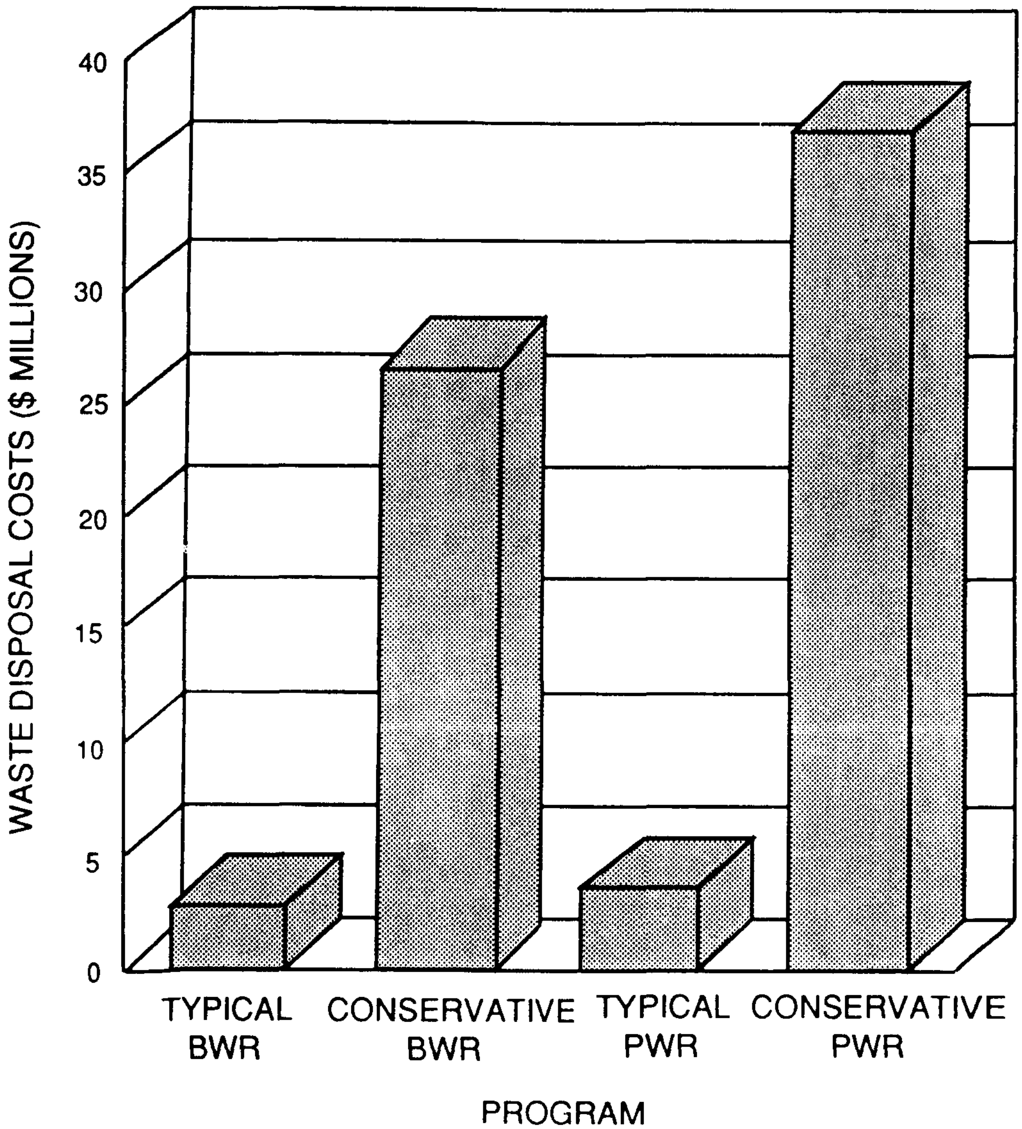

Figure B.12 Incremental waste disposal costs.

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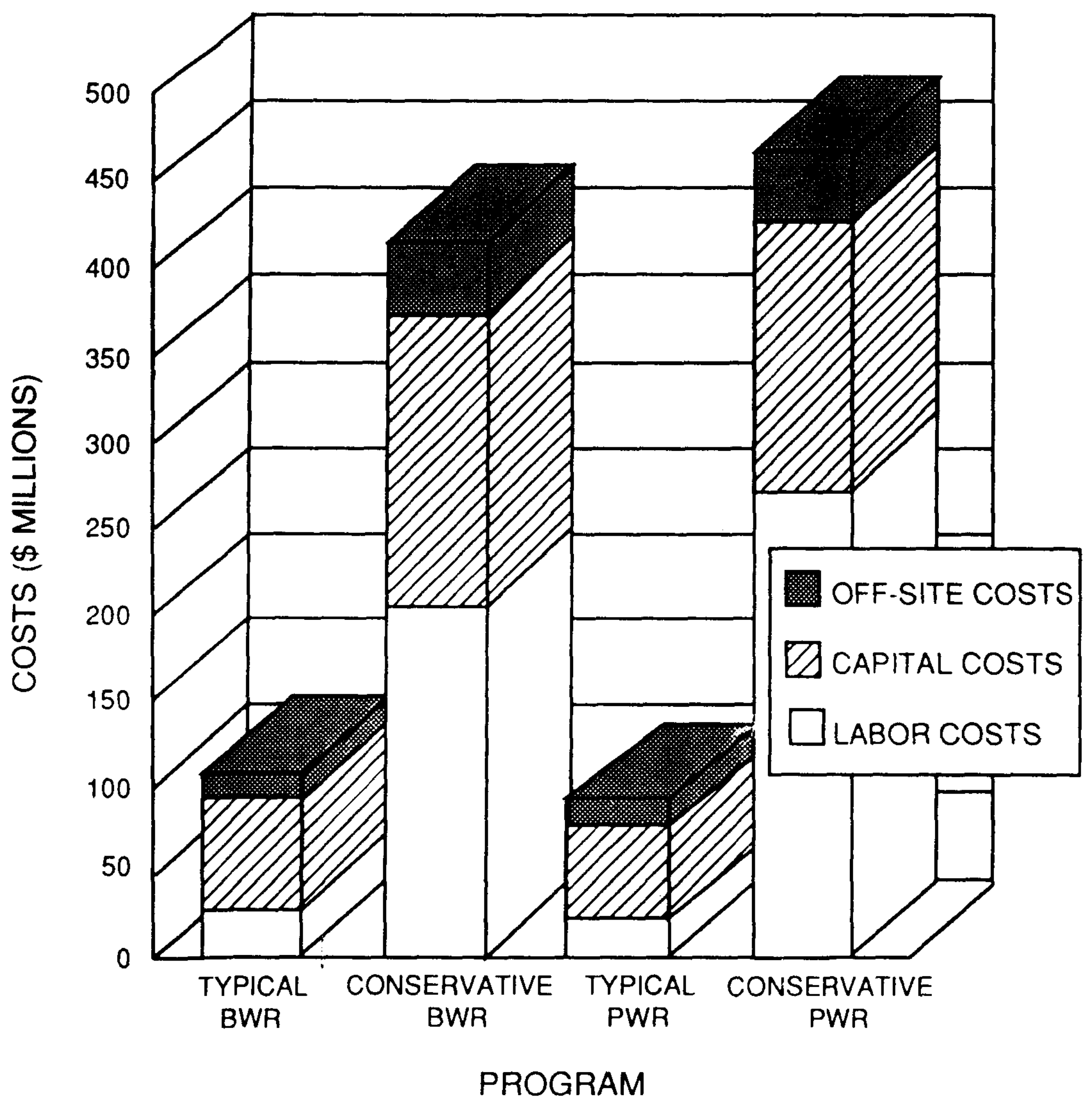

Figure B.13 Incremental capital and labor costs.

category carried out in support of the SMITTR and refurbishment activities. Off-site labor costs are depicted in Figure B.13.

B.4.1.7 Total Costs

All costs shown in Tables B.4 and B.5 are in 1994 dollars. They also are presented as "overnight" (undiscounted) costs. That is, they represent costs as if all activities of each program were performed in a very short period of time rather than being spread over approximately 28 years as is envisioned for the actual scenarios. Time-value-of-money effects are not included in Tables B.4 or B.5, and no allowance has been included for costs of financing during the construction/refurbishment stages. Also, replacement energy costs are excluded from the figures presented in these tables. Those costs are discussed below.

Table B.4 indicates that the total program costs for the typical BWR are estimated to be about $110 million, and the corresponding PWR costs are about $90 million. Based on a 1000-MW(e) reference plant size, these estimates indicate license renewal-related costs of roughly $100/KW(e) for the typical renewal cases. Table B.5 indicates that the conservative case program costs are estimated to be in the range of $440 million to $500 million, with corresponding unit costs between $440/KW(e) and $500/KW(e).

B.4.1.8 Replacement Energy Costs

Replacement energy costs were estimated based on a rate of $290,000 per day of plant downtime for BWRs and $340,000 per day for PWRs (NUREG/CR-4012 1992). The typical BWR and PWR license renewal programs have a cumulative incremental downtime of 5 months, whereas for the conservative case scenarios the incremental downtime is estimated to be about [illegible] months. This is the time required to accomplish the SMITTR and major refurbishment activities making up the programs. Cumulative downtime costs, therefore, are estimated to be about $44 million for BWRs and $52 million for PWRs for the typical scenarios and about $130 million to $155 million per plant for BWRs and PWRs, respectively, for the conservative case scenarios (overnight costs).

Figure B.14 illustrates the total estimated license renewal-related costs previously discussed, including replacement energy costs. This figure indicates the relative magnitude of the major cost components.

B.4.1.9 Local Purchases

Of the capital costs reported in Tables B.4 and B.5, a small fraction may possibly be spent locally. Items such as concrete, rebar, formwork, certain electrical wire and cables, and similar materials could conceivably be purchased from local suppliers in the vicinity of nuclear plants. The cost of these items used here for the typical programs was estimated to be less than $1 million for each plant type, and possibly about $5 million total for each conservative case scenario. These purchases occur for activities performed during the current-term outages and the major refurbishment outage.

B.4.2 Comparisons to Industry Costs for Plant Life Extension

The nuclear power industry, the U. S. Department of Energy, and other entities have evaluated the benefits and costs of nuclear plant life extension. They have estimated both the likely costs associated with plant life extension and the break-even costs. The break-even costs indicate the point at which nuclear plant life extension is

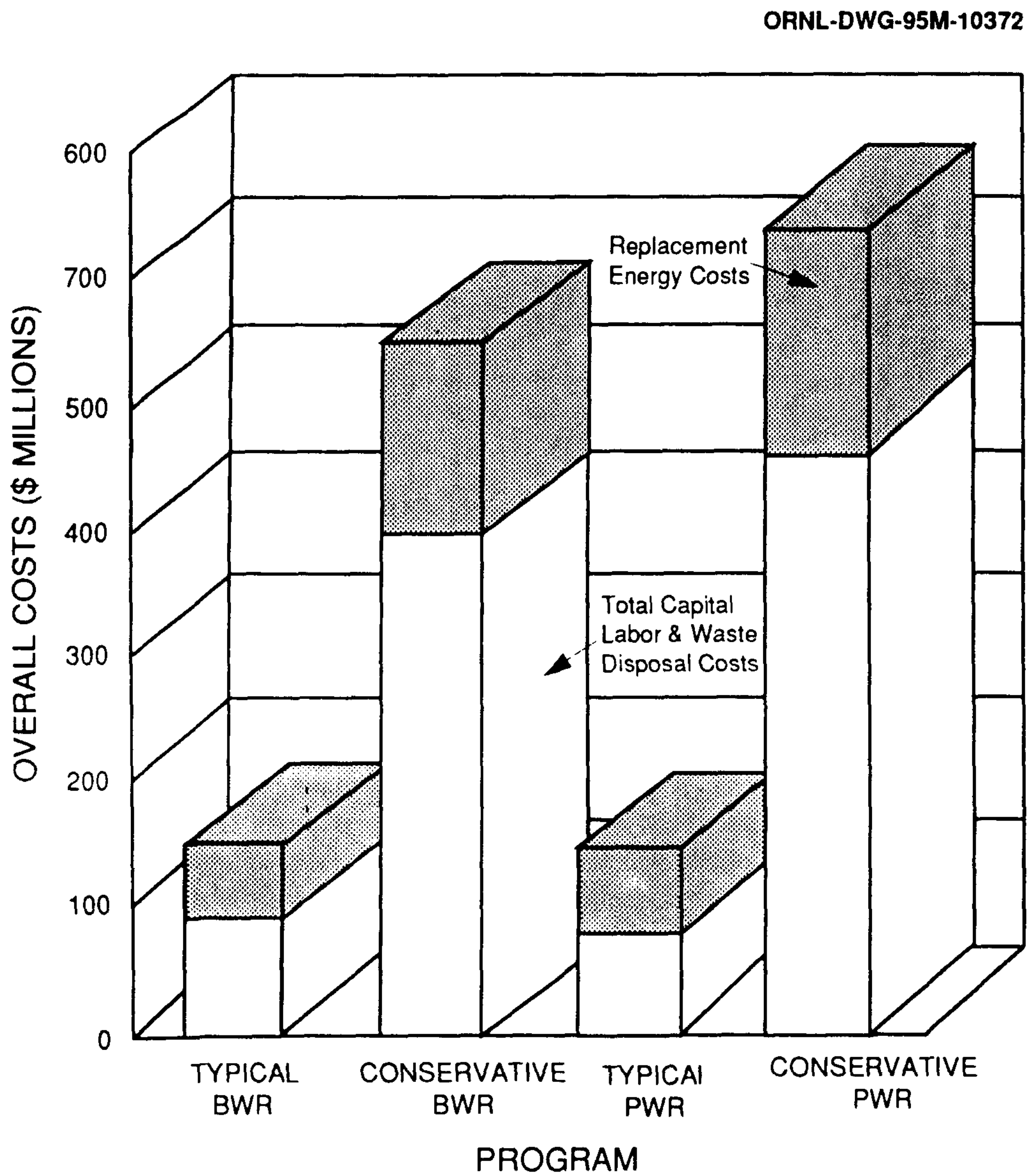

Figure B.14 Total license renewal costs.

as costly as would be the construction of alternative power sources such as a new coal plant or a new nuclear plant.

Table B.6 compares the costs of license renewal and extended plant life developed for the GEIS with estimates prepared by industry. The table includes both typical and conservative case estimates. The GEIS estimates as presented in the table are all given on an overnight basis (i.e., both financing costs and present-worth effects have been excluded from the figures). The GEIS estimates include all cost elements presented in Tables B.4 and B.5, and they include replacement energy costs as well. These are shown separately for BWRs and PWRs. Table B.6 indicates that the GEIS estimates for plant lift extension costs range from about $150 million to $570 million for the BWR typical and conservative case license renewal programs, respectively, and about $140 million to $650 million for the corresponding PWR programs. On a dollar per kilowatt basis, and based on the reference 1000-MW(e) plant size, these costs are in the range of $140 to $150/kw for the typical scenarios and from about $570 to $650/kw for the conservative case scenarios. The available industry estimates for plant life extension are shown in Table B.6 in dollars per kilowatt (SAND88-7095 1988; McCutchan 1988). They range from about $230/kw to almost $700/kw. The GEIS estimates fall roughly within the range developed by the industry sources. The typical case scenarios fall somewhat below the industry estimates, whereas the conservative case estimates are at the higher end of the industry estimates.

B.4.3 Other Impacts and Considerations

This section briefly discusses two aspects related to license renewal program costs. These are the time-value-of-money effects (present worth) and the portions of the programs directly attributable to meeting the new aging management requirements imposed by 10 CFR Part 54, Rules for Nuclear Plant License Renewal.

B.4.3.1 Present Worth Considerations

The estimates presented in Tables B.4, B.5, and B.6 were given on an "overnight" cost basis, and did not account for the fact that the expenditures are spread out in time over a considerable period. Table B.7 shows the effects of considering the time-value-of-money on the total program costs. Present value program costs are shown for three discount rates: 0 percent, 5 percent, and 10 percent. All costs are given in 1994 dollars. The datum time used to develop the values in Table B.7 is a representative point in a program at which a licensee would submit the application for license renewal to the NRC. As was shown in Figure 2.3 of Chapter 2, this point is assumed to occur 12 years before the expiration of the initial 40-year license period, and is 32 years before the end of plant life, assuming a total plant life of 60 years. The figures shown for the 0 percent discount rate are the same as those presented in Tables B.4, B.5, and B.6, and they include off-site labor costs and replacement energy costs.

The example license renewal programs incurred the major portion of the costs in the first 12 years following the submittal of a license renewal application. This is the period when major refurbishment/replacement activities are assumed to take place. In spite of the fact that these expenditures are not assumed to occur further out in time relative to the datum time point used, discounting does significantly reduce the effective cost of the license renewal programs.

Table B.6 Comparisons of industry plant life extension cost estimates (all costs in millions of 1994 dollars)

	PWR[a]		BWR[b]	
	Conservative	Typical	Conservative	Typical
GEIS estimates (million dollars)				
On-site labor cost	269	21	202	28
Capital costs	155	54	171	63
Total on-site costs	461	78	399	92
Off-site labor	38	13	42	15
Incremental replacement energy costs[c]	155	52	132	44
Total estimated costs	**654**	**143**	**573**	**151**
$/kw	654	143	573	151
Industry estimates ($/kw)[d]				
Monticello				634
General Electric				230
Surry		1331		
Westinghouse		698		

[a]PWR = pressurized-water reactor
[b]BWR = boiling-water reactor
[c]@$287,000 per day (BWR) or $342,000 per day (PWR)
[d]SAND88-7095, escalated to 1994 dollars

Table B.7 Time-value-of-money effects on nuclear plant license renewal program costs

	Program costs (million dollars)			
	PWR[a]		BWR[b]	
Discount rate (%)	Conservative	Typical	Conservative	Typical
0	694	183	605	186
5	436	107	381	107
10	291	68	256	67

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

B.4.3.2 10 CFR Part 54 Impacts

Certain of the aging management activities making up the example programs used here are incremental requirements called for by 10 CFR Part 54. The example list of activities assumed attributable to the Part 54 rule are identified in Table B.8, and they represent a subset of those presented in Tables B.1 and B.2. The list of activities in Table B.8 was derived from the 10 CFR Part 54 Regulatory Analysis (NUREG/CR-1362) and from evaluations of the actions contemplated for the lead plant programs (Sciacca January 3, 1993; January 13, 1993). Other interpretations of these sources could yield different results. However, the example lists of activities presented in Table B.8 are thought to be reasonably representative of what might be needed to satisfy the requirements of the license renewal rule. This list is adequate for estimating impacts attributable to 10 CFR Part 54.

Many of the activity descriptions in Table B.8 are presented on a per-SSC basis, but the total program includes many repetitions of each activity to cover multiple similar SSCs as well as repeat actions on the same SSC. The activities listed are all SMITTR actions, as opposed to major refurbishment activities. Also, these actions address only those SSCs which are important to license renewal, and the Part 54 impacts exclude actions likely to be taken by licensees solely for economic and plant availability purposes.

Table B.9 presents estimates of the impact initiators attributable to the enhanced aging management activities called for by 10 CFR Part 54. The figures indicate that the impacts attributable to the Part 54 rule are only a small fraction of the conservative values shown in Tables B.4 and B.5. The costs shown in Table B.9 represent overnight costs, and do not reflect any discounting for expenditures incurred over the 30 or more years assumed for the conduct of the subject activities.

The capital costs reflect the addition of new or enhanced monitoring and surveillance systems and equipment, as well as the costs of replacement hardware for SSCs

Table B.8 Example list of activities attributable to the proposed changes to 10 CFR Part 54 activities

Component	Activity
	Boiling-water reactor
Actuation	Inspect connectors and penetrations for channels
Bellows	Inspect refueling and dry well bellows assembly
Compressed air	Inspect wall thickness of tanks and piping of compressed air system
Containment	Examine fabrication welds (ultrasonic testing and visual) and base and concrete core sample (remove and replace a 6-in. square of concrete)
	Conduct enhanced inspection for entire containment structure: reinforcing steel condition, boroscopic examination of surface next to penetrations, exterior and interior concrete surfaces, ground water properties, etc.
Containment	Renew protective coating on containment structure
	Inspect suppression pool and vent system exterior
EDG[a]	Inspect wall thickness and welds of 5 percent of susceptible areas for diesel generator fuel and oil support systems for emergency diesel generator
Fuel pool	Visually inspect liner
HVAC[b]	Inspect ducting, fans and motors, flex-joints, and dampers for degradation
	Conduct ISTM[c] of HVAC of building with radiation.
Main piping	Install on-line vibration and dynamic efficiency monitoring system to monitor condition of recirculation and feedwater piping system, including piping vibration and dynamic effects measurements
NSSS[d] supports	Torque a statistical sample of component support anchor bolts
Pipe	Install humidity sensor system in main reactor building compartment or HVAC intakes for leak detection
	Add fatigue monitoring system to reactor vessel nozzles and safe ends and to key piping locations
RCB[e]	Replace containment electrical penetrations
Recirculation pump	Conduct detailed inspection (disassembly/reassembly) of pump and motor

See footnotes at end of table

Table B.8 (continued)

Component	Activity
RPV[f]	Visually assess condition of entire vessel exterior; inspect/evaluate specimen for fracture toughness and tensile strength
	Install excore neutron dosimeters near one of the predicted peak fluence locations at beltline
	Replace closure stud bolts
RPV internals	Conduct underwater inspection of core plate for IGSCC, inspect jet pump brace and safe ends, inspect shroud-to-shroud support flange and access hold cover, bolt inspection method, and ultrasonic testing of top guide
	Install an enhanced system for monitoring loose parts throughout reactor internals in accordance with proposed ASME OM-12
	Conduct ultrasonic testing of top guide in central core region for IGSCC, shroud-shroud support cylinder welds, core spray inlet tee attachment, jet pump riser elbow to thermal sleeve weld region, and jet pump diffuser-to-adapter weld joint
Structures	Conduct one-time inspection of structures, anchors, and protective coatings in spray pond, cooling tower bases, intake structure, and other pools
	Conduct enhanced inspection of entire structures: reinforcing steel condition, boroscopic examination of surface next to penetrations, exterior and interior concrete surfaces, ground water properties, etc.
	Pressurized-water reactor
Actuation	Inspect connectors and penetrations for channels
Compressed air	Inspect wall thickness of tanks and piping of compressed air system
Containment	Examine fabrication welds (ultrasonic testing and visual) and base and concrete core sample (remove and replace a 6-in. square of concrete)
	Conduct enhanced inspection of entire containment structure: reinforcing steel condition, boroscopic examination of surface next to penetrations, exterior and interior concrete surfaces, ground water properties, etc.
Containment	Renew all concrete protective coating on containment structure

See footnotes at end of table

Table B.8 (continued)

Component	Activity
EDG	Inspect wall thickness and welds of 5 percent of susceptible areas for diesel generator fuel and oil support systems EDG
Fuel pool	Visually inspect liner
HVAC	Inspect ducting, fans and motors, flex-joints, and dampers for degradation; conduct ISTM of HVAC of building with radiation
NSSS supports	Torque a statistical sample of component support anchor bolts
Pipe	Add fatigue monitoring system to reactor vessel nozzles and safe ends and to key piping locations
	Install humidity sensor system in main reactor building compartment or HVAC intakes for leak detection
RCB	Replace containment electrical penetrations
Reactor coolant pump	Conduct detailed inspection (disassembly, reassembly) of reactor coolant pump, shaft, and motor
RPV	Visually assess condition of entire vessel exterior; inspect/evaluate specimen for fracture toughness and tensile strength
	Inspect condition of dry lubricants in sliding foot area
	Replace closure stud bolts
	Install excore neutron dosimeters near one of the predicted peak fluence locations at beltline
RPV internals	Install reactor internals vibration monitoring system
	Inspect core support plate, core shroud, and top guide using visual and UT or similar methods; inspect welds and critical areas
	Install on-line loose parts monitoring system
Steam generator	Add secondary side transducers to incorporate generator into loose parts monitoring system

See footnotes at end of table

Table B.8 (continued)

Component	Activity
Structures	Conduct enhanced inspection of entire structures: reinforcing steel condition, boroscopic examination of surface next to penetrations, exterior and interior concrete surfaces, ground water properties, etc. Conduct one-time inspection of structures, anchors, and protective coatings in spray pond, cooling tower bases, intake structure, and other pools

[a]EDG = emergency diesel generator
[b]HVAC = heating, ventilating, and air conditioning
[c]ISTM = inspection, surveillance, testing, and maintenance
[d]NSSS = nuclear steam supply system
[e]RCB = reactor containment building
[f]RPV = reactor pressure vessel
[g]IGSCC = intergranular stress-cracking corrosion

Table B.9 Contributions to the license renewal environmental impact initiators from Part 54 activities

	BWR[a]	PWR[b]
Labor hours	24,000	150,000
Exposure (person-rem)	340	170
Labor cost (million 1994 dollars)	11.0	6.5
Capital cost (million 1994 dollars)	4.2	3.7
Waste volume (m^3)	105	74

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

Note: Multiply person-rem by 0.01 to find sieverts.
Multiply m^3 by 35.32 to find ft^3.

on a routine basis. An example of the latter is valve internal components.

B.4.4 Consideration of Other License Renewal Programs

The current effort focused on license renewal environmental impact initiators for two generic light-water reactor types: BWRs and PWRs. The resulting estimates are believed to encompass a high percentage of the potential environmental impact initiators which may accrue as plants undertake license renewal and plant life extension activities. The estimates of environmental impacts associated with nuclear plant license renewal can be refined in a number of ways.

Because no commercial light-water reactors have yet applied for license renewal, the nature and characteristics of actual programs have yet to be fully defined. As noted previously, each plant's program is expected to be somewhat unique.

Alternative programs for license renewal and plant life extension are certainly likely, and the impacts of these alternative programs could be evaluated. Differences from the reference programs used to develop the current estimates are likely for both major refurbishment activities and SMITTR activities. The SMITTR programs used here are based on the safety-centered approach developed for the License Renewal Regulatory Analysis (Sciacca January 25, 1990; Sciacca February 20, 1990). Other ISTM programs are certainly possible, some of which may have greater impacts than those defined herein. Similarly, different major refurbishment programs can also produce significantly different environmental impacts from the representative programs used here. For example, a program could be based on a much more extensive use of ISTM, with less reliance on major refurbishment, than the programs used in the current assessments.

Although alternative programs could have been evaluated, the license renewal programs used to develop the current estimates of environmental impact initiators are believed to bound what might actually occur at most plants.

B.5 ENDNOTES

1. A discussion of the SI units used in measuring radioactivity and radiation dose is given in Appendix E, Section E.A.3.

B.6 REFERENCES

The following references include those for Attachment 1.

Abbott, S. L., et al., "Westinghouse Reactor Vessel Life Extension Variance Study," p. 210 in *Proceedings of the Topical Meeting on Nuclear Power Plant Life Extension,* Vol. 1, American Nuclear Society, Snowbird, Utah, July 31-August 3, 1988.

DOE/CR-5764, *Phase VIII Update (1986) BWR Supplement for the Energy Economic Data Base Program,* United Engineers and Constructors, August 1986.

DOE/NE-0051/1, *Phase VIII Update (1986) Report for the Energy Economic Data Base Program,* United Engineers and Constructors, August 1986.

Eckert, G. (Kraftwerk Union Aktiengesellschaft, Offenbach, Federal Republic of Germany), "Replacement of Steam Generators and Recirculation Pipes in LWRs as Long-Lasting Measures to Extend Plant Lifetime," pp.

237–50 in *Proceedings of an NEA Symposium Held in Cooperation with the IAEA Nuclear Plant Life Extension,* February 1987.

EPRI NP-2418, *Extended Life Operation of Light Water Reactors: Economic and Technological Review*, Vols. 1–2, Electric Power Research Institute, Palo Alto, California, June 1982.

EPRI NP-4208, *The Longevity of Nuclear Power Systems*, Electric Power Research Institute, Palo Alto, California, August 1985.

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.

Katz, L. R., "The PLEX Aspects of the Storage or Disposal of Replaced Nuclear Components," p. 276 in *Proceedings of the Topical Meeting on Nuclear Power Plant Life Extension,* Vol. 1, American Nuclear Society, Snowbird, Utah, July 31–August 3, 1988.

Lott, R. G., and T. R. Mager, "Reactor Vessel Life Extension by Thermal Annealing," pp. 127–32 in *Proceedings of the ASME Pressure Vessel and Piping Conference,* Honolulu, July 1989.

Massie, H. W., et al., "A Systematic and Cost-Effective Approach to Nuclear Plant Life Extension," pp. 31–34 in *Proceedings of the International Conference on Nuclear Power Plant Aging, Availability Factor, and Reliability Analysis,* San Diego, 1985.

McBrien, H. W., "Pipes Replaced at Vermont Yankee in Record Time," *Nuclear Engineering International (UK)*, 32, 28 (April 1987).

McCutchan, D. A., et al., "Analysis of Integrated Plant Upgrading/Life Extension Programs," p. 232 in *Proceedings of the Topical Meeting on Nuclear Power Plant Life Extension,* Vol. 1, July 31–August 3, 1988, Snowbird Utah.

Miselis, V., "The Westinghouse Reactor Vessel Life Extension Variance Study," *Proceedings of the Topical Meeting on Nuclear Power Plant Life Extension,* American Nuclear Society, Snowbird, Utah, July 31–August 3, 1988.

MITRE Corp., *A Topical Study on the Use of Nuclear Plant Aging Information in the Regulatory Analysis of License Renewal Alternatives,* WP-8800477, December 1988.

Moore, T., "Nuclear Plants: Life after 40," *EPRI Journal*, pp. 20–29, October/November 1990.

Morency, K. R., and M. S. McGough, "The Evolution of Steam Generator Replacement Projects in the United States," *Nuclear Plant Journal*, pp. 72, May/June 1989.

"North Anna-1 Steam Generator Changeout Beats Goals," *Nuclear News*, p. 38, June 1993.

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-4012, J. C. Van Kuiken et al., *Replacement Energy Costs for Nuclear Electricity-Generating Units in the United States: 1987–1991*, Vol. 2, prepared by Argonne National Laboratory for the

U.S. Nuclear Regulatory Commission, Washington, D.C., 1986.

NUREG/CR-4555, R. Clark et al., *Generic Cost Estimates for the Disposal of Radioactive Wastes,* Rev. 1, prepared by Science and Engineering Associates, Inc., for the U.S. Nuclear Regulatory Commission, Washington, D.C., September 1988.

NUREG/CR-4627, E. Claiborne et al., *Generic Cost Estimates: Abstracts from Generic Studies for Use in Preparing Regulatory Impact Analyses,* Rev. 1, prepared by Science and Engineering Associates, Inc., for the U.S. Nuclear Regulatory Commission, Washington, D.C., December 1988.

NUREG/CR-4731, V. N. Shah and P. E. MacDonald, *Residual Life Assessment of Major Light Water Reactor Components: Overview,* prepared by Idaho National Engineering Laboratory for the U.S. Nuclear Regulatory Commission, Washington, D.C., June 1987.

NUREG/CR-4921, H. M. Smith and E. J. Ziegler, *Engineering and Quality Assurance Cost Factors Associated with Nuclear Plant Modification,* U.S. Nuclear Regulatory Commission, Washington, D.C., April 1987.

NUREG/CR-5035, S. K. Beal et al., *Database of System-Average Dose Rates at Nuclear Power Plants,* prepared by Science and Engineering Associates, Inc., for the U.S. Nuclear Regulatory Commission, Washington, D.C., October 1987.

NUREG/CR-5236, F. W. Sciacca et al., *Radiation-Related Impacts for Physical Modifications at Nuclear Power Plants,* prepared by Science and Engineering Associates, Inc., for the U.S. Nuclear Regulatory Commission, Washington, D.C., October 1989.

NUREG/CR-5248, I. Levy et al., *Prioritization of TIRGALEX-Recommended Components for Further Aging Research,* prepared by Battelle Pacific Northwest Laboratories for the U.S. Nuclear Regulatory Commission, October 1988.

NYPA (New York Power Authority), *1989 Outage ALARA Report,* NYPA (Indian Point 3), 1989

Rippon, S., "The Dampierre-1 Steam Generator Replacement," *Nuclear News,* p. 84, September 1990.

SAND88-7095, Forest, L. R. Jr. et al., *Cost Savings from Extended Life Nuclear Plants,* September 1988.

Sciacca, F. W., Science and Engineering Associates, Inc., letter to D. Cleary, U.S. Nuclear Regulatory Commission, "Transmittal of Discussion of Direct Consequences for Inclusion in Draft License Renewal Regulatory Analysis," January 25, 1990.

Sciacca, F. W., Science and Engineering Associates, Inc., letter to D. Cleary, U.S. Nuclear Regulatory Commission, "Transmittal of Appendix D of Draft License Renewal Regulatory Analysis," February 20, 1990.

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.

Sciacca, F. W., et al., Science and Engineering Associates, Inc., *Cost Analysis of Alternative LWR License Renewal Regulations,* Report

SEA 87-288-09-A:1, U.S. Nuclear Regulatory Commission, March 1989.

Sciacca, F. W., et al., *Impact Driver Definition for Nuclear Plant License Renewal Generic Environmental Impact Study*, Report SEA 89-461-09-A:1, U.S. Nuclear Regulatory Commission, August 1990.

"Steam Generator Replacement at Dampierre 1, France," *Nuclear Plant Journal*, pp. 93–95, May/June 1990.

Zachary, J., et al., "ALARA at the Peach Bottom-3 Pipe Replacement Project," *Nuclear News*, pp. 34–37, September 1989.

APPENDIX B—ATTACHMENT 1

RECENT INDUSTRY EXPERIENCE FOR MAJOR REFURBISHMENTS AND ESTIMATES FOR PLANT LIFE EXTENSION COSTS

A literature search for plant life extension and license renewal related cost information was conducted in support of the draft Generic Environmental Impact Statement published for comment in August 1991. That literature search focused on obtaining industry-derived data on inspection, surveillance, test, and maintenance (ISTM) actions and on major repair, replacement, or refurbishment actions undertaken in the past or planned in support of license renewal and plant life extension (PLEX) activities. The information collected is discussed in this attachment. Since the search was performed in 1991, all information cited dates from 1991 or earlier. The cost information has not been updated to 1994 dollars.

For each activity of interest to this evaluation (e.g., reactor pressure vessel replacement, steam generator replacement), information such as capital cost, labor, radiation exposure incurred, radioactive waste type and volume generated, and outage duration was obtained, if available. This search resulted in the identification of numerous references; however, most did not provide the needed detail on the aforementioned items. Many of the references presented overall PLEX cost in dollars per kilowatt but did not provide a breakdown of individual activities. It is important to note that most references recognized that the PLEX costs will vary significantly depending upon the reactor type and the vintage.

The following sections present information organized by specific component or topic. Following these sections is a list of references reviewed.

STEAM GENERATORS

Although several utilities have replaced their steam generators, the majority are searching for ways to extend the life of their operating steam generators, such as heat treating and sleeving to avoid the cost of replacement. In "Steam Generator Replacement at Dampierre 1, France," *Nuclear Plant Journal* May/June 1990, it is reported that a steam generator replacement at Dampierre 1, France, had a cost estimate of $106 million, including $3.5 million for three steam generators. Additionally, Rippon 1990 reported the steam generator replacement took 200,000 work hours and resulted in an exposure of 220 person-rem.

In Eckert (1987), the replacement of steam generators in a two-loop plant was estimated by Kraftwerk Union to require 2.5 months using 140,000 work hours and result in a total dose of 700 person-rem. Additionally, the planning of the steam generator replacement took 45,000 work hours.

In SAND88-7095, the replacement of steam generators is assigned a probability. This probability will be zero if the component has been replaced, or low if the component is of current design. However, older plants will have a high probability of replacement. The cost of steam generator replacement has been estimated at $20 million (1986 dollars) multiplied by the number of loops multiplied by the probability of replacement.

Item	Palisades	Turkey Point	Surry
Direct cost (million dollars)	75	102	81
Replacement power cost (million dollars)	200	124	—
Total (million dollars)	275	226	—
Outage time	2 yrs	207 days	8.5 mos

EPRI NP-2418 provides the following information on steam generator replacement or partial steam generator replacement at three plants.

For Turkey Point and Surry, the operation involved a partial replacement of the steam generators.

In EPRI NP-4208, the following table outlines steam generator replacement cost, outage time, and the collective dose.

In NYPA 1989, information was presented on worker exposure in person-rem for the steam generator replacement at Indian Point 3. For an outage which included refueling and maintenance and steam generator replacement, the total dose was 852 person-rem. Of the 852 person-rem, 541 person-rem were attributed to the steam generator replacement.

Plant	Rating [MW(e)]	Replacement year	Outage (months)	Cost (million dollars)	Collective dose (person-rem)
Surry 2	775	1979–80	10	80	2140
Surry 1	775	1980	—	—	1760
Turkey Point 3	666	1981–82	10		2150
Turkey Point 4	666	1982–83	7	190[a]	1305
Point Beach 1	497	1983–84	6	50	590
Robinson 2	665	1984–85	8	85	1207

[a]For both Turkey Point 3 and 4.

Figure B-1.1 presents a comparison of seven steam generator replacement projects with respect to outage duration and personnel exposure. It was presented in Morency and McGough 1989.

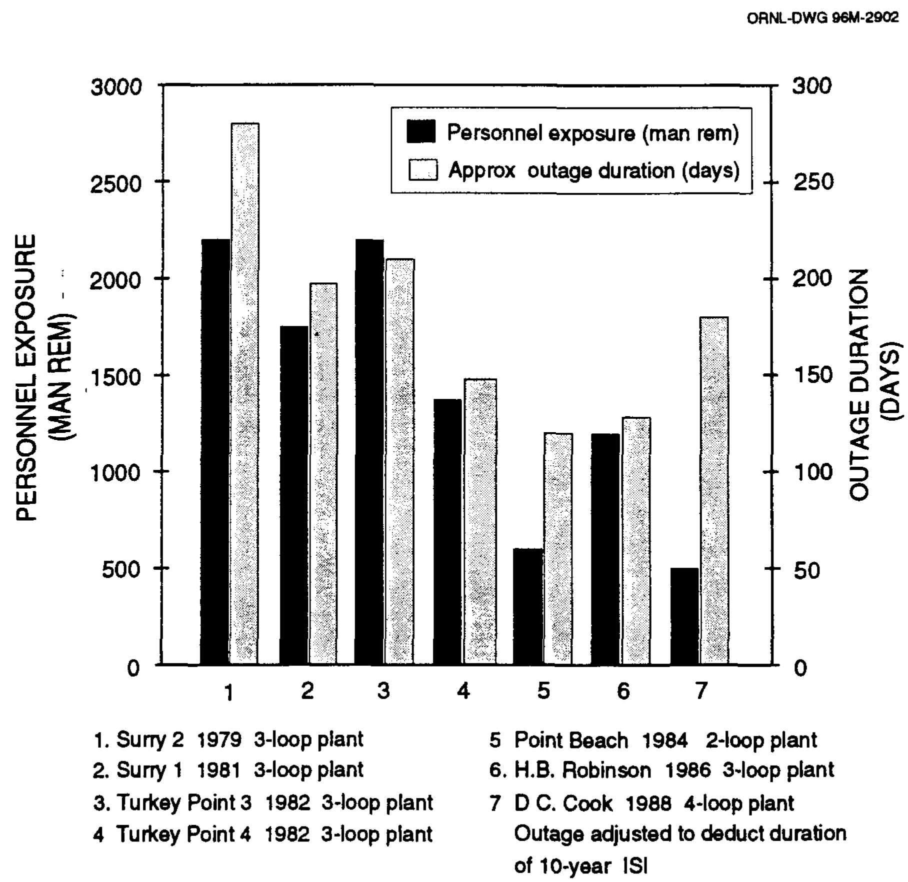

Figure B-1.1. Outage duration and personnel exposure in seven steam generator replacement projects.

Katz (1988) indicates that for steam generator replacement in a two-loop plant, the exposure in person-rem and the labor in work hours are estimated to be 1,387 and 624,000, respectively. The estimated cost for on-site storage of the steam generator is $735,000.

The cost to immediately cut up and ship the steam generator is estimated to be $20,980,000.

The following table provides information on steam generator size, weight, and storage volumes.

Plant	Length (ft)	Diameter min/max (ft)	Nozzle size (in)	Dry weight (tons)	Total storage volume (ft^3)	Portion of storage allotment[a] (%)
Plant A (4 loop)	46	10/12	29	209	37,340	56
Plant B (2 loop)	63	10.6/13/6	31	305	31,653	48
Plant C (3 loop)	63	10.6/13/6	31	305	47,470	67
Plant D (3 loop)	67.6	11.3/14/6	31	331	57,864	82

[a]The portion of storage allotment refers to allocations for the disposal of low-level radioactive wastes at existing U.S. civilian disposal sites.

Note: To convert ft to m, multiply by 0.305.
To convert in. to cm, multiply by 2.54.
To convert ft^3 to m^3, multiply by 0.03.

BWR RECIRCULATION PIPE REPLACEMENT

Eckert (1987) has estimated that the exchange of two recirculation loops and six risers will require 2.5 months, 50,000 work hours for the preplanning, and 220,000–380,000 work hours to execute the activities (including training) and will result in 500–800 person-rem of total dose.

In Zachary et al. (September 1989), the radiation exposure for BWR major pipe replacement was reported for Peach Bottom 2 and 3 and compared with other plants.

In SAND88-7095, the replacement of piping is assigned a probability. This probability will be zero if the component has been replaced, or low if the component is of current design.

Radiation exposure incurred for boiling-water major pipe replacement (person-rem)	
Peach Bottom 2	2200
Peach Bottom 3	1074
PL-A	1900
PL-B	1785
PL-C	1785
PL-D	1638
PL-E	1580

Note: To convert person-rem to person-sievert, multiply by .01.

However, older plants will have a high probability of replacement. The cost of boiling-water reactor (BWR) piping replacement costs were estimated to be $75 million multiplied by the probability of replacement. BWRs with Mark I designs probably will be more problematic to refurbish than those with Mark II or Mark III designs. A rough estimate is that refurbishment of the Mark I design will cost $25 million more than refurbishment of the Mark II or Mark III.

In EPRI NP-4208, the following table is presented which outlines BWR piping estimated replacement cost and outage time.

The costs and downtime that have been reported for BWR recirculation pipe replacements range from $19 million to $65 million and from 6 to 10 months, respectively.

According to McBrien (April 1987), during a 9-month refueling outage in 1986 at Vermont Yankee, the entire recirculation piping and part of the plant's residual heat removal system were replaced at a cost of approximately $60 million dollars. Workers at the plant acquired a total exposure of 1786 person-rem.

Plant	Rating [MW(e)]	Estimated costs (million dollars)	Estimated outage (months)
Browns Ferry	1067	42 (budget)	6
Dresden 3	794	40 (budget)	9–10
Hatch 2	806	—	6
Monticello	536	19 (budget)	6
Nine Mile Point 1	610	65	10
Pilgrim 1	670	40 (budget)	9–10

PRESSURE VESSEL COSTS AND THERMAL ANNEALING

In EPRI-4208, it is reported that a dry anneal at 850°F for 168 hours will restore most fracture toughness properties lost during irradiation embrittlement. However, this indicates that the vessel internals must be removed and a heating system installed. However, there are problems related to post-anneal behavior that need to be resolved. These include the following.

- Re-irradiation rates of embrittlement as a function of impurity and alloying element concentrations need to be better established to determine probable time effectiveness of annealing during re-irradiation.
- The vessel needs to be requalified in accordance with applicable codes and standards, including nondestructive examination of the vessel after annealing.

In EPRI NP-2418, the following reactor pressure vessel replacement information is presented. The total cost is in 1979 dollars and excludes the cost of money and replacement power. The total time of replacement is approximately 5 months.

Reactor pressure vessel replacement costs
(million dollars)

Direct costs	
Material	34
Labor ($25–35/h)	17
Indirect costs	
Occupational exposure	13
Project supervisors	17
Consultants, management ($40 h)	
Subtotal	81
Contingency (50%)	41
Total	122

In EPRI NP-4208, reactor pressure vessel replacement has been estimated to cost $100 million to $150 million (1979 dollars) and to require 2–3 years.

Abbot et al. (1988) report a cost of $20 million to $50 million for three potential tasks as outlined:

- modified/radical fuel assemblies to reduce vessel fluence,
- lower internals replacement, and
- thermal annealing of vessel.

In Lott and Mager (1984), the estimated costs for a severely embrittled reactor vessel and a moderately embrittled vessel are presented. In some circumstances it may be advantageous to anneal the vessel earlier in plant life to accrue the benefits of annealing immediately. A severely embrittled vessel is one in which the embrittlement surpasses reasonably acceptable limits. For the severely embrittled reactor vessel, if the vessel can be annealed for less than $200 million then the cost of annealing is less than the savings associated with deferring the construction of a replacement plant by 1 year. This assessment is based upon a modest replacement cost of $2 billion for the power station and an annual cost of capital of $200 million, based upon financing rates of 10 percent. The moderately embrittled vessel is one for which embrittlement is projected to exceed acceptable limits before the end of the useful life of the reactor. There is a clear savings from deferring the large costs associated with the annealing. However, if the annealing can be used to increase the plant availability, then there is a clear benefit to annealing. An analysis conducted indicates that an increase in total plant availability of 1 day is approximately equivalent to $500,000. To make performing an early anneal financially advantageous, the annual cost benefit from annealing should exceed the financing costs associated with the anneal. Assuming an interest rate of 10 percent, the plant availability would have to increase by 2 days per year to justify a $10 million expense on annealing.

NUPLEX CAPITAL COSTS AND REPLACEMENT POWER COSTS

In SAND88-7095, a range of \$250–\$500/kW (1986 dollars) for nuclear plant-life extension (NUPLEX) refurbishment on an overnight basis (\$300–\$600/kW including financing) is reported. The overnight costs for Surry Unit 1 pressurized-water reactor have been estimated at \$250/kW and for the Monticello BWR the costs have been estimated at \$500/kW. More recent information presented in Moore (1990), indicates that the Monticello overall cost for extending operation is estimated to be \$200/kW. That same source cites \$150/kW as the capital cost for the Yankee Rowe plant for running a 20-year renewal term. Westinghouse has estimated the cost of NUPLEX refurbishment as ranging from \$240/kW to \$900–\$1000/kW based upon the amount of refurbishment needed. The higher estimate is a result of replacement of most major components and annealing of the pressure vessel.

McCutchen et al. (1988) reports a life extension program cost of \$270/kW or \$318 million.

Massie et al. (1985) assumed in their calculations a typical Westinghouse three-loop plant rated at 775 MW(e), with a mid-life in year 1992, and replacement power costs of \$350,000/day in 1985 dollars.

BIBLIOGRAPHY FOR APPENDIX B ATTACHMENT 1

Braun, C., "Economic Factors Related to Life Extension of Nuclear and Coal-Fired Plants," *Transactions of the American Nuclear Society*, **46**, 558–59 (June 1984).

Byron, J., and M. Lapides, "Guidelines for the Life Extension of Nuclear Power Plants," Draft EPRI Document, July 1988.

"Interim Draft for Generic Environmental Impact Statement for License Renewal of Nuclear Power Plants," Prepared for U.S. Nuclear Regulatory Commission, October 15, 1990.

Katz, L. R., "The Codes and Standards Aspects of Nuclear Plant Life Extension," pp. 131–38 in *Proceedings of the ASME Pressure Vessel and Piping Conference,* Pittsburgh, June 19–23, 1988.

Lapides, M. E., "Making Decisions on Plant Life Extension," *Nuclear Engineering International (UK)*, **34**, 26–27 (August 1989).

Moylan, M. F., et al., "Reactor Vessel Life Extension," in *Proceedings of the ASME Pressure Vessel and Piping Conference,* San Diego, June 28–July 2, 1987.

Stancavage, P. P., "BWR Life Extension Economics," pp. 309–315 in *Proceedings of the 1986 Joint ASME/ANS Nuclear Power Conference: Safe and Reliable Nuclear Power Plants,* Philadelphia.

Tipping, P., et al., "Study of the Mechanical Property Changes of Irradiation Embrittled Pressure Vessel Steels and Their Response to Annealing Treatments," in *Transactions of the 9th International Conference on Structural Mechanics in Reactor Technology,* Vol. G, *Fracture Mechanics and NDE,* pp. 115–27, Lausanne, Switzerland, August 1987.

APPENDIX C

SOCIOECONOMICS

SOCIOECONOMICS

C.1 RESEARCH METHODS

The social impact assessment methods employed in this project were designed to identify the significance level of potential socioeconomic impacts during refurbishment and the license renewal term and to identify relationships between key social factors (impact predictors) and the intensity of impacts. The research methods used consisted of a literature review, a search of newspaper citations, a survey of all nuclear utilities, and seven detailed case studies.

The impact categories examined were limited primarily to those socioeconomic effects associated with project-induced employment (direct and indirect), population growth, expenditures, and tax payments. This approach is traditionally followed in preparing environmental impact statements (EISs) involving the construction and operation of nuclear power plants. The key socioeconomic topics suggested for in-depth examination by the literature search and citation review were (1) population, (2) housing, (3) taxes, (4) public services, (5) off-site land use, (6) economic structure, and (7) historic and aesthetic resources.

The following sections provide additional detail on the literature review, the review of newspaper citations, the utility survey, the seven case studies, and the techniques used to analyze the past and projected impacts associated with nuclear power plants.

C.1.1 Literature Review

The purpose of the literature review was to identify important socioeconomic issues, to obtain an industry-wide summary of the impacts that had occurred in those subject areas as a result of past nuclear plant construction and operations, and to identify possible causal factors related to those impacts. The literature review focused largely on EISs prepared for nuclear power plants at the time of their application for an operating license [Atomic Energy Commission (AEC) and U.S. Nuclear Regulatory Commission (NUREG) final environmental statements]. In addition to projecting the future impacts of plant operation, many of these documents summarize the impacts that occurred during plant construction. Along with these EISs, several detailed retrospective studies of impacts that had occurred at specific nuclear power plants were examined. Section C.2.1 provides a detailed discussion of the literature review.

C.1.2 Review of Newspaper Citations

Citations from five major metropolitan newspapers and a national wire service were examined to check the completeness of the socioeconomic impact categories suggested through the literature review. The newspapers were the *Atlanta Constitution*, the *Houston Post*, the *Los Angeles Times*, the *New York Times*, and the *Washington (D.C.) Post*. The wire service was United Press International. The search spanned 1989 and the first 5 months of 1990. Potentially relevant articles were identified through a computer database search, using the key words "nuclear power" and "nuclear power plant" in conjunction with a number of other words and phrases including "public reaction," "public concern," and "public opinion." Over 400 articles were identified through this search, although upon review, many were found to be irrelevant for this study. Overall, the traditional socioeconomic impact areas described have received little recent attention in the print media.

C.1.3 Survey of Utilities

Two written surveys of the nation's nuclear utilities were conducted. The survey instruments were designed by Oak Ridge National Laboratory (ORNL), with substantial input from the Nuclear Regulatory Commission (NRC) and the Nuclear Management and Resources Council (NUMARC). Both were administered by NUMARC.

The first survey instrument, sent to all U.S. nuclear utilities, was designed to elicit important descriptive information on plant operations. The respondents provided an industry-wide picture of current and past numbers of plant workers and of nuclear plant financial contributions to host communities. Usable data were received for some portion of these questions for 66 of the 74 nuclear plant sites nationwide.

The second survey instrument was sent to the utilities that operate the seven socioeconomic case study plants, and responses were received from all seven utilities. The purpose of these items was to gather detailed information on worker residential location, plant expenditures, and tax payments to local communities so that the causal factors related to past impacts could be identified and future impacts could be predicted.

C.1.4 Case Studies

The seven nuclear plants were chosen for detailed study as representative of all U.S. nuclear plants in terms of the socioeconomic characteristics of their host communities. The site-selection methodology and the plants chosen are described below. The case study examination was designed to provide detailed information on past impacts at a sample of nuclear power plants that represent the range of plants nationwide and to allow the projection of future impacts in key issue areas.

Detailed information was obtained on the seven case study sites through a review of EISs and site-specific NUREG reports, as well as through telephone interviews conducted with state and local officials and other expert sources. The sources were chosen for their expertise in the socioeconomic issue areas addressed (e.g., housing, land use) and included employees of local planning agencies, chambers of commerce, and economic development agencies; local tax assessors and treasurers; officials at state employment offices; and local media personnel. Nearly 300 telephone interviews were conducted at the seven case study sites. A detailed telephone protocol was used to collect data at the five sites previously studied by Mountain West Research, Inc. (NUREG/CR-2749, vols. 1, 4, 5, 7, 12), in a postlicensing study conducted for the NRC. A more exhaustive protocol was used for the two case study sites that had not been studied previously by Mountain West and for which more information was needed. Section C.7 contains the questions asked in these interview protocols.

The seven case study sites chosen represent roughly 10 percent of the U.S. nuclear power plant sites. The primary factor considered when selecting sites for socioeconomic study was the population of the area surrounding the plant. Population was chosen as the primary factor because the literature reviewed and other previous experience suggested a strong relationship between an area's remoteness and the magnitude of impacts related to population growth, employment, expenditures, and taxes. Plant age and location were also considered so that the sample includes sites representing various licensing dates, population characteristics, and geographic sections of the United States.

In considering plants for this study, preference was given to those sites for which detailed historical data about socioeconomic impacts were available. Thus, 12 plants studied by Mountain West Research, Inc. (NUREG/CR-2749), and 2 plants studied by the Electric Power Research Institute (EPRI) were considered first: Arkansas Nuclear One (ANO), Bellefonte, Calvert Cliffs, D. C. Cook, Crystal River, Diablo Canyon, Nine Mile Point, Oconee, Peach Bottom, Rancho Seco, St. Lucie, San Onofre, Surry, and Three Mile Island (TMI).

Each of these plants was classified according to the remoteness of its location, based on a classification scheme developed by Battelle Human Affairs Research Centers for Sandia National Laboratories (NUREG/CR-2239). Site remoteness involves population density in the area near the plant and the plant's distance from large cities. Battelle combined both these factors to measure "sparseness" and "proximity." Sparseness measures population density and city size within 32 km (20 miles) of the site, whereas proximity focuses on density and city size within 80 km (50 miles). Each measure involves four categories. Although Battelle expressed these categories in terms of numbers of people within 32- and 80-km (20- and 50-mile) radii, the absolute numbers were converted to the number of persons per square kilometer so that 1986 census data could be used for comparison and site selection. The sparseness and proximity measures used to classify potential case study sites are shown in Table C.1.

Three population classifications take into account the combination of the four-point sparseness and proximity scales. The three population classes are low, medium, and high population. Low corresponds to the most sparse population category and sites not in close proximity to large cities, whereas high corresponds to the least sparse population category and sites that *are* in close proximity to large cities. The bounds of each population classification are shown in Figure C.1.

Because only 1 of the 14 previously studied plants listed earlier fell into the low population category, 4 additional low-population sites were considered for inclusion in this study: Big Rock Point, Cooper, Wolf Creek, and Hatch. The Indian Point site also was added because it is located in an area with high population density and in close proximity to New York City. The applicable population classification for each of the 19 potential case study sites is shown in Table C.2.

The seven case study sites selected from those listed above were chosen to represent a broad range of population remoteness, geographic location, and plant age. The major characteristics of the plants chosen are shown in Table C.3. Their geographic distribution is illustrated in Figure C.2. All the sample plants have pressurized water reactors (PWRs), which in the bounding case scenario will require 84 percent more workers for refurbishment than will boiling water reactors (BWRs). The main analysis of potential socioeconomic impacts is based on this bounding case scenario. In the typical case scenario, the work force required to refurbish BWRs is projected to be 72 percent larger than that required for PWRs. (See Section 3.3.1.1 for details about work force projections.)

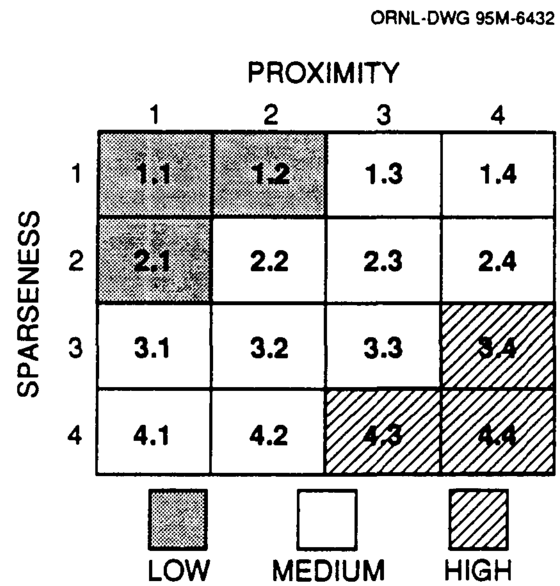

Figure C.1 Population categories, by sparseness and proximity.

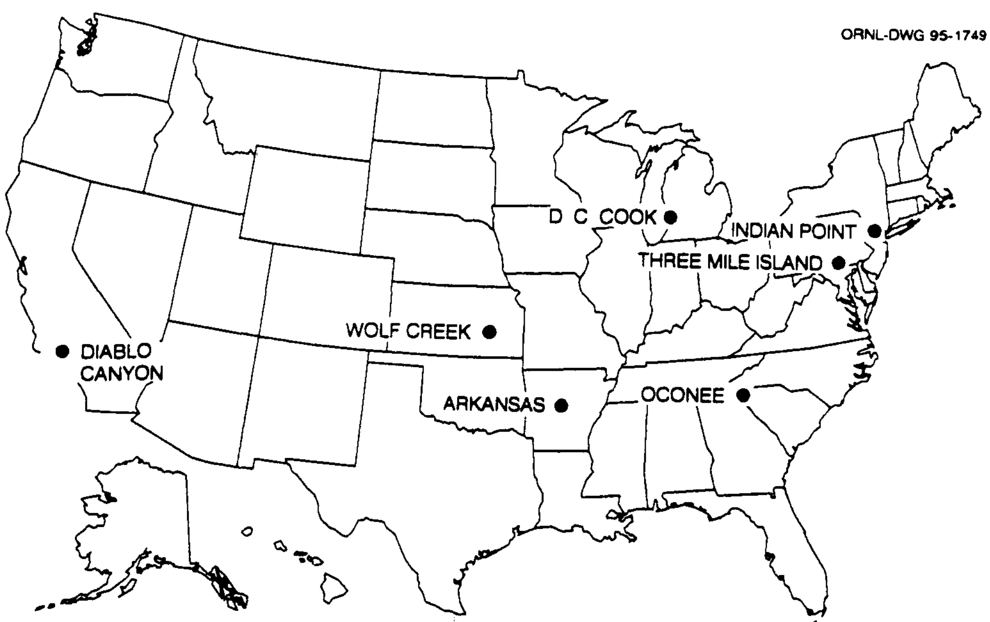

Figure C.2 The seven case study nuclear plants.

C.1.5 Analysis of Impacts

C.1.5.1 Defining Significance Levels for Each Impact Category

For each socioeconomic topic, the characteristics of small, moderate, and large levels of impact were defined. These definitions were developed on the basis of Council on Environmental Quality regulations (40 CFR Part 1500), information from site-specific nuclear EISs and NUREG studies, interviews with local information sources, studies concerning nity response to nuclear and non-nuclear technologies, and best professional judgment. The definitions of significance for each socioeconomic topic are presented in Sections 3.7.2 through 3.7.7 and Sections 4.7.2 through 4.7.7.

C.1.5.2 Characterizing Past Impact Levels and Identifying Impact Predictors

Descriptions of past impacts in all socioeconomic issue areas were gathered through the data-collection methods described in Sections C.1.1 through C.1.4. These impacts then were characterized as small, moderate, or large on a site-specific basis, using the significance level definitions discussed in Chapters 3 and 4. A description of past impacts for each of the case study sites is presented in Sections C.4.1 through C.4.7. From these site-specific characterizations of the representative case study plants, generalizations were made concerning the range of past impacts for all nuclear plants nationwide.

In examining the impacts identified in available reports and EISs and through the detailed case studies, it is apparent that the extent to which socioeconomic impacts are experienced at a given project site would depend on several factors. These factors, which will be referred to as impact "predictors," consist of characteristics of the project (called "drivers" in Appendix B) as well as characteristics of the area in which a plant is located. The specific predictors identified include local population characteristics; the employment, expenditures, and tax revenues generated by the project; and the existing infrastructure of the project's host community or communities. By looking at impact predictors and the resulting impacts that occurred at many different sites during plant construction and operations, the relationships between predictor magnitude and impact significance were identified. These relationships are discussed in Sections 3.7.2.3 through 3.7.7.3 and in Sections 4.7.2.3 through 4.7.7.3.

C.1.5.3 Projecting Future Impacts

The first step in projecting impacts was to obtain projections of the number of direct workers required for refurbishment-related activities and for operations during the license renewal term. Projections of the *refurbishment work force* were prepared by Science and Engineering Associates, Inc. (SEA 1994); they are presented in Chapter 2 and in greater detail in Appendix B, and are discussed in Section C.3.1.1. The number of *refueling and maintenance workers* employed at a typical plant during past outages was obtained from the survey of all U.S. nuclear utilities (Section C.1.3) and verified by SEA. SEA used information from the survey and the literature regarding the number of person-months required for normal refueling outages to develop an estimate of the number of refueling workers likely to be on-site during current-term and final refurbishment outages. The number of *operations workers* currently employed at each case study plant was obtained from the survey of all U.S. nuclear utilities, whereas the number of additional permanent workers required for plant operation during the license renewal term came from descriptions of proposed inspection, surveillance, testing, maintenance (ISTM) tasks (Section C.3.1.2). Additional detail about work forces required during refurbishment outages and the license renewal term are provided in Sections C.3.1.1 and C.3.1.2, respectively.

To project the maximum impacts likely to result from a plant's license renewal refurbishment activities, the staff based its socioeconomic impact analysis on the bounding case work forces projected by SEA (1994). The conservative nature of the bounding case scenario is described in Appendix B. Because the bounding case work force estimate for PWRs (2273 workers at peak) is larger than the estimate for BWRs (1482 workers), the staff conducted its primary analysis of potential socioeconomic impacts using the projected PWR work force. This analysis has identified some issues for which moderate or large adverse impacts are possible. For these issues, the potential for less severe impacts associated with the bounding case work force at BWR sites has been considered. For these issues, an analysis of the potential impacts at BWR sites is provided and is based on the 1500-person work force associated with the bounding case BWR refurbishment scenario. For those issues where moderate or large adverse impacts were determined to be possible with 1500 workers, an analysis of the typical case refurbishment work force (1017 workers at BWR sites) has been conducted. Those issues for which moderate or large adverse impacts were found to be possible with a work force smaller than 1017 (i.e., operations-period refueling work forces) have not been subjected to these additional analysis.

Using the work force projections, the staff determined the number of indirect jobs that would be created as a result of refurbishment and license renewal. Indirect employment was projected using the Regional Industrial Multiplier System (RIMS) direct/indirect job ratios calculated for each plant in the NUREG/CR-2749 study. Using the employment projections for direct and indirect workers, projected changes in local population were calculated based on patterns of worker residential location, in-migration, and family size identified in the site-specific NUREG reports. Patterns for refurbishment and refueling/maintenance workers were assumed to follow those established by plant construction workers, and patterns for additional permanent license renewal term workers were assumed to follow those established by current term plant staff (Section C.4.1.1). Population changes caused by temporary refueling and maintenance workers involved in periodic plant outages during the license renewal term were not studied in detail because these workers would be employed for very short periods of time, but evidence about past effects during such outages was collected and considered in the analysis.

The projections of direct and indirect employment associated with refurbishment and routine (nonoutage) operations were used to assess the economic impacts of refurbishment and license renewal. Economic impacts were projected by comparing estimated plant-related employment (direct and indirect) with projections by the National Planning Association (NPA) of total employment for the study areas during the refurbishment period and the license renewal term (Section C.4.1.6). For the refurbishment period, employment estimates for all refurbishment-related workers (including refueling/maintenance workers) were used. For the operations period, estimates of all permanent (nonoutage) workers were used; this includes additional jobs and those continuing from past operations.

Because many socioeconomic impacts are driven by population growth, the next step in projecting the impacts of refurbishment and license renewal was to use the population growth projected for each case study area in assessing impacts to housing, public services, and off-site land use. For each of these topic areas, impact predictions were made by comparing levels of impact significance associated with past plant-related population growth to projected population growth and by examining projected conditions of key infrastructure components. The analysis assumes that no other major construction project will occur concurrently with plant refurbishment and subsequent refueling and maintenance activities. If other large construction projects are ongoing when these activities occur, impacts could be greater than those predicted. Housing impacts were projected for refurbishment and continued operations, respectively, by comparing the housing demand expected to result from the in-migration of refurbishment-related workers and of additional permanent operations workers with projections concerning local housing markets (number of units and vacancies) generated from U.S. Census data (Section C.4.1.2). In addition, evidence concerning past impacts associated with the influx of refueling and maintenance workers during plant outages was gathered and used as an indicator of possible outage-related impacts during the license renewal term at the one site where significant growth-induced housing impacts were predicted for the refurbishment period. Public service impacts were projected by comparing the number of refurbishment-related workers and additional permanent operations workers expected to in-migrate with the local communities' projected capacity to provide public services, as indicated by local information sources (Section C.4.1.4). As with housing, evidence was gathered at one site concerning outage-induced transportation impacts. For off-site land use, impacts were projected by examining the size of anticipated population growth resulting from refurbishment-related workers and additional permanent operations workers relative to state data center projections of a study area's total population. Potential changes in land-use patterns caused by plant tax payments were also considered in projecting the impacts of license renewal (Section C.4.1.5).

Unlike the subjects already discussed, impacts to taxes and to historic resources and aesthetic resources are not driven primarily by changes in employment and population. For these three topics, impacts examined for the refurbishment period are those that result solely from changes induced by refurbishment-related activities (i.e., increased tax assessments and modified plant structure). In contrast, the assessment of license renewal term impacts includes continuing impacts from past operations and the new impacts already discussed. A detailed discussion of the methods used to predict impacts in each of these subject areas is presented in Sections C.4.1.3 and C.4.1.7, respectively.

Socioeconomic impacts identified and analyzed here are site-specific; they have no statewide or nationwide consequence. Therefore, simultaneous relicensing of several nuclear power plants will not result in cumulative regional or national impacts.

Judgments on whether or not potential environmental impacts in each subject area would need to be further addressed in each individual license renewal application were made based on the nature of the projected impact and its level of significance. These conclusions are not discussed in Appendix C but are presented in the body of the Generic Environmental Impact Statement (GEIS). Because of uncertainty surrounding the number of workers that would actually be required for plant refurbishment, a sensitivity analysis was performed wherein socioeconomic impacts were predicted in response to a work force roughly 50 percent larger than the estimated peak work force for the major refurbishment outage provided in Section C.3.1.1 (even though the estimate given in that section was designed to be an upper bound for a typical plant). The discussion of conclusions for each socioeconomic topic in the body of the GEIS states whether or not the conclusion category (1 or 2) expected for the preferred estimate would change in response to the larger work force.

Sections C.4.1 through C.4.7 present a detailed discussion of projected socioeconomic impacts in each of the above subject areas for each case study site, and Sections 3.7.2 through 3.7.7 and Sections 4.7.2 through 4.7.7 summarize these impacts and project impacts for all nuclear plant sites based on the case study predictions. These nationwide predictions are considered valid because the impacts predicted at the case study sites represent the range of potential impacts at existing nuclear plants. Population, which is considered an impact predictor rather than an actual impact, is discussed in Sections C.4.1.1 through C.4.7.1, 3.7.1, and 4.7.1.

C.2 BASELINE DESCRIPTION

C.2.1 Overview of Past Population- and Tax-Driven Nuclear Plant Impacts

C.2.1.1 Objectives

This literature review summarizes the results of previous case studies that examined the socioeconomic impacts of nuclear power plants. The objective of the review was to identify

- kinds of impacts that have occurred (e.g., schools, government expenditures);
- causal factors behind those impacts (e.g., size of work force, extent of existing community infrastructure); and
- impact thresholds, if any (e.g., taxes from plant as a disproportionate share of local tax base, no city of a certain size within commuting distance of the plant).

Socioeconomic impacts occurring during either construction or operation are of interest. Construction impacts provide an upper bound to what might happen during a major plant refurbishment, whereas operations impacts typify what would occur after license renewal, allowing for adjustments for refurbishment-induced changes in work forces, taxes, or other impact drivers.

C.2.1.2 Literature Reviewed

Several categories of literature were reviewed. One major category is EISs for nuclear plant operating licenses (OLs) (Section C.5.3 lists the EISs reviewed). This category is potentially useful because the EISs not only consider impacts from plant operations but often summarize impacts that occurred during construction. They are official documents in support of the NRC's regulatory process and, presumably, carry a measure of credibility in respect to what the regulatory process requires in terms of data, findings, and content. The second category of literature includes case studies commissioned by organizations closely involved with the nuclear industry. The NRC has conducted several such plant-specific studies (NUREG/CR-2750, ORNL/NUREG/TM-22, and NUREG/CR-0916). EPRI also conducted a series of case studies of power plants, two of which were nuclear (EPRI/EA-2228). The third category of literature encompasses studies of single nuclear plants that are usually sponsored by utilities as part of the regulatory process or by some other organization interested in documenting socioeconomic impacts.

C.2.1.3 Types of Impacts

This literature review reveals no population- or tax-driven socioeconomic impacts other than those typically assessed in environmental impact documents. Those documents written in support of the National Environmental Policy Act of 1969 (NEPA) process almost always focus on readily quantifiable impacts to public services, housing, the economy, and land use. Exceptions in which the assessment is qualitative include aesthetic and cultural resources impacts, which are almost always considered in EISs, and recreational impacts, which are discussed in 44 of the 78 (56 percent) OL EISs examined. Impacts to these resources, however, are seldom found to be population- or tax-driven. Consequently, they are defined by general statements about appearances of the plant, transmission lines (sometimes the lines are rerouted to avoid negative impact to residents in the vicinity), and compatibility with nearby cultural resources. Recreation impacts are generally defined as positive contributions such as visitor centers; boating, fishing, and hiking activities; and dedication of land on the plant site to natural resources conservation and education. Typically, non-NEPA documents do not examine these resources.

Among public service impacts identified, the assessments focus on schools, transportation, and public safety; less emphasis is placed on utilities, water and sewer facilities, and health and welfare services. These same impacts are covered in the other case studies examined in the literature, and there is a strong consensus that all should be treated as valid kinds of socioeconomic impacts under NEPA. Housing is another impact that understandably receives considerable emphasis in NEPA and non-NEPA assessments, with residential distribution being foremost in importance, followed by housing type and costs. Generally, housing impacts are treated before public service impacts because most services generally support people by place of residence.

Economic impacts are almost always assessed in environmental documents and related case studies. They are readily quantifiable and tangible impacts that are easy to understand. Minimally, the project work force total and annual payrolls are included (although early NRC EISs did not note these basic impacts). Emphasis normally is on totals of direct employment and payroll generated by the nuclear plant, indirect jobs in the local economy, amounts of money contributed to the regional economy, and tax contributions to the local tax base—particularly property and sales taxes. Additional types of taxes and amounts of revenue that flow to the state governments generally are not considered in NEPA documentation, although case study reports produced by NRC more adequately assess these latter impacts.

Land-use impacts created directly by the plant itself and its transmission lines are assessed in 78 percent of OL EISs. Generally, such impacts are considered in terms of acres disturbed, people relocated, and land flooded for cooling lakes. Only rarely is attention directed at what effect plant siting would have on broader community land use and associated growth. These generalizations hold true for the other literature categories reviewed, with the exception of the NRC's series of 12 case studies, which gives considerable attention to land use and associated community growth and finds that land-use changes related to plant siting and worker in-migration "strengthened overall patterns of change and development" (NUREG/CR-2750).

C.2.1.4 Causal Factors of Impacts

Most of the socioeconomic impacts created by nuclear plants are driven by the plant-related population or taxes. Nuclear power plants require large numbers of workers to construct and, to a lesser extent, operate, and they generally pay significant amounts of taxes. The amounts of jobs and taxes tend to correlate fairly directly with the size of the plant. In many communities where nuclear plants are located, the plant is very likely to be one of the largest, or even the largest, employer and contributor to the tax base. Therefore, its workers create impacts on schools, public services, housing, utilities, transportation, and health and welfare services. Of particular importance are in-migrating workers and their families, who must be accommodated by expansion of such services. If the communities are small and the plant site is located beyond commuting distance of a reasonably large population center, then worker in-migration would be higher and resulting demands of services would be increased—perhaps to the point that major expansion is required.

Taxes from the plant and its workers provide a major benefit to local communities in helping to pay for public services. Once built, a nuclear plant typically contributes millions of dollars annually to the local tax base. The range may be as low as $1 or 2 million and as high as $42 million (1990 dollars), depending upon the assessed plant value and tax structure, according to the 69 percent of OL EISs that discuss the issue. An even broader range of tax payments was reported by utility respondents to a recent questionnaire (Section C.2.2). Although the effects of plant tax payments are primarily positive, potentially negative tax-related issues can involve (1) the timing of tax revenues that may be too late to pay for construction-period impacts caused by in-migrating workers; (2) discontinuities between jurisdictions that can tax the plant and jurisdictions in which many of the employees reside; and (3) the disproportionately large amount of the tax base represented by the power plant, which can pose a major problem in the future for local real estate tax revenues. A fourth issue is how to pay for public services in the case of nuclear plants owned by the government that pay no local property taxes and only small payments in lieu of taxes. As in the case of population impacts, tax-related impacts have the potential for being much larger in rural areas with small tax bases.

C.2.1.5 Impact Thresholds

In developing a license renewal rule, the emphasis is on identifying socioeconomic impacts that could be particularly problematic for local communities and the conditions under which these could occur. For example, is the labor requirement so large and the community so remote from a population center that in-migration to the plant's area would be large enough to significantly stress the public infrastructure?

Or, in regard to taxes, is the assessed value of the plant so large relative to the existing tax base that local governments would be highly dependent on plant-related revenues? An impact threshold can be thought of as the set of conditions (e.g., a particular number of plant-related workers in conjunction with a host community's population and distance from major urban areas) under which significant impacts can be expected.

Before addressing the issue of thresholds, it is useful to generalize very briefly about the severity of these kinds of impacts that could result from nuclear plants. The literature that specifically deals with the issue (NUREG/CR-2750; NUREG/CR-0916) notes that nuclear plants seldom, if ever, create massive (boomtown-level) impacts to community infrastructure on the scale of mine-mouth coal plants or hydroelectric dams because nuclear plants are not sited in remote western regions of the country where such severe impacts can occur. This finding is supported by the OL EISs, which fail to identify any potential or actual case of a boomtown-level impact from a nuclear plant. Indeed, the overall findings from the literature reviewed argue strongly for the proposition that population- and tax-driven impacts of nuclear plants during the construction period overwhelmingly are small to noticeable for affected communities and well below boomtown proportions. Significant negative impacts have occurred, however, at a few plant sites. During plant operation, employment and tax revenues can be a substantial benefit for local communities, and their loss would be equally significant. Of particular concern would be cases in which nuclear plants make up a large percentage of the tax base.

In regard to the identification of impact thresholds during plant refurbishment and continued operations, the literature alone does not give any clear answers. However, in conjunction with the case studies detailed in Section C.4, a number of impact predictors were identified that can be used to indicate whether significant impacts are likely to occur at a given site in several socioeconomic subject areas. These impact predictors are discussed in Sections 3.7 and 4.7.

C.2.2 Overview of Current and Past Socioeconomic Characteristics for All Plants

This section summarizes information on selected socioeconomic characteristics for U.S. nuclear plants. Specific topics include the plants' operating period employment; characteristics of typical planned outages, in-service inspections (ISIs), and largest single outages; assessed value; and tax payments. The section is intended to provide an overview of the entire U.S. commercial nuclear industry. Information used to prepare this report was obtained through questionnaires mailed to all utilities that operate nuclear plants.

Considerable differences exist among nuclear plants in terms of the size of their operating work forces. Table C.4 provides a summary of data concerning current operating-period employment at nuclear plants grouped by the number of units at each plant. Although the employment figures are intended to represent the number of permanent personnel on-site, they might overstate that figure because it is likely that temporary workers were included in some utilities' responses. The incremental increase in the mean number of workers per unit is not linear, because the mean for one-unit plants constitutes over 66 percent of the mean for two-unit plants, whereas the mean for two-unit plants represents only 52 percent of the mean at three-unit plants. The number of units at each station represents those licensed by 1990; therefore, for some two- and three-unit plants, employment may have been considerably lower in past years depending upon the number of units that were actually on-line and their levels of operation. Table C.5 depicts changes in mean operating-period employment at the plants from 1975 to 1990.

U.S. nuclear plants also differ in the number of workers, the costs, and the length of time required per unit for various types of outages. Table C.6 depicts the minimum, maximum, and mean number of workers, costs, and time required per unit for a typical planned outage during which refueling and other routine tasks are performed. Table C.7 presents the same information for an ISI outage. The two tables should be read in columns, not rows, because the plant that had the minimum number of workers, for example, is not necessarily the same as the plant with the lowest cost or the shortest outage. The numbers presented in Tables C.6 and C.7 might be high because some utilities probably included permanent operations workers in their count of workers used during outages, even though they were asked to list only *additional* on-site workers. Also, the numbers count each worker who came on-site at some time during the outage, regardless of the duration of the stay. These numbers, therefore, are almost certainly higher than the peak number of workers on-site during a single day or week. The maximum number of 2600 is particularly suspect; the next highest number of workers given for a typical planned outage was 1500.

Table C.8 summarizes information on the largest single outage experienced for one unit at those nuclear plants providing data for this topic. The tasks performed during these large outages vary but can include steam generator replacement, core support barrel repair, recirculation system piping replacement, and refueling. The table, which contains data on the number of additional workers, the total costs, and the time involved in the responding plants' largest outages, is designed to be read in columns. As with preceding tables, Table C.8 presents numbers that are higher than actual work force peaks because some utilities included operations workers in their count of *additional* workers and because the numbers count each worker who came on-site, regardless of the duration of the stay. In general, the amount by which these numbers overstate actual peaks can be expected to increase with the length of the outage.

Sizeable differences also exist among nuclear plants in terms of their assessed values. Table C.9 provides a summary of data concerning current assessed values at nuclear plants grouped by the number of units at each plant. The incremental increase in the mean assessed value per unit is not linear, because the mean for one-unit plants constitutes almost 66 percent of the mean for two-unit plants, whereas the mean for two-unit plants represents only 26 percent of the mean at three-unit plants. The number of units at each plant represents those licensed by 1990; therefore, for some two- and three-unit plants, assessed values may have been considerably lower in past years depending upon the number of units actually on-line. Table C.10 depicts changes in the minimum, maximum, and mean assessed values from 1980 to 1985.

The amount of local and state taxes paid on nuclear plants by the utilities that own them also varies considerably. Table C.11 depicts information about the local and state taxes paid on nuclear plants grouped by the number of units at each plant. Once again, the incremental increase in the mean total amount of taxes paid is not linear, because the mean for one-unit plants constitutes over 65 percent of the mean for two-unit plants, whereas the mean for two-unit plants represents only 28 percent of the mean at three-unit plants. For some two- and three-unit plants, tax payments were probably lower in past years because one or more of the plants' units may not have been on-line. Table C.12 depicts changes in the minimum, maximum, and mean amounts of local and state taxes paid from 1980 to 1985. A relatively small number of utilities explicitly mentioned paying state taxes; however, where such taxes are paid, the mean payment is substantially greater than the mean for local taxes. Because a large number of utilities reported only *total* tax payments without specifying the jurisdictions to which the taxes are paid, it is possible that the utilities pay more state taxes than are indicated here.

C.3 DESCRIPTION OF LICENSE RENEWAL

C.3.1 Work Force and Expenditures Required for Plant Refurbishment and the License Renewal Term

License renewal for a commercial nuclear power plant will involve two time periods: the refurbishment period and the license renewal term. The length of the refurbishment period, the number of additional workers who would be on-site to perform refurbishment tasks, and the costs of refurbishment would vary among nuclear plants. The license renewal term will be 20 years, but the number of additional personnel that will be required to operate a plant will vary. This section describes the estimates of refurbishment period length, costs, and work force sizes used in the GEIS to assess the socioeconomic impacts of license renewal. Section C.3.1.1 describes the estimates of refurbishment outage length, work force, and costs provided by SEA (Appendix B; SEA 1994). Section C.3.1.2 describes the estimates of the license renewal term work force.

C.3.1.1 The Refurbishment Period

For a nuclear power plant, the refurbishment period is expected to begin several years before a unit's original operating license expires. Plant refurbishment would probably involve bringing additional workers to the site to perform certain tasks during four regularly scheduled current term outages and one major refurbishment outage. GEIS predictions are based on a bounding case (conservative) refurbishment work force scenario prepared by SEA (1994). The scenario provides refurbishment work force estimates that are expected to represent the upper bound of work force requirements for a typical plant. The impact assessment performed for the GEIS is based on the projected work force required to refurbish a PWR because that represents the worst-case situation and because all the socioeconomic case study plants are equipped with PWRs. It is assumed that refurbishment activities for multiple units at a nuclear power plant would be performed sequentially, even where two units' licenses expire in the same year (Table 2.1), because the utilities are not expected to shut down more than one unit at a time. For a PWR, the peak number of 2273 refurbishment workers is expected to be reached during the major refurbishment outage (SEA 1994). For a BWR, the peak work force (1500 persons, including refurbishment and refueling workers) would be on-site during the current term outages (Chapter 2, Appendix B).

A second work force scenario—the typical case—has been developed by SEA (1994). In this scenario, the peak work force at PWRs (874 persons) will occur during current term outages, while the BWR peak work force (1017 persons) will occur during the final refurbishment outage.

Four current term outages per unit are expected, starting 8 to 10 years before the original operating license expires (Figure C.3). Each outage would last approximately 4 months in the bounding case scenario, and it is assumed that outages would be separated from each other by 18 months of normal operation. All the current term outages would consist of refurbishment activities conducted while the reactor is shut down for refueling and routine maintenance.

During current term outages, only the refurbishment workers required for license renewal can be expected to cause *new* impacts, because the refueling and maintenance workers' presence is related to continued operations under the original license. However, normal plant staff and refueling and maintenance workers who are on-site during refurbishment can be expected to contribute to the overall magnitude of impacts.

One major outage is assumed in the year before the expiration of a unit's operating license, to allow performance of any remaining refurbishment tasks not completed during the previous four current term outages. This assumed refurbishment outage is expected to last 9 months and require, at its peak, approximately 2273 direct refurbishment workers at a PWR.[1]

C.3.1.2 The License Renewal Term

The license renewal term for a nuclear power plant would begin 10 years before the end of the initial 40-year license period (see Figure 2.3). The renewed operating license would allow 20 additional years of plant operation subsequent to the 40-year operating license. The license renewal term work force is expected to include those personnel on-site during the original operating period. In addition, it is expected that continued operations during the license renewal term could require some additional workers because of the requirement for more frequent surveillance and inspection (NUREG-1398). Past descriptions of proposed ISTM tasks indicate that these are likely to require between 20 and 60 additional workers per unit. To provide a realistic upper bound to potential population-driven impacts associated with continued plant operations, the high end of the projected range of ISTM workers (60 per unit) is used to approximate the number of additional permanent workers required for ongoing ISTM tasks during the license renewal term.[2]

As with the original operating period at all nuclear power plants, periodic refueling and maintenance would be performed during the license renewal term. In addition, each unit would undergo two 5-year ISIs and one 10-year ISI during the license renewal term. The conditions under which renewed operating licenses would be granted are expected to require more maintenance and ISI workers to perform these tasks than during the term of the original licenses. It is estimated that each of the 8 normal refueling outages that would occur during the license renewal term for both PWRs and BWRs would require approximately 30 more workers for refueling and maintenance than are currently required. In addition, it is

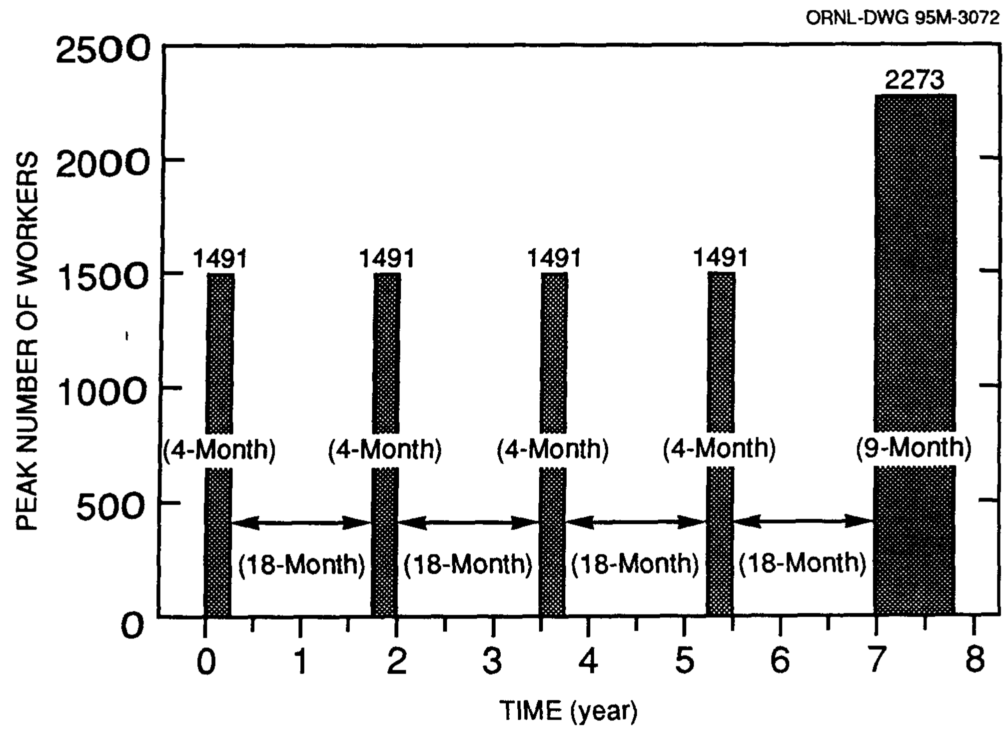

Figure C.3 Conservative scenario refurbishment work force estimates (PWR).

estimated that each license renewal term refueling would cost approximately $1 million more than refueling during the original term. Further, it is projected that each of the two license renewal term 5-year ISI outages (1) would require approximately 30 more workers at a PWR and 70 more workers at a BWR and (2) would cost approximately $1.5 million more at a PWR and $3 million more at a BWR than 5-year ISIs during the original term. Finally, it is estimated that the one license renewal term 10-year ISI outage (1) would require about 50 more workers at a PWR and 110 more workers at a BWR and (2) would cost approximately $2.5 and $5 million more, respectively, than a 10-year ISI outage during current operations. The GEIS does not systematically assess the impacts associated with these periodic outage workers because such workers would not be permanent plant staff and their presence in the community is likely to be very short-lived. However, as noted earlier, evidence about past effects during such outages was collected and considered in the analysis.

C.3.2 Changes in Taxable Value of the Plant and in Tax Distributions Following Refurbishment

The taxable value of nuclear power plants is expected to increase early in the license renewal term because of improvements made during refurbishment. Subsequent depreciation is possible, although this depends on the basis of the assessed value and is likely to be gradual during the 20-year license renewal term. Furthermore, inflation would offset the effects of depreciation so that the assessed value may decrease some in real terms but would increase or remain stable in nominal terms. Overall, tax payments to local jurisdictions are expected to remain roughly similar (with some increase) to those made during current plant operations. Also, future increases in value would accompany any additional plant improvements.

Two case study sites in this evaluation illustrate past increases in the taxable assessed value of nuclear plants during normal operation. The ANO facility had a taxable assessed value of $139 million in 1980, which rose to $184 million in 1989. This increase is 3.2 percent compounded yearly and is close to the inflation rate of this time period [the implicit price deflator of the gross national product (GNP) for this 9-year period is 4.4 percent]. The D. C. Cook nuclear facility increased in taxable assessed value from $365 million to $520 million during this same time period, for a compounded growth rate of 4.0 percent. These annual increases in assessed value are the result of the continued maintenance and replacement of equipment and the general inflation level driving replacement value and income-earning ability of the plant higher.

Taxing policies of the relevant state and local governments also affect the taxable assessed value of a nuclear plant. For example, the Oconee plant is exempt from payment of property taxes on pollution control equipment installed at the plant during its operation, resulting in somewhat smaller tax payments than would otherwise be required. Although county governments often assess the taxable value of nuclear plants, their assessments are frequently based on state guidelines. Additionally, some nuclear plant sites are assessed only by the state, and the local taxing authorities apply their own millage rates to these assessments.

The ANO, Diablo Canyon, and Wolf Creek nuclear plants are typical of plants that are assessed by rules mandated by state tax departments. The local taxing authorities of Arkansas, California, and Kansas employ the unitary approach method to develop the annual taxable assessed value for nuclear plant sites. This method bases the plant valuation on a reasonable value that an investor or business would pay for the plant. The assessed value is based on the following weighted factors: the cost that the parent utility would need to acquire the plant assets, the income-earning ability of the plant, and the stock market valuation of the parent utility (with the market value of the plant apportioned from the value of the utility). The taxable assessed value determined by the state is then multiplied by the individual millage rates of the local taxing authorities to calculate the nuclear plant tax payment.

The increase in taxable assessed value resulting from refurbishment is likely to be greater than past increases in the taxable value of nuclear plants. Although capital expenditures for replacement of plant equipment and maintenance expenditures have occurred during normal operation of the plant, expenditures are likely to be made at a higher level during refurbishment. This would cause the assessed value of the plant to increase at a higher-than-normal growth rate immediately following refurbishment.

The trend in distribution of property taxes paid by the case study nuclear plants to local taxing authorities varies considerably depending on the particular circumstances affecting each plant. If the growth of the local economy is sufficiently large, as in the case of the Oconee plant, the proportion of total local property taxes contributed by the plant would probably decrease. In some cases, the millage levy for various taxing authorities changes over time. For example, the property taxes assessed on the Wolf Creek nuclear facility have been increased at a 17.7 percent annual rate by Coffey County over the past decade, whereas the Burlington School District has had its property tax assessments increase at a smaller, 8.0 percent annual rate since 1980. At the ANO site, tax rates on the nuclear plant for the county and the local school district have been lowered. This was the result of changes in state tax laws in 1986 that caused a rollback on millages, resulting in lower property taxes. This has caused the county and the local school district to receive lower property tax payments in the past 4 years and to consider general tax increases to avoid deficits. In most cases, however, periodic capital expenditures made by the case study nuclear plants have allowed their property tax payments to remain at least stable in real terms over the past decade and to increase in nominal terms.

C.4 DESCRIPTION OF CASE STUDY SITES

The following sections detail impacts that occurred during construction and operation of each case study plant and project impacts for the refurbishment period and operations during the 20 years following the expiration of the initial license. The ANO case study includes a discussion of the methodology used to assess each impact category at each case study site.

C.4.1 Arkansas Nuclear One

The impact area (those places in which the most pronounced socioeconomic impacts might result from refurbishment and license renewal) for the ANO plant consists of Pope County, Arkansas, and the largest community within Pope County, Russellville. The selection of this area is based on worker residence patterns, employment, expenditures, and tax payments. Figure C.4 depicts the impact area, and Figure C.5 shows the region in which it is located.

C.4.1.1 Population

This section discusses the local population growth associated with the construction, operation, and license renewal of the ANO plant. Plant-related population growth is driven by the number of workers who migrate into nearby communities to work at a nuclear plant. These individuals and their families, and other persons and their families who move into the area to work in indirect jobs generated by the plant's presence, add to the communities' population totals. Such increases in population constitute the main driver of public service, housing, and land-use impacts, as well as many local economic impacts. Thus, to predict the socioeconomic impacts of a nuclear plant's license renewal, it is necessary to calculate projections of plant-related population growth.

The projections of population growth calculated in the GEIS are based on a number of assumptions. First, it is assumed that certain key characteristics of the refurbishment and license renewal term work forces would be analogous to those of the original construction and operating work forces, respectively. These key characteristics are (1) the percentage of the work force residing in the study area, (2) the percentage

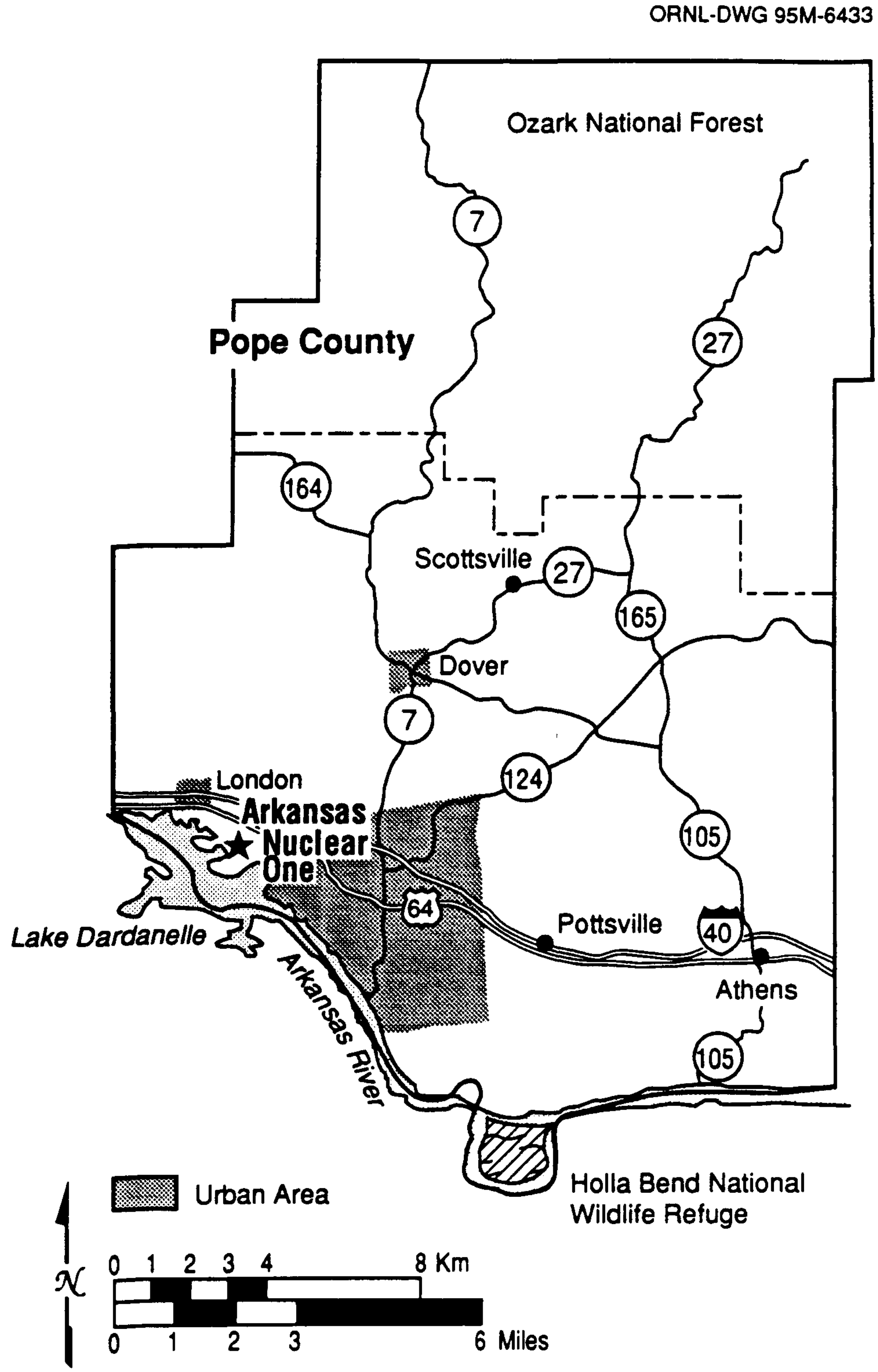

Figure C.4 Socioeconomic impact area associated with Arkansas Nuclear One refurbishment: Pope County.

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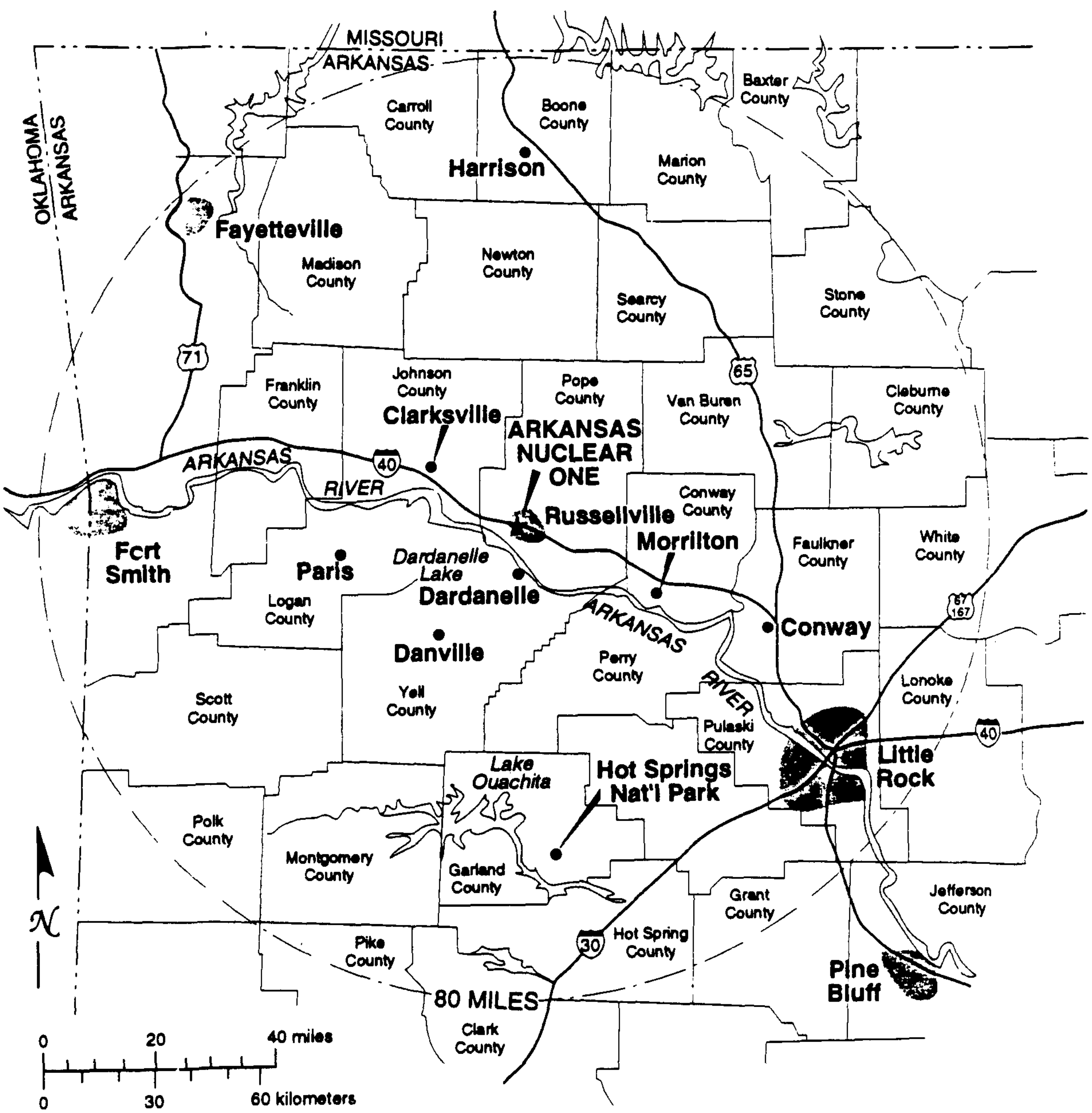

Figure C.5 Region surrounding the Arkansas Nuclear One nuclear plant.

of the work force who in-migrated to the study area, (3) the percentage of in-migrants accompanied by their families, and (4) the ratio of direct to indirect jobs created by work force in-migration. Second, future population growth is represented as occurring during the peak refurbishment year and in the first year of the license renewal term. The population growth because of license renewal would result from the influx of workers over the entire license renewal period, which could last up to 30 years (10 years for refurbishment and 20 years for the license renewal term). But population growth is projected for a single year to provide a worst-case estimate for predicting population-driven impacts. Finally, population growth is projected using U.S. Census 1990 estimates of average family size for the case study states.

Given these assumptions, data concerning construction and operating work force characteristics, and estimates of refurbishment and license renewal term work force sizes, the staff has projected population growth associated with license renewal. Tables throughout this section illustrate the calculations involved in making the projections. Data used to prepare this section were obtained from *Socioeconomic Impacts of Nuclear Generating Stations: Arkansas Nuclear One Station Case Study* (NUREG/CR-2749, vol. 1); *Environmental Assessment Proposed Rule for Nuclear Plant License Renewal* (NUREG-1398); SEA refurbishment work force estimates (Appendix B); population projections by the Arkansas State Data Center; and the Arkansas Power and Light Company (AP&L) (AP&L 1990).

The discussion of population growth is organized into two time periods. Section C.4.1.1.1 identifies the population growth that Pope County experienced as a result of the construction and operation of ANO from 1969 to 1989. Section C.4.1.1.2 projects the population growth expected to result from ANO's refurbishment period and license renewal term operations beginning in 2014 (Unit 1) based on the growth associated with the plant's initial construction. Also, Section C.4.1.1.2 projects the population growth expected to result from ANO's license renewal term based on the growth associated with operations in the past.

C.4.1.1.1 Growth Resulting from Plant Construction and Operations

ANO's construction resulted in large population increases in Pope County (Table C.13). During the peak construction year, 1974, ANO personnel and their families who migrated to the area to work at the plant, and others who moved into the area to work in jobs generated by the plant's presence, totalled approximately 2756 persons. This influx of new residents represented 8.3 percent of Pope County's total population in 1974 (NUREG/CR-2749, vol. 1, p. 86).

Operations at the ANO plant also have resulted in large population increases in Pope County. In 1989, 2205 permanent plant staff were on-site at ANO; additional contract workers were on-site during outages, but they have not been included because their presence at the plant was temporary. Of the permanent work force, 90 percent (1985) lived in Pope County (AP&L 1990). Based on the residential settlement pattern of ANO's 1977 work force, the staff estimated that 43.8 percent (869) of those residing in Pope County in 1989 were prior residents who obtained jobs and that 56.2 percent (1116) were workers who migrated into the area for jobs (Table C.14). Also following the pattern set during plant operations, it is estimated that 60 percent of the in-migrants (670) were accompanied by their families. Assuming the 1990 Arkansas average family size of 3.06 persons, this represents a total in-migration of 2496 residents for the county. Based on the ratio of nonplant jobs created in Pope County in 1977, it is estimated that ANO's 1989 operations created an additional 860 indirect jobs in service industries supported by the spending of ANO workers (NUREG/CR-2749, vol. 1, pp. 56–86). As a result of these indirect jobs, an estimated 454 additional workers and their families (a total of 922 persons) moved into Pope County (Table C.14). In all, approximately 3418 new residents are estimated to have moved into Pope County as a result of ANO's 1989 operations. These new residents made up about 7.7 percent of Pope County's 1989 population of 44,534 (NUREG/CR-2749, vol. 1, pp. 56–86; McFarland 1990).

C.4.1.1.2 Predicted Growth Resulting from License Renewal

As discussed in Section C.3.1, ANO's license renewal would require the completion of a number of refurbishment tasks for Units 1 and 2. Many of the refurbishment tasks are expected to be completed during scheduled refueling outages at each unit during the 10 years that precede the expiration of the initial license. However, the final refurbishment work is expected to be completed during one large refurbishment outage scheduled for each unit in the year before the unit's initial operating license expires.

Assuming the refurbishment schedule as described in Section C.3.1, the peak refurbishment year for ANO Unit 1 is expected to be 2013, and the peak refurbishment year for ANO Unit 2 is expected to be 2017. For each unit, the on-site refurbishment work force would be about the same size, and the work force would be on-site for approximately the same period of time. However, because uncertainties exist concerning the length of the outage and the size of the work force required to complete the refurbishment of a given unit, this section examines a bounding case work force scenario as described in Section C.3.1.

Given the work force scenario detailed in Section C.3.1, it is estimated that 2273 workers would be on-site to complete refurbishment of ANO 1 in 2013 and ANO 2 in 2017 (SEA 1994). Further assuming that the residential distribution of refurbishment workers would be similar to that of the 1974 ANO construction work force, it is estimated that 65 percent (1477) would reside in Pope County. Based on plant construction and operating experience, it is projected that 43.8 percent (516) of those residing in Pope County would be prior residents who obtain refurbishment jobs and that 56.2 percent (830) would be workers who migrate into the area for refurbishment jobs (Table C.15). Also following the pattern set during plant construction and operations, it is assumed that 60 percent of the in-migrants (498) would be accompanied by families. Using the Arkansas average family size of 3.06 persons, total refurbishment worker in-migration would result in 1856 new residents for the county. Based on the ratio of nonplant jobs created in Pope County in 1974, ANO's refurbishment is projected to create an additional 473 indirect jobs in service industries supported by the spending of ANO refurbishment workers. As a result of these indirect jobs, an estimated 246 additional workers and their families (a total of 499 persons) would be projected to move into Pope County (Table C.15). In all, approximately 2355 new residents would be expected to move into Pope County as a result of ANO's refurbishment under the work force scenario. That would represent a 3.7 percent increase in Pope County's projected population of 63,395 in 2014 (NUREG/ CR-2749, vol. 1, pp. 58–71, 82–83).

Once plant refurbishment is completed for ANO Units 1 and 2, the work force would consist mostly of permanent plant staff. There would be additional refurbishment/refueling workers temporarily on-site approximately every 2 years, but they would not be permanent, on-site plant staff; and many of them are expected to commute from outside the study area. It is expected that a maximum of 60 additional permanent workers per unit would be required during the license renewal term, adding 120 workers to ANO's existing work force. Assuming that the new workers' residential distribution would be the same as that of the current workers, approximately 90 percent (108) would reside in Pope County. Based on worker in-migration in 1977, it is expected that 43.8 percent (47) of those residing in Pope County would be prior residents who obtain jobs and 56.2 percent (61) would be workers who migrate into the area for jobs (Table C.16). Also following the pattern set during plant operations, 60 percent of the in-migrants (37) would be accompanied by their families. Using the Arkansas average family size of 3.06 people, total in-migration would result in 137 new residents for the county. Based on the ratio of nonplant jobs created in Pope County in 1977, ANO's license renewal term is projected to create an additional 47 indirect jobs in service industries supported by the spending of ANO workers. As a result of these indirect jobs, an estimated 25 additional workers and their families (a total of 52 persons) would be projected to move into Pope County (Table C.16). In all, approximately 189 new residents would be expected to move into Pope County as a result of ANO's license renewal term. That would represent 0.3 percent of Pope County's projected population in 2014 (NUREG/ CR-2749, vol. 1, pp. 58–71, 80–82).

C.4.1.2 Housing

The following sections examine the housing impacts that occurred in Pope County during construction and operation of the ANO plant and predict housing impacts that would result from refurbishment activities and continued operation. Possible impacts to housing include changes in the number of housing units, particularly the rate of growth of the housing stock; changes in occupancy rates; changes in the characteristics of the housing stock; and changes in rental rates or property values. The general methodology used to assess past impacts and predict refurbishment- related housing impacts is discussed in Section C.1.5. U.S. Census information; local agencies' housing data; and interviews with local government officials, planners, and realtors provided information about impacts that resulted from the construction and operation of the seven nuclear power plants used as case study sites. These sources provided information about past impacts of a known magnitude that resulted from a known number of in-migrating workers. This provided a basis of comparison when predicting future impacts of refurbishment.
Refurbishment-related housing impacts are predicted by comparing refurbishment-related housing demand to the projected housing market (number of units and vacancies). Project-related housing demand is based on the assumption that some unaccompanied workers would share accommodations and is determined by the following equation:

project-related housing demand = workers with families + 0.85 × unaccompanied workers.

Projections of the number of housing units present in the study area at peak refurbishment time are based on historical growth rates of the local housing market. This assumes that average growth rates would remain constant. Non-project-related housing demand at the time of refurbishment is determined by dividing projected population by average household size. The 1990 household size is used in this calculation. Household size is expected to continue its gradual decline, thus suggesting a greater demand for housing. It is believed, however, that the housing market would adequately respond to such a gradual change; therefore, housing vacancies, even though household size decreases, would be very much the same as those predicted using the known 1990 household size.

C.4.1.2.1 Impacts from Plant Construction and Operation

The following discussion begins with a description of the housing market at the time of ANO construction and details project-related housing demand in the study area. A discussion of changes that occurred in the housing market and impacts on housing induced by plant construction follows. Finally, impacts from the operation of ANO on local housing are assessed.

Between 1970 and 1978, 4361 new housing units were added to the existing housing stock of Pope County (based on the number of electrical connections), bringing the total number of units to 14,243 (NUREG/CR-2749, vol. 1; U.S. Bureau of the Census 1972). This 44.3 percent increase represents a rate of growth consistent with census reports of a 50.8 percent increase in housing in Pope County during the 1970–80 intercensal period. Nine hundred of these new units, or 21 percent, were located in Russellville (Figure C.4).

Project-related demand for housing in Pope County has been estimated according to the number of construction workers who moved to the area (NUREG/CR-2749, vol. 1). The ANO work force peaked in 1977 at an average annual employment of 1445 persons. Project-related demand for housing in Pope County peaked in 1977 at 858 units (6.25 percent of the 1977 housing). At this time, ANO Unit 1 had begun commercial operation and ANO Unit 2 was under construction. New housing units added to the Pope County market totaled 3486 between 1969, when the project began, and 1977, when it peaked. In 1970, 391 housing units were either for rent or for sale in Pope County. In Russellville, the homeowner vacancy rate was 2.6 percent and the rental vacancy rate was 10.4 percent. Housing shortages may have occurred infrequently and lasted for only a short duration (NUREG/CR-2749, vol. 1), but the existing vacancies and the rapidly expanding housing stock for the most part kept pace with project- and non-project-related demand.

The construction of ANO was an important factor in the rapid growth of the Pope County housing stock. Other factors included non-project-related population growth resulting from economic opportunities and the expansion of Arkansas Tech University in Russellville (NUREG/CR-2749, vol. 1). Several housing projects were undertaken during and possibly in response to ANO construction. A 35-ha (87-acre), multi-unit project was begun in 1967 after the announcement of ANO. Widely held local belief is that this development was linked to ANO; however, developers and local realtors indicated that it occurred in response to general population growth that had begun to occur before ANO (NUREG/ CR-2749, vol. 1). Five new mobile home parks were established during plant construction and, along with existing mobile home parks, accommodated as many as one-third of the construction workers and their families. Another development related to construction workers' demand for rental units was the conversion of old single-family homes into apartments (NUREG/CR-2749, vol. 1).

Between 1970 and 1977, considerable construction of multifamily units occurred. In Russellville, where approximately 75 percent of the construction workers located, 50 percent of the new units were multifamily units. Although single-family housing increased 16 percent between 1970 and 1977, multifamily units increased by 42.7 percent.

During the 1970s, when the project-related demand for housing might have affected housing values, the increase in the median value and median rent of housing in Pope County was comparable to that experienced in the state. Median value rose 181 percent in Pope County and 190 percent in the state of Arkansas, whereas median rent rose 73.3 percent in Pope County and 76.4 percent in Arkansas. However, local residents and officials have indicated that during peak ANO construction years, housing values escalated to levels above national trends and rents increased in response to construction workers' demands for housing (NUREG/CR-2749, vol. 1). The addition of multifamily structures in the middle and late 1970s brought housing values and rental rates once again in line with normal inflationary increases occurring statewide.

The end of construction at ANO did not have a destabilizing effect on the housing market. The project-related demand declined gradually and was abated by the gradual in-migration of the operations work force. By 1980, when both units were in commercial operation, housing vacancy rates in Pope County were comparable to those in the state of Arkansas. The home-owner vacancy rate was 2.1 percent in Pope County and 1.6 percent in Arkansas, whereas rental vacancy rate was 8.0 percent in Pope County and 8.8 percent in Arkansas.

Operation of ANO has had little effect, if any, on housing in the area. The roads and water and gas lines associated with the plant have facilitated residential development in areas neighboring the plant but have not been as big an attraction as the aesthetic quality of Lake Dardanelle. Indirectly, the plant may have had some effects on property values because the good wages employees receive have enabled them to buy or build homes that are considered expensive relative to other homes in the area.

In summary, substantial changes occurred in the housing market, housing characteristics, and property values during the construction period of ANO. The conversion of large homes into apartments, the increase in multifamily housing, and the temporary increase in housing values and rental rates are examples of this change. ANO may have been the impetus for, or a contributing factor to, these changes; however, other industrial development and the growth of the local college also spawned some of this change. For example, the tremendous growth in the housing market had begun before the construction of ANO. Also, housing occupied by construction workers was absorbed into the market and occupied by non–project-related population. Considering all these factors, the impact on housing during ANO construction was moderate.

C.4.1.2.2 Predicted Impacts of License Renewal

Project-related population increase and the commensurate housing demand would be the cause of new housing-related impacts during refurbishment activities. A summary of recent and anticipated growth in housing is provided. This is followed by predictions of possible impacts during refurbishment and the license renewal term.

In the period 1980–90, housing in Pope County increased 23.8 percent above the 1980 level. Assuming this rate of growth will continue, there would be approximately 30,900 housing units in Pope County in 2014. Based on a projected population of 63,395 and a 1990 average household size of 2.61 persons, 24,259 housing units would be required to accommodate Pope County's 2014 population. This suggests that there will be available housing, possibly as many as 6500 units in 2014. Even if Pope County's growth were to slow considerably, e.g., to 1.6 percent annually (a rate equal to the average annual rate that occurred between 1980 and 1986), there will be about 25,650 housing units in 2014 and over 1300 vacancies.

According to the estimate of the number of refurbishment workers required for the project and based on plant construction experience, 830 workers of the total work force of 2273 are expected to migrate to Pope County for refurbishment jobs. Of these in-migrants, 498 are expected to be accompanied by families. Some doubling-up is expected to occur among the 332 unaccompanied workers, so that each unaccompanied mover would require 0.85 housing unit. In 2013, the refurbishment-related housing demand would be 780 housing units (where *refurbishment-related housing demand* = *workers with families* + 0.85 × *unaccompanied workers*). In addition, numerous indirect jobs are expected to result from project workers' spending. An additional 196 indirect workers are projected to move to Pope County, bringing the total project-related housing demand in the peak year of refurbishment to 976 units.

The projected refurbishment-related housing demand is larger than the original construction-related housing demand of 858 units, but the number of housing units in the study area will have increased 86 to 117 percent under the conservative and current growth rates, respectively, between peak construction and refurbishment periods. Refurbishment-related housing demand would account for 3.8 or 3.2 percent (under the conservative and current growth rates, respectively) of the projected housing units in the study area in 2014, compared to construction- related demand in 1977 accounting for 6.25 percent of the housing units. Changes in the characteristics of the Pope County housing market that have occurred during or since plant construction should improve the accommodation of refurbishment-related workers. These changes include a greater proportion of multifamily units and the addition of mobile home parks. Some of the demand may be met by construction workers' recreational vehicles or mobile homes; this may require, however, the temporary addition or expansion of mobile home parks. However, no substantial construction of new housing units is expected to occur during refurbishment activities unless other economic and industrial growth warrants it, as was the case before and during ANO construction. Because housing demand would be small relative to the existing housing market, would not exceed projected vacancies, and would be even less than that experienced during construction, refurbishment-related housing demand is expected to have a small new impact on the study area housing market.

Housing impacts related to refueling activities and housing value and marketability that would occur as a result of continued plant operation during the license renewal term are the same as those currently being experienced (Section C.4.1.2.1). The 120 additional operations workers (60 per unit) and the commensurate housing demand would cause only small new housing impacts.

C.4.1.3 Taxes

The local impact of plant-related property taxes is presented here and in the other six case study presentations. Where information is available, the assessed valuation of the nuclear plant and the study area is presented to show the importance to the tax base from the start of construction to the current period. The impact of taxes on specific taxing authorities, such as local school districts, is presented. For these jurisdictions, the magnitude of plant-related property taxes relative to total local jurisdiction revenues is shown, again from the beginning of construction to the latest tax period in which information was available.

Each case study lists (1) the taxing authorities receiving revenues from the nuclear plants and (2) the property tax payments and tax or millage rates from the nuclear plants. At case study sites where the state assesses the value of the nuclear plant, the state tax valuation method is described. Tax reform legislation affecting the tax revenues from nuclear plants has been enacted in a few of the states where case study nuclear plant sites are located. The impact on total tax revenues and the taxing authority in general is described in sites where such legislation has been passed.

Tax and total revenue information was obtained directly from the governments that tax the case study nuclear plants. This information was obtained, where available, for the years 1980, 1985, and 1989. This longitudinal tax and revenue data allowed the evaluation of trends in nuclear plant tax revenue impacts over the past decade.

C.4.1.3.1 Impacts from Plant Construction and Operation

The jurisdictions that receive the bulk of the taxes paid by AP&L for ANO station are Pope County and the Russellville School District. Property taxes are the principal source of revenue for Arkansas counties and municipalities. Table C.17 shows AP&L's annual tax payments to Pope County for ANO during the 1968–89 period (NUREG/CR-2749, vol. 1).

From 1968 through 1989, Pope County's assessed valuation increased at an annual rate of 10.1 percent in real terms. During this same time period, ANO had its assessed valuation increase at a 21.9 percent real annual rate. ANO's portion of Pope County's total assessed valuation increased sharply from 1968 to 1980, from 5.4 to 73.6 percent. Thereafter, ANO's portion has dropped to 46.2 percent in 1989. Taxes paid to Pope County increased considerably as construction of the plant progressed in the early 1970s and more than tripled between 1972 and 1976 once construction was completed.

In 1980, the state legislative passed Amendment 59, which prevented reduction in taxes on utility properties for the first

5 years after the amendment's passage. It required a gradual reduction (to occur over the succeeding 5 years) in the millage rates assessed against utility property. Because of Amendment 59, ANO's tax revenues to the county have steadily decreased from approximately $1.6 million in 1985 to $1.2 million in 1989.

The recipient of the largest tax payments within Pope County was the Russellville School District. In 1978, property within the jurisdiction of the Russellville School District was assessed at a tax rate of 50 mills, whereas the tax rate for Pope County was 9 mills (Arkansas State Department of Education 1990). However, this millage rate for the school district has been falling throughout the 1980s. In 1985 the combined millage rate for real estate and personal property components in the Russellville School District was 48.1, but by 1989 it had fallen to 22.5. During the 1980s, the assessed value of property within the district rose steadily from $176.5 million in 1980 to $275.6 million in 1985 and to $341.1 million in 1989. In real terms, the assessed valuation in the Russellville School District grew at an annual rate of 3.1 percent. Table C.18 shows the revenue impact of ANO.

To compare the amount of taxes paid to the Russellville School District in real terms during the 1980s, the assessed valuation of the school district is deflated in real terms by the GNP deflator and then multiplied by the millage rate for the school district for the year in question. The resulting estimated taxes for Russellville School District increased at a 3 percent annual real rate from 1980 through 1985 but then declined at a 15.4 percent annual real rate from 1985 to 1989. Decreased millage rates resulting from Amendment 59 are largely the cause for the decreased revenue. As tax revenues decline, the school district will likely seek a tax increase in the future.

The Russellville School District ranked 66th out of the 329 school districts in the state of Arkansas for expenses per student in 1989. This is up from a ranking of 132 in 1988. The district is currently ranked 7th out of 329 in teachers' salaries in 1989 (the comparable ranking in 1988 was 25th).

Currently, Pope County is in a period of transition from a farm-oriented community to an area of light industrial development. Industrial development has increased substantially over the last 20 years. Undoubtedly, some of the development in the county is associated with the substantial tax revenues from ANO; however, the introduction of Interstate 40 through the county has had a major impact on development in the area. Officials at Pope County and Russellville School District have indicated that improvements in the county and school district and substantially reduced tax rates were possible because of ANO.

C.4.1.3.2 Predicted Impacts of License Renewal

A new tax-related impact is expected to occur during refurbishment of ANO. This new impact does not involve capital improvements that take place during the final refurbishment outage. Rather, it results from capital improvements that are undertaken during the current term outages, which would increase the assessed value of the plant during this time and, thus, increase ANO's tax payments to local jurisdictions. The magnitude of the impact depends on AP&L's decision about which improvements would occur early on and which would be done during the final outage. For example, if the steam generator is replaced during a current term outage, the assessed value may increase considerably before the license renewal term begins. If steam generator replacement and other major capital improvements are not undertaken early on, the increase in assessed valuation may be only minor. The increase, in either case, is expected to cause only an small to moderate new tax impact.

During the license renewal term, the tax-related impact would be primarily the continuation of tax payments ANO is currently making to local jurisdictions. A new impact would result from the increase in tax payments from improvement made at ANO during the final refurbishment period. Thus, tax revenues would increase in absolute terms but may remain constant as a percentage of total revenues of Pope County and the Russellville School District. ANO's contribution to the county's total revenues has fallen during the past decade, from 49 percent of the total revenues in 1980 to 26 percent in 1989. The additional tax payments during the license renewal term may halt this trend. Based on current conditions, ANO tax revenues—the continuing and additional payments combined—are expected to continue to make up a large share of the total revenues. Decreased millages that have resulted from ANO's substantial tax contributions may remain, although Amendment 59 does allow for millage increases. The large tax-related impact currently being experienced would continue during the license renewal term.

C.4.1.4 Public Services

The general methodological approach used to predict future impacts is discussed in Section C.1. For most public services, impacts were calculated based on the projected number of in-migrating workers and on the projected state of the local infrastructure. The expected number of in-migrants was calculated separately for each case study site, based on the in-migration patterns observed in past studies at these same sites. Where historic data were not available, in-migration rates were estimated on the basis of comparisons with sites that were similar in terms of population density and proximity to metropolitan areas. Only in the area of transportation was in-migration considered unimportant, since all project workers (and plant-related equipment) will use local roads to access the project site.

To project impacts to local educational systems, two important factors were the number of in-migrating workers accompanied by their families and the associated family size. Assumptions about these key variables were based on past patterns observed at the case study sites. Specifically, the number of in-migrating workers expected to bring their families with them at any given site was calculated based on the percentage of past workers accompanied by their families at the same site. Refurbishment workers were assumed to follow the same pattern as past construction workers, and future operations workers were assumed to be the same as past operation workers. Average household size for each site was determined from current state- specific data. For each family at a given site, the number of children was considered to be this average family size minus the two parents. The total number of additional children of plant workers was calculated by multiplying the number of in-migrating families by the expected number of children per family. Assuming that dependent children were equally distributed between the ages of 0 and 18, 68.4 percent of the children were projected to be of school age (6–18 years). This was the number of additional children expected to be enrolled in local schools.

C.4.1.4.1 Impacts from Plant Construction and Operations

ANO has affected public services in several surrounding counties, municipalities, and school districts, but three jurisdictions have been affected more than others: the Russellville School District, Pope County, and the city of Russellville. Each entity provides different services and has been affected in varying ways by ANO, as discussed below. A few construction impacts were noticeable in education and public utilities, but projected impacts from relicensing should be less significant. Information regarding expenditures is discussed in detail in Section C.4.1.3.

Education

The Russellville School District has seen much change as a result of the ANO plant. During the 1960s, the school district was facing severe financial difficulty and overcrowding. Even though Russellville's economy was growing and the population was growing with it, the Russellville School District had problems coping with the rise in enrollment. Student/teacher ratios reached as high as 35 to 1 during the 1960s, and a tax hike was approved to fund the building of a new high school.

Local residents saw the ANO plant as a solution to the problem. Taxes from ANO in its first 3 years of construction helped to pay for the new high school, but it was not until several years later (about 1973) that the Russellville School District's situation stabilized. It was difficult to accommodate new students brought in by ANO's construction and other growth, but once the high school was complete, assimilation was easy (NUREG/CR-2749, vol. 1, p. 116).

The student/teacher ratio began falling steadily after 1968; by 1980, it had fallen to 20 to 1 and the Russellville School District teachers were being paid more than others in Arkansas. Through ANO's tax payments, the biggest impact on the system, the district was able to recruit highly qualified teachers, which played a part in encouraging further economic growth in Russellville (NUREG/CR-2749, vol. 1, p. 116).

Like the plant's construction, operations have generated economic growth in Russellville, which in turn has affected the Russellville School District. Several informants noted that firms have transferred employees to Pope County, and some new businesses have appeared because of ANO's location. For instance, one recent company move into Russellville is expected to increase school enrollment in the area by 50 to 100 students. Refueling activities also have an effect on the Russellville School District, but the concurrent rises in enrollment are minor and short-lived.

Although the positive financial impacts of the ANO plant were tremendous, the district is once again experiencing financial difficulty. The state's constitution was amended in 1980 to modify its taxation policies. The new taxation policies caused a reduction in utility tax payments beginning in 1985. This resulted in lower revenues for the school district. As ANO taxes are a major source of monies for the Russellville School District, the drop in funds has left the school system in a financial dilemma. The district will likely seek a tax increase in the future, because of program expansion during the affluent years.

Transportation

The transportation network in Pope County, which was already a well-developed system, did not suffer as a result of ANO's construction. In fact, taxes paid by ANO by 1980 aided in the resurfacing of approximately one-third of all county roads. AP&L improved and extended the highway system to the ANO site and port facilities, both of which are on the Lake Dardanelle peninsula. Informants also reported that unloading facilities were constructed near the plant and that port activity increased during construction.

Key information sources indicated that ANO's construction created no problems with traffic congestion. Commuters to the plant generally bypassed the city, and construction workers who moved into Russellville were well dispersed throughout the community, which further diminished traffic impacts (NUREG/CR-2749, vol. 1, p. 119).

The city was also well served with a rail system, since it is a regional rail hub. A rail spur was constructed from the main east-west county line to the plant site for the shipment of construction equipment (NUREG/CR-2749, vol. 1, p. 118).

Since ANO began operations, no sources indicated problems with traffic congestion nor have sources reported impacts from maintenance and refueling at the plant.

Public Safety

Public safety services in Pope County have benefitted fiscally from ANO. Expenditures for public protection increased rather steadily during construction, enabling Pope County's police force to approximately double during that period, and the county ambulance service was expanded during construction. The Russellville Police Department also added several employees, but the relatively large full-time fire department, which was established before ANO was built, was less affected (NUREG/CR-2749, vol. 1, p. 119).

No countywide fire protection system exists, but the county does assist communities financially to establish municipal systems, and there are numerous rural volunteer fire companies. AP&L also undertook the development of a countywide emergency communications system, linking ANO directly to hospitals, police, and fire departments. ANO also funded emergency programs and drills (NUREG/CR-2749, vol. 1, p. 119). Also, the city has a nuclear emergency contingency plan as part of its comprehensive plan. One source stated the emergency plan has been tested and proven successful.

No impacts from ANO's operations and maintenance/refueling outages were reported by any public safety official.

Social Services

Social services have not been affected by the plant. There is no evidence attributing increased demands on social services to the construction of ANO (NUREG/CR-2749, vol. 1, p. 120). No informant reported impacts on services because of plant operations or refurbishments.

Public Utilities

In Pope County, sources noted that public utilities have not been affected by ANO, except that the water system was described as very inadequate. Other informants stated that demands on sewer and water increased at that time, but the strain on the system was manageable.

In much of the county area outside Russellville, water is currently provided by wells on-site. However, part of rural Pope County is in a water district north of Russellville, and there are plans to expand the system farther into the rural areas of the county.

Russellville's water supply is getting smaller, which will affect water availability and recreation in the county. New water sources will be sought in the future. Meanwhile, ANO is currently the third largest individual consumer of water in Russellville; thus, its operations do affect the system moderately. The plant's demand is increasing also.

Tourism

Reports indicated that the ANO plant has had only small effects on tourism in the area. There is some tourism on Lake Dardanelle, one of the largest recreational resources in the area, and across the reservoir from the plant is the popular Lake Dardanelle State Park. One official from the chamber of commerce stated that during construction there was a short-lived increase in visitors to Pope County. Another noted that a number of travelers on nearby I-40 still stop to see the plant.

Recreation

Recreation was not affected by construction activities at ANO as much as it has been from operations. However, these impacts have still been small. One official noted a short-lived increase in water recreation during construction, but the city recreation director was uncertain about effects on organized recreation.

It was also reported that operations at the plant have had only slight effects on recreation, although the city is experiencing much growth in its recreation programs. Another source reported that Lake Dardanelle and its corresponding state park are popular sites for fishing, boating, and other activities. Loop also indicated that fishing near the plant was very good and that no recreational areas along the reservoir had been affected adversely by ANO. The chamber of commerce also noted an increase in outdoor recreation and tourism attributable to operations at ANO, but these effects have been insignificant.

No impacts on recreation from refurbishments were reported. The water supply in Russellville, previously mentioned, is also becoming an issue with water recreation in some areas.

C.4.1.4.2 Predicted Impacts of License Renewal

Based on the estimated 2273 direct workers required during peak refurbishment, the staff estimates that 498 direct workers and 123 indirect workers will migrate with their families to Pope County (Section C.4.1.1.2). The number of children accompanying these workers is estimated using the Arkansas average family size (3.07) and assuming that all families include two adults. Children are expected to be evenly distributed in age from ≤1 to 18 years. Assuming 72.2 percent of these children are school-age (5 to 18 years), there will be an average of 0.77 school-age children per in-migrating family, or a total of 478 new students in Pope County. This represents a 4.0 percent increase above the projected number of school-age children in Pope County in 2014 (assuming the 1990 age distribution of the population) and equates to an average of 37 students per grade level. Moderate impacts could result, especially if the students are concentrated geographically (e.g., in Russellville).

An analysis of the projected BWR bounding case work force (1500 persons) was conducted to determine if a smaller work force would result in a lesser impact. (This is a hypothetical scenario because ANO is a PWR.) The 411 in-migrating direct and indirect workers who bring their families to Pope County would be accompanied by 321 school-age children (or 25 per grade). This would result in a 2.6 percent increase in the projected number of school age children in Pope County in 2013. Although only small impacts are likely, moderate impacts could result if the children are concentrated geographically or if facilities and classes are already at their peak capacity.

An analysis of potential impacts to education under the BWR typical work force scenario (1017 workers) finds that there would be 279 direct and indirect workers migrating to Pope County with their families. The associated 215 new school-age children (or 16.5 per grade level) would result in a 1.8 percent increase in the projected number of school-age children in Pope County in 2013. This increase in enrollment will likely cause only small impacts to the education system.

During ANO construction, when the number of in-migrants peaked at 2756 (an 8.3 percent increase in Pope County population), there were small impacts on transportation, social services, public utilities, tourism, and recreation. Projected refurbishment-related in-migration (15 percent less than construction in-migration) will increase the population 3.7 percent. Therefore, projected impacts on these public services from refurbishment will be small. Public safety, which has been fiscally affected by ANO, also should see only minor changes during the refurbishment period.

Impacts to all public services from continued operations also should be small because only a slight increase in population will occur. However, the public water system may be moderately affected because of the diminishing local water supply and increasing water usage by the plant.

C.4.1.5 Off-Site Land Use

This section describes the off-site land-use impacts of the construction, operation, and license renewal of the ANO plant. The discussion of impacts is primarily concerned with land use in the immediate vicinity of the plant, but impacts for the remainder of Pope County are described where appropriate. Land-use impacts are examined for two time periods. First, Section C.4.1.5.1 identifies the land-use impacts of ANO's construction and operation. Next, Section C.4.1.5.2 projects the land-use impacts of ANO's refurbishment period based on the impacts that occurred during the plant's construction. Also, Section C.4.1.5.2 projects the land-use impacts of the plant's license renewal term based on the impacts that have occurred during operations. Information sources for this report include the *Final Environmental Statement Related to the Arkansas Nuclear One, Units 1 and 2* (AEC Dockets 50-313 and 50-368); the *Final Environmental Statement Related to Operation of Arkansas Nuclear One, Unit 2* (NUREG-0254); *Socioeconomic Impacts of Nuclear Generating Stations: Arkansas Nuclear One Station Case Study* (NUREG/CR-2749, vol. 1); and interviews with key information sources in Pope County.

The assessment of land-use impacts began with a review of EISs for a number of nuclear plants and site-specific reports on the seven case studies. This review identified land-use impacts that had occurred during plant construction and operations and key issues that would be addressed in assessing the impacts of license renewal. The key land-use issues identified were

- changing land-use patterns influenced by plant location, plant-related population growth, and plant tax payments;
- changing residential, commercial, and industrial development rates and patterns influenced by plant location, plant-related population growth, and plant tax payments; and
- changing land-use regulations or zoning patterns resulting from plant-induced changes in land use and development patterns.

With these key issues, telephone survey forms were developed and administered to local planners, economic development specialists, and realtors in the seven case study areas (Section C.7). By combining the results of the literature review with those of the telephone survey, the factors most useful in predicting land-use impacts were identified. By comparing the impact predictors to the impacts that had been observed at the seven case studies, conclusions could be drawn concerning the relationships between predictor magnitude and impact significance. The impacts of plant refurbishment and license renewal were projected for each case study on the basis of relationships between the magnitude of impact predictors, the local areas' existing land-use and development patterns, and the significance of the land-use impacts that occurred in the past.

C.4.1.5.1 Impacts from Plant Construction and Operation

ANO was constructed on a rural 471-ha (1164-acre) site situated on a peninsula on the northern bank of Lake Dardanelle near Russellville. The land upon which the plant was built previously had been used for marginal farming and livestock grazing. In 1968, when plant construction began, the land in the immediate vicinity of the ANO site was almost wholly undeveloped and not under any form of zoning or land-use regulation. Some rural residences were on the peninsula, but primary land uses there included commercial forestry, agriculture, and recreational uses associated with Lake Dardanelle.

The construction and operation of ANO have had moderate direct impacts on land use in the immediate vicinity of the plant. The rural character of the peninsula upon which ANO is located has been altered somewhat because the plant has served as a direct impetus for much of the mixed-use development that has occurred there. This mixed-use development has been fairly limited, but it consists mostly of buildings used by contractors and engineering firms (such as Bechtel) associated with ANO. In addition, the Pope County Evacuation Team is located on the peninsula near the nuclear plant. However, ANO has neither directly encouraged nor impeded large-scale commercial or industrial development of the peninsula.

ANO's presence on the peninsula also has resulted in moderate indirect land-use impacts. Before ANO was constructed, a number of small houses and cabins were on the peninsula with no discernable pattern of subdivision or residential development. Since plant construction began, rural subdivisions with single family homes have been built near the ANO site [some within 0.4 km (0.25 mile)]. Many of these homes, especially those with lakefront lots, are relatively expensive in the context of the local real estate market. Key information sources indicated that the primary reason for this residential development was the availability of lakefront property with scenic mountain vistas. But ANO's presence also encouraged residential land use on the peninsula indirectly, as builders began to take advantage of the roads and water lines put in place for the plant's use to develop lakefront residential properties.

ANO's construction and operation have also had moderate direct and indirect impacts on land use in other parts of Pope County. In the early 1970s, developers further subdivided the western section of Russellville for single family residential use. The subdivision and development were the result, in part, of the influx of residents associated with ANO, as construction-related population growth represented as much as 8.3 percent of Pope County's total population in 1974. This growth, combined with the economic benefits the plant brought to the county, helped create additional housing demand. However, the residential construction that occurred did not create significant changes in land-use or development patterns.

The economic benefits of ANO's operation, such as the generation of both direct and indirect jobs, salaries, and tax expenditures in the local economy, continue to help shape Russellville's residential and commercial growth rates and development patterns. Key informants agreed that ANO's direct and indirect residential and commercial land-use impacts had been very positive for Russellville and Pope County but that ANO's impacts in terms of helping recruit new industries to the area had been only neutral or slightly positive (NUREG/CR-2749, vol. 1, p. 140).

C.4.1.5.2 Predicted Impacts of License Renewal

With the plant-related population increase projected for Pope County, the land-use impacts of ANO's refurbishment are expected to be small. Using the bounding-case work force scenario, refurbishment-related population growth is projected to represent approximately a 9.3 percent increase in the county's projected population in 2014. Increases of this size would result in small new impacts to land-use and development patterns, especially when compared to those driven by the construction-related growth peak of 8.3 percent in 1974. ANO's refurbishment and operation would continue to attract some plant-related mixed-use development to the peninsula directly, but this development is not expected to cause major changes in local land-use patterns.

The indirect land-use impacts of ANO's license renewal term are expected to be moderate. Population growth associated with the plant's continued operation is projected to represent only a 0.3 percent increase in Pope County's projected 2014 population, so the new land-use impacts of worker in-migration are expected to be minimal. However, key sources expect residential development to continue on the peninsula because of the availability of desirable lakefront property. As in the past, this continued residential development would be guided by the provision of roads and water service, an indirect impact of ANO's presence. The plant's operation also would result in continued economic benefits such as direct and indirect salaries and tax contributions for Pope County. But the tax benefits may be less than those previously available because of Amendment 59, which in the mid- to late 1980s caused reductions in tax payments on utility property.

Nonetheless, ANO's operation would provide Pope County with economic benefits that would continue to shape land-use and development patterns in Russellville and the rest of the county through the provision of municipal services.

C.4.1.6 Economic Structure

Employment and income effects on the nuclear plant case study areas were identified using historical data generated by Mountain West Research, Inc., in site-specific studies (NUREG/CR-2749, vols. 1–12) and from time series information (from 1968 and forecasted to 2010) on county employment and income provided by NPA. Past plant-related employment was estimated by Mountain West using the RIMS methodology; employees were classified as direct basic, indirect basic, other basic, or nonbasic; and the number of jobs filled by current residents and by in-migrants was identified.

To determine the magnitude of plant-related employment relative to total local employment, the projected number of plant-related jobs filled by people living in the study area (prior residents or in-migrants) was divided by the NPA employment projections. The NPA county-level figures describe employment by place of work rather than by place of residence; however, these values were used as a surrogate for employment by place of residence. This approach was chosen to avoid the substantial error that could be introduced by projecting employment, in light of the large uncertainties concerning future population, family size, family work patterns, and other important parameters. If the study area makes up only part of a county, future study area employment was projected from the current work force of the study area using the same growth rate NPA projected for the county in which the plant is sited. Projected employment effects are presented for the refurbishment scenario and for continued operations during the license renewal term.

For descriptive purposes, the magnitude of plant-related income relative to total study area income also was determined. Projected income for direct basic workers residing in the study area was calculated by multiplying the projected number of direct workers in the study area by the projected average wage for transportation, communication, and public utility workers for the study area county. This average wage was determined by dividing the NPA projection of total county income for that sector by the projected number of workers in that sector countywide.

Projected income for indirect basic and nonbasic workers (employed in jobs produced by plant expenditures and spending by direct employees in the study area) was calculated by multiplying the projected number of these workers residing in the study area by the projected average wage for this type of employment. Plant-related indirect basic and nonbasic workers were assumed to be largely retail and service workers, so their average wage was calculated by summing the projected average wages in those two sectors, weighting the retail salary as 30 percent and the service salary as 70 percent. The average wage in each of these sectors was determined in the manner described above for transportation, communication, and public utility workers.

The magnitude of future plant-related income relative to total study area income was calculated by summing projected incomes for direct, indirect basic, and nonbasic workers and dividing by the total income that NPA projected for the study area.

C.4.1.6.1 Impacts from Plant Construction and Operation

ANO's construction and operation have had moderate and large impacts, respectively, on Pope County's economic structure. Pope County's labor pool has provided employees for the plant, both during construction and operations, and the plant has provided county residents with jobs that have higher incomes than were previously available. Secondary employment and income have also resulted from the spending of ANO workers in local communities, and the taxes paid to the Pope County government and the Russellville School District by ANO have led to increased employment and income.

Table C.19 gives the estimated employment and expenditure effects of ANO for residents of Pope County. Construction employment at ANO rose steadily from 1969 to 1974, gaining fivefold from 215 to 1100. The operations work force increased at a slower pace; from 196 in 1972 to 462 in 1980. Operations employment in 1989 was about 2205 workers, of whom 1985 were Pope County residents.

C.4.1.6.2 Predicted Impacts of License Renewal

The work force scenario detailed in Section C.3.1 was used to estimate the employment effects of refurbishment at ANO. Table C.20 shows the total direct and indirect plant-related employment of Pope County residents during refurbishment.

It is projected that in 2013 ANO would employ 1477 county residents as refurbishment workers (Section C.4.1.1.2). Indirect employment that would result from purchases of goods and services during refurbishment is projected to create 454 additional jobs for Pope County residents.

The total direct and indirect employment affecting Pope County during the peak refurbishment year is therefore projected to be 1931. This employment is projected to be 5.8 percent of the total Pope County work force in 2013, resulting in moderate impacts.

Relatively few new plant-related jobs would be created at ANO during the license renewal term. Nearly all plant-related employment (and associated impacts) expected during that time period would represent a continuation of employment (and impacts) from past operations. Table C.21 shows the impact of the increased labor requirements at ANO after 2013.

The license renewal term work force for ANO would require an estimated 120 additional employees (Section C.4.1.1.2). Of these additional employees, 108 are projected to be Pope County residents. An estimated 47 indirect jobs would also be created because of the license renewal term, and 45 of the jobs are expected to be filled by Pope County residents. With the continued effects of the plant's current employment and the additional jobs to be created, total direct and indirect license renewal term employment is projected to represent 8.9 percent of Pope County employment in 2013. Because Pope County meets the conditions described in Section 4.7.6.1, license renewal term employment represents a large impact to Pope County.

C.4.1.7 Historic and Aesthetic Resources

The assessment of the impacts of (1) past construction and operation and (2) projected refurbishment and postrelicensing operation of nuclear power plants on historic and aesthetic resources began with a review of the original license application documents, the professional literature, and the popular literature. From these, the staff gleaned a sense of the projected and realized impacts at the various power plants. These experiences were examined in some detail through use of case studies conducted at seven representative nuclear power plants across the United States.

By using the original license application documents and telephone interviews with key local informants (see Section C.7 for a sample of the questions asked), those factors most useful in projecting impacts were identified. By examining the associations between these impact predictors and the resulting impacts at the seven sites, the staff drew conclusions concerning the relationships between predictor magnitude and impact significance. The staff then made projections about the impacts of power plant refurbishment and post-relicensing operation for each case study site based on relationships among the magnitude of these impact predictors, the current and anticipated states of critical infrastructure components, and the significance of impacts observed during analogous past periods.

The assessment varies from more traditional aesthetic analyses in that it relies heavily on the opinions and representations of key local sources of information as proxies for the lay local residents' and other users' feelings and preferences. Because of the selection of only these few sources, there could be errors of commission or omission in communicating these values or in the staff's interpretations of the elicited concerns.

This section describes the impacts that the construction and operation of the ANO power plant have had on historic and aesthetic resources and projects the expected impacts of the plant's refurbishment and post-relicensing operations. Information sources include the *Final Environmental Statement Related to the Arkansas Nuclear One, Unit 1* (AEC Docket 50-313); the *Final Environmental Statement Related to Operation of Arkansas Nuclear One, Unit 2* (NUREG-0254); and interviews with key information sources in Pope County, Arkansas.

C.4.1.7.1 Impacts from Plant Construction and Operation

ANO is located in the Arkansas Valley, an area that contains many important American Indian archaeological sites, and key sources indicated that ANO's construction did disturb some of the sites. In addition, one respondent (Dr. Stewart-Abernathy of the Arkansas Archaeological Survey and Arkansas Technological University) stated that ANO's operation, particularly the use of service roads to access the station's transmission lines, had caused the erosion of archaeological sites. The respondent did not know the extent to which the sites had been researched or the relative significance of the sites. He was not sure of the extent to which they had been damaged by ANO's construction and operation, and did not know whether mitigation had been attempted at all or, if attempted, whether it had been unsuccessful. However, all respondents agreed that Lake Dardanelle's—impoundment, which predated and was not related to ANO's construction—had inundated a number of relatively significant archaeological sites and that the lake's creation had had a much greater impact than ANO's construction. The Arkansas Archeological Survey Coordinating Office, the Arkansas State Parks and Tourism Commission, and the Arkansas State Historic Preservation Office all determined that the construction and operation of the station would not affect any historic structures or sites listed in the *National Register of Historic Places* (AEC Docket 50-313, p. 2-15; NUREG-0254, p. 2-2). In general, local sources felt that ANO's construction and operation had disturbed some American Indian archaeological sites, but they agreed that the power plant had no effect on other historic resources in Pope County. Overall, the construction and operation of the ANO plant have had generally small impacts on historic resources in Pope County.

ANO's construction and operation have also had small to moderate impacts on aesthetic resources in Pope County. The most noticeable aesthetic impact of ANO's operation results from the presence of Unit 2's 140-m (450-ft) high, natural-draft cooling tower and the steam plume it emits (staff observation and Stewart-Abernathy). The station's cooling tower is visible from at least 16 km (10 miles) away, and its plume can be seen from a much greater distance (AEC Docket 50-313). The cooling tower and its plume have adverse effects on the natural beauty of the area, but key informants indicated that the station's appearance had not discouraged residential or recreational land uses on Lake Dardanelle and had not been a subject of protest.

C.4.1.7.2 Predicted Impacts of License Renewal

Because ANO's refurbishment is not expected to change the visible profile of the plant, the impacts of refurbishment on aesthetic resources would be much smaller than those experienced during construction. However, the impacts of post-relicensing operations are likely to be the same as those experienced during the original operating period. Operations impacts would result from the presence of ANO's cooling tower and steam plume. As in the past, the station would have small to moderate impacts on aesthetic resources.

ANO's refurbishment is not expected to involve the physical conversion of additional land for the station's use; however, any disturbance of land (e.g., grading an area for storage of refurbishment equipment or parts, or constructing a new service road) introduces the potential for impacts to archaeological resources. Although impacts to historic resources (including archaeological resources) are expected to be small during both refurbishment and operations, this determination must be made according to the National Historic Preservation Act of 1966 through consultation with the state historic preservation officer (SHPO). Impacts, if any, during the license renewal term are expected to be small; however, consultation with the SHPO is required.

C.4.2 D. C. Cook

The impact area—the area in which the most pronounced socioeconomic impacts might result from refurbishment and license renewal for D. C. Cook—consists of Berrien County, the city of Bridgman, and Lake Township, Michigan. For the purpose of assessing the impacts of D. C. Cook on taxes and economic structure, the impact area is limited to Bridgman and Lake Township. Both of these are jurisdictions within Berrien County that are close to the plant. The selection of this area is based on worker residence patterns, employment, expenditures, and tax payments. Figure C.6 depicts the impact area, and Figure C.7 shows the region in which it is located.

C.4.2.1 Population

This section discusses the local population growth associated with the construction, operation, and license renewal of the D. C. Cook Nuclear Plant. Section C.4.1 describes the methodology used to project population growth for all plants. Data used to prepare this section were obtained from *Socioeconomic Impacts of Nuclear Generating Stations: D. C. Cook Case Study* (NUREG/CR-2749, vol. 4); *Environmental Assessment Proposed Rule for Nuclear Plant License Renewal* (NUREG-1398); SEA refurbishment work force estimates (Appendix B; SEA 1994); population projections by the Southwestern Michigan Regional Planning Commission; and the Indiana and Michigan Power Company.

The discussion of population growth is organized into two time periods. Section C.4.2.1.1 identifies the population growth that the study area experienced as a result of the construction and operation of D. C. Cook from 1969 to 1990. Section C.4.2.1.2 projects the population growth that is expected to result from D. C. Cook's refurbishment period and license renewal term operations beginning in 2015 (Unit 1) based on the growth associated with the plant's initial construction. Section C.4.2.1.2 also projects the population growth expected to result from D. C. Cook's license renewal term based on the growth associated with operations in the past.

C.4.2.1.1 Growth Resulting from Plant Construction and Operation

D. C. Cook's construction resulted in noticeable population increases in the Bridgman/Lake Township area surrounding the plant (Table C.22). During the peak construction year, 1972, D. C. Cook personnel and their families who migrated to the area to work at the plant and others who moved into the area to work in jobs generated by the plant's presence, totalled approximately 175 persons. This influx of new residents represented 4.6 percent of the two communities' populations.

In 1990, 1252 permanent plant staff were on-site at D. C. Cook. (Additional contract workers have been on-site during outages, but they are not included because their presence at the plant was temporary.) Based on the residential settlement pattern of D. C. Cook's 1978 work force, it was estimated that 10.6 percent (133) of the permanent work force in 1990 resided in Bridgman/Lake Township (NUREG/CR-2749, vol. 4, pp. 88–89). Also based on previous plant operating experience, it was estimated that 54 percent (72) of those residing in Bridgman/Lake Township in 1990 were previous residents who obtained jobs and that 46 percent (61) were workers who migrated into the area for jobs. Following the pattern set during plant operations, it was estimated that 60 percent of the in-migrants (37) were accompanied by their families (Table C.23). Using the 1990 Michigan average family size of 3.16 persons, this represented a total in-migration of 141 new residents for Bridgman/Lake Township. Based on the ratio of nonplant to plant jobs created in 1978, D. C. Cook's 1990 operations created an additional 424 indirect jobs in industries supported by the spending of D. C. Cook workers. Approximately 15 of these indirect jobs were filled by current

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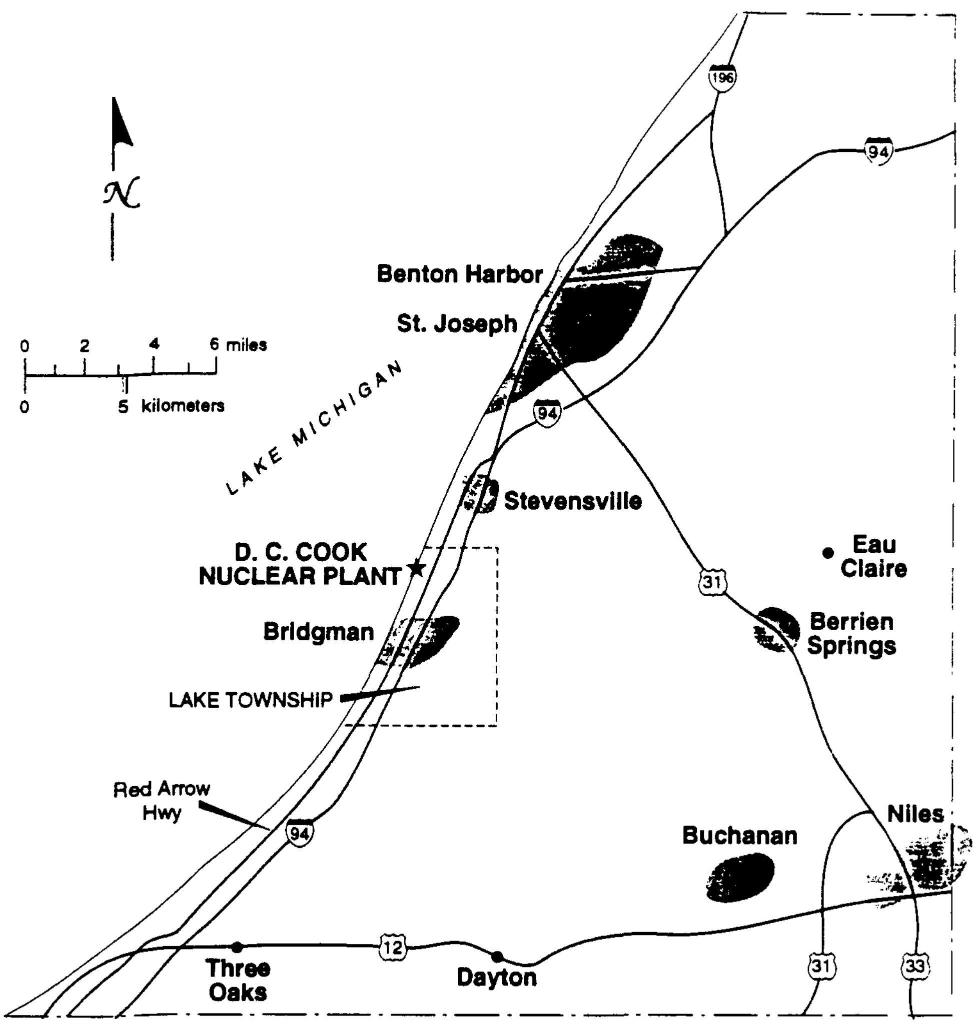

BERRIEN COUNTY

Figure C.6 Socioeconomic impact area associated with D. C. Cook refurbishment, including Berrien County, Lake Township, and Birdgman.

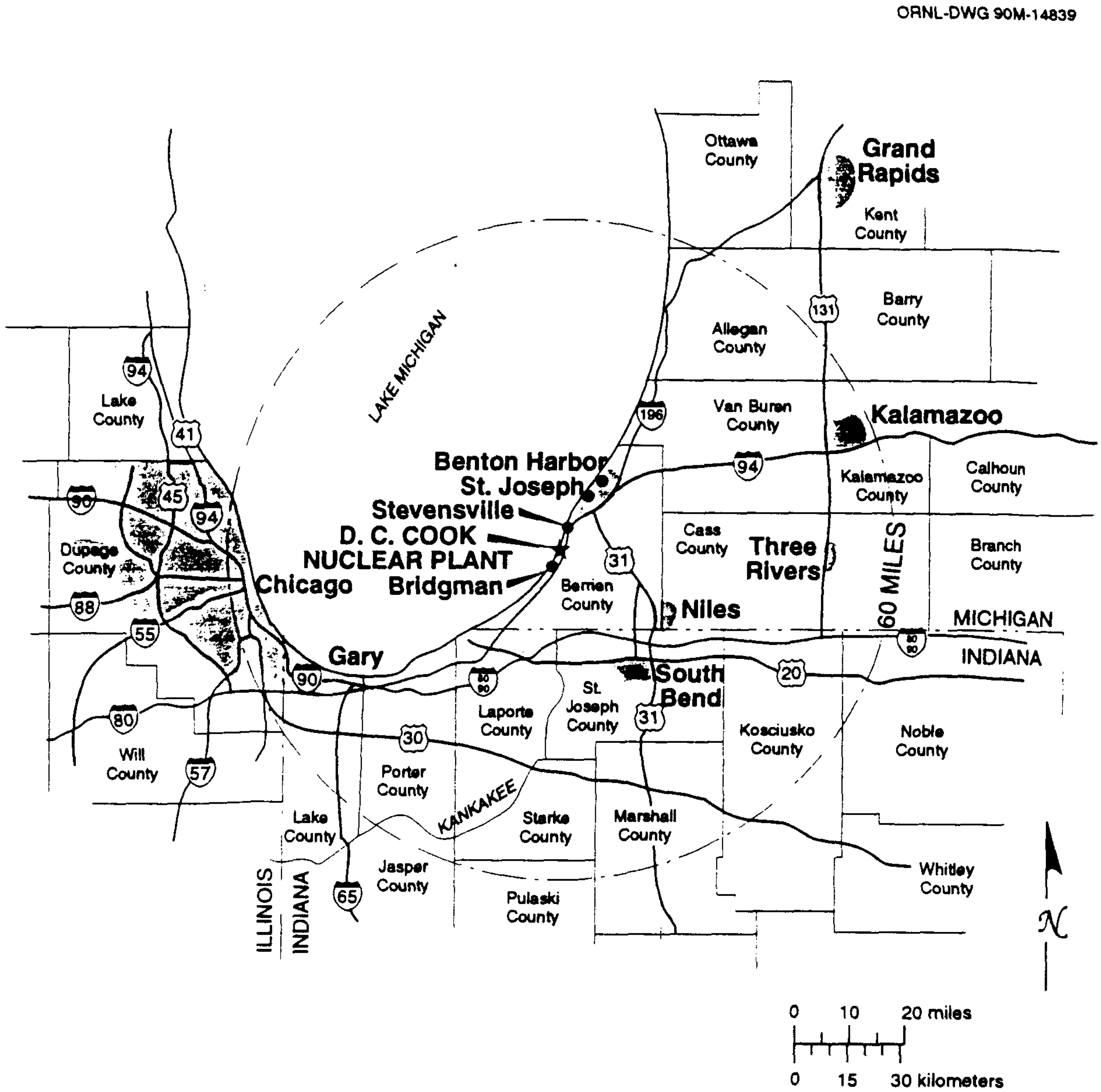

Figure C.7 Region surrounding the D. C. Cook nuclear plant.

residents of Bridgman/Lake Township; no additional in-migration resulted from indirect employment. In all, approximately 141 new residents moved into Bridgman/Lake Township as a result of D. C. Cook's 1990 operations (Table C.23). These new residents make up about 3.0 percent of the communities' 1990 population of 4627 (NUREG/CR-2749, vol. 4, p. 88–115).

The larger jurisdiction of Berrien County has experienced proportionally less population growth as a result of the D. C. Cook plant. In 1972, D. C. Cook personnel and their families who migrated to the county to work at the plant and others who moved into the area to work in jobs generated by the plant's presence totalled approximately 2193 persons, representing only 1.3 percent of the county's population. In 1990, based on the residential pattern of D. C. Cook's 1978 work force, it was estimated that 80 percent (1002) of the permanent plant staff of 1252 resided in Berrien County (NUREG/CR-2749, vol. 4, pp. 88–89). Also based on previous plant operating experience, it was estimated that 54 percent (541) of those residing in Berrien County in 1990 were prior residents who obtained jobs and that 46 percent (461) were workers who migrated into the area for jobs. Also following the pattern set during plant operations, about 60 percent of the in-migrants (277) were accompanied by their families. Assuming the 1990 Michigan average family size of 3.16 persons, this represents a total in-migration of 1059 new residents for Berrien County (Table C.24). Based on the ratio of nonplant to plant jobs created in 1978, D. C. Cook's 1990 operations created an additional 424 indirect jobs. As a result of these indirect jobs, an estimated 22 additional workers and their families (a total of 50 persons) moved into the county. In all, approximately 1109 new residents moved into Berrien County as a result of D. C. Cook's 1990 operations (Table C.24). These new residents made up about 0.7 percent of the county's 1990 population of 161,378 (NUREG/CR-2749, vol. 4, pp. 88–115).

C.4.2.1.2 Predicted Growth Resulting from License Renewal

As discussed in Section C.3.1, D. C. Cook's license renewal would require the completion of a number of refurbishment tasks for Units 1 and 2. Many of the refurbishment tasks are expected to be completed during scheduled refueling outages at each unit during the 10 years that precede the expiration of the initial operating license. However, the final refurbishment work is expected to be completed during one large refurbishment outage scheduled for each unit in the year before the unit's initial operating license expires. Because the final refurbishment outage would involve more workers on-site over a longer period of time than any of the preceding refueling outages, it represents the peak refurbishment period. For other assumptions concerning the refurbishment work force, refer to Section C.3.1 and Section C.4.1.1.2.

Given the refurbishment schedule previously described and in Section C.3.1, the peak refurbishment year for D. C. Cook Unit 1 is expected to be 2014, and the peak refurbishment year for D. C. Cook Unit 2 is expected to be 2017. For each unit, the on-site refurbishment work force would be about the same size, and the work force would be on-site for approximately the same period of time (Section C.4.1.1.2 for other work force assumptions). However, because there are uncertainties concerning the length of the outage and the size of the work force required to complete the refurbishment of a given unit, this section examines a bounding case work force scenario as described in Section C.3.1.

Given the work force scenario detailed in Section C.3.1, it is estimated that 2273 workers would be on-site to complete refurbishment of D. C. Cook Unit 1 in 2014 and D. C. Cook Unit 2 in 2017 (SEA 1994). Further, assuming that the residential distribution of refurbishment workers would be similar to that of the 1972 D. C. Cook construction work force, it is estimated that 66 percent (1500) would reside in Berrien County and that 5.4 percent (123) would reside in Bridgman/Lake Township (NUREG/CR-2749, vol. 4, pp. 69, 80). Based on plant construction experience, it is estimated that 44.7 percent (534) of those residing in Berrien County would be prior residents who obtain refurbishment jobs and 55.3 percent (830) would be workers who migrate into the area for refurbishment jobs (Table C.25). Also following the pattern set during plant construction, half of the in-migrants (415) would be accompanied by families. Using an average family size of 3.16 persons, total refurbishment worker in-migration would result in 1726 new residents for Berrien County (of whom 141 would reside in Bridgman/Lake Township) (Tables C.25 and C.26). Based on the ratio of nonplant jobs created in Berrien County in 1972, D. C. Cook's refurbishment is projected to create an additional 832 indirect jobs in service industries supported by the spending of refurbishment workers. As a result of these indirect jobs, an estimated 43 additional workers and their families (a total of 99 persons) would be projected to move into Berrien County (Table C.25). In all, approximately 1825 new residents would be expected to move into Berrien County and 141 new residents into Bridgman/Lake Township (Table C.26) as a result of D. C. Cook's refurbishment under the bounding case work force scenario. That would represent 1.0 percent of Berrien County's projected population of 186,626 in 2015 and 3.1 percent of Bridgman/Lake Township's projected population of 4548 in 2015 (NUREG/CR-2749, vol. 4, pp. 69–109).

Once plant refurbishment is completed for D. C. Cook Units 1 and 2, the work force would consist mostly of permanent plant staff. Additional refurbishment/refueling workers would be temporarily on-site approximately every 2 years, but they would not be permanent, on-site plant staff, and many of them are expected to commute from outside the study area. It is expected that a maximum of 60 additional permanent workers per unit would be required during the license renewal term, adding 120 workers to D. C. Cook's existing work force (NUREG-1398). Assuming that the new workers' residential distribution would be the same as that of current staff, approximately 80 percent (96) would reside in Berrien County, of whom 13 would reside in Bridgman/Lake Township (NUREG/CR-2749, vol. 4, pp. 88–89). Based on worker in-migration in 1978, it is expected that 54 percent (52) of those residing in Berrien County would be prior residents who obtain operations jobs and that 46 percent (44) would be workers who migrate into the area for jobs (Table C.27). Also following the pattern set during plant operations, 60 percent of the in-migrants (26) would be accompanied by their families. Using an average family size of 3.16 people, total in-migration would result in 100 new residents for Berrien County (of whom 15 would reside in Bridgman/Lake Township) (Tables C.27 and C.28). Based on the ratio of nonplant jobs created in Berrien County in 1978, D. C. Cook's continued operation is projected to create an additional 41 indirect jobs in service industries supported by the spending of plant workers. As a result of these indirect jobs, an estimated two additional workers and eir families (a total of about four persons) would be projected to move into Berrien County (Table C.27). In all, approximately 104 new residents would be expected to migrate into Berrien County as a result of D. C. Cook's license renewal term, 15 of whom would live in Bridgman/Lake Township (Table C.28). That would represent less than 0.1 percent of Berrien County's projected population of 186,626 in 2015 and 0.3 percent of Bridgman/Lake Township's population of 4548 in 2015 (NUREG/CR-2749, pp. vol. 4, 88–113).

C.4.2.2 Housing

The following sections examine the housing impacts that occurred in Bridgman, Lake Township, and Berrien County during construction and operation of D. C. Cook Nuclear Plant and predict housing impacts that would result from refurbishment activities and continued operation. Possible impacts to housing include changes in the number of housing units, particularly the rate of growth of the housing stock; changes in occupancy rates; changes in the characteristics of the housing stock; and changes in rental rates or property values.

Section C.4.1.2 includes a complete discussion of methodology and assumptions used to predict housing impacts.

C.4.2.2.1 Impacts from Plant Construction and Operation

The following discussion begins with a description of the housing market at the time of D. C. Cook's construction and details project-related housing demand in the study area. A discussion follows of changes that occurred in the housing market and impacts on housing induced by plant construction. Finally, impacts from the operation of D. C. Cook on local housing are assessed.

During plant construction, 1969 through 1978, 10,073 new housing units were built in Berrien County (based on the number of permits issued), approximately 1090 of which were subsidized housing units (NUREG/CR-2749, vol. 4). Of these new units, 320 were in Bridgman and 146 were in Lake Township. This represents a 16.9 percent increase in the 1970 housing stock. For comparison, in the 1960s and 1950s, respectively, 11,720 and 11,165 housing units were constructed in Berrien County (NUREG/CR-2749, vol. 4). Fewer new housing units were added to the housing stock during the construction period than in the two previous decades.

Project-related demand for housing in Berrien County and the study area has been estimated according to the number of plant construction workers who moved to the area (NUREG/CR-2749, vol. 4). In 1972, project-related work force peaked at 2377, while commensurate housing demand peaked at 902 and 81 units, respectively, in Berrien County and the study area. Housing starts during 1969, 1970, and 1971 were over 3000 (2510 excluding subsidized units) for Berrien County and 87 for the study area. Vacancy rates in Berrien County, of units either for sale or for rent, were 2.2 percent in 1960, 2.8 percent in 1970, and 10.3 percent in 1975. Homeowner vacancy rates went from 1.3 percent in 1970 to 1.4 percent in 1974, whereas rental vacancy rates fell from 7.1 percent in 1970 to 5.6 percent in 1974. (The discrepancy between 1974 and 1975 vacancy rates is consistent with a decline in project-related demand for housing.) This demonstrates that the housing stock was expanding faster than project-related demand.

During the project construction period, a substantial number of multifamily units were built in Bridgman and Berrien County. There were 230 multifamily units built in Bridgman in the period from 1969 through 1978—70 percent of all units constructed. In Berrien County, 4460, or 44.3 percent, of all units constructed during this period were multifamily units. This contrasts with 1970 census figures that report that 21.3 percent of the year-round units in Bridgman and 18.7 percent of the year-round units in Berrien County were multifamily units. Lake Township did not experience a great increase in the number of multiunit structures. The in-migration of project-related workers either induced or accelerated the construction of apartment buildings. Another source of housing during the plant construction period was mobile homes. However, local ordinances of Bridgman and Lake Township prohibited the establishment of mobile home parks. Because of poor land drainage, septic tanks required large areas of land. However, in the neighboring Baroda and Lincoln Townships, mobile home parks were built or expanded and accommodated many project-related residents.

Property values have changed little as a result of the D. C. Cook plant. Between 1970 and 1980, comparable increases in the median value of houses occurred in Berrien County and the state of Michigan (U.S. Bureau of the Census 1978, 1988). The median value of houses in Bridgman increased 146 percent between 1970 and 1980, whereas the value increased 126 percent and 122 percent in Berrien County and Michigan, respectively. Property values in the study area have increased more because of the public water and sewer system and because of high prices paid by seasonal residents for lakefront property than because of the plant's presence. During construction of the D. C. Cook plant, the Bridgman area had a lower average selling price for residential units than did the neighboring areas of St. Joseph and Lincoln Township (NUREG/CR-2749, vol. 4). Rental rates increased between 1970 and 1980 by 126 percent in Bridgman and by 154 percent in Michigan (U.S. Bureau of the Census 1972, 1982).

In summary, peak project-related demand for housing in the study area and Berrien County and Bridgman/Lake Township was 6.6 percent and 1.8 percent, respectively, above the existing 1970 housing stock. This demand may have brought on or hastened construction of apartments in the area and increased the occupancy rates of short-term rental units, but the large pool of available housing within the county meant there was little or no impact on property and rental values.

C.4.2.2.2 Predicted Impacts of License Renewal

Project-related population increase and the commensurate housing demand would bring about the new housing-related impacts during refurbishment activities. A summary of recent and anticipated growth in housing is provided. This is followed by predictions of possible impacts during refurbishment and the license renewal term.

Between 1980 and 1990, the number of housing units in Berrien County increased 1.1 percent (U.S. Bureau of the Census 1988, 1990). If this growth rate remains constant, there may be about 71,500 housing units in Berrien County in 2014.

Population projections for Berrien County in 2015 estimate a county population of 186,626. Based on the average household size of 2.6 persons (U.S. Bureau of the

Census 1990), this is the equivalent of 71,779 households. Although adjustment in housing growth will be made according to population growth, the current rate of growth suggests that housing availability will be limited in the study area during refurbishment activities.

According to the estimate of the number of workers required for plant refurbishment and based on plant construction experience, 830 workers of the projected work force of 2273 are expected to migrate to Berrien County for refurbishment jobs; 68 of these would locate in Bridgman/Lake Township. Of these in-migrants, 415 are expected to be accompanied by families. Some doubling-up is expected to occur among the 415 unaccompanied workers, so that each unaccompanied mover would require 0.85 housing unit. In-migration of these workers to Berrien County would result in a total refurbishment-related housing demand in the peak year of refurbishment of 768 housing units. In addition, numerous indirect jobs are expected to result from the spending of refurbishment workers. An additional 43 workers are projected to move to Berrien County, bringing the total project-related housing demand in the peak year of refurbishment to 811 units.

Refurbishment-related housing demand is less than the original construction-related housing demand of 902 units, and the number of housing units in Berrien County will have increased about 25 percent between peak construction and refurbishment periods. Refurbishment-related housing demand would account for 1.1 percent of the possible 71,500 housing units in the study area in 2014. However, based on the current housing growth rate there remains the possibility that availability will only slightly exceed non-refurbishment-related housing demand. Therefore, even a 1.1 percent increase in demand may result in moderate impacts to housing during refurbishment. If the growth rate accelerates only slightly to 2 percent per 10 years (a very low rate compared to state and national averages), sufficient housing should be available in Berrien County, and only small impacts would occur.

Housing impacts related to housing value and marketability that would occur during the license renewal term are the same as those that have occurred during current plant operation (Section C.4.2.2.1). As during current operations, housing values would not be affected in the license renewal term. The 120 additional operations workers (60 per unit) required during the license renewal term and the commensurate housing demand would cause only small new housing impacts.

C.4.2.3 Taxes

C.4.2.3.1 Impacts from Plant Construction and Operation

The D. C. Cook plant had an important effect on taxes during construction and operation. As the state equalized value (SEV) of the D. C. Cook plant increased during construction, it became the predominant source of funds in Lake Township and the Bridgman Public School District. It also became the largest single SEV property for Berrien County.

The jurisdictions that tax the D. C. Cook Nuclear Plant are the state of Michigan, Berrien County, Lake Township, and the Bridgman Public School District. Although the city of Bridgman does not tax the D. C. Cook plant, it is within the Bridgman Public School District, so the total property tax bill of city residents is affected by the school district. The revenues for Berrien County shown in Table C.29 have been adjusted by the GNP implicit price index to 1988 dollars so that amounts can be compared without being distorted by inflation. Data are included for 1967, the year before plant construction; 1972, the peak year of construction; 1978, the first year in which both units were operating; and 1988, the most recent year for which data are available. Note that from 1967 until 1988, the price index changed by greater than a factor of 3.

Table C.30 presents the assessed valuation of the D. C. Cook plant as a percentage of the total assessed valuation of each taxing jurisdiction. Note that D. C. Cook's contribution to the local tax base increased rapidly during construction. D. C. Cook's share of the total assessed value of the three local tax jurisdictions has continued to increase since commercial operation began.

The large assessed value of D. C. Cook resulted in two effects on local government—lower tax burdens and better public services. These effects were limited, primarily occurring within Lake Township and the Bridgman School District but to a lesser extent in Berrien County. Because the value of the nuclear plant and equipment was so large relative to the total assessed value, property tax rates yielded very high revenues per resident in these taxing jurisdictions. This resulted in millage rates much lower than otherwise required for the level of services provided. For instance, the Bridgman School District levies about one-fourth of average property tax rate (millage) for all Michigan school districts. At the same time, its expenditures are about twice the Michigan average per pupil ($7000 vs $3500). Average teacher salaries are considerably higher than the state average, and the school district has built a swimming pool, an unusual occurrence for a school district that has only 850 pupils for grades kindergarten through 12. Lake Township has a more limited ability to levy property tax. However, it does have its own water supply and participates in a sewer system. These services are unusual for a township and can be attributed to the large value of the D. C. Cook plant. The levies for sewer and water systems would be 10 times as high without D. C. Cook in the tax base.

In both Lake Township and the Bridgman School District, revenues from property tax increased as a source of total revenues from about 50 percent before construction began on D. C. Cook to more than 90 percent. There was a large real increase in the total revenues. Bridgman School District revenues increased by more than four times, going from approximately $1.2 million in 1967, to $4.2 million in 1978, to $5.5 million in 1988. Lake Township revenues increased from about $137,000 in 1968 to $1.4 million in 1978 (NUREG/CR-2749, vol. 4) and $3.2 million in 1989.

Berrien County revenues from property taxes have doubled between 1967 and 1988. However, much less of this increase can be attributed to D. C. Cook than in the case of Lake Township and Bridgman School District. Property taxes as a percentage of total revenues have fluctuated considerably in Berrien County (Table C.29).

The total current property tax millage levied on D. C. Cook is slightly over 24 mills. D. C. Cook's contribution to taxes is most important within the school district, which levies about 8.4 mills on the SEV. Berrien County levies about 5.4 mills for its general fund. No other levy is more than 3 mills. Table C.31 presents the most recent millage rates that apply to D. C. Cook's most recent SEV of $532 million and the revenues provided by D. C. Cook to various county and subcounty jurisdictions. D. C. Cook provided 14 percent of Berrien County's $20.3 million revenues in 1989, 88 percent of Lake Township's $3.2 million revenues, and 81 percent of the Bridgman School District's $5.5 million revenues.

In general, the Bridgman School District and Lake Township are quite dependent on revenues from the D. C. Cook plant. The school district has low tax rates and excellent facilities as a result of the plant. It receives almost no aid from the state of Michigan because of its high valuation per pupil. Lake Township receives much higher than average property tax revenues per resident. As a result, it can provide more and better township services, including water and sewer services.

Revenues from D. C. Cook have had a noticeable impact for Berrien County and a significant impact for the school district and Lake Township, which have a much smaller total tax base and much smaller populations.

C.4.2.3.2 Predicted Impacts of License Renewal

The new tax-related impact expected to occur during refurbishment of D. C. Cook results from capital improvements undertaken during the current term outages. The assessed value of the plant would increase during this time, thus increasing D. C. Cook's tax payments to local jurisdictions. This new impact does not involve capital improvements that take place7 during the final refurbishment outage and that would be reflected in the plant's assessed value during the license renewal term. The magnitude of the new impact depends on which improvements would occur at D. C. Cook early on and which would be done during the final outage. For example, if the steam generator is replaced during a current term outage, the assessed value may increase considerably before the license renewal term begins. If steam generator replacement and other major capital improvements are not undertaken early on, the increase in assessed valuation may be only minor. The increase, in either case, is expected to cause only an small to moderate new tax impact.

During the license renewal term, the tax-related impact primarily would be the continuation of tax payments D. C. Cook is currently making to local jurisdictions. D. C. Cook currently provides 14 percent of Berrien County's revenues, 86 percent of Lake Township's, and 80 percent of Bridgman School District's. A new impact would also result from the increase in tax payments because of improvements made at D. C. Cook during the final refurbishment period. Thus, tax revenues would increase in absolute terms but may remain constant or increase as a percentage of total revenues of the taxing jurisdictions. The assessed valuation may continue to increase slightly throughout the license renewal term because it is based partly on replacement costs. Based on current conditions, D. C. Cook tax revenues—the continuing and additional payments combined—are expected to continue to make up a large share of the total revenues in the smaller taxing jurisdictions of Lake Township and Bridgman School District and a noticeable share of revenue in Berrien County. During the license renewal term, tax-related impacts would continue to be large in Lake Township and Bridgman School District.

C.4.2.4 Public Services

C.4.2.4.1 Impacts from Plant Construction and Operation

Before the construction of the D. C. Cook plant, the majority of public services in the study area were provided by Berrien County. Lake Township and the city of Bridgman, which provided some limited services, have benefitted most from the D. C. Cook plant because of the amount and distribution of the plant's property tax payments. For example, per capita public service expenditures nearly doubled between 1967 and 1978. Since operations at D. C. Cook began, existing facilities have been upgraded in the area and new ones have been built.

Because Berrien County and the city of Bridgman do not receive direct property tax benefits from the plant, they have not realized the same positive economic impacts as Lake Township and the Bridgman School District. Information pertaining to expenditures is discussed in detail in Section C.4.2.3.

Education

The D. C. Cook plant's construction labor force had only a minor impact on enrollment in the Bridgman School District, as total enrollment increased from 774 in 1968 to 788 in 1972, the year of peak construction. Annual enrollment continued to increase for several years during construction and operations. However, the total enrollment increase of 114 students from 1968 to 1978 indicates that the plant's construction and operations work forces have not affected the demand for educational services in the Bridgman School District (NUREG/CR-2749, vol. 4, p. 161).

The D. C. Cook plant has had a positive impact on the availability of funds for educational services and facilities in the school district. Before the construction of the D. C. Cook plant, approximately 40 percent of the district's revenues came from state funding; by 1978, state funds made up only 3.6 percent of the district's revenues. Currently, the state of Michigan does not contribute funds to the Bridgman School District because the district's expenditure per student is $7000, twice the average for the state (NUREG/CR-2749, vol. 4, pp. 163–164). Funds from the D. C. Cook plant's tax contributions allowed the construction of school facilities and a swimming pool, an increase in per student expenditures, and a reduction in the student-staff ratio from 19 to 1 in 1969 to 9 to 1 in 1978 (NUREG/CR-2749, vol. 4, p. 164).

Local officials mentioned the quality of the Bridgman School District's curriculum and facilities as a source of community pride and a factor that has attracted home buyers.

Transportation

Transportation has been affected by the D. C. Cook plant in varying ways. During construction, the increase in traffic was substantial, as it has been with operations. The most heavily affected areas were county roads in the vicinity of the plant. Most of the problem was alleviated by installing a traffic light at the intersection of the plant's access road and Red Arrow Highway. Traffic has also been affected moderately in Bridgman, but impacts have not caused increases in the demand for city road maintenance.

Bridgman, which does not collect revenues directly from the plant, made improvements in its road system between 1968 and 1978, but it did so with monies from the state motor vehicle highway fund, not from revenues of the D. C. Cook plant (NUREG/CR-2749, vol. 4, p. 167). Berrien County's Road Commission is responsible for the maintenance of county roads and contracts to provide road maintenance and repair for Lake Township. The county also contracts with the city of Bridgman to maintain its portion of the Red Arrow Highway. Local highway officials "thought that the construction and operation of the project did not have a substantial effect" on highway maintenance or repair in Berrien County, although the increased traffic was substantial (NUREG/CR-2749, vol. 4, p. 166).

In Lake Township, however, some major road improvements have been undertaken. Plant-related revenues helped finance the upgrades (NUREG/CR-2749, vol. 4, p. 167), which were made even though the D. C. Cook plant did not create additional needs in terms of road maintenance. These improvements amount to a positive economic impact of the D. C. Cook plant.

Public Safety

Construction, operations, and refurbishments at the D. C. Cook plant have had insignificant impacts on the demand for public safety. However, the fiscal impacts on public safety have been positive. Police, fire, and rescue units in the area all grew and improved after the plant's construction began (NUREG/CR-2749, vol. 4, pp. 170–171).

When construction began, the Berrien County Sheriff's Department contracted to provide police protection for Lake Township. During D. C. Cook's construction, Lake Township worked with Baroda Township to create a joint police department with three officers and one elected constable. However, this increase was not related to any increased demand for police services caused by the plant, and no taxes from D. C. Cook were specifically marked for police services. Like the Lake/Baroda Department, the county sheriff's department's services have not been affected by the plant's presence, as no changes in demand have been attributed to the D. C. Cook project.

Similarly, in Bridgman the plant did not affect demand for services or availability of revenues related to the expansion. Between 1967 and 1978, the Bridgman Police Department expanded from one part-time and one full-time officer to four full-time officers. In addition, the police department began to offer 24-hour service in 1977.

Bridgman's expenditures for fire and ambulance services doubled (in constant 1972 dollars) between 1967 and 1978. By 1978, the Bridgman Fire Department was manned by 16 part-time firefighters. The city also participated with Lake Township and the city of Baroda in providing emergency rescue service. Similarly, the property tax contributions from the D. C. Cook plant probably provided for a great percentage of the cost of upgrading the emergency rescue service operated jointly by Bridgman, Baroda, and Lake Township. Other than the participation of members of the Bridgman Fire Department in training at the D. C. Cook plant, there is no indication that the plant's presence has affected the demand for or provision of the city of Bridgman Fire Department or emergency rescue services.

By the time D. C. Cook was completed in 1978, the Lake Township Fire Department was manned by 17 part-time firefighters. The township had just purchased two new fire trucks, upgraded the fire department's communications system, and installed hydrants throughout the township. Although the additional funds Lake Township derived from the D. C. Cook plant helped fund its purchases for fire-fighting improvements, the actual impact of the plant is not clear because it would be impossible to accurately measure the plant's influence.

The D. C. Cook plant's construction and operations have had no effects on demand or the availability of funds for civil defense and emergency preparedness in Berrien County.

Social Services

During construction and operations, the Berrien County Department of Social Services administered social programs in the study area. Because no property tax revenue was allocated for this department, there was no notable impact on social services during either the construction or operation periods because of increased tax revenues (NUREG/CR-2749, vol. 4, pp. 172). Also, no impacts were reported from project-related personnel.

Public Utilities

The director of the County Planning Commission and of the County Department of Public Works reported that the construction and operations of the D. C. Cook plant have had no direct effect on the county's public services. Tax revenues have supported the provision of a number of services and amenities, however. These include the township's water and sewer system and copper-roofed Township Hall.

In the late 1960s, the township had no water system, so residents relied on individual wells. The local geology also created problems in terms of quality, quantity, and location of water. A system was in demand. This desire was strengthened in 1969 when a large firm expressed interest in locating a plant in Bridgman or Lake Township but indicated that its location decision was dependent on the availability of public water (NUREG/CR-2749, vol. 4, p. 173).

Lake Township has now installed an $8.5 million water system, financing it through a bond issue. Although the water system was not built because of added demands created by the D. C. Cook plant or its employees, the availability of property tax revenues from the plant "made feasible the financing of the project" (NUREG/CR-2749, vol. 4, p. 173). The Lake Township supervisor confirmed this, stating that if the plant had not been located there, public water or sewers would have been unavailable in the township (Wasko 1990). This substantially improved the availability of a public service but had relatively low costs to the average resident of the township (NUREG/CR-2749, vol. 4, p. 173).

The D. C. Cook plant continues to have positive effects on the township. The Lake Township supervisor reported that the township recently made a $4.5 million expansion to the water plant. The township sold bonds to finance the expansion and will repay the debt with revenue earned from selling surplus water to neighboring jurisdictions. He also stated that the D. C. Cook plant's presence did not require an expansion but that extra millage from the plant enabled the township to expand the system and sell water. The upgrade has increased the plant's output from 7600 to 23,000 m^3 (2 million to 6 million gallons) of water per day (Wasko 1990).

Recreation and Tourism

The construction and operation of the D. C. Cook plant have had positive effects on recreation and tourism in Berrien County. The plant is located in an area that attracts tourism because of its natural beauty and proximity to Interstate 94 between Chicago and Detroit. Many tourists visit the D. C. Cook plant's Energy Information Center, which provides information on nuclear energy and technology and offers an auditorium, a canteen, and a picnic pavilion overlooking Lake Michigan. Key information sources indicated that the center is one of the county's top tourist attractions, hosting over 740,000 registered visitors between 1970 and 1979. Some visitors, such as school groups, come from as far away as Chicago and Grand Rapids to visit D. C. Cook's Energy Information Center. But the center is also popular with local area residents, and its auditorium is frequently used for community events such as arts and crafts shows. Key local informants agreed that the D. C. Cook plant has had positive impacts on tourism and recreation in Berrien County (NUREG/CR-2749, vol. 4, p. 28).

C.4.2.4.2 Predicted Impacts of License Renewal

Based on the estimated 2273 direct workers required during peak refurbishment, the staff estimated that 415 direct workers and 26 indirect workers will migrate with their families to Berrien County (Section C.4.2.1.2). The number of children accompanying these workers is estimated using the Michigan average family size (3.16) and assuming that all families include two adults. Children are expected to be evenly distributed in age from ≤1 to 18 years. Assuming 72.2 percent of these children are school age (5 to 18 years), there will be an average of 0.84 school-age children per in-migrating family, or a total of 370 new students in Berrien County. This represents a 1.0 percent increase above the projected number of school-age children in Berrien County in 2015 (assuming the 1990 age distribution of the population). This slight increase will result only in small impacts to education.

During the construction of D. C. Cook, there were insignificant increases in demands for social services, public utilities, and public safety. Because refurbishment would bring in fewer people (1825) than the initial construction (2193) and the population in the study area in 2015 would be larger, any impacts on these public services would be small.

The fact that the Lake Township/Bridgman area will be better able to provide public service for future population growth reflects one of the D. C. Cook plant's indirect impacts on public service in the study area. In the past, the Lake Township/Bridgman area has been able to expand and upgrade its public service programs and facilities because of the plant's contribution to the jurisdictions' property tax base. This would continue with license renewal, and the overall economic benefits the Lake Township/Bridgman area would accrue with the plant's continued operations. This could change, however, if Michigan state laws were revised to require distribution of taxes on the plant throughout the entire state.

Transportation experienced small to moderate impacts during the construction of D. C. Cook. The refurbishment work force would be less than it was during construction, leading toward smaller impacts, but a continuation of impacts associated with past operations coupled with the additional refurbishment-induced impacts could create moderate future impacts.

Based on past operations, impacts of future operations on public services are expected to be small except for transportation impacts, which would range from small to moderate. The positive small impacts to recreation and tourism will continue.

C.4.2.5 Off-Site Land Use

This section describes the off-site land-use impacts of the construction, operation, and license renewal of the D. C. Cook Nuclear Plant. The discussion of impacts is primarily concerned with land use in the immediate vicinity of the plant, but impacts for the remainder of Berrien County are described where appropriate. Land-use impacts are examined for two time periods. First, Section C.4.2.5.1 identifies the land-use impacts of D. C. Cook's construction and operation. Next, Section C.4.2.5.2 projects the land-use impacts of D. C. Cook's refurbishment period based on the impacts that occurred during the plant's construction. Also, Section C.4.2.5.2 projects the land-use impacts of the plant's license renewal term based on the impacts that have occurred during operations. Information sources for this report include the *Final Environmental Statement Related to the Operation of Donald C. Cook Nuclear Plant, Units 1 and 2* (AEC Dockets 50-315 and 50-316); *Socioeconomic Impacts of Nuclear Generating Stations: D. C. Cook Case Study* (NUREG/CR-2749, vol. 4); and interviews with key information sources in Berrien County. Section C.4.1.5 describes the methods used to assess and project land-use impacts for all case study plants.

C.4.2.5.1 Impacts from Plant Construction and Operation

The 260-ha (650-acre) site upon which the D. C. Cook plant is located includes 1326 m (4350 ft) of beach property on the eastern shore of Lake Michigan near Bridgman. The plant is situated in a waterfront area known for its geologically and ecologically unique wooded sand dunes. At the time construction began in 1968, the D. C. Cook property was bounded by a residential area to the north, the Red Arrow Highway to the east, land that was zoned for agricultural use to the south, and Lake Michigan to the west. The general area in which the plant is located was used primarily as agricultural land, with no large-scale development in the immediate vicinity of the plant site.

The construction of the D. C. Cook plant had an immediate direct impact on shoreline land use in Berrien County. Because the plant site had to be rezoned before construction could begin, it became the first lakeshore property zoned for industrial use within Lake Township. Thus, the construction of the D. C. Cook plant started the industrialization of the previously undeveloped lakefront dune area (AEC Dockets 50-315 and 50-316).

Overall, however, the construction and operation of the D. C. Cook plant have not had significant direct impacts on land use in the plant's immediate vicinity or in Berrien County. Population increases resulting from the plant's construction and operation have been relatively small and have not created significant changes in local land use or residential development patterns. Before the plant's construction, the adjacent lands to the north and south were developing as residential-use areas along the lakeshore, and the plant's construction and operation has neither impeded nor encouraged that development. Residential land-use is well established in the Rosemary Beach area north of the plant, with a combination of new houses and older second-home cottages. In the Livingston Hills and Wildwood Dunes areas south of the plant, residential development has continued throughout D. C. Cook's operations period. Many of the residences south of the plant in Livingston Hills are refurbished second-home cottages, but most of the development in Wildwood Dunes has been made up of new, relatively expensive homes. To the east of the D. C. Cook property, between Red Arrow Highway and Jericho Road, there is a mixture of light industrial and commercial land uses. Much of this land was rezoned from agricultural to industrial in 1984, and a few industries have located there. However, key sources said that the D. C. Cook plant had neither positive nor negative direct impacts in terms of recruiting industrial development to Berrien County. In general, key informants indicated that the land in the immediate vicinity of the D. C. Cook plant had good development potential for residential and light industrial uses and that the plant's presence had only neutral direct impacts on such development.

The D. C. Cook plant has had moderate indirect impacts on land use around the plant and in other parts of Berrien County. Key sources cited Lake Township's 1984 decision to rezone land east of the plant (an area on both sides of Livingston Road, between Jericho Road and Red Arrow Highway) to industrial use as an example. The rezoning was not solely because of the D. C. Cook plant's presence, but the plant was a factor in the decision. Also, because it receives the benefits of the D. C. Cook plant's property tax payments, Lake Township has been able to extend its water and sewer services to almost all parts of the township. According to key informants, the provision of water and sewer services has helped guide residential development in the township. The water and sewer system also has been an impetus to industrial land use, as was the case in siting the Hoover-Ugine plant in Lake Township in the early 1970s. In addition, the Bridgman School District's above-average curriculum and facilities, which would not have been possible without the D. C. Cook plant's tax contributions, are said to have helped encourage residential land use in Lake Township.

C.4.2.5.2 Predicted Impacts of License Renewal

The land-use impacts of the D. C. Cook plant's refurbishment in the immediate vicinity of the plant and in Berrien County are expected to be small. Refurbishment-related population growth is predicted to represent approximately 3.1 percent of Bridgman/Lake Township's projected population in 2015 and approximately 1.0 percent of Berrien County's projected population in 2015. Increases of this size would result in minimal new impacts to land-use and development patterns, especially when compared to those driven by the peak construction-related growth in 1972.

The indirect impacts of D. C. Cook's license renewal term are expected to be greater than the direct impacts of refurbishment. Population growth associated with D. C. Cook's license renewal term is projected to represent only 0.3 percent and less than 0.1 percent of Bridgman/Lake Township's and Berrien County's respective populations in 2015, so new population-driven land-use impacts are expected to be small. However, moderate indirect impacts might continue as a result of the benefits Lake Township and the Bridgman School District receive from the plant's property tax payments. Sewer and water system improvements and expansion, lower property taxes, and improved educational services and facilities are all likely to continue guiding land-use and development patterns in the future, as they have during D. C. Cook's operation thus far.

The D. C. Cook plant's license renewal is not expected to attract or discourage new residential or commercial development directly. Key sources agree that some areas south of the plant, particularly the Wildwood Dunes area, would continue to develop residentially. Certain areas along Jericho Road also are likely to develop as residential-use properties because water and sewer lines are in place and because the area has not been heavily developed. Light industrial development is expected to continue in the area zoned for industrial use just east of the D. C. Cook plant, and continued commercial development is expected along the Red Arrow Highway. As during the D. C. Cook plant's construction and operation, the plant's refurbishment and license renewal are not likely to have large impacts on land use or development.

C.4.2.6 Economic Structure

C.4.2.6.1 Impacts from Plant Construction and Operation

The construction and operation of the D. C. Cook plant have resulted in direct and indirect jobs and income for Berrien County and Bridgman/Lake Township (Table C.32). It is estimated that, in 1972, approximately 137 Bridgman/Lake Township residents were employed directly or indirectly as a result of the project (NUREG/CR-2749, vol. 4). These residents earned an estimated income of $6.3 million (1989 dollars). For all of Berrien County, construction employment represented 2569 jobs and $90 million in income for residents. These figures represented about 8.8 percent of Bridgman/Lake Township's total employment (noticeable impact) and 3.6 percent of Berrien County's total employment (insignificant impact). This income represented 5.3 percent of Berrien County's total income. (*Note:* No data exist on total income for Bridgman/Lake Township.)

In 1978, the plant created an estimated 90 jobs for Bridgman/Lake Township residents and 854 for Berrien County residents. This represented about 4.7 percent of total employment in Bridgman/Lake Township and 1.1 percent of total employment in Berrien County, resulting in insignificant impacts to both areas. In 1978, income from the plant was about $24 million for Berrien County, or 1.4 percent of total income (NUREG/CR-2749, vol. 4).

The income and employment reported in Table C.32 were directly linked to the construction and operation of the D. C. Cook plant. Employment includes (1) persons who already lived in Bridgman/Lake Township or Berrien County and who were hired to work at the plant and (2) persons who moved into the area to gain employment. Additional income and jobs were generated through wages and salaries, as employees spent part of their incomes in Berrien County.

C.4.2.6.2 Predicted Impacts of License Renewal

The impacts of refurbishment and license renewal are expected to be similar in type to the impacts of initial construction and operation. Employment generated by the D. C. Cook plant after license renewal would, for the most part, represent a continuation of the levels generated before refurbishment.

The work force scenario detailed in Section C.3.1 was used to estimate the employment effects of refurbishment at

D. C. Cook. Table C.33 shows the total direct and indirect plant-related employment of residents in Bridgman/Lake Township and Berrien County during refurbishment. Rows 4 and 6 of Table C.33 give the percentage of employment and income, respectively, for Bridgman/Lake Township (column 1) and Berrien County (column 2).

It is projected that D. C. Cook would employ 1500 county residents as refurbishment workers in 2014 (Section C.4.2.1.2). Indirect employment that would result from purchases of goods and services during refurbishment is projected to create 790 additional jobs for Berrien County residents.

The total direct and indirect employment affecting Berrien County during the peak refurbishment year is therefore projected to be 2290. This employment is projected to be 3.3 percent of the total Berrien County work force in 2014, resulting in small impacts.

There would be a moderate employment impact on the Bridgman/Lake Township area assuming the refurbishment work force scenario. The projected number of Bridgman/Lake Township residents employed in plant-related jobs in 2014 is 152. Of these workers, 123 would be conducting refurbishment activities and 23 would be in indirect jobs created by refurbishment. It is estimated that this would represent 7.5 percent of the employment generated in the Bridgman/Lake Township area.

Relatively few new plant-related jobs would be created at D. C. Cook during the license renewal term. Nearly all plant-related employment (and associated impacts) expected during that time period would represent a continuation of employment (and impacts) from past operations.

Table C.34 shows the impact of the increased labor requirements at D. C. Cook after 2014.

The license renewal term work force for D. C. Cook would require an estimated 120 additional employees (Section C.4.2.1.2). Of these additional employees, 96 are projected to be Berrien County residents. An estimated 41 indirect jobs would also be created because of the license renewal term, and 39 of the jobs are expected to be filled by Berrien County residents. With the continued effects of the plant's current employment and the additional employment to be created, total direct and indirect license renewal term employment is estimated to represent 1.8 percent of Berrien County employment in 2014. This would result in small impacts.

A greater impact would be felt by the Bridgman/Lake Township area because of license renewal term employment, as 13 of the 120 additional plant staff are projected to reside there. It is also estimated that one indirect job would be created in the area by the additional personnel. Total direct and indirect license renewal term employment in Bridgman/Lake Township is expected to represent 8.1 percent of total employment, resulting in moderate impacts.

C.4.2.7 Historic and Aesthetic Resources

This section describes the impacts that the construction and operation of the D. C. Cook Nuclear Plant have had on historic and aesthetic resources and projects the expected impacts of the plant's refurbishment and post-relicensing operations. Information sources include the *Final Environmental Statement Related to Operation of Donald C. Cook Nuclear Plant, Units 1 and 2* (AEC Dockets 50-315 and

50-316) and interviews with key information sources in Berrien County, Michigan.

C.4.2.7.1 Impacts from Plant Construction and Operation

The construction and operation of the D. C. Cook power plant have had insignificant impacts on historic resources in Berrien County. In the early 1970s, the state of Michigan liaison officer for historic preservation determined that "the construction of the station will not result in an adverse impact on the historic and archaeological resources of the state other than what may have occurred during the already completed construction work" (AEC Dockets 50-315 and 50-316, pp. II-24). The 1973 *Final Environmental Statement* concluded that the construction work had no impact on historical or archaeological resources and projected that the plant's operation also would have no impacts. Key local respondents agreed that the construction and operation of the D. C. Cook plant have not affected historic resources in Berrien County.

The D. C. Cook plant's construction and operation have also had insignificant impacts on aesthetic resources in Berrien County, although the impacts have been slightly more pronounced than those on historic resources. Because of the natural beauty of the lakefront area's geologically and ecologically distinctive wooded sand dunes, the D. C. Cook plant was designed with aesthetic compatibility as a high priority. In addition, the power plant was constructed among trees and high sand dunes so that it could not be seen from adjacent properties, and all of the plant's buildings (except for the reactor containment buildings) were painted to blend with the natural landscape. Key sources indicated that the plant is visible from Lake Michigan, but that it is not visible from Interstate 94 or from adjacent properties. The informants added that they had rarely heard anyone mention the plant in terms of its physical appearance, and that the impacts of its visual presence were neutral. Because of its remote siting and because the D. C. Cook station was designed and constructed to blend with the natural environment to the maximum extent possible, its aesthetic impacts have been minimal.

C.4.2.7.2 Predicted Impacts of License Renewal

The impacts of the D. C. Cook plant's refurbishment and post-relicensing operation on historic and aesthetic resources in Berrien County would likely be less pronounced than those that have occurred during construction and would be a continuation of the minor impacts from current operations. As in the past, the plant, which is not highly visible and is not near any historic sites, likely would have only small impacts. However, a determination of potential impacts to historic resources must be made through consultation with the SHPO.

C.4.3 Diablo Canyon

The impact area—those places where the most pronounced socioeconomic impacts might result from refurbishment and license renewal—for Diablo Canyon consists of San Luis Obispo County, California. Emphasis is placed on those jurisdictions within the county closest to the plant site, where many workers reside. These include Avila Beach, Pismo Beach, and the city of San Luis Obispo. The selection of this area is based on worker residence patterns, employment, expenditures, and tax payments relative to the surrounding region. Figure C.8 depicts

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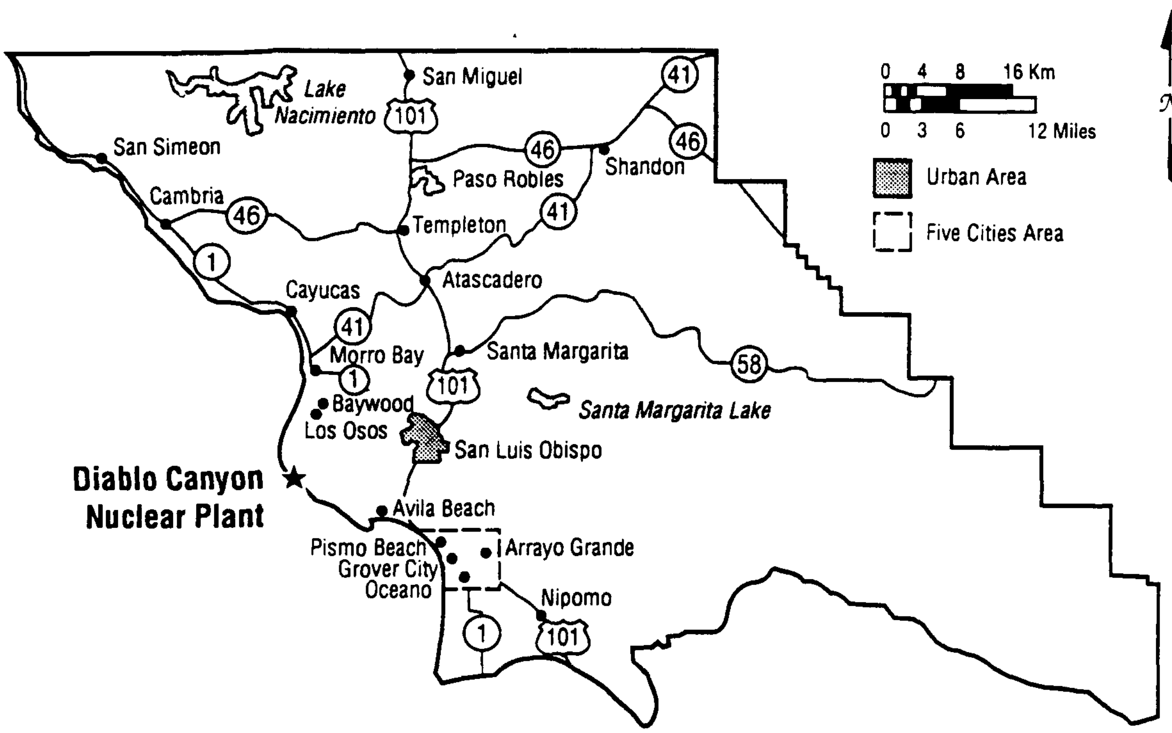

Figure C.8 Socioeconomic impact area associated with Diablo Canyon refurbishment: San Luis Obispo County.

the impact area, and Figure C.9 shows the region where it is located.

C.4.3.1 Population

This section discusses the local population growth associated with the construction, operation, and license renewal of the Diablo Canyon Nuclear Generating Station. Section C.4.1 describes the methodology used to project population growth for all plants. Data used to prepare this section were obtained from *Socioeconomic Impacts of Nuclear Generating Stations: Diablo Canyon Case Study* (NUREG/CR-2749, vol. 5); *Environmental Assessment Proposed Rule for Nuclear Plant License Renewal* (NUREG-1398); SEA refurbishment work force estimates (Appendix B; SEA 1994); population projections by the California Department of Finance (Demographic Research Unit); and the Pacific Gas and Electric Company (PG&E).

The discussion of population growth is organized into two time periods. Section C.4.3.1.1 identifies the population growth that San Luis Obispo County experienced as a result of the construction and operation of Diablo Canyon from 1969 to 1990. Section C.4.3.1.2 projects the population growth that is expected to result from Diablo Canyon's refurbishment period and license renewal term operations beginning in 2024 (Unit 1) based on the growth associated with the plant's initial construction. Also, Section C.4.3.1.2 projects the population growth expected to result from Diablo Canyon's license renewal term based on the growth associated with operations in the past.

C.4.3.1.1 Growth Resulting from Plant Construction and Operation

Diablo Canyon's construction resulted in noticeable population increases in San Luis Obispo County (Table C.35). During the peak construction year, 1975, Diablo Canyon personnel and their families who migrated to the area to work at the plant and others who moved into the area to work in jobs generated by the plant's presence totalled approximately 3308 persons. This influx of new residents represented 2.6 percent of San Luis Obispo County's total population in 1975 (NUREG/CR-2749, vol. 5, p. 89).

Operations at the Diablo Canyon plant have resulted in smaller population increases than did the plant's construction. In 1990, 1300 permanent plant staff were on-site at Diablo Canyon (additional contract workers were on-site during an outage, but these workers have not been included because their presence at the plant was temporary). Of the permanent work force, approximately 89.2 percent (1160) reside in San Luis Obispo County (PG&E 1990). Because Diablo Canyon is located in a relatively rural area, based on residential settlement patterns of the plant's 1975 work force, it is estimated that approximately 30 percent (348) of those residing in San Luis Obispo County in 1990 were prior residents who obtained jobs and that 70 percent (812) were workers who migrated into the area for jobs. Based on experience during operations at other nuclear plants, it is estimated that approximately 66 percent of the 1990 in-migrants (536) were accompanied by their families. Assuming the 1990 California household size of 3.32 persons, this represents a total in-migration of 2056 new residents for the county (Table C.36). Based on work force in-migration and the ratio of nonplant jobs created at other nuclear plants during operating periods, Diablo Canyon's

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Figure C.9 Region surrounding the Diablo Canyon nuclear plant.

1990 operations created an additional 832 indirect jobs in service industries supported by the spending of Diablo Canyon workers. As a result of these indirect jobs, an estimated 37 additional workers and their families (a total of 93 persons) moved into San Luis Obispo County (Table C.36). In all, approximately 2149 new residents moved into San Luis Obispo County as a result of Diablo Canyon's 1990 operations. These new residents made up about 1.0 percent of San Luis Obispo County's 1990 population of 217,162 (U.S. Bureau of the Census 1990).

C.4.3.1.2 Predicted Growth Resulting from License Renewal

As discussed in Section C.3.1, Diablo Canyon's license renewal would require the completion of a number of refurbishment tasks for Units 1 and 2. Many of the refurbishment tasks are expected to be completed during scheduled refueling outages at each unit during the 10 years that precede the expiration of the initial operating license. However, the final refurbishment work is expected to be completed during one large refurbishment outage scheduled for each unit in the year before the unit's initial operating license expires. Because the final refurbishment outage would involve more workers on-site over a longer period of time than any of the preceding refueling outages, it represents the peak refurbishment period. For other assumptions concerning the refurbishment work force, refer to Section C.3.1 and Section C.4.1.1.2.

Assuming the refurbishment schedule as described in Section C.3.1, the peak refurbishment year for Diablo Canyon Unit 1 is expected to be 2023, and the peak refurbishment year for Unit 2 is expected to be 2024. For each unit, the on-site refurbishment work force would be about the same size, and the work force would be on-site for approximately the same period of time (refer to Section C.4.1.1.2 for other work force assumptions). However, because uncertainties exist concerning the length of the outage and the size of the work force required to complete the refurbishment of a given unit, this section examines a bounding case work force scenario as described in Section C.3.1.

Given the work force scenario detailed in Section C.3.1, it is estimated that 2273 workers would be on-site to complete refurbishment of Diablo Canyon Unit 1 in 2023 and Unit 2 in 2024 (SEA 1994). Further assuming that the residential distribution of refurbishment workers would be similar to that of the 1975 Diablo Canyon construction work force, it is estimated that 85 percent (1932) would reside in San Luis Obispo County. Based on plant-construction experience, it is projected that 531 (27.5 percent) of those residing in San Luis Obispo County would be prior residents who obtain refurbishment jobs and that 1401 (72.5 percent) would be workers who migrate into the area for refurbishment jobs (Table C.37). Also following the pattern set during plant construction, 61.7 percent of the in-migrants (864) would be accompanied by families. Using the California average family size of 3.32 persons, total refurbishment worker in-migration would result in 3405 new residents for the county. Based on the ratio of nonplant jobs created in San Luis Obispo County in 1975, Diablo Canyon's refurbishment is projected to create an additional 1455 indirect jobs in service industries supported by the spending of refurbishment workers. As a result of these indirect jobs, an estimated 68 additional workers and their families (a total of 226 persons) would be projected to move into San Luis Obispo County (Table C.37). In all, approximately 3631 new residents would be expected to move into San Luis Obispo County as a result of Diablo Canyon's refurbishment under the work force scenario. That would represent 0.8 percent of San Luis Obispo County's projected population of 445,180 in 2024 (NUREG/CR-2749, vol. 5, pp. 55–85).

Once plant refurbishment is completed for Diablo Canyon Units 1 and 2, the work force would consist mostly of permanent plant staff. Additional refurbishment/refueling workers would be temporarily on-site approximately every 2 years; however, they would not be permanent, on-site plant staff, and many of them are expected to commute from outside the study area. It is expected that a maximum of 60 additional permanent workers per unit would be required during the license renewal term, adding 120 workers to Diablo Canyon's existing work force. Assuming that the new workers' residential distribution would be the same as current workers', approximately 89.2 percent (107) would reside in San Luis Obispo County. Based on worker in-migration at nuclear plants in comparable locales and construction experience at Diablo Canyon, it is estimated that 32 (30 percent) of those residing in San Luis Obispo County would be prior residents who obtain jobs and that 75 (70 percent) would be workers who migrate into the area for jobs (Table C.38). Also, following the pattern set by personnel in-migrating to work at other nuclear plants, 66 percent of the in-migrants (50) would be accompanied by their families. Using the California average family size of 3.32 people, total in-migration would result in 191 new residents for the county. Based on work force in-migration and the ratio of nonplant jobs created at other nuclear plants during operating periods, Diablo Canyon's license renewal term is projected to create an additional 77 indirect jobs in service industries supported by the spending of plant workers. As a result of these indirect jobs, an estimated three additional workers and their families (a total of about eight persons) would be projected to move into San Luis Obispo County (Table C.38). In all, approximately 199 new residents would be expected to move into San Luis Obispo County as a result of Diablo Canyon's license renewal term. That would represent less than 0.1 percent of San Luis Obispo County's projected population in 2024.

C.4.3.2 Housing

The following sections examine the housing impacts that occurred in San Luis Obispo County during construction and operation of Diablo Canyon and predict housing impacts that would result from refurbishment activities and continued operation. Possible impacts to housing include changes in the number of housing units, particularly the rate of growth of the housing stock; changes in occupancy rates; changes in the characteristics of the housing stock; and changes in rental rates or property values.

Section C.4.1.2 includes a complete discussion of the methodology and assumptions used to predict housing impacts.

C.4.3.2.1 Impacts from Plant Construction and Operation

The following discussion begins with a description of the housing market at the time of Diablo Canyon's construction and details project-related housing demand in the study area. A discussion of changes that occurred in the housing market and impacts on housing induced by plant construction follows.

Construction at Diablo Canyon began in 1969 and continued through 1980. During this time, approximately 29,000 year-round units were added to San Luis Obispo's housing stock (U.S. Bureau of the Census 1982; NUREG/CR-2749, vol. 5), bringing the total number of year-round units in San Luis Obispo to 66,070. The new units represent very rapid growth, a full 77 percent increase in the 1970 housing stock. This rate of growth compares to a 32 percent increase in California between 1970 and 1980 (U.S. Bureau of the Census 1972, 1982) and a 28 percent increase in housing units in San Luis Obispo County during the intercensal 1960–1970 period (U.S. Bureau of the Census 1967, 1972). Areas within the county that experienced the greatest growth were the Baywood/Los Osos, area with a 167.6 percent increase in housing units between 1970 and 1978; Nipomo, with a 74.4 percent increase; Atascadero (and the surrounding area), with a 65.8 percent increase; and Arroyo Grande, with a 64.8 percent increase (NUREG/CR-2749, vol. 5). The 40.5 percent increase in housing units in the city of San Luis Obispo was relatively low during this period; however, the 4183 housing units added there represent the greatest increase in absolute number.

Several factors influenced this housing growth commensurate to the increase in population in the county. One factor was the expanding student population associated with California State Polytechnic University in the city of San Luis Obispo. During the 1970s, enrollment increased by more than 4000 students (Cass 1969, 1979). The need for housing suitable for the student population at least partly explains why both the percentage of rental units in the city of San Luis Obispo and the percentage of multifamily units increased between 1970 and 1980, from 37.9 to 46.5 percent and from 49.2 to 53.5 percent, respectively. The county, particularly the coastal communities, was also developing as a retirement community and popular tourist area. These factors, combined with the in-migration of Diablo Canyon construction workers, were the causes for the rapid growth that occurred in San Luis Obispo County.

Project-related housing demand in San Luis Obispo County peaked in 1975 at 1297 units when the construction work force was 2116 (NUREG/CR-2749, vol. 5). New housing units added to San Luis Obispo County housing stock between 1970 and 1975 totalled 9898 (NUREG/CR-2749, vol. 5). Based on a average of 2.7 persons per household (U.S. Bureau of the Census 1972), these new units could accommodate approximately 26,725 persons. The non-project-related population increase through 1975 was approximately 23,500 [derived by subtracting project-related population increase from 1976 population (NUREG/CR-2749, vol. 5)], requiring approximately 8703 housing units. The remaining 1195 new housing units are approximately 100 units less than the project-related demand for 1297. In 1970, 1040 housing units were vacant in San Luis Obispo County. These vacancies might have supplied the 100 units required for project-related demand not supplied by new construction. Nonetheless, the growing population and project-related demand resulted in a vacancy rate of approximately 2.5 percent.

Because of the limited availability of housing in the area, occupancy density increased, particularly in the Five Cities area of San Luis Obispo County, where approximately 48 percent of the construction workers resided (NUREG/CR-2749, vol. 5). The small hotels in the Five Cities area were filled with construction workers (Morrow 1990), as were most recreational vehicle parks. The combined pressures of increased population resulted in occasions when people slept in cars or lived in parks. Housing conversions that resulted from combined housing demand included garages that were rented as apartments and the rental of privately owned seasonal homes (NUREG/CR-2749, vol. 5).

Both the median value of owner-occupied units and the median contract rent increased dramatically during the construction of the Diablo Canyon plant. Between 1970 and 1980, median value and median rent increased 329 percent and 181 percent, respectively, in San Luis Obispo County. For comparison, in the state of California, median value and median rent increased 266 percent and 124 percent. Some local realtors and planners indicated that the demand for rental units associated with plant construction did have an effect on rental rates, but in the city of San Luis Obispo, the presence of Section 8 (government-subsidized) and non–Section 8 renters in the same properties kept rental rates from soaring even higher. Local realtors and developers attribute the increase in housing values, like rental rates, to the combined population pressures of construction contractors and in-migrating retirees and workers from Southern California to this popular rural beach area.

The housing market did not experience a sudden drop when construction at Diablo Canyon was completed. Construction declined gradually, and some workers sought other jobs in the area. Also, non–project-related growth continued in San Luis Obispo County. However, the departure of construction workers allowed rental vacancies to increase to 4–5 percent, and rental rate increases slowed.

The operation of Diablo Canyon has had little effect on housing in San Luis Obispo County. Residential development closest to the plant is in the unincorporated Avila Beach, approximately 8 km (5 miles) away. Neither housing values nor quality have been affected by the proximity of Diablo Canyon.

In summary, project-related population increase and commensurate housing demand accounted for only 12 percent of the total increase in population between 1970 and 1975. However, it appears that at times during construction, demand for housing (particularly reasonably priced housing) exceeded availability. Also, rental rates and housing values increased 63 percent and 57 percent more, respectively, than in the state of California during the same time. The contribution of project-related demand to the net effect on housing was great enough to have been a causal factor in these impacts.

C.4.3.2.2 Predicted Impacts of License Renewal

Project-related population increase and the commensurate housing demand would bring about new housing impacts during refurbishment activities. A summary of recent and anticipated growth in housing is provided. This is followed by predictions of possible impacts during refurbishment and the license renewal term.

If housing in San Luis Obispo County continues to expand at the 1980–90 rate of 35.1 percent (U.S. Bureau of the Census 1982, 1990), then it is possible that by 2023, when the operating license of Unit 1 expires, there would be about 246,000 housing units in San Luis Obispo County. This greatly exceeds the 175,960 units that will be required in 2025, based on population projections and average household size (U.S. Bureau of the Census 1990; Section C.4.3.1).

However, it is conceivable that the growth rate could be cut by half or more as a result of growth-control measures enacted partly because of severe water shortages. If this is the case, the number of housing units in the county in 2023 will be 154,250, far short of those necessary to accommodate the projected population in 2023. Thus, housing availability would be very limited, and competition for existing housing would be greatly increased.

This slower growth rate is a reasonable assumption because local governments are concerned with recent rapid growth and have taken steps to address this. Local community leaders named growth (i.e., a too-rapid rate of growth and associated water shortages) as the issue currently causing greatest concern. Communities throughout San Luis Obispo County are acting to slow the rate of growth that has occurred in past years. Arroyo Grande is now aiming for an annual growth rate of 2.5 percent, down from the previous annual rate of 5 percent. Morro Bay has enacted a "no-growth measure" that allows only 77 housing starts per year if adequate water is available. As of June 1990, because water was not available, no new housing starts had been allowed since the beginning of the calendar year. The comprehensive plan of the city of San Luis Obispo suggests a growth rate of 1 percent or less per year. Pismo Beach has grown so fast that an override of Proposition 13 spending limits was required to provide basic fire and protection services. Also, there is a countywide moratorium on development that will remain in effect until two initiatives limiting countywide growth are deliberated and enacted by the county board of supervisors. These growth-control measures could easily prevent the continuation of the 1980–90 growth rate of 35.1 percent.

According to the estimate of the number of workers required for plant refurbishment and based on plant construction experience, 1401 workers of the total work force of 2273 are expected to migrate to San Luis Obispo County for refurbishment jobs. Of these in-migrants, 864 are expected to be accompanied by families. Some doubling-up (sharing of living accommodations) is expected to occur among the 537 unaccompanied workers, so that each unaccompanied mover would require 0.85 housing unit. In-migration of these workers to San Luis Obispo County would result in refurbishment-related housing demand in the peak year of refurbishment of 1320 housing units. In addition, numerous indirect jobs are expected to result from the spending of project workers. An additional 68 workers are projected to move into San Luis Obispo County, bringing the total project-related demand for housing to 1388 units.

Refurbishment-related housing demand is greater than the original construction-related housing demand of 1297 units, but the number of housing units in the study area may have increased by as much as 415 percent—or, in a slower growth scenario, by 223 percent—between peak construction and refurbishment periods. Refurbishment-related housing demand would account for between 0.56 and 0.9 percent of the possible number of units in the study area of 2023, compared to construction-related demand in 1975, accounting for 2.7 percent of the housing units. Demand would be small relative to the existing housing market. In the absence of growth-control measures, impacts to housing are expected to be small. However, project-related housing demand in the presence of growth-control measures that limit housing development may exacerbate an already competitive housing market, particularly for reasonably priced housing.

Increased demand may increase rental rates and housing values and seriously reduce the already limited housing availability. Housing conversions, such as making apartments out of a single-family home or converting garages to apartments, may occur if allowed under the growth-control restrictions. It is thus possible that moderate—possibly even large—new housing impacts could occur.

Housing impacts related to housing value and marketability that would occur during the license renewal term are the same as those currently being experienced (Section C.4.3.2.1). The 120 additional workers (60 per unit) required during the license renewal term and the commensurate housing demand would cause only small housing impacts.

C.4.3.3 Taxes

C.4.3.3.1 Impacts from Plant Construction and Operation

PG&E pays taxes on the Diablo Canyon plant primarily to taxing authorities in San Luis Obispo County; only a relatively small amount of sales and use taxes have been paid to the state of California.

In California, the State Board of Equalization assesses public utility property. In most other states, this function is carried out by local county assessors. The State Board of Equalization currently allocates the utility system's assessed value among county tax code areas weighing three indices. A reproduction cost net less depreciation allocation procedure is used to determine the value of the facility and property. Cost estimates of the Diablo Canyon plant and all other facilities owned by PG&E are estimated on a yearly basis. The utility is required to report any construction or refurbishment of the facilities annually to the State Board of Equalization. These improvements add to the assessed valuation of the plant. In addition, utility income reported for the plant and common stock indices are used as weights to arrive at a final assessed valuation by the state. The local tax rate is then applied to the utility's assessed value within each tax code area to determine tax liability.

Before California's tax reform of 1978, an assessment ratio of 25 percent was applied to an estimate of the market value of the facility to obtain the assessed value, upon which ad valorem taxes are levied. Because of the passage of Proposition 13 in 1978, the taxable portion of the assessed value has risen to 100 percent, and the levy of a single tax rate of $4 per $100 of assessed valuation was applied to all property. Also, largely because of Proposition 13, the county's basic tax rate has declined from a high of 3.33 percent in 1972 to 1.07 percent in 1989. Table C.39 provides the San Luis Obispo County basic tax rate from 1967 to 1989, the estimated basic property tax levy, and total county general revenues. In addition, property tax as a percentage of the total county general revenues is shown in the last column. The county property tax levy had increased at a 10.2 percent annual rate from 1967 to 1968 and from 1977 to 1978. From 1977 to 1978 and from 1988 to 1989, the property tax levy increased at an 8.8 percent annual rate. Property taxes currently make up 36.0 percent of the county's total revenues. Diablo Canyon's property taxes provide 10.6 percent of San Luis Obispo County's total revenues.

Approximately 12 taxing authorities within San Luis Obispo County are included within the distribution of property tax payments by the Diablo Canyon plant. The recipients of the largest tax payments were the San Luis Obispo Coastal Unified School District and

San Luis Obispo County. Table C.40 presents the distribution of property tax payments to the major taxing authorities in San Luis Obispo County. Total property taxes paid by the Diablo Canyon plant were approximately $6.3 million in 1974–75, $12.4 million in 1977–78, and $34.1 million in 1988–89. Proportional distribution of Diablo Canyon's total tax payment has varied during this time period. Currently, San Luis Obispo County and the San Luis Coastal Unified School District receive 36.1 percent and 38.9 percent, respectively, of the total tax payment. The Diablo Canyon property tax payments, adjusted in real terms by the GNP implicit price deflator, have substantially increased during the 1974–75 to 1988–89 time period. The property tax payments paid by Diablo Canyon have increased in real terms by 7.32 percent annually from 1974–75 to 1988–89. This annual rate of increase slowed to 4.66 percent from the 1977–78 period to 1990.

The San Luis Coastal Unified School District has relied heavily on property taxes as a major portion of its income. Table C.41 gives the amounts of local property tax income and total school district income for the school district between 1969 and 1989. From 1969 to 1970 through 1988–89 the percentage of total school district income that came from property taxes rose from 75.9 to 80.1 percent. The share of total local revenues provided by the Diablo Canyon plant have increased over time, from 31.1 percent in 1977–78 to 38.9 percent in 1988–89.

C.4.3.3.2 Predicted Impacts of License Renewal

During refurbishment of Diablo Canyon, a new tax-related impact is expected to occur. This new impact involves increases in tax payments that would result from capital improvements that take place during the current term outages. Tax increases resulting from improvements made in the final refurbishment outage would affect taxes only during the license renewal term. The magnitude of the impact depends on PG&E's decision about which improvements would occur early on and which would be done during the final outage. For example, if the steam generator is replaced during a current term outage, the assessed value may increase considerably before the license renewal term begins. If steam generator replacement, and other major capital improvements, are not undertaken early on, the increase in assessed valuation may be only minor. The increase, in either case, is expected to cause only a small to moderate new tax impact.

During the license renewal term, the primary tax-related impact would be the continuation of tax payments that Diablo Canyon is currently making to San Luis Obispo County and San Luis Coastal Unified School District. There would also be a new impact resulting from the increase in tax payments because of improvements made at Diablo Canyon during the final refurbishment period. Thus, tax revenues would increase in absolute terms, although they may not provide a proportionally larger share of the total revenues of either taxing jurisdiction. Based on current conditions, Diablo Canyon tax revenues—the continuing and additional payments combined—are expected to continue to make up a substantial share of the total revenues. The large tax-related impact currently being experienced in the school district and the moderate impact occurring in the county would continue during the license renewal term.

C.4.3.4 Public Services

C.4.3.4.1 Impacts from Plant Construction and Operation

For public services, the study area consists of the municipalities of Pismo Beach, Arroyo Grande, Grover City, San Luis Obispo City, and San Luis Obispo County. The governments in these municipalities are mostly of the city council/administrative officer type (NUREG/CR-2749, vol. 5, p. 103). This area has experienced rapid population growth, primarily because of being located between the large cities of Los Angeles and San Francisco. The period of construction and operations of the Diablo Canyon Nuclear Plant was characterized by political conflict, not only because of the plant but also because of the allocation of the increased revenues from the plant (NUREG/CR-2749, vol. 5, p. 103). County planning commissions were also very active during the 1970s. The major public services that are most responsive to public demand are education, public safety, and transportation. These services received the most impact from the construction and operation of the Diablo Canyon Nuclear Plant.

Education

Public education in San Luis Obispo County is provided by the San Luis Coastal Unified School District. Funding for public education comes from federal, state, and local sources, with the local property tax being the largest source of funding. During the construction phase, the major educational impacts of the Diablo Canyon plant were concentrated on two public school districts—the San Luis Coastal Unified School District and the Lucia Mar Unified School District (NUREG/CR-2749, vol. 5, p. 112).

While Diablo Canyon Nuclear Plant is situated in the San Luis Coastal Unified School District, impacts from the plant affected two school districts. In the San Luis Coastal Unified School District, the impact was related to the large tax revenues generated by the facility. In the Lucia Mar Unified School District, the impact occurred in relation to the influx of school-age children accompanying Diablo Canyon construction workers (NUREG/CR-2749, vol. 5, p. 112).

The Lucia Mar Unified School District was at overcapacity during the peak construction period and was forced to add portable classrooms to accommodate the additional student population. Funding was an impact that had a positive effect on the San Luis Coastal Unified School District while creating a negative impact on the Lucia Mar Unified School District. This inequity in funding resulted because new school districts were established shortly before the final siting decision on Diablo Canyon was made. Several factors were considered before the districts were created. Estimates of wealth, or assessed valuation, were based on the plant being sited in the Lucia Mar school district. However, the plant was built in the San Luis school district. Therefore, Lucia Mar gained additional students without the additional revenues from the construction that went to the San Luis school district (NUREG/CR-2749, vol. 5, p. 113).

Local officials indicated that many construction workers moved into the area for short periods with no major impact. Currently, a change is occurring in the schools. The emphasis continues to be on academics, but a need is growing for a vocational/technical curriculum.

Transportation

The major roads in the study area that provide access to the Diablo Canyon Nuclear Plant are State Highway 101, Avila Road, and San Luis Bay Drive. The county maintains all county-designated roads, while California Transportation (CalTrans) supports all state roads. Any city-designated roads are maintained by the municipality in which they are located (NUREG/CR-2749, vol. 5, p. 115).

During peak construction, over 2000 workers were employed at the site. To accommodate additional traffic, San Luis Obispo County made several improvements to Avila Road and San Luis Bay Drive. PG&E aided in the funding of these improvements (NUREG/CR-2749, vol. 5, p. 116).

Local officials gave no indication of any major problems stemming from the construction or operation of the Diablo Canyon Nuclear Plant.

Public Safety

Public safety expenditures remained constant from 1967 to 1973 and then rose by 6 percent from 1973 to 1978. The municipalities within the study area provide police protection within their boundaries. Police protection in the rural areas is provided by the county sheriff and the California Highway Patrol. Diablo Canyon projects' tax contributions enabled the expansion of public safety services (NUREG/CR-2749, vol. 5, p. 116).

The California Department of Forestry is located in San Luis Obispo County regional office. The San Luis Obispo County contracts with the Department of Forestry for local fire protection (NUREG/CR-2749, vol. 5, p. 116). The majority of fire departments for the other municipalities in the study area are a combination of volunteer and paid full-time people. There is a countywide emergency management plan, and each municipality also has its own plan. Local officials contacted gave no indication of any problems arising about public safety during either construction or operation of the plant.

Social Services

Social services are provided by the counties in the study area. Local officials stated that a whole range of services was provided from homeless shelters to "Meals on Wheels" for the elderly. One municipality has a senior citizens' advisory committee that works with the city council and assists in making decisions for the seniors in its jurisdiction.

Public Utilities

Public utilities are provided in a variety of combinations in the county. The county provides some services, and there are special districts with privately provided services. In the majority of municipalities, sewer and water are provided by the municipality itself. One local official interviewed indicated that water availability was a problem. Currently, the county is trying to implement a water conservation program. Local offices indicated that it is hard to specify which services were specifically affected by the construction and operation of the plant and that it was a major difficulty to absorb some of the changes.

Tourism and Recreation

Local leaders indicated that no adverse impacts resulted from the construction or operation of the Diablo Canyon Nuclear Plant. Some officials indicated that during the construction phase it was a "site to see":

"I would have to say it has had a positive effect on the tourism draw." The director of recreation in Grover City stated that PG&E is very supportive of recreational groups. Arroyo Grande has a standard of approximately 1.6 ha (4 acres) per 1000 residents and would like to keep that standard even if continued growth occurs.

C.4.3.4.2 Predicted Impacts of License Renewal

Based on the estimated 2273 direct workers required during peak refurbishment, the staff estimates that 864 direct workers and 68 indirect workers will migrate with their families to San Luis Obispo County (Section C.4.3.1.2). The number of children accompanying these workers is estimated using the California average family size (3.32) and assuming that all families include two adults. Children are expected to be evenly distributed in age from ≤1 to 18 years. Assuming 72.2 percent of these children are school age (5 to 18 years), there will be an average of 0.95 school-age children per in-migrating family, or a total of 885 new students in San Luis Obispo County. This represents a 0.1 percent increase above the projected number of school-age children in San Luis Obispo County in 2015 (assuming the 1990 age distribution of the population). This slight increase will result in only small impacts to education.

During the construction phase, improvements were made to several roads leading to the plant. An additional increase of 2273 direct workers and 3631 new residents during refurbishment should have a small impact on traffic flow on a road system currently accommodating over 200,000 residents. Likewise, refurbishment-related population increases should have little or no impact on other public services, such as social services, public safety, tourism, and recreation.

A water supply shortage has plagued all of southern California in the recent past. In San Luis Obispo County sufficient processing capacity exists, but severely limited water availability has resulted in water-use restrictions and has contributed to the enactment of growth control measures. The water supply shortage began after the construction and early operations phase of Diablo Canyon; therefore, the effect of a plant-related increase in population is unknown. An increase in water demand resulting from an additional 3600 persons might, however, result in moderate impacts to public water availability. Absent this water supply shortage, only small impacts to public utilities will result.

Based on past operations information, impacts of license renewal term operations to most public services are likely to be small. The projected operations-related population increase is small (200 persons) and will result in extremely small increase in demand for public services. The public water supply, however, may be moderately affected during refueling activities in the license renewal term if the water supply shortage continues.

C.4.3.5 Off-Site Land Use

This section describes the off-site land-use impacts of the construction, operation, and license renewal of the Diablo Canyon Nuclear Generating Station. The discussion of impacts is primarily concerned with land use in the immediate vicinity of the plant, but impacts for the remainder of San Luis Obispo County are described where appropriate. Land-use impacts are examined for two time periods. First, Section C.4.3.5.1 identifies the land-use impacts of Diablo Canyon's construction and operation. Next, Section C.4.3.5.2 projects the land-use impacts of Diablo Canyon's refurbishment period based on the impacts that occurred during the plant's construction. Also, Section C.4.3.5.2 projects the land-use impacts of the plant's license renewal term based on the impacts that have occurred during operations. Information sources for this report include the *Final Environmental Statement Related to the Nuclear Generating Station Diablo Canyon, Units 1 and 2* (AEC Dockets 50-275 and 50-323); *Socioeconomic Impacts of Nuclear Generating Stations: Diablo Canyon Case Study* (NUREG/CR-2749, vol. 5); and interviews with key information sources in San Luis Obispo County. Section C.4.1.5 describes the methods used to assess and project land-use impacts for all case study plants.

C.4.3.5.1 Impacts from Plant Construction and Operation

Diablo Canyon was constructed on a 300-ha (750-acre) site on the California coast. In 1968, when plant construction began, the area in the immediate vicinity of the site was very remote and almost wholly undeveloped. The nearest development was in Avila Beach, a small residential area about 11 km (7 miles) southwest of the plant. The property upon which the plant was built had previously been part of the Marré Ranch, and the land had been idle or used for cattle grazing for several years. Close to the ocean, the site's terrain was made up of very rugged shoreline areas with steep, rocky slopes unsuitable for development. The property had been rezoned to commercial and recreational use in 1962, but there was no residential, industrial, commercial, or recreational land use on the site when excavation began (AEC Dockets 50-275 and 50-323).

The construction and operation of Diablo Canyon have not had significant impacts on land use in the plant's immediate vicinity. Diablo Canyon was constructed on part of a 2800-ha (7000-acre) private ranch in a very remote, rugged section of San Luis Obispo County. This meant that there were very few existing land uses to impact in the immediate vicinity and that the area was relatively free from heavy development pressures because of a lack of roads and utilities. The area surrounding the plant is still very rural and undeveloped, and primary land uses are still agriculture and livestock grazing. Local sources indicated that it was not Diablo Canyon's presence but the remoteness and inaccessibility of the area that had restricted further development (NUREG/CR-2749, vol. 5, pp. 181–182).

In developed areas near Diablo Canyon, such as the communities of Avila Beach and Pismo Beach, the plant's land-use impacts also have been minimal. Since the early 1980s, both Avila Beach and Pismo Beach have grown as resort areas with relatively expensive housing, condominium, and hotel/motel development brought about by the region's expanding tourist industry. San Luis Bay Estates, a 480-ha (1200-acre) complex located in Avila Beach about 10 km (6 miles) from Diablo Canyon, represents part of this growth. When completed, San Luis Bay Estates will include a hotel and cottages with 225 rooms, about 800 homes, and a golf course. Another residential development, comprising about 1000 ha (2500 acres), 100 homes, and a golf course, is being planned for the Pecho Ranch property adjoining San Luis Bay Estates. Some of the homes in the new Pecho Ranch complex will be within 6.5 km (4 miles) of Diablo Canyon, the closest residential development to the plant thus far. Sources indicated that the plant's presence had neither encouraged nor impeded residential or commercial development of this type. In general, Diablo Canyon's overall land-use impacts have been neutral in both Avila Beach and Pismo Beach.

Despite some negative housing impacts from worker in-migration during the plant's construction (peak construction-related growth constituted about 2.6 percent of the county's population), Diablo Canyon has had relatively minor effects on land use in San Luis Obispo County as a whole. One reason for this is Diablo Canyon's extremely remote location. Also, sources felt that the county's residential, commercial, and industrial development patterns were much more susceptible to influences other than Diablo Canyon's presence. Some of the more important determinants of the county's land-use and development patterns were said to include the presence of the University of California at San Luis Obispo and the need to provide student housing; the beauty of the area's beaches coupled with growth in the regional tourist industry; the limited availability of developable land, particularly in urban areas; the local implementation of slow-growth policies; the limited availability of an adequate water supply; and development pressures resulting from the in-migration of residents from Los Angeles and San Francisco. In general, both the direct and indirect land-use impacts of Diablo Canyon's construction and operation have been neutral for the county as a whole.

C.4.3.5.2 Predicted Impacts of License Renewal

The direct and indirect land-use impacts of Diablo Canyon's refurbishment and license renewal term are expected to be small for the area in the plant's immediate vicinity and for San Luis Obispo County as a whole. Land use in the immediate vicinity of the plant is expected to remain unchanged, with agriculture and livestock grazing being the primary uses. Because of its remoteness and lack of public services, the area is expected to remain undeveloped indefinitely.

Although San Luis Obispo County might experience some housing shortages during the refurbishment period, large-scale residential development is not anticipated as a result of Diablo Canyon's license renewal. Refurbishment-related population growth is projected to be approximately 0.8 percent of the county's projected 2024 population. The population growth projected to result from Diablo Canyon's license renewal term is even smaller, less than 0.1 percent of the county's projected 2024 population. Because increases this small are not likely to create a significant housing demand, the plant's impact on residential development in San Luis Obispo County is expected to remain neutral or be minimal. Future residential, commercial, and industrial development patterns will be increasingly influenced by some of the factors that help dictate the county's land-use patterns now. The most important factors are likely to be the availability of developable land, the enforcement of slow- or no-growth policies, the availability of an adequate water supply, and the continued in-migration of residents from Los Angeles and San Francisco. Tourism- and resort-related residential and commercial development is expected to continue in Avila Beach and Pismo Beach, with neither positive nor negative impacts from Diablo Canyon. Overall, Diablo Canyon's direct and indirect land-use impacts are expected to be small, as has been the case during construction and operation.

C.4.3.6 Economic Structure

C.4.3.6.1 Impacts from Plant Construction and Operation

The construction and operation of Diablo Canyon have resulted in noticeable and insignificant economic impacts, respectively. Table C.42 gives the estimated employment and expenditure effects of the Diablo Canyon plant for residents of San Luis Obispo County. The employment is the sum of direct basic, indirect basic, other basic, and nonbasic employment as described by Mountain West Research, Inc., in *Socioeconomic Impacts of Nuclear Generating Stations: Diablo Canyon Case Study* (NUREG/CR-2749, vol. 5).

Overall, peak construction period employment in 1975 represented 6.5 percent of San Luis Obispo County's total employment, indicating a noticeable impact. Operating term employment in 1990 is approximately 1300 workers, of whom 1160 are residents of San Luis Obispo County. Total Diablo Canyon-related direct and indirect employment in 1990 is estimated to be 1909, or 1.8 percent of the county's total employment. This represents an insignificant impact.

C.4.3.6.2 Predicted Impacts of License Renewal

The impacts of refurbishment and license renewal are expected to be similar to the type of impacts experienced during initial construction and operation. Employment generated by the Diablo Canyon plant after license renewal would, for the most part, represent a continuation of the levels generated before refurbishment.

The work force scenario detailed in Section C.3.1 was used to estimate the employment effects of refurbishment at Diablo Canyon. Table C.43 shows the total direct and indirect plant-related employment of San Luis Obispo County residents. The methodology used to determine the employment impacts is developed in the Mountain West Research, Inc., study for Diablo Canyon (NUREG/CR-2749, vol. 5). It is projected that Diablo Canyon would employ 1932 county residents as refurbishment workers in 2023 (Section C.4.3.1.2). In addition, indirect employment that would result from purchases of goods and services during refurbishment is projected to create 1310 jobs for San Luis Obispo County residents. The total direct and indirect employment affecting San Luis Obispo County during the peak refurbishment year is therefore projected to be 3242. This employment is projected to represent 1.85 percent of total employment in San Luis Obispo County in 2023, resulting in small impacts.

Relatively few new plant-related jobs would be created at Diablo Canyon during the license renewal term. Nearly all plant-related employment (and associated impacts) expected during that time period would represent a continuation of employment (and impacts) from past operations. Table C.44 shows the impact of the increased labor requirements at Diablo Canyon after 2023.

The license renewal term work force for Diablo Canyon would require an estimated 120 additional employees (Section C.4.3.1.2). Of these additional workers, 107 are projected to be San Luis Obispo County residents. An estimated 77 indirect jobs would also be created by the license renewal term, and 69 of the jobs are expected to be filled by San Luis Obispo County residents. With the continued effects of the plant's current employment and the additional employment to be created, total direct and indirect license renewal term employment is projected to represent 1.2 percent of San Luis Obispo County's employment in 2023. The employment figure represents a small impact.

C.4.3.7 Historic and Aesthetic Resources

This section describes the impacts that the construction and operation of the Diablo Canyon Nuclear Generating Station Units 1 and 2 have had on historic and aesthetic resources and projects the expected impacts of the plant's refurbishment and post-relicensing operations. Information sources include the *Final Environmental Statement Related to the Nuclear Generating Station Diablo Canyon Units 1 and 2* (AEC Dockets 50-275 and 50-323) and interviews with key informants in San Luis Obispo County and elsewhere in California.

C.4.3.7.1 Impacts from Plant Construction and Operation

The plant's construction and operation have affected no sites on the National Register of Historic Places. During the preconstruction phase, archaeologists hired to survey the site found several prehistoric campsites along Diablo Creek, one dating back 9300 years (the San Luis Obispo 2 site). This was considered an important finding, establishing a new chronology for this area of Central California. Portions of this site have been preserved, but construction of the plant and access road did destroy other sites. The continued operation of the plant has resulted in damage to one of the sites. An evaporation pond sprang a leak and water ran through a site, causing some erosional damage. Another continuing impact on prehistoric resources related to the plant is the continuing loss of land through sloughing off of a bluff near the plant. Although this erosion problem appears to be unrelated to actual construction of the power plant, restricted access because of plant security has prevented other parties from responding to this problem. Conversely, one source said that the fact that the site and its surroundings are owned by the licensee has protected the area and its historic and aesthetic resources from development more effectively than if the site had been under the ownership of private parties.

Aesthetically, the construction and operation of the plant have had an insignificant impact on the surroundings. This is not because of the physical design of the plant [it is not a low-profile facility: the containment structures are 46 m (150 ft) in diameter and 60 m (200 ft) tall, and the turbine building is 43 m (140 ft) tall and 230 m (750 ft) long] but because of its remote location within an extensive private ranch. The only visual access to the plant for the public is from the Pacific Ocean. The plant cannot be seen even from the private access road until within 1.2 km (0.75 mile) because of the rocky terrain. Along the 19 km (12 miles) of privately held coastline adjacent to the Diablo Canyon site, there is no beach use, swimming, fishing, or beachcombing because of the rocky cliffs and poor accessibility. Hiking, camping, picnicking, and artistic pursuits could be enjoyed on the bluffs above the plant if there were any public access (AEC Dockets 50-275 and 50-323). Erosional scars from the 2400-ha (6000-acre) transmission line right-of-way and its service roads are a source of adverse aesthetic impacts (AEC Dockets 50-275 and 50-323).

C.4.3.7.2 Projected Impacts of License Renewal

The impacts of the Diablo Canyon plant's refurbishment and post-relicensing operation on historic and aesthetic resources in San Luis Obispo County and on the immediate Pacific Coast environs would likely be less pronounced than those that have occurred during construction and operation of the facility. As in the past, the power plant, which is highly visible only from the Pacific Ocean, would likely have only small aesthetic impacts. If the private land holdings that surround the site were to be developed, there could be extensive public visual access to the site, raising the potential for an adverse impact. Such an impact could be reflected in property values not reaching their full potential.

A respondent cautioned that if additional construction or road maintenance were to occur with refurbishment, there could be impacts to the area's prehistoric and historic resources. However, evaluation of potential impacts to historic resources must occur through consultation with the SHPO as mandated by the National Historic Preservation Act (NHPA) of 1966.

C.4.4 Indian Point

The impact area—those places in which the most pronounced socioeconomic impacts might result from refurbishment—for Indian Point consists of Westchester and Dutchess counties. The assessment of land use and public services involves only Westchester County. The selection of this area is based on worker residence patterns, employment, expenditures, and tax payments. Figure C.10 depicts the impact area, and Figure C.11 shows the region in which it is located.

C.4.4.1 Population

This section discusses the local population growth associated with the construction, operation, and license renewal of the Indian Point Nuclear Generating Plant.

Section C.4.1 describes the methodology used to project population growth for all plants. Data used to prepare this section were obtained from the *Final Environmental Statements Related to the Operation of Indian Point Nuclear Generating Plant, Units 2 and 3* (AEC Dockets 50-247 and 50-286); *Environmental Assessment for Proposed Rule on Nuclear Plant License Renewal* (NUREG-1398); SEA refurbishment work force estimates (Appendix B; SEA 1994); population projections by the New York Department of Commerce (Division of Economic Research and Statistics) (Kraushárr 1990); the Consolidated Edison Company (ConEd) of New York; and the New York Power Authority.

The discussion of population growth is organized into two time periods. Section C.4.4.1.1 identifies the population growth that Dutchess and Westchester counties have experienced as a result of the construction and operation of Indian Point Units 2 and 3 from 1965 to 1990. Section C.4.4.1.2 projects the population growth that is expected to result from Indian Point's refurbishment period and license renewal term operations beginning in 2013 (Unit 2) based on the growth associated with the plant's initial construction. Also, Section C.4.4.1.2 projects the population growth expected to result from Indian Point's license renewal term based on the growth associated with operations in the past.

C.4.4.1.1 Growth Resulting from Plant Construction and Operation

Because Indian Point was not included in the NUREG/CR-2749 study, estimates of worker in-migration are based on the construction experience at other nuclear plants in comparable locales, especially Oconee and Three Mile Island. Indian

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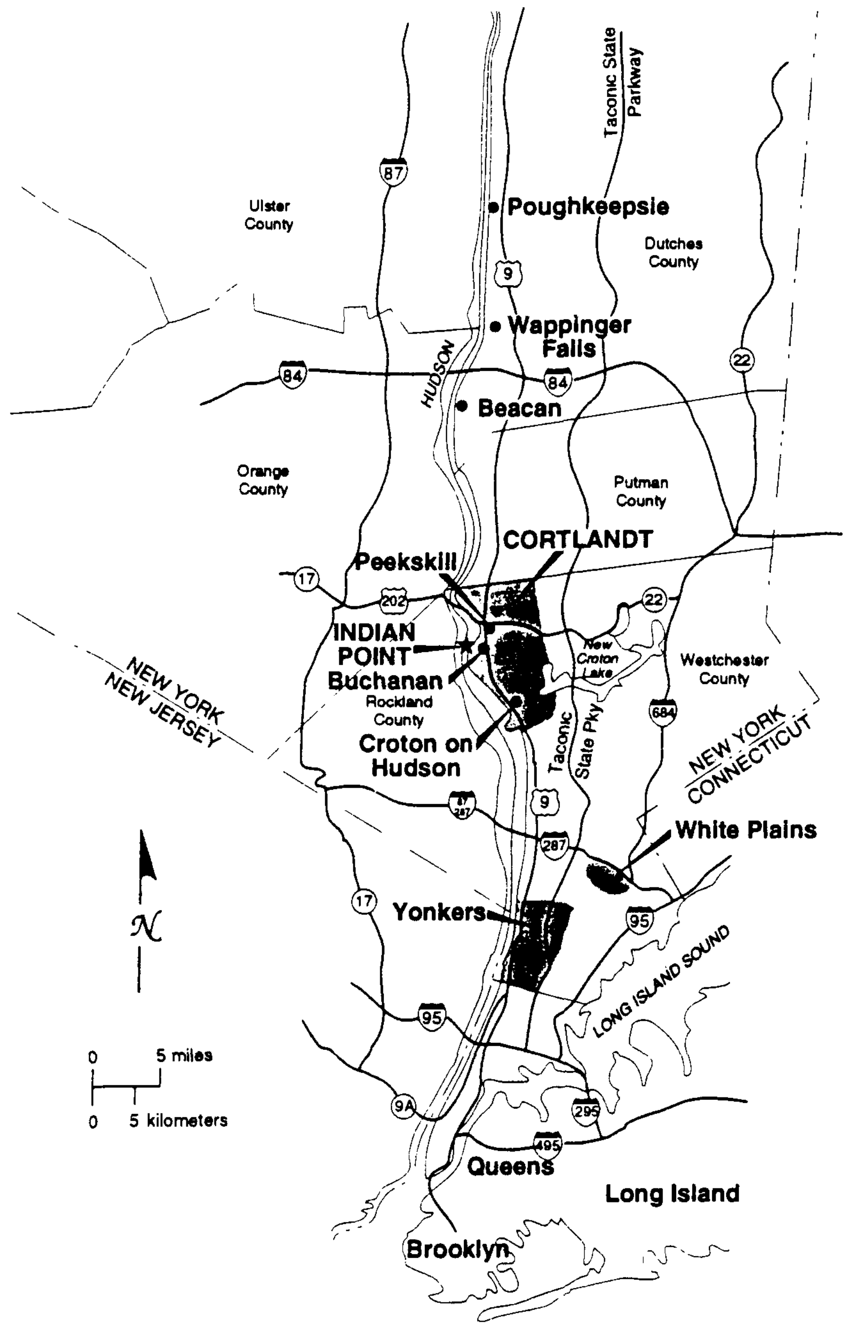

Figure C.10 Socioeconomic impact area associated with Indian Point refurbishment: Westchester and Dutchess counties.

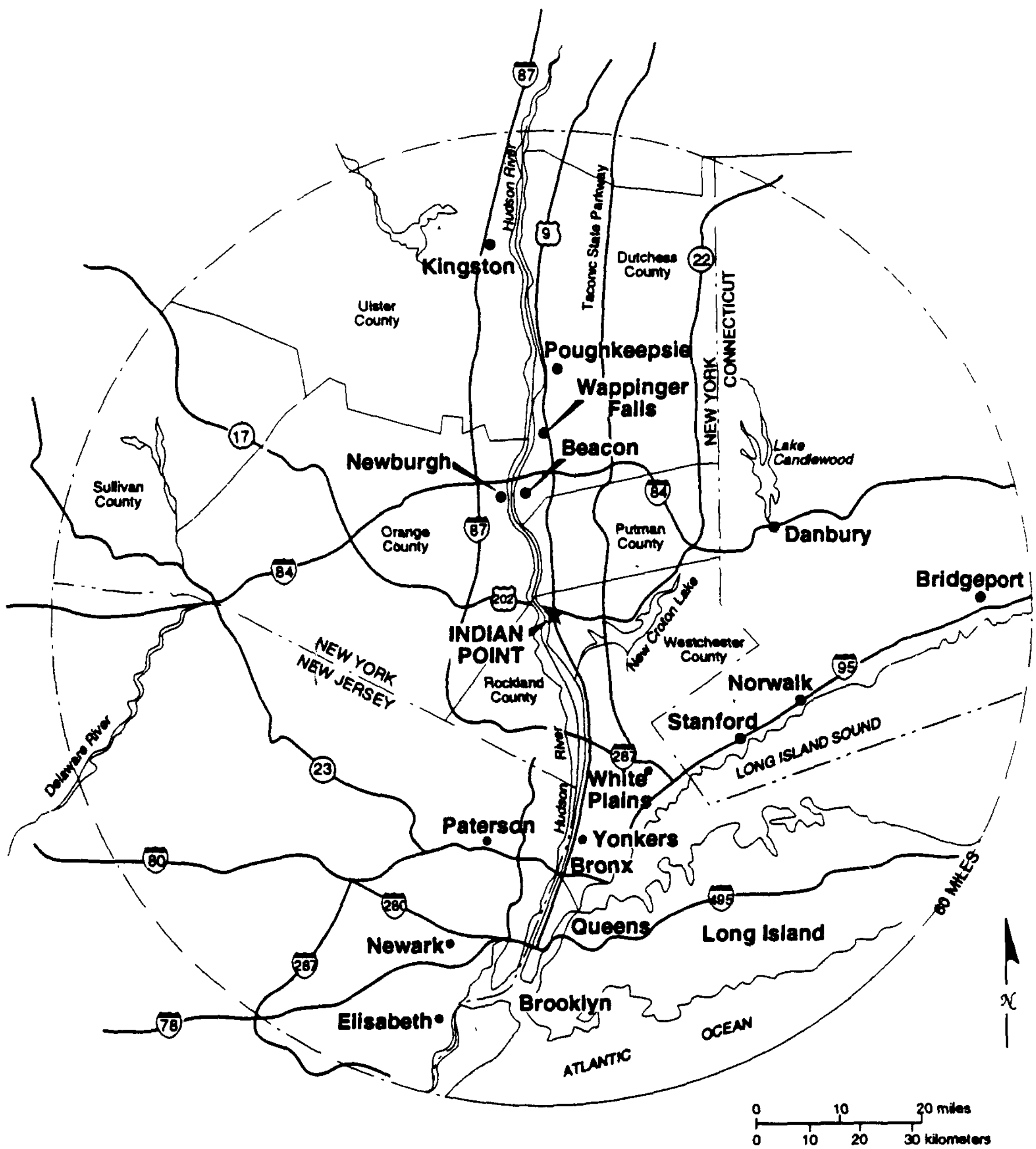

Figure C.11 Region surrounding the Indian Point nuclear plant.

Point's construction resulted in very small population increases in Dutchess and Westchester counties (Table C.45). During the peak construction period at Unit 2, there were approximately 1200 construction workers on-site (AEC Docket 50-247, p. IV-4). Assuming the same size work force for Unit 3, as many as 2400 workers were on-site while both units were under construction during the early 1970s. Based on construction experience at other nuclear plants with similar locales—i.e., areas with relatively low population density compared to larger urban areas located within a short commuting distance—it is estimated that approximately 17.3 percent (415 persons) of the peak construction period work force lived in Dutchess County and 12.7 percent (305) lived in Westchester County (Tables C.46 and C.47). This distribution reflects current work force distribution at Indian Point (ConEd 1990; PASNY 1990). An estimated 30 percent of the construction work force lived in the study area. It is estimated that 35 percent of the construction workers residing in Dutchess or Westchester counties (252 persons) were workers who migrated to the study area for jobs at the plant (Tables C.46 and C.47). Based on the pattern of construction workers' in-migration at other nuclear projects, it is estimated that 51 percent of the in-migrants (129 workers) were accompanied by their families and that their average household size was 3.25 persons. Together, this represents a total in-migration of 312 residents for Dutchess County and 231 new residents for Westchester County. Based on construction in-migration and the ratio of nonplant jobs created during peak construction periods at nuclear plants in comparable locales, it is estimated that Indian Point's peak construction period created an additional 1560 jobs in service industries supported by the spending of construction workers. As a result of these indirect jobs, an estimated 31 additional workers and their families (a total of 78 persons) moved into each study area county (Tables C.46 and C.47).

In all, approximately 390 new residents moved into Dutchess County and 309 people migrated into Westchester County as a result of Indian Point's peak construction period. These residents made up about 0.2 percent of Dutchess County's 1972 population of 226,673 and about 0.03 percent of Westchester County's 1972 population of 888,691.

Operations at Indian Point have resulted in less population growth than did the plant's construction. In 1990, 1335 permanent plant staff were on-site at Indian Point (additional contract workers have been on-site during outages, but they are not included in this number because their presence at the plant was temporary). Of the permanent work force, 37.8 percent (505) resided in Dutchess County and 27.8 percent (371) resided in Westchester County (ConEd 1990; PASNY 1990). Based on the residential settlement pattern of workers at nuclear plants in comparable locales and on construction experience at Indian Point, it is estimated that 30 percent (263) of the workers residing in Dutchess and Westchester counties in 1990 were persons who migrated to the study area to work at the plant (Tables C.48 and C.49). Also following the pattern set by personnel in-migrating to work at other nuclear plants, it is estimated that 66 percent (174) of the in-migrants were accompanied by their families. Assuming the 1990 New York average family size of 3.22 persons, this represented a total in-migration of 374 new residents for Dutchess County and 275 new residents for Westchester County (Tables C.48 and C.49). Based on work force in-migration and the ratio of plant to nonplant jobs created at other nuclear plants during operating periods, it is estimated that Indian Point's 1990 operations created an additional 868 indirect jobs in service industries supported by the spending of plant workers. As a result of these indirect jobs, an estimated 17 additional workers and their families (a total of 41 persons) moved into each study area county (Tables C.48 and C.49).

In all, approximately 415 new residents moved into Dutchess County, and 316 persons into Westchester County, as a result of Indian Point's 1990 operations. These new residents made up about 0.16 percent of Dutchess County's 1990 population of 259,462 and about 0.04 percent of Westchester County's 1990 population of 874,866.

C.4.4.1.2 Predicted Growth Resulting from License Renewal

As discussed in Section C.3.1, Indian Point's license renewal would require the completion of a number of refurbishment tasks for Units 2 and 3. Many of the refurbishment tasks are expected to be completed during scheduled refueling outages at each unit during the 10 years that precede the expiration of the initial operating license. However, the final refurbishment work is expected to be completed during one large refurbishment outage scheduled for each unit in the year before the unit's initial operating license expires. Because the final refurbishment outage would involve more workers on-site over a longer period of time than any of the preceding refueling outages, it represents the peak refurbishment period. For other assumptions concerning the refurbishment work force, refer to Sections C.3.1 and C.4.1.1.2.

Assuming the refurbishment schedule as described in Section C.3.1, the peak refurbishment year for Indian Point Unit 2 is expected to be 2012, and the peak refurbishment year for Indian Point Unit 3 is expected to be 2015. For each unit, the on-site refurbishment work force would be about the same size, and the work force would be on-site for approximately the same period of time (refer to Section C.4.1.2 for other work force assumptions). However, because of uncertainties concerning the length of the outage and the size of the work force required to complete the refurbishment of a given unit, this section examines a bounding case work force scenario as described in Section C.3.1.

Given the work force scenario detailed in Section C.3.1, it is estimated that 2273 workers would be on-site to complete refurbishment of Indian Point Unit 2 in 2012 and Unit 3 in 2015 (SEA 1994). Further assuming that the residential distribution of refurbishment workers would be similar to that estimated for the 1972 construction work force, it is estimated that approximately 30 percent (543) would reside in either Dutchess County or Westchester County. Based on the residential distribution of Indian Point plant staff, it is estimated that 17.3 percent (393) would reside in Dutchess County and that 12.7 percent (289) of the total work force would reside in Westchester County (Tables C.50 and C.51). For Indian Point, estimates of refurbishment worker in-migration are based on construction experience at nuclear plants located in areas with similar characteristics to the region in which Indian Point is located. It is estimated that 35 percent (239) of the refurbishment workers living in either Dutchess County or Westchester County would be workers who migrate into the area for jobs at Indian Point. Based on the pattern of construction workers' in-migration at other nuclear projects, 51 percent of the in-migrants (122) would be accompanied by families. Using the New York average family size of 3.22 persons, total refurbishment worker in-migration would be expected to result in 293 new residents for Dutchess County and 216 new residents for Westchester County. Based on construction in-migration and the ratio of nonplant jobs created during peak construction periods at nuclear plants in comparable locales, it is estimated that Indian Point's refurbishment would create an additional 1477 indirect jobs in service industries supported by the spending of refurbishment workers. As a result of these indirect jobs, an estimated 59 additional workers and their families (a total of 148 persons) would be projected to move into the study area. Of these additional in-migrants, 74 would move into each study area county (Tables C.50 and C.51). In all, approximately 367 new residents would be expected to move into Dutchess County and 290 new residents into Westchester County, as a result of Indian Point's refurbishment. That would represent 0.1 percent of Dutchess County's projected population of 310,809 in 2013 and less than 0.1 percent of Westchester County's projected population of 846,861 in 2013.

Once plant refurbishment is completed for Indian Point Units 2 and 3, the work force would consist mostly of permanent plant staff. Additional refurbishment/refueling workers would be temporarily on-site approximately every 2 years; however, they would not be permanent, on-site plant staff, and many of them are expected to commute from outside the study area. It is expected that a maximum of 60 additional permanent workers per unit would be required during the license renewal term, adding 120 workers to Indian Point's existing work force. Assuming that the new workers' residential distribution would be the same as current workers', approximately 37.8 percent (45) would reside in Dutchess County, and 27.8 percent (33) would reside in Westchester County (ConEd 1990; PASNY 1990). Based on operating experience at nuclear plants in comparable locales and on construction experience at Indian Point, it is estimated that 30 percent (23) of the plant staff who would reside in Dutchess County or Westchester County would be persons who migrated to the area to work at Indian Point (Tables C.52 and C.53). Also following the pattern set by personnel in-migrating to work at other nuclear plants, 66 percent of the in-migrants (16) would be accompanied by their families. Using the New York average family size of 3.22 people, total in-migration would be expected to result in 33 new residents for Dutchess County and 26 new residents for Westchester County. Based on work force in-migration and the ratio of nonplant jobs created at other nuclear plants during operating periods, it is estimated that Indian Point's license renewal term would create an additional 78 indirect jobs in service industries supported by the spending of plant workers. As a result of these indirect jobs, an estimated two additional workers (six persons including families) would be projected to move into each study area county (Tables C.52 and C.53). In all, approximately 39 new residents would be expected to move into Dutchess County and 32 new residents into Westchester County, as a result of Indian Point's license renewal term. That would represent less than 0.1 percent of Dutchess County's projected population and less than 0.1 percent of Westchester County's projected population in 2013.

C.4.4.2 Housing

The following sections (1) examine the housing impacts that occurred in Westchester and Dutchess counties during construction and operation of Indian Point and (2) predict housing impacts that would result from refurbishment activities and continued operation during the license renewal term. Possible impacts to housing include changes in the number of housing units, particularly the rate of growth of the housing stock; changes in occupancy rates; changes in the characteristics of the housing stock; and changes in rental rates and property values.

Section C.4.1.2 includes a complete discussion of the methodology and assumptions used to predict housing impacts.

C.4.4.2.1 Impacts from Plant Construction and Operation

The following discussion begins by describing project-related housing demand in Westchester and Dutchess counties and compares it to the 1970 housing market. Impacts from the operation of Indian Point on local housing are then described. Because Indian Point was not included in the NUREG/CR-2749 study, estimates of worker in-migration are based on the construction experience at other nuclear plants in comparable locales (Section C.4.4.1).

Peak construction work force of 2400 occurred in the early 1970s when both Units 2 and 3 were under construction. Because such a large labor pool existed within reasonable commuting time in the local area and in New York City, very little in-migration occurred. Only 252 project workers moved to Westchester and Dutchess counties combined to work at the site. In Dutchess County, in-migrating workers required 134 housing units, and those who moved to Westchester County required 99 housing units. Indirect jobs created by the spending of project workers brought in another 60 workers to Dutchess County and 44 to Westchester. Thus, the total project-related housing demand was for 194 units in Dutchess County and 143 units in Westchester. Project demand accounted for only 0.28 percent of the year-round housing units in Dutchess County and 0.04 percent of the year-round units in Westchester.

Westchester County in 1970 had over 3000 vacant rental units and 812 units for sale (U.S. Bureau of the Census 1972). Project-related demand would occupy only a fraction of the vacant units. Similarly, 1400 vacant rental units and 517 units were for sale in Dutchess County. Because project-related demand made up only a minuscule portion of the housing markets of both Dutchess and Westchester counties, no discernable change in the housing market or in housing values occurred.

Most local planners and realtors believe that the operation of the Indian Point plants has not inhibited residential growth in neighboring communities of Buchanan, Peekskill, and Verplank, and the town of Cortlandt. Rather, the low property taxes and good school district have served to encourage residential development and facilitate the quick sale of existing housing. Local residents express no reluctance about living near the plants, although occasionally an outside buyer is deterred from the area because of the plants. However, there are always other buyers for the property, so the housing market has not slowed. Conversely, one realtor maintains that more development in communities neighboring Indian Point would have occurred had it not been for Indian Point.

Local realtors agree that housing values in communities neighboring the plant have not been deflated because of the presence of Indian Point. Homes in the immediate area are moderately priced and are currently selling very fast on the market. Developments within 3 km (2 miles) of the plant include homes in the $400,000 to $600,000 range. Representatives of the Westchester County Office of Community Development believe otherwise, however, and indicated that the presence of the plant had perpetuated the image of these communities being low to middle class.

In summary, it appears that neither construction nor operation of the Indian Point plants has considerably affected housing in the communities neighboring the plants or in the whole of Westchester and Dutchess counties.

C.4.4.2.2 Predicted Impacts of License Renewal

Project-related population increase and the commensurate housing demand would be the cause of new housing impacts during refurbishment activities. A summary of recent and anticipated growth in housing is provided. This is followed by predictions of possible impacts during refurbishment and the license renewal term.

Housing in Westchester County expanded between 1980 and 1990 by 6.3 percent (U.S. Bureau of the Census 1990). If expansion continues at this rate, there would be about 419,500 housing units in 2012, the peak year of refurbishment at Indian Point Unit 2. Historical growth trends in Dutchess County suggest that by 2012 there could be about 126,500 housing units (U.S. Bureau of the Census 1988, 1990). The projected populations of Westchester and Dutchess counties in 2012 are 846,861 and 310,809, respectively, and will require approximately 321,000 and 115,500 housing units. Although adjustments in housing growth will be made according to population growth, the current rate of growth suggests that there will be available housing in the study area during refurbishment activities.

According to the estimate of the number of workers required for plant refurbishment and based on plant construction experience, 138 workers of the total work force of 2273 are expected to migrate to Dutchess County and 101 workers are expected to migrate to Westchester County for refurbishment jobs. Of these in-migrants, 51 percent are expected to be accompanied by families. Some doubling-up is expected to occur among the unaccompanied workers, so that each unaccompanied mover would require 0.85 housing unit. This results in a refurbishment-related housing demand in the peak year of refurbishment of 128 housing units in Dutchess County and 94 units in Westchester County. Also, in-migrants filling indirect jobs created by the spending of project workers would require 30 units in each study area county, bringing the total project-related housing demand to 158 and 124 units in Dutchess County and Westchester County, respectively.

Refurbishment-related housing demand is less than the original construction-related housing demand of 194 and 143 units in Dutchess and Westchester counties. The number of housing units will have increased by about 85 percent in Dutchess County and 44 percent in Westchester County between peak construction and refurbishment periods. Refurbishment-related housing demand would account for 0.1 percent and 0.02 percent of the projected number of housing units in 2012 in Dutchess and Westchester counties, respectively. Housing demand during refurbishment would be tiny relative to the existing housing market and is even less than that experienced during construction. Only small new impacts on housing would result.

Housing impacts related to housing value and marketability that occur during the license renewal term are the same as those currently being experienced (Section C.4.4.2.1). The 120 additional workers (60 per unit) required during the license renewal term and the commensurate housing demand would cause only small new housing impacts.

C.4.4.3 Taxes

Two operating reactors are currently at Indian Point. Indian Point Unit 2 is owned and operated by ConEd, and Indian Point Unit 3 is owned and operated by the Power Authority of the State of New York (PASNY). Although PASNY is not subject to local taxes, it makes payments in lieu of tax based on its assessed valuation.

C.4.4.3.1 Impacts from Plant Construction and Operation

The town of Cortlandt and the village of Buchanan both collect taxes from Indian Point Unit 2. The town of Cortlandt is a political jurisdiction in Westchester County that provides services to unincorporated areas within its boundaries. It collects taxes for its general budget and special districts, fire districts, and the Hendrick Hudson School District. The village of Buchanan, where Indian Point Nuclear Plant is located, is an incorporation within the town of Cortlandt's boundaries. It is a separate taxing jurisdiction and independently assesses and levies taxes on Indian Point Unit 2. The Verplank Fire District, which includes the Indian Point Nuclear Plant, had an $8.21 tax rate per $1000 of assessment (Town of Cortlandt 1990b). The assessment of Indian Point Unit 2 is approximately 5.76 percent of the fair market value of the property. The existing tax rate is 0.123 in the village of Buchanan and an additional 0.245 in the town of Cortlandt, which is a combined effective tax rate of about 2.1 percent on fair market value. Westchester County does not receive tax revenues from Indian Point.

Table C.54 presents the taxes paid by Indian Point Unit 2 and the payments in lieu of tax from Indian Point Unit 3. The Hendrick Hudson School District is the only special taxing jurisdiction detailed because it receives such a large share of local tax revenues. These tax revenues indicate that Indian Point Unit 2 has been an increasing source of tax revenues, whereas Indian Point Unit 3 has been declining in importance as a source of revenues. The net effect has been a fairly constant stream of revenues. Indian Point Unit 3 will continue to decline as a source of revenues according to a formula that reduces each annual assessment by 2 percent of the total property tax assessment in the village of Buchanan and the Hendrick Hudson School District.

Table C.55 demonstrates that the tax base provided by the Indian Point Nuclear Plant is very important to the town of Cortlandt, the village of Buchanan, and the Hendrick Hudson School District. Together, Indian Point Units 2 and 3 make up the majority of each jurisdiction's total assessed valuation; but Buchanan, where 91.8 percent of the total assessed value is provided by Indian Point Units 2 and 3, is the most notable. The town of Cortlandt does not receive revenue from Indian Point Unit 2 except for the Verplank Fire District. The fire district had a transitional assessed value for Indian Point Unit 3 of about $10 million in 1990, which translated into $81,464 in lieu of tax revenues. The Hendrick Hudson School District has about 5 percent of its assessed value attributed to Indian Point Unit 3, and the village of Buchanan has about 29 percent of its value from Indian Point

Unit 3. Indian Point Unit 3 will cease to be a source of revenues for the school district within about 2 years and will continue to gradually decline in importance as a source of revenues for the village of Buchanan and the Verplank Fire District as a result of the assessment formula previously noted.

Table C.56 provides the total revenues and revenues received from Indian Point for each taxing jurisdiction. The contribution Indian Point makes to the total revenues of each of these jurisdictions is significant and ranges from 33.3 to 49.6 percent.

The practical effect of the property tax valuation of Indian Point and the resulting revenues has been the local government's ability to maintain a high level of service with relatively low property tax rates. For instance, the Hendrick Hudson School District has an average of 11 students per teacher (on par with most Westchester County school districts and considerably lower than the statewide average) (New York State Education Department 1990) while having the third lowest rate of taxation out of 40 school districts in Westchester County.

C.4.4.3.2 Predicted Impacts of License Renewal

The new tax-related impact expected to occur during refurbishment of Indian Point results from capital improvements undertaken during the current term outages. The assessed value of the plant would increase during this time and thus increase the tax payments of Indian Point Unit 2 to local jurisdictions. Whether PASNY would have to pay additional taxes (or payments in lieu of tax) to local jurisdictions because of improvements to Indian Point Unit 3 is unknown. This new impact does not involve capital improvements that take place during the final refurbishment outage, and that would be reflected in the plant's assessed value during the license renewal term. The magnitude of the new impact depends on which improvements would occur at Indian Point early on and which would be done during the final outage. For example, if the steam generator is replaced during a current term outage, the assessed value may increase considerably before the license renewal term begins. If steam generator replacement and other major capital improvements are not undertaken early on, the increase in assessed valuation may be only minor. The increase, in either case, is expected to cause only a small to moderate new tax impact.

During the license renewal term, the primary tax-related impact would be the continuation of tax payments that Indian Point Unit 2 is currently making to local jurisdictions. Again, it is unclear whether taxing arrangements regarding Indian Point Unit 3 would change so that PASNY would make payments to local jurisdictions during the license renewal term. There would also be a new impact resulting from the increase in tax payments because of improvements made at Indian Point during the final refurbishment period. Thus, tax revenues of Indian Point Unit 2 would increase in absolute terms but might remain constant or decrease as a percentage of total revenues of the taxing jurisdictions. Based on current conditions, Indian Point Unit 2 tax revenues—the continuing and additional payments combined—would continue to be a large source of local revenues during the license renewal term and would allow local taxing jurisdictions to maintain adequate levels of local government service, including education and highways.

C.4.4.4 Public Services

C.4.4.4.1 Impacts from Plant Construction and Operation

Westchester County is divided into towns and villages. All social services are provided by the county. Schools are divided into districts (43 in the county), with town governments having no involvement in the education. One village, Buchanan, made strategic plans during the construction of the plant for growth of its infrastructure. Buchanan experienced good fiscal growth, and several services were made possible as a direct result of the Indian Point Nuclear Plant.

Education

The state of New York is divided into numerous school districts. School districts within 0.8 km (0.5 mile) of Indian Point are the Lakeland School District, Peekskill School District, Hendrick Hudson School District, and the Croton Harmon School District. Indian Point is located in the Hendrick Hudson School District.

The Hendrick Hudson School District had the same number of schools before the construction of the plant. However, two of the elementary school buildings were replaced, one in 1965 and the other in 1974. The local school administrator indicated that the construction and operations phases of Indian Point have not had an effect on schools in the district. An increase in enrollment was concurrent with the development of Indian Point. However, there was also a nationwide baby boom at this time, so this enrollment cannot be directly linked to the plant.

Local school officials in each of the school districts were interviewed, and the overall finding was insignificant impacts because of the construction or operation of the plant. The Croton Harmon director of pupil services indicated very little change since the construction of the plant. The Lakeland School District experienced substantial growth in the 1950s and 1960s, reaching a peak enrollment in 1973. Although this growth occurred at roughly the same time as the plant construction, the construction itself did not have a major effect on the district. The Lakeland School District has been more heavily influenced during operations by industry in the Poughkeepsie and Yorktown area as opposed to the operation of the plant.

Transportation

Transportation in Westchester County consists of approximately 240 km (150 miles) of county roads and more than 970 km (600 miles) of state roads. Local officials interviewed gave no indication of major problems stemming from the construction or the operations of Indian Point Nuclear Plant.

Public Safety

Some municipalities have local police departments, whereas others contract with the New York State Police for police protection. Individuals interviewed in the municipality of Buchanan indicated that because of the fiscal growth associated with Indian Point, the services and staff of the village also grew. For instance, the police force has essentially doubled in size. More than 70 percent of the fire departments are on a volunteer basis. Local emergency management is operated through the Office of Defense and Emergency Services.

A four-county nuclear safety committee is in the area, with Westchester County being the lead county. An in-depth plan is in place, and the department works closely with the state, the Federal Emergency Management Agency (FEMA), ConEd, and PASNY. One major drill and 10 to 20 mini-drills are conducted each year. Money for this department comes from assessment of Indian Point and from the county government.

Social Services

Social services are provided for at a county level. Local officials interviewed stated that since plant operations began, there had been no increase in the demand for services from the department. However, it was indicated that more staff was required in the beginning to develop a new emergency plan for the county. Some municipalities have senior citizen programs or "Meals on Wheels.".

Public Utilities

Two power companies supply gas and electricity to Westchester County. Water in the area is provided by the Montrose District. Some of the smaller municipalities have a split between private and public sewer systems. Local officials interviewed gave no indication of any impacts from the construction or operation of Indian Point.

Tourism and Recreation

Local leaders interviewed indicated no change in tourism. Most people do not remember the plant is even there. The county operates an extensive park system of 65–78 km^2 (25–30 square miles). The plant did, however, provide one municipality with the capability of building a recreation complex and a public pool.

Indian Point now has an emergency preparedness plan in effect. This plan is noteworthy to the tourist industry because it not only accounts for the needs of the residents near the plant but also addresses plans for evacuating the transient population and tourists in the area.

ConEd operates an information center at the plant site. This center is visited mostly by school and tour groups. At the plant, visitors can see the control room, watch films, and see hands-on exhibits.

C.4.4.4.2 Predicted Impacts of License Renewal

Based on the estimated 2273 direct workers required during peak refurbishment, the staff estimates that 122 direct workers and 40 indirect workers will migrate with their families to the study area counties (Section C.4.4.1.2). The number of children accompanying these workers is estimated using the New York average family size (3.22) and assuming that all families include two adults. Children are expected to be evenly distributed in age from ≤1 to 18 years. Assuming 72.2 percent of these children are school age (5 to 18 years), there will be an average of 0.88 school-age children per in-migrating family, or a total of 144 new students in the study area counties. This would represent a tiny increase in the school enrollments of the study area counties, even if all new students were concentrated in one school district. Impacts to education, if any, will be small.

During construction and operation of Indian Point, there were no notable impacts on any of the public services. Future impacts are projected to be largely the same as those that occurred during past operations.

C.4.4.5 Off-Site Land Use

This section describes the off-site land-use impacts of the construction, operation, and license renewal of Indian Point. The discussion of impacts is primarily concerned with land use in the immediate vicinity of the plant, but impacts to the town of Cortlandt, the villages of Buchanan and Peekskill, and Westchester County are described where appropriate. Land-use impacts are examined for two time periods. First, Section C.4.4.5.1 identifies the land-use impacts of Indian Point's construction and operation. Next, Section C.4.4.5.2 projects the land-use impacts of Indian Point's refurbishment period, based on the impacts that occurred during the plant's construction. Also, Section C.4.4.5.2 projects the land-use impacts of the plant's license renewal term, based on the impacts that have occurred during operations. Information sources for this report include the *Final Environmental Statement Related to the Operation of Indian Point Nuclear Generating Plant, Units 2 and 3* (AEC Dockets 50-247 and 50-286) and interviews with key information sources in Westchester County. Section C.4.1.5 describes the methods used to assess and project land-use impacts for all case study plants.

C.4.4.5.1 Impacts from Plant Construction and Operation

Indian Point is located on a 96.7-ha (239-acre) site on the Hudson River. Before the beginning of Indian Point's construction in 1956, the plant property was the abandoned site of the Palisades Amusement Park, and much of the surrounding property was vacant. By the time Units 2 and 3 began operations, land in the immediate vicinity of the plant site had been zoned for heavy industrial use, and some of it had been developed. The Georgia-Pacific Corporation operated a wallboard factory just southwest of the Indian Point site, and a number of industrial facilities were owned by the Standard Brands Corporation in Peekskill, just north of the nuclear plant's property boundary. The plant site was bounded by Broadway, a minor public road, to the east and by the Hudson River to the west. In Buchanan, land use in the plant's general vicinity consisted mostly of low-density, single-family residential development and some limited commercial uses. The mountainous, wooded property on the west bank of the Hudson across from Indian Point was part of the Palisades Interstate Park and was mostly devoid of development.

Indian Point's construction had very minor direct land-use impacts on property in the immediate vicinity of the plant. The abandoned amusement park site provided more than adequate land area for the three units and their associated buildings and storage facilities. Because the site was so large and had been developed previously, the disruption of additional property outside the park's boundaries was not necessary (AEC Dockets 50-247 and 50-286).

However, the plant's construction did have noticeable direct land-use impacts on the village of Buchanan. Since the late nineteenth century, development along the Hudson River near Buchanan had been made up largely of river-oriented commercial land uses such as quarrying. But by the time Indian Point's construction began, much of this commercial development had slowed to a halt. The commercial void turned Buchanan into an economically depressed area with no industrial development to support the existing residential land use. According to one key informant, Indian Point's construction gave Buchanan the opportunity to develop industrial properties.

This was because the village had rezoned much of its land along the river to the industrial classification for Indian Point's construction, and some of the surrounding property was subsequently developed for other industrial uses. The industrial growth included the Georgia-Pacific and Standard Brands facilities south and north of Indian Point, respectively. This new development helped bolster Buchanan's economy and established the industrial land-use pattern that has dominated development along the Hudson in Buchanan since Indian Point's construction.

Indian Point's operation has also had noticeable land-use impacts in the immediate vicinity of the plant, in the town of Cortlandt and in Buchanan and Peekskill. Some informants stated that the plant, and especially its transformers and transmission lines, might have deterred some residential development in Buchanan. This is one explanation offered for the existence of some large, vacant properties near the plant. The informants cited development pressures and the demand for housing in the region, as well as the favorable location of the properties in terms of transportation routes and the Hudson River, and asserted that the plant's presence might account for the fact that the properties are not developed. Conversely, some informants felt that Indian Point's local tax contributions had allowed the town of Cortlandt and the village of Buchanan to maintain relatively low property tax rates and that this had encouraged new residential development. Either way, Buchanan is still primarily a residential area, with some relatively expensive homes built within 1.5 km (1 mile) of Indian Point. Because residential growth has continued in Buchanan within a short distance of Indian Point, the overall land-use impacts of the plant's presence seem to be neutral in terms of residential development patterns.

Key sources also indicated that the nuclear plant's presence and the industrial development that it helped spawn in Buchanan had helped encourage industrial development in Peekskill. North of Indian Point, the village of Peekskill has developed the old Standard Brands complex into the Charles Point Industrial Park. The Charles Point complex, which is the site of the Charles Point Resource Recovery Plant (the county's waste disposal facility), has been very successful in attracting small industries. Indian Point's successful location and operation encouraged the villages of Buchanan and Peekskill to promote industrial development around the nuclear plant and at Charles Point. This development has established industry as the dominant land use along the river in the two villages. In general, operations at Indian Point have had noticeable impacts on both residential and industrial development patterns in Buchanan and Peekskill.

C.4.4.5.2 Predicted Impacts of License Renewal

The direct impacts of Indian Point's refurbishment and license renewal term on land use in the immediate vicinity of the plant, in Buchanan and Peekskill, and in Westchester County are expected to be small. Refurbishment-related population growth is projected to represent less than 0.1 percent of Westchester County's projected population in 2013. Population growth associated with the license renewal term is also projected to account for less than 0.1 percent of the county's projected population in 2013. Increases this small during refurbishment and the license renewal term are likely to have no impacts in terms of residential development patterns.

Because much of the land in the plant's vicinity has been zoned for industrial use and because the industrial land-use pattern has become well established along the river in Buchanan, it is expected that the area would continue to attract some industrial development. This is especially true for the Charles Point Industrial Park, which would continue to cater to smaller, light industries and warehouse operations. Also, there are two large, vacant properties, one zoned for manufacturing and the other for light industry, in Buchanan near Indian Point. The parcel zoned for light industrial use is adjacent to the Indian Point property and is currently being developed as warehouse space. Because the residential and industrial land-use patterns that exist in Buchanan have been established for many years, Indian Point's new direct land-use impacts are expected to be small.

The indirect land-use impacts of the license renewal term at Indian Point are also expected to be small. This is because Indian Point Unit 3 was acquired by PASNY in 1978, and the authority has been making annually decreasing payments in lieu of tax to the local jurisdictions since that time. Thus, the village of Buchanan and the town of Cortlandt have had to increase their property tax rates to compensate for losing those portions of their tax bases that had been provided by ConEd for Unit 3. Key informants felt that this increase in property tax rates had already caused a decrease in the demand for residential development in the area and that this indirect land-use impact is likely to continue. Overall, however, Indian Point's refurbishment and license renewal term are expected to have small direct and indirect land-use impacts.

C.4.4.6 Economic Structure

C.4.4.6.1 Impacts from Plant Construction and Operation

The construction and operation of Indian Point have resulted in insignificant economic impacts to Westchester and Dutchess counties. Table C.57 presents the estimated employment and income effects of Indian Point on residents of the two counties. The plant has increased employment and income for residents employed during its construction and operation, and this direct employment and income has generated local expenditures resulting in indirect employment and income. But the percentage of each county's employment and income that is derived from Indian Point indicates the insignificance of the plant's economic impacts on the counties.

C.4.4.6.2 Predicted Impacts of License Renewal

The work force scenario detailed in Section C.3.1 was used to estimate the employment and economic effects of refurbishment at Indian Point. Table C.58 shows the total direct and indirect plant-related employment of Dutchess and Westchester county residents during refurbishment.

It is projected that Indian Point would employ 393 Dutchess County residents and 289 Westchester County residents as refurbishment workers in 2012 (Section C.4.4.1.2). Indirect jobs that would result from purchases of goods and services during refurbishment are expected to employ 591 residents of each study area county.

Therefore, the total direct and indirect employment affecting Dutchess County during the peak refurbishment year is projected to be 984. This employment is projected to represent 0.5 percent of the total employment in Dutchess County in 2012, resulting in small impacts.

There would be smaller employment impacts in Westchester County, assuming the bounding case work force scenario. The total direct and indirect employment affecting Westchester County during the peak refurbishment year is projected to be 880. It is projected that this would represent only 0.2 percent of the county's employment in Westchester County in 2012. The impacts to employment in Westchester County are expected to be small.

Relatively few new plant-related jobs would be created at Indian Point during the license renewal term. Nearly all plant-related employment (and associated impacts) expected during that time period would represent a continuation of employment (and impacts) from past operations. Table C.59 shows the estimated impact on Dutchess and Westchester counties from the increased labor requirements at Indian Point after refurbishment in 2015.

The license renewal term work force for Indian Point would require an estimated 120 additional employees (Section C.4.4.1.2). Of those additional workers, 45 are projected to be Dutchess County residents and 33 are projected to be Westchester County residents. In addition, license renewal is expected to create indirect jobs for 45 Dutchess County residents and 33 Westchester County residents. With the continued effects of the plant's current employment and the additional employment to be created, total license renewal term employment is estimated to represent 0.60 percent of Dutchess County employment, resulting in small impacts. Total license renewal term employment is projected to represent 0.13 percent of Westchester County employment, also representing small impacts.

Table C.59 indicates that the economic effect of Indian Point on Dutchess and Westchester counties is small in relative terms but is still a crucial component of employment for the town of Cortlandt, the village of Buchanan, and the Hendrick Hudson School District in Westchester County. License renewal would also maintain Indian Point as a source of property tax revenues, which could enable these localities to maintain lower residential and business tax rates and thereby attract economic development.

C.4.4.7 Historic and Aesthetic Resources

This section describes the impacts that the construction and operation of Indian Point have had on historic and aesthetic resources and projects the expected impacts of the plant's refurbishment and post-relicensing operations. Information sources include the *Final Environmental Statement Related to Operation of Indian Point Nuclear Generating Plant, Unit 2* (AEC Docket 50-247), *Final Environmental Statement Related to Operation of Indian Point Nuclear Generating Plant, Unit 3* (AEC Docket 50-286), and interviews with key information sources in Westchester County and elsewhere in New York.

C.4.4.7.1 Impacts from Plant Construction and Operation

The construction and operation of Indian Point have had noticeable impacts on historic resources and significant impacts on the aesthetic resources of the area. The site is located within 40 km (25 miles) of the city limits of New York City, in affluent and influential Westchester County, arguably the birthplace of the country's environmental movement. The plant is built near the gateway to the Hudson Highlands, one of only two highly scenic areas remaining along the Hudson River between New York City and Albany that retains much of the nineteenth-century appearance and character. The area is important historically as a locale for American Revolutionary War battlefields and activities and is located near the U.S. Military Academy at West Point. One informant characterized this importance as being "extreme," both statewide and nationally. Another characterizes the Indian Plant environs as being "one of the most important historic areas in the state." It should be noted that the plant is visible from very few historic resources, based on a viewshed analysis (Jones & Jones 1975).

The plant's location—on the east banks of a point of land near a large bend in the Hudson River—accentuates the visibility of its containment vessels. Although the general area, particularly north of the plant, is noted for its scenic quality, the immediate plant environs has other industrial uses that detract from the overall scenic context. The whole facility is easily viewed by passengers riding the heavily traveled Amtrak trains running between New York City and Albany. One informant characterizes this impact alone as a "big visual impact." Several sections of the Palisades Interstate Park on the west bank of the Hudson River are at this point, as well as parks and beaches on the east bank and various fishermen's landings. Both commercial and pleasure boating predominate in this area of the Hudson River.

Repeated comments from key sources document the uniform sense of intrusion that the plant has given to the area's aesthetic quality. Among the chief concerns has been the visibility of the plant from Harriman State Park and Bear Mountain State Park.

The impact results from the effect of strong visual symbols of twentieth-century technology such as the three identical large domed containment structures near the entry to an area (Hudson Highlands) that is largely nineteenth-century in appearance. Although the plant was designed to present a pleasant and attractive appearance, and the general site plan includes a freshwater lake, a new visitors' center, and a 30-ha (80-acre) woodland recreational facility (AEC Dockets 50-247 and 50-286), these amenities have not proved sufficient to overshadow the plant's perceived intrusion into the area's sense of place and historic character. One source summarizes this situation: "The visual impact affects the historic river communities in a broad sense. You can see the plant from so many areas that it has diminished the historic character of the areas and the aesthetic appeal in general. It definitely intrudes and disturbs the overall sense that one gets from viewing the area."

Archaeological sites at or near the power plant already were disturbed severely before construction of the plant, and the impacts from plant construction and operation here are considered to have been insignificant (AEC Docket 50-247). The National Register of Historic Places (including designated National Historic Landmarks) and the Hudson River Valley Commission's preliminary inventory of historic resources list numerous buildings and sites within several kilometers of Indian Point, but none has been directly affected by the plant's construction (AEC Docket 50-247). Many structures are not listed and are thereby unprotected in any planning processes, but they have considerable historic value nonetheless; many of these may be eligible for listing but have not undergone the lengthy qualification process. The noticeable impacts have come from the indirect impacts to these and other historic resources. In what may be an isolated anecdotal account, one respondent cited this experience: one homeowner was encouraged to restore a building that had historic value but declined, discounting the building's significance because of its proximity to the plant.

C.4.4.7.2 Predicted Impacts of License Renewal

Refurbishment and relicensing of Indian Point would probably mean a continuation of the persistent negative perception of the plant's effects on aesthetics and historic resources. The relicensing process and the refurbishment activity would likely bring the plant to the public's awareness and provide a gauge of the degree to which the public has become adapted to and accepting of the plant. The plant's continued presence most likely would continue to remind recreationists and other viewers of the presence of this modern technology among the river communities and historic features of the areas, a fact that to this point has been perceived as negative. One informant states that if the Indian Point facility were being proposed now, its proponents would have a "large fight on their hands from the aesthetics point of view."

Potential impacts to historic resources must be determined through consultation with the SHPO.

C.4.5 Oconee

The impact area—the locations where the most pronounced socioeconomic impacts might result from refurbishment and license renewal—for the Oconee Nuclear Station (ONS) consists of Oconee County, South Carolina. The selection of this area is based on worker residence patterns, employment, expenditures, and tax payments. Figure C.12 depicts the impact area, and Figure C.13 shows the region in which it is located.

C.4.5.1 Population

This section discusses the local population growth associated with the construction, operation, and license renewal of ONS. Section C.4.1 describes the methodology used to project population growth for all plants. Data used to prepare this section were obtained from *Socioeconomic Impacts of Nuclear Generating Stations: Oconee Case Study* (NUREG/CR-2749, vol. 7); *Environmental Assessment Proposed Rule on Nuclear Plant License Renewal* (NUREG-1398); SEA refurbishment work force estimates (Appendix B; SEA 1994); population projections by the State of South Carolina Division of Research and Statistical Services; and Duke Power Company (1990).

The discussion of population growth is organized into two time periods. Section C.4.5.1.1 identifies the population growth that Oconee County has experienced as a result of the construction and operation of ONS from 1967 to 1990. Section C.4.5.1.2 projects the population growth expected to result from ONS's refurbishment period and license renewal term operations beginning in 2013 (Units 1 and 2) based on the growth associated with the plant's initial construction. Also, Section C.4.5.1.2. projects the population growth expected to result from ONS's license renewal term based on the growth associated with operations.

C.4.5.1.1 Growth Resulting from Plant Construction and Operation

ONS's construction resulted in small population increases in Oconee County

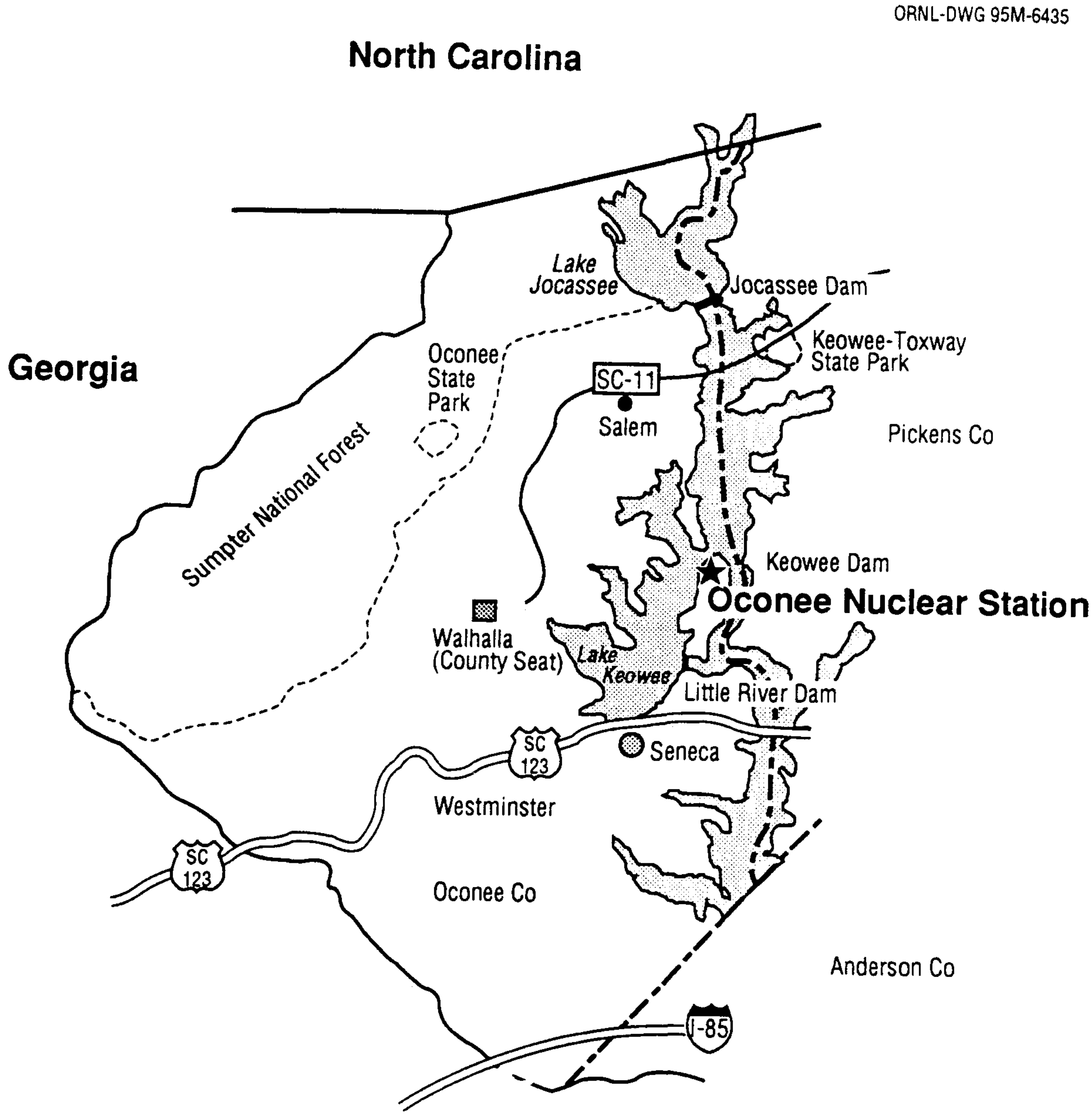

Figure C.12 Socioeconomic impact area associated with Oconee Nuclear Station refurbishment: Oconee County.

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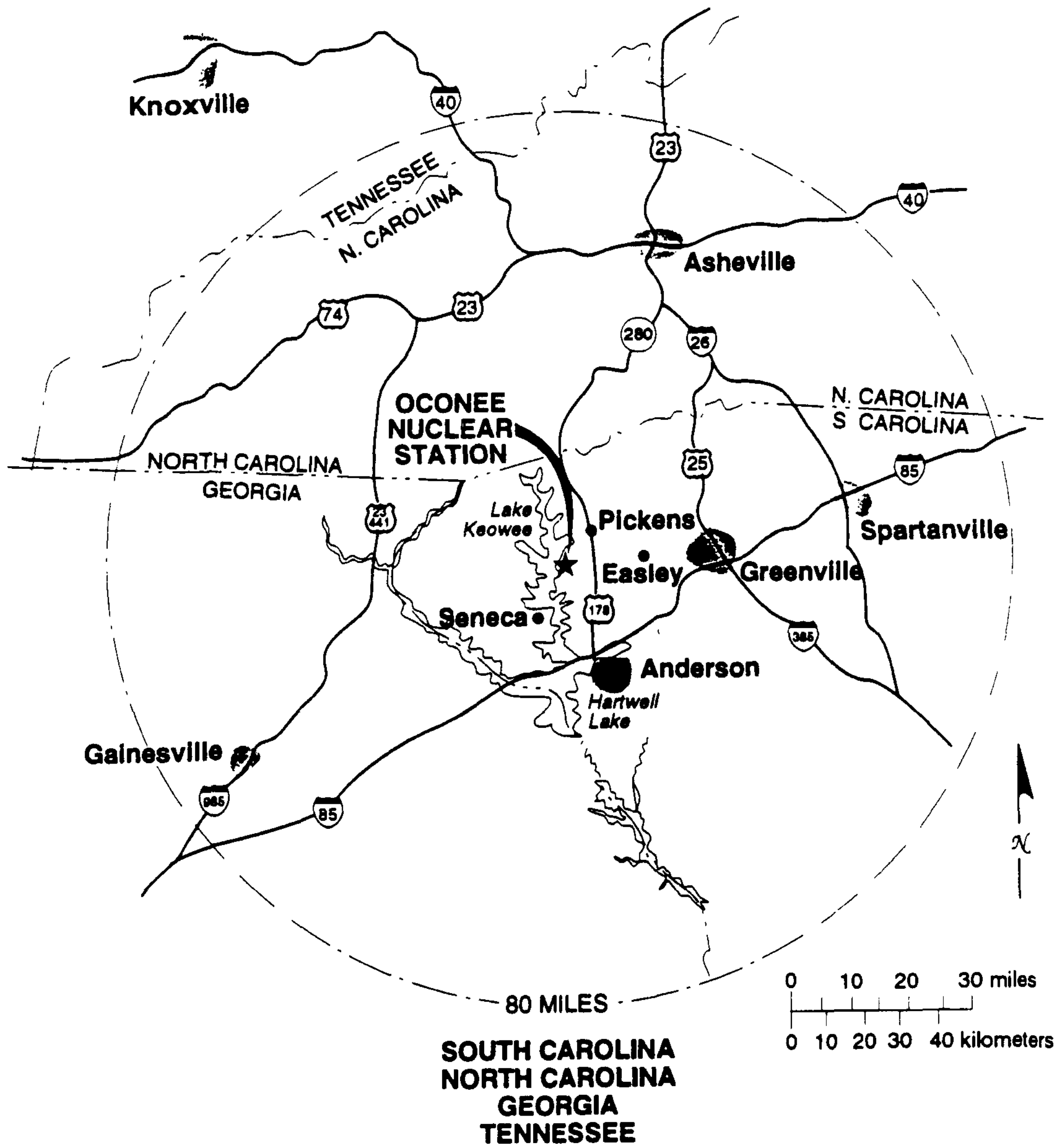

Figure C.13 Region surrounding the Oconee Nuclear Station nuclear plant.

(Table C.60). During the peak construction year, 1971, ONS personnel and their families who migrated to the area to work at the plant, and others who moved into the area to work in jobs generated by the plant's presence, totalled approximately 701 persons. This influx of new residents represented 1.7 percent of Oconee County's total population in 1971 (NUREG/CR-2749, vol. 7, p. 89).

Operations at ONS have resulted in smaller population increases than did the plant's construction. In 1990, 2300 permanent plant staff were on-site at ONS (this figure includes regular plant staff and Duke Power's Construction Department, which was permanently located on-site at ONS in 1985). In past operating years, additional contract workers have been on-site for planned outages, but they have not been included here because their presence at the plant was temporary.

Of the permanent plant staff, 50 percent (1150) reside in Oconee County (Duke Power Company 1990). Based on the residential settlement pattern of ONS's 1975 work force, it is estimated that 83.6 percent (961) of those residing in Oconee County in 1990 were prior residents who obtained jobs and that 16.4 percent (189) were workers who migrated into the area for jobs (Table C.61). Also following the pattern set during plant operations, it is estimated that 77 percent of the in-migrants (146) were accompanied by their families. Assuming the 1990 South Carolina average family size of 3.16 persons, this represents a total in-migration of 504 new residents for the county. Based on the distribution of nonplant jobs created in Oconee County during earlier operating periods, it is estimated that ONS's 1990 operations created an additional 948 indirect jobs in service industries supported by the spending of Oconee workers. However, it is assumed that no additional residents moved into Oconee County for these indirect jobs, as all additional employment opportunities are expected to have been filled by persons who resided in Oconee County or by long-distance commuters. In all, an estimated 504 new residents moved into Oconee County as a result of ONS's 1990 operations (Table C.61). These new residents made up about 0.9 percent of Oconee County's 1990 population of 57,494 (NUREG/CR-2749, vol. 7, pp. 65–87; MacFarlane 1990).

C.4.5.1.2 Predicted Growth Resulting from License Renewal

As discussed in Section C.3.1, ONS's license renewal would require the completion of a number of refurbishment tasks for Units 1, 2, and 3. Many of the refurbishment tasks are expected to be completed during scheduled refueling outages at each unit during the 10 years that precede the expiration of the initial operating license. However, the final refurbishment work is expected to be completed during one large refurbishment outage scheduled for each unit a year or two before the initial operating license expires. Because the final refurbishment outage would involve more workers on-site over a longer period of time than any of the preceding refueling outages, it represents the peak refurbishment period. For other assumptions concerning the refurbishment work force, refer to Sections C.3.1 and C.4.1.1.2.

Assuming the refurbishment schedule described in Section C.3.1, the peak refurbishment years for ONS Units 1 and 2 would probably be 2011 and/or 2012, and the peak refurbishment year for ONS Unit 3 is expected to be 2013. For each unit, the on-site refurbishment work force would be about the same size and would be on-site for approximately the same period of time (refer to Section 6.4.1.1.2 for other work force assumptions). However, because uncertainties exist concerning the length of the outage and the size of the work force required to complete the refurbishment of a given unit, this section examines a bounding case work force scenario as described in Section C.3.1.

Given the work force scenario detailed in Section C.3.1, it is estimated that 2273 workers would be on-site to complete refurbishment of ONS Units 1 and 2 in 2011 or 2012 and Unit 3 in 2013 (SEA 1994). Further, assuming that the residential distribution of refurbishment workers would be similar to that of the 1971 ONS construction work force, it is estimated that 25.4 percent (577) would reside in Oconee County. Based on plant construction experience, it is projected that 50 percent (230) of those residing in Oconee County would be prior residents who obtain refurbishment jobs, and 289 would be workers who migrate into the area for refurbishment jobs (Table C.62). Also following the pattern set during plant construction, 33.3 percent of the in-migrants (96) would be accompanied by families. Using the South Carolina average family size of 3.16 persons, total refurbishment worker in-migration would result in 496 new residents for the county. Based on the ratio of plant to nonplant jobs created in Oconee County in 1971, ONS's refurbishment is projected to create an additional 118 indirect jobs in service industries supported by the spending of ONS refurbishment workers (Table C.62). However, no additional residents are expected to move into Oconee County for these indirect jobs, as all additional employment opportunities would be filled by persons who already reside in the county or by long-distance commuters. In all, approximately 496 new residents would be expected to move into Oconee County as a result of ONS's refurbishment under the work force scenario. That would represent 0.7 percent of Oconee County's projected population of 73,542 in 2013 (NUREG/CR-2749, vol. 7, pp. 62–86).

Once plant refurbishment is completed for ONS Units 1, 2, and 3, the work force would consist mostly of permanent plant staff. Additional refurbishment/refueling workers would be temporarily on-site approximately every 2 years, but they would not be permanent, on-site plant staff, and many of them are expected to commute from outside the study area. It is expected that a maximum of 60 additional permanent workers per unit would be required during the license renewal term, adding 180 workers to ONS's existing work force. Assuming that the new workers' residential distribution would be the same as that of current plant staff, approximately 50 percent (90) would reside in Oconee County. Based on worker in-migration in 1975, it is expected that 83.6 percent (75) of those residing in Oconee County would be prior residents who obtain jobs and 16.4 percent (15) would be workers who migrate into the area for jobs (Table C.63). Also following the pattern set during plant operations, 77 percent of the in-migrants (12) would be accompanied by their families. Using the South Carolina average family size of 3.16 people, total in-migration would result in 41 new residents for the county. Based on the ratio of plant to nonplant jobs created in Oconee County in 1975, ONS's license renewal term is projected to create an additional 74 indirect jobs in service industries supported by the spending of ONS workers (Table C.63). However, no additional residents would be moving into Oconee County as a result of these indirect jobs, as they are expected to be filled by county residents and commuters. In all, approximately 41 new residents would be expected to move into Oconee County as a result of ONS's license renewal term. That would represent less than 0.1 percent of Oconee County's projected population in 2013 (NUREG/CR-2749, vol. 7, pp. 62–86).

C.4.5.2 Housing

The following sections examine the housing impacts that occurred in Oconee County during construction and operation of ONS and predict housing impacts that would result from refurbishment activities and continued operation. Possible impacts to housing include changes in the number of housing units, particularly the rate of growth of the housing stock; changes in occupancy rates; changes in the characteristics of the housing stock; and changes in rental rates or property values.

Section C.4.1.2 includes a complete discussion of the methodology and assumptions used to predict housing impacts.

C.4.5.2.1 Impacts from Plant Construction and Operation

The following discussion begins with a description of project-related housing demand in Oconee County. A discussion of the housing market at the time of ONS construction and changes that occurred in the housing market follows. Finally, impacts from the operation of ONS are assessed.

Project-related population increase and commensurate demand for housing in Oconee County peaked in 1971, when the average annual employment at ONS reached 2342. Project-related population increase in Oconee County was 701 persons (including family), while off-site housing demand reached 167 units (NUREG/CR-2749, vol. 7). Population increase was kept low because of Duke's local hiring policy. Also, Duke Power provided on-site "bachelor's quarters" accommodating 150 workers. Thus, project-related demand for housing was quite low relative to the peak number of employees. Project-related demand at its peak in 1971 accounted for 1.2 percent of the 1970 Oconee County year-round housing stock.

The 1970 Census reported a 3.0 percent vacancy rate, or 411 vacancies, either for sale or rent in Oconee County (U.S. Bureau of the Census 1972). These vacancies existed despite a project-related demand for 85 units in 1965 and 145 units in 1970. These vacancies, together with continued expansion of the housing stock in 1970 and 1971 and the proximity of the metropolitan areas of Greenville and Anderson, were adequate in meeting project-related demand.

Changes in the housing stock experienced during construction include an increase in the number of multifamily units and the number of mobile homes. In the intercensal period 1970–80, a net increase of 315 multifamily units occurred in Oconee County (U.S. Bureau of the Census 1972, 1982). This was a 41.2 percent increase over the 1970 multifamily stock. The most significant change was the addition of structures with four or more units. The period of quickest growth in this housing type occurred between 1971 and 1974, when 248 multifamily units were built in Oconee County (NUREG/CR-2749, vol. 7). The number of mobile homes in Oconee County doubled in the intercensal 1970–80 period, so that by 1980 there were 2881 mobile homes (U.S. Bureau of the Census 1972, 1982).

The median monthly rental rates in Oconee County were $37 in 1960, $36 in 1970, and $90 in 1980. The median rental rates in

South Carolina for the same years were $32, $50, and $130. Rental rates in Oconee County increased at a slower rate than those in the state of South Carolina despite the addition of numerous new multifamily units in Oconee County. Local perception is that the rental rate of nonsubsidized units, which ranged between $120 and $250 per month in 1979, increased beyond inflation-induced effects because of the increased demand for housing and because in-migrants had incomes larger than local residents (NUREG/CR-2749, vol. 7).

In summary, housing in Oconee County adequately met project-related demand, and little change in housing characteristics or value resulted because of project-related demand. Construction-related impacts on housing were insignificant.

The operation of ONS has had only insignificant impacts on housing. Lake Keowee has attracted substantial residential development; however, the plant itself has had no substantial effect on development. Occasionally, a new home is built for operation workers. The values of properties in the vicinity of the plant have not been negatively affected by its operation.

C.4.5.2.2 Predicted Impacts of License Renewal

Project-related population increase and the commensurate housing demand would be the cause of new housing impacts during refurbishment activities. This section summarizes recent and anticipated growth in housing and estimates possible housing impacts during refurbishment and the license renewal term.

Between 1970 and 1980, the number of housing units in Oconee County increased 44 percent above the 1970 housing stock (U.S. Bureau of Census 1972, 1982). Residential development occurred primarily along the Keowee Lake. The rate of growth slowed somewhat during the 1980s, so that the 1980 housing stock increased by 28.5 percent between 1980 and 1990. If the rate of growth experienced in the 1980s continues through 2010, shortly before the peak refurbishment year, there will be 42,900 housing units in Oconee County. The projected population of Oconee County in 2013 is 73,542 and will require 28,840 housing units. Although adjustment in housing growth will be made according to population growth, the current rate of growth suggests that there will be available housing in Oconee County during refurbishment activities.

According to the estimate of the number of workers required for refurbishment activities and based on plant construction experience, 289 workers of the total work force of 2273 are expected to migrate to Oconee County for refurbishment jobs. Of these in-migrants, 96 would be accompanied by families. Some doubling-up is expected to occur among the remaining 193 in-migrants, so that each mover would require 0.85 housing unit. Worker migration to Oconee County would result in a total project-related housing demand in the peak year of refurbishment of 260 housing units.

Refurbishment-related housing demand is greater than the construction-related housing demand of 167 units, but the number of housing units in Oconee County will have increased 200 percent between construction and refurbishment periods. Housing demand would account for about 0.6 percent of the possible 42,900 housing units in Oconee County during refurbishment. Because demand in the bounding case scenario would be so small relative to the existing housing market and because impacts would be even less than those experienced during plant construction, refurbishment-related housing demand is expected to have only small new impacts on the Oconee County housing market.

Housing impacts related to housing value and marketability that would occur during the license renewal term are the same as those currently being experienced (Section C.4.5.2.1). The 180 additional workers (60 per unit) required during the license renewal and the commensurate housing demand would cause only small new housing impacts.

C.4.5.3 Taxes

C.4.5.3.1 Impacts from Plant Construction and Operation

Oconee County is the only political jurisdiction that taxes ONS. Besides collecting taxes for its own use, the county collects property tax levies for the Oconee School District. The state of South Carolina appraises electric utility property, including ONS, using the unit valuation method. This method assigns a value to the licensee's power plant based on the historical cost of assets less depreciation; capitalization of a future income stream over a 3-year period; and stock value and debt approach over a 3-year period. After exemptions for nontaxable assets, the value is apportioned to the local jurisdiction by gross investment. Much of the information used in the appraisal is from Federal Regulatory Commission Form 1, which is public information. The appraised value is multiplied by 10.5 percent to calculate the assessed value that the county uses to apply tax rates.

The power plant has been an important source of revenue for Oconee County (Table C.64). The county received about $7.6 million in taxes from the licensee in 1975 (constant 1989 dollars) and about $6.6 million in 1989. In 1975, property tax from the licensee accounted for about 50 percent of property taxes in the county and about 25 percent of total revenue. Oconee County's assessments increased from $111 million in 1975 to approximately $173 million in 1989, with the licensee's contribution in terms of total tax revenues falling from 50.1 percent to 29.1 percent, still demonstrating a heavy reliance by the county on the power plant. In the same time period, the power plant's portion of total county revenue fell from nearly 25 percent to 14.2 percent.

The Oconee School District has had strongly increasing revenues from state and local sources. In 1981, total revenues were approximately $20.2 million (1989 dollars). By 1989, total revenues were approximately $32.8 million. The contribution to school district taxes from the licensee increased from about $3.5 million to $4.6 million from 1981 to 1989. While this was a declining percentage of the total Oconee School District revenues (from 18 percent to 14 percent over this period), the power plant still had a moderate impact.

The overall trend has been a decline in the importance of ONS as a direct, primary source of revenues and taxes. This trend has been the result of strong economic growth in Oconee County and the much higher county property assessments that ensued. Also, Oconee School District revenues have sharply increased, partly as the result of state programs promoting improved education.

The tax effects of the power plant have been quite favorable to the local school district. For instance, in the 1987–88 school year, Oconee School District ranked 10th out of the 91 school districts in South Carolina in assessed value per pupil. The Oconee School District ranked 82nd out of 91 school districts in its tax effort, yet it ranked 57th in revenue received per pupil, 26th for local taxes per pupil for current operations, and 13th in per pupil expenditures for capital outlay. Thus, while having a relatively low taxation rate, the property tax base in Oconee County allowed Oconee School District to maintain its schools at respectable expenditure levels. During this period, the assessed valuation per pupil was about twice the median for all school districts in the state (Hill 1989).

An earlier study of Oconee indicated that county employment and capital expenditures increased dramatically, with large increases in tax revenues associated with the power plant (NUREG/CR-2749, vol. 7). This trend seems to have contributed to economic growth in Oconee County. The Oconee County auditor indicated that high-technology industry had been moving into Oconee, a trend attributable to the man-made lakes associated with the power plant and the water and sewer systems installed in the mid-1980s. The increase in property tax revenue from the power plant made many of the improvements in infrastructure possible without correspondingly large increases in the tax rate.

C.4.5.3.2 Predicted Impacts of License Renewal

During refurbishment of ONS, a new tax-related impact is expected to occur. This new impact involves increases in tax payments that would result from capital improvements during the current term outages. Tax increases resulting from improvements made in the final refurbishment outage would affect taxes only during the license renewal term. The magnitude of the impact depends on Duke Power's decision about which improvements would occur early on and which would be done during the final outage. For example, if the steam generator is replaced during a current term outage, the assessed value may increase considerably before the license renewal term begins. If steam generator replacement and other major capital improvements are not undertaken early on, the increase in assessed valuation may be only minor. The increase, in either case, is expected to cause only a small to moderate new tax impact.

During the license renewal term, the primary tax-related impact would be the continuation of tax payments that ONS is currently making to Oconee County and the Oconee School District. A new impact also would result from the increase in tax payments resulting from improvements made at Oconee during the final refurbishment period. Thus, tax revenues would increase in absolute terms, although they may not provide a proportionally larger share of the total revenues of either taxing jurisdiction. This is especially true because currently the tax base in Oconee County is increasing rapidly. This trend was expected to continue with the addition in 1992 of the Bad Creek Pumped Storage Hydro Power Facility. The increase in assessed valuation of ONS after refurbishment may offset this trend so that ONS tax revenues—continuing and additional payments combined—would continue to make up a substantial share of the total revenues. The moderate tax-related impact currently being experienced in the school district and the county would continue during the license renewal term.

C.4.5.4 Public Services

C.4.5.4.1 Impacts from Plant Construction and Operation

Municipalities in the Oconee study area have a council-mayor form of government that provides both legislative and executive supervision of municipal services such as water, sewers, roads, fire, police, and recreation. The majority of services are provided for at a county or state level (NUREG/CR-2749, vol. 7, p. 105). Before 1975, when the county-council form of government was established, the Oconee County government was run by local delegates, with daily activities being the responsibility of a board of county commissioners. Although it is not known if the change to county-council government was directly related to the plant, the change provided significant local control of county services. During the period immediately after operations began (1978), the scope and type of county services were expanded and a number of new departments were created. Several new programs were added, and existing ones were upgraded, particularly public safety, social services, and educational institutions (NUREG/CR-2749, vol. 7, p. 113). Information pertaining to expenditures is discussed in detail in Section C.4.5.1.

Education

Public education in Oconee County is provided by one school district that serves the whole county. Before 1966 (preconstruction phase), the county operated two school systems, one for the black population and another for the white population. Desegregation began after 1967, and by 1969, total integration of the schools was achieved (NUREG/CR-2749, vol. 7, p. 114).

The overall change in enrollment throughout the 1970s was relatively small, never falling below 10,000 students. Oconee County schools have consistently had a better pupil/teacher ratio than the state. The ratio dropped from 22 to 1 in 1966 to 19.52 to 1 in 1981. During the mid-1970s, and coinciding with Duke tax payments on ONS and changes in the form of county government, school expenditures increased significantly (NUREG/CR-2749, vol. 7, p. 117).

The data on enrollments do not show any significant increases that could be associated with ONS's employment patterns. This was because daily commuters made up almost 75 percent of the peak construction work force and approximately half the operations work force; these workers created no new demand for local services. The total number of children of workers who moved into the county to take project-related jobs was not more than 140 students during plant construction in 1971 (1.4 percent of total enrollment) and 43 students during plant operations in 1978 (0.5 percent of total enrollment) (NUREG/CR-2749, vol. 7, p. 118).

The superintendent of education in Oconee County indicated that the power plant, along with many other industries, has had an impact on the educational system. He also stated that Duke Power is very supportive of all local efforts to improve schools and education in general. The operation of ONS did not put an immediate demand on education but, rather, had an impact over the long term. Local officials stated that Oconee County was previously a textile/agricultural area. This has changed over time. Industry today (the nuclear industry included) is more high-tech; therefore, the educational system has changed to meet the demand for technological skills.

Transportation

Oconee County is responsible for maintaining the primary and secondary road system under its jurisdiction. Money for the upkeep of local roads is provided through state and local contributions. Between 1970 and 1980, expenditures on the roads increased fourfold. However, there is no indication that this increase was directly related to the plant construction. During construction of the Keowee-Toxaway Project, Duke Power Company spent $5 million on relocating 34.6 km (21.5 miles) of roads. One of these roads was Oconee County Highway 183, which, upon relocation, ran directly past the proposed site for the ONS. Local officials gave no indication of major transportation problems stemming from the construction or operation of ONS (NUREG/CR-2749, vol. 7, p. 121).

Public Safety

Public safety expenditures increased steadily from 1967 to 1980, increasing from $107,500 to $954,200 per year. There were substantial improvements in police protection and fire-fighting equipment during this period. Expenditures from the budget were made primarily to purchase new police cars and fire equipment. Other large outlays were also made on repairs to the jail (NUREG/CR-2749, vol. 7, p. 113). Oconee County has an elected sheriff and 30 full-time paid deputies. The county has a rural volunteer fire department, and some municipalities also have their own fire departments with paid firefighters. The town of Seneca recently purchased an aerial ladder truck for $500,000, which was funded from tax dollars.

The emergency preparedness center for Oconee County is supported through federal and county tax revenues. According to the local director for emergency preparedness, the construction phase had a minor impact on the demand for emergency services. The operations phase has had more of an impact in terms of all types of increases in the center's workload, ranging from additional paperwork to additional training. As far as refurbishment and refueling activities are concerned, the indication from the director was that there was more awareness of the potential for a nuclear accident throughout the county after the Three Mile Island accident.

Social Services

In 1967, social services in Oconee County consisted primarily of public assistance and food stamps. Little expansion in services occurred during the plant construction period. Beginning in 1974 (when construction was completed) several additional services were offered by the county. This coincided with a large increase in local tax revenues. Since then county expenditures in social services have remained fairly constant. According to the Department of Social Services in Walhalla, the construction phase had a definite impact on the demand for services, but the operations phase has had no impact on the level of services provided.

Public Utilities

Public utilities (water, sewer, electricity) in Oconee County increased from 0.5 percent of the budget in 1967 to 2.6 percent of the budget in 1980. Expenditures in the budget allowed for a countywide solid waste disposal capability in 1973 (NUREG/CR-2749, vol. 7, p. 113). An increased level of public services was provided, while the tax rates declined somewhat as a result of ONS's significant contribution to county revenues. The plant construction phase had an impact on the public utilities system, specifically water consumption; and the operation phase caused an increase in the demand for water and sewer services. Officials gave no indication that this demand was a burden on the utilities.

Tourism and Recreation

Local leaders interviewed indicated no adverse impacts from the construction or operation of the ONS. On the contrary, most people interviewed said that the plant has been an asset and that "water-related activities have increased since the plant moved in" because of the large cooling lake constructed for the plant. The town of Seneca recently completed a multimillion-dollar sports facility. A planner with the Community Development Department in Seneca thought the in-migration of executives associated with the plant increased use of recreation facilities and caused an upgrade in the quality of recreation in the area.

Duke Power operates a visitor's center, the World of Energy, which provides information about energy development and what is going on in the Oconee area in regard to energy. One local official indicated that, although there may be no tangible or visible impacts from the plant, it "has a positive effect on tourism; people visit the area and then go and tour the plant."

C.4.5.4.2 Predicted Impacts of License Renewal

Based on the estimated 2273 direct workers required during peak refurbishment, the staff estimates that 96 direct workers and no indirect workers will migrate with their familties to Oconee County (Section C.4.5.1.2). The number of children accompanying these workers is estimated using the South Carolina average family size (3.16) and assuming that all families include two adults. Children are expected to be evenly distributed in age from ≤1 to 18 years. Assuming that 72.2 percent of these children are school age (5 to 18 years), there will be an average of 0.84 school-age children per in-migrating family, or a total of 81 new students in Oconee County. This represents a <1.0 percent increase above the projected number of school-age children in Oconee County in 2013 (assuming the 1990 age distribution of the population). This slight increase will result in only small impacts to education.

During peak construction at ONS in 1971, approximately 701 persons moved into the area. These 701 persons accounted for only 1.7 percent of Oconee County's population in 1971 (Section C.4.5.1.1). During the construction of ONS, impacts on transportation, tourism, and recreation were small. Public safety and social services both increased in terms of financial improvements during the construction phase.

Peak refurbishment activities will bring 496 in-migrants to Oconee County. This population is smaller than the construction-related in-migrating population and represents a <1 percent increase in Oconee's projected population in 2013. The operations related in-migration is projected to be 41 persons. Adverse impacts, if any, to public services will be small during refurbishment and license renewal term operations. The positive effects on recreation will continue.

C.4.5.5 Off-Site Land Use

This section describes the off-site land use impacts of the construction, operation, and license renewal of ONS. The discussion of impacts is primarily concerned with land use in the immediate vicinity of the plant, but impacts for Oconee County are described where appropriate. Land-use impacts are examined for two time periods. First, Section C.4.5.5.1 identifies the land-use impacts of ONS's construction as part of Duke Power Company's larger Keowee-Toxaway Project. Section C.4.5.5.1 also describes the land-use impacts of ONS's operation as an entity separate from the Keowee-Toxaway Project. Next, Section C.4.5.5.2 projects the land-use impacts of ONS's refurbishment period based on the impacts that occurred during the plant's construction. Also, Section C.4.5.5.2 projects the land-use impacts of the plant's license renewal term based on the impacts that have occurred during operations. Information sources for this report include the *Final Environmental Statement Related to the Operation of Oconee Nuclear Station, Units 1, 2, and 3* (AEC Dockets 50-269, 50-270, and 50-287); *Socioeconomic Impacts of Nuclear Generating Stations: Oconee Case Study* (NUREG/CR-2749, vol. 7); and interviews with key information sources in Oconee County. Section C.4.1.5 describes the methods used to assess and project land-use impacts for all case study plants.

C.4.5.5.1 Impacts from Plant Construction and Operation

ONS is located on a 206-ha (510-acre) site on Lake Keowee near Seneca. The nuclear plant was built as part of Duke Power Company's Keowee-Toxaway Project. ONS's construction, which began in 1967, was integrated with the impoundment of Lake Keowee (and the construction of Duke's hydroelectric plant) and the impoundment of Lake Jocassee (and the construction of Duke's pumped-storage facility). Because Lake Keowee and Lake Jocassee are integral to ONS's role in the Keowee-Toxaway Project, the impacts of their impoundment are considered as part of the land-use impacts of the nuclear plant's construction.

Together, the ONS site, Lake Keowee, and Lake Jocassee cover more than 10,700 ha (26,500 acres) of the 63,500 ha (157,000 acres) Duke Power purchased for the Keowee-Toxaway Project. Most of the land that Duke Power acquired was woodland, and the remainder (about 10 percent) had previously been used as marginal farmland and pasture land. No commercial or industrial development was on the property; however, there were over 300 rural residences and cabins, and nearly 900 residents (AEC Dockets 50-269, 50-270, and 50-287).

ONS's construction—and more specifically the impoundment of Lakes Keowee and Jocassee—had significant direct land-use impacts on Oconee County. The Keowee-Toxaway Project land purchase made the Crescent Land and Timber Company (a Duke Power subsidiary) the largest single private land owner in Oconee County. All of the residents on the Duke property were relocated, and all of the structures and much of the timber were removed from the plant site and from the areas that were to be inundated. Oconee County's road system underwent extensive change because of the project, as more than 34.6 km (21.5 miles) of road (including six major bridges) were constructed between 1967 and 1970 to compensate for the effects of the lakes' presence on the regional transportation network (AEC Dockets

50-269, 50-270, and 50-287; NUREG/CR-2749, vol. 7).

Lake Keowee and Lake Jocassee continued to have significant land-use impacts in Oconee County after their impoundment. Since the late 1960s, the lakes (especially Keowee) have become the focal point for Oconee County's residential and recreational land uses. The southern end of Lake Keowee, near Seneca, has attracted a great deal of the new residential development in the county. Much of the growth that has occurred in that area consists of very expensive resort-type homes and condominiums. Because of the area's climate, beauty, and recreational amenities, many of the developments on Lake Keowee have been targeted towards wealthy in-migrants, especially retirees. Keowee Keys—a retirement community that features private homes and condominiums, a marina, tennis courts, a country club, and a golf course—has some of the more expensive homes in the county. It also has been the most successful of the higher-priced developments on Lake Keowee, despite the fact that it is the residential area closest to the nuclear plant. Key informants indicated that the lakes' impoundment also had positive indirect impacts on residential development patterns in Oconee County. One of the important indirect effects results from the property tax payments that have been generated by the expensive developments on Lake Keowee. It is believed that the influx of new property tax revenues has allowed the municipalities within the county to extend their provision of public services (NUREG/CR-2749, vol. 7).

In terms of recreational land uses, much of the lakeshore property has been developed (either privately or by Duke Power) with campgrounds, boat launch areas, marinas, golf courses, and small retail establishments. Further development for recreational use has resulted from Duke Power's decision to deed much of its original land purchase to the state of South Carolina. The utility donated 400 ha (1000 acres) for the Keowee-Toxaway State Park, over 40,000 ha (100,000 acres) to the South Carolina Wildlife Resources Commission, and, more recently, 200 ha (500 acres) for Devil's Fork State Park. In general, key informants felt that the lakes were a very positive force in guiding recreational land use in Oconee County (NUREG/CR-2749, vol. 7).

ONS's operation, considered here separately from the existence of Lake Keowee and Lake Jocassee, has had moderate direct and indirect land-use impacts on Oconee County. According to key sources, the Oconee Station's presence has not been a deterrent to residential land use. Keowee Keys is the closest residential development to the plant, and it has been successful in sales, despite its relatively expensive property and housing costs and the nuclear plant's close proximity. Also, informants indicated that ONS's property tax contributions have enabled the local governments to expand their public services while lowering property tax rates and that this has helped guide residential, commercial, and industrial land-use and development patterns in other parts of the county.

The plant's presence has had a positive effect on recruiting industries, but many felt that it did not have as large an effect on industrial development as it has on residential and recreational land uses. Most of the county's industrial development has occurred in the 15-km (9-mile) triangle between Seneca, Walhalla, and West Minster. This is because the county has installed the infrastructure necessary for industrial development (particularly sewer and water lines) in the area, and because the county's wastewater treatment facilities are located in the three towns that form the triangle. In terms of industrial recruitment, it was believed that companies who were interested in locating in Oconee County saw ONS (and the whole Keowee-Toxaway Project) as a stabilizing influence on the regional economy and as a reliable source of electric power. Sources felt that with the combination of a stable economy, a reliable power source, relatively low property tax rates, and the installation of infrastructure industries needed, Oconee County had been able to attract a number of desirable industries in the past two decades. These attractive benefits are mainly because of ONS and the Keowee-Toxaway Project. Overall, respondents felt that ONS's operation, in terms of the benefits that the station provides, has had positive impacts on land-use and development patterns in Oconee County.

C.4.5.5.2 Predicted Impacts of License Renewal

The direct land-use impacts of ONS's refurbishment and license renewal term on property in the immediate vicinity of the plant and on Oconee County are expected to be small. Using the bounding case work-force scenario, refurbishment-related population growth is projected to represent approximately 0.7 percent of Oconee County's projected population in 2013. Population growth associated with the license renewal term is projected to account for less than 0.1 percent of the county's projected 2013 population. Such small increases during refurbishment and the license renewal term are likely to have minimal new impacts in terms of residential development patterns.

As in the past, the plant itself is not expected to attract or discourage new residential development directly. Sources agree that residential construction, particularly of higher-priced resort and retirement communities, would continue on Lake Keowee despite ONS's presence because of the amenities the lake offers. Also, it is likely that recreational land uses would continue to flourish near Lake Keowee because recreation and tourism play a big role in Oconee County's overall economic development picture. In general, however, the direct land-use impacts of ONS's refurbishment and license renewal term would be small.

In terms of land use, the new indirect impacts of ONS's license renewal term are expected to be moderate. The effects of license renewal would probably be greater than the direct impacts of the plant's refurbishment and comparable to the indirect impacts of operations under the original 40-year license. ONS's property tax contributions would continue to help local governments improve and expand their municipal services, further defining the county's residential, commercial, and industrial land-use and development pattern. Residential land use is expected to continue north of Seneca near Lake Keowee as sewer and water lines are extended beyond the city's boundaries. Industrial and commercial growth is expected to continue along Highway 123 in the triangle between Seneca, Walhalla, and West Minster. Because ONS helps promote the region's economic stability, provides a reliable source of power, and allows the county to lower property tax rates while expanding services, it also would continue to be an asset in recruiting industries to the area. Overall, the new indirect land use impacts of ONS's license renewal term are likely to be similar to the impacts that the plant has had during operations thus far.

C.4.5.6 Economic Structure

C.4.5.6.1 Impacts from Plant Construction and Operation

The construction and operation of ONS have resulted in insignificant and noticeable impacts, respectively, on Oconee County. The plant has directly increased employment and income for residents of the county engaged in its construction and operation. Also, direct employment and income have resulted in indirect employment and income, and the plant's tax payments have helped provide the infrastructure for attracting business into the county.

Table C.65 presents the estimated employment and expenditure effects of ONS for residents of Oconee County. In 1971, construction activity was at a peak, and by 1978 the plant was in full operation. However, total employment related to the plant almost tripled between 1978 and 1989. Thus, the economic impact from employment and income generated by ONS has increased over time, as the percentages of county employment and income provided by the plant have become greater.

C.4.5.6.2 Predicted Impacts of License Renewal

The main impact of license renewal at ONS would be the continued employment benefits of the plant's operation. The size of the benefits should be similar to those that existed in 1989, but the relative importance of the benefits is expected to decline as Oconee County's economy is projected to grow in other sectors.

The work force scenario detailed in Section C.3.1 was used to estimate the employment effects of refurbishment at ONS. Table C.66 shows the total direct and indirect plant-related employment of Oconee County residents during refurbishment. It is projected that ONS would employ 577 Oconee County residents as refurbishment workers in 2012 (Section C.4.5.1.2). Indirect employment that would result from purchases of goods and services during refurbishment is projected to create 118 jobs for Oconee County residents. Total refurbishment-related direct and indirect employment, therefore, is expected to be 695 in 2012. This represents 1.9 percent of the county's projected 2012 total employment, resulting in small impacts.

Relatively few new plant-related jobs would be created at ONS during the license renewal term. Nearly all plant-related employment (and associated impacts) expected during that time period would represent a continuation of employment (and impacts) from past operations. Table C.67 shows the impact of the increased labor requirements at ONS during the license renewal term.

The license renewal term work force for ONS would require an estimated 180 additional employees (Section C.4.5.1.2). Of the additional workers, 90 are projected to be Oconee County residents. An estimated 74 indirect jobs would also be created for county residents during the license renewal term. With the continued effects of the plant's current employment and the additional employment to be created, total direct and indirect license renewal term employment of Oconee County residents is projected to be 1314, or 3.6 percent of Oconee County's projected employment in 2013. This represents a small impact.

C.4.5.7 Historic and Aesthetic Resources

This section describes the impacts that the construction and operation of ONS Units 1, 2, and 3 have had on historic and aesthetic resources and projects the expected impacts of the station's refurbishment and postlicensing operations. Information sources include the *Final Environmental Statement Related to the Operation of Oconee Nuclear Station, Units 1, 2, and 3* (AEC Dockets 50-269, 50-270, and 50-287) and interviews with key individuals in Oconee County and Pickens County, South Carolina.

C.4.5.7.1 Impacts from Plant Construction and Operation

Lake Keowee, with 7490 ha (18,500 acres) and 480 km (300 miles) of shoreline, was created from 1968 to 1971 by the licensee to serve the cooling requirements of ONS, with ancillary use as a hydroelectric power facility, a site for fish propagation, and a recreation and sports facility. The lake covers a land area that formerly included the site of Old Fort Prince George (an early British outpost) and the site of old Keoweetown (headquarters of the lower Cherokee Nation). Before the impoundment of the lake, extensive archaeological diggings were made at these two sites (AEC Dockets 50-269, 50-270, and 50-287). Artifacts found are now in the possession of state and local museums. While funds were made available for more site investigations, archaeologists were unable to complete all studies of the historic and prehistoric resources before the area was inundated. Some unexplored resources were lost. All graves and cemeteries in the areas inundated by the lake were moved to new locations, as was a covered bridge that crossed the Keowee River. The licensee also moved the Alexander Hill House (an early-nineteenth-century structure) from its original site, which would have been right below the new dam, to a county park on Lake Keowee. No properties other than these were listed on the National Register of Historic Places. The state liaison officer for historic preservation had no comment on the construction and operation of the nuclear power plant.

One source believes that the aesthetic impacts from construction and operation of the power plant are more positive than negative. The licensee has developed Keowee Keys, an upscale retirement community on the new Lake Keowee, the Foothills Hiking Trail [a 130-km (80-mile) national trail], the new Devil's Fork State Park, the Keowee-Toxaway State Park, and the World of Energy visitor's center at the nuclear power plant. The source believes that the area looks better since construction of the lakes and that the development of the new residential communities has given a positive image to an area that previously was characterized by low-productivity farms and small woodlots in a rural hilly area of the Piedmont Crescent where the southern Blue Ridge Mountains join the Piedmont.

C.4.5.7.2 Predicted Impacts of License Renewal

The impacts of refurbishment of the Oconee power plant on local historic and aesthetic resources are projected to be much less than those experienced during the original construction of the plant. Original construction involved inundation of 7,000 ha (17,000 acres) of land and conversion of rural, low-intensity agricultural lands to residential and recreational uses. Some historic and prehistoric resources were lost or at least relocated from their original landscape settings during the flooding for development of Lake Keowee. None of these impacts would recur with refurbishment. Such land conversion and land-use change are not expected to result from refurbishment or license renewal term operations. The impacts of post-relicensing operations are likely to be a continuation of the small impacts experienced during the original operating period. However, determination of impacts to historic resources must be made through consultation with the SHPO.

C.4.6 Three Mile Island

The impact area—the area in which the most pronounced socioeconomic impacts might result from refurbishment and license renewal—at Three Mile Island (TMI), consists of Londonderry Township and the boroughs of Middletown and Royalton in Dauphin County, Pennsylvania. The selection of this area is based on worker residence patterns, employment, expenditures, and tax payments. Figure C.14 depicts the impact area, and Figure C.15 shows the region in which it is located.

C.4.6.1 Population

This section discusses the local population growth associated with the construction, operation, and license renewal of TMI. Dauphin County was not chosen as part of the study area because plant-related growth has had little effect on the county's total population relative to the plant's effect in the local jurisdictions. Section C.4.1 describes the methodology used to project population growth for all plants. Data used to prepare this section were obtained from *Socioeconomic Impacts of Nuclear Generating Stations: Three Mile Island Case Study* (NUREG/CR-2749, vol. 12); *Environmental Assessment* for *Proposed Rule on Nuclear Power Plant License Renewal* (NUREG-1398), SEA refurbishment work force estimates (Appendix B; SEA 1994), population projections by the Pennsylvania State Data Center (1990); and the General Public Utilities Corporation (GPU 1990).

The discussion of population growth is organized into two time periods. Section C.4.6.1.1 identifies the population growth that the study area has experienced as a result of the construction and operation of TMI from 1968 to 1990. Section C.4.6.1.2 projects the population growth expected to result from the refurbishment period and license renewal term operations of TMI Unit 1 beginning in 2014, based on the growth associated with the plant's initial construction. Also, Section C.4.6.1.2 projects the population growth expected to result from TMI's license renewal term, based on the growth associated with operations in the past.

C.4.6.1.1 Growth Resulting from Plant Construction and Operation

TMI's construction resulted in noticeable population increases in Londonderry Township, Middletown, and Royalton (Table C.68). During the peak construction year, 1972, TMI personnel and their families who migrated to the area to work at the plant, and others who moved into the area to work in jobs generated by the plant's presence, totalled approximately 310 persons. This influx of new residents represented 2.2 percent of the study area's total population in 1972.

Operations at TMI have resulted in smaller population increases than did the plant's construction. In 1990, 1086 permanent plant staff were on-site at TMI (additional contract workers have been on-site during outages, but they have not been included because their presence at the plant was temporary). Of the permanent plant staff, 23 percent (250) reside in the study area

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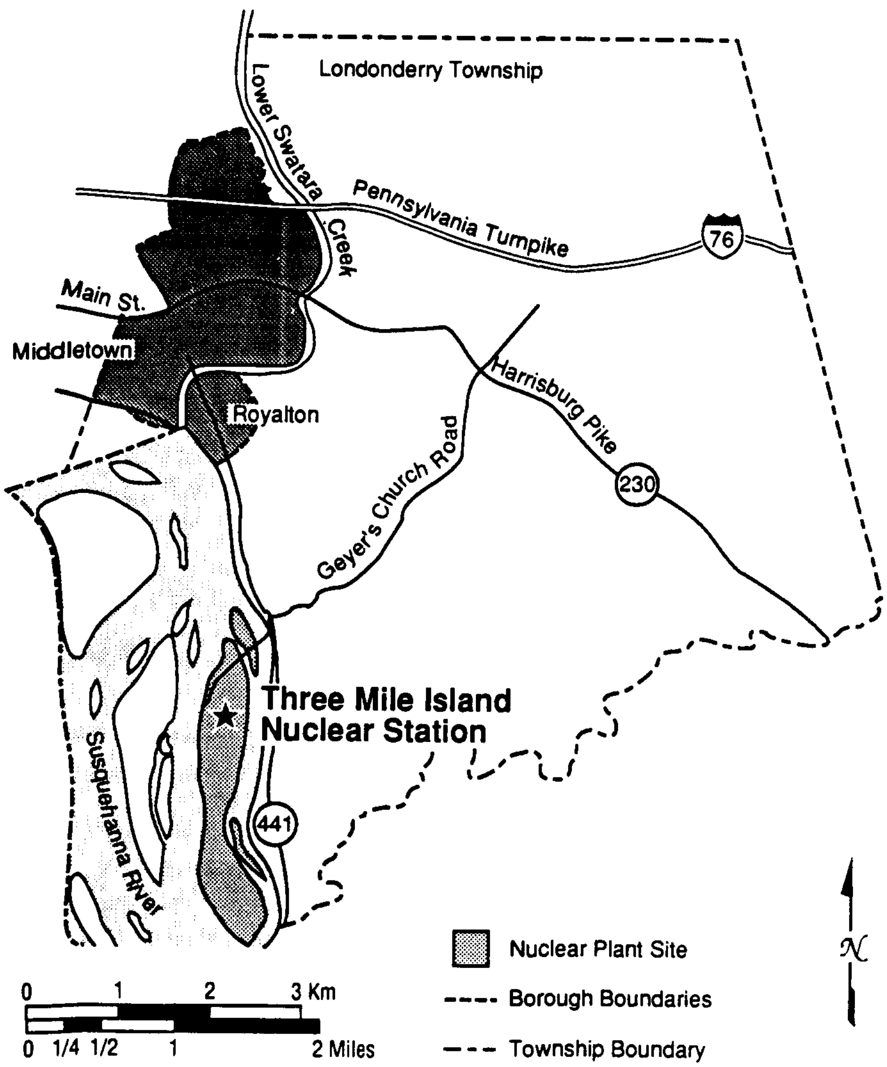

Figure C.14 Socioeconomic impact area associated with Three Mile Island refurbishment: Middletown, Royalton, and Londonderry Township.

ORNL DWG 90M-14632

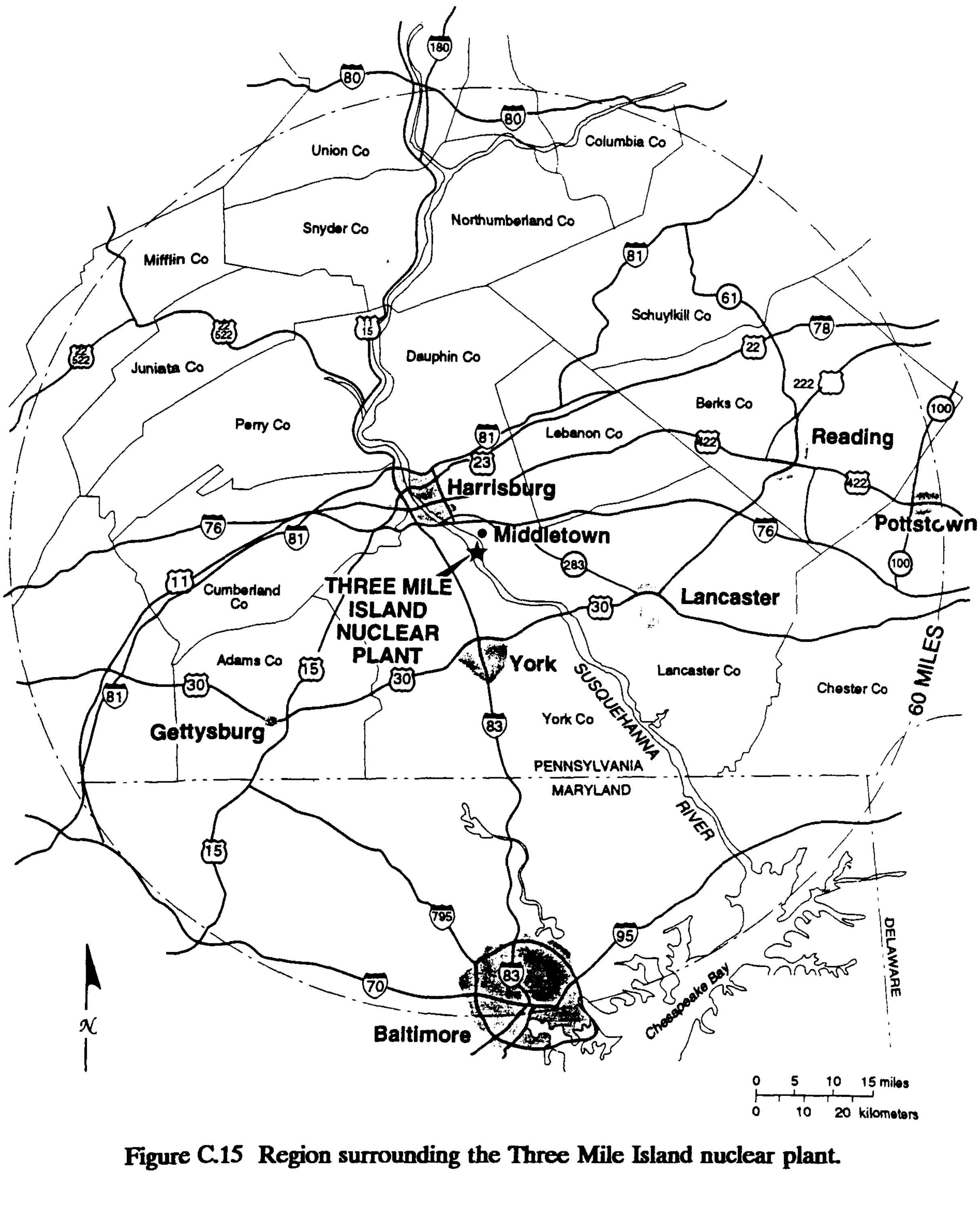

Figure C.15 Region surrounding the Three Mile Island nuclear plant.

(GPU 1990). Based on the residential settlement pattern of TMI's 1978 work force, it is estimated that 195 (78 percent) of those residing in the study area in 1990 were prior residents who obtained operations jobs and that 55 (22 percent) were workers who have migrated into the area for jobs (Table C.69). Also following the pattern set during plant operations, it is assumed that all of the in-migrants were accompanied by their families. Assuming the 1990 Pennsylvania average family size of 3.1 persons, this represents a total in-migration of 171 new residents for the study area. Based on the distribution of nonplant jobs created in the study area in 1978, it is projected that TMI's 1990 operations created an additional 115 indirect jobs in service industries supported by the spending of TMI workers. As a result of these indirect jobs, an estimated 33 additional workers and their families (a total of 75 persons) moved into the study area (Table C.69). In all, it is estimated that approximately 246 new residents moved into the study area as a result of TMI's 1990 operations. These new residents make up about 1.7 percent of the study area's 1990 population of 14,636 (NUREG/CR-2749, vol. 12, pp. 66–78; U.S. Bureau of the Census 1990).

C.4.6.1.2 Predicted Growth Resulting from License Renewal

As discussed in Section C.3.1, TMI's license renewal would require the completion of a number of refurbishment tasks for Unit 1. Many of the refurbishment tasks are expected to be completed during scheduled refueling outages during the 10 years that precede expiration of the initial operating license. However, the final refurbishment work is expected to be completed during one large refurbishment outage in 2013, the year before the initial operating license expires. As this final refurbishment outage would involve more workers on-site over a longer period of time than any of the preceding refueling outages, it represents the peak refurbishment period for TMI Unit 1. However, because uncertainties exist concerning the length of the outage and the size of the work force required to complete the refurbishment of a given unit, this section examines a bounding case work force scenario as described in Sections C.3.1 and C.4.1.1.2.

Given the work force scenario detailed in Section C.3.1, it is estimated that 2273 workers would be on-site to complete refurbishment of TMI Unit 1 in 2013 (SEA 1994). Further, assuming that the residential distribution of refurbishment workers would be similar to that of the 1972 TMI construction work force, it is estimated that 8 percent (182) would reside in the study area. Based on plant construction experience, it is projected that 28 percent (51) of those residing in the study area would be prior residents who obtain refurbishment jobs and that 72 percent (131) would be workers who migrate into the area for refurbishment jobs (Table C.70). Also following the pattern set during plant construction, 9 percent of the in-migrants (12) would be accompanied by families. Using the Pennsylvania average family size of 3.1 persons, total refurbishment worker in-migration would result in 156 new residents for the study area.

Based on the ratio of nonplant jobs created in the study area in 1972, TMI's refurbishment is projected to create an additional 50 indirect jobs in service industries supported by the spending of TMI refurbishment workers. As a result of these indirect jobs, an estimated 14 additional workers and their families (a total of 33 persons) would be projected to move into the study area (Table C.70). In all, approximately 189 new residents would be expected to move into the study area as a result of TMI's refurbishment under the work force scenario. That would represent 1.0 percent of the study area's projected population of 18,223 in 2014 (NUREG/CR-2749, vol. 12, pp. 50–55, 74–76).

Once plant refurbishment is completed for TMI Unit 1, the work force would consist mostly of permanent plant staff. Additional refurbishment/refueling workers would be temporarily on-site approximately every 2 years; however, they would not be permanent, on-site plant staff, and many of them are expected to commute from outside the study area. It is expected that a maximum of 60 additional permanent workers would be required to operate the relicensed unit. Assuming that the new workers' residential distribution would be the same as the current plant staff's, approximately 23 percent (14) would reside in the study area. Based on worker in-migration in 1978, it is expected that 78 percent (11) of those residing in the study area would be prior residents who obtain jobs and that 22 percent (3) would be workers who migrate into the area for jobs (Table C.71). Also following the pattern set during plant operations, it is assumed that all of the in-migrants would be accompanied by their families. Using the Pennsylvania average family size of 3.1 people, total in-migration would result in 9 new residents for the study area. Based on the ratio of nonplant jobs created in the study area in 1978, TMI's license renewal term is projected to create an additional 6 indirect jobs in service industries supported by the spending of plant workers. As a result of these indirect jobs, an estimated 2 additional workers (one with a family, for a total of about 4 persons) would be projected to move into the study area (Table C.71). In all, approximately 13 new residents would be expected to move into the study area as a result of TMI's license renewal term. That would represent less than 0.1 percent of the study area's projected population in 2014 (NUREG/CR-2749, vol. 12, pp. 58–60, 76).

C.4.6.2 Housing

The following sections examine the housing impacts that occurred in Middletown, Londonderry Township, and Royalton during construction and operation of TMI and predict housing impacts that would result from refurbishment activities and continued operation. Possible impacts to housing include changes in the number of housing units, particularly the rate of growth of the housing stock; changes in occupancy rates; changes in the characteristics of the housing stock; and changes in rental rates or property values.

Section C.4.1.2 includes a complete discussion of methodology and assumptions used to predict housing impacts.

C.4.6.2.1 Impacts from Plant Construction and Operation

The following discussion begins with a description of the housing market at the time of TMI's construction and details project-related housing demand in the study area. A discussion of changes that occurred in the housing market and plant construction-induced impacts on housing follows. Finally, impacts from the operation of TMI on local housing are assessed.

Between 1970 and 1978, when construction at TMI was completed, building permits were issued for 1364 units in Londonderry Township, Middletown, and Royalton combined. Of these new units, 1113 were in Middletown, 238 in Londonderry, and only

13 in Royalton (NUREG/CR-2749, vol. 12). The majority of new units in Middletown were multifamily units, including two low-income projects, a very large (>700 units) development called Village of Pineford, and the conversion of old homes into apartments. New units in Londonderry were mostly single-family units. These additional units made up a 30 percent increase in the 1970 housing stock and marked a turnaround in the declining growth that had been experienced before 1970. In the intercensal period 1960–70, the housing stock decreased by more than 400 units, a decline largely attributed to the closing of Olmstead Air Force Base (NUREG/CR-2749, vol. 12).

Project-related demand for housing in the study area has been estimated according to the number of plant construction and operations workers who moved to the area (NUREG/CR-2749, vol. 12). During 1972, the average annual project-related work force peaked at 2746, resulting in a demand for 146 units in the study area. This demand is the equivalent of 2.8 percent of the 5190 housing units in the study area in 1972.

The study area housing stock was expanding much faster than project-related demand. There were 55 rental units and 22 for-sale units vacant in 1970 in Middletown (U.S. Bureau of the Census 1972). In 1970 and 1971, over 600 multifamily units were added to the Middletown housing stock, while Londonderry experienced an increase of 39 multifamily units (NUREG/CR-2749, vol. 12). The construction of the multifamily units in Middletown (the Village of Pineford), it appears, had little to do with project-related demand. After construction of TMI was completed, the vacancy rate of this development did not increase (NUREG/CR-2749, vol. 12).

Another change in the housing stock was the development of five mobile home parks in Londonderry Township in the early 1970s. Some in the area saw a conspicuous association between the mobile home parks and the construction of TMI, though three of the park owners reported that they never had more than six TMI workers located in their parks (NUREG/CR-2749, vol. 12).

Property values and rental rates are not believed to have been affected by TMI construction. Increases in rates or values were no greater than the overall inflation rate. Between 1970 and 1980, housing values increased 187 percent in Middletown and the state of Pennsylvania. However, rental rates in Middletown increased 200 percent, whereas a 75 percent increase occurred in Pennsylvania. The numerous new rental units that were added to Middletown's housing market between 1970 and 1980 were a primary cause for the increase in rental rates.

Although discernible changes in the housing market and in housing values and rental rates did occur during the construction period of TMI, it appears that TMI had little do to with these changes. In summary, construction of TMI had only an insignificant effect on housing.

Because of the 1979 accident at TMI Unit 2, there has been unique potential for impacts to housing in the surrounding area. Possible impacts resulting from the occurrence and aftermath of the accident might include changes in housing value and in patterns of housing development. Most realtors and planners contacted in the course of this research agreed that normal operation of the TMI units had no effect on housing development or values. One thought that residential development had been encouraged by the permanent location of operations workers in the area, whereas another thought that residential development that had been occurring on the east bank of the Susquehanna River slowed when the plant began operations.

Most informants reported that any negative effects from the accident at TMI Unit 2 on the housing market were short-lived if at all existent. Construction of a townhouse development in Lower Swatara Township (neighboring Londonderry) ceased as a result of the accident, and the developer did not resume the project. Although one informant cites TMI and the accident as the most likely reason for the absence of development in the area near the plant, another believes a more likely reason is the lack of public sewer and water service there. The number of building permits issued in the study area followed the trend occurring throughout the Harrisburg Standard Metropolitan Statistical Area. The trend in this three-county area was a decrease in the number of building permits issued between 1978 and 1979 and between 1979 and 1980, followed by an increase in permits between 1980 and 1981 (TCRPC 1982). Londonderry Township followed this trend closely but did not experience an increase in permitting until 1982. Middletown, on the other hand, experienced an increase in building permits both in 1980 (22 percent more than those issued in 1979) and 1981 (27 percent more than those issued in 1980).

Immediately after the accident, some home buyers from outside the local area were averse to living near TMI. This was the case particularly with homes that looked out over the cooling towers. This resulted in longer selling time for these homes. In only a few instances have homeowners sold or tried to sell their residences because of the TMI accident.

Opinions differ regarding the effect of the TMI accident on housing values. Some local realtors and planners believed that there had been no effect. Another realtor, whose business is primarily in Middletown and Londonderry Township, reported that values of houses and property in two small subdivisions (30 to 50 homes each) close to the plant had been affected negatively by the accident at Unit 2. Housing values there dipped below fair market price for a period of approximately 5 years, although these homes are now selling at fair market price. Another respondent believed that values of homes in close proximity to the plant had not kept pace with the value of homes in other areas of Middletown.

In summary, the accident's effects on housing values were minor and of short duration. Similarly, effects on housing development were minor; the cancellation of the townhouse development project (noted above) because of the TMI accident was an isolated case.

C.4.6.2.2 Predicted Impacts of License Renewal

Project-related population increase and the commensurate housing demand would be the cause of housing impacts during refurbishment activities. A summary of recent and anticipated growth in housing is provided below. This is followed by predictions of possible impacts during refurbishment and the license renewal term.

Housing in Londonderry Township, Middletown, and Royalton expanded between 1980 and 1988 at an average annual rate of approximately 0.5 percent (U.S. Bureau of the Census 1982; Dauphin County Planning Commission 1988). If expansion continued at this rate, there would be 7376 housing units in 2013, the peak year of refurbishment at TMI Unit 1. The projected population of the study area in 2013 is 17,091 (Section C.4.6.1) and will require 6975 housing units. Although adjustment in housing growth will be made according to population growth, the current rate of growth suggests that there will be housing available in the study area during refurbishment activities.

According to the estimate of the number of refurbishment workers required and based on plant construction experience, 131 workers of the 273-member work force are expected to migrate to the area for refurbishment jobs. Of these in-migrants, only 12 are expected to be accompanied by families. Some doubling-up is expected to occur among the 119 unaccompanied workers, so that each unaccompanied mover would require 0.85 housing unit. The in-migration of these refurbishment workers would result in a housing demand in the study area of 113 housing units. In addition, some indirect jobs would be created by the spending of refurbishment workers. An additional 11 workers are expected to move to the study area, bringing the total project-related housing demand to 124 units.

Refurbishment-related housing demand is less than the original construction-related housing demand of 146 units, and the number of housing units in the study area would have increased 42 percent between peak construction and refurbishment periods. Refurbishment-related housing demand would account for 1.7 percent of the possible 7376 housing units in the study area in 2013. Because demand would be small relative to the projected housing market and would be even less than that experienced during construction (when only small housing impacts occurred), new impacts to housing in the study area are expected to be small.

Housing impacts involving marketability and value expected during the license renewal term would be a continuation of current impacts (Section C.4.6.2.1). New impacts involving housing demand and availability caused by the additional 60 workers required during the license renewal term would be small.

C.4.6.3 Taxes

C.4.6.3.1 Impacts from Plant Construction and Operation

The construction of Unit 1 of TMI began in May 1968, with operation beginning in September 1974. Unit 2 construction began in November 1969, and its operations began in December 1978. In March 1979, a major accident at Unit 2 led to the permanent shutdown of this part of the facility.

The impacts of tax revenues from TMI on its surrounding municipalities and jurisdictions are minimal in that the Pennsylvania tax structure is designed so that local areas do not benefit directly from property taxes on electric generating facilities. In general, the operation of TMI has had insignificant effects of taxing jurisdictions in the area because these local municipalities did not receive direct property tax payments. This is not the case in most other power plant locations in the United States. The Public Utility Realty Tax Assessment of 1970 (PURTA) imposed an annual tax on the depreciated cost of utility real estate at a rate of 30 mills per $1,000 of assessed valuation. The state distributes to each locality throughout the state an amount proportional to its share of all property taxes collected in the state.

The PURTA taxes paid by General Public Utilities Corporation (GPU) for TMI increased from $1 million in 1970 to

$5.8 million in 1978. With the removal of Unit 2 from operation in 1979, PURTA tax payments fell to $2.8 million in 1980. PURTA tax payments rose steadily in the 1980s to $3.2 million in 1985 and $4 million in 1989.

The boroughs (towns) nearest the TMI site are Middletown and Royalton (combined population of 10,000 in 1970 and 12,000 in 1990). The plant is located in Londonderry Township (population of 3453 in 1970 and 5500 in 1990), where there have been income-related tax collections that were a relatively high proportion of the total revenues of the township.

As shown in Table C.72, total revenue in Londonderry Township increased from $277,177 to $330,953 (1980 dollars) between 1980 and 1989; this amounts to a 19.4 percent increase. Occupational privilege taxes (place-of-work taxes) during the study period have been reduced sharply compared to the peak construction effort in the 1970s. The occupational privilege tax was at its peak in 1972 at $58,527 and fell steadily through 1989, when the tax was $13,255. This reduction reflects the decrease in the number of construction workers residing in the township. The PURTA tax distributions from the state are a very small fraction of total revenues for the township, ranging from a high (but still insignificant) contribution of only 1 percent to a low of 0.7 percent during the 1980s.

Earned income taxes have been the largest source of revenues for Londonderry Township. This tax is levied on all workers living in Londonderry Township. These tax receipts are especially large during construction periods, because workers residing in states other than Pennsylvania are required to pay the 1 percent tax to the township. For workers who are residents of Pennsylvania, the tax is split evenly between the township and the school district in which the worker resides.

Middletown Borough

As can be seen from Table C.73, total revenues in the borough of Middletown have increased steadily in recent years, largely the result of the reselling to local residents of electricity purchased wholesale under a long-term contract with Metropolitan Edison. The borough's purchase contract with Metropolitan Edison is not contingent on the existence or operation of TMI.

Royalton Borough

In a contractual relationship similar to that of the borough of Middleton, the borough of Royalton has steadily increased its total revenues through a heavy reliance on the resale of electricity purchased from Metropolitan Edison (Table C.74).

Middletown Area and Lower Dauphin School Districts

The Middletown Area School District (MASD) and the Lower Dauphin School District (LDSD) are the major school districts in the TMI study area. Enrollments in the two school districts have declined steadily from the start of construction of Unit 1 in 1968 to the present. The LDSD enrollment was 4021 in 1968 and fell 16 percent, to 3385, in 1990. Enrollments in MASD declined from 3102 in 1968 to 2625 in 1990, for a decrease of 15.4 percent. Apparently, there has been no correlation between the work force at TMI and enrollment at the two school districts.

Mountain West Research, Inc., estimated the project-related enrollment of the two school districts in 1978 to be 35 and for MASD and LDSD, respectively (NUREG/CR-2749, vol. 12). We estimate the current project-related enrollment to be 13 and 3, respectively, because of the drop in work force at the plant from 2872 in 1978 to 1086 in 1989.

Local taxes paid to the school districts are a combination of real estate taxes, a 0.5 percent earned income tax for residents of the school district, a per capita tax, a real estate transfer tax, and an occupation tax. In addition, the PURTA taxes are apportioned to the school districts in a way similar to those for municipalities. The contribution of taxes paid by TMI to the school districts is insignificant compared to the district's total revenues, with PURTA taxes alone currently accounting for less than 1 percent of the total taxes received for both school districts.

C.4.6.3.2 Predicted Impacts of License Renewal

During refurbishment of TMI, a new tax-related impact is expected to occur. This new impact involves increases in tax payments because of capital improvements that take place during the current term outages. Tax increases resulting from improvements made in the final refurbishment outage would affect taxes only during the license renewal term. The impact of the additional tax revenues would be small in the local jurisdictions because new revenue (i.e., the PURTA taxes) would be distributed statewide.

During the license renewal term, the primary tax-related impact would be the continuation of TMI's PURTA tax payments. A new impact would also result from the increase in tax payments resulting from improvements made at TMI Unit 1 during the final refurbishment period. Thus, total PURTA tax revenues would increase in absolute terms, although PURTA tax distribution to individual municipalities would continue to constitute only small portions of their total revenues.

C.4.6.4 Public Services

C.4.6.4.1 Impacts from Plant Construction and Operation

The construction and operation of TMI have coincided with a period of growth in southern Dauphin County, and with that growth have come greater revenues and expenditures. The presence of TMI affects the varying jurisdictions and their services differently; overall, the impacts have been greater on Londonderry Township than on Royalton and the two nearest school districts, and much more than on Middletown.

Middletown and Royalton are designated as boroughs, of which there are 16 in Dauphin County; the county also comprises 25 townships. A township is a subcounty area with the status of a legal municipality, originally established for administrative purposes, whereas boroughs are small towns within townships. Londonderry Township is governed by a three-member board of supervisors, elected at large, who serve in both legislative and executive capacities.

Both of the boroughs, Middletown and Royalton, have mayor-council governments. In Pennsylvania, townships and municipalities designated as boroughs have a high degree of administrative autonomy in several areas, such as the regulation of taxes (by determining millage rates, for example); structure of government, zoning, and planning policy; and provision of public services (NUREG/CR-2749, vol. 12, p. 91–93).

Information pertaining to revenues and expenditures is discussed in detail in Section C.4.3.3.

Education

Two school districts are in the study area, MASD and LDSD. Londonderry Township and three other townships make up LDSD, and about 32 percent of the students in that district reside in Londonderry Township. The only school in the township is Londonderry Elementary, and it is attended by Londonderry Township residents only. In 1972, its enrollment was 666 students, 32 percent of all elementary students in LDSD. During construction of TMI, enrollment in LDSD decreased, but the decline was erratic, following no regular trend. There is no evident correlation in the pattern of decline and the number of construction workers at TMI. Construction-related enrollment in LDSD was not very large, amounting to only 0.1 to 0.2 percent of all students in 1972–73 and 1978–79, respectively (NUREG/CR-2749, vol. 12, pp. 106–108).

A local respondent reported insignificant effects of TMI's construction on district enrollment, and it was noted that employees were evenly distributed throughout the area. The most visible effect of TMI's construction was monetary, but the only real direct effect of the construction was a one-time real estate transfer tax of $250,000 collected by LDSD when Unit 2 changed hands from Jersey Central Power and Light to Metropolitan Edison (NUREG/CR-2749, vol. 12, p. 110).

Both Middletown and Royalton are part of MASD, which also includes neighboring Lower Swatara Township. Roughly 70 percent of the students in the district resided in the study area during construction, but the project-related enrollment was estimated to be only 1.0 to 1.2 percent of the total enrollment (33 to 35 students). An initial rise in enrollment occurred after construction began, but numbers declined steadily after 1972. An official of MASD confirmed that although TMI drew many people with school-aged children into the area, there was no stress put upon the school system (Strohecker 1990). As with LDSD, there does not appear to be any correlation between the pattern of decline and the number of construction workers at TMI (NUREG/CR-2749, vol. 12, p. 106).

Operations at TMI have also had insignificant impacts in the school districts. The accident in 1979 caused the schools to be closed down for a few days, and evacuation plans have also been developed following the accident. While many workers were involved in the clean-up effort, the presence of extra workers did not have an impact on the schools.

Transportation

During construction at TMI, there were moderate impacts on transportation in the study area. Increased traffic from the TMI work force created congestion and some inconvenience along Highway 441. However, it dissipated quickly because of the nearby interchanges with Interstate I 283. Along Geyer's Church Road and Highway 230, especially during shift changes, increased traffic was also noted. As Table C.75 shows, counts at the peak of construction, in 1972, were nearly twice the traffic levels of a decade earlier. Nevertheless, the TMI construction traffic was modest on Highway 230 in comparison to the daily traffic generated by nearby Olmstead Air Force Base, which employed approximately 10,000 civilians before its closing (NUREG/CR-

2749, vol. 12, p. 114). The impacts of operations at TMI on transportation have been insignificant. None of the informants reported a change in the demand on transportation since TMI began operations.

The effects of maintenance activities have been greater than those during normal operations but still not as large as at the time of construction. There is no indication that TMI traffic has had a substantial effect on road maintenance requirements or that it has changed long-term transportation patterns in the study area (NUREG/CR-2749, vol. 12, p. 114).

Public Safety

Each of the jurisdictions provides varied levels of public protection; in each, however, public safety services have improved because of the construction of TMI. Middletown's police force changed little during construction. Two police officers were added after 1974, raising the number to 18; the department budget rose accordingly. There was a consistent rise in the frequency of calls for service, but there was no evidence that construction work at TMI caused an increase in police activities (NUREG/CR-2749, vol. 12, p. 115). Royalton also maintains its own police department, which was a part-time force of two officers for most of the construction period; in extraordinary cases, it depends on state police forces or neighboring municipalities for assistance.

Unlike the boroughs, Londonderry Township has no police department, relying totally on the state police for protection. An informant at the Pennsylvania State Police Department stated that construction at TMI had no large impact on the services of his department.

Fire protection and rescue services have also improved in the study area. The three fire companies located in Middletown serve Middletown and Royalton boroughs and have separate specialties. Similarly, ambulance and emergency services for both are coordinated through a communications center located on the premises of the Middletown Police Department.

In 1974, near the end of construction, one of the fire companies moved to new housing that was federally funded, and all of the companies became more professional. Londonderry Township maintains its own fire department, and during the construction period it acquired an ambulance and rescue unit. Public safety expenditures experienced slow, steady growth through the construction period in Londonderry Township. However, those interviewed did not see any effects from TMI's construction on the demand for public safety (NUREG/CR-2749, vol. 12, pp. 115–117).

Municipalities are required to have a volunteer emergency management squad. The Dauphin County Emergency Management Office reported that squads were in place before TMI was built. In Middletown, the emergency squad remained small throughout the construction period. However, the Middletown squad is concerned with other facilities in addition to TMI, such as a chemical plant and railroads in the borough and the nearby Harrisburg International Airport. Additionally, an 8-km (5-mile) evacuation plan was developed.

Operations and refurbishments at TMI have definitely affected public safety in the study area, especially because of the demands on emergency management: the evacuation plan is now much more detailed. The police have also been affected, not so much by the plant's daily operations, according to the state police, as by the evacuation following the 1979 accident.

The mayor of Middletown reported that operations at the plant greatly affect the borough; its emergency management plan must be kept up to date and be in place for TMI to operate. The power company works closely with the municipalities to formulate their emergency evacuation plans, and it strives to maintain good public relations.

Social Services

No social or health services are provided by Londonderry Township or by the two boroughs. Social programs are run by the county or the state, and residents must go to Harrisburg to receive any of these services. The only social programs located in the study area are a day-care center for low-income working mothers (NUREG/CR-2749, vol. 12, p. 117) and some programs for senior citizens (Hoke 1990; Hamer 1990). No informant reported effects from TMI on demands or funding for social and health services during construction. Also, there were no reports of impacts from operations or refurbishments.

Public Utilities

Like social services, public utilities have experienced only insignificant impacts from TMI. Londonderry Township provides no water or sewerage treatment. The chairman of the Londonderry Township planning commission said that growth in the area could not be attributed to TMI. Middletown, which also produces and distributes its own electricity, does provide sewer, water, and sanitation services. Local informants were unsure whether there was any effect on public utilities during TMI's construction, but it is believed that effects were small. Informants reported no increase in demand on public utilities since operations began. In fact, the Middletown planning commission chairman noticed a decrease in demand on services after TMI was completed and began operations. No reports indicated that refurbishments at TMI affect public utilities.

Tourism

Some positive impacts to local tourism were observed during construction. Most of the local leaders reported an increase in tourism in the study area during the construction of TMI, although some variation existed in their reports of its popularity. One noted that the visitor's center was established at that time and that the plant construction was an impressive sight and a strong attraction. However, tourism was already well established in the region, with several nationally popular sites, such as Lancaster County, Gettysburg, and Hershey. Additionally, Middletown is a historic community—the oldest in Dauphin County.

All of the local leaders interviewed noted that tourism at the plant has continued during its operation (especially after the accident in 1979). Although the plant had a slight effect on regional tourism, it has become a small tourist attraction in its own right, attracting visitors into the study area. Local leaders note no adverse effects from increased tourism.

Recreation

Effects on recreation in the study area have been small, although there have been substantial improvements in facilities. Several leaders interviewed stated that TMI's construction had no impact on recreation in the area, although funding rose in Middletown for parks and recreation.

Probably the biggest change in the study area has been in Londonderry Township, which spent several hundred thousand dollars from 1973 to 1975 to acquire land and develop a golf course (NUREG/CR-2749, vol. 12, pp. 103–104); another is under construction now. During the construction of TMI, several new parks were also established in Londonderry Township, but the township planning commission chairman pointed out that these were built to accommodate the needs of community residents already living in the township.

Operations at TMI have had some impacts. For example, a public boat launch and fishing pier have been built on the island. And despite the plant, recreation has grown on the Susquehanna River. A public boat launch and a boat club are in the vicinity.

C.4.6.4.2 Predicted Impacts of License Renewal

Based on the estimate of 2273 direct workers, 189 in-migrants (direct and indirect) would result from TMI's refurbishment (Section C.4.6.1.2). The 21 workers (direct and indirect) who are projected to migrate to the study area with their families will each bring an average of 0.79 school-age children for a total of 17 new school-age children. This assumes an average family size of 3.1 and an even distribution of children from ages ≤1 to 18. This small increase would have a small impact on area schools.

During the construction of TMI, impacts on social services, tourism, and recreation were small. Because refurbishment would bring in fewer workers than did initial construction and the population in the study area in 2013 would be larger, any impacts on these public services also would be small.

Public safety, which has been affected mostly by requirements for emergency plans and increased funding, also should experience small effects during the refurbishment period. Public utilities, which were not affected by the construction of TMI, would not be affected by its refurbishment. There would be, however, new changes concurrent with and indirectly related to the plant's continued operations, as Londonderry Township plans to build additional water and sewer systems in the next 30 years or so.

Transportation, which was affected moderately during the construction of TMI, would probably experience effects similar to those that occurred during construction because the operations and refurbishment work force combined would be somewhat larger than the construction force. The combined effects of the operations and refurbishment work forces are likely to create a moderate impact. Transportation impacts of license renewal term operations will be much the same as the small impacts occurring currently.

For *all* public services, impacts during the license renewal term would be essentially unchanged from those experienced during past operations. This means that impacts are expected to be small for all services.

C.4.6.5 Off-Site Land Use

This section describes the off-site land-use impacts of the construction, operation, and license renewal of TMI. The discussion of impacts is concerned primarily with land use in the immediate vicinity of the plant, but impacts for Middletown, Royalton, and Londonderry Township are described where appropriate. Land-use impacts are examined for two time periods. First, Section C.4.6.5.1 identifies the land-use impacts of TMI's construction and operation. Next, Section C.4.6.5.2 projects the land-use impacts of TMI's refurbishment period, based on the impacts that occurred during the plant's construction. Also, Section C.4.6.5.2 projects the land-use impacts of the plant's license renewal term based on the impacts that have occurred during operations. Information sources for this report include the *Final Environmental Statement Related to Operation of Three Mile Island Nuclear Station, Units 1 and 2* (AEC Dockets 50-289 and 50-320); *Socioeconomic Impacts of Nuclear Generating Stations: Three Mile Island Case Study* (NUREG/CR-2749, vol. 12); and interviews with key sources in Dauphin County. Section C.4.1.5 describes the methods used to assess and project land-use impacts for all case study plants.

C.4.6.5.1 Impacts from Plant Construction and Operation

TMI was constructed on an 80-ha (200-acre) site on Three Mile Island, a 191-ha (472-acre) island in the Susquehanna River near Middletown. The Metropolitan Edison Company had owned the island since 1906 and had acquired several of the surrounding islands by the time TMI's construction began in 1967. Before the plant's construction, more than half the island had been leased for farming, and much of the remaining land was wooded. There were also 70 rental cabins, a picnic area, and a boat dock on the island (AEC Dockets 50-289 and 50-320; NUREG/CR-2749, vol. 12).

Overall, TMI's construction had insignificant land-use impacts in the immediate vicinity because the direct impacts of construction were almost completely confined to the island. Most of the 80-ha (200-acre) plant site had previously been cleared for agricultural use, and only 11 ha (28 acres) of additional wooded area had to be cleared. All but 2 of the 70 cabins that were on the island before construction were moved to nearby Beshore Island. Because the cabins belonged to the Metropolitan Edison Company, their removal did not entail relocating permanent residents. A small section of state-owned Sandy Beach Island was affected by the construction of piers for the bridge erected from TMI to Highway 441. On the river's east bank, Metropolitan Edison purchased 3 ha (8 acres) of farmland (which included three farmhouses) to construct the visitor's center and 0.8 ha (2 acres) of woodland to construct a substation. In general, these off-site construction activities had only insignificant effects on land use in the island's vicinity (AEC Dockets 50-289 and 50-320; NUREG/CR-2749, vol. 12).

TMI's construction had even fewer land-use impacts in Middletown, Royalton, and Londonderry Township. When the plant's construction began, Middletown and Royalton were small, older urban residential areas with some limited commercial and industrial development. Londonderry Township was predominantly rural, with scattered farmhouses and some very limited suburban residential development. Some residential construction occurred, in part because of the influx of construction workers, but key informants indicated that the growth was not significant enough to affect the area's general residential development pattern. The respondents felt that, overall, TMI's construction had neither positive nor negative land-use impacts in any of the three communities.

TMI's operation, including the 1979 accident at Unit 2, also has had relatively insignificant direct and indirect land-use impacts in the study area. Key sources stated that even after the accident the plant's presence had not been a deterrent to residential development along the Susquehanna River near the island, or in Middletown, Royalton, or Londonderry Township. Respondents believe that the plant has had neither positive nor negative impacts in terms of attracting industries to the area and that it has had only minor indirect effects in fostering positive commercial development. In general, land use in the area from Middletown south to Marietta along the east bank of the Susquehanna has not changed significantly since before TMI's construction. However, sources attributed this lack of residential, commercial, and industrial development to a number of factors other than TMI's presence. Some of the more important factors included the following: (1) Middletown and Royalton were already "built up," and little land was available for new development in either jurisdiction; (2) Londonderry Township did not provide the public sewer and water services necessary for large-scale development; (3) the general size and condition of the area's roads were inadequate to support industrial development; and (4) the region was experiencing an economic decline related to a downturn in the steel industry and the closing of the Bethlehem plant in Steelton. Overall, sources agreed that TMI's operations have had only very minor land-use impacts in the vicinity of TMI or in Middletown, Royalton, or Londonderry Township.

C.4.6.5.2 Predicted Impacts of License Renewal

The direct impacts of TMI's refurbishment and license renewal term on land use in the immediate vicinity of TMI and in Middletown, Royalton, and Londonderry Township are expected to be small. The plant itself is not expected to attract or discourage new residential, commercial, or industrial development directly.

Refurbishment-related population growth is projected to represent 1.0 percent of the study area's projected population in 2014. The license renewal term is projected to result in population growth of less than 0.1 percent in the study area in 2014. During both refurbishment and the license renewal term, increases this small are likely to have only minimal new impacts in terms of residential development patterns.

Key information sources agree that land-use patterns in Middletown and Royalton are well-established and that the area has a general lack of developable land. Therefore, TMI's license renewal is expected to have only minimal new impacts on the two jurisdictions' land use. Growth is expected in Londonderry Township, as the township plans to extend its sewer and water services to allow for (1) residential and commercial development along Route 230 and (2) commercial and industrial development near Interstate 283 and at the southern end of the township near Conewago Creek. TMI's refurbishment might contribute slightly to this growth, but the township's land-use and development patterns are not likely to be strongly influenced either positively or negatively.

Because Pennsylvania state law provides for the statewide distribution of public utilities' property tax payments, Londonderry Township does not receive a disproportionate share of the benefit from TMI's tax payments. Thus, the township's land-use and development patterns are influenced less by the indirect effects of a nuclear plant's tax payments (i.e., lower property taxes and superior public services) than are those of jurisdictions that receive the majority of the tax benefits of a nuclear plant in some other states. In general, then, both the direct and indirect land-use impacts of TMI's refurbishment and license renewal term are expected to be small.

C.4.6.6 Economic Structure

C.4.6.6.1 Impacts from Plant Construction and Operation

The construction and operation of TMI have resulted in insignificant and significant impacts, respectively, on Middletown, Royalton, and Londonderry Township. Table C.76 presents the estimated employment and expenditures for residents of the three-municipality study from 1972 to 1990. In 1972, direct and indirect employment resulting from TMI's construction represented only 2.1 percent of the study area's total employment. That represents an insignificant impact.

The 1990 work force at TMI numbered 1086, of whom 250 were study area residents. The operation of the plant has also resulted in 98 indirect jobs, for a total of 348 jobs for study area residents. This level of employment represented 13 percent of the study area's total employment, so the impact is large. The income of this work force represented 17.0 percent of the study area's total income in 1990.

C.4.6.6.2 Predicted Impacts of License Renewal

The work force scenario detailed in Section C.3.1 was used to estimate the employment and economic effects of refurbishment at TMI. Table C.77 shows the total direct and indirect plant-related employment of study area residents during refurbishment.

It is projected that TMI would employ 182 study area residents as refurbishment workers in 2013 (Section C.4.6.1.2). In addition, indirect employment that would result from purchases of goods and services during refurbishment is projected to create 43 jobs for study area residents. The total direct and indirect employment affecting the study area during the peak refurbishment year is therefore estimated to be 225. This employment is projected to be 6.0 percent of the total study area work force in 2013, resulting in moderate impacts.

Relatively few new plant-related jobs would be created at TMI during the license renewal term. Nearly all plant-related employment (and associated impacts) expected during that time period would represent a continuation of employment (and impacts) from past operations. Table C.78 shows the impact of the increased labor requirements at TMI.

The license renewal term work force for TMI would require an estimated 60 additional employees (Section C.4.1.2). Of these additional workers, 14 are projected to be study area residents. An estimated six indirect jobs are projected to be created by license renewal, and five of these jobs are expected to be filled by study area residents. With the continued effects of the plant's current employment and the additional employment to be created, total direct and indirect license renewal term employment is projected to represent 9.8 percent of study area employment in 2013. This employment level represents a large impact.

C.4.6.7 Historic and Aesthetic Resources

This section describes the impacts that the construction and operation of the TMI nuclear station have had on historic and aesthetic resources and projects the expected impacts of the plant's refurbishment and post-relicensing operations. Information sources include the

Final Environmental Statement Related to the Operation of Three Mile Island Nuclear Station, Units 1 and 2 (AEC Dockets 50-289 and 50-320); the *Draft Supplement to the Final Environmental Statement Related to the Operation of Three Mile Island Nuclear Station, Unit 2* (NUREG-0066); and key information sources from Dauphin County, York County, and elsewhere in Pennsylvania.

C.4.6.7.1 Impacts from Plant Construction and Operation

The construction and operation of TMI have had moderate impacts on the aesthetic resources of the area and small impacts on the historic resources of its surroundings. There were no known archaeological sites on the island before construction. A preconstruction survey turned up artifacts from the Early and Middle Woodland Indian cultures of about 4000 B.C. to 1000 A.D. and some from later times. It was these Early and Middle Woodlands artifacts that were of interest to archaeologists because these eras in Pennsylvania are poorly known (AEC Dockets 50-289 and 50-320). There have been no important impacts to historic structures from the construction and operation of the plant. Fourteen structures listed on the National Register of Historic Places are located within 1.6 km (1 mile) of the plant's 770 ha (1900 acres) of transmission line rights-of-way, but there have been no reports of any impacts (NUREG-0066). The impacts to historic resources that have occurred involve perceptions that the site has changed from a rural area of rolling eighteenth- and nineteenth-century farmsteads to one punctuated with industrial facilities. The perception of this intrusion is made across substantial distances because of the facility's three 110-m-high (370-ft-high) natural draft cooling towers.

The cooling towers and their visible plumes also create the facility's primary aesthetic impacts. One respondent states: "The principal impacts would be visual. ... The towers and the power lines are an intrusion on the rural landscape. Looking at the rural landscape as a part of the historic environment, with all the eighteenth- and nineteenth-century farmhouses, the facilities have a visual impact. There are other types of power plants along the Susquehanna, but they are smaller and not nearly as visible. The steam is an even greater identifier of the plant. You can see it from further away than the towers. And the power lines that come from the station are very visible." At river level (where the visitor's center and a major area highway are), existing trees for the most part obscure a view of the plant's other structures.

The other major aesthetic impact comes from the feelings that persist regarding the accident at TMI in 1979. Such feelings have to some degree colored people's attitudes about nuclear power and therefore their aesthetic perceptions. One source stated: "It's not that the plant's unsightly, it's just that the sight of the plant reminds people of the accident. The area around the plant is in a very sylvan setting, in really pretty countryside with lots of old farmhouses, until you see the plant. When you see the towers over the horizon, it puts people off." Another person referred to the cooling towers as "looming on the horizon for a good distance." One respondent suggested that, all thing being equal, home buyers since the accident have generally made decisions to purchase property out of the viewshed of the plant and that new construction of higher-valued homes has generally not favored areas near the plant. This individual posits that decisions to locate outside the viewshed are probably made more with an eye to optimizing the investment aspect of the property (reduction of risk to property values from another accident) than with concerns about the direct aesthetic impact of the plant and other development in the area on the perceived day-to-day quality of life.

C.4.6.7.2 Predicted Impacts of License Renewal

The impacts of TMI's refurbishment and postlicense renewal operation on historic and aesthetic resources in the area would likely be less pronounced than those that have occurred during construction and normal operation. The 1979 accident sensitized many people to the plant's presence and to its potential for problems. This undoubtedly has affected people's aesthetic preferences and values. Should another major problem occur at this plant (or, possibly, elsewhere), large aesthetic impacts can be expected because the cooling towers and their plumes remind people of the nuclear power plant's presence. Given normal operation during the license renewal term, impacts on aesthetic and historic resources are expected to be a continuation of the current levels of impact. However, determination of impacts to historic resources from refurbishment and license renewal operations must be made through consultation with the SHPO.

C.4.7 Wolf Creek

The impact area—the area in which the most pronounced socioeconomic impacts might result from refurbishment and license renewal—at the Wolf Creek Generating Station (WCGS), consists of Coffey County and towns and communities within Coffey County, Kansas, the largest of which is Burlington. The selection of this area is based on worker residence patterns, employment, expenditures, and tax payments. Figure C.16 depicts the impact area, and Figure C.17 shows the region in which it is located.

C.4.7.1 Population

This section discusses the local population growth associated with the construction, operation, and license renewal of WCGS. Section C.4.1 describes the methodology used to project population growth for all plants. Data used to prepare this section were obtained from the *Final Environmental Statement Related to the Operation of the Wolf Creek Generating Station, Unit No. 1* (NUREG-0878); *Environmental Assessment for Proposed Rule on Nuclear Plant License Renewal* (NUREG-1398); SEA refurbishment work force estimates (Appendix B; SEA 1994); population projections by the University of Kansas Institute for Public Policy and Business Research (Helyar); and the Wolf Creek Nuclear Operating Corporation.

The discussion of population growth is organized into two time periods. Section C.4.7.1.1 identifies the population growth that Coffey County experienced as a result of the construction and operation of WCGS from 1977 to 1989. Section C.4.7.1.2 projects the population growth expected to result from WCGS's refurbishment period and license renewal term operations beginning in 2025, based on the growth associated with the plant's initial construction. Also, Section C.4.7.1.2 projects the population growth expected to result from WCGS's license renewal term, based on the growth associated with operations in the past.

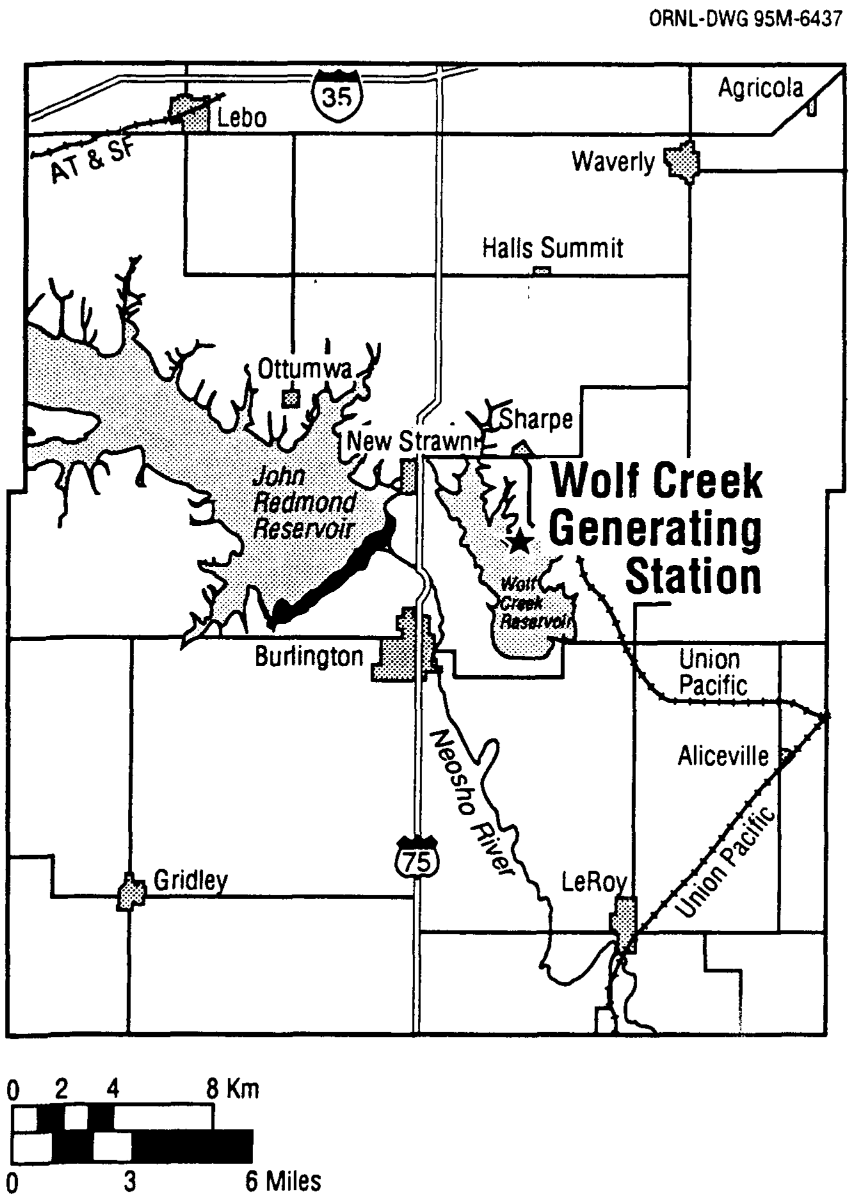

Figure C.16 Socioeconomic impact area associated with Wolf Creek Generating Station refurbishment: Coffey County.

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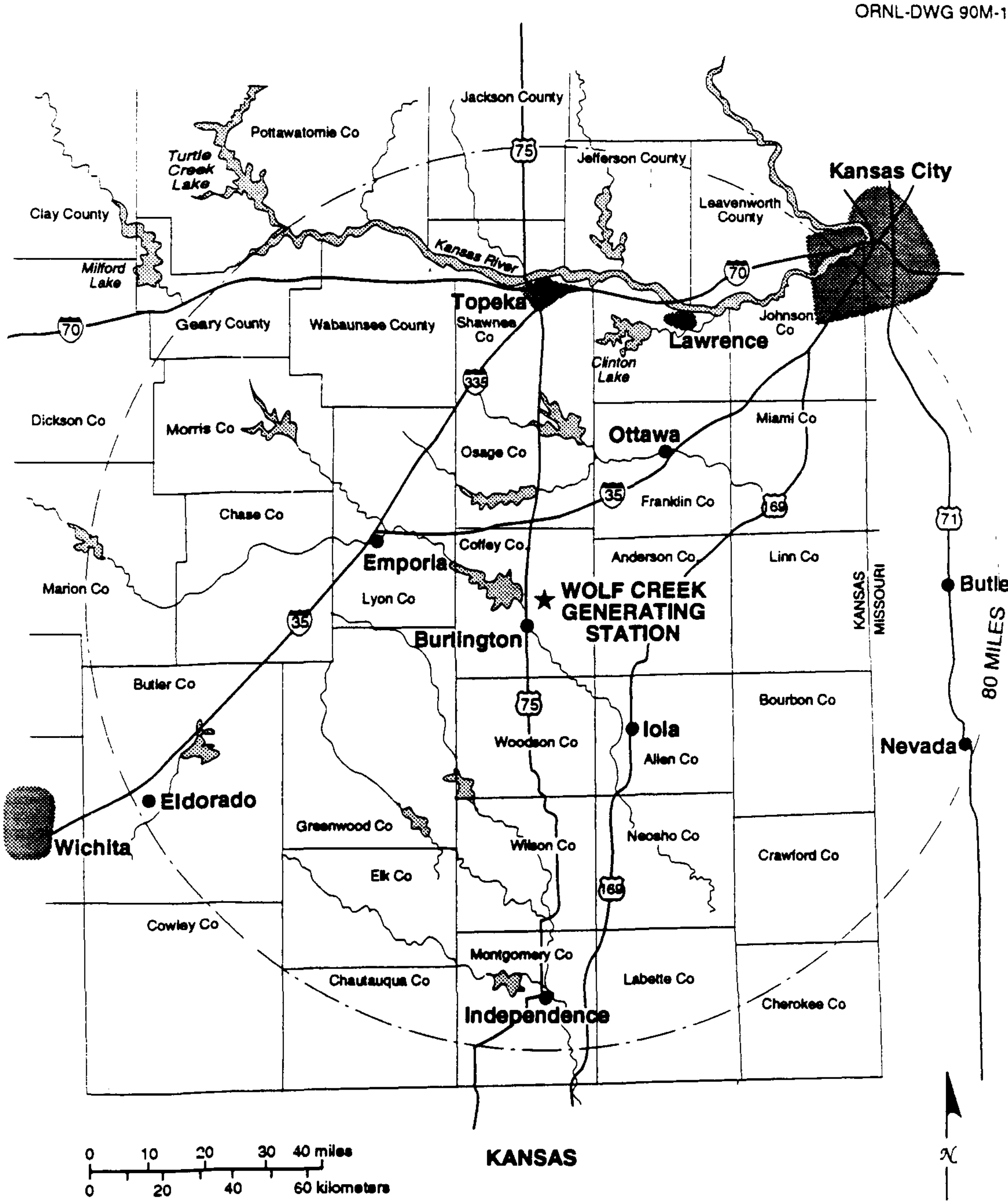

Figure C.17 Region surrounding the Wolf Creek Generating Station nuclear plant.

C.4.7.1.1 Growth Resulting from Plant Construction and Operation

Because Wolf Creek was not included in the NUREG/CR-2749 study, estimates of worker in-migration are based on the construction experience at other nuclear plants in comparable locales. WCGS's construction resulted in very large population increases in Coffey County (Table C.79). During the peak construction year, 1984, approximately 5500 construction workers were on-site at WCGS. Because Wolf Creek is located in a rural county that has no major urban population center and based on residential settlement patterns of construction work forces at other nuclear plants, it is estimated that approximately 20 percent (1100 persons) of the peak construction work force lived in Coffey County (Table C.80). The remainder are estimated to have commuted to the job site (NUREG-75/096). Also, it is estimated that 70 percent of the construction work force residing in Coffey County (770 persons) were workers who migrated to the study area for jobs at the plant. Based on the pattern of construction workers' in-migration at other nuclear projects, it is estimated that 51 percent of the in-migrants (393 workers) were accompanied by their families. Assuming the 1990 average family size for Kansas (3.08), this represents a total in-migration of 1587 residents for Coffey County.

Based on construction in-migration and the ratio of nonplant jobs created during the peak construction periods at nuclear plants in comparable locales, it is estimated that Wolf Creek's peak construction period created an additional 275 jobs in service industries supported by the spending of WCGS construction workers. As a result of these indirect jobs, an estimated 144 additional workers and their families (a total of 342 persons) moved into the study area (Table C.80). In all, it is estimated that approximately 2329 new residents moved to Coffey County as a result of Wolf Creek's peak construction period. This influx of new residents represented 20.5 percent of Coffey County's total population in 1984.

Operations at WCGS have resulted in smaller population increases than did the plant's construction, but the increase still has been relatively large. In 1989, 1044 permanent plant staff were on-site at WCGS (additional contract workers have been on-site during outages, but they have not been included because their presence at the plant was temporary). Of the permanent plant staff, approximately half (522) live in Coffey County (Wolf Creek Nuclear Operating Corporation 1990). Based on residential settlement patterns of workers at nuclear plants in comparable locales, it is estimated that 50 percent (261) of those residing in Coffey County in 1989 were prior residents who obtained jobs and that 261 were workers who migrated into the area for jobs (Table C.81). Also following the pattern set by personnel in-migrating to work at other nuclear plants, it is estimated that 66 percent of the in-migrants (172) were accompanied by their families. Assuming the 1990 Kansas average family size of 3.08 persons, this represents a total in-migration of 619 residents for the county. Based on work force in-migration and the ratio of nonplant jobs created at other nuclear plants during operating periods, it is estimated that Wolf Creek's 1989 operations created an additional 418 indirect jobs in service industries supported by the spending of WCGS workers. As a result of these indirect jobs, an estimated 218 additional workers and their families (a total of 518 persons) moved into Coffey County (Table C.81). In all, it is estimated that approximately 1137 new residents moved into Coffey County as a result of WCGS's 1989 operations. These new residents made up about 13.3 percent of Coffey County's 1989 population of 8559.

C.4.7.1.2 Predicted Growth Resulting from License Renewal

As discussed in Section C.3.1, Wolf Creek's license renewal would require the completion of a number of refurbishment tasks. Many of the refurbishment tasks are expected to be completed during scheduled refueling outages during a period of 8 to 10 years before the actual license renewal date. However, the final refurbishment work is expected to be completed during one large refurbishment outage scheduled for the year before the unit's license renewal date. As this final refurbishment outage would involve more workers on-site over a longer period of time than any of the preceding refueling outages, it represents the peak refurbishment period. However, because there are uncertainties concerning the length of the outage and the size of the work force required to complete the refurbishment of a given unit, this section examines a work force scenario as described in Sections C.3.1 and C.4.1.1.2.

Given the work force scenario detailed in Section C.3.1, it is estimated that 2273 workers would be on-site to complete refurbishment of WCGS in 2024 (SEA 1994). Further assuming that the residential distribution of refurbishment workers would be similar to that estimated for the 1984 WCGS construction work force, it is estimated that 20 percent (455) would reside in Coffey County. For Wolf Creek, estimates of refurbishment worker in-migration are based on construction experience at nuclear plants located in areas similar to Coffey County. It is estimated that 70 percent (319) of the refurbishment workers living in Coffey County would be workers who migrate into the area for jobs at WCGS (Table C.82). Also following the pattern set by construction workers' in-migration at other nuclear projects, 51 percent of the in-migrants (163) would be accompanied by families. Using the Kansas average family size of 3.08, total refurbishment worker in-migration would result in 658 new residents for Coffey County. Based on construction in-migration and the ratio of nonplant jobs created during peak construction periods at nuclear plants in comparable locales, Wolf Creek's refurbishment is projected to create an additional 114 indirect jobs in service industries supported by the spending of refurbishment workers. As a result of these indirect jobs, an estimated 59 additional workers and their families (a total of 140 persons) would be projected to move into Coffey County (Table C.82). In all, approximately 798 new residents would be expected to move into Coffey County as a result of WCGS's refurbishment under the work force scenario. That would represent 9.1 percent of Coffey County's projected population of 8763 in 2025.

Once plant refurbishment is completed for WCGS, the work force would consist mostly of permanent plant staff. Additional refurbishment/refueling workers would be temporarily on-site approximately every 2 years; however, they would not be permanent, on-site plant staff, and many of them are expected to commute from outside the study area. It is expected that a maximum of 60 additional permanent workers per unit would be required during the license renewal term. Assuming that the new workers' residential distribution would be the same as current workers', approximately 50 percent (30) would reside in Coffey County. Based on worker in-migration at nuclear plants in comparable locales, it is estimated that 50 percent (15) of those residing in Coffey County would be prior residents who obtain jobs and that 15 would be workers who migrate into the area for jobs (Table C.83). Also following the pattern set by personnel in-migrating to work at other nuclear plants, 66 percent of the in-migrants (10) would be accompanied by their families. Using the Kansas average family size of 3.08 people, total in-migration would result in 36 new residents for the county. Based on work force in-migration and the ratio of nonplant jobs created at other nuclear plants during operating periods, it is estimated that WCGS's license renewal term would create an additional 24 indirect jobs in service industries supported by the spending of plant workers. As a result of these indirect jobs, an estimated 13 additional workers and their families (a total of 32 persons) would be projected to move into Coffey County (Table C.83). In all, approximately 68 new residents would be expected to move into Coffey County as a result of WCGS's license renewal term. That would represent 0.8 percent of Coffey County's projected population in 2025.

C.4.7.2 Housing

The following sections examine the housing impacts that occurred in Coffey County during construction and operation of WCGS and predict housing impacts that would result from refurbishment activities and continued operation. Possible impacts to housing include changes in the number of housing units, particularly the rate of growth of the housing stock; changes in occupancy rates; changes in the characteristics of the housing stock; and changes in rental rates or property values.

Section C.4.1.2 includes a complete discussion of the methodology and assumptions used to predict housing impacts.

C.4.7.2.1 Impacts from Plant Construction and Operation

The following section details project-related housing demand in Coffey County and describes the housing market at the time of Wolf Creek construction. A discussion of changes that occurred in the housing market and plant construction-induced impacts on housing follows. Finally, impacts from the operation of Wolf Creek on local housing are assessed. Because Wolf Creek was not included in the NUREG/CR-2749 study, estimates of worker in-migration are based on the construction experience at other nuclear plants in comparable locales (Section C.4.7.1).

Construction of Wolf Creek began in 1977 and was completed in 1985. The construction work force peaked in 1984 at approximately 5500. Only 20 percent of the work force resided in Coffey County, but 70 percent of those workers migrated to the area for refurbishment jobs. Other workers, both prior residents and in-migrants, commuted from places within 120 km (75 miles) of the site. Project-related housing demand in Coffey County peaked in 1984 at 713 units. This demand represents 18 percent of the 3928 housing units in Coffey County in 1984.

Year-round housing in Coffey County in 1970, before construction of WCGS, totaled 3067 units. Of these, 92.8 percent were in one-unit structures. Of the occupied units, 21 percent were renter-occupied. The vacancy rate (for sale or rent only) was 3.3 percent. A local source reported that the vacancy rate had increased considerably between 1970 and the beginning of WCGS construction.

Local sources have indicated that during construction, housing occupancy rates, particularly of rental housing, reached 100 percent. Although many construction workers chose to live in an area more urban than Coffey County, others were forced to do so simply because there was no available housing. Thus, in-migrants located as far away as Kansas City, Wichita, Topeka, and Ottawa. The 1980 census reported a vacancy rate of 3.6 percent in Burlington and 3.3 percent in Coffey County. However, at that time the construction work force was only 2266 members (Braid 1981).

Several changes in the housing stock occurred during WCGS construction. A plant-site mobile home park was added, as were additional connections in the already existing Coffey County mobile home parks. By 1980, 153 mobile homes were in Coffey County, 33 percent more than in 1970. Another change involved the reoccupation of older, dilapidated housing that had previously been unoccupied.

No large-scale developments were initiated during the construction of the plant; however, more houses were built annually during construction than at any time before or since. During the 7-year period before construction, an annual average of 14.4 housing units were built in Burlington (housing permit information before 1977 is not available for other areas of Coffey County). Of these, 80 percent were built in the 3 years before WCGS construction. In the 5 years since construction has been completed, an annual average of 6.8 units have been built. During plant construction, an annual average of 16.4 units were built, about 40 percent of which were in multiunit structures (U.S. Bureau of the Census 1971–90). In 1970, only 12.2 percent of the units in Burlington had been in multiunit structures (U.S. Bureau of the Census 1972).

Rental rates and housing values rose between 1970 and 1980 at a much quicker rate in Coffey County than in the state of Kansas, as is shown in Table C.84. Local sources indicated that no substantial upgrading or new construction occurred to warrant the great increase in rental rates. Rather, the cause for the increases was WCGS project-related demand. It is likely that project-related demand for housing resulted in even greater increases in rental rates and housing values in 1984, the peak construction year.

Since the completion of WCGS construction, rental rates have gone down again and are now 25–30 percent less than they were during construction. Also, housing vacancies, particularly of rental units, are up once again.

Operation of WCGS has had some effect on the Coffey County housing market. A few new homes have been built for operations workers, but no substantial housing development has occurred. The plant has not negatively affected property values; rather, during a recent economic decline in the region, the economic stability provided by the plant, including steady employment, prevented property values from dropping as sharply as would otherwise have occurred. During refueling periods, however, rental occupancy rates approach 100 percent, and all available trailer pads are used. A typical planned outage at Wolf Creek has involved about 640 additional on-site workers.

In summary, housing demand during WCGS construction caused housing availability to be sharply reduced and rental rates to be sharply increased. Despite this, substantial new housing construction did not occur, rather, trailer parks were expanded or added. WCGS operation has not changed the housing market or housing values;

however, the presence of workers involved in refueling activities causes rental occupancy rates to rise considerably.

C.4.7.2.2 Predicted Impacts of License Renewal

Project-related population increases and the commensurate housing demand would be the cause of new housing impacts during refurbishment activities. A summary of recent and anticipated growth in housing is provided. This is followed by predictions of possible impacts during refurbishment and the license renewal term.

Since the completion of WCGS, approximately 10 new units have been added annually to the Coffey County housing stock (U.S. Bureau of the Census 1971–90). At this rate of expansion, there could be 4200 housing units in 2024, the peak year of refurbishment at WCGS. However, many of these housing units are associated with the in-migration of WCGS construction and operations work forces. New housing units are currently being built only when requested by an in-migrating family or to replace an existing structure. The latter case is a likely circumstance considering that 50 percent of the housing units in Coffey County were constructed before 1940. The projected population of the study area in 2024 is 8763; this is 359 persons more than the 1990 population (Section C.4.7.1; U.S. Bureau of the Census 1990). This slow population growth is not expected to sustain the housing growth that has occurred during the last two decades. If half as many houses are built annually between 1990 and 2024 as were built between 1971 and 1990, there would be 3862 units in 2024. The population in 2024 is projected to required 3519 housing units, leaving 343 units vacant. This would result in a 8.9 percent vacancy rate. The 1990 housing vacancy rate in Coffey County was 10.8 percent.

According to the estimate of the number of workers required for plant refurbishment and based on plant construction experience, 319 workers of the total work force of 2273 are expected to migrate to Coffey County for refurbishment jobs. Of these in-migrants, 163 are expected to be accompanied by families. Some doubling-up is expected to occur among the 156 unaccompanied workers, so that each unaccompanied mover would require 0.85 housing unit. The in-migration of these workers would result in a total refurbishment-related housing demand in the peak year of 296 housing units. In addition, some indirect jobs are expected to result from the spending of project workers. An additional 59 workers are projected to move into Coffey County, bringing the total project-related demand for housing to 355.

Refurbishment-related housing demand is far less than that which occurred during construction, yet it still accounts for 9.2 percent of the projected housing stock. Because projected demand exceeds projected vacancy, housing availability may be drastically reduced and approach zero availability. Competition for existing units may cause great increases in rental rates. Existing mobile home parks will likely be expanded, or new mobile home parks may be added to accommodate project workers. New housing construction would not result because of the brief duration of this peak demand, but previously abandoned housing may be returned to residential use. In summary, large new impacts to housing are possible during refurbishment.

Housing impacts involving marketability and value that would occur during the license renewal term are the same as those currently being experienced (Section C.4.1.2.1). The 60 additional workers (60 per unit) required during the license renewal term and the commensurate housing demand would cause only small new housing impacts. However, the number of refueling and maintenance workers required periodically would be slightly increased (by approximately 30 workers). Thus, the large housing impacts that are currently experienced in Coffey County during refueling periods would continue and may be slightly exacerbated by the additional workers during the license renewal term.

C.4.7.3 Taxes

C.4.7.3.1 Impacts from Plant Construction and Operation

The construction permit on WCGS was granted in 1977, and commercial operation began in 1985. WCGS was not part of the Mountain West or any other systematic study; therefore, historical data on economic effects are limited.

WCGS pays property taxes to several taxing jurisdictions, although most of them are very small (e.g., water districts, cemeteries) and the taxes paid are insignificant. Substantial amounts are paid to the state of Kansas and significant amounts to Coffey County and the Burlington School District in Coffey County (Fritz). Table C.85 indicates the taxes paid to these jurisdictions for 1980, 1985, and 1989.

The taxes paid by WCGS dominate Burlington School District and Coffey County revenues since the nuclear plant's tax payments make up over 60 percent of the taxes levied by this school district (and about 63 percent of its total revenues) and nearly 45 percent of the total revenues for Coffey County (Burlington Unified School District 1980, 1985, and 1989).

An indication of the importance of WCGS to the local tax bases can be seen from the increase in total revenue before and after taxes were levied. In 1977, total county revenue was $1.7 million (all amounts in constant 1989 dollars); by 1985 it had increased to $10.4 million and reached $14.7 million in 1988. This was a greater than eightfold increase in revenue over an 11-year period. More than 85 percent of this increase was from increased tax collections. Another indication of tax effects is that per capita tax revenues in 1977 were $157, and by 1988 they had increased to $1417. The total per capita property tax paid by WCGS to Coffey County and the Burlington School District was $2381. This was more than four times the per capita property tax revenues for the entire state of Kansas, which averaged $520 (1989 dollars) in 1981–82 (U.S. Bureau of the Census 1986).

Taxes paid to the Burlington School District have shown a similar sharp increase. General fund property tax revenues were $683,000 in 1977–78 (1989 dollars), increasing to $3.8 million in the proposed 1989–90 budget. The tax revenues paid to the Burlington School District significantly increased expenditures per pupil. The Burlington School District is in a generally poor area of southeastern Kansas; however, the general fund budget per pupil in 1988–89 was $4605, which was 3 percent above the statewide median for similar-size school districts (Unified School Districts of Kansas 1990). Classroom teacher salaries were also slightly above the statewide average (Kansas Education Department 1990). An important advantage of the large tax base provided by WCGS for the Burlington School District is in the ability to generate capital funds for facilities and school purchases of equipment and materials. In this respect, the district has significantly better facilities than the surrounding school districts. Expenditures related to the general fund, however, do not fully reflect the large property tax valuation within the Burlington School District because there is a state-imposed cap on annual increases has limited Burlington to annual increases of 2 percent over the last several years (Kansas State Board of Education 1990). The capital outlay fund can be applied to a limit of 4 mills and has no cap on annual increases. However, the teacher salaries and other everyday expenses are paid from the general fund, which has expenditures near the state median but above those of surrounding school districts.

Another effect of WCGS is property tax rates in the local taxing jurisdictions. The Burlington School District has the lowest mill levy of any school district in Kansas. The 1989 total mill levy for Burlington School District was 14.60, compared to the statewide median of 56.39 (Kansas Education Department 1989).

C.4.7.3.2 Predicted Impacts of License Renewal

The new tax-related impact expected to occur during refurbishment of WCGS results from capital improvements undertaken during the current term outages. The assessed value of the plant would increase during this time and thus increase WCGS's tax payments to Coffey County and the Burlington School District. This new impact does not involve capital improvements that take place during the final refurbishment outage and that would be reflected in the plant's assessed value during the license renewal term. The magnitude of the new impact depends on which improvements would occur at WCGS early on and which would be done during the final outage. For example, if the steam generator is replaced during a current term outage, the assessed value may increase considerably before the license renewal term begins. If steam generator replacement and other major capital improvements are not undertaken early on, the increase in assessed valuation may be only minor. The increase, in either case, is expected to cause only a small to moderate new tax impact.

During the license renewal term, the primary tax-related impact would be the continuation of tax payments that WCGS is currently making to local jurisdictions. WCGS currently provides 45 percent of Coffey County's revenues and 63 percent of Burlington School District's revenues. A new impact would also result from the increase in tax payments resulting from improvement made at the WCGS during the final refurbishment period. Thus, tax revenues would increase in absolute terms but may remain constant or decrease as a percentage of total revenues of the taxing jurisdictions. Based on current conditions, WCGS tax revenues—the continuing and additional payments combined—are expected to continue to make up a large share of the total revenues of the county and the school district.

C.4.7.4 Public Services

C.4.7.4.1 Impacts from Plant Construction and Operation

In terms of public services, WCGS affects several surrounding communities and school districts, especially Coffey County and the incorporated cities of New Strawn and Burlington. These incorporated cities maintain certain utilities and their streets, and Burlington has a police department. The majority of services, however, are provided at a county or state level, and recreational facilities for both communities are provided through a district recreation commission. WCGS also has affected the schools in Burlington, Lebo/Waverly, and Leroy, and there have been some effects on the city of Emporia in neighboring Lyon County. There have also been significant impacts on transportation north of the plant.

Since operations at WCGS began, existing facilities have been upgraded in the area, and other new ones have been built. This has happened especially in the areas of education, transportation, public safety, recreation, and public utilities. Information pertaining to expenditures is discussed in detail in Section C.4.7.3.

Education

WCGS is located in the Burlington School District, Unified School District 244, but the presence of the facility also affects the nearby school districts in Lebo/Waverly and Leroy. Before the construction of WCGS, the Burlington School District maintained three schools: an elementary, a middle, and a high school. The Burlington superintendent reported that the plant's construction had noticeable impacts on district enrollment, as it did in Lebo/Waverly and Leroy. Unlike the two neighboring school districts, there was no large drop in enrollment in Burlington after construction of WCGS was complete.

The superintendent in the Lebo/Waverly school district, Unified School District 243, indicated that a period of higher enrollment lasted for 6 to 7 years, but it was followed by a sharp drop in the number of students. Enrollment at Leroy also grew during WCGS's construction but has dropped nearly 19 percent since its completion. However, the drop in enrollment was due more to the loss of jobs in nearby oil fields over the last 5 years and was not as bad as had been predicted.

Operations at WCGS have had a small effect on enrollment in the districts. Maintenance and refueling activities at WCGS also have caused only small impacts on enrollment in all of the school districts. However, as noted in Section 4.7.3, tax funds from WCGS have been very important to the Burlington School District, allowing an addition onto the elementary school and new buildings for the middle and high schools.

Transportation

Informants in Burlington and the small town of New Strawn reported that the construction of WCGS did not affect traffic or street repair in these communities. However, the city manager in Emporia stated that traffic problems increased in his city during construction. Roads and bridges in the area were unimproved and in a state of disrepair before construction. Revenues from WCGS have since funded the repairs of roads and bridges, and they are now in good condition. This was made possible by a shift in road funding from the townships to the county. Burlington's city manager reported that the county also had been assisting the city with street maintenance funds.

Although there were minor impacts in the areas mentioned above, traffic on the highways leading toward the plant from the west, north, and northeast experienced large impacts. The Coffey County engineer estimated that, during construction, the surge in traffic at shift changes caused congestion as far away as 100 km (60 miles). Construction workers who commuted into Coffey County lived in various larger cities, such as Emporia, Topeka, Ottawa, and Olathe. Traffic from these communities approached WCGS mainly on two highways, Interstate 35 and U.S. 75. The main access to the plant was from the intersection of these two highways, about 24 km (15 miles) north of the plant. Traffic was bottlenecked from this intersection south almost to New Strawn, where the plant road intersects with U.S. 75.

Following plant construction, the on-site work force was reduced substantially, and improvements were made to roads leading to and from the plant. Accordingly, large plant-related traffic impacts no longer are experienced in the study area, either during normal operations or during periodic plant outages for refueling (with an average of 640 additional workers) although traffic is noticeably heavier during outages than during normal operations, so that there are small to moderate impacts.

Public Safety

The city of Burlington provides police protection to its citizens and formerly had a volunteer fire department. In January 1990, the fire department was put under the control of county, which has greater financial resources. Coffey County will also build and maintain a new volunteer fire station in New Strawn in the near future.

New Strawn does not provide police protection, but Emporia provides police protection and has a paid fire department. No informant reported an increase in demands on fire protection in any community since WCGS's construction began. One respondent did state that problems with law enforcement in Emporia existed during the construction period, but this was not reported elsewhere.

No informant reported impacts on public safety from operations at WCGS or from refurbishments at the plant.

Social Services

Social services and health programs in Burlington and New Strawn are provided by the state and Coffey County, as is the case generally in Emporia. No informant reported impacts from the construction at WCGS. Beginning in 1984 the Lyon County Health Department had increased demands, but this was attributed to other factors, not to Wolf Creek's operations. No impacts were reported from refurbishment activities.

Public Utilities

Burlington's public utilities experienced noticeable impacts during WCGS's construction. The city provides water, sewage disposal, and electricity to residents, and these were noticeably affected. One informant reported that these services were expanded during construction. However, the city manager stated that utilities were well enough established at the time construction began that there were no significant effects because of WCGS's demands.

New Strawn provides water to its residents, and the water system was affected more during construction than any other service of New Strawn because the large influx of construction personnel put great demands on the water system. A new water plant was necessary, regardless of the employees' presence, so a new one was built. Property taxes and water bills paid by the WCGS workers contributed substantially to its funding.

The city of Emporia has provided water, sewage treatment, and refuse disposal for residents since before construction began at

WCGS. No informant reported large impacts on these services during the plant's construction.

The cities of Burlington, New Strawn, and Emporia report no impacts on city services as a result of operations and refurbishments at WCGS.

Tourism

The construction and operation of WCGS has had small effects on tourism in the area. No one reported major tourist activities in Burlington before the construction of WCGS began, but one informant stated that during construction the plant was open to the public often, that many people visited it, and that it is still open occasionally.

Operations at the plant also have encouraged tourism, both directly and indirectly. Tour buses make stops at the plant and its education center. In-migrants are credited with the survival of a puppet factory, another tourist attraction in Burlington. Several sites in and near Emporia may be developed in the future for increased tourism. The combination of these factors in Lyon County resulted in the formation of a convention and visitor's bureau in 1984 and the creation of a bed tax in Emporia; however, overall effects have not been significant to date. The Emporia Convention and Visitor's Bureau reports that the plant at WCGS has not resulted in a decrease in tourism.

Recreation

During construction, there were small impacts on public sports leagues and facilities in Burlington and New Strawn. New Strawn, as part of the Burlington School District, is also in the jurisdiction of the Burlington Recreation Commission.

Recreation in Emporia experienced moderate effects from the construction of WCGS. The Emporia Recreation Commission noted an increase in participation and a definite difference in recreational programs during that time; after construction workers left, cutbacks had to be made.

Recreation in Burlington has changed a great deal since WCGS began operating; most of the plant's impacts have been monetary. One respondent reported that funds from the plant had brought about the high school's new football and track facilities and that these facilities are used heavily, boosting retail business as well (S. Smith 1990). Burlington's recreation center, similarly financed, is a welcome amenity according to several sources. It was also noted by two informants that the cooling pond at WCGS would be a welcome addition to recreational facilities in the area, but the reservoir is not open to the public at this time.

There were no indications that operations and maintenance activities affect recreation in Burlington, and there were reports of insignificant impacts on Emporia's recreation programs. For instance, WCGS visitors and employees frequent the golf course, and organized recreational activities have slight increases during outages.

C.4.7.4.2 Predicted Impacts of License Renewal

Based on the estimated 2273 direct workers required during peak refurbishment, the staff estimates that 163 direct workers and 39 indirect workers will migrate with their families to Coffey County (Section C.4.7.1.2). The number of children accompanying these workers is estimated using the Kansas average family size (3.08) and assuming that all families include two adults. Children are expected to be evenly distributed in age from ≤1 to 18 years. Assuming that 72.2 percent of these children are school age (5 to 18 years), there will be an average of 0.78 school-age children per in-migrating family, or a total of 158 new students in Coffey County, or about 12 per grade. This represents a 8.9 percent increase above the projected number of school-age children in Coffey County in 2024 (assuming the 1990 age distribution of the population). This considerable increase could easily require additional staff, might require temporary classrooms or conversions of facility use, and may result in moderate to large impacts to education.

An analysis of the projected BWR bounding case work force (1500 persons) was conducted to determine if a smaller work force would result in a lesser impact. (This is a hypothetical scenario because ANO is a PWR.) The 133 in-migrating direct and indirect workers who bring their families to Coffey County would be accompanied by 104 school-age children (or 8 per grade). This would result in a 5.8 percent increase in the number of school-age children in Coffey County in 2025 and could cause moderate impacts, especially if the children are concentrated geographically (e.g., in Burlington).

An analysis of potential impacts to education under the typical work force scenario (1017 workers) finds that there would be 89 direct and indirect workers migrating to Coffey County with their families. The associated 69 new school-age children (or 5.5 per grade level) would result in a 3.8 percent increase in the projected number of school-age children in Coffey County in 2025. This increase in enrollment will likely cause small impacts, but moderate impacts to the education system could result if the students are concentrated geographically or if the facilities and classes are already at their peak capacity.

During the construction of WCGS, impacts on social services and tourism were insignificant. Because refurbishment would bring in fewer people than did the initial construction (2329), any future impacts to these public services would be small. (Coffey County's 1984 population was 9001 excluding WCGS construction-related in-migration.)

Public safety in Coffey County, which has been affected fiscally by WCGS, should also see small changes during the refurbishment period. Recreation, which experienced moderate impacts during the construction of WCGS, would probably experience only small impacts during refurbishment in 2024 because the recreation facilities themselves have been significantly improved since WCGS construction. A 9.1 percent increase in population may result in small to moderate impacts to public utilities.

Transportation effects hinge on three factors: the number of workers, the state of the roads, and the number of access points. Currently, one major access point leads into WCGS via a two-lane road. Based on the level of impacts that occurred during original plant construction, it is expected that the use of local roads by the peak refurbishment work force could result in large transportation impacts, despite road improvements made after initial construction.

During the license renewal term, only small impacts are expected for any public service, including transportation.

C.4.7.5 Off-Site Land Use

This section describes the off-site land-use impacts of the construction, operation, and license renewal of WCGS. The discussion of impacts is primarily concerned with land use in the immediate vicinity of the plant, but impacts to Coffey County are described where appropriate. Land-use impacts are examined for two time periods. First, Section C.4.7.5.1 identifies the land-use impacts of WCGS's construction and operation. Next, Section C.4.7.5.2 projects the land-use impacts of WCGS's refurbishment period based on the impacts that occurred during the plant's construction. Also, Section C.4.7.5.2 projects the land-use impacts of the plant's license renewal term based on the impacts that have occurred during operations. Information sources for this report include the *Final Environmental Statement Related to Construction of Wolf Creek Generating Station, Unit 1* (NUREG-75/096); the *Final Environmental Statement Related to the Operation of Wolf Creek Generating Station, Unit 1* (NUREG-0878); and interviews with key sources of information in Coffey County. Section C.4.1.5 describes the methods used to assess and project land-use impacts for all case study plants.

C.4.7.5.1 Impacts from Plant Construction and Operation

WCGS and its cooling lake were built on 3973-ha (9818-acre) tract of land near Burlington. The cooling lake inundated approximately 2100 ha (5100 acres) of land, and the actual plant site, including the lake's dam and dikes, covers approximately 80 ha (200 acres). Before the plant's construction, the land had been used almost exclusively for agriculture and livestock grazing, although 25 farm-related homes were on the site. The general area in the plant's vicinity was very rural, and agriculture, livestock grazing, and low-density, farm-related residences were the primary land uses. There were only two small industries (a total of 33 employees) and some storage facilities (for petroleum products, grains, and fertilizer) within 8 km (5 miles) of the plant site at the time construction began. The town of Burlington, about 5.6 km (3.5 miles) southwest of the plant, was primarily a rural residential town with little commercial and almost no industrial land use (NUREG-75/096; NUREG-0878).

WCGS's construction had significant impacts on land use in the vicinity of the plant. Part of the impact included removing 25 homes and relocating some federal-aid secondary-route roads. Another immediate impact was on property ownership. In an effort to avoid subdividing previous owners' property beyond economic usefulness, the Kansas Gas and Electric Company purchased entire tracts of land, refusing to purchase only portions of an owner's property. This meant that the company acquired a great deal of excess land for the WCGS site. The land acquisition, the plant's construction, and the lake's inundation involved removing over 3600 ha (8800 acres) of agricultural and range land from production. There was some concern, before construction, that removing the agricultural and range land from production would have negative effects on the local economy. However, the impacts to range land have been somewhat alleviated by the fact that the Kansas Gas and Electric Company leases much of its excess property as range land to area farmers. In addition, the impacts of WCGS's operation, discussed below, have more than compensated for the local economy's loss of productive agricultural land (NUREG-75/096).

The plant's construction had moderate impacts on land use elsewhere in Coffey

County. Informants indicated that land use in some of the towns, particularly Burlington and New Strawn, was temporarily affected by the presence of the unusually large construction work force (approximately 5500 workers were on-site during the peak construction year). In 1984, construction-related population growth accounted for as much as 20.5 percent of Coffey County's total population. The primary impact of such growth involved the construction of temporary housing and the influx of mobile homes to provide housing for the construction workers. Informants felt that the number of mobile homes that came into the area was too great for the local mobile home parks to accommodate and that this had negative effects on some of the parks in Burlington and New Strawn. These effects were temporary, however, as most of the workers took their mobile homes with them as they left the area when the plant's construction was completed. Also, the presence of such a large construction force attracted some commercial and service businesses to Burlington. However, most of these were temporary businesses that moved into vacated buildings in Burlington when the plant's construction began and moved out of town when construction was completed. Overall, the influx of construction workers had only temporary land-use impacts and did not create permanent changes in land-use or development patterns in Coffey County (NUREG-75/096).

Operations at WCGS have had only minimal direct land-use impacts on Coffey County. Key sources indicated that the plant's presence had not been a deterrent to residential development. Conversely, the informants felt that the plant's operation had not directly encouraged residential development in Coffey County. This is because half the operations work force resides outside of Coffey County, with many workers commuting from Emporia and Ottawa. The plant's presence also has had neutral impacts in terms of directly attracting support industries and commercial growth to the county.

However, WCGS's operation has had large indirect impacts on land use in Coffey County. The plant's property tax payments have allowed the county to lower its property tax rates while upgrading its provision of municipal services. Coffey County also has used much of its tax revenue from the plant to purchase industrial buildings and machinery. The county buys the building or the machinery and then leases it at a discount to the company on a lease-purchase basis. The company benefits by paying less for facilities and equipment, and the county benefits by attracting industrial development. According to key sources, the combination of low property taxes, above-average municipal services, and relatively low plant and equipment costs has been successful in attracting small and medium-sized industries to Coffey County.

WCGS's positive contributions to the county's overall quality of life also serve as a tool in recruiting industries. The tax base, employment, and salaries that the nuclear plant provides have encouraged commercial development, particularly in the incorporated towns in Coffey County, and have helped make the region's economy more stable. Key sources felt that the plant's tax payments were responsible for improving the county's hospital, roads, sewers, schools, and recreation facilities and that these improvements were a selling point to industrial prospects. Also, informants felt that the plant had brought a more highly educated, technical work force to the county and that the workers would continue to support the types of community improvements that would be attractive to industries.

Since WCGS's construction, industries have begun to locate in Burlington and, more recently, in Waverly, Lebo, and Leroy. Although most of the industries are small, their presence does create changes in the county's land-use and development patterns. Burlington, a town that had only two small rural industries when WCGS's operation began, now has two industrial parks. The second industrial park attracted Tricon Industries, a company that provides approximately 500 jobs in producing fiberglass vaults for communications equipment. Although Coffey County is still rural, with agriculture as its primary land use, WCGS's tax payments and overall positive contributions to the community's quality of life have enabled the county to attract significant industrial development for the first time. This represents a trend away from the county's traditional rural land-use pattern, as more agricultural and range land is converted to industrial uses. Overall, informants felt that the nuclear plant's land-use impacts on Coffey County had been very positive.

C.4.7.5.2 Predicted Impacts of License Renewal

With the population increase projected for Coffey County, the direct land-use impacts of WCGS's refurbishment are expected to be moderate. Using the bounding case work force scenario, refurbishment-related population growth is projected to represent a 9.1 percent increase in the county's projected population in 2025. However, the new impacts are likely to be much smaller than those that occurred during the construction-related growth peak of 20.5 percent in 1984. The influx of refurbishment workers might cause some temporary housing shortages; however, based on what occurred during the plant's construction, it is not likely that the shortages would result in any new large-scale residential development or changes in land-use patterns.

An analysis of the projected 1500-person BWR bounding case work force was conducted to determine whether a smaller work force would result in a lesser impact to land use. The in-migrating population associated with a BWR bounding case work force would be 526, or a 6.0 percent increase in Coffey County's projected population in 2024. This would result in moderate impacts to land use.

An analysis of potential impacts to land use under the typical work force scenario (1017 workers), finds that the projected in-migrating population of 353 (or a 4 percent increase in Coffey County's 2024 population) would likely result in only small impacts to land use.

Coffey County is still predominantly rural, and land in the plant's immediate vicinity will be used for agriculture and livestock grazing, as it has been during the plant's operation. Local officials expect some small-scale industrial and commercial growth in the county's incorporated towns, particularly in Burlington and New Strawn. However, the nuclear plant's presence is not expected to attract support industries or commercial development directly and is likely to neither encourage nor deter residential development.

Because WCGS is located in a rural area that depends largely upon agriculture for its economic stability and because the nuclear plant and its property account for over 90 percent of Coffey County's taxable assessed valuation, the new indirect land-use impacts of WCGS's license renewal term are expected to be large. As during operations thus far, WCGS's tax payments would continue to allow Coffey County to provide above-average municipal services with relatively low property tax rates. Sources indicated that the plant's tax payments had allowed the county to upgrade its services and provide amenities that improved residents' overall quality of life. They noted that some plant staff who had chosen to live in larger communities outside Coffey County when operations began were now moving into the county as a result of its above-average services and amenities. If this trend continues, a greater proportion of WCGS's plant staff would live in Coffey County in the future. It is expected that this in-migration would result in some additional residential development, especially in Burlington, and that this development could create changes in the county's land-use pattern.

Also, because of WCGS's tax payments, the county would be able to continue its successful economic development program of providing lease-purchase options for prospective industries' plant and equipment needs. By attracting small and medium-sized industries to the area, these benefits also would promote commercial and residential growth and further change Coffey County's land-use pattern. Although the county's land-use pattern is expected to remain predominantly agricultural, the new indirect impacts of WCGS's license renewal term would have large effects on land-use and development patterns in Coffey County.

C.4.7.6 Economic Structure

C.4.7.6.1 Impacts from Plant Construction and Operation

The construction and operation of WCGS have resulted in large economic impacts to Coffey County. First, they have directly increased employment and income for county residents employed in the construction and operation of the plant. Second, direct employment and income have generated local expenditures resulting in indirect employment and income, and increased tax revenues from WCGS have helped provide the necessary infrastructure for attracting new business into the county. Table C.86 presents the estimated employment and income effects of WCGS's operation for residents of Coffey County.

As the table indicates, the economic effects of operating WCGS are very important to the local community. One indication of the impact on the local economy is the increase in per capita income compared to that in neighboring counties. For instance, from 1975 to 1990, Coffey County per capita income increased by 52 percent. By contrast, in the neighboring counties of Lyon, Osage, and Anderson, per capita income increased by 29, 35, and 43 percent, respectively, over the same time period. Over this same period, Coffey County employment by place of business increased by 75 percent, whereas combined employment in the neighboring counties increased by only 22 percent.

C.4.7.6.2 Predicted Impacts of License Renewal

Tables C.87 and C.88 indicate that although the economic effect of WCGS on Coffey County would decline in relative terms, it would still be a crucial component of county employment during refurbishment and after license renewal.

The main impact of license renewal at WCGS would be the continued employment and income benefits of the plant's operation. The benefits should be similar in size to those that existed in 1989, but the relative importance of the benefits would decline because Coffey County's economy is projected to grow in other sectors.

The work force scenario detailed in Section C.3.1 was used to estimate the employment and economic effects of refurbishment at WCGS. Table C.87 shows the total direct and indirect plant-related employment of study area residents during refurbishment. It is projected that WCGS would employ 455 county residents as refurbishment workers in 2024 (Section C.4.7.1.2). Indirect employment that would result from purchases of goods and services during refurbishment is projected to create 108 additional jobs for Coffey County residents. Together, WCGS-related direct and indirect employment is projected to total 563 workers in Coffey County. This is a moderate impact, as those workers represent approximately 6.8 percent of Coffey County's total projected employment in 2024.

Relatively few new plant-related jobs would be created at WCGS during the license renewal term. Nearly all plant-related employment (and associated impacts) expected during that time period would represent a continuation of employment (and impacts) from past operations. Table C.87 shows the impact of the increased labor requirements at WCGS after 2025. The license renewal term work force for WCGS would require an estimated 60 additional workers; 30 are projected to be Coffey County residents. In addition, an estimated 23 indirect jobs are projected to be created for county residents by license renewal. With the continued effects of the plant's current employment and the additional employment to be created, total direct and indirect license renewal term employment is projected to be 575, or 7.1 percent of Coffey County's total employment in 2025. This employment level represents a moderate impact.

C.4.7.7 Historic and Aesthetic Resources

This section describes the impacts that the construction and operation of the Wolf Creek Generating Station have had on historic and aesthetic resources and projects the expected impacts of the plant's refurbishment and post-license renewal operations. Information sources include the *Final Environmental Statement Related to the Operation of Wolf Creek Generating Station, Unit 1* (NUREG-0878) and interviews with key sources in Coffey County and elsewhere in Kansas.

C.4.7.7.1 Impacts from Plant Construction and Operation

The construction and operation of the Wolf Creek nuclear facility have had insignificant impacts to Coffey County's historic resources. According to the *Final Environmental Statement* (NUREG-0878), no listed natural or historic landmarks or sites are within 8 km (5 miles) of the plant. Since publication of the *Final Environmental Statement* in 1982, none has been added or identified as eligible for inclusion in the National Register of Historic Places or the National Registry of Natural Landmarks. At the time of the issuance of the *Final Environmental Statement*, the state historic preservation officer stated that no historic sites or buildings would be affected by the construction or operation of the Wolf Creek power plant. Sources report that the plant's construction, operation, and community taxes have resulted in a slight indirect benefit to the community in terms of historic preservation (Sirico 1990; Reams 1990). Members of the construction and operating work forces have brought their own personal experiences of the benefits of historic preservation to the community. They have purchased some depressed properties of historic significance and restored them. Community taxes have helped fund the construction and operation of a new museum.

Numerous archaeological sites were identified before construction, and some were further investigated, but from the additional analyses it was concluded that none of the sites was significant enough to warrant nomination to the National Register. The transmission line corridors followed alignments purposely created in part to avoid archaeologically sensitive areas. A railroad spur built to facilitate construction at the power plant site threatened an archaeological site; the area was excavated before construction.

Surrounding the site is a low-density rural agricultural area. The plant relies on an artificial impoundment for cooling water; therefore, no strong, stark, towering cooling structure is needed among the flat to rolling farmlands. The sources reported no complaints or problems with the aesthetics of the plant or its effects on the aesthetic resources of the community.

C.4.7.7.2 Predicted Impacts of License Renewal

The impacts of refurbishment of the Wolf Creek plant on local historic and aesthetic resources are projected to be less than those minor ones experienced during the original construction of the plant. However, determination of impacts to historic resources from refurbishment and license renewal term operations must be made through consultation with the SHPO.

C.5 ENDNOTES

1. The PWR conservative work force number used in this analysis is taken from a work force estimate provided by Science and Engineering Associates, Inc. (SEA), that differs slightly from SEA's work force estimate discussed in Chapter 2 and Appendix B. The slight difference would not affect the conclusions.
2. Estimates in Chapter 2 and Appendix B of additional work force required during license-renewal-term operations indicate that only one additional worker will be required on a continuous basis for maintenance and inspection activities. The more conservative figure (60 persons per unit) is used in the analysis to account for workers (contractors or rotating utility employees) who are not associated with refueling but may be on-site intermittently. The 60 persons per unit analysis represents an upper bound of the possible socioeconomic impacts.

C.6 REFERENCES

The references that follow are divided into three sections: Section C.5.1—printed material that is cited in the text; Section C.5.2— personal communications cited in the text; and Section C.5.3—final environmental statements on which the text has drawn but which are not specifically cited.

C.6.1 Printed Sources

AEC Docket 50-247, *Final Environmental Statement Related to Operation of Indian Point Nuclear Generating Plant, Unit 2,* U.S. Atomic Energy Commission, September 1972.

AEC Docket 50-269, *Final Environmental Statement Related to the Operation of Oconee Nuclear Station, Unit 1,* U.S. Atomic Energy Commission, March 1972.

AEC Docket 50-270, *Final Environmental Statement Related to the Operation of Oconee Nuclear Station, Unit 2,* U.S. Atomic Energy Commission, March 1972.

AEC Docket 50-275, *Final Environmental Statement Related to the Nuclear Generating Station Diablo Canyon, Unit 1,* U.S. Atomic Energy Commission, May 1973.

AEC Docket 50-286, *Final Environmental Statement Related to the Operation of Indian Point Nuclear Generating Plant, Unit 3,* U.S. Atomic Energy Commission, February 1975.

AEC Docket 50-287, *Final Environmental Statement Related to the Operation of Oconee Nuclear Station, Unit 3,* U.S. Atomic Energy Commission, March 1972.

AEC Docket 50-289, *Final Environmental Statement Related to Operation of Three Mile Island Nuclear Station, Unit 1,* U.S. Atomic Energy Commission, December 1972.

AEC Docket 50-313, *Final Environmental Statement Related to the Arkansas Nuclear One, Unit 1,* U.S. Atomic Energy Commission, February 1973.

AEC Docket 50-315, *Final Environmental Statement Related to the Operation of Donald C. Cook Nuclear Plant, Unit 1,* U.S. Atomic Energy Commission, August 1973.

AEC Docket 50-316, *Final Environmental Statement Related to the Operation of Donald C. Cook Nuclear Plant, Unit 2,* U.S. Atomic Energy Commission, August 1973.

AEC Docket 50-320, *Final Environmental Statement Related to Operation of Three Mile Island Nuclear Station, Unit 2,* U.S. Atomic Energy Commission, December 1972.

AEC Docket 50-323, *Final Environmental Statement Related to the Nuclear Generating Station Diablo Canyon, Unit 2,* U.S. Atomic Energy Commission, May 1973.

AEC Docket 50-368, *Final Environmental Statement Related to the Arkansas Nuclear One, Unit 2,* U.S. Atomic Energy Commission, September 1972.

AP&L (Arkansas Power and Light Company), Survey Responses from the Arkansas Power and Light Company, 1990.

Arkansas State Department of Education, *Annual Statistical Report of the Public Schools of Arkansas*, Statistics Department, January 1990.

Berrien County, *Report on Audit of Combined Financial Statements with Supplementary Financial Data, 1988,* Niles, Michigan, 1989.

Braid, R. B., "Better Work Force Projections Needed for Nuclear Plant Construction," *Power Engineering*, 85(4), 91–95, April 1981.

Burlington Unified School District, Financial Statements for 1980, 1985, and 1989, Burlington, Kansas.

California Department of Finance, *Population and Housing Estimates for California Cities and Counties: Summary Report*, Sacramento, California, 1990.

Cass, J., and M. Birnbaum, *Comparative Guide to American Colleges for Students, Parents, and Counselors*, 1970–1971 edition, Harper and Row, New York, 1969.

Cass, J., and M. Birnbaum, *Comparative Guide to American Colleges for Students, Parents, and Counselors*, 9th ed., Harper and Row, New York, 1979.

ConEd (Consolidated Edison Company of New York), Survey Responses from the Consolidated Edison Company of New York, 1990.

County of San Luis Obispo, California, Comprehensive Annual Financial Report, June 1989.

Dauphin County Planning Commission, *Annual Report 1988*, Harrisburg, Pennsylvania, 1988.

Duke Power Company, Survey Responses from the Duke Power Company, 1990.

EPRI/EA-2228, *Socioeconomic Impacts of Power Plants*, Electric Power Research Institute, Denver Research Institute, February 1982.

GPU (General Public Utilities Corporation), Survey Responses from the General Public Utilities Corporation, 1990.

Hill, R. R., "Rankings of the Counties and School Districts of South Carolina, 1987–88," Division of Administration and Planning, Deputy Superintendent, South Carolina Department of Education, May 1989.

Hudson School District, *Hendrick Hudson School District Newsletter*, New York State, April 1990.

Indiana and Michigan Power Company, Survey Responses from the Indiana and Michigan Power Company, 1990.

Jones & Jones, *Visual Impact Study: Statement of Findings, Alternative Closed-Cycle Systems, Indian Point Nuclear Generating Plant*, prepared for the U.S. Nuclear Regulatory Commission, Seattle, November 1995.

Kansas Education Department, General Fund Mill Levies of the 303 Unified School Districts of Kansas, 1985–1989, 1989.

Kansas Education Department, Average Classroom Teachers' and Principals' Salaries for the 304 Unified School Districts of Kansas for 1988–89 and 1989–90, Topeka, Kansas 1990.

Kansas State Board of Education Reports, Topeka, Kansas.

Londonderry Township, Financial Statements for 1980, 1985, and 1989 for Board of Supervisors, Londonderry Township, Pennsylvania, May 1990.

Middletown Borough, Pennsylvania, Financial Statements for 1980, 1985, and 1989 for Middletown Borough.

National Association of Counties, *Nuclear Power Plant Development—Boom or Bust?* NACO Case Studies on Energy Impacts, No. 4, Washington, D.C., July 1976.

New York State Education Department, *Statistical Profiles of Public School Districts*, University of the State of New York/State Education Department, Office of Planning Research and Program Accountability, Albany, New York, January 1990.

NPA (National Planning Association), "Economic Projections," *Regional Economic Projection Series, 1990*, NPA Data Services, Inc., Washington, D.C., 1990.

NUREG-0020, vol. 9, *Licensed Operating Reactors, Summary Status Report*, U.S. Nuclear Regulatory Commission, Office of Resource Management, Division of Budget and Analysis, October 1985.

NUREG-0066, *Draft Supplement to the Final Environmental Statement Related to the Operation of Three Mile Island Nuclear Station, Unit 2*, U.S. Nuclear Regulatory Commission, Docket No. 50-320, July 1976.

NUREG-0254, *Final Environmental Statement Related to Operation of Arkansas Nuclear One, Unit 2*, U.S.

Nuclear Regulatory Commission, June 1977.

NUREG-0878, *Final Environmental Statement Related to the Operation of Wolf Creek Generating Station, Unit 1*, U.S. Nuclear Regulatory Commission, June 1982.

NUREG-1398, *Environmental Assessment for Proposed Rule on Nuclear Plant License Renewal*, U.S. Nuclear Regulatory Commission, 1990.

NUREG-75/096, *Final Environmental Statement Related to Construction of Wolf Creek Generating Station, Unit 1*, U.S. Nuclear Regulatory Commission, October 1975.

NUREG/CR-0916, M. A. Shields et al., *Socioeconomic Impacts of Nuclear Power Plants: A Paired Comparison of Operating Facilities*, Oak Ridge National Laboratory, Oak Ridge, Tennessee, July 1979.

NUREG/CR-2239, D. C. Aldrich et al., *Technical Guidance for Siting Criteria Development*, Sandia National Laboratories, Albuquerque, New Mexico, December 1982.

NUREG/CR-2749, vol. 1, *Socioeconomic Impacts of Nuclear Generating Stations: Arkansas Nuclear One Case Study*, Mountain West Research, Inc., for U.S. Nuclear Regulatory Commission, 1982.

NUREG/CR-2749, vol. 4, *Socioeconomic Impacts of Nuclear Generating Stations: D. C. Cook Case Study*, Mountain West Research, Inc., for U.S. Nuclear Regulatory Commission, 1982.

NUREG/CR-2749, vol. 5, *Socioeconomic Impacts of Nuclear Generating Stations: Diablo Canyon Case Study*, Mountain West Research, Inc., for U.S. Nuclear Regulatory Commission, 1982.

NUREG/CR-2749, vol. 7, *Socioeconomic Impacts of Nuclear Generating Stations: Oconee Case Study*, Mountain West Research, Inc., for U.S. Nuclear Regulatory Commission, 1982.

NUREG/CR-2749, vol. 12, *Socioeconomic Impacts of Nuclear Generating Stations: Three Mile Island Case Study*, Mountain West Research, Inc., for U.S. Nuclear Regulatory Commission, 1982.

NUREG/CR-2750, *Socioeconomic Impacts of Nuclear Generating Stations: Summary Report on the NRC Post-Licensing Studies*, Mountain West Research, Inc., for U.S. Nuclear Regulatory Commission, July 1982.

Oconee County, 1980–81 County Budget Ordinance, Oconee, South Carolina, 1980.

Oconee County, 1985–86 County Budget Ordinance, Oconee, South Carolina, 1985.

Oconee County, 1989–90 County Budget Ordinance, Oconee, South Carolina, 1989.

Oconee County, Independent Auditor's Report, Oconee County, South Carolina.

ORNL/NUREG/TM-22, *A Post Licensing Study of Community Effects at Two Operating Nuclear Power Plants*, B. J. Purdy, et al., Oak Ridge National Laboratory, Oak Ridge, Tennessee, September 1977.

PASNY (Power Authority of the State of New York), Survey Responses from the New York Authority, 1990.

Pennsylvania State Data Center, 1990 Population Projections, Philadelphia, Pennsylvania, 1990.

PG&E (Pacific Gas and Electric Company), Survey Responses from the Pacific Gas and Electric Company, 1990.

Pope County, Arkansas, Financial Statements, 1980, 1985, and 1989, Russellville, Arkansas.

Royalton Borough, Financial Statements for 1980, 1985, and 1989 for Royalton Borough, Pennsylvania, May 1990.

SEA (Science and Engineering Associates, Inc.), Refurbishment Work Force Estimates, Albuquerque, 1994.

TCRPC (Tri-County Regional Planning Commission), Building Permits Issued, Harrisburg, Pennsylvania, 1982.

Town of Cortlandt, Adopted Budget, FY 1990, Town Supervisor's Office, Croton-on-Hudson, New York, 1990a.

Town of Cortlandt, Town of Cortlandt Assessed Valuation—Levied—Tax Rates for the 1989–1990 School Year, Town of Cortlandt, Croton-on-Hudson 1990b.

Unified School Districts of Kansas, Report on Enrollments and General Fund Budget per Pupil, 1989-90, 1990.

U.S. Bureau of the Census, *County and City Data Book, 1966*, 1967.

U.S. Bureau of the Census, *Construction Reports—Housing Authorized by Building Permits and Public Contracts*, Annual Series, 1970 through 1989, 1971–1990.

U.S. Bureau of the Census, *1970 Census of Housing*, 1972.

U.S. Bureau of the Census, *State and Metropolitan Area Data Book, 1986*, 1986.

U.S. Bureau of the Census, *County and City Data Book, 1977*, 1978.

U.S. Bureau of the Census, *1980 Census of Housing*, 1982.

U.S. Bureau of the Census, *County and City Data Book, 1988*, 1988.

U.S. Bureau of the Census, *1990 Census of Population*, 1990.

Westchester County Department of Planning, *Westchester County and Municipality Population and Housing Estimates, January 1989*, White Plains, New York, June 1989.

Wolf Creek Nuclear Operating Corporation, Survey Responses from the Wolf Creek Nuclear Operating Corporation, 1990.

C.6.2 AEC and NUREG Final Environmental Statements

AEC Docket 50-206, *Final Environmental Statement Related to Operation of San Onofre Nuclear Generating Station, Unit 1*, U.S. Atomic Energy Commission, October 1973.

AEC Docket 50-213, *Final Environmental Statement Related to the Haddam Neck (Connecticut Yankee) Nuclear Power Plant*, U.S. Atomic Energy Commission, October 1973.

AEC Docket 50-220, *Final Environmental Statement Related to Operation of Nine Mile Point Nuclear Station, Unit 1*, U.S. Atomic Energy Commission, January 1974.

AEC Docket 50-237, *Final Environmental Statement Related to Operation of Dresden Nuclear Power Station, Unit 2*, U.S. Atomic Energy Commission, November 1973.

AEC Docket 50-244, *Final Environmental Statement Related to Operation of R. E. Ginna Nuclear Power Plant, Unit 1*, U.S. Atomic Energy Commission, December 1973.

AEC Docket 50-245, *Final Environmental Statement Related to the Continuation of Construction of Unit 2 of Millstone Nuclear Power Station*, U.S. Atomic Energy Commission, June 1973.

AEC Docket 50-249, *Final Environmental Statement Related to Operation of Dresden Nuclear Power Station, Unit 3*, U.S. Atomic Energy Commission, November 1973.

AEC Docket 50-250, *Final Environmental Statement Related to Operation of Turkey Point Plant*, U.S. Atomic Energy Commission, July 1972.

AEC Docket 50-251, *Final Environmental Statement Related to Operation of Turkey Point Plant*, U.S. Atomic Energy Commission, July 1972.

AEC Docket 50-254, *Final Environmental Statement Related to Operation of Quad-Cities Nuclear Power Station, Unit 1*, U.S. Atomic Energy Commission, September 1972.

AEC Docket 50-255, *Final Environmental Statement Related to Operation of Palisades Nuclear Generating Plant*, U.S. Atomic Energy Commission, June 1972.

AEC Docket 50-263, *Final Environmental Statement Related to Operation of Monticello Nuclear Generating Plant*, U.S. Atomic Energy Commission, November 1972.

AEC Docket 50-265, *Final Environmental Statement Related to Operation of Quad-Cities Nuclear Power Station, Unit 2*, U.S. Atomic Energy Commission, September 1972.

AEC Docket 50-266, *Final Environmental Statement Related to Operation of Point Beach Nuclear Plant, Unit 1*, U.S. Atomic Energy Commission, May 1972.

AEC Docket 50-271, *Final Environmental Statement Related to Operation of Vermont Yankee Nuclear Power Station*, U.S. Atomic Energy Commission, July 1972.

AEC Docket 50-272, *Final Environmental Statement Related to Operation of Salem Nuclear Generating Station, Unit 1*, U.S. Atomic Energy Commission, April 1973.

AEC Docket 50-277, *Final Environmental Statement Related to Operation of Peach Bottom Atomic Power Station, Unit 2*, U.S. Atomic Energy Commission, April 1973.

AEC Docket 50-278, *Final Environmental Statement Related to Operation of Peach Bottom Atomic Power Station, Unit 3*, U.S. Atomic Energy Commission, April 1973.

AEC Docket 50-280, *Final Environmental Statement Related to Operation of Surry Power Station, Unit 1*, U.S. Atomic Energy Commission, May 1972.

AEC Docket 50-281, *Final Environmental Statement Related to Operation of Surry Power Station, Unit 2*, U.S. Atomic Energy Commission, June 1972.

AEC Docket 50-282, *Final Environmental Statement Related to Operation of Prairie Island Nuclear Generating Plant*, U.S. Atomic Energy Commission, May 1973.

AEC Docket 50-285, *Final Environmental Statement Related to Operation of Fort Calhoun Station Unit 1*, U.S. Atomic Energy Commission, August 1972.

AEC Docket 50-293, *Final Environmental Statement Related to Operation of Pilgrim Nuclear Power Station*, U.S. Atomic Energy Commission, May 1972.

AEC Docket 50-295, *Final Environmental Statement Related to Operation of Zion Nuclear Power Station, Unit 1*, U.S. Atomic Energy Commission, December 1972.

AEC Docket 50-298, *Final Environmental Statement Related to Operation of Cooper Nuclear Station*, U.S. Atomic Energy Commission, February 1973.

AEC Docket 50-301, *Final Environmental Statement Related to Operation of Point Beach Nuclear Plant, Unit 2*, U.S. Atomic Energy Commission, May 1972.

AEC Docket 50-302, *Final Environmental Statement Related to the Proposed Crystal River, Unit 3*, U.S. Atomic Energy Commission, May 1973.

AEC Docket 50-304, *Final Environmental Statement Related to Operation of Zion Nuclear Power Station, Unit 2*, U.S. Atomic Energy Commission, December 1972.

AEC Docket 50-305, *Final Environmental Statement Related to Operation of Kewaunee Nuclear Power Plant*, U.S. Atomic Energy Commission, December 1972.

AEC Docket 50-306, *Final Environmental Statement Related to Operation of Prairie*

Island Nuclear Generating Plant, U. Atomic Energy Commission, May 1973.

AEC Docket 50-309, *Final Environmental Statement Related to Operation of Maine Yankee Atomic Power Station*, U.S. Atomic Energy Commission, July 1972.

AEC Docket 50-311, *Final Environmental Statement Related to Operation of Salem Nuclear Generating Station, Unit 2*, U.S. Atomic Energy Commission, April 1973.

AEC Docket 50-312, *Final Environmental Statement Related to Operation of Rancho Seco Nuclear Generating Station, Unit 1*, U.S. Atomic Energy Commission, March 1973.

AEC Docket 50-317, *Final Environmental Statement Related to Operation of Calvert Cliffs Nuclear Power Plant, Unit 1*, U.S. Atomic Energy Commission, April 1973.

AEC Docket 50-318, *Final Environmental Statement Related to Operation of Calvert Cliffs Nuclear Power Plant, Unit 2*, U.S. Atomic Energy Commission, April 1973.

AEC Docket 50-321, *Final Environmental Statement for the Edwin I. Hatch Nuclear Plant, Unit 1*, U.S. Atomic Energy Commission, October 1972.

AEC Docket 50-322, *Final Environmental Statement Related to Operation of Shoreham Nuclear Power Station*, U.S. Atomic Energy Commission, September 1972.

AEC Docket 50-324, *Final Environmental Statement Related to the Continued Construction and Proposed Issuance of an Operating License for the Brunswick Steam Electric Plant, Unit 1*, U.S. Atomic Energy Commission, January 1974.

AEC Docket 50-325, *Final Environmental Statement Related to the Continued Construction and Proposed Issuance of an Operating License for the Brunswick Steam Electric Plant, Unit 2*, U.S. Atomic Energy Commission, January 1974.

AEC Docket 50-331, *Final Environmental Statement Related to Operation of Duane Arnold Energy Center*, U.S. Atomic Energy Commission, March 1973.

AEC Docket 50-333, *Final Environmental Statement Related to Operation of James A. Fitzpatrick Nuclear Power Plant*, U.S. Atomic Energy Commission, March 1973.

AEC Docket 50-334, *Final Environmental Statement Related to the Beaver Valley Power Station, Unit 1*, U.S. Atomic Energy Commission, July 1973.

AEC Docket 50-335, *Final Environmental Statement Related to the St. Lucie Plant, Unit 1*, U.S. Atomic Energy Commission, June 1973.

AEC Docket 50-336, *Final Environmental Statement Related to the Operation of Units 1 and 2 of Millstone Nuclear Power Station*, U.S. Atomic Energy Commission, June 1973.

AEC Docket 50-338, *Final Environmental Statement Related to the Continuation of Construction and the Operation of Unit 1 of North Anna Power Station*, U.S. Atomic Energy Commission, April 1973.

AEC Docket 50-339, *Final Environmental Statement Related to the Continuation of Construction and the Operation of Unit 2 of North Anna Power Station*, U.S. Atomic Energy Commission, April 1973.

AEC Docket 50-344, *Final Environmental Statement Related to Operation of Trojan Nuclear Plant*, U.S. Atomic Energy Commission, August 1973.

AEC Docket 50-348, *Final Environmental Statement Related to Operation of Joseph M. Farley Nuclear Plant, Unit 1*, U.S. Atomic Energy Commission, December 1974.

AEC Docket 50-352, *Final Environmental Statement Related to the Proposed Limerick Generating Station, Unit 1*, U.S. Atomic Energy Commission, November 1973.

AEC Docket 50-353, *Final Environmental Statement Related to the Proposed*

Limerick Generating Station, Unit 2, U.S. Atomic Energy Commission, November 1973.

AEC Docket 50-364, *Final Environmental Statement Related to Operation of Joseph M. Farley Nuclear Plant, Unit 2*, U.S. Atomic Energy Commission, December 1974.

AEC Docket 50-366, *Final Environmental Statement for the Edwin I. Hatch Nuclear Plant, Unit 2*, U.S. Atomic Energy Commission, October 1972.

AEC Docket 50-404, *Final Environmental Statement Related to the Construction of Unit 3 of North Anna Power Station*, U.S. Atomic Energy Commission, April 1973.

AEC Docket 50-405, *Final Environmental Statement Related to the Construction of Unit 4 of North Anna Power Station*, U.S. Atomic Energy Commission, April 1973.

AEC Docket 50-440, *Final Environmental Statement Related to the Proposed Perry Nuclear Power Plant, Unit 1*, U.S. Atomic Energy Commission, April 1974.

AEC Docket 50-441, *Final Environmental Statement Related to the Proposed Perry Nuclear Power Plant, Unit 2*, U.S. Atomic Energy Commission, April 1974.

NUREG-0020, vol. 9, Licensed Operating Reactors, Summary Status Report, Nuclear Regulatory Commission, Office of Resource Management, Div. of Budget Analysis, October 1985.

NUREG-0063, *Final Environmental Statement Related to Operation of William B. McGuire Nuclear Station, Units 1 and 2*, U.S. Nuclear Regulatory Commission, April 1976.

NUREG-0285, *Final Environmental Statement Related to Operation of Shoreham Nuclear Power Station, Unit 1*, U.S. Nuclear Regulatory Commission, October 1977.

NUREG-0343, *Final Environmental Statement Related to Operation of Palisades Nuclear Generating Plant*, U.S. Nuclear Regulatory Commission, February 1978.

NUREG-0486, *Final Environmental Statement Related to Operation of Lasalle County Nuclear Power Station, Units 1 and 2*, U.S. Nuclear Regulatory Commission, November 1978.

NUREG-0490, *Final Environmental Statement Related to the Operation of San Onofre Nuclear Generating Station, Units 2 and 3*, U.S. Nuclear Regulatory Commission, April 1981.

NUREG-0498, *Final Environmental Statement Related to Operation of Watts Bar Nuclear Plant, Units 1 and 2*, U.S. Nuclear Regulatory Commission, December 1978.

NUREG-0564, *Final Environmental Statement Related to the Operation of Susquehanna Steam Electric Station, Units 1 and 2*, U.S. Nuclear Regulatory Commission, June 1981.

NUREG-0719, *Final Environmental Statement Related to the Operation of Virgil C. Summer Nuclear Station, Unit 1*, U.S. Nuclear Regulatory Commission, May 1981.

NUREG-0769, *Final Environmental Statement Related to the Operation of Enrico Fermi Atomic Power Plant, Unit 2*, U.S. Nuclear Regulatory Commission, August 1981.

NUREG-0775, *Final Environmental Statement Related to the Operation of Comanche Peak Steam Electric Station, Units 1 and 2*, U.S. Nuclear Regulatory Commission, September 1981.

NUREG-0777, *Final Environmental Statement Related to Operation of Grand Gulf Nuclear Station, Units 1 and 2*, U.S. Nuclear Regulatory Commission, September 1981.

NUREG-0779, *Final Environmental Statement Related to the Operation of Waterford Steam Electric Station, Unit 3*, U.S. Nuclear Regulatory Commission, September 1981.

NUREG-0812, *Final Environmental Statement Related to the Operation of WPPSS Nuclear Project No. 2*, U.S. Nuclear Regulatory Commission, December 1981.

NUREG-0813, *Final Environmental Statement Related to the Operation of Callaway Plant, Unit 1*, U.S. Nuclear Regulatory Commission, January 1982.

NUREG-0841, *Final Environmental Statement Related to the Operation of Palo Verde Nuclear Generating Station*, U.S. Nuclear Regulatory Commission, February 1982.

NUREG-0842, *Final Environmental Statement Related to the Operation of St. Lucie Plant, Unit 2*, U.S. Nuclear Regulatory Commission, April 1982.

NUREG-0848, *Final Environmental Statement Related to the Operation of Byron Station, Units 1 and 2*, U.S. Nuclear Regulatory Commission, April 1982.

NUREG-0854, *Final Environmental Statement Related to the Operation of Clinton Power Station, Unit 1*, U.S. Nuclear Regulatory Commission, May 1982.

NUREG-0895, *Final Environmental Statement Related to the Operation of Seabrook Station, Units 1 and 2*, U.S. Nuclear Regulatory Commission, December 1982.

NUREG-0921, *Final Environmental Statement Related to the Operation of Catawba Nuclear Station, Units 1 and 2*, U.S. Nuclear Regulatory Commission, January 1983.

NUREG-0972, *Final Environmental Statement Related to the Operation of Shearon Harris Nuclear Power Plant, Units 1 and 2*, U.S. Nuclear Regulatory Commission, October 1983.

NUREG-1026, *Final Environmental Statement Related to the Operation of Braidwood Station, Units 1 and 2*, U.S. Nuclear Regulatory Commission, June 1984.

NUREG-1064, *Final Environmental Statement Related to the Operation of Millstone Nuclear Power Station, Unit 3*, U.S. Nuclear Regulatory Commission, December 1984.

NUREG-1073, *Final Environmental Statement Related to the Operation of River Bend Station*, U.S. Nuclear Regulatory Commission, January 1985.

NUREG-1085, *Final Environmental Statement Related to the Operation of Nine Mile Point Nuclear Station, Unit 2*, U.S. Nuclear Regulatory Commission, May 1985.

NUREG-1087, *Final Environmental Statement Related to the Operation of Vogtle Electric Generating Plant*, U.S. Nuclear Regulatory Commission, March 1985.

NUREG-1094, *Final Environmental Statement Related to the Operation of Beaver Valley Power Station, Unit 2*, U.S. Nuclear Regulatory Commission, September 1985.

NUREG-1171, *Final Environmental Statement Related to the Operation of South Texas Project, Units 1 and 2*, U.S. Nuclear Regulatory Commission, August 1986.

NUREG-75/097, *Final Environmental Statement Related to Operation of Davis-Besse Nuclear Power Station, Unit 1*, U.S. Nuclear Regulatory Commission, October 1975.

C.7 TABLES

Table C.1 Sparseness and proximity measures used to classify potential case study sites

	Category	**Sparseness**
Most sparse	1.	<40 persons per square mile and no community with 25,000 or more persons within 20 miles
	2.	40 to 60 persons per square mile and no community with 25,000 or more persons within 20 miles
	3.	60 to 120 persons per square mile or less than 60 persons per square mile with at least one community with 25,000 or more persons within 20 miles
Least sparse	4.	≥120 persons per square mile within 20 miles

	Category	**Proximity**
Not in close proximity	1.	No city with 100,000 or more persons and <50 persons per square mile within 50 miles
	2.	No city with 100,000 or more persons and between 50 and 190 persons per square mile within 50 miles
	3.	One or more cities with 100,000 or more persons and <190 persons per square mile within 50 miles
In close proximity	4.	≥190 persons per square mile within 50 miles

Source: Adapted from NUREG/CR-2239.
Note: Metric equivalents are as follows:
1 square mile = 2.6 km^2
20 miles = 32 km
50 miles = 80 km

Table C.2 Population classification of each potential case study site

Low	Arkansas Big Rock Point Cooper Hatch Wolf Creek
Medium	Bellefonte Crystal River Diablo Canyon Oconee St. Lucie
High	Calvert Cliffs D. C. Cook Indian Point Nine Mile Point Peach Bottom Rancho Seco San Onofre Surry Three Mile Island

Source: Staff computations.

Table C.3 Case study sites

Site	Population size	Location	Year(s) licensed
Arkansas	Low	Arkansas	1974, 1978
Wolf Creek	Low	Kansas	1985
Diablo Canyon	Medium	California	1984, 1985
Oconee	Medium	South Carolina	1973, 1973, 1974
D. C. Cook	High	Michigan	1974, 1977
Indian Point	High	New York	1973, 1976
Three Mile Island	High	Pennsylvania	1974

Source. Staff computations; NUREG-0020, vol. 9.

Table C.4 Current[a] operating-period employment at nuclear power plants

Employment	One-unit plants	Two-unit plants	Three-unit plants
Minimum	201	467	1750
Maximum	1800	2500	3340
Mean	832	1247	2404
(Number of plants)	(34)	(28)	(4)

[a]Approximately half the respondents reported data for 1989 and half for 1990.
Source ORNL/NUMARC survey of all utilities (see Section C.1.3).

Table C.5 Changes in mean operating-period employment at nuclear power plants over time

Time	One-unit plants[a]	Two-unit plants[a]	Three-unit plants[a]
1989/1990[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.
Source· ORNL/NUMARC survey of all utilities (see Section C.1.3).

Table C.6 Employment, cost, and time associated with typical planned outage at nuclear power plants

Employment	Total no. of workers	Cost ($ × 10^6)	Length of outage (days)
Minimum	60	4.5	32
Maximum	2600	56.5	139
Mean	783	21.7	76
(Number of plants)	(58)	(39)	(62)

Source: ORNL/NUMARC survey of all utilities (see Section C.1.3).

Table C.7 Employment, cost, and time associated with an in-service inspection outage at nuclear power plants

Employment	Total no. of workers	Cost ($\$ \times 10^6$)	Length of outage (days)
Minimum	35	1.6	16
Maximum	1986	40.0	325
Mean	734	22.0	107
(Number of plants)	(23)	(14)	(27)

Source: ORNL/NUMARC survey of all utilities (see Section C.1.3).

Table C.8 Employment, cost, and time associated with largest single outage at nuclear power plants

Employment	Total no. of workers	Cost ($\$ \times 10^6$)	Length of outage (days)
Minimum	80	5.4	43
Maximum	3000	210.0	1,004
Mean	1223	53.7	199
(Number of plants)	(45)	(30)	(41)

Source: ORNL/NUMARC survey of all utilities (see Section C.1.3).

Table C.9 Current[a] assessed value of nuclear power plants (in dollars)

	One-unit plants	Two-unit plants	Three-unit plants
Minimum	8,309,867	16,619,733	40,514,729
Maximum	4,351,797,390	8,023,653,676	12,035,480,510
Mean	732,615,112	1,113,824,421	4,283,239,036
(Number of plants)	(23)	(21)	(4)

[a]Approximately half the respondents reported data for 1989 and half for 1990.
Source: ORNL/NUMARC survey of all utilities (see Section C.1.3).

Table C.10 Past assessed value of nuclear power plants (in dollars)

Value	One-unit plants 1980	One-unit plants 1985	Two-unit plants 1980	Two-unit plants 1985	Three-unit plants 1980	Three-unit plants 1985
Minimum	6,542,066	7,957,867	13,084,133	15,915,733	341,222,806	1,147,319,438
Maximum	460,383,107	2,195,586,755	4,309,013,892	6,645,073,248	6,463,520,838	9,967,609,872
Mean	137,952,092	409,168,905	497,568,490	943,272,817	2,454,988,141	4,281,860,682
(Number of plants)	(17)	(19)	(19)	(19)	(3)	(3)

Source: ORNL/NUMARC survey of all utilities (see Section C.1.3).

Table C.11 Current[a] taxes paid by nuclear power plants (in dollars)

	One-unit plants	Two-unit plants	Three-unit plants
Minimum local	19,000	16,617	5,510,003
Minimum state	229,000	42,183	10,215,660
Minimum total	19,000	750,000	5,510,003
Maximum local	33,786,685	34,132,316	91,262,791
Maximum state	37,540,707	92,792,182	139,118,273
Maximum total	52,000,000	92,792,182	139,118,273
Mean local	8,740,879	8,172,250	48,386,397
Mean state	14,600,201	28,011,507	74,701,967
Mean total	12,647,941	19,360,839	69,066,815
(No. paying local taxes)	(21)	(19)	(2)
(No. paying state taxes)	(6)	(9)	(2)
(Total no. reporting)	(29)	(23)	(4)

[a]Approximately half the respondents reported data for 1989 and half for 1990.
Source: ORNL/NUMARC survey of all utilities (see Section C.1.3).

Table C.12 Past taxes paid by nuclear power plants (in dollars)

	One-unit plants		Two-unit plants		Three-unit plants	
	1980	1985	1980	1985	1980	1985
Minimum local	77,196	21,000	11,624	13,765	10,373,174	30,059,769
Minimum state	182,564	184,000	35,355	37,813	4,265,285	—4,589,278
Minimum total	529,692	21,000	617,000	695,000	13,221,211	34,649,047
Maximum local	9,832,452	16,273,095	10,800,000	27,969,568	10,373,174	30,059,769
Maximum state	33,266,428	37,487,911	66,532,857	75,299,185	68,205,671	112,948,777
Maximum total	33,343,625	37,615,236	66,687,249	75,299,185	68,205,671	112,948,777
Mean local	3,720,242	6,240,207	4,156,061	7,527,656	10,373,174	30,059,769
Mean state	12,039,844	12,962,231	17,264,470	25,825,159	36,235,478	58,769,028
Mean total	5,184,430	8,400,823	10,807,676	17,441,883	32,021,780	- -61,238,849
(No. paying local taxes)	(15)	(19)	(16)	(16)	(1)	(1)
(No. paying state taxes)	(3)	(5)	(8)	(8)	(2)	(2)
(Total no. reporting)	(20)	(25)	(21)	(21)	(3)	(3)

Source: ORNL/NUMARC survey of all utilities (see Section C.1.3).

Table C.13 Population growth associated with Arkansas Nuclear One: Pope County, Arkansas, 1970–1989

Year	Work force			Project-related in-migrant population[a]	County's total population[b]	Increase as % of total
	Construction	Operations	Total			
1970	420	0	420	846	28,607	3.0
1974	1,100	248	1,348	2,756	33,200	8.3
1975	928	293	1,221	2,576	33,600	7.7
1980	0	462	462	682	39,021	1.7
1985	0	1,984	1,984	2,736	42,109	6.5
1989	0	2,205	2,205	3,418	45,883[c]	7.4

[a]Includes both direct and indirect workers and their families.
[b]Population assumed to grow at a constant annual rate between known points
[c]1990 U.S. Census figure used.
Sources: NUREG/CR-2749, vol 1, pp. 20, 26, and 86; AP&L 1990; ORNL staff computations.

Table C.14 Estimated plant-related population growth in Pope County, Arkansas, 1989

Direct growth	
Number of direct workers	2205
Number of study area residents (90% of total)	1985
Number of in-migrants (56.2% of residents)	1116
Number of in-migrants with families (60%)	670
Average family size	× 3.06
Total in-migrants plus families	2050
Number of in-migrants without families (40%)	+ 446
Total direct growth	2496
Indirect growth	
Ratio indirect/direct jobs	0.39
Number of indirect workers	860
Number of study area residents (96% of total)	826
Number of in-migrants (55% of residents)	454
Number of in-migrants with families (50%)	227
Average family size	× 3.06
Total in-migrants plus families	695
Number of in-migrants without families (50%)	+ 227
Total indirect growth	922
Total growth	
Total direct growth	2496
Total indirect growth	+ 922
Total estimated plant-related growth	3418

Sources: Number of direct workers and percentage of study area residents from AP&L 1990. Average family size from 1990 U.S. Census of Population. Other data from NUREG/CR-2749, vol. 1, pp. 56–86; ORNL staff computations.

Table C.15 Projected refurbishment-related population growth in Pope County, Arkansas, 2013

Direct growth	
Number of direct workers	2273
Number of study area residents (65% of total)	1477
Number of in-migrants (56.2% of residents)	830
Number of in-migrants with families (60%)	498
Average family size	× 3.06
Total in-migrants plus families	1524
Number of in-migrants without families (40%)	+ 332
Total direct growth	1856
Indirect growth	
Ratio indirect/direct jobs	0.208
Number of indirect workers	473
Number of study area residents (96% of total)	454
Number of in-migrants (54.2% of residents)	246
Number of in-migrants with families (50%)	123
Average family size	× 3.06
Total in-migrants plus families	376
Number of in-migrants without families (50%)	123
Total indirect growth	499
Total growth	
Total direct growth	1856
Total indirect growth	400
Total projected refurbishment-related growth	2355

Sources: Direct workers from SEA 1994. Average family size from 1990 U.S. Census of Population. Other data from NUREG/CR-2749, vol. 1, pp. 56–86; ORNL staff computations.

Table C.16 Projected plant-related population growth in Pope County, Arkansas, during the license renewal term

Direct growth	
Number of direct workers	120
Number of study area residents (90% of total)	108
Number of in-migrants (56.2% of residents)	61
Number of in-migrants with families (60%)	37
Average family size	× 3.06
Total in-migrants plus families	113
Number of in-migrants without families (40%)	+ 24
Total direct growth	137
Indirect growth	
Ratio indirect/direct jobs	0.39
Number of indirect workers	47
Number of study area residents (96% of total)	45
Number of in-migrants (55% of residents)	25
Number of in-migrants with families (50%)	13
Average family size	× 3.06
Total in-migrants plus families	40
Number of in-migrants without families (50%)	+ 12
Total indirect growth	52
Total growth	
Total direct growth	137
Total indirect growth	+ 52
Total estimated operations-related growth	189

Sources: Direct workers from NRC work force estimates (1989). Average family size from 1990 U.S. Census of Population. Other data from NUREG/CR-2749, vol. 1, pp. 56–86; ORNL staff computations.

Table C.17 Arkansas Nuclear One (ANO) station assessed value and taxes paid to Pope County, 1968–1989, in current dollars

Year	Assessed value ($)		ANO valuation as % of county valuation	Millage	Taxes paid by ANO ($)
	Pope County	ANO			
1968	17,100,000	930,053	5.4	.057	53,093
1972	52,607,000	25,817,219	49.1	.064	1,652,302
1976	136,640,000	100,589,373	73.6	.059	5,934,773
1980	193,993,250	142,718,270	73.6	.0107	1,529,051
1985	334,683,819	173,679,771	51.9	.0091	1,583,831
1989	410,290,842	189,419,497	46.2	.0064	1,204,632

Sources: NUREG/CR-2749, vol. 1; Duval 1990; Rye 1990.

Table C.18 Arkansas Nuclear One (ANO) Station project revenue impact to Russellville School District

Year	Total assessed valuation ($ × 10^6)	School district revenues ($ × 10^3)			ANO revenues as % of	
		Total	Property taxes	ANO taxes	Property taxes	Total revenues[a]
1968	14.9	NA[b]	745	46.5	6.2	NA
1970	19.9	NA	995	189.2	19.0	NA
1972	44.3	2600	2215	1290.9	58.3	49.7
1974	81.7	4958	4085	3246.6	79.5	65.5
1976	125.6	7898	6280	5029.5	80.1	63.7
1977	142.2	8740	7110	5739.6	80.7	65.7
1980	NA	NA	NA	6950.2	NA	NA
1985	NA	NA	NA	6816.1	NA	NA
1989	341.1	12,574	7675	5222.3	68.0	41.5

[a]Total revenues consist of revenues from property assessments and state and federal funding sources.
[b]NA = not applicable.
Source: NUREG/CR-2749, vol. 1; Pope County 1980, 1985, and 1989; Rye 1990; Duval 1990.

Table C.19 Estimated economic effects of Arkansas Nuclear One on Pope County

	1974	1978	1989
Employment			
Direct basic	889	772	1,985
Indirect	75	127	826
Total	964	899	2,811
Percentage of study area employment	6.4	5.3	11.6
Income (1989 $)			
Direct	20,679,000	26,656,000	73,713,000
Indirect	1,886,000	3,421,000	12,446,000
Total	22,565,000	30,077,000	86,159,000
Percentage of study area income	7.5	7.8	14.3

Source: For 1974 and 1978 estimates, NUREG/CR-2749, vol. 1. The 1989 estimate is based on the approach used in the Mountain West study.

Table C.20 Projected employment effects of Arkansas Nuclear One (ANO) refurbishment on Pope County, 2013

Refurbishment direct employment	1477
Refurbishment indirect employment	454
Total ANO-related employment	1931
Percentage of Pope County employment	5.8

Source: ORNL staff computations based on the approach used in the Mountain West study (NUREG/CR-2749, vol. 1).

Table C.21 Projected employment effects of Arkansas Nuclear One license renewal on Pope County, 2013

Existing total direct and indirect plant-related employment	2811
Increase in direct employment	108
Increase in indirect employment	45
Total plant-related employment	2964
Percentage of Pope County employment	8.9

Source: ORNL staff computations based on the approach used in the Mountain West study (NUREG/CR-2749, vol. 1).

Table C.22 Population growth associated with D. C. Cook: Bridgman/Lake Township and Berrien County, 1970–1990

	Work force			Bridgman/Lake Township			Berrien County		
Year	Construction	Operations	Total	Project-related in-migrant population[a]	Area's total population[b]	Project-related population as % of total	Project-related in-migrant population[a]	County's total population[b]	Project-related population as % of total
1970	914	24	938	61	3,767	1.6	802	163,875	0.5
1972	2,377	148	2,525	175	3,782	4.6	2,193	167,000	1.3
1975	292	279	571	72	3,910	1.8	595	170,100	0.3
1980	0	746	746	81	4,514	1.8	644	171,267	0.4
1985	0	1,110	1,110	108	4,386	2.5	877	163,600	0.5
1990	0	1,252	1,252	141	4,627	3.0	1,109	161,378	0.7

[a]Includes both direct and indirect workers and families.

[b]Population assumed to grow at constant annual rate between known points.

Sources: NUREG/CR-2749, vol. 4, p. 115; Indiana and Michigan Power Company 1990; U.S. Bureau of the Census 1990; ORNL staff computations.

Table C.23 **Estimated plant-related population growth in Bridgman/Lake Township, Michigan, 1990**

Direct growth	
Number of direct workers	1252
Number of study area residents (10.6% of total)	133
Number of in-migrants (46% of residents)	61
Number of in-migrants with families (60%)	37
Average family size	× 3.16
Total in-migrants plus families	117
Number of in-migrants without families (40%)	+ 24
Total direct growth	141
Indirect growth	
Ratio indirect/direct jobs	0.339
Number of indirect workers	424
Number of study area residents (3.5% of total)	15
Number of in-migrants (0% of residents)	0
Number of in-migrants with families (0%)	0
Average family size	× 3.16
Total in-migrants plus families	0
Number of in-migrants without families (0%)	+ 0
Total indirect growth	0
Total growth	
Total direct growth	141
Total indirect growth	+ 0
Total estimated plant-related growth	141

Sources: Number of direct workers from Indiana and Michigan Power Company 1990. Average family size from 1990 U.S. Census of Population. Other data from NUREG/CR-2749, vol. 4, pp 88–115; ORNL staff computations

Table C.24 Estimated plant-related population growth in Berrien County, Michigan, 1990

Direct growth	
Number of direct workers	1252
Number of study area residents (80% of total)	1002
Number of in-migrants (46% of residents)	461
Number of in-migrants with families (60%)	277
Average family size	× 3.16
Total in-migrants plus families	875
Number of in-migrants without families (40%)	+ 184
Total direct growth	1059
Indirect growth	
Ratio indirect/direct jobs	0.339
Number of indirect workers	424
Number of study area residents (95% of total)	403
Number of in-migrants (5.5% of residents)	22
Number of in-migrants with families (60%)	13
Average family size	× 3.16
Total in-migrants plus families	41
Number of in-migrants without families (40%)	+ 9
Total indirect growth	50
Total growth	
Total direct growth	1059
Total indirect growth	+ 50
Total estimated plant-related growth	1109

Sources Number of direct workers from Indiana and Michigan Power Company 1990. Average family size from 1990 U S Census of Population Other data from NUREG/CR-2749, vol 4, pp. 88–115; ORNL staff computations

Table C.25 Projected refurbishment-related population growth in Berrien County, Michigan, 2014

Direct growth	
Number of direct workers	2273
Number of study area residents (66% of total)	1500
Number of in-migrants (55.3% of residents)	830
Number of in-migrants with families (50%)	415
Average family size	× 3.16
Total in-migrants plus families	1311
Number of in-migrants without families (50%)	+ 415
Total direct growth	1726
Indirect growth	
Ratio indirect/direct jobs	0.366
Number of indirect workers	832
Number of study area residents (95% of total)	790
Number of in-migrants (5.4% of residents)	43
Number of in-migrants with families (60%)	26
Average family size	× 3.16
Total in-migrants plus families	82
Number of in-migrants without families (40%)	+ 17
Total indirect growth	99
Total growth	
Total direct growth	1726
Total indirect growth	99
Total projected refurbishment-related growth	1825

Sources: Direct workers from SEA 1994. Average family size from 1990 U.S. Census of Population. Other data from NUREG/CR-2749, vol. 4, pp. 88–115, ORNL staff computations.

Table C.26 **Projected refurbishment-related population growth in Bridgman/ Lake Township, Michigan, 2014**

Direct growth	
Number of direct workers	2273
Number of study area residents (5.4% of total)	123
Number of in-migrants (55.3% of residents)	68
Number of in-migrants with families (50%)	34
Average family size	× 3.16
Total in-migrants plus families	107
Number of in-migrants without families (50%)	+ 34
Total direct growth	141
Indirect growth	
Ratio indirect/direct jobs	0.366
Number of indirect workers	832
Number of study area residents (3.5% of total)	29
Number of in-migrants (0% of residents)	0
Number of in-migrants with families (0%)	0
Average family size	× 3.16
Total in-migrants plus families	0
Number of in-migrants without families (0%)	+ 0
Total indirect growth	0
Total growth	
Total direct growth	141
Total indirect growth	0
Total projected refurbishment-related growth	141

Sources: Direct workers from SEA 1994. Average family size from 1990 U.S. Census of Population. Other data from NUREG/CR-2749, vol. 4, pp. 88–115; ORNL staff computations.

Table C.27 **Projected plant-related population growth in Berrien County, Michigan, during the license renewal term**

Direct growth	
Number of direct workers	120
Number of study area residents (80% of total)	96
Number of in-migrants (46% of residents)	44
Number of in-migrants with families (60%)	26
Average family size	× 3.16
Total in-migrants plus families	82
Number of in-migrants without families (40%)	+ 18
Total direct growth	100
Indirect growth	
Ratio indirect/direct jobs	0.339
Number of indirect workers	41
Number of study area residents (95% of total)	39
Number of in-migrants (5.4% of residents)	2
Number of in-migrants with families (60%)	1
Average family size	× 3.16
Total in-migrants plus families	3
Number of in-migrants without families (40%)	+ 1
Total indirect growth	4
Total growth	
Total direct growth	100
Total indirect growth	+ 4
Total projected plant-related growth	104

Sources: Direct workers from NRC work force estimates (1989). Percentage of study area residents from Indiana and Michigan Power Company 1990. Average family size from 1990 U.S. Census of Population. Other data from NUREG/CR-2749, vol. 4, pp. 88–115; ORNL staff computations.

Table C.28 Projected plant-related population growth in Bridgman/Lake Township, Michigan, during the license renewal term

Direct growth	
Number of direct workers	120
Number of study area residents (10.6% of total)	13
Number of in-migrants (46% of residents)	6
Number of in-migrants with families (60%)	4
Average family size	× 3.16
Total in-migrants plus families	13
Number of in-migrants without families (40%)	+ 2
Total direct growth	15
Indirect growth	
Ratio indirect/direct jobs	0.339
Number of indirect workers	41
Number of study area residents (3.5% of total)	1
Number of in-migrants (0% of residents)	0
Number of in-migrants with families (0%)	0
Average family size	× 3.16
Total in-migrants plus families	0
Number of in-migrants without families (0%)	+ 0
Total indirect growth	0
Total growth	
Total direct growth	15
Total indirect growth	+ 0
Total projected plant-related growth	15

Sources: Direct workers from NRC work force estimates (1989). Percentage of study area residents from Indiana and Michigan Power Company 1990. Average family size from 1990 U.S. Census of Population. Other data from NUREG/CR-2749, vol. 4, pp 88–115; ORNL staff computations

Table C.29 Berrien County revenues (constant 1988 dollars)

Fiscal year	Property taxes	State aid	Charges for services	Other	Total
1967					
Amount ($)	7,668,000	NA[a]	NA	NA	10,343,653
Percentage of total revenues	74.1				100
1972					
Amount ($)	9,021,603	2,032,351	1,261,970	586,184	12,902,108
Percentage of total revenues	69.9	15.8	9.8	4.5	100
1978					
Amount ($)	10,651,576	5,959,953	1,845,206	2,253,562	20,710,297
Percentage of total revenues	51.4	28.8	8.9	10.9	100
1988					
Amount ($)	11,859,469	3,544,135[b]	3,079,413	1,803,630	20,289,597[c]
Percentage of total revenues	58.5	17.5	15.2	8.9	100

[a]NA = not applicable.
[b]This state aid includes $1,975,440 from income tax diversion.
[c]There was an unexplained discrepancy of $2950 in audit report for the year ending December 31, 1988.
Sources: NUREG/CR-2749, vol. 4; Berrien County 1989.

Table C.30 Equalized assessed valuation of D. C. Cook Nuclear Plant as a percentage of total equalized assessed value for taxing jurisdictions

Jurisdiction	1967	1973	1976	1980	1988
Berrien County	0	5.7	12.6	20.7	21.5
Lake Township	0	79.7	86.7	90.0	90.6
Bridgman School District	0	68.9	79.9	82.9	88.0

Sources: NUREG/CR-2749, vol. 4; Schuller 1990; Stockman 1990; Winslow 1990.

Table C.31 Distribution of property tax payments from D. C. Cook to various taxing jurisdictions/recipients in 1989

	Millage	D. C. Cook's tax contribution at SEV[a] of $531,797,266
County, general	5.3908	$2,866,813
Lake Township, general	1.0000	531,797
Lake Michigan College	2.0414	1,085,611
Intermediate School District, general	0.1976	105,083
Intermediate School District, special	2.4827	1,320,293
Bridgman School District	8.376	4,454,334
Lake Township sewer	2.4	1,276,313
Lake Township water	1 9	1,010,415
Senior Center	0.2314	123,058
911 special phone assistant	0.1987	105,668
Drug abuse	0.12	63,816
Total levy	24.3386	12,943,201

[a]SEV = state equalized value.
Sources: Millage rates, Schuller 1990; SEV for D. C. Cook Nuclear Plant, Stockman 1990

Table C.32 Estimated economic effects of D. C. Cook on Bridgman/Lake Township

	1972	1978	1990
Employment			
Direct basic	137	82	133
Secondary	3	8	15
Total	140	90	148
Percentage of study area employment	8.8	4.7	7.7
Income (1989 $)			
Direct	6,312,000	2,878,000	4,951,000
Secondary	70,000	114,000	234,000
Total	6,382,000	2,992,000	5,185,000
Percentage of study area income	14.4	5.3	8.8

Source: For 1972 and 1978 estimates, NUREG/CR-2749, vol. 4 The 1990 estimate is based on the approach used in the Mountain West study.

Table C.33 Projected employment effects of D. C. Cook refurbishment, 2014

Area affected	Bridgman/Lake Township	Berrien County
Refurbishment direct employment	123	1500
Refurbishment indirect employment	29	790
Total D. C. Cook-related employment	152	2290
Percentage of study area employment	7.5	3.3

Source: ORNL staff computations based on the approach used in NUREG/CR-2749, vol. 4

Table C.34 Projected employment and economic effects of D. C. Cook license renewal, 2013

Area affected	Bridgman/Lake Township	Berrien County
Existing direct and indirect plant-related employment	148	1405
Increase in direct employment	13	96
Increase in indirect employment	1	39
Total plant-related employment	162	1540
Percentage of study area total employment	8.1	1.8

Source: ORNL staff computations based on the approach used in NUREG/CR-2749, vol. 4.

Table C.35 Population growth associated with Diablo Canyon: San Luis Obispo County, California, 1970–1990

Year	Work force			Project-related in-migrant population[a]	County's total population[b]	Project-related population as % of total
	Construction	Operations	Total			
1970	705	0	705	1,102	105,690	1.0
1975	2,116	0	2,116	3,308	126,500	2.6
1979	1,472	0	1,472	2,473	147,718	1.7
1985	0	764	764	980	192,218	0.5
1990	0	1,300	1,300	2,149	217,162	1.0

[a]Includes both direct and indirect workers and families.
[b]Population assumed to grow at a constant annual rate between known points.
Sources: NUREG/CR-2749, vol. 5, p. 89; PG&E 1990; ORNL staff computations.

Table C.36 Estimated plant-related population growth in San Luis Obispo County, California, 1990

Direct growth	
Number of direct workers	1300
Number of study area residents (89.2% of total)	1160
Number of in-migrants (70% of residents)	812
Number of in-migrants with families (66%)	536
Average family size	× 3.32
Total in-migrants plus families	1780
Number of in-migrants without families (33%)	+ 276
Total direct growth	2056
Indirect growth	
Ratio indirect/direct jobs	0.64
Number of indirect workers	832
Number of study area residents (90% of total)	749
Number of in-migrants (5.0% of residents)	37
Number of in-migrants with families (66%)	24
Average family size	× 3.32
Total in-migrants plus families	80
Number of in-migrants without families (33%)	+ 13
Total indirect growth	93
Total growth	
Total direct growth	2056
Total indirect growth	+ 93
Total estimated plant-related growth	2149

Sources: Number of direct workers and percentage of study area residents from PG&E 1990. Average family size from 1990 U.S. Census of Population Other data from NUREG/CR-2749, vol. 5; ORNL staff computations.

Table C.37 Projected refurbishment-related population growth in San Luis Obispo County, California, 2023

Direct growth	
Number of direct workers	2273
Number of study area residents (85% of total)	1932
Number of in-migrants (72.5% of residents)	1401
Number of in-migrants with families (61.7%)	864
Average family size	× 3.32
Total in-migrants plus families	2868
Number of in-migrants without families (38.3%)	+ 537
Total direct growth	3405
Indirect growth	
Ratio indirect/direct jobs	0.64
Number of indirect workers	1455
Number of study area residents (95% of total)	1310
Number of in-migrants (5.2% of residents)	68
Number of in-migrants with families (100%)	68
Average family size	× 3.32
Total in-migrants plus families	226
Number of in-migrants without families (0%)	+ 0
Total indirect growth	226
Total growth	
Total direct growth	3405
Total indirect growth	+ 226
Total projected refurbishment-related growth	3631

Sources: Direct workers from SEA 1994. Average family size from 1990 U.S. Census of Population. Other data from NUREG/CR-2749, vol. 5, pp. 55–85; ORNL staff computations.

Table C.38 **Projected plant-related population growth in San Luis Obispo County, California, during the license renewal term**

Direct growth	
Number of direct workers	120
Number of study area residents (89.2% of total)	107
Number of in-migrants (70% of residents)	75
Number of in-migrants with families (66%)	50
Average family size	× 3.32
Total in-migrants plus families	166
Number of in-migrants without families (33%)	+ 25
Total direct growth	191
Indirect growth	
Ratio indirect/direct jobs	0.64
Number of indirect workers	77
Number of study area residents (90% of total)	69
Number of in-migrants (5.0% of residents)	3
Number of in-migrants with families (66%)	2
Average family size	× 3.32
Total in-migrants plus families	7
Number of in-migrants without families (33%)	+ 1
Total indirect growth	8
Total growth	
Total direct growth	191
Total indirect growth	+ 8
Total projected refurbishment-related growth	199

Sources: Number of direct workers from NRC work force estimates (1989). Percentage of study area residents from PG&E 1990. Average family size from 1990 U.S. Census of Population. Other data from NUREG/CR-2749, vol. 5; ORNL staff computations.

Table C.39 County basic tax rates, property tax levies, and total county revenues for San Luis Obispo County, 1968–1989

Fiscal year	County basic tax rate (%)	Est. county basic property tax levy ($ × 10^3)	Total county general revenues ($ × 10^3)	Property tax as % of total
1967–68	2.69	6,721.9	18,190.9	37.0
1969–70	2.96	7,683.7	22,066.1	34.8
1971–72	3.33	10,511.7	26,010.8	40.4
1973–74	3.16	11,408.7	30,168.5	37.8
1975–76	2.86	14,218.7	35,968.5	39.5
1977–78	2.55	17,697.7	51,152.1	34.6
1988–89	1.07	44,156.6	122,730.2	36.0

Source: County of San Luis Obispo 1989.

Table C.40 Distribution of property tax payments from Diablo Canyon, 1975, 1978, and 1988 (in dollars)

	1974–75	1977–78	1988–89
San Luis Obispo County	2,357,254	4,309,248	13,081,327
Port San Luis Harbor District	103,531	211,166	580,329
City of Pismo Beach	11,323	3,206	30,592
Special districts		3,479	524,021
County schools department	309,731	591,780	1,643,189
Atascadero Unified School District	33,348	70,615	454,024
Lucia Mar Unified School District	69,225	80,915	470,700
Paso Robles	20,584	37,884	312,187
San Luis Coastal Unified School District	2,532,841	5,866,220	14,092,286
Shandon Unified School District	690	1,001	86,735
Templeton Unified School District	4,902	7,800	87,080
Community College District	870,197	1,229,082	2,769,846
Total property taxes	6,313,626	12,412,396	34,132,316

Source: NUREG/CR-2749, vol. 5; Stillwell 1990.

Table C.41 San Luis Coastal Unified School District tax rate and tax income, 1969–1989

Fiscal year	Tax rate (%)	Local property tax income ($ × 10^3)	Total school district income ($ × 10^3)	Property tax as % of total income
1969–70	4.47	5,409.9	7,124.1	75.9
1972–73	4.68	7,500.3	9,560.8	78.4
1975–76	4.03	10,655.3	13,583.0	78.4
1977–78	3.95	15,456.7	18,836.5	82.1
1987–88	NA[a]	26,639.4	32,446.3	82.1
1988–89	NA	29,026.0	36,233.5	80.1

[a]NA = not applicable.
Sources For 1969 through 1978 figures, NUREG/CR-2749, vol. 5. For 1987–89 values, Stillwell 1990

Table C.42 Estimated economic effects of Diablo Canyon on San Luis Obispo County

	1975	1978	1990
Employment			
Direct basic employment	1,799	1,121	1,160
Indirect employment	1,354	920	749
Total employment	3,153	2,041	1,909
Percentage of study area employment	6.5	3.5	1.8
Income (1989 $)			
Direct income	120,094,200	80,425,800	49,839,400
Indirect income	19,821,900	13,462,200	13,418,000
Total income	139,916,100	93,888,000	63,257,000
Percentage of study area income	9.1	4.7	1.7

Sources: For 1975 and 1978 estimates, NUREG/CR-2749, vol. 5. The 1990 estimate is based on the approach used in the Mountain West study.

Table C.43 Projected employment effects of Diablo Canyon refurbishment on San Luis Obispo County, 2023

Refurbishment direct employment	1932
Refurbishment indirect employment	1310
Total Diablo Canyon–related employment	3242
Percentage of San Luis Obispo County employment	1.8

Source: ORNL staff computations based on the approach used in NUREG/CR-2749, vol. 5.

Table C.44 Projected employment effects of Diablo Canyon license renewal on San Luis Obispo County, 2023

Existing direct and indirect employment	1909
Increase in direct employment	107
Increase in indirect employment	69
Total plant-related employment	2085
Percentage of San Luis Obispo County employment	1.2

Source: ORNL staff computations based on the approach used in NUREG/CR-2749, vol 5.

Table C.45 Population growth associated with Indian Point Units 2 and 3: Dutchess and Westchester counties, 1972–1990

	Work force			Dutchess County			Westchester County		
Year	Construction	Operations	Total	Project-related in-migrant population[a]	County's total population[b]	Project-related population as % of total	Project-related in-migrant population[a]	County's total population[b]	Project-related population as % of total
1972	2,400	0	2,400	390	226,673	0.17	309	888,691	0.03
1975	0	500	500	158	233,403	0.07	123	880,187	0.01
1980	0	825	825	259	245,055	0.10	189	866,599	0.02
1985	0	1,110	1,110	344	252,182	0.14	262	870,810	0.03
1990	0	1,335	1,335	415	259,462	0.16	316	874,866	0.04

[a]Includes both direct and indirect workers and families.
[b]Population assumed to grow at constant annual rate between known points.
Sources: U.S. Bureau of the Census 1988; Krausharr 1990; ConEd 1990; PASNY 1990; ORNL staff computations.

Table C.46 Estimated construction-related population growth in Dutchess County, New York, 1972

Direct growth	
Number of direct workers	2400
Number of direct workers in Dutchess County (17.3% of total)	415
Number who in-migrated (35% of residents)	145
Number of in-migrants with families (51%)	74
Average household size	× 3.25
Total in-migrants plus families	241
Number of in-migrants without families (49%)	+ 71
Total direct growth	312
Indirect growth	
Ratio indirect/direct jobs	0.65
Number of indirect workers	1560
Number of study area residents (40% of total)	624
Number of in-migrants (5% of residents)	31
Number of in-migrants with families (66%)	21
Average household size	× 3.25
Total in-migrants plus families	68
Number of in-migrants without families (33%)	+ 10
Total indirect growth	78
Total growth	
Total direct growth	312
Total indirect growth	+ 78
Total estimated construction-related growth	390

Sources Number of direct workers from AEC Docket 50-247, p. IV-4. Percentage of study area residents from ConEd 1990 and PASNY 1990 Average household size from NUREG/CR-2750 Other data from construction experience at other nuclear stations; ORNL staff computations

Table C.47 Estimated construction-related population growth in Westchester County, New York, 1972

Direct growth	
Number of direct workers	2400
Number of workers in Westchester County (12.7% of total)	305
Number who in-migrated (35% of residents)	107
Number of in-migrants with families (51%)	55
Average family size	× 3.25
Total in-migrants plus families	179
Number of in-migrants without families (49%)	+ 52
Total direct growth	231
Indirect growth	
Ratio indirect/direct jobs	0.65
Number of indirect workers	1560
Number of study area residents (40% of total)	624
Number of in-migrants (5% of residents)	31
Number of in-migrants with families (66%)	21
Average family size	× 3.25
Total in-migrants plus families	68
Number of in-migrants without families (33%)	+ 10
Total indirect growth	78
Total growth	
Total direct growth	231
Total indirect growth	+ 78
Total estimated construction-related growth	309

Sources Number of direct workers from AEC Docket 50-247, p. IV-4. Percentage of study area residents from ConEd 1990 and PASNY 1990. Average family size from NUREG/CR-2750. Other data from construction experience at other nuclear stations; ORNL staff computations.

Table C.48 Estimated plant-related population growth in Dutchess County, New York, 1990

Direct growth	
Number of direct workers	1335
Number of direct workers in Dutchess County (37.8% of total)	505
Number of in-migrants (30% of residents)	152
Number of in-migrants with families (66%)	100
Average family size	× 3.22
Total in-migrants plus families	322
Number of in-migrants without families (33%)	+ 52
Total direct growth	374
Indirect growth	
Ratio indirect/direct jobs	0.65
Number of indirect workers	868
Number of study area residents (40% of total)	347
Number of in-migrants (5% of residents)	17
Number of in-migrants with families (66%)	11
Average family size	× 3.22
Total in-migrants plus families	35
Number of in-migrants without families (33%)	+ 6
Total indirect growth	41
Total growth	
Total direct growth	374
Total indirect growth	+ 41
Total estimated plant-related growth	415

Sources: Number of direct workers and percentage of study area residents from ConEd 1990 and PASNY 1990. Average family size from 1990 U.S. Census of Population. Other data from operating experience at other nuclear stations; ORNL staff computations.

Table C.49 **Estimated plant-related population growth in Westchester County, New York, 1990**

Direct growth	
Number of direct workers	1335
Number of direct workers in Westchester County (27.8% of total)	371
Number of in-migrants (30% of residents)	111
Number of in-migrants with families (66%)	74
Average family size	× 3.22
Total in-migrants plus families	238
Number of in-migrants without families (33%)	+ 37
Total direct growth	275
Indirect growth	
Ratio indirect/direct jobs	0.65
Number of indirect workers	868
Number of study area residents (40% of total)	347
Number of in-migrants (5% of residents)	17
Number of in-migrants with families (66%)	11
Average family size	× 3.22
Total in-migrants plus families	35
Number of in-migrants without families (33%)	+ 6
Total indirect growth	41
Total growth	
Total direct growth	275
Total indirect growth	+ 41
Total estimated plant-related growth	316

Sources: Number of direct workers and percentage of study area residents from ConEd 1990 and PASNY 1990. Average family size from 1990 U.S. Census of Population. Other data from operating experience at other nuclear stations; ORNL staff computations.

Table C.50 Projected refurbishment-related population growth in Dutchess County, New York, 2012

Direct growth	
Number of direct workers	2273
Number of workers projected to live in Dutchess County (17.3% of total)	393
Number of in-migrants (35% of residents)	138
Number of in-migrants with families (51%)	70
Average family size	× 3.22
Total in-migrants plus families	225
Number of in-migrants without families (49%)	+ 68
Total direct growth	293
Indirect growth	
Ratio indirect/direct jobs	0.65
Number of indirect workers	1477
Number of study area residents (40% of total)	591
Number of in-migrants (5.0% of residents)	30
Number of in-migrants with families (66%)	20
Average family size	3.22
Total in-migrants plus families	64
Number of in-migrants without families (33%)	+ 10
Total indirect growth	74
Total growth	
Total direct growth	293
Total indirect growth	+ 74
Total projected refurbishment-related growth	367

Sources: Number of direct workers from SEA 1994. Average family size from 1990 U.S. Census of Population. Percentage of study area residents from ConEd 1990 and PASNY 1990. Other data from estimates concerning the construction of Indian Point and other nuclear stations; ORNL staff computations.

Table C.51 Projected refurbishment-related population growth in Westchester County, New York, 2012

Direct growth	
Number of direct workers	2273
Number of workers projected to live in Westchester County (12.7% of total)	289
Number of in-migrants (35% of residents)	101
Number of in-migrants with families (51%)	52
Average family size	× 3.22
Total in-migrants plus families	167
Number of in-migrants without families (49%)	+49
Total direct growth	216
Indirect growth	
Ratio indirect/direct jobs	0.65
Number of indirect workers	1477
Number of study area residents (40% of total)	591
Number of in-migrants (5.0% of residents)	30
Number of in-migrants with families (66%)	20
Average family size	3.22
Total in-migrants plus families	64
Number of in-migrants without families (33%)	10
Total indirect growth	74
Total growth	
Total direct growth	216
Total indirect growth	+74
Total projected refurbishment-related growth	290

Sources: Number of direct workers from SEA 1994. Average family size from 1990 U.S. Census of Population. Percentage of study area residents from ConEd 1990 and PASNY 1990. Other data from estimates concerning the construction of Indian Point and other nuclear stations; ORNL staff computations.

Table C.52 Projected plant-related population growth in Dutchess County, New York, during the license renewal term

Direct growth	
Number of direct workers	120
Number of workers projected to live in Dutchess County (37.8% of total)	45
Number of in-migrants (30% of residents)	13
Number of in-migrants with families (66%)	9
Average family size	× 3.22
Total in-migrants plus families	29
Number of in-migrants without families (33%)	+ 4
Total direct growth	33
Indirect growth	
Ratio indirect/direct jobs	0.65
Number of indirect workers	78
Number of study area residents (40% of total)	31
Number of in-migrants (5% of residents)	2
Number of in-migrants with families (66%)	2
Average family size	× 3.22
Total in-migrants plus families	6
Number of in-migrants without families (33%)	+ 0
Total indirect growth	6
Total growth	
Total direct growth	33
Total indirect growth	+ 6
Total projected plant-related growth	39

Sources Number of direct workers from NRC work force estimates (1989). Average family size from 1990 U.S. Census of Population Percentage of study area residents from ConEd 1990 and PASNY 1990. Other data from operations at Indian Point and other nuclear stations; ORNL staff computations

Table C.53 Projected plant-related population growth in Westchester County, New York, during the license renewal term

Direct growth	
Number of direct workers	120
Number of workers projected in live in Westchester County (27.8% of total)	33
Number of in-migrants (30% of residents)	10
Number of in-migrants with families (66%)	7
Average family size	× 3.22
Total in-migrants plus families	23
Number of in-migrants without families (33%)	+ 3
Total direct growth	26
Indirect growth	
Ratio indirect/direct jobs	0.65
Number of indirect workers	78
Number of study area residents (40% of total)	31
Number of in-migrants (5% of residents)	2
Number of in-migrants with families (66%)	2
Average family size	× 3.22
Total in-migrants plus families	6
Number of in-migrants without families (33%)	+ 0
Total indirect growth	6
Total growth	
Total direct growth	26
Total indirect growth	+ 6
Total projected plant-related growth	32

Sources Number of direct workers from NRC work force estimates (1989). Average family size from 1990 U.S. Census of Population. Percentage of study area residents from ConEd 1990 and PASNY 1990. Average family size from U.S. Census of Population Estimates (1985). Other data from operations at Indian Point and other nuclear stations; ORNL staff computations.

Table C.54 Indian Point tax payments to local government (1989 dollars)

Jurisdiction	1980	1985	1989
Indian Point Unit 2			
Town of Cortlandt	4,653,344	4,783,440	5,743,766[a]
Buchanan	1,311,318	1,211,437	1,396,344
Hendrick Hudson School District	7,934,365	7,188,180	9,086,374
Total	13,899,027	13,183,057	16,226,484
Indian Point Unit 3			
Town of Cortlandt	1,698,601	408,255	81,464
Buchanan	915,226	635,389	558,480
Hendrick Hudson School District	3,349,628	1,889,939	841,712
Total	5,963,455	2,933,583	1,481,656
Total both units	19,862,482	19,993,105	17,708,140

[a]Indian Point Unit 2 tax to town of Cortlandt is for 1990.
Sources: Partenheimer 1990; ORNL/NUMARC survey of all utilities (see Section C.6).

Table C.55 Assessed value of Indian Point Units 2 and 3 as a percentage of total assessed value, 1989–1990

	Assessed value (dollars)			Assessed value of Units 2 and 3 as % of jurisdiction's total
Jurisdiction	Indian Point Unit 2	Indian Point Unit 3	All properties in jurisdiction	
Cortlandt	40,112,900	9,922,590	79,740,587	62.7
Hudson School District	40,112,900	3,715,840	80,867,329	54.2
Buchanan	37,200,880	12,826,470	54,451,569	91.8

Sources Town of Cortlandt 1990a, b; Hudson School District 1990; Jankowski 1990; Burchman 1990; Partenheimer 1990.

Table C.56 Revenue provided by Indian Point to taxing jurisdictions, 1989–1990

Taxing jurisdiction	Total revenues ($ × 10^3)	Revenue from Indian Point ($ × 10^3)	Revenue from Indian Point as % of total
Cortlandt	17,740.7	5,906.7	33.3
Hudson School District	26,600.0	9,928.1	37.2
Buchanan	3,940.5	1,954.8	49.6

Sources: Town of Cortlandt 1990a; Partenheimer 1990; Burchman 1990; Jankowski 1990.

Table C.57 Estimated economic effects of Indian Point on Dutchess and Westchester counties, 1990

	Dutchess County	Westchester County
Employment		
Direct basic	505	371
Indirect	500	368
Total	1,005	739
Percentage of study area employment	0.83 (est.)	0.14
Income (1989 $)		
Direct	18,791,100	13,805,900
Indirect	11,307,900	8,322,700
Total	30,099,000	22,128,700
Percentage of study area income	0.38 (est.)	0.08

Source: ORNL staff computations based on the approach used in NUREG/CR-2750.

Table C.58 Projected employment effects of Indian Point refurbishment on Dutchess and Westchester counties, 2012

Affected area	Dutchess County	Westchester County
Refurbishment direct employment	393	289
Refurbishment indirect employment	591	591
Total Indian Point-related employment	984	880
Percentage of county's employment	0.5	0.2

Source: ORNL staff computations based on the approach used in NUREG/CR-2750.

Table C.59 Projected employment effects of Indian Point license renewal on Dutchess and Westchester counties, 2015

Affected area	Dutchess County	Westchester County
Existing direct and indirect plant-related employment	1005	739
Increase in direct employment	45	33
Increase in indirect employment	45	33
Total plant-related employment	1095	805
Percentage of study area employment	0.60	0.13

Source: ORNL staff computations based on the approach used in NUREG/CR-2750.

Table C.60 Population growth associated with the Oconee Nuclear Station: Oconee County, South Carolina, 1970–1990

Year	Work force			Project-related in-migrant population[a]	County's total population[b]	Project-related population as % of total
	Construction	Operations	Total			
1970	2,108	NA[c]	2,108	631	40,728	1.5
1971	2,342	NA	2,342	701	41,800	1.7
1975	0	462	462	277	43,700	0.6
1979	0	833	833	416	46,000	0.9
1985	300	900	1,200	232	51,973	0.4
1990	899	1,401	2,300	504	57,494	0.9

[a]Includes both direct and indirect workers and families.
[b]Population assumed to grow at a constant annual rate between known points.
[c]NA = not applicable.
Sources: NUREG/CR-2749, vol. 7, p. 89; 1990 U.S. Census of Population; Duke Power Company 1990; ORNL staff computations.

Table C.61 Estimated plant-related population growth in Oconee County, South Carolina, 1990

Direct growth	
Number of direct workers	2300
Number of study area residents (50% of total)	1150
Number of in-migrants (16.4% of residents)	189
Number of in-migrants with families (77%)	146
Average family size	× 3.16
Total in-migrants plus families	461
Number of in-migrants without families (23%)	+ 43
Total direct growth	504
Indirect growth	
Ratio indirect/direct jobs	0.41
Number of indirect workers	943
Number of study area residents (100% of total)	943
Number of in-migrants (0% of residents)	0
Number of in-migrants with families	0
Average family size	× 3.16
Total in-migrants plus families	0
Number of in-migrants without families	+ 0
Total indirect growth	0
Total growth	
Total direct growth	504
Total indirect growth	+ 0
Total estimated plant-related growth	504

Sources· Number of direct workers and percentage of study area residents from the Duke Power Company 1990. Average family size from 1990 U.S. Census of Population. Other data from NUREG/CR-2749, vol. 7. pp. 65–87; ORNL staff computations.

Table C.62 Projected refurbishment-related population growth in Oconee County, South Carolina, 2012

Direct growth	
Number of direct workers	2273
Number of study area residents (25.4% of total)	577
Number of in-migrants (50% of residents)	289
Number of in-migrants with families (33.3%)	96
Average family size	× 3.16
Total in-migrants plus families	303
Number of in-migrants without families (66.6%)	+ 193
Total direct growth	496
Indirect growth	
Ratio indirect/direct jobs	0.052
Number of indirect workers	118
Number of study area residents (100% of total)	118
Number of in-migrants (0% of residents)	0
Number of in-migrants with families	0
Average family size	× 3.16
Total in-migrants plus families	0
Number of in-migrants without families	+ 0
Total indirect growth	0
Total growth	
Total direct growth	496
Total indirect growth	+ 0
Total projected refurbishment-related growth	496

Sources: Direct workers from SEA 1994. Average family size from 1990 U.S. Census of Population. Other data from NUREG/CR-2749, vol. 7, pp. 62–87; ORNL staff computations.

Table C.63 Projected plant-related population growth in Oconee County, South Carolina, during the license renewal term

Direct growth	
Number of direct workers	180
Number of study area residents (50% of total)	90
Number of in-migrants (16.4% of residents)	15
Number of in-migrants with families (77%)	12
Average family size	× 3.16
Total in-migrants plus families	38
Number of in-migrants without families (0%)	+ 3
Total direct growth	41
Indirect growth	
Ratio indirect/direct jobs	0.41
Number of indirect workers	74
Number of study area residents (100% of total)	74
Number of in-migrants (0% of residents)	0
Number of in-migrants with families (0%)	0
Average family size	× 3.16
Total in-migrants plus families	0
Number of in-migrants without families (0%)	+ 0
Total indirect growth	0
Total growth	
Total direct growth	41
Total indirect growth	+ 0
Total projected plant-related growth	41

Sources Direct workers from NRC work force estimates (1989). Average family size from 1990 U S. Census of Population Other data from NUREG/CR-2749, vol. 7, pp. 62–87; ORNL staff computations

Table C.64 Oconee County property taxes (1989 dollars)

Source of revenue	1975–76	1980–81	1985–86	1989–90
County assessment	111,034,000	91,198,000	122,277,000	172,718,000
Total county property taxes	15,166,000	12,058,000	14,150,000	22,675,000
Licensee taxes	7,592,000	4,791,000	5,098,000	6,588,000
Total county revenue	30,489,000	29,915,000	35,442,000	46,329,000
Percentage of total tax revenues from licensee	50.1	39.7	36.0	29.1
Percentage of total revenues from licensee	24.9	16.0	14.4	14.2

Sources: NUREG/CR-2749, vol. 7; Oconee County 1980, 1985, and 1989, Budget Ordinances: 80-7, 85-5, and 89-3; Oconee County Independent Auditor's Report; Bridges 1990.

Table C.65 Estimated economic effects of Oconee Nuclear Station on Oconee County

Affected area	1971	1990
Employment		
Direct basic	595	1,150
Indirect	111	948
Total	706	2,098
Percentage of county employment	3.3	6.5
Income (1989 $)		
Direct	15,097,000	46,033,000
Indirect	1,424,000	17,940,000
Total	16,520,000	63,973,000
Percentage of county income	4.4	7.5

Source: For 1971, NUREG/CR-2749, vol. 7. Other estimates based on employment estimates from Section C.4.5.1 and multipliers from NUREG/CR-2749 Estimates of county employment and income used to calculate percentages are from NPA 1990.

Table C.66 Projected employment effects of Oconee Nuclear Station refurbishment on Oconee County, 2012

Refurbishment direct employment	577
Refurbishment indirect employment	118
Total plant-related employment	695
Percentage of Oconee County employment	1.9

Source: ORNL staff computations based on the approach used in NUREG/CR-2749, vol. 7.

Table C.67 Projected employment and economic effects of Oconee Nuclear Station license renewal on Oconee County, 2013

Existing direct and indirect plant-related employment	1150
Increase in direct employment	90
Increase in indirect employment	74
Total plant-related employment	1314
Percentage of Oconee County employment	3.6

Source: ORNL staff computations based on the approach used in NUREG/CR-2749, vol. 7.

Table C.68 Population growth associated with Three Mile Island: Londonderry Township, Middletown, and Royalton, Pennsylvania, 1970–1990

Year	Work force			Project-related in-migrant population[a]	Area's total population[b]	Project-related population as % of total
	Construction	Operations	Total			
1970	1,991	86	2,077	223	13,573	1.6
1972	2,746	126	2,872	310	14,225	2.2
1975	1,453	342	1,795	256	15,316	1.7
1979	0	565	565	110	16,243	0.7
1984	0	1,399	1,399	272	16,790	1.6
1990	0	1,086	1,086	246	14,636	1.7

[a]Includes both direct and indirect workers and families.

[b]Population assumed to grow at a constant annual rate between known points.

Sources: NUREG/CR-2749, vol. 12, p. 77; General Public Utilities Corporation 1990; ORNL staff computations.

Table C.69 Estimated plant-related population growth in Middletown, Royalton, and Londonderry Township, Pennsylvania, 1990

Direct growth	
Number of direct workers	1086
Number of study area residents (23% of total)	250
Number of in-migrants (22% of residents)	55
Number of in-migrants with families (100%)	55
Average family size	× 3.1
Total in-migrants plus families	171
Number of in-migrants without families (0%)	+ 0
Total direct growth	171
Indirect growth	
Ratio indirect/direct jobs	0.106
Number of indirect workers	115
Number of study area residents (85% of total)	98
Number of in-migrants (33.3% of residents)	33
Number of in-migrants with families (61%)	20
Average family size	× 3.1
Total in-migrants plus families	62
Number of in-migrants without families (39%)	+ 13
Total indirect growth	75
Total growth	
Total direct growth	171
Total indirect growth	+ 75
Total estimated plant-related growth	246

Sources: Number of direct workers and percentage of study area residents from General Public Utilities Corporation 1990. Average family size from 1990 U.S. Census of Population. Other data from NUREG/CR-2749, vol. 12, pp. 66–78; ORNL staff computations.

Table C.70 Projected refurbishment-related population growth in Middletown, Royalton, and Londonderry Township, Pennsylvania, 2013

Direct growth	
Number of direct workers	2273
Number of study area residents (8.0% of total)	182
Number of in-migrants (72% of residents)	131
Number of in-migrants with families (9.0%)	12
Average family size	× 3.1
Total in-migrants plus families	37
Number of in-migrants without families (91%)	+ 119
Total direct growth	156
Indirect growth	
Ratio indirect/direct jobs	0.022
Number of indirect workers	50
Number of study area residents (85% of total)	43
Number of in-migrants (33% of residents)	14
Number of in-migrants with families (62%)	9
Average family size	× 3.1
Total in-migrants plus families	28
Number of in-migrants without families (38%)	+ 5
Total indirect growth	33
Total growth	
Total direct growth	156
Total indirect growth	+ 33
Total projected refurbishment-related growth	189

Sources: Number of direct workers from SEA 1994. Average family size from 1990 U.S. Census of Population. Other data from NUREG/CR-2749, vol. 12, pp. 50–55, 74–76; ORNL staff computations.

Table C.71 Projected plant-related population growth in Middletown, Royalton, and Londonderry Township, Pennsylvania, during the license renewal term

Direct growth	
Number of direct workers	60
Number of study area residents (23% of total)	14
Number of in-migrants (22% of residents)	3
Number of in-migrants with families (100%)	3
Average household size	× 3.1
Total in-migrants plus families	9
Number of in-migrants without families (0%)	+ 0
Total direct growth	9
Indirect growth	
Ratio indirect/direct jobs	0.106
Number of indirect workers	6
Number of study area residents (85% of total)	5
Number of in-migrants (33.3% of residents)	2
Number of in-migrants with families (61%)	1
Average family size	× 3.1
Total in-migrants plus families	3
Number of in-migrants without families (39%)	+ 1
Total indirect growth	4
Total growth	
Total direct growth	9
Total indirect growth	+ 4
Total projected plant-related growth	13

Sources: Number of direct workers from NRC work force estimates (1989). Percentage of study area residents from General Public Utilities Corporation 1990. Average family size from 1990 U.S. Census of Population. Other data from NUREG/CR-2749, vol. 12, pp. 66–78; ORNL staff computations.

Table C.72 Londonderry Township revenue and taxes received (total revenue in constant 1980 dollars)

Source of funds	1980	1985	1989
Real estate transfer taxes	11,189	15,931	17,780
Earned income taxes	181,858	235,599	268,818
Occupational privilege taxes	11,819	14,697	13,255
Amusement tax	0	393	139
Total taxes	204,866	266,620	299,992
Payment in lieu of taxes (PURTA[a] receipts)	1,988	3,390	3,723
Other revenue	70,323	60,697	180,787
Total revenue	277,177	255,178[b]	330,953[c]

[a]PURTA = Public Utility Realty Tax Assessment of 1970.
[b]Actual total was $330,707; converted to 1980 $.
[c]Actual total was $484,502; converted to 1980 $.
Source: Londonderry Township 1990.

Table C.73 Borough of Middletown revenue and taxes received, 1980–1988 (in dollars)

Source of funds	1980	1985	1988
Taxes and assessments	461,582	619,595	653,728
Other general revenues	1,425,752	410,952	522,498
Special revenues and other financing sources	1,157,301[a]	542,006	685,378
Electricity/utility sales	1,572,283	3,273,839[a]	4,027,375[a]
Total revenues	4,616,918	4,842,392	5,888,979

[a]Includes sewer and water service billings.
Source: Middletown Borough combined Financial Statements 1980, 1985, and 1988.

Table C.74 Borough of Royalton revenue and taxes received, 1980–1989 (in dollars)

Source of funds	1980	1985	1989
Real estate	15,677	15,288	18,332
Per capita taxes	2,350	2,528	2,618
Real estate			
Transfer taxes	884	1,422	3,870
Earned income taxes	24,463	27,630	42,323
Total taxes	43,374	46,868	67,143
Sales of electricity	167,216	196,135	240,293
Other revenue	41,130	49,817	191,807
Total revenue	251,720	292,820	499,243

Source: Royalton Borough 1990; Young 1990.

Table C.75 Traffic counts in the vicinity of Three Mile Island,[a] selected years

Year	Route 441 at Royalton	Route 230 at Geyer's Church
1963	5,900	18,500
1966	6,200	18,000
1972	10,900	12,900
1975	8,800	12,800

[a]Counts in both directions aggregated.
Source: NUREG/CR-2749, vol. 12, p. 113.

Table C.76 Estimated economic effects of Three Mile Island on study area

Affected area	1972	1978	1990
	Employment		
Direct basic	258	178	250
Indirect	1	2	98
Total	259	180	348
Percentage of study area	2.1	1.2	13.0
	Income (1989 $)		
Direct	11,809,000	4,636,000	9,208,000
Indirect	24,000	31,000	1,843,000
Total	11,833,000	4,667,000	11,051,000
Percentage of study area	2.7	2.0	17.0

Sources: For 1972 and 1978 estimates, NUREG/CR-2749, vol. 12. The 1990 estimate is based on the approach used in the Mountain West study

Table C.77 Projected employment effects of Three Mile Island refurbishment on the study area, 2013

Refurbishment direct employment	182
Refurbishment indirect employment	43
Total plant-related employment	225
Percentage of study area employment	6.0

Source ORNL staff computations based on the approach used in NUREG/CR-2749, vol. 12.

Table C.78 Projected employment effects of Three Mile Island license renewal on the study area, 2013

Existing direct and indirect employment	348
Increase in direct employment	14
Increase in indirect employment	5
Total plant-related employment	367
Percentage of study area employment	9.8

Source ORNL staff computations based on the approach used in NUREG/CR-2749, vol 12.

Table C.79 Population growth associated with Wolf Creek Generating Station: Coffey County, Kansas, 1984–1989

Year	Work force: Construction	Work force: Operations	Work force: Total	Project-related in-migrant population[a]	Area's population[b]	Project-related population as % of total
1984	5500	0	5500	2329	9001	20.5
1985	0	692	692	755	8910	8.5
1989	0	1044	1044	1137	8559	13.3

[a]Includes both direct and indirect workers and families.

[b]Population assumed to change at a constant annual rate between known points; excludes refurbishment population that arrived after 1980 and left before 1990 census takings. Population in 1980 and 1990 was 9370 and 8404, respectively.

Sources: Wolf Creek Nuclear Operating Corporation 1990; other data from construction at other nuclear plants; ORNL staff computations; U.S. Bureau of the Census 1988, 1900.

Table C.80 Estimated construction-related population growth in Coffey County, Kansas, 1984

Direct growth	
Number of direct workers	5500
Number of study area residents (20% of total)	1100
Number of in-migrants (70% of residents)	770
Number of in-migrants with families (51%)	393
Average family size	× 3.08
Total in-migrants plus families	1210
Number of in-migrants without families (44%)	+ 377
Total direct growth	1587
Indirect growth	
Ratio indirect/direct jobs	0.05
Number of indirect workers	275
Number of study area residents (95% of total)	261
Number of in-migrants (55% of residents)	144
Number of in-migrants with families (66%)	95
Average family size	× 3.08
Total in-migrants plus families	293
Number of in-migrants without families (33%)	+ 49
Total indirect growth	342
Total growth	
Total direct growth	1587
Total indirect growth	+ 342
Total estimated construction-related growth	2329

Sources Number of direct workers from the Wolf Creek Nuclear Operating Corporation 1990. Average family size from 1990 U.S. Census of Population. Other data from construction-period experience at other nuclear plants; ORNL staff computations.

Table C.81 Estimated plant-related population growth in Coffey County, Kansas, 1989

Direct growth	
Number of direct workers	1044
Number of study area residents (50% of total)	522
Number of in-migrants (50% of residents)	261
Number of in-migrants with families (66%)	172
Average family size	× 3.08
Total in-migrants plus families	530
Number of in-migrants without families (33%)	+ 89
Total direct growth	619
Indirect growth	
Ratio indirect/direct jobs	0.4
Number of indirect workers	418
Number of study area residents (95% of total)	397
Number of in-migrants (55% of residents)	218
Number of in-migrants with families (66%)	144
Average family size	× 3.08
Total in-migrants plus families	444
Number of in-migrants without families (33%)	+ 74
Total indirect growth	518
Total growth	
Total direct growth	619
Total indirect growth	+ 518
Total estimated plant-related growth	1137

Sources: Number of direct workers and percentage of study area residents from the Wolf Creek Nuclear Operating Corporation 1990. Average family size from 1990 U.S. Census of Population. Other data from operations period experience at other nuclear plants; ORNL staff computations.

Table C.82 Projected refurbishment-related population growth in Coffey County, Kansas, 2024

Direct growth	
Number of direct workers	2273
Number of study area residents (20% of total)	455
Number of in-migrants (70% of residents)	319
Number of in-migrants with families (51%)	163
Average family size	× 3.08
Total in-migrants plus families	502
Number of in-migrants without families (49%)	+ 156
Total direct growth	658
Indirect growth	
Ratio indirect/direct jobs	0.05
Number of indirect workers	114
Number of study area residents (95% of total)	108
Number of in-migrants (55% of residents)	59
Number of in-migrants with families (66%)	39
Average family size	× 3.08
Total in-migrants plus families	120
Number of in-migrants without families (33%)	+ 20
Total indirect growth	140
Total growth	
Total direct growth	658
Total indirect growth	+ 140
Total projected refurbishment-related growth	798

Sources: Number of direct workers from SEA 1994. Average family size from 1990 U.S. Census of Population. Other data from construction period experience at other nuclear plants; ORNL staff computations.

Table C.83 Projected plant-related population growth in Coffey County, Kansas, during the license renewal term

Direct growth	
Number of direct workers	60
Number of study area residents (50% of total)	30
Number of in-migrants (50% of residents)	15
Number of in-migrants with families (66%)	10
Average family size	× 3.08
Total in-migrants plus families	31
Number of in-migrants without families (33%)	+ 5
Total direct growth	36
Indirect growth	
Ratio indirect/direct jobs	0.4
Number of indirect workers	24
Number of study area residents (95% of total)	23
Number of in-migrants (55% of residents)	13
Number of in-migrants with families (66%)	9
Average family size	× 3.08
Total in-migrants plus families	28
Number of in-migrants without families (33%)	+ 4
Total indirect growth	32
Total growth	
Total direct growth	36
Total indirect growth	+ 32
Total projected plant-related growth	68

Sources: Number of direct workers from NRC work force estimates (1989). Percentage of study area residents from the Wolf Creek Nuclear Operating Corporation 1990. Average family size from 1990 U.S. Census of Population. Other data from operations period experience at other nuclear plants; ORNL staff computations.

Table C.84 Increases in rental rates and housing values, Coffey County and state of Kansas, 1970 and 1980 (in dollars)

	Coffey County	State of Kansas
	Rental rates	
1970	46	75
1980	156	168
Percentage change	239	124
	Housing values	
1970	6,300	12,100
1980	24,300	37,800
Percentage change	286	212

Sources: For 1970, U.S. Bureau of the Census 1972; for 1980, U.S. Bureau of the Census 1982.

Table C.85 Taxes paid by Wolf Creek Generating Station, 1980–1989 (constant 1989 dollars)

Jurisdiction	1980	1985	1989
State of Kansas	268,004	732,610	729,602
Coffey County	3,249,980	9,869,732	14,061,868
Burlington School District	3,557,468	7,117,846	7,102,472

Source: ORNL/NUMARC survey of all utilities (see Section C.6).

Table C.86 Estimated economic effects of Wolf Creek Generating Station on Coffey County, 1989

Employment	
Direct basic	522
Indirect	397
Total plant-related	919
Percentage of Coffey County employment	17.5
Income (1989 $)	
Direct	27,601,000
Indirect	9,752,000
Total plant-related	37,352,000
Percentage of Coffey County income	22 5

Source: ORNL staff computations based on approach used in NUREG/CR-2750.

Table C.87 Projected employment effects of Wolf Creek Generating Station refurbishment on Coffey County, 2024

Refurbishment direct employment	455
Refurbishment indirect employment	108
Total plant-related employment	563
Percentage of Coffey County employment	6.8

Source ORNL staff computations based on approach used in NUREG/CR-2750

Table C.88 Projected employment effects of Wolf Creek Generating Station license renewal on Coffey County, 2025

Existing direct and indirect employment	522
Increase in direct employment	30
Increase in indirect employment	23
Total plant-related employment	575
Percentage of Coffey County employment	7.1

Source ORNL staff computations based on approach used in NUREG/CR-2750.

APPENDIX D

AQUATIC MICROORGANISMS AND HUMAN HEALTH

AQUATIC MICROORGANISMS AND HUMAN HEALTH

Some aquatic microorganisms normally present in surface waters whose presence may be enhanced by thermal additions have been recognized as pathogenic for humans. Among these are *Salmonella* species (sp.), *Shigella* sp., *Pseudomonas* sp., thermophilic fungi, Legionnaires' disease (LD) bacteria [*Legionella* (*L.*) sp.], and the free-living amoebae of the genera *Naegleria* (*N.*) sp., the causative agents of various human infections.

Salmonella sp. is classified as a facultative intracellular parasite that has an incubation period of 10 to 14 days and can cause symptoms that include continued fevers, intestinal inflammation, formation of intestinal ulcers, splenic enlargement, toxemia, and the production of a characteristic "rose-spot" eruption on the abdomen. These bacteria are usually associated with areas of poor sanitation but can also be transmitted by the common house fly. The organisms do not multiply in water but can live for several weeks in water and can be transported over large distances.

Shigella sp. is similar to *Salmonella* sp. in its mode of transmission but has a much shorter incubation period (1 to 7 days). It produces severe dysentery with production of a potent exotoxin. The optimum growth temperature for the organism is 37°C (99°F), but it can grow at much higher temperatures.

Aeromonas sp. is also a facultative anaerobe and has been isolated from tap water, rivers, soil, and marine environments, as well as various foods. It has been isolated from healthy individuals, as well as those with diarrheal symptoms. It is primarily an opportunistic pathogen, although some strains produce a potent enterotoxin that increases its pathogenicity.

Pseudomonas aeruginosa can be found in soil, humidifiers, hospital respirators, water, and sewage and on the skin of healthy individuals. Certain strains can produce a potent endotoxin, and the organism can cause symptoms that include fever, bacteriuria, bacteremia, pneumonia, otitis, and opportunistic wound and ophthalmic infections. The organism can survive and grow in a wide range of environmental conditions.

Actinomycetes are ubiquitous and can be found in soil, water, and the oral flora of man (usually associated with caries). Infections are primarily opportunistic, but very aggressive strains can produce pulmonary disease; cervical or intestinal infections are not uncommon. This organism can also survive a wide range of environmental conditions, with thermophilic types being the most pathogenic.

Although the above-mentioned organisms are ubiquitous, the ingestion or inhalation of small quantities of these organisms would not adversely affect the health of individuals who are not immunosuppressed. However, inhalation of endotoxins and exotoxins produced by several of these organisms, which are readily aerosolized, may theoretically affect even healthy individuals who come in contact with mist, vapor, or minute droplets of water. No reports have been identified that suggest such occurrences in power plant workers. *Legionella* sp. infections, on the other hand, can be infectious for uncompromised healthy workers.

The clinical significance of *Legionella* sp. was dramatized by the namesake outbreak in 1976 at an American Legion convention in Philadelphia (McDade et al. 1977). At this convention more than 100 people became ill and 34 died. After an intensive effort, laboratory isolations were made of the causative agent, *L. pneumophila*. Since 1977, various serogroups of *L. pneumophila* and more than 30 species of *Legionella* have been discovered (Thornsberry et al. 1984). *Legionella* sp. are gram-negative rods approximately 0.5 × 2.4 μm in size. Infection generally occurs by inhalation of the aerosolized bacteria. Two disease syndromes can be manifested by infection with *Legionella* sp. Legionnaires' Disease is a pneumonia with associated cough, fever, and malaise (Lattimer and Ormsbee 1981). The disease can be fatal, although Erythromycin is effective in treating it. Legionellosis may also be expressed as Pontiac fever, a nonpneumonic, flu-like illness that also responds to Erythromycin therapy (Fraser et al. 1979).

Estimates of the number of cases of Legionellosis range from 25,000 to 200,000 per year (W. H. Wilkinson, telephone interview with R. L. Tyndall, Oak Ridge National Laboratory, Oak Ridge, Tenn., 1982). Some of the known Legionellosis outbreaks were traceable to the aerosolization of water-borne *Legionella* sp. by cooling towers and evaporative condensers (NUREG/CR-1207; Berendt et al. 1980). The cooling devices are presumably seeded with *Legionella* sp. from their potable and natural water supplies. That *Legionella* sp. in fact are normal components of the aquatic flora was first demonstrated by Fliermans et al. (1981) and has been confirmed by subsequent studies (Fliermans 1985). In view of this ubiquity in natural surface waters, it is not surprising that water in cooling towers and evaporative condensers contains *Legionella* sp. These devices can then amplify *Legionella* sp. concentrations and disperse the pathogen through aerosolization.

In contrast to *Legionella* sp., the presence of *Naegleria* sp. in water and soil was known before their clinical significance was recognized. Butt (1966) and Carter (1970) described the first cases of *Naegleria* sp. infection in Floridian and Australian children who were infected by swimming or bathing in *Naegleria* sp.-infested waters. *Naegleria* sp. are small amoebae capable of using dissolved organic material or gram-negative bacteria as a food source. They are eukaryotic cells that generally have a single nucleus and a centrally located nucleolus. Locomotion is by means of eruptive pseudopodia. Four species of *Naegleria* have been isolated. *N. gruberi* and *N. jadini* have not shown any pathogenic potential in experimental animals or in man. *N. australiensis* is pathogenic for mice but as yet has not been implicated in human diseases. *N. fowleri* is pathogenic for humans and mice (Rondanelli 1987).

On entry into the nasal passage of a susceptible individual, *N. fowleri* will penetrate the nasal mucosa and migrate along the olfactory nerve through the cribriform plate to the cerebrum. The ensuing infection results in a rapidly fatal meningoencephalitis (Rondanelli 1987). Antibiotic therapy is generally ineffectual. Fortunately, primates in general are resistant to infection with *N. fowleri*. This has been demonstrated in laboratory studies with chimpanzees and in epidemiologic studies at sites where fatal cases of primary amoebic meningoencephalitis (PAME) occurred (Wong et al. 1975). In such cases, hundreds of individuals were exposed, but only a single case of PAME occurred. Reasons for the susceptibility of the occasional individual are unknown. After reports of fatal cases of PAME in Australia and Florida, other cases of PAME were reported. Sources of infections included heated swimming pools (Cerva 1971), thermal springs (Hecht et al. 1972), and a variety of naturally or artificially heated surface waters (Fliermans et al. 1979; DeJonckheere 1978). One of the largest clusters of PAME occurred in Virginia, where 16 cases were reported over a 9-year period (Duma et al. 1971). Unlike the thousands of cases of Legionellosis per year in the United States alone, only 100 to 200 cases of PAME have been reported to date worldwide. Hallenbeck and Brenniman (1989) reviewed the world literature to derive a risk analysis model that would be helpful in the management of PAME. They concluded that the management of PAME risk was difficult; the prevention, almost impossible. However, they estimated the lifetime risk of PAME to be 4×10^{-5}, assuming 10 exposures per swimming season and 10 swimming seasons. As with *Legionella* sp., simple, rapid assays for detecting and quantifying *N. fowleri* in aquatic environments are not generally available.

In 1981, cooling waters of 11 nuclear power plants and associated control source waters were studied for the presence of thermophilic free-living amoebae, including *N. fowleri*. Presence of pathogenic *N. fowleri* was demonstrated by mouse inoculations. While all but one test site was positive for thermophilic free-living amoebae, only two test sites were positive for pathogenic *N. fowleri*. Pathogenic *N. fowleri* were not found in control source waters (NUREG/CR-2980). A recent analysis of heated water from a nuclear plant that began operations within the past 3 years also showed the presence of *N. fowleri*. Water from the plant impacts a public swimming area (Huizinga and McLaughlin 1990).

In addition to testing for pathogenic amoebae in cooling waters, the 11 nuclear power plants in the 1981 study were also studied for the presence of *Legionella* sp. (NUREG/CR-2980). Concentrations of *Legionella* sp. were determined microscopically by fluorescent antibody analysis, and infectious *Legionella* sp. were demonstrated by guinea pig inoculation. In general, the artificially heated waters showed only a slight increase (i.e., ≤ 10-fold) in concentrations of *Legionella* sp. relative to source water. In a few cases, source waters had higher levels than did heated waters. Infectious *Legionella* sp. were found in 7 of 11 test waters and 5 of 11 source waters.

Subsequently, a more detailed study of *Legionella* sp. presence in the environs of coal-fired electric power plants was undertaken to determine the distribution, abundance, and infectivity and aerosolization of *Legionella* sp. in power plant cooling systems (NUREG/CR-3364; EPRI/EA-4017; EPRI/EA-3153).

This study found that the infrequent occurrence of positive air samples at locations not adjacent to cleaning operations suggests that aerosolized *Legionella* sp. associated with downtime procedures have minimal impact beyond these locations. Even within plant boundaries, detectable airborne *Legionella* sp. appear to be confined to very limited areas. In these areas, however, the more contact individuals have with the most concentrated *Legionella* sp. populations—particularly if these become aerosolized as they do in some downtime operations—the more likely it becomes that workers may be exposed.

Exposure to *Legionella* sp. from power plant operations, while a potential problem for a subset of the work force, would not generally impact the public because concentrated aerosols of the bacteria would not traverse plant boundaries. Plant personnel most likely to come in contact with *Legionella* aerosols would be workers who dislodge biofilms, where *Legionella* are often concentrated, such as during cleaning of condenser tubes and cooling towers. Since Legionellosis is a respiratory disease, workers engaged in such activities should be protected by wearing appropriate respiratory protection.

Because the route of infection with *N. fowleri* is nasal, workers exposed to aerosols of this pathogen also should be protected with respiratory protection. If involved in underwater maintenance or other activities associated with thermally altered discharge waters known to harbor *N. fowleri*, workers should wear appropriate gear to prevent entry of the amoebae into the nasal cavity. The observed risk to swimmers from waters infected with *N. fowleri* is low but not zero (Hallenbeck and Brenniman 1989). Nevertheless, heavily used bodies of fresh water merit special attention and possibly routine monitoring for pathogenic *Naegleria*. Policies for public swimming and water skiing in plant discharges known or suspected to harbor *N. fowleri* should be reviewed by state health departments. Since *Naegleria* concentrations in fresh water can be enhanced by thermal additions, nuclear power plants that utilize cooling lakes, canals, ponds, or small rivers may enhance the naturally occurring thermophilic organisms.

REFERENCES

Berendt, R. F., et al., "Dose-Response of Guinea Pigs Experimentally Infected with Aerosols of *Legionella pneumophila*," *Journal Infectious Diseases*, 141(2), 186, 1980.

Butt, C., "Primary Amoebic Meningoencephalitis," *New England Journal of Medicine*, 274, 1473–76, 1966.

Carter, R. F., "Description of a *Naegleria* sp. Isolated from Two Cases of Primary Amoebic Meningoencephalitis," *Journal of Pathology*, 100, 217–44, 1970.

Cerva, L., "Studies of *Limax Amoebae* in a Swimming Pool," *Hydrobiologia*, 38, 141–61, 1971.

DeJonckheere, J. F., "Quantitative Study of *Naegleria fowleri* in Surface Waters," *Protistogica*, 14, 475–81, 1978.

Duma, R. J., et al., "Primary Amoebic Meningoencephalitis: A Survey in Virginia," *Archives of Environmental Health*, 23, 43–47, 1971.

EPRI/EA-3153, S. W. Christensen et al., *Legionnaire's Disease Bacterium in Power Plant Cooling Systems: Phase I Final Report*, Electric Power Research Institute, Palo Alto, California, 1983.

EPRI/EA-4017, R. L. Tyndall et al., *Legionnaires' Disease Bacteria in Power Plant Cooling Systems: Phase II Final Report*, Electric Power Research Institute, Palo Alto, California, 1985.

Fliermans, C. B., et al., "Isolation of *Naegleria fowleri* from Artificially Heated Waters," *Journal Thermal Biology*, 4, 303–6, 1979.

Fliermans, C. B., et al., "Ecological Distribution of *Legionella pneumophila*," *Applied Environmental Microbiology*, 41(1), 9–16, 1981.

Fliermans, C. B., "Ecological Niche of *Legionella pneumophila*," *Critical Reviews in Microbiology*, 1985.

Fraser, D. W., et al., "Nonpneumonic, Short-Incubation-Period Legionellosis (Pontiac Fever) in Men Who Cleaned a Steam Turbine Condenser," *Science*, **205**, 690–91, 1979.

Hallenbeck, W. H., and G. R. Brenniman, "Risk of Fatal Amoebic Meningoencephalitis from Waterborne *Naegleria fowleri*," *Environmental Management*, **13**(2), 227–32, 1989.

Hecht, R. H., et al., "Primary Amebic Meningoencephalitis in California," *California Medicine*, **117**, 69–73, 1972.

Huizinga, H. W., and G. L. McLaughlin, "Thermal Ecology of *Naegleria Fowleri* from a Power Plant Cooling Reservoir," *Applied Environmental Microbiology*, 2200–05, July 1990.

Lattimer, G. L., and R. A. Ormsbee, *Legionnaires' Disease*, Mercel Dekker, New York, 1981.

McDade, J. E., et al., "Legionnaires' Disease: Isolation of a Bacterium and Demonstration of Its Role in Other Respiratory Disease," *New England Journal of Medicine*, **297**, 1197–203, 1977.

NUREG/CR-1207 (ANL/ES-83), A. P. Adams and B. A. G. Lewis, *Microbial Aerosols from Cooling Towers and Cooling Sprays: A Pilot Study*, Argonne National Laboratory, Argonne, Illinois, 1979.

NUREG/CR-2980, R. L. Tyndall, *Presence of Pathogenic Micro-Organisms in Power Plant Cooling Waters, Report for October 1, 1979 to September 30, 1981*, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1981.

NUREG/CR-3364 (ORNL/TM-8809), R. L. Tyndall, *Presence of Pathogenic Microorganisms in Power Plant Cooling Waters: Final Report for October 1, 1981, to June 30, 1983*, Oak Ridge National Laboratory, Oak Ridge, Tennessee, 1983.

Rondanelli, E. G., ed., "Infectious Diseases," Color Atlas Monographs 1, *Amphizoic Amoebae Human Pathology*, Piccin, Pavia, Italy, 1987.

Thornsberry, C., et al., eds., *Legionella, Proceedings of the 2nd International Symposium*, American Society for Microbiology, Washington, D.C., 1984.

Wong, M. M., et al., "Experimental Infections with Pathogenic Free-Living Amoebae in Laboratory Primate Hosts. (A) A Study of Susceptibility to *N. fowleri*," *Journal Parasitol*, **61**, 199–208, 1975.

APPENDIX E

RADIATION PROTECTION CONSIDERATIONS FOR NUCLEAR POWER PLANT LICENSE RENEWAL

Radiation Protection Considerations for Nuclear Power Plant License Renewal

Radiological issues are associated with the process of refurbishment and with normal operation in the period after license renewal. Both occupational personnel and members of the public will be affected by these processes as a result of radiation exposures in the plants and as a result of small losses of radioactive materials in the gaseous and liquid effluents.

This appendix is intended to provide pertinent background information for analyses and to supplement discussions in the Generic Environmental Impact Statement (GEIS).

E.1 THE REGULATORY STANDARDS PROCESS

Government agencies establish basic radiation protection standards that are consistent with guidance to federal agencies issued by the President. This guidance is prepared by interagency committees and reflects recommendations published by expert groups such as the International Commission on Radiological Protection (ICRP) and the National Council on Radiation Protection and Measurements (NCRP). In the preparation of their reports, the ICRP and NCRP scientific committees rely heavily on information published by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and other publicly available information. The UNSCEAR reports contain detailed radiobiological and epidemiological information that has been acquired on a worldwide basis. Through this system, the U.S. federal agencies maintain consistency in their basic standards, and scientific consensus on an international basis is ensured. The standards are published in the *Federal Register* for public comment before issuance in final form, and public hearings are often held.

E.2 RADIATION PROTECTION STANDARDS

E.2.1 Occupational

E.2.1.1 Basic Standards

The occupational radiation protection standards of primary interest are those for exposure of the whole body. These standards have changed at different times, as shown in Table E.1. The downward trend is evident, from 1.0 R/week (or 50 R/year) in 1947 to the current 5.0 rem/year total effective dose equivalent (TEDE). The table does not reveal the fact that, before introduction of the TEDE quantity, the permitted dose from radionuclides deposited in the body was in addition to the permitted dose from external sources. The dose data for nuclear power plant (NPP) workers are presented in Section E.3.1.

The U.S. Atomic Energy Commission (AEC) regulatory/Nuclear Regulatory Commission (NRC) standards in 10 CFR Part 20 have changed infrequently. Tables E.2 and E.3 present a summary of the occupational standards which were in effect from 1960 through 1990 (old Part 20) and standards in effect from 1991 (new Part 20). On an annual basis, the whole-body limit has decreased from 15 R (3 R/quarter) in 1957

Table E.1 Occupational radiation dose limits for the whole body[a]

Year	NCRP[b]	ICRP[b]	Federal guidance	AEC/DOE[b]	AEC-REG/NRC[b]
1947	0.1/day 0.5/week	0.2/day 1.0/week	—	0.1/day	—
1949	0.3/week	—	—	—	—
1950	—	3.0/week	—	0.3/week	—
1954	3.0/quarter 0.3/week	—	—	3.0/quarter 0.3/week	—
1957	—	—	—	—	0.3/week
1958	3.0/quarter 5.0/year average	—	—	3.0/quarter 0.3/week 5.0/year average	—
1960	—	—	3.0/quarter 5.0/year average	3.0/quarter 5.0/year average	—
1961	—	—	—	—	1.25/quarter or 3.0/quarter with 5.0/year average
1965	—	3.0/quarter 5.0/year maximum	—	—	—
1971	3.0/quarter 5.0/year maximum	—	—	—	—
1977	—	5.0/year EDE	—	—	—
1987	5.0/year EDE	—	5.0/year EDE	—	—
1988	—	—	—	5.0/year EDE	—
1991	—	—	—	—	5.0/year TEDE

[a]Units: 1947–57, the roentgen; 1958–76, the rem dose equivalent (DE); 1977 to present, the rem effective dose equivalent (EDE). The rem unit signifies the DE quantity except for the final entry in each column, where the quantity is the EDE. EDE is external, internal, or both The ICRP has announced its intention to reduce its limit to 2 rem/year total EDE, with a provision for operational flexibility. To convert rem to sievert, multiply by 0 01

[b]NCRP = National Council on Radiation Protection and Measurements; ICRP = International Council on Radiation Protection; AEC = Atomic Energy Commission; DOE = U.S Department of Energy; NRC = Nuclear Regulatory Commission.

(external radiation only) to 5 rem effective dose equivalent (EDE) (external plus internal). Regulatory control over the intake of radioactive materials in the workplace has always been a complex issue. Details are presented as a matter of interest in Attachment E.A. Before the new Part 20, limits on the intake of radioactive material into the body were based on the critical organ concept. The critical organ for a nuclide was the organ receiving the greatest radiation insult (considering its dose limit)

Table E.2 Occupational dose limits for adults under "Old Part 20" guidelines[a]

Tissue	External radiation	Internal radiation
Whole body	3 rem/quarter maximum, 5 rem/year average	
Lens	3 rem/quarter maximum, 5 rem/year average	
Extremities, including skin	18.75 rem/quarter	
All other skin	7.5 rem/quarter	
Thyroid		30 rem/year
Bone		30 rem/year
Marrow		5 rem/year
Gonads		5 rem/year
All other organs		15 rem/year

[a]Old Part 20 guidelines were in effect since 1960; the new Part 20 came into effect in 1991.
Note: To convert rem to sievert, multiply by 0.01.

from the intake of a specific radionuclide in a certain chemical form. AEC/NRC licensees were required to limit the quarterly intake of a given radionuclide to an amount that, under equilibrium conditions (rate of intake equal to the rate loss by decay or elimination), would deliver to the critical organ a dose equal to the limit for that organ. (The dose to the organ from radiation sources external to the body was not considered.) If a nuclide would not achieve equilibrium in the critical organ within 50 years, the quarterly intake limit would produce, at the end of 50 years, an annual dose equal to the limit for that organ.

This method of control did not take into consideration the risk to organs other than the critical organ. Beginning in 1991, NRC abandoned the critical organ approach in favor of the method published by the ICRP in its Publication 26 (described in Attachment E.A). Under the ICRP method, the dose to each significantly irradiated organ is weighted according to its sensitivity. The weighted doses are summed to produce an EDE that can be added to the dose from external sources.

The revised Part 20 provides additional flexibility for establishing more accurate dose controls. It allows the use of actual particle-

Table E.3 Occupational dose limits for adults under "New Part 20" guidelines[a]

Tissue	External radiation	Internal plus external radiation
Whole body	5 rem/year total dose equivalent,[b] not to exceed 50 rem/year total dose equivalent to any individual organ or tissue other than the lens of the eye	5 rem/year total effective dose equivalent,[c] not to exceed 50 rem/year total dose equivalent to any individual organ or tissue other than the lens of the eye
Lens	15 rem/year	
Extremities, including skin	50 rem/year	
All other skin	50 rem/year	
Thyroid		
Bone		
Marrow		
Gonads		
All other organs		

[a]New Part 20 guidelines became effective in 1991.
[b]The total dose equivalent is the sum of the external dose equivalent (at 1 cm depth) and the committed dose equivalent from nuclides deposited in the body.
[c]The total effective dose equivalent is the sum of the external dose equivalent (at 1 cm depth) and the committed effective dose equivalent from nuclides deposited in the body.
Note: To convert rem to sievert, multiply by 0.01.

size distribution and physiochemical characteristics of airborne particulates to define site-specific derived air concentration limits. With NRC approval, these modified concentration limits can be used in lieu of generic values provided in Part 20. Such adjustments result in the use of more precise estimates that use actual exposure conditions as compared with generic assumptions.

Although these adjustments might permit higher airborne radionuclide concentration limits to be used, the same degree of health protection would exist because the radiation dose (and risk) would remain the same as that intended in the generic values.

E.2.1.2 ALARA

Following the accident at Three Mile Island, the NRC required a number of improvements that caused the industry-wide annual collective dose (and the individual annual average) to increase temporarily. However, for two primary reasons, these dose values soon began to decrease and have continued to do so. First, the NRC and a new industry organization, the Institute of Nuclear Power Operations, began to demand better performance with respect to dose reduction. Second, additional risk information, primarily from the atomic bomb survivor study, became available. In 1977, the ICRP adopted risk estimates of 1.25 cancer fatalities and 0.4 serious genetic effects among 10,000 people (and their progeny for two generations) receiving 10,000 person-rem (ICRP Publication 26); in 1980, the National Academy of Sciences (NAS) published a revision of the 1972 Biological Effects of Ionizing Radiation (BEIR-I) report. The new report, BEIR-III, contained a range of radiation-risk estimates that, together with the ICRP estimate, caused the risk value previously mentioned to be doubled. It was recognized that the resulting 5 percent fatality estimate (to be associated with 5 rem/year for a working lifetime) was derived from instantaneous exposure, that actual lifetime occupational doses were far fewer than 250 rem as used in the estimate, and that the estimate was therefore of limited use in the standards development process. However, largely because of nonquantitative information indicating that instantaneous radiation was more carcinogenic than had been believed, efforts to ensure that radiation doses were as low as reasonably achievable (ALARA) were redoubled. Without specific regulations, the average annual occupational dose for the nuclear power plant (NPP) worker population fell below 0.5 rem, meeting or exceeding the ICRP overall occupational risk criterion of 1 fatality per 10,000 workers per year (ICRP Publication 26). In 1968, the percentage of NPP workers who received more than 5 rem was 0.5 percent, and three persons had doses in excess of 12 rem. By 1986, the percentage of workers receiving more than 5 rem was less than 0.01 percent, and no individual received more than 12 rem.

Two regulatory guides have been issued to provide guidance on ALARA programs for NPPs, one on ALARA philosophy (NRC Regulatory Guide 8.10, Rev. 1R) and one on implementation (NRC Regulatory Guide 8.8, Rev. 3). NPP licensees are required to maintain and implement adequate plant procedures that contain ALARA criteria. During plant licensing, applicants commit to implement ALARA programs consistent with Regulatory Guides 8.8 and 8.10. The 1991 revision to 10 CFR Part 20 codifies this requirement that licensees implement a program to maintain radiation doses ALARA. Compliance with the commitments is required through 10 CFR Part 50 and the technical specifications.

Recent developments among the Japanese atomic bomb survivors (as discussed in Section E.4) have revealed that gamma (and possibly neutron) radiation delivered uniformly at high doses and high dose rates is an even more efficient carcinogen than was believed (RERF TR 12-87). The new occupational risk estimates that result imply that an average annual dose of 0.5 rem may not meet the ICRP criteria of one fatality per year among 10,000 workers. ICRP has published revised recommendations concerning dose limits. Increased emphasis on the ALARA concept is therefore indicated and is adopted in the 1991 revision of Part 20.

E.2.2 Public

E.2.2.1 Basic Standards for Dose from Controlled Sources

The current federal guidance on radiation protection for the general public was issued in 1960 (FR 25, 97, May 18, 1960) and is now undergoing revision by an interagency committee chaired by the U.S. Environmental Protection Agency (EPA). The annual dose-equivalent limit for the whole body specified in the 1960 guidance is 0.5 rem.

For many years, the ICRP and NCRP recommended dose limits for the public that were 10 percent of those for workers. During the 1980s, both organizations adopted a more conservative value of 2 percent. In 1985, following a meeting of the ICRP in Paris, France, the ICRP released a statement that its principal limit for the whole body is 0.1 rem/year EDE (ICRP 1985). However, a subsidiary limit of 0.5 rem/year is authorized provided that the average dose does not exceed 0.1 rem/year. The ICRP limit for the skin and lens of the eye is 5 rem/year. In 1987, the NCRP recommended limits of 0.1 rem/year EDE for the whole body under conditions of continuous or frequent exposure and 0.5 rem/year for infrequent exposure (NCRP 1987). The NCRP limit for the lens of the eye, skin, and extremities is 5 rem/year.

Prior to the 1991 version of 10 CFR Part 20, the AEC and NRC required applicants for a license to operate a nuclear facility to demonstrate that an individual would be unlikely to receive in excess of 0.5 rem to the whole body in a year. In 1991, a limit of 0.1 rem/year EDE was imposed.

With regard to limits on radioactive material deposited in the body, until the advent of the EDE, annual average concentration values [or maximum permissible concentrations (MPCs)] were specified that would deliver (under equilibrium conditions) the following doses to critical organs: thyroid and bone, 1 rem/year; whole body and gonads, 0.05 rem/year; all other organs, 0.5 rem/year (ICRP 1960). The MPCs were recommended by the ICRP and NCRP and used in 10 CFR Part 20 (until 1991). The revised Part 20 employs the annual limits on intake (ALIs) and derived air concentrations (DACs) now recommended by these organizations. When these values are used, the EDE is limited to 0.1 rem/year. To provide additional protection for children and others who are smaller than the "reference man" used for the calculation of the ALIs, the new 10 CFR Part 20 specifies ALIs and DACs based on 0.05 rem/year.

E.2.2.2 ALARA Standards

In addition to the basic standards mentioned above, 10 CFR Part 50.36(a) contains license conditions that are imposed on licensees in the form of technical specifications applicable to effluents from nuclear power reactors. These specifications will ensure that releases of radioactive materials to unrestricted areas during normal operations, including expected operational occurrences, remain ALARA. Appendix I to 10 CFR Part 50 provides numerical guidance on dose-design objectives and limiting conditions for operation for light-water reactors (LWRs) to meet the ALARA requirements. As a part of the licensing process, all licensees have provided reasonable assurance that the design objectives will be met for all unrestricted areas. 10 CFR Part 20 requires compliance with EPA regulation 40 CFR Part 190, which also contains ALARA limits. The dose constraints are summarized in Tables E.4 and E.5.

E.3 NUCLEAR POWER PLANT EXPOSURE DATA

E.3.1 Occupational

E.3.1.1 Past Data

Individual occupational doses are measured by NRC licensees as required by the basic NRC radiation protection standard, 10 CFR Part 20. The measurement results of primary interest are those recorded for exposure of the whole body to radiation from sources that are external to the body. The whole-body dose must be determined at a depth of 1 cm from the surface of the body. Measurements of the whole-body dose are normally derived from personal dosimeters worn by each worker. Since 1984, many of the NPPs have provided dosimetry programs accredited by the National Bureau of Standards [NBS, now National Institute of Standards and Technology (NIST)]; in general, ±50 percent accuracy is required. In 1988, NBS/NIST accreditation became an NRC requirement.

Whole-body dose data from NRC-licensed LWRs are shown in Tables E.6 and E.7 for the years 1973 through 1992. For each year, the number of reactors, the number of workers receiving measurable exposures, the workers' average annual dose, the collective (person-rem) dose for all reactors combined, and the number of individuals exceeding 12 rem are given. (The collective dose is the sum of all personal doses.) The collective and average annual doses appear to be leveling at about 30,000 person-rem and 0.3 rem respectively.

With regard to individual doses, Table E.8 reveals that fewer than 500 workers (0.5 percent) received whole-body doses exceeding 2 rem during 1992. No worker exposure exceeded 5 rem during that calendar year.

The NRC regulates the dose to the gonads and the lens of the eye by including those organs in the definition of whole body. Also included in this definition are the blood-forming organs, which are susceptible to radiation-induced leukemia. No other organs are specifically named in the definition. The dose to the extremities and the skin is regulated, although higher doses are allowed because of the lower risks. The data presented in Tables E.6–E.8 for the whole body apply to the gonads, eye lens, and bone marrow as well (neglecting attenuation). Data for the extremities and skin are recorded by licensees, but these data are listed in NRC reports only in connection with regulatory overexposures. NPP workers are exposed to airborne radioactive material—primarily fission and corrosion products—but such exposures have normally been small in comparison with external doses. Under old Part 20, licensees were not required to report inhalation exposures unless a quarterly intake limit was exceeded. Therefore, reports of internal dose issued by NRC included overexposures only. Some NPP licensees voluntarily include internal dose data in employee termination dose reports to NRC. A study of these data indicated that for ^{58}Co and ^{60}Co, the most prevalent nuclides, very few of the workers had organ burdens of more than 1 percent of the maximum permissible (see Tables E.9, E.10, and E.11).

These data indicate that occupational exposures within the nuclear power industry have been significantly reduced since 1973. Individual doses are characteristically far

Table E.4 Ten CFR Part 50, Appendix I, design objectives and annual limits on radiation doses to the general public from nuclear power plants[a]

Tissue	Gaseous	Liquid
Total body	5 mrem	3 mrem
Any organ (all pathways)	—	10 mrem
Ground-level air dose	10 mrad gamma and 30 mrad beta	—
		—
Any organ[b] (all pathways)	15 mrem	—
Skin	15 mrem	

[a]Calculated doses.
[b]Particulates, radioiodines.
Note: To convert millirem to millisievert, multiply by 0.01.

Table E.5 Forty CFR 190, Subpart B, annual limits on doses to the general public from nuclear power operations[a]

Tissue	Limit	Source
Total body	25 mrem	All effluents and direct radiation from nuclear power operations
Thyroid	75 mrem	"
Any other organ	25 mrem	"

[a]Calculated doses.
Note: To convert millirem to millisievert, multiply by 0.01.

below the regulatory limit currently in effect, and the annual average is less than 10 percent of the 5 rem/year limit that is now in effect. Effective implementation of the ALARA concept is largely responsible. The theoretical risks associated with the exposure data are discussed in Section E.4.

E.3.1.2 Considerations for the Future

The current 10 CFR Part 20 became effective in 1991. The new regulation adopted a 5-rem/year TEDE dose limit and applies this limit to external and internal doses combined. Although these constraints

Table E.6 Occupational whole-body dose data at light-water reactors

Year	Number of workers with measurable doses	Collective dose (person-rem)	Average annual dose (rem)	Number of reactors	Number of persons exceeding 12 rem in a year
1973	14,780	13,962	0.94	24	1
1974	18,139	13,650	0.75	33	1
1975	25,419	20,879	0.82	44	1
1976	34,192	26,107	0.76	52	3
1977	42,266	32,508	0.77	57	1
1978	45,978	31,801	0.69	64	3
1979	64,073	39,982	0.62	67	1
1980	80,331	53,795	0.67	68	0
1981	82,106	54,144	0.66	70	1
1982	84,381	52,190	0.62	74	0
1983	85,646	56,472	0.66	75	0
1984	90,099	55,235	0.56	78	0
1985	92,870	43,042	0.46	82	2
1986	100,923	42,381	0.42	90	0
1987	104,334	40,401	0.39	96	0
1988	103,226	40,769	0.39	102	0
1989	108,252	35,930	0.33	107	0
1990	108,658	36,592	0.34	110	0
1991	98,761	28,515	0.29	111	0
1992	103,143	29,309	0.28	110	0

Source: NUREG-0713.
Note: To convert rem to sievert, multiply by 0.01.

Table E.7 Light-water reactor (LWR) occupational whole-body dose data for boiling-water reactors (BWRs) and pressurized-water reactors (PWRs)

	Annual average whole-body dose (rem)		
Year	All LWRs	All BWRs	All PWRs
1973	0.94	0.85	1.00
1974	0.74	0.81	0.68
1975	0.82	0.86	0.76
1976	0.75	0.71	0.79
1977	0.84	0.89	0.65
1978	0.74	0.74	0.65
1979	0.66	0.73	0.56
1980	0.72	0.87	0.52
1981	0.71	0.73	0.61
1982	0.66	0.76	0.53
1983	0.70	0.82	0.56
1984	0.59	0.66	0.49
1985	0.46	0.54	0.41
1986	0.42	0.51	0.37
1987	0.39	0.40	0.38
1988	0.40	0.45	0.36
1989	0.34	0.36	0.33
1990	0.34	0.38	0.31
1991	0.29	0.31	0.27
1992	0.28	0.32	0.26

Source: NUREG-0713.
Note: To convert rem to sievert, multiply by 0.01

Table E.8 Number of workers at boiling-water reactor (BWR), pressurized-water reactor (PWR), and light-water reactor (LWR) installations who received whole-body doses within specified ranges during 1992

Dose range (rem)	BWRs	PWRs	LWRs
<0.1 (measurable)	17,740	28,220	45,960
0.1–0.25	8,094	12,503	20,597
0.25–0.5	6,883	10,259	17,142
0.5–0.75	3,995	4,926	8,881
0.75–1.00	2,339	2,287	4,626
1.00–2.00	2,366	2,602	5,468
2.00–3.00	204	245	449
3.00–4.00	11	6	17
4.00–5.00	3	0	3
5.00–6.00	0	0	0
6.00–7.00	0	0	0
7.00–12.00	0	0	0
>12.00	0	0	0
Totals	42,095	61,048	103,143

Source: NUREG-0713.
Note: To convert rem to sievert, multiply by 0.01.

are more stringent, they are not expected to have a significant impact on occupational exposures at NPPs for three reasons. First, the new regulation requires external/internal dose addition only if each type of exposure separately exceeds 0.5 rem in a year. Very few, if any, NPP workers are expected to exceed 0.5 rem from internal sources. Second, although the ICRP system being adopted by the NRC involves the determination of organ doses from external sources (as opposed to the whole-body dose at 1-cm depth), the new 10 CFR Part 20 continues to require measurement at 1 cm. Third, data in Tables E.6 and E.8 show that few, if any, workers will be affected by a reduction in the limit from essentially 12 to 5 rem/year.

The ICRP has announced its intention to reduce the 5-rem/year limit, which it currently recommends, to 2 rem/year, with a provision for maintaining operational flexibility (Radiological Protection Bulletin, No. 111). In ICRP-60, it is suggested that the 2 rem/year be applied over defined periods of 5 years. Further, provision is made that the effective dose should not exceed 5 rem in any single year.

Table E.9 Organ burden estimates submitted on employment termination reports from power reactors, 1975–1981

Year	Nuclide	Number of records	Organ burden estimates
1975	^{58}Co	22	all burdens <1% MPOB[a]
	^{60}Co	22	all burdens <1% MPOB
1980	^{58}Co	1410	98% of burdens <1% MPOB
	^{60}Co	5098	98% of burdens <2% MPOB
1981	^{58}Co	1246	98% of burdens <1% MPOB
	^{60}Co	4418	98% of burdens <2% MPOB

[a]MPOB = maximum permissible organ burden
Source· NUMARC (1989).

Table E.10 Estimated number of workers with organ burdens (in % MPOB[a]) from ^{58}Co and ^{137}Cs, 1983–1987[b]

Year	<1%	1–2%	2–3%	>3%
1983	8042	2	0	1
1984	5024	4	0	3
1985	2744	0	0	0
1986	2255	4	1	4
1987	1154	0	0	0

[a]MPOB = maximum permissible organ burden.
[b]Data taken from termination reports for employees of power reactors.
Source: NUMARC (1989).

Table E.11 Estimated number of workers with organ burdens (in % MPOB[a]) from ^{60}Co, 1983–1987[b]

Year	<1%	1–2%	2–3%	>3%
1983	3480	8	1	0
1984	2284	4	1	3
1985	764	2	0	0
1986	772	2	1	1
1987	596	0	0	0

[a]MPOB = maximum permissible organ burden.
[b]Data taken from termination reports for employees of power reactors.
Source· NUMARC (1989).

E.3.2 Public

The radiation dose to people who live in the vicinity of a U.S. NPP averages about 0.8 μrem/year. Pertinent data are provided in the following paragraphs.

Each year, the NRC issues a report titled *Population Dose Commitments Due to Radioactive Releases from Nuclear Power Plant Sites in XXXX*. The most recent volume covers the year 1989 (NUREG/CR-2850, vol. 11, February 1993) (see Table E.12). Radioactive material is released in gaseous and aqueous effluents under stringently controlled conditions in accordance with technical specifications and NRC regulations. The term "dose commitment" indicates that the reported doses come from the inhalation and ingestion of radionuclides, as well as from external radiation from noble gases; the population dose caused by direct radiation from plant buildings is negligible. The doses are calculated by the licensees in accordance with guidance provided by the NRC and based on measurements made at the point of release as well as in the environment. These measurements are performed and recorded by the licensees; however, the NRC conducts its own verification measurements. The prescribed calculation methods include several basic assumptions to ensure that the results are conservative. Table E.13 presents results obtained for a 15-year period ending in 1989. The numerical entries are person-rem received by those who live within an 80-km (50-mile) radius of a site; data for individual sites also appear in this report.

The total population dose within 80 km (50 miles) of each plant is calculated (Table 4 in NUREG/CR 2850, vol. 11) for each operating reactor in the United States. The number of person-rem is obtained by adding the individual doses received by this population. For 1989, the total number of person-rem varied from a low of 0.0017 at Grand Gulf to a high of 16 at McGuire. Seventy-five percent of the total came from 9 of the 67 sites, as shown in Table E.14. In the site summaries section of each report, dose data for each site are provided for airborne and waterborne pathways and are categorized by total body and individual organs. The doses received by workers at the plants and members of the public are shown in Table E.13 for comparison.

Projections into the future can be made on the basis of current trends. Therefore, an analysis of dose commitment information was performed. The first objective was to determine to what extent known information about the sites could be used to predict what the dose commitment values for the sites were for the years 1979–1989. The second objective, if prediction of current dose commitments could be done adequately, was to use the models to predict future dose commitment for U.S. sites by extrapolating into future years the characteristics used in the model and the population projections for the sites. Table E.15 portrays information that was available about U.S. nuclear power reactor sites.

Using these variables, other site characteristics were computed. These include the following:

- Interval from startup to observation (calendar year–year of startup).
- Status. This variable was based on the capacity factor. If the capacity factor was below 25 percent for the year, the site was designated as "down." If the capacity factor was above 25 percent, status was designated as "up" for that year. The cutoff point was chosen based on the observation that sites generally

Table E.12 Individual public dose data from power plant effluents, 1988

Individual dose range (mrem)	Percent of total	Cumulative percent
0 to 0.000001	6%	6%
0.000001 to 0.00001	4%	10%
0.00001 to 0.00003	18%	28%
0.00003 to 0.0001	30%	58%
0.0001 to 0.0003	21%	79%
0.0003 to 0.001	13%	92%
0.001 to 0.003	5%	97%
0.003 to 0.01	< 2%	99%
0.01 to 0.03	< 1%	100%

Source NUREG/CR-2850.
Note: To convert millirem to millisievert, multiply by 0 01.

were either substantially below that value or above it by a large margin. Status is a categorical variable representing the level of operation for a given year.

- Total output, which is the product of total megawatt size and capacity factor and is an estimate of output for a given year. A linear model was fitted to the dose data using combinations of the above variables as independent variables. Clearly, observed doses cannot be negative, and the model predictions also should not be negative. For this reason, the linear model was fit to *ln*(dose). The resulting model was then of the form

Dose = exp (linear function of independent variables) .

The resulting model also provided a considerably improved fit to the data over the linear model, based on the proportion of variability accounted for by the model.

Because population total dose commitment is the sum of the estimated population liquid dose commitment and the population air dose commitment, the liquid and air components were estimated separately, and the sum of the two estimates was used as the model estimate for the total population dose commitment. This proved to produce a better estimate than did a direct fit to the population total dose commitment.

To determine the best fit, various combinations of independent variables were tried based on percentage of total variability accounted for by the model. Not all variables can be included at one time because some are determined by combinations of others. Because all boiling water reactors (BWRs) in this analysis were manufactured by General Electric Co. (GE), it was not

Table E.13 Summary of population and occupational doses (person-rem) for all operating nuclear power plants combined

Year	Population			Occupational
	Liquid	Air	Total	
1975	76	1,300	1,300	20,879
1976	82	390	470	26,107
1977	160	540	700	32,508
1978	110	530	640	31,801
1979	220	1,600	1,800	39,982
1980	120	57	180	53,795
1981	87	63	150	54,144
1982	50	87	140	52,190
1983	95	76	170	56,472
1984	160	120	280	55,235
1985	91	110	200	43,042
1986	71	44	110	42,381
1987	56	22	78	40,401
1988	65	9.6	75	40,769
1989	68	16	84	35,980
1990	—[a]	—	—	35,592
1991	—	—	—	28,515
1992	—	—	—	29,309

[a]Data not available.
Source: NUREG/CR-2850; NUREG-0713.
Note: To convert person-rem to person-sievert, multiply by 0.01.

Table E.14 Highest public dose data from nuclear power plant effluents, 1988

Plant	Population dose (person-rem)	Population within 50 miles (80 km) (persons)	Average individual dose (mrem)
McGuire	16	1,800,000	0.0091
Summer	13	900,000	0.014
Zion	7.2	7,300,000	0.001
E. I. Hatch	6.4	350,000	0.018
Clinton	4	2,700	0.0015
Oconee	3.8	9,900	0.0039
Oyster Creek	2.2	3,600,000	0.0006
Harris	1.8	1,400,000	0.0013
Calvert Cliffs	1.7	2,800	0.00061
All sites	75	150,000,000[a]	0.0005

[a]This figure is inflated because not all sites are 100 miles apart, and some persons within each 50-mile radius were counted more than once.
Source Adapted from NUREG/CR-2850.
Note: To convert person-rem to person-sievert or millirem to millisievert, multiply by 0.01.

Table E.15 Information on U.S. nuclear power reactor sites that was used to model future trends

Age-time characteristics	Reactor operating characteristics
Year of first startup (first year of operation of any reactor at the site)	Total megawatt capacity by calendar year (sum of capacities of all reactors)
Calendar year (year of observation of dose value)	Capacity factor by calendar year (percentage of total megawatt capacity output in calendar year)
	Site reactor type (boiling water or pressurized water)
	Reactor manufacturer (if more than one, designated mixed). Manufacturers were General Electric Company, Westinghouse, Combustion Engineering, Babcock-Wilcox, and mixed

possible to include both site type [BWR/pressurized water reactor (PWR)] and vendor as independent variables. Including vendors proved to produce a better-fitting model. The independent variables that proved to be most predictive of the *ln*(dose) values included the following:

- calendar year,
- year of startup,
- size in megawatts,
- vendor or manufacturer, and
- status (up or down).

The first three variables are continuous and are included as covariates in the model. The last two are categorical variables and are treated as class variables in the model. Because the manufacturer proved to be an important factor in the relationship of dose to the independent variables, the vendor was taken into account for each reactor in the prediction equations. To do this, estimates of the coefficients (and significance) for the remaining independent variables were made separately for the vendor categories. Because the covariates were estimated *within* the different manufacturer (vendor) categories, differences in the values of the covariates among vendors are not taken into account when vendors are compared. Thus, for example, if sites with GE reactors have larger megawatt capacities than do other reactors, that difference influences the comparisons for the vendors.

Three sites proved to be highly variable in dose commitments and thus tended to unduly influence the linear model fit: Browns Ferry, Nine Mile Point, and Oyster Creek (all of which were GE BWRs). To exclude undue influence of these three sites on the results, the results reported are those for the model fitted to the subset, not including these sites. Three Mile Island (Babcock-Wilcox, PWR) was also excluded because it represented an accident scenario rather than routine releases, and the dose values were substantially larger for certain years than at any other reactor sites.

Tables E.16, E.17, and E.18 give the results of the linear model fitted to *ln*(dose) for liquid, air, and average individual doses, respectively. If a variable (startup year, for example) has a different pattern in the two site types, the *p* value for each site type is given because an overall value is no longer meaningful. The overall model accounts for approximately 42 percent of the variation in the *ln*(air dose) values.

Overall, liquid doses are much less predictable than air doses, as the resulting model fit for the liquid doses indicates. For liquid doses, the best-fitting model accounted for only about 20 percent of the overall variability in the model.

The linear model accounts for 27 percent of the variability in the log of the average individual dose commitment values.

Using the coefficients estimated within the analysis, it is evident that the population dose commitments by site and by calendar year are being systematically lowered. Results of the analysis were used to plot historical data against predicted doses. (See example figures in Attachment E.C.) These figures portray how each reactor has performed with respect to other reactors in its class (i.e., age, size, and vendor). The dominant theme is the decline in population dose commitment, observed nearly universally. However, if the decline in dose to the public suddenly ceased, levels are sufficiently low that they already represent an insignificant insult to humans.

Data on maximally exposed individuals from airborne emissions are also reported semi-annually to the NRC by each nuclear utility.

Table E.16 Linear model for estimation of liquid dose

Parameter	Significance (*Pr* > *T*)	Remarks
Vendor	0.0001	Babcock and Wilcox (B&W) manufactured reactors have significantly higher liquid doses than do reactors made by other manufacturers; General Electric (GE) reactors are next highest. Mixed sites have the lowest liquid doses
Status (by vendor)	0.01 (B&W) 0.10 (CE)[a] 0.05 (GE) 0.06 (mix) 0.21 (Westinghouse)	GE and mixed sites have higher doses from liquid sources when they are down (below 25 percent of theoretical maximum output). Many mixed sites are partly GE reactors. Reactors made by all other manufacturers, all of which are PWRs[b], have lower doses when they are operating below 25 percent capacity (classified as down)
Calendar year (by vendor)	0.39	Liquid emissions are not decreasing significantly with time for any of the five types, although the coefficients are negative except for the mixed sites. Thus the general trend with time is for air doses to be decreasing considerably, while doses from liquid sources are not decreasing significantly. The decreasing trend in total dose commitment is caused by the lower air dose estimates
Year of startup (by vendor)	0.29 (B&W) 0.80 (CE) 0.0001 (GE) 0.11 (mix) 0.63 (Westinghouse)	Liquid doses are higher in older reactors only for GE reactor sites. For others, there is not a significant trend with reactor age (start year)
Total size, MW (by vendor)	0.57 (B&W) 0.19 (CE) 0.0001 (GE) 0.78 (mix) 0.03 (Westinghouse)	For GE and Westinghouse reactors, the larger sites had higher liquid doses. The increase in liquid dose with megawatt capacity was much higher for GE reactors than for the other types

[a]CE = Combustion Engineering
[b]PWRs = pressurized-water reactors.

Table E.17 Linear model for estimation of air dose[a]

Parameter	Significance ($Pr > T$)	Remarks
Vendor	0.0003	Manufacturer with highest air doses is Babcock-Wilcox [but highly variable—next highest is General Electric (GE)]. Lowest is Combustion Engineering (CE)
Status (by vendor)	0.0001	For all reactor types (manufacturers), air doses decrease significantly when the reactor is operating at less than 25 percent capacity. This is not necessarily true for doses from liquid sources
Calendar year (by vendor)	0.005	Air doses are decreasing with calendar year (for 1979–87) for all reactor types. Rate of decrease is fastest for GE reactors. Rate of decrease is much smaller for CE reactors than for others, partly because these are lower to begin with
Year of startup (by vendor)	0.02 (B&W) 0.004 (CE) 0.0001 (GE) 0.13 (mixed) 0.0001 (Westinghouse)	With the exception of CE, all types have higher air doses in older reactors. For CE, newer reactors have higher doses
Total size, MW (by vendor)	0.0001	Larger reactors had higher air doses. This relationship was strong and was a major contributor to the prediction of dose for each reactor site. This held true for all manufacturers but was much less evident in B&W reactors. The increase in air dose with size was largest for GE and Westinghouse reactors

[a]The overall model accounts for approximately 42 percent of the variation in the *ln*(air dose) values.

These data for the period 1985–1987 were compiled in NUMARC (1989). These data are presented in Table E.19. Inspection of this table reveals that the highest organ and thyroid exposures to the maximally exposed individual are on the order of 5 mrem. The exposure level for the typical maximally exposed individual is orders of magnitude less.

The NRC design criteria for NPPs are 5 mrem/year from stack releases plus 3 mrem from aqueous effluents. The EPA annual dose limit (fuel cycle facilities) is 25 mrem. The anticipated new NRC limit from

Table E.18 Linear model for estimation of average individual dose commitment

Parameter	Significance (*Pr* > *T*)	Remarks
Vendor	0.0001	General Electric (GE)-manufactured reactors have significantly higher individual doses than do reactors by other manufacturers.
Status (by vendor)	0.08 (B&W) 0.11 (CE) 0.04 (GE) 0.96 (mix) 0.09 (Westinghouse)	Sites with GE reactors have higher individual doses when they are down. This is presumably because of the higher liquid doses. The doses from other manufacturers' reactors generally decrease, but not significantly.
Calendar year (by vendor)	0.63 (B&W) 0.98 (CE) 0.04 (GE) 0.18 (mix) 0.04 (Westinghouse)	Only significant for GE and Westinghouse reactors, for which individual doses have been decreasing continuously through successive calendar years.
Year of startup (by vendor)	0.94 (B&W) 0.47 (CE) 0.0001 (GE) 0.007 (mix) 0.02 (Westinghouse)	For GE sites, older reactor sites have significantly higher individual dose estimates. For Westinghouse and mixed sites, the newer sites have higher individual dose commitments
Total size, MW (by vendor)	0.0001	Same relationship as for the air doses. Larger sites have higher estimated individual dose commitments because of the air dose component

all sources (other than medical and natural background) is 100 mrem/year. It is evident that these plants are operating far below government requirements with respect to effluent control.

E.4 RISKS FROM RADIATION EXPOSURE

In January 1990, the National Research Council-NAS published a report on the health effects of exposure to low levels of ionizing radiation (BEIR-V). This report was prepared by a committee on BEIR organized by the council for this purpose and known as the BEIR-V Committee. The BEIR-V report concluded that the risk of radiation exposure was greater than previously estimated. The bases and limitations of these estimates are described in Section E.4.1 of this GEIS.

In light of these data, the ICRP requested comment from a number of organizations on a draft of its revised recommendations on radiation protection (ICRP/60/G-01); on June 22, 1990, the ICRP issued a press release recommending more stringent control over occupational exposures. These developments are very likely to affect the regulation of NPPs in the future but only

Table E.19 Doses (mrem) to the maximally exposed individual from routine airborne emissions[a]

			1985		1986		1987	
Plant	Unit	Docket	Total body	Thyroid	Total body	Thyroid	Total body	Thyroid
Arkansas One	1	50-313	NR[b]	NR	0.0017	0.036	0.0023	0.0070
	2	50-368			0.0060	0.83	0.0044	0.0054
Beaver Valley	1	50-334	NR	NR	0.023	0.092	0.0014	0.0017
	2							
Bellefonte Nuclear Plant	1	—	NR	NR	NR	NR	NR	NR
	2							
Big Rock Point Nuclear Plant	1	—	NR	NR	NR	NR	NR	NR
Braidwood Station	1	—	NR	NR	NR	NR	NR	NR
	2							
Browns Ferry Nuclear Power Station	1	50-296	0.060	NR	NR	NR	NR	NR
	2							
	3							
Brunswick Steam Electric Plant	1	50-324	NR	NR	NR	NR	0.028	0.093
	2							
Byron Station	1	—	NR	NR	NR	NR	NR	NR
	2							
Callaway Plant	1							
Calvert Cliffs Nuclear Power Plant	1	50-317	NR	NR	NR	NR	NR	0.44
	2							
Catawba Nuclear Station	1	50-413	0.88	NR	2.2	NR	0.89	0.67
	2							
Clinton Power Station	1	—	NR	NR	NR	NR	NR	NR
Comanche Peak Steam Electric Station	1	—	NR	NR	NR	NR	NR	NR
	2							
Donald C. Cook Nuclear Power Plant	1	50-315	0.057	1.9	0.020	0.27	0.024	1.3
	2							
Cooper Nuclear Station	1	50-298	0.57	0.60	0.40	0.56	0.018	0.097
Crystal River Nuclear Plant	3	50-302	0.022	0.31	0.21	0.0038	0.20	0.027
Davis-Besse Nuclear Power Station	1	50-346	0.0081	0.056	0.00064	0.00064	0.12	0.040
Diablo Canyon Nuclear Power Plant	1	50-275	NR	0.0014	NR	0.0043	NR	0.0047
	2	50-323	NR	0.0041	NR	0.0035	NR	0.0029

See footnotes at end of table.

Table E.19 (continued)

Plant	Unit	Docket	1985 Total body	1985 Thyroid	1986 Total body	1986 Thyroid	1987 Total body	1987 Thyroid
Dresden Nuclear Power Station	2 3	50-249	NR	NR	NR	NR	NR	NR
Duane Arnold Energy Center	1	—	NR	NR	NR	NR	NR	NR
Joseph M. Farley Nuclear Plant	1 2	50-348	0 13	0.18	0.12	0.090	0.081	0.054
Enrico Fermi Atomic Power Plant	2	—	NR	NR	NR	NR	NR	NR
James A. FitzPatrick Nuclear Power Plant	1	—	NR	NR	NR	NR	NR	NR
Fort Calhoun Station	1	—	NR	NR	NR	NR	NR	NR
Robert Emmett Ginna Nuclear Power Plant	1	—	NR	NR	NR	NR	NR	NR
Grand Gulf Nuclear Station	1	50-416	0 090	NR	0 068	NR	0.34	0 94
Haddam Neck Point (Connecticut Yankee)	1	50-213	1.0	0.14	0.39	0 087	0.66	0 073
Shearon Harris Nuclear Power Plant	1	50-400	NR	NR	NR	NR	0.022	0.022
Edwin I Hatch Nuclear Plant	1 2	50-321	0.093	0.00065	0.0040	0.29	0.13	0.26
Hope Creek Generating Station	1	—	NR	NR	NR	NR	NR	NR
Indian Point Station	2 3	50-286	0.00078	0 029	0 00049	0 062	NR	NR
Kewaunee Nuclear Power Plant	1	50-305	NR	NR	0.12	0.013	0.00001	0.022
LaSalle Country Station	1 2	—	NR	NR	NR	NR	NR	NR
William B McGuire Nuclear Station	1 2	50-369 50-370	NR 1.8	NR 2 6	0 15 NR	NR 0.42	0.081 0.0036	NR NR
Millstone Nuclear Power Plant	1 2 3	50-245 50-336 50-423	0.007 0 015 NR	0.0007 0 038 NR	0.22 0.01 0.00052	0.0007 0.043 0.1	0.083 0.013 0.017	0.0015 0.04 0.014

See footnotes at end of table

Table E.19 (continued)

Plant	Unit	Docket	1985 Total body	1985 Thyroid	1986 Total body	1986 Thyroid	1987 Total body	1987 Thyroid
Monticello Nuclear Generating Plant	1	50-263	NR	1.3	NR	1.2	NR	2.6
Nine Mile Point Nuclear Station	1 2	—	NR	NR	NR	NR	NR	NR
North Anna Power Station	1 2	50-338	NR	1.3	NR	0.80	NR	0.44
Oconee Nuclear Station	1 2	50-287	0.15	NR	0.087	0.97	NR	NR
Oyster Creek Generating Station	1	50-219	1.4	8.8	4.3	0.81	0.17	17
Palisades Nuclear Plant	1	50-255	NR	0.10	NR	0.0073	NR	NR
Palo Verde Generating Station	1 2 3	—						
Peach Bottom Atomic Power Station	2 3	50-278	0 041	1.2	0.12	0.70	0.015	0.13
Perry Nuclear Power Station	1		NR	NR	NR	NR	NR	NR
Pilgrim Nuclear Power Station	1	50-293	0.49	0.18	0.027	0.064	NR	NR
Prairie Island Nuclear Generating Plant	1 2	50-232	NR	NR	NR	NR	NR	NR
Point Beach Nuclear Plant	1 2	—	NR	NR	NR	NR	NR	NR
Quad-Cities Station	1 2	50-254 50-265	0.0020 0 0020	0.16 0.16	NR NR	NR NR	0.0025 0.0021	0.12 0.10
H. B. Robinson Plant	2	50-261	NR	NR	0.016	0.35	0.068	0.11
Salem Nuclear Generating Station	1 2	50-311	0.016	NR	0.028	NR	0.047	NR
San Onofre Nuclear Generating Station	1 2 3	50-206 50-361	NR NR	0.16 0.41	NR NR	NR 0.14	NR NR	0.014 0.049
Seabrook Station	1	—	NR	NR	NR	NR	NR	NR
Sequoyah Nuclear Plant	1 2	50-327	0.19	0.054	0.0020	NR	NR	NR

See footnotes at end of table

Table E.19 (continued)

Plant	Unit	Docket	1985 Total body	1985 Thyroid	1986 Total body	1986 Thyroid	1987 Total body	1987 Thyroid
Shoreham Nuclear Power Station	1	—	NR	NR	NR	NR	NR	NR
South Texas Project	1 2	—	NR	NR	NR	NR	NR	NR
St. Lucie Plant	1 2	50-335 50-389	0.013 0.0062	4.2 2 4	0.011 0.0021	5.8 0.89	0.0023 0.0028	0.76 1.1
Virgil C. Summer Nuclear Station	1	50-395	NR	NR	0.00051	NR	0.00000 1	NR
Surry Power Station	1 2	50-281	NR	NR	NR	0.035	NR	0.36
Susquehanna Steam Electric Station	1 2	50-238	0.10	0.14	0.0069	NR	0.011	NR
Three Mile Island Nuclear Station	1	50-289	NR	NR	0 019	NR	0.0028	NR
Trojan Nuclear Plant	1	50-344	0.069	NR	NR	NR	NR	NR
Turkey Point Plant	3 4	50-250 50-251	NR NR	NR NR	0 0038 0.0042	0.032 0.025	0.0087 0.0088	0.20 0.22
Vermont Yankee Nuclear Power Station	1	50-271	NR	NR	NR	NR	NR	0.42
Watts Bar Nuclear Plant	1 2	—	NR	NR	NR	NR	NR	NR
Washington Nuclear Project	2	50-220	NR	NR	0.013	0 48	0 024	0.73
Wolf Creek Generation Station	1	—	NR	NR	NR	NR	NR	NR
Yankee Nuclear Power Station	1	50-29	NR	NR	NR	NR	NR	NR
Zion Nuclear Plant	1 2	50-295	0.044	0.0078	0.092	0.029	0 00047	NR

[a]Data compiled from semi-annual reports submitted to the Nuclear Regulatory Commission by each nuclear utility. Adapted from NUMARC 1989.
[b]Not recorded in source document.
Note: To convert millirem to millisievert, multiply by 0.01.

after the current Presidential Guidance to Federal Agencies is modified to take them into account. With regard to this GEIS, the primary importance of these developments lies in the selection of the most appropriate radiation risk coefficients to use for evaluating health effects; it is therefore necessary to recount earlier developments.

E.4.1 Background

E.4.1.1 Stochastic Effects

In 1972, NAS had sufficient epidemiological information, primarily from the study of Japanese atomic bomb survivors, to publish (in BEIR-I) a radiation risk estimate that was widely interpreted as 1 cancer fatality among 10,000 people receiving 10,000 person-rem. This estimate was applicable to large populations receiving acute doses instantaneously, such as persons exposed to nuclear-weapon explosions. The validity of such estimates for large or small doses received over a lifetime was (and remains) unknown. With additional information from the atomic bomb survivor study, the NAS in 1980 published (in BEIR-III) a range of radiation-risk estimates that, in general, doubled federal agencies' estimates. It was recognized that the new estimates were derived from instantaneous exposure data and were therefore of limited use in the standards development process. The BEIR-III committee's linear quadric dose-response model for solid cancers did, however, contain an implicit dose rate factor of nearly 2.5.

Subsequently, two developments in the atomic bomb survivor study caused another doubling of the overall risk estimate. First, a reassessment of the radiation doses received by the survivors was completed (National Research Council 1987). This study indicated that any gamma-radiation-induced malignancies at Nagasaki had been caused by less radiation than previously believed. However, the opposite effect was observed among the Hiroshima survivors. The new dose estimates include more structural shielding and also include shielding by tissues overlying the affected organs.

The second development concerned the number of survivors who later died from solid tumors, which was greater than had been anticipated. In the 1980 BEIR-III report, the committee expressed its preference for a risk model that essentially assumed that subsequent excess death rates would be similar to those already observed. However, within a few years, publications issued by the Radiation Effects Research Foundation (RERF) reported a departure from this model, attributable to deaths from solid tumors (RERF TR 12-87). The newer data tend to fit a model that predicts that the excess cancer deaths from atomic-bomb radiation will be a constant percentage increase over the cancer deaths from all other causes. In consideration of these findings, federal agencies began to use a risk estimate of 4 or 5 excess cancer deaths among 10,000 people receiving 10,000 person-rem. For example, the EPA used 4 per 10,000 to arrive at the 10 mrem/year limit promulgated in 40 CFR Part 61 (FR 54, 9612, March 7, 1989). NRC used 5 per 10,000 in the development of its *Below Regulatory Concern: Policy Statement* (1990). The following statement appears in the executive summary of the BEIR-V report:

> On the basis of the available evidence, the population-weighted average lifetime excess risk of death from cancer following an acute dose equivalent to all body organs of 0.1 Sv [0.1 Gy of low—linear energy transfer (LET) radiation] is estimated to be 0.8 percent, although the lifetime risk varies considerably with age at the time of exposure. For

low-LET radiation, accumulation of the same dose over weeks or months, however, is expected to reduce the lifetime risk appreciably, possibly by a factor of 2 or more.

The 0.8 percent estimate is equivalent to 800 excess cancer fatalities among 100,000 people, each exposed to 10 rem. It is important to note that the risk values tabulated in the report are for a population size of 100,000 and that the 0.8 percent estimate is applicable to instantaneous, uniform irradiation of all organs. With regard to the lower extreme of the dose range over which the estimate is applicable, the committee observes elsewhere in the BEIR-V report that "In general, the estimates of risk derived in this way for doses of less than 0.1 Gy are too small to be detectable by direct observation in epidemiological studies."

An absorbed dose of 0.1 Gy corresponds to a gamma radiation dose equivalent of 10 rem. It is also important to note that the report does not provide a risk estimate for instantaneous doses of fewer than 10 rem. The committee's estimate is considered useful for estimating fatalities among large populations, including all ages, that are irradiated instantaneously and uniformly to individual external radiation doses of 10 rem or more. Risk assessments based on the Japanese experience are only theoretical under the following conditions:

- exposures are protracted,
- the people are irradiated nonuniformly,
- the exposed population is small,
- individual doses are fewer than 10 rem,
- the irradiation is caused by internally deposited radionuclides,
- the exposed population differs significantly from the atomic bomb survivor study group,
- some combination of these conditions exists, or
- any of an almost infinite list of unknowns applies.

The risk estimate published in the 1990 BEIR-V report is consistent with estimates published earlier by RERF scientists (RERF TR 12-87) and by UNSCEAR (1988). Their estimates, shown in Table E.20, reveal the greater susceptibility of populations that include children, as well as the reduced effects if the radiation doses are low and delivered at low dose rates (i.e., protracted). In the pertinent literature, this phenomenon of reduced effects is usually referred to as the dose rate effectiveness factor (DREF). Risk estimates for instantaneous exposure are divided by the DREF to obtain estimates that can be applied to protracted exposure conditions. Lack of data on humans dictates primary reliance on animal studies for DREF estimates. For the values reported in Table E.20, a DREF of 2.5 was used by the RERF authors. A DREF range of 2 to 10 was used in the UNSCEAR report.

For its new reactor safety study, the NRC has published a DREF of 3 (NUREG/CR-4214). In the 1990 BEIR-V report, a DREF of 2 or more is mentioned for low-LET radiation (gamma) as previously quoted; and a DREF of 4 is given as the "single best estimate" for tumorigenesis identified in laboratory animal studies. The ICRP is considering the use of a DREF of 2 in the forthcoming major revision of its recommendations. The DREF question is critical to risk assessments and to decisions regarding dose limits and ALARA requirements.

Table E.21 shows the progression in the risk estimate values used by federal government agencies following the publication of authoritative reports on the subject, as discussed in the preceding narrative.

Table E.20 RERF[a] and UNSCEAR[b] risk coefficients; excess cancer fatalities

	All ages		Adults	
	RERF	UNSCEAR	RERF	UNSCEAR
High doses and dose rates	12	3–11	8	4–8
Low doses and dose rates	5	0.3–5.5	3	0.4–4

[a]Radiation Effects Research Foundation (RERF) authors used a dose rate effectiveness factor (DREF) of 2.5.
[b]United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) authors used a DREF range of 2 to 10.

Table E.21 Radiation risk estimates used by federal agencies following publication of the documents shown

Publication	Excess cancer fatalities among 100,000 people receiving instantaneous external radiation doses of 10 rem
1972 BEIR-I report	100
ICRP Publication 26	200
1980 BEIR-III report	200
RERF Publications	400–500
1990 BEIR-V report	800

Note: To convert millirem to millisievert, multiply by 0.01.

Note that the 1980 BEIR-III report used a DREF in the preparation of tabulated risk estimates and that the 1990 BEIR-V report did not. The occupational risk estimates of current interest from both reports are given in Table E.22.

Because 88 percent of the deaths included in the later data from the atomic bomb survivor study are from solid tumors, leukemia is now considered a small contribution to the total risk. It is important to recognize that if a DREF of 2 is used for solid tumors as well as leukemia, the BEIR-V fatality estimate is reduced from 2975 to 1666 excess cancer fatalities among 100,000 adults each receiving 1 rem/year for a working lifetime.

Table E.22 Radiation risk estimates to 100,000 adult workers (50 percent male and 50 percent female) for continuous exposure to 1 rem/year during a working lifetime using the relative risk projection model

	BEIR-III	BEIR-III	BEIR-V
Model	L-Q[a]	L[b]	L-Q; L[c]
Excess fatal cancers	551	2336	2975

[a]Linear-quadratic dose response model.
[b]Linear dose response model (combines leukemia and solid tumor deaths).
[c]Linear-quadratic dose response model for leukemia; linear dose response model for solid tumors.
Note: To convert rem to sievert, multiply by 0.01.

E.4.1.2 Nonstochastic Effects

Nonstochastic effects do not occur unless the radiation dose exceeds a threshold, permitting the use of limiting values that prevent rather than control the probabilities of occurrence of the effects. For parts of the body (organs and tissues) such as the lens of the eye, the skin, and the extremities, radiation protection standards are intended primarily to control the dose from external sources. For the internal organs, it is necessary to control the dose from internally deposited radioactivity as well. Because radiation can damage or kill any living cell if the dose is sufficiently high, a nonstochastic dose limit must also be established for all tissues, including tissues other than those mentioned above. A significant point to consider in connection with an effect that has an accurately known threshold is that the implementation of the ALARA concept to reduce doses to levels below the threshold will not offer additional protection against that effect. However, if the organ or tissue under consideration is also susceptible to radiation-induced cancer, such implementation will reduce that probability. For this reason, the ALARA concept is applicable to the nonstochastic inhalation standards.

ICRP Publication 41 (1983) provides the database supporting the position that, with the exception of the lens of the eye, nonstochastic effects will not be observed among adults if every organ and tissue receives fewer than 50 rem/year. The NRC is not aware of later radiobiological information indicating that this dose limit should be changed and notes that the ICRP has proposed the retention of this value in the forthcoming revision of its recommendations (ICRP/90/G-01).

E.4.2 Risk Coefficient Selection for this Generic Environmental Impact Statement

E.4.2.1 The 1990 BEIR-V and the 1988 UNSCEAR Reports

The BEIR-V risk estimate can be arithmetically converted to the more familiar terminology of 8 cancer fatalities among 10,000 people exposed to 10,000 person-rem, leading to a convenient expression, or risk coefficient, of 8×10^{-4} fatalities per person-rem. This coefficient is considered useful for estimating fatalities among large populations irradiated instantaneously and uniformly to individual external radiation doses of 10 rem or more. However, since no DREF is included in this risk factor, as the individual doses and the size of the exposed population become progressively smaller, the fatality estimates become speculative. As noted in the previous section, a DREF of 2 is considered appropriate for use in the GEIS analysis for license renewal.

An additional source of uncertainty is that many of the exposed people who were included in the atomic bomb survivor study are still alive. The risk estimate is therefore based in part on a projection of future excess cancer deaths that may or may not occur. For making this projection, the BEIR-V committee chose a method (the relative risk projection model) that involves multiplying solid tumor cancer fatality rates within an unexposed U.S. population by a constant percentage increase factor determined for a Japanese population. The number of excess fatalities on which the risk estimates are based is epidemiologically small. Of the 93,669 "in-city" members of the study group, 37,874 (or 40 percent) had died by the end of 1989; 8,422 (or 9 percent) of the deaths were caused by cancer. RERF epidemiologists estimate that 505 (or 0.5 percent) of the cancer deaths are attributable to radiation from the bombs.

The collective dose to a population must become a great deal larger than current doses from NPPs if health effects are to be a concern. In its 1988 report (paragraph 251), UNSCEAR stated:

> The product of risk coefficients appropriate for individual risk and the relevant collective dose will give the expected number of cancer deaths in the exposed population, provided that the collective dose is at least of the order of 100 man Sv. If the collective dose is only a few man Sv, the most likely outcome is zero deaths.

A collective dose of 100 man-sievert is equivalent to 10,000 person-rem. In the 1990 BEIR-V report (p. 181), the NAS Committee on BEIR stated:

> Moreover, epidemiologic data cannot rigorously exclude the existence of the threshold in the millisievert dose range. Thus the possibility that there may be no risks from exposures comparable to external natural background radiation cannot be ruled out. At such low doses and dose rates, it must be acknowledged that the lower limit on the range of uncertainty in the risk estimates extends to zero.

One millisievert is equivalent to 100 mrem. An important perspective to recognize is that the approximately 140 million people who live within 50 miles of a U.S. NPP receive about 43 million person-rem every year from natural background radiation.

E.4.2.2 Risk Coefficients Selected

The risk coefficients used in this GEIS are listed in Table E.23. These coefficients are consistent with the risk factors repeated in BEIR-V if a DREF of 2 is applied to 88 percent of the cancer fatality risk (i.e., to solid tumors) and are the same as those recently published by the ICRP in connection with a revision of its recommendations (ICRP/60/G-01).

The somewhat higher public risk coefficients reflect the fact that individuals under age 18 at the time of exposure are more susceptible to radiation-induced cancer. To receive occupational radiation exposure, a person must be 18 years or older. Excess hereditary effects are listed separately 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 people receiving instantaneous and near-uniform exposures of 10 rem or more. Considering the range of uncertainty, the lower limit of the range is assumed to be zero because there may be biological mechanisms that can repair damage caused by radiation at low doses and/or dose rates.

*E.5 OVERVIEW AND PERSPECTIVE

E.5.1 Program Costs

The data presented in Section E.2 of this document provide convincing evidence that the U.S. nuclear power industry is conducting a highly successful radiation protection program. The recent annual average doses are about 0.3 rem for workers (5-rem/year regulatory limit) and about 1 μrem for members of the general public (25-mrem/year regulatory limit) who live within 50 miles of a NPP. This performance leaves reason to believe that the planned refurbishment operations and operation under license renewal can and will be conducted in a radiologically safe manner.

Actual industrial costs for achieving this record have not been made available and may not be known. A comprehensive analysis of programmatic effectiveness would have to include the costs, in particular the cost in dollars per person-rem averted. These values could then be compared with the criterion of $1000 per person-rem used in Appendix I, 10 CFR Part 50, and with the considerably lower criteria used in Europe. Considering the distribution of radiation protection resources between workers and the public, this type of analysis would provide a basis for prioritization.

Table E.23 Nominal probability coefficients used in this generic environmental impact statement[a]

Health effect	Occupational	Public
Fatal cancer	4	5
Hereditary	0.6	1

[a]Estimated number of excess effects among 10,000 people receiving 10,000 person-rem. Coefficients are based on "central" or "best" estimates. To convert person-rem to person-sievert, multiply by 0.01.
Source: ICRP-60.

E.5.2 Risks

The costs of radiation protection are recovered by the nuclear utilities through charges for electric power. Ideally, radiation-protection costs would be commensurate with the risk averted. However, even if the costs were accurately known, it would not be possible to determine whether actual risks were being averted. The radiation risk data base does not provide the answers, creating a dependence on hypotheses and assumptions. This problem is becoming more serious as the costs become larger and resources are demanded for other public health concerns. Because of the higher individual doses, the technical justification that can be offered for worker-protection costs is stronger than that for public protection. However, studies of exposed workers within recommended limits have not actually verified the existence of a low-level radiation risk.

The most definitive study to date of the possibility of occupational radiation-induced health effects among workers conducting Department of Energy operations has recently been published (Gilbert et al. 1989). This study included almost 36,000 workers at the Hanford site, at Oak Ridge National Laboratory, and at the Rocky Flats Weapons Plant. About 8 percent of the workers had lifetime doses exceeding 10 rem. There was no evidence of a correlation between radiation exposure and mortality when examining all cancers combined or when examining leukemia. When examining other specific cancers, the only one found to exhibit a statistically significant correlation with radiation exposure was multiple myeloma. Twelve deaths occurred from this disease at the Hanford site; none at the other two locations. The researchers report that it is not clear whether the Hanford correlation results from a cause and effect relationship. Only three of the deaths occurred among workers receiving more than 5 rem. There is a 50/50 chance of observing all three deaths in the same population. Overall, Gilbert et al. found that cancer fatalities occurred less often among the more significantly exposed workers: "The relationship of cancer mortality and radiation exposure was in the negative direction in all three populations." When a suspected carcinogen is examined in an epidemiological study, a correlation in the positive direction (progressively higher disease incidence among the more highly exposed groups) is usually followed by the study of individual cases. A statistically significant correlation in the negative direction is often interpreted to mean that such case studies are unnecessary. It may be important to note that the negative direction finding has been replicated in studies that have been reported of people (including children) who live in areas of abnormally high natural background radiation. Despite these findings, the NRC is operating under a policy of caution. It is recognized that not all of the workers in the Gilbert study have died yet, and people in the high-background studies tend to live in areas where the average life span is relatively short. It is possible that many of them do not live long enough to develop cancer that could otherwise be induced by natural background radiation. For this and other reasons, the NRC has strengthened its occupational radiation protection program by clearly stating, in the new 10 CFR Part 20, the role of the ALARA process within the radiation protection program of each NPP.

Several workers in the nuclear power industry have lifetime doses exceeding 10 rem; however, in a very large majority of these cases, the dose was accumulated over a period of many years. In the Japanese atomic bomb survivor studies, statistically significant increases in cancers have been detected only for the situation in which large populations were irradiated instantaneously and uniformly to external radiation doses of 10 rem or more. The dose rate effect for humans is not well understood, creating a dependence on animal data and molecular and cellular studies. Repair mechanisms have been demonstrated and are being studied. It may eventually be possible to identify a dose rate below which human health effects either do not occur or have a probability of occurrence that is sufficiently small to be of no concern. Until that happens, it would be wise to maintain the present interest in occupational ALARA programs.

E.5.3 Standards

E.5.3.1 Occupational

The new 10 CFR Part 20 contains a codified requirement on the ALARA process, which is in keeping with current trends in radiation risk information. Greater emphasis would not necessarily mean greater costs, particularly if cost-beneficial source-term reduction methods are adopted.

If, in the future, the NRC decides to lower the dose limit from 5 to 2 rem/year, this limit will ensure a lower lifetime risk for a few of the most highly exposed individuals. If some provision for operational flexibility were made, a 2 rem/year limit should not be disruptive or needlessly costly, particularly if dose reduction were achieved through cost-effective and cost-beneficial measures.

The impact on plant refurbishment plans should be preparatory in nature (i.e., planning should take full advantage of reasonable dose-reduction opportunities).

E.5.3.2 Public

The current and limiting standards of 40 CFR Part 190 are not expected to be changed for some time, but it does appear likely that 40 CFR Part 61 will be finalized and will lower the annual total body dose limit for members of the public from 25 to 10 mrem/year for airborne radionuclides. Doses from NPPs are so low that this change in the limit is not expected to have an effect.

E.5.4 Conclusions

With respect to the radiological health aspects of extending NPP licenses, under normal operating conditions, it is evident that the radiation protection programs currently in place are adequate in the case of worker protection and more than adequate for protection of the general public. Experience following the Three Mile Island accident indicates that refurbishment operations can temporarily increase occupational doses. Experience has also shown that the judicious implementation of the ALARA concept can minimize such increases at low cost.

Although radiation doses are a tangible measure for evaluating the license-extension question, the major issue comprises two intangibles: the existence of risk from these doses and the probability that health effects will actually occur. The existence of risk has not been verified for protracted low-level radiation. Under the assumption that the risks are without threshold and real, the probability of risk expression becomes the key issue. But until more is known about dose rate effectiveness, continued caution is indicated for lifetime occupational doses.

E.6 REFERENCES

BEIR-I, *The Effects on Populations of Exposure to Low Levels of Ionizing Radiations*, National Research Council, Advisory Committee on the Biological Effects of Ionizing Radiation, National Academy of Sciences, Washington, D.C., 1972.

BEIR-III, *The Effects on Populations of Exposure to Low Levels of Ionizing Radiation: 1980*, National Research Council, Advisory Committee on the Biological Effects of Ionizing Radiation, National Academy of Sciences, Washington, D.C., 1980.

BEIR-V, *Health Effects of Exposure to Low Levels of Ionizing Radiation*, National Research Council, Advisory Committee on the Biological Effects of Ionizing Radiation, National Academy of Sciences, Washington, D.C., 1990.

Gilbert, E. S., et al., "Analyses of Combined Mortality Data on Workers at the Hanford Site, Oak Ridge National Laboratory, and Rocky Flats Nuclear Weapons Plant," *Radiation Research*, 120, 19-35, 1989.

ICRP Publication 26, "Recommendations of the International Commission on Radiological Protection," *Annals of the ICRP* 1(3), International Commission on Radiological Protection, Pergamon Press, New York, 1977.

ICRP Publication 27, "Problems Involved in Developing an Index of Harm," *Annals of the ICRP*, 1(4), International Commission on Radiological Protection, Pergamon Press, New York, 1977.

ICRP Publication 37, *Cost-Benefit Analysis in the Optimization of Radiation Protection*, International Commission on Radiological Protection, Pergamon Press, New York, 1983.

ICRP Publication 41, *Nonstochastic Effects of Ionizing Radiation*, 14(3), International Commission on Radiological Protection, Pergamon Press, New York, 1983.

ICRP (International Commission on Radiological Protection), "Report of ICRP Committee II on Permissible Dose for Internal Radiation (1959)," *Health Physics*, 3, 1960.

ICRP (International Commission on Radiological Protection), "Statement from the 1985 Paris Meeting of the ICRP," *Health Physics*, 48, 828, 1985.

ICRP (International Commission on Radiological Protection), *Recommendations of the Commission*, ICRP Publication 60, Pergamon Press, New York, 1991.

NBS (National Bureau of Standards), *Permissible Dose from External Radiation: Recommendations of the National Committee on Radiation Protection*, National Bureau of Standards Handbook 59, 1954.

National Research Council, *An Assessment of the New Dosimetry for A-Bomb Survivors*, Advisory Committee on the Radiation Effects Research Foundation, National Academy of Sciences, Washington, D.C., 1987.

NCRP (National Council on Radiation Protection and Measurements), *Influence of Dose and Its Distribution in Time on Dose-Response Relationships for Low-LET Radiations*, Report No. 64, Bethesda, Maryland, 1980.

NCRP (National Council on Radiation Protection and Measurements), *Recommendations on Limits for Exposure to Ionizing Radiation*, Report No. 91, Bethesda, Maryland, 1987.

NRC (U.S. Nuclear Regulatory Commission), *Below Regulatory Concern: Policy Statement*, available in the NRC Public Document Room, Washington, D.C., July 3, 1990.

NRC Regulatory Guide 8.8, Rev. 3, *Information Relevant to Ensuring That Occupational Radiation Exposures at Nuclear Power Stations Will Be As Low As Reasonably Achievable*, U.S. Nuclear Regulatory Commission, 1978.

NRC Regulatory Guide 8.10, Rev. 1R, *Operating Philosophy for Maintaining Occupational Radiation Exposures As Low As Reasonably Achievable*, U.S. Nuclear Regulatory Commission, 1977.

NUMARC (Nuclear Management and Resources Council), *Study of Generic Environmental Issues Related to License Renewal*, Washington, D.C., 1989.

NUREG-0713, *Occupational Radiation Exposure at Commercial Nuclear Power Reactors and Other Facilities, 1992*, Vol. 11, U.S. Nuclear Regulatory Commission, 1993.

NUREG/CP-0101, *Workshop on Rules for Exemption from Regulatory Control*, U.S. Nuclear Regulatory Commission, 1989.

NUREG/CR-2850, D. A. Baker, *Population Dose Commitments Due to Radioactive*

Releases from Nuclear Power Plant Sites in 1989, U.S. Nuclear Regulatory Commission, 1993.

NUREG/CR-4214, S. Abrahamson et al., *Health Effects Models for Nuclear Power Plant Accident Consequence Analysis; Low LET Radiation; Scientific Bases for Health Effects Models*, U.S. Nuclear Regulatory Commission, 1989.

Radiological Protection Bulletin, No. 111, *A Summary of the Draft Recommendations of the ICRP, 1990*, National Radiological Protection Board, 1990.

RERF TR 12-87, *Comparison of Risk Coefficients for Site-Specific Cancer Mortality Based on the DS86 and T65R Shielded Kerma and Organ Doses*, Radiation Effects Research Foundation, Life Span Study Report 1 Pt. 1, 1987.

SECY-89-184, *Proposed Commission Policy Statement on Exemptions from Regulatory Control*, U.S. Nuclear Regulatory Commission, available in the NRC Public Document Room, 1989.

UNSCEAR (United Nations Scientific Committee on the Effects of Atomic Radiation), *Sources, Effects and Risk of Ionizing Radiation: 1988 Report to the General Assembly, Forty-third Session*, Supplement No. 45 (A/43/45), United Nations, New York, 1988.

ATTACHMENT E.A

CONCEPTS, TERMINOLOGY, QUANTITIES, AND UNITS USED IN THE OLD AND NEW VERSIONS OF 10 CFR PART 20

10 CFR Part 20 was first promulgated in 1957. In 1961, the regulation was amended to add an appendix containing maximum permissible concentrations (MPCs) and a new dose limit structure for whole-body exposure to external radiation (1.25 rem/quarter, or 3 rem/quarter with 5 rem/year average as a limit on the cumulative dose). The most recent revision went into effect in 1991. The 1961–1991 version is often called "the old Part 20"; the 1991 version, "the new Part 20." The new version differs considerably from the old, particularly with respect to basic concepts, terminology, radiation dose quantities, and the associated dose units. This attachment is included for those who need to become familiar with important details that underlie the coming changes in federal regulations.

E.A.1 CONVENTIONAL QUANTITIES AND UNITS

E.A.1.1 Old Part 20 Quantities and Units

In the old Part 20, the unit "rad" is usually used for the quantity "radiation absorbed dose" whenever early biological effects are the concern. When latent effects (e.g., cancer and genetic effects) are being considered, the unit "rem" is used for the dose equivalent (DE) quantity. The absorbed dose in rads is multiplied by an overall efficiency factor Q to obtain the DE in rem. Each type of radiation has its own value of Q, which in a very rough way makes absorbed doses from different radiations additive for latent effects. Values of Q in the old Part 20 are indicated in Table E.A.1.

These values of Q reflect the overall efficiency of a given type of radiation in causing latent effects and are not used for early effects such as acute radiation syndrome. In the old Part 20, these Q values are also applied to protection of the eye lens from cataracts and protection of the skin from cosmetic effects. The values were derived in consideration of the ability of the various radiations to ionize atoms in water as well as the relative biological effectiveness factors (RBEs) observed for specific effects. Most of the dose limits given in the old Part 20 are DE, and the rem unit is used.

The DE was used to calculate the MPCs in the old rule. The MPC is defined as the concentration of a radionuclide in air that, if the hypothetical standard man were exposed to it for a working lifetime of 50 years, would cause an annual DE to the critical (most highly exposed) organ after 50 years of exposure. Values are shown in Table E.A.2. The quantity of a radionuclide maintained continuously in an organ that will cause the DE is referred to as the maximum permissible organ burden (MPOB).

The old Part 20 allows the worker to receive external radiation at the rate of 5 rem/year average plus a DE to each organ, as shown in Table E.A.2. This regulation also ignores the internal radiation risk from the DE to noncritical organs and ignores the DE received by an organ from nuclides located in other organs.

Table E.A.1 Efficiency for different radiation types

Radiation	Absorbed dose (rads)	Q	Dose equivalent (rem)
250-kVp X-rays	1	1	1
Gamma	1	1	1
Beta	1	1	1
Beta (< 0.03 MeV max)	1	1.7	1.7
Alpha	1	10	10
Neutron (spectrum unknown)	1	10	10

Note: To convert rem to sievert, multiply by 0.01.

Table E.A.2 Annual dose equivalent limits used for calculating the maximum permissible concentrations

Organ	*r* (rem)
Thyroid	30
Bone	30
Gonads	5
Marrow	5
All others	15

Note: To convert rem to sievert, multiply by 0 01.

E.A.1.2 Collective Dose

The old Part 20 makes no use of the collective dose equivalent (person-rem). However, this quantity is used extensively by the Nuclear Regulatory Commission (NRC) in risk analyses and in its decision-making processes. The collective DE may be obtained as the sum of all individual doses or as the product of the average individual dose and the number of people exposed. The linear-nonthreshold hypothesis is accepted by the NRC for purposes of standards setting. Such acceptance means that standards based on the hypothesis, coupled with the as-low-as-reasonably-achievable concept, are believed to provide an adequate degree of protection.

E.A.2 NEW PART 20 QUANTITIES AND UNITS

All of the quantities and units discussed above remain in use in the new Part 20; the only change is that the "penetrating dose equivalent" is now called the "deep dose equivalent." However, NRC licensees must become familiar with several additional International Commission on Radiological Protection (ICRP) concepts and quantities.

The ICRP system is based on the recognition of two basic types of radiation-induced health effects: stochastic and nonstochastic. The stochastic (cancer and hereditary) effects are considered to be probabilistic in nature, and the objective is to control the probability to acceptable levels. For stochastic effects, the severity is not dose dependent (i.e., once caused, a malignancy from 100 rem is no worse than one from 50 rem). In contrast, nonstochastic effects are not caused at all unless a threshold dose is exceeded. The objective is to prevent nonstochastic effects, for which severity is dose dependent; for example, a radiation-induced cataract caused by 400 rem will impair vision more than one caused by 300 rem.

E.A.2.1 Nonstochastic Effects

In ICRP Publication 41, technical justification is presented for the ICRP position that, with the exception of cataracts in the lens of the eye, nonstochastic effects will not occur among humans if the DE from external and internal radiation combined, to every organ and tissue, is limited to 50 rem or fewer in a year. To achieve compliance, it is necessary during a given year to ensure that the organ or tissue receiving the highest DE does not exceed this limit.

E.A.2.2 Stochastic Effects

For these effects, the ICRP in 1977 adopted the risk then associated with 5 rem in a year, delivered to every organ, as the basis for its dose-limitation system. Therefore, the stochastic annual limit on intake (ALI) for each radionuclide is the quantity that, if inhaled, would cause the same stochastic risk as a uniform, whole-body dose of 5 rem delivered by external sources in 1 year. To establish these ALIs, the ICRP considered the possibility that a given nuclide taken into the body eventually reaches the bloodstream and is then distributed selectively to the various organs and tissues, where DEs are delivered over a time course determined by the retention capabilities of the organ or tissue and the physical characteristics of the nuclide. Using a radiation risk coefficient specific for each organ or tissue and the 50-year integrated DE for each of these, the risk associated with each is estimated. The total fatality risk to the worker per microcurie of this nuclide inhaled is the sum of the individual organ or tissue risks. The intake that will produce the same overall stochastic risk as 5 rem of uniform external radiation can then be readily calculated as the ALI. Of course, the worker may be exposed to several airborne nuclides and to external radiation as well. When this happens, the total risk is still limited to that associated with 5 rem in a year from uniform external radiation. Compliance is achieved if the fraction of the external dose limit that is received, added to the fraction(s) of the ALI(s) inhaled, does not exceed unity.

The risk of hereditary effects is included in a special way that, in the view of the ICRP, renders it additive to the cancer fatality risk. The ICRP considered only detrimental effects that the worker is likely to experience personally, so that effects manifested after the second generation are not included in the genetic risk coefficient used. The coefficient is also limited to very serious genetic effects (i.e., those comparable in severity to premature death).

E.A.2.3 Weighting Factors

Although all organs and tissues receive the same DE under uniform exposure conditions, the cancer risks often are not the same. Each organ or tissue contributes its own fraction of the risk. This fraction is called the weighting factor; the sum of all of the weighting factors is unity. The product of the weighting factor and the DE is the effective dose equivalent (EDE). This quantity is used for both external and internal irradiation and may be used for individual organs and tissues or for the sum of all organs and tissues. The unit used for either quantity is the same as for the DE, namely, the rem (or sievert). In the unique case of uniform irradiation of all organs and tissues, the sum of their EDEs is by definition equal to the whole-body DE. The EDE may be determined irrespective of the degree of uniformity among the organ or tissue doses. The sum of the EDEs is not allowed to exceed 5 rem in a year. The committed dose equivalent (CDE) is a familiar quantity defined as the 50-year integrated DE to a specific organ or tissue following the inhalation of a radionuclide. This quantity is still used, but only in connection with nonstochastic effects. The committed effective dose equivalent (CEDE) is the same quantity as the CDE, with the exception that, in the case of the CEDE, each DE is multiplied by a weighting factor. The rem (or sievert) is also the unit for both of these quantities.

The mathematical weighting method used by the ICRP is shown in Table E.A.3. The first column lists the organs, and the second column lists the risk coefficients from ICRP-26 and their sum; namely, 1.65×10^{-4}. This sum is the total annual risk to the exposed person, assuming exposure to these organs at 1 rad/year. [Multiplication by 5 gives the annual risk at 5 rads/year (i.e., 8.25×10^{-4} per year). This risk value means that if groups of 10,000 workers were to receive the dose limit every year for their entire careers, data as of the mid-1970s indicate that an average of 8.25 fatal occupational radiation-induced cancers per year would occur within each group. Assuming the approximate worst case of 45 years of exposure, the toll theoretically would be about 370 deaths per group, or almost 4 percent.] The fraction of this risk per rad for each organ can be obtained by dividing its risk coefficient by 1.65×10^{-4}. These fractions represent the relative sensitivity of the organs; they are the weighting factors and are designated by the symbol w_T, where T represents the organ or tissue. The weighting factors appear in column three of the table. If T is the DE to tissue T, then $w_T H_T$ is the weighted dose equivalent. For example, w_T for the lung is 0.12. If a weighted lung dose of H rem is set equal to a highly penetrating, uniform whole-body dose of 5 rem,

$$\begin{aligned} 0.12\ H &= 5 \text{ rem and} \\ H &= 41.7 \text{ rem ;} \end{aligned}$$

by hypothesis and analogy, an annual DE of 41.7 rem to only the lung would have the same effect as 5 rem to all of the organs combined. For this reason, $w_T H_T$ is called the EDE.

Nonstochastic effects have thresholds, and they become more severe as the dose gets larger. ICRP believes that none of the thresholds will be exceeded if the annual dose does not exceed 50 rad. This nonstochastic limit is reflected in column five of the table, where it is evident that

Table E.A.3 International Commission on Radiological Protection-26 risk weighting system

Organs	Risk coefficients (effects per organ-rem)	Weighting factors	Organ dose equivalent (DE) causing same risk as 5 rem to whole body (rem)	Annual DE permitted, exposure of one organ (rem/year)
Gonads	4×10^{-5}	0.25	20	20
Breasts	2.5×10^{-5}	0.15	33-1/3	33-1/3
Lung	2×10^{-5}	0.12	41-2/3	41-2/3
Red marrow	2×10^{-5}	0.12	41-2/3	41-2/3
Bone	5×10^{-6}	0.03	166-2/3	50
Thyroid	5×10^{-6}	0.03	166-2/3	50
1st RO[a]	1×10^{-5}	0.06	83-1/3	50
2nd RO	1×10^{-5}	0.06	83-1/3	50
3rd RO	1×10^{-5}	0.06	83-1/3	50
4th RO	1×10^{-5}	0.06	83-1/3	50
5th RO	1×10^{-5}	0.06	83-1/3	50
Totals	1.65×10^{-4}	1.0		

[a]The remainder organs (ROs) are the five organs that receive, from a given radionuclide, the highest effective dose equivalent, integrated over 50 years.
Note: To convert rem to sievert, multiply by 0.01.

nonstochastic effects are controlling for all but four organs that have the largest weighting factors—the most sensitive organs with respect to highly serious effects.

E.A.3 INTERNATIONAL SYSTEM OF UNITS

The International System (SI) units of particular interest to health physicists are the gray, sievert, and becquerel, shown in Table E.A.4. The SI units are part of the metric system; however, they are not yet widely used in the United States. The new Part 20 prohibits their use in records required by the NRC. The major concern of the NRC staff is that use of both the conventional and SI units would introduce confusion under emergency conditions.

Table E.A.4 Conventional and International System (SI) units

Quantity	Conventional unit	SI unit	SI unit equivalent
Absorbed dose	Rad (100 ergs/gram)	Gray (10,000 ergs/gram)	100 rad
Dose equivalent	Rem (Q × rad)	Sievert (Q × gray)	100 rem
Activity	Curie (3.7×10^{10} d/s)[a]	Becquerel (1 d/s)[a]	3×10^{-11} Ci

[a]Disintegration per second.

ATTACHMENT E.B

THE ICRP DOSE LIMITATION SYSTEM

In International Commission on Radiological Protection (ICRP) Publication 26, a three-tiered system of dose limitation, was introduced—justification, optimization, and limitation. This system was adopted for occupational radiation protection in the 1987 Presidential guidance to federal agencies. Revised Presidential guidance for protection of the public is in preparation.

E.B.1 JUSTIFICATION

The first tier, justification, is an admonition that governments should take radiation risks into full consideration before adopting programs that would involve the exposure of personnel to radiation or radioactive material. An example of such a programmatic consideration would be a decision to construct and operate nuclear electric power plants. Another example, on a much smaller scale, would be a decision to permit the use of jewelry containing small amounts of radioactivity induced by neutron irradiation.

E.B.2 OPTIMIZATION

In ICRP Publications 26 and 37, the phrase as low as reasonably achievable (ALARA) was discontinued (for ICRP purposes) in favor of the term "optimization." The ICRP considers the terms to be synonymous but apparently feels that "optimization" is more descriptive of the intent of its recommendation. In the United States, ALARA has traditionally been a concept used to justify radiation protection measures that further reduce doses already within regulatory limits. The probabilistic nature of stochastic radiation effects supports continuation of the application of the concept to the point at which the probabilities become too small to be of concern.

In the case of public protection, the Environmental Protection Agency (EPA) (40 CFR Part 190) and the Nuclear Regulatory Commission (NRC) (10 CFR Part 50) have established ALARA limits that are enforced rather than the considerably larger limits recommended by the ICRP and the National Council on Radiation Protection and Measurements (NCRP). The ALARA limits were derived using analytic techniques to identify approximately the point at which the cost of providing additional protection would exceed the risk averted. A more qualitative approach has been taken in the implementation of the occupational ALARA concept—no ALARA limits have been set. The basic dose limits have been coupled with the avoidance of unnecessary exposure. Soon after the ICRP introduced optimization in 1977, a more aggressive approach was initiated. Operators began to identify dose-reduction measures that were cost effective or even cost beneficial. Annual average doses among occupational groups are now characteristically below 10 percent of the limits. It is evident that actual doses to workers or the public are controlled by the ALARA concept rather than by dose limits, and that is why the ICRP lists optimization as the second tier of its system.

ICRP optimization is an analytical method through which the financial costs of dose reduction are compared with those of radiation-induced health effects to find the point at which the total costs of both are minimized (i.e., optimized). ICRP optimization takes only radiation risks into account.

E.B.3 LIMITATION

The third tier is limitation (i.e., the establishment and enforcement of dose limits for workers and the public). Compliance with a dose limit normally involves the measurement or calculation and recording of radiation doses to individuals to demonstrate that the doses did not exceed any limit established by cognizant government authorities. Because the primary risks of radiation are proportional to the lifetime accumulated dose, it is considered to be safe in the case of workers to allow a relatively large dose infrequently as long as the dose is compensated for in previous or subsequent years by commensurately smaller doses. This situation permits operational flexibility without sacrificing control of the lifetime risk. The ICRP and NCRP have therefore recommended dose limits for workers that are not to be approached routinely, but infrequently, if at all, as special operational needs arise.

ATTACHMENT E.C

PLOTS OF POPULATION DOSE COMMITMENTS BY REACTOR

LEGEND:

Δ Predicted total dose commitment (model)

* Air Dose Commitment (Data)

□ Liquid Dose Commitment (Data)

◇ Total Dose Commitment (Data)

ORNL-DWG 95-1763

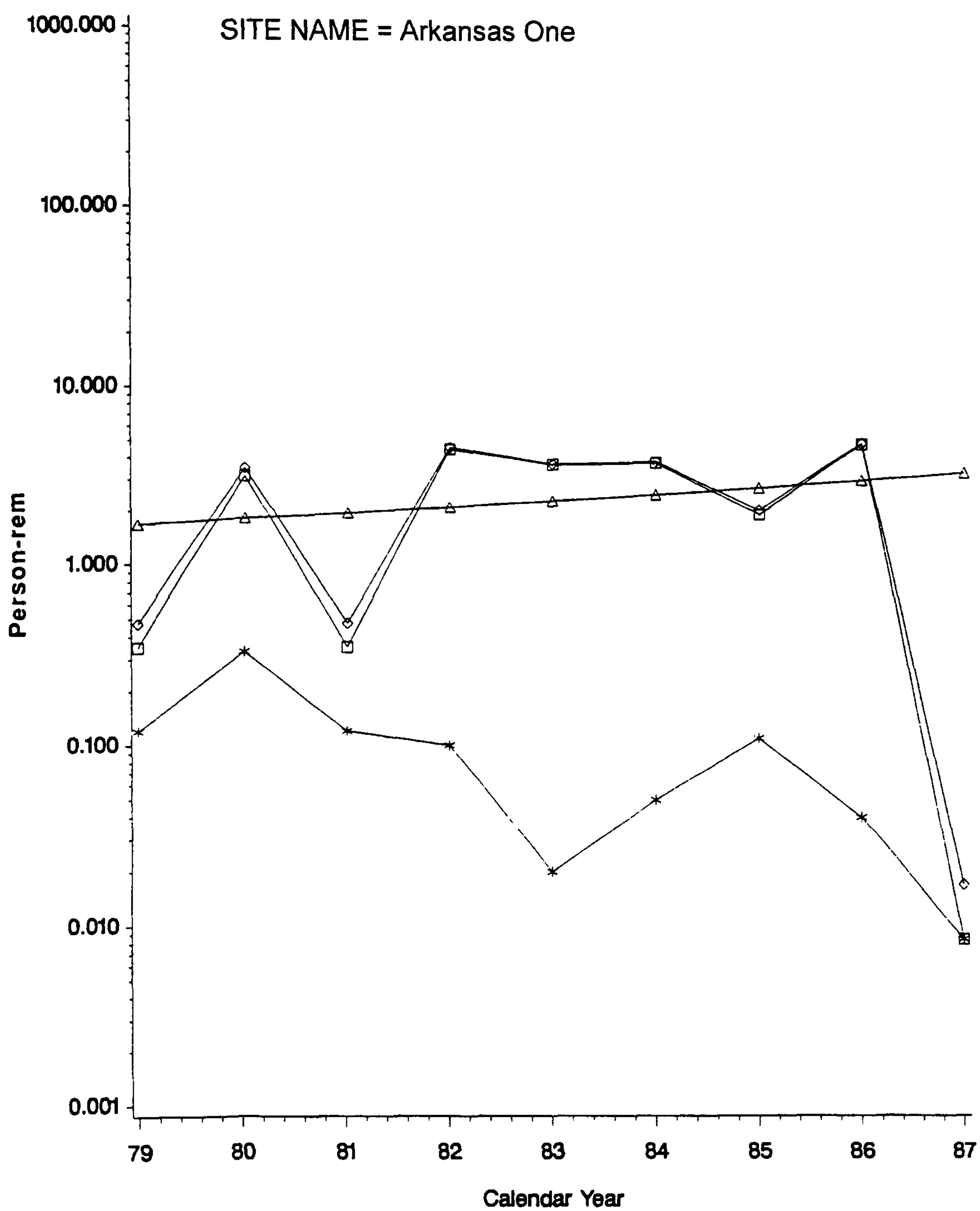

Figure E.C.1 Person-rem per year for Arkansas One.

ORNL-DWG 95-1764

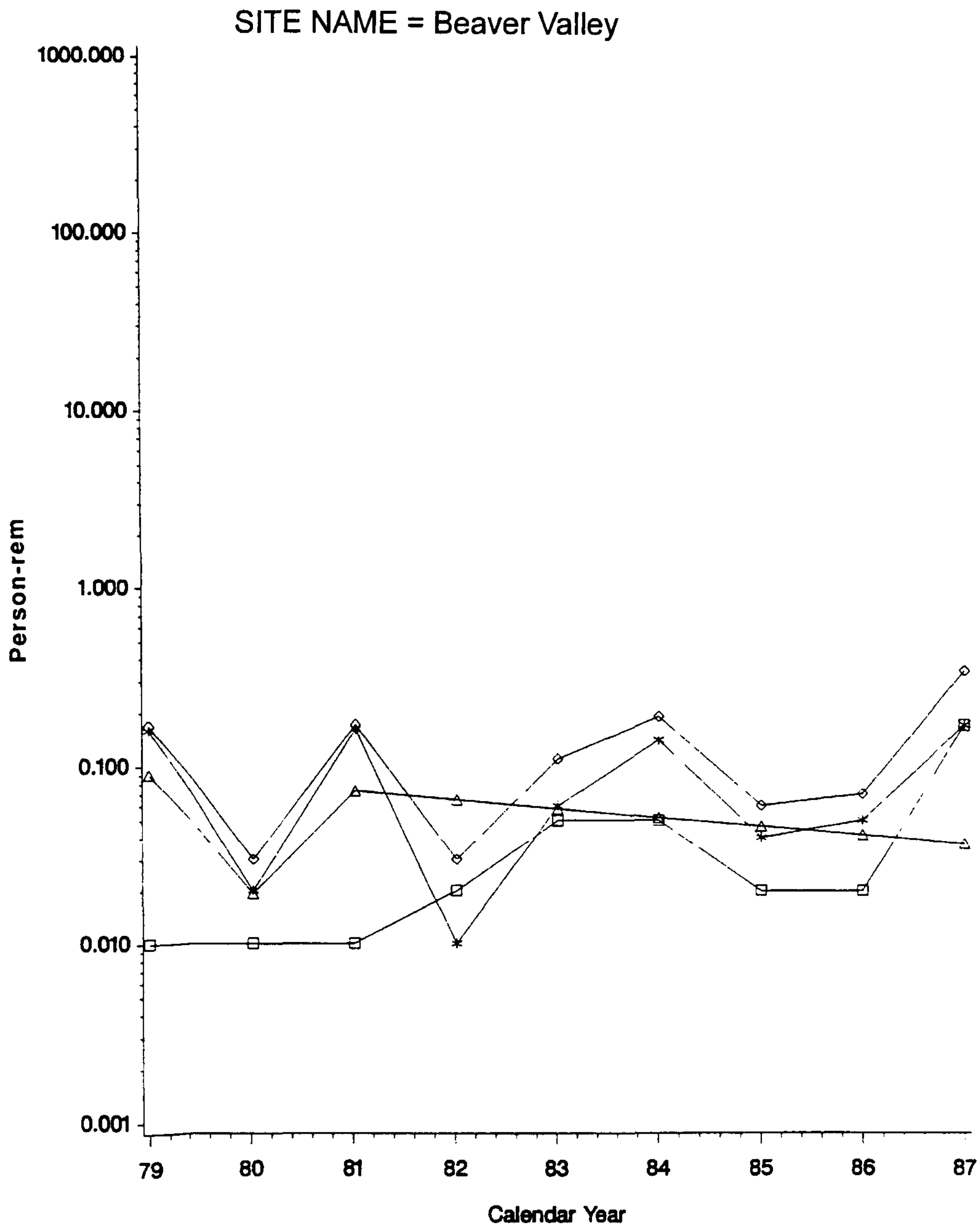

Figure E.C.2 Person-rem per year for Beaver Valley.

ORNL-DWG 95-1770

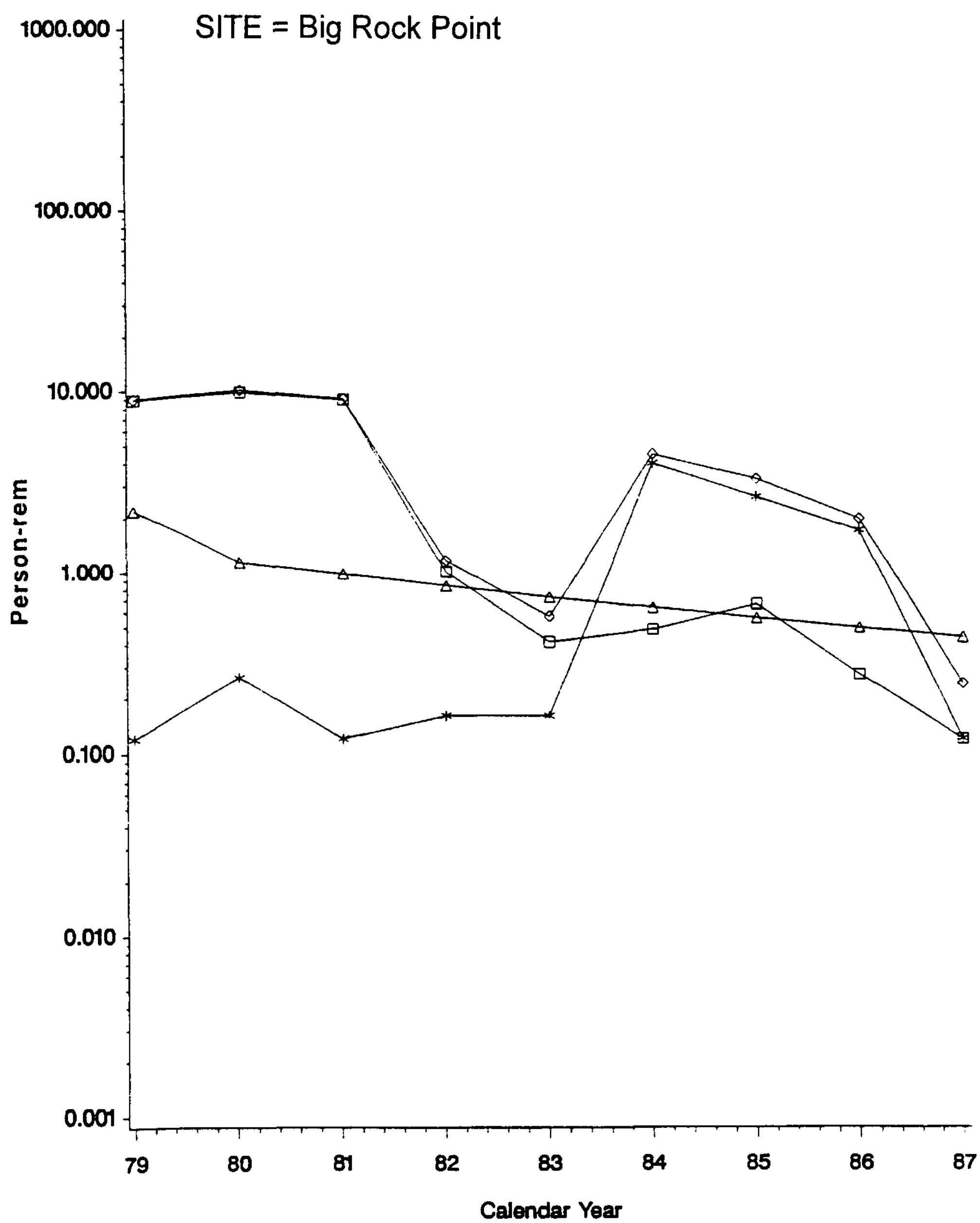

Figure E.C.3 Person-rem per year for Big Rock Point.

ORNL-DWG 95-1771

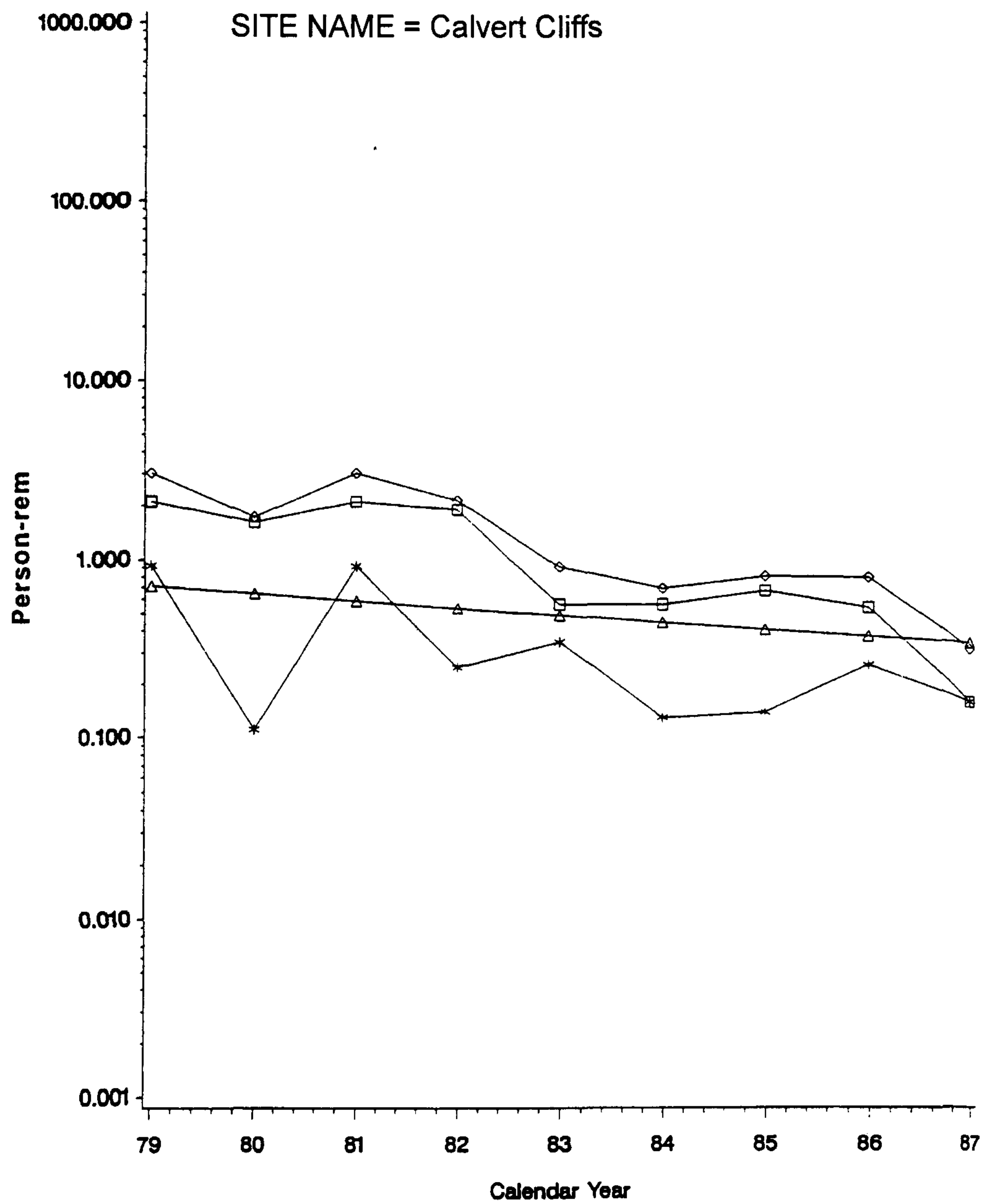

Figure E.C.4 Person-rem per year for Calvert Cliffs.

APPENDIX F

METHODOLOGY FOR ASSESSING IMPACTS TO AQUATIC ECOLOGY AND WATER RESOURCES

METHODOLOGY FOR ASSESSING IMPACTS TO AQUATIC ECOLOGY AND WATER RESOURCES

F.1 LIST OF ISSUES

The nonradiological aquatic effects of continuing operations during a license renewal period are not unique to nuclear power plants but instead are typical of potential impacts from any large steam-electric power plant (whatever the fuel type) and operation of the associated condenser cooling systems. The aquatic resources issues listed in Table F.1 have been identified from literature reviews, reviews of environmental impact statements (EISs), and professional contacts.

All of the issues listed in Table F.1 are addressed in Chapters 3 and 4, but primary emphasis is on the areas of water use, intake effects (entrainment and impingement), and thermal and chemical discharges. These areas consistently have been the most common issues raised in power plant impact assessments and permitting actions, and they have been the subject of considerable study and postoperational monitoring.

F.2 SOURCES OF INFORMATION

Information about historical and ongoing aquatic impacts associated with nuclear power plants was obtained from three general sources: (1) contacts with state and federal resource and regulatory agencies, (2) a survey of utilities that operate nuclear power plants, and (3) published literature.

Agencies with responsibility either for regulating the construction and operation of protection and maintenance of aquatic resources in the vicinity of the power plants were contacted for this document. For example, the U.S. Environmental Protection Agency (EPA) is responsible for protecting the quality of waters receiving discharges from the power plants and regulating the operation of the condenser cooling water intake and discharges. Regulation of intake and discharge effects to prevent significant impacts to aquatic communities is carried out by issuance and periodic renewal of National Pollutant Discharge Elimination System (NPDES) permits and, if necessary, by Clean Water Act Section 316(a) and (b) determinations (see Section 4.2 for a discussion of these regulatory requirements). Most often these permitting responsibilities have been delegated to the water quality regulatory agencies of the individual states. Although the state fish and wildlife agencies, the U.S. Fish and Wildlife Service (FWS), and the National Marine Fisheries Service (NMFS) do not issue permits to the nuclear power plants, they are concerned about the protection and enhancement of aquatic resources and thus have an essential consulting role with the U.S. Nuclear Regulatory Commission (NRC). Resource agency concerns may range from maintenance or enhancement of sport and commercial fisheries to protection of threatened and endangered species to restoration of anadromous fish or aquatic habitats.

Information request letters were sent to 151 individuals representing 74 state regulatory and resource agencies and to representatives in all of the regions of EPA, FWS, and NMFS. The letters solicited agency input

Table F.1 Aquatic resources issues associated with the refurbishment and operation of nuclear power plants

Refurbishment

- Soil erosion and sedimentation
- Water quality degradation from spilled chemicals

Operation

Water quality, hydrology, and use issues

- Water use conflicts
- Effects of consumptive water use on riparian communities
- Altered current patterns at intake and discharge structures
- Altered salinity gradients
- Temperature effects on sediment transport capacity
- Altered thermal stratification of lakes
- Scouring caused by discharged cooling water
- Eutrophication
- Discharge of chlorine or other biocides
- Discharge of other chemical contaminants (e.g., metals)
- Discharge of sanitary wastes

Aquatic ecology issues

- Threatened or endangered species
- Impingement of large organisms on the intake screens
- Entrainment of organisms into the condenser cooling water system
- Heat shock
- Cold shock
- Effects on movements and distribution of aquatic organisms
- Premature emergence of aquatic insects
- Stimulation of nuisance organisms (e.g., shipworms)
- Increased losses caused by predation, parasitism, and disease among organisms exposed to sublethal stresses
- Gas supersaturation (gas bubble disease)
- Low dissolved oxygen in the discharge
- Accumulation of contaminants (e.g., chlorinated organic materials or metals) in sediments or biota

about any existing or potential problems associated with operation of nuclear power plants in their state or region and any issues to be treated in thelicense renewal effort. An example information request letter is shown in Figure F.1. Responses were received from 17 federal agency regions and 55 state agencies, some of which provided references to specific studies that had been conducted to assess power plant impacts. These responses were used to augment information available from other sources on power plant effects.

A survey of all electric utilities that operate nuclear power plants was developed by Oak Ridge National Laboratory (ORNL) staff and administered by the Nuclear Management and Resources Council (NUMARC). The survey was intended to obtain the utilities' overview of the impacts of their power plants on aquatic resources. The survey contained nine questions related to aquatic resources; these are listed in Table F.2. As with the agency information requests, the utility responses to the survey were used as another source of information for assessment of power plant effects on aquatic resources.

For further information on aquatic impacts of power plant operations, published literature was reviewed, including peer-reviewed scientific journal articles that resulted from impacts studies, as well as periodic and topical reports submitted to or prepared by agencies [e.g., NRC EISs for the construction permit and operating license, environmental monitoring reports to the NRC, periodic reports to agencies associated with NPDES permits, and Section 316(a) and (b) demonstrations].

F.3 ANALYTICAL APPROACH

Analysis of impacts to aquatic resources focused on effects of power plant operation on water quality, water use, and aquatic biota. The potential impacts to these resources stem mainly from operation of the cooling water systems, although possible effects of refurbishment during the license renewal period were also examined.

Potential impacts to aquatic resources during the license renewal period result primarily from operation of the condenser cooling system. Water quality and availability can be altered by (1) use of biocides to prevent condenser tube fouling; (2) loss of water through evaporation, especially from cooling towers; (3) discharge of salts, metals, and other chemical contaminants; and (4) discharge of heated effluents. Aquatic biota can be affected by entrainment, impingement, and water quality changes from discharge of heated effluents and chemical contaminants. All of these effects were considered by the NRC in the EISs associated with the construction permit and operating license; they continue to be evaluated by the EPA or the state water quality permitting agency as part of the issuance and periodic renewal of the NPDES permit.

The approach used to assess effects of license renewal of existing nuclear power plants was to obtain information relating to these aquatic resources issues from monitoring data, other published information, and utility and regulatory agency contacts. If no impacts have been demonstrated for a given issue during the initial operating period of any plant, then continued operation under similar circumstances during the relicense period would not be expected to result in significant impacts. If impacts have been demonstrated

ORNL-DWG-90-16007

Date

Dear ________:

Oak Ridge National Laboratory is developing a report for the U.S. Nuclear Regulatory Commission that will evaluate environmental impacts of relicensing of nuclear power plants. Information on 118 reactors at 74 sites in the U.S. is being gathered to evaluate potential impacts from relicensing and an additional 20 or more year relicense period (beginning 40 years after the original license).

The results of this study will be used to modify 10 CFR 51 "Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions." These modifications may result in some issues no longer being considered for nuclear plants in National Environmental Protection Agency evaluations at their time of relicensing. Therefore, it is important that we obtain information from your office to help in evaluating any impacts of nuclear plants in your state with regard to fish and wildlife resources.

We would appreciate any information you may have on existing impacts and on the presence of important fish and wildlife resources that may be affected by continued operation of the _______ Nuclear Plant(s) and their power lines. For your convenience, a list of such resources and potential impacts is attached.

We would like to have your response by June 30, so that we can use the information in preparing the draft report. Thank you for your assistance.

Sincerely,

Glenn F. Cada
Aquatic Ecologist
Bldg. 1505, MS-6036
Phone: 615/574-7320

Roger L. Kroodsma
Terrestrial Ecologist
Bldg. 1505, MS-6038
Phone: 615/574-7310

Figure F.1 Example information request letter sent to state fish and wildlife resource agencies, state water pollution control agencies, and regions of the U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Environmental Protection Agency.

List of Important Fish and Wildlife Resources and Potential or Known Impacts

- Important sport and commercial fisheries and level of harvest
- Important spawning, nursery, or other habitats for aquatic fauna
- Impacts of entrainment, impingement, or thermal and chemical releases on aquatic biota
- Adverse effects of water withdrawals or discharges on water quality and water use
- Other sources of impacts (e.g., other power plants, industrial discharges, agricultural runoff) that could contribute to cumulative impacts to aquatic resources
- Construction impacts (construction for relicensing is expected to be relatively minor and entirely contained within existing site boundaries)
- Aquatic or terrestrial flora and fauna that are listed as threatened or endangered
- Salt drift and icing impacts on vegetation as a result of cooling towers or cooling ponds
- Bird mortality due to collision with power lines and natural draft cooling towers
- Impacts on fauna as a result of vegetation cutting and herbicides in power line corridors
- Rare plant communities
- Bird colonies
- Bird roosts (e.g., raptors)
- Waterfowl staging areas
- Wetlands
- Breeding/strutting/wintering grounds for big game or certain gallinaceous birds

Figure F.1 **Example information request letter sent to state fish and wildlife resource agencies, state water pollution control agencies, and regions of the U.S. Fish and Wildlife Service, National Marine Fisheries Service, and U.S. Environmental Protection Agency.** (continued)

Table F.2 Questions relating to nuclear power plant impacts on aquatic resources that were part of the electric utility survey

1. Post-licensing modifications or changes in operations of intake or discharge systems may have altered the effects of the power plant on aquatic resources or may have been made specifically to mitigate impacts not anticipated in the design of the plant. Describe any such modifications or operational changes to the condenser cooling water intake and discharge systems since the issuance of the operating license

2. Summarize and describe (or provide documentation of) any known impacts to aquatic resources (e.g., fish kills, violations of discharge permit conditions) or National Pollutant Discharge Elimination System (NPDES) enforcement actions that have occurred since issuance of the operating license. How have these been resolved or changed over time? The response to this item should indicate whether impacts are ongoing or were the result of start-up problems that were subsequently resolved

3. Changes to the NPDES permit during operation of the plant could indicate whether water quality parameters were determined to have no significant impacts (and were dropped from monitoring requirements) or were subsequently raised as a water quality issue. Provide a brief summary of changes (and when they occurred) to the NPDES permit for the plant since issuance of the operating license

4. An examination of time trends in the results of aquatic resources monitoring can indicate whether impacts have increased, decreased, or remained relatively stable during operation. Describe and summarize (or provide documentation of) results of monitoring of water quality and aquatic biota (e.g., related to NPDES permits, environmental technical specifications, site-specific monitoring required by federal or state agencies). What trends are apparent over time?

5. Summarize types and numbers (or provide documentation) of organisms entrained and impinged by the condenser cooling water system since issuance of the operating license. Describe any seasonal patterns associated with entrainment and impingement. How have entrainment and impingement changed over time?

6. Aquatic habitat enhancement or restoration efforts (e.g., anadromous fish runs) during operation may have enhanced the biological communities in the vicinity of the plant and increased its impacts beyond that originally anticipated. Alternatively, degradation of habitat or water quality may have resulted in loss of biological resources near the site. Describe any changes to aquatic habitats (both enhancement and degradation) in the vicinity of the power plant since the issuance of the operating license that may have resulted in different plant impacts from those initially predicted

Table F.2 (continued)

7. Plant operations may have had positive, negative, or no impacts on the use of aquatic resources by others. Harvest by commercial or recreational fishermen may be constrained by plant operation or may be relatively large compared with fish losses caused by the plant. Describe (or provide documentation for) other nearby uses of waters affected by cooling water systems (e.g., swimming, boating, annual harvest by commercial and recreational fisheries) and how these have changed since issuance of the operating license

8. Describe other sources of impacts to aquatic resources (e.g., industrial discharges, other power plants, agricultural runoff) that could contribute to cumulative impacts. What are the relative contributions by percentage of these sources, including the contributions due to the power plant, to overall water quality degradation and losses of aquatic biota?

9. Provide a copy of your Section 316(a) and (b) Demonstration Report required by the Clean Water Act. What 316(a) and (b) determinations have been made by the regulatory authorities?

at some plants, then the analysis attempted to define the source and extent of the problem, to examine efforts to mitigate the problem, and to determine whether these site-specific impacts represent potential issues for the entire industry. The conclusions of this analysis were used to make judgments about limiting or eliminating the treatment of particular issuesin the license renewal applications of particular types of plants.

Because this Generic Environmental Impact Statement (GEIS) is intended to consider potential impacts across the industry and is not a site-specific license renewal action, the corresponding information required for the analysis is different. The objective is not to evaluate in detail the effects of each nuclear power plant on aquatic ecosystems but rather to examine information available from a variety of sources from a large sampling of plants with a view toward defining common, industry-wide issues that may need to be addressed in (or can be eliminated from) future license renewal actions. The assessments of aquatic resources issues in this GEIS are necessarily less detailed than the full analyses typically performed at the initial licensing stage. In such full analyses, the applicant supplied an environmental report containing detailed results of sampling programs, with appropriate analyses. The NRC staff reviewed this material, usually obtaining clarification and further information, and visited the site and discussed the information in detail as part of their independent analyses of the costs and benefits of the proposed action.

The possible endpoints of the evaluation of aquatic ecological effects in this GEIS are also constrained, regardless of the amount of information available from operation during the initial license period. Power plant impacts cannot be measured simply by comparing preoperational data with postoperational data. To accurately evaluate the impact of a power plant, one needs to know what the environment would have been like if the power plant had not been built (NUREG-CONF-002). This is not generally possible for aquatic systems. Reservoirs change as they age (in productivity and potentially in species composition). Even in rivers or estuaries, standing crops of fish change from year to year, or even from decade to decade. These systems' responses to changes in environmental, biological, and anthropogenic factors are poorly understood. Power plants superimpose their effects on a mosaic of background influences from water flow rates, temporal pattern of runoff, temperature, productivity of other trophic levels, competition and predation, chemical pollution, habitat modification, fishing pressure, and other factors. However, the acceptability of power plant effects must be periodically reconsidered in the renewal of NPDES permits. The judgment that a facility employs "best available technology" or ensures a "balanced, indigenous population of shellfish, fish and wildlife" connotes that such effects, although real, are acceptable.

Because the nuclear power plants considered in this GEIS are now operating, some kinds of local (near-field, short-term) impacts (e.g., on benthic organisms) can be measured from localized studies at the intake and discharge. Mainly of interest, however, are the system-level (ultimate, long-term, population-level) effects, particularly on fish and shellfish. Models and professional judgment have been used to extrapolate the local power plant impacts to the resulting long-term, far-field effects on the whole system (Section F.4). Comparisons can also be made with sites not directly affected. Because of the interfering effect of other factors, however, such comparisons do not represent the actual system-level effects attributable solely to a power plant.

It is possible to measure the behavior of aquatic systems affected by operating nuclear power plants through time. Usually, a limited amount of data is collected before power plant operation. If the effects of the plant were drastic enough, an obvious change coinciding with operation could be detected when preoperational data were compared with postoperational data. Combined with information about near-field plant impacts, the change could be attributed to the plant. With less drastic plant impact, monitoring might show maintenance of a balanced and indigenous aquatic community. This does not always mean that the plant is without impact but could indicate that we are unable to detect a change from preoperational conditions (whether in spite of, because of, or regardless of the effects of the plant). However, it is reasonable to conclude that system-level effects are not evident, and whatever effects the plant is having are acceptable.

When the amount of preoperational data available is small, our confidence that the plant's impact is not serious is greatly reduced (Van Winkle et al. 1981). Uncertainties also arise when changes in the system occur that may be caused primarily by natural or anthropogenic factors (e.g., fish restoration projects or changes in fishing regulations).

The main purpose of our assessments is to identify aquatic ecology issues that generally do not need to be considered in the license renewal process as opposed to those that may or do need to be considered. By examining evidence for system-level effects (e.g., from entrainment and impingement) based largely on operational information, we can determine whether there is clear evidence for effects or whether the importance of these effects is still uncertain and may need to be resolved before license renewal. In this latter case, we cannot dismiss the issue for all plants, but its potential importance for many plants would be greatly lessened.

F.4 PLANT-SPECIFIC ANALYSIS

In addition to the review of all aquatic resources issues, selected issues were examined in greater detail for a subset of power plants. These issues, entrainment and impingement of fish and the effects of thermal discharges on aquatic biota, were the most common concerns expressed by the agencies. Because of factors such as large cooling water withdrawal and discharge rates, high Δ-Ts (large increases in temperature between intake and discharge) (Table 2.3), unique characteristics of the water body, or concerns expressed by the resources agencies, the power plants selected for detailed evaluation are believed to represent the types of power plants with the greatest potential for intake and discharge effects. These examples also represent a variety of aquatic systems affected by nuclear power plant operations, including reservoirs [Arkansas Nuclear One (ANO) and William B. McGuire Nuclear Station], the Great Lakes (D. C. Cook Nuclear Power Plant and the cumulative effects of Lake Michigan nuclear power plants), large rivers (cumulative effects of Hudson River power plants), and marine systems [San Onofre Nuclear Generating Station (SONGS) and the Crystal River Nuclear Plant]. Although some power plants with once-through cooling systems operate in relative isolation from other obvious sources of man-induced stress to aquatic biota, most of the examples considered here may affect aquatic resources in conjunction with other nuclear and coal-fired power plants, and therefore may represent the most severe cases. Where appropriate, the cumulative effects of these combined sources of stress have also been discussed.

F.4.1 Arkansas Nuclear One

The ANO station is a 2-unit, 1762-MW(e) plant located in Pope County, Arkansas, on Lake Dardanelle, an impoundment of the Arkansas River completed in the 1960s. Unit 1 uses a once-through cooling system, whereas Unit 2 has a natural-draft cooling tower system. Intake water is withdrawn from the Illinois Bayou arm of Lake Dardanelle through a 981-m (3220-ft) canal. The discharge is through a 158-m (520-ft) canal to an embayment of Lake Dardanelle. The Δ-T at full load is 8.3°C (15°F) for Unit 1. Because of the small volumes of blowdown associated with the closed-cycle cooling system of Unit 2, its contribution to discharge temperature increases is negligible. Arkansas Power and Light (AP&L) has conducted an extensive environmental monitoring program relating to the effects of ANO on Lake Dardanelle, including the effects of heated water discharges, impingement, and entrainment.

ANO has operated under a series of NPDES permits issued by EPA; no Section 316(a) demonstration has been required. Utility consultations with EPA Region 6 in the early 1980s confirmed that there was no 316(b) requirement; reevaluation would be needed only if there were a dramatic change in impact [AP&L, response to NUMARC survey (NUMARC)]. The following sections discuss the impacts of ANO operation.

F.4.1.1 Thermal Discharges

A portion of AP&L's monitoring program is designed to assess the impacts of the thermal discharge on fish and aquatic life (AP&L 1984). Discharge temperature is limited to 35°C (95°F), with a maximum increase over ambient of 2.8°C (5°F) based on a monthly average of daily depth-averaged values measured at unspecified locations in Lake Dardanelle (Geo-Marine, Inc. 1976; AP&L 1984). Most of the heat added to the water is dissipated within 2.5 km (1.6 miles) of the point of discharge (Rickett 1983).

The plant discharge has been studied with respect to effects on physicochemical parameters, phytoplankton, zooplankton, and fish. Statistically significant differences in turbidity, suspended solids, chloride, and hardness, but not conductivity, were found between the intake area and an upstream area in Lake Dardanelle, but not between the intake and the discharge (Rickett and Watson 1985). The differences appear to be small and may be the result of characteristically different water quality in the Illinois Bayou and the Arkansas River mainstream (e.g., Geo-Marine, Inc. 1976). A comparison of the phytoplankton communities at close versus distant sampling stations after power plant operation began showed (1) no noticeable effects on phytoplankton abundance and the number of taxa and (2) no significant effects on diversity (Rickett and Watson 1983b), although an indication is given that phytoplankton were stimulated at close stations (Rickett and Watson 1983a). The heated effluent was considered to have slightly suppressed overall abundance and variety, but not diversity, of the zooplankton community, and to have generally increased the ratio of phytoplankton to zooplankton abundance at close stations (Rickett and Watson 1983a). Also attributed to the power plant was a dominance exchange between the rotifer genera *Brachionus* and *Polyarthra*, with the latter genus moving from third to first rank in terms of the number of times it was dominant at individual sampling stations (both close and distant). Such a shift is consistent with experimental results showing an increase in abundance of *Polyarthra major* in a heated enclosure relative to an unheated control (CONF-740820).

Evaluating effects of the discharge on fish communities is one of the main objectives of multiyear fish surveys conducted by AP&L. Fish are attracted to the discharge area in the winter and to the intake area in the summer; sport fish tend to avoid the discharge area in the summer because of the elevated temperatures [AP&L, response to NUMARC survey (NUMARC)]. Concern was expressed in the Final Environmental Statement (FES) for Unit 1 (AEC Docket 50-313) about potential cold shock in the event of rapid plant shutdown during the winter. Recent information [AP&L, response to NUMARC survey (NUMARC 1990)] does not discuss whether such shutdowns have occurred, but only one significant fish kill incident (excluding entrainment and impingement mortality) is reported from 1974 through 1989. The deaths, in the discharge area, were related to lordosis (humpback or crooked spine). This abnormality may have been caused primarily by toxaphene, an agricultural pesticide that washed into the reservoir from the surrounding watershed and was enhanced by the thermal discharge. Toxaphene was banned, and lordosis has rarely been observed after 1978 [AP&L, response to NUMARC survey (NUMARC 1990)].

Time trends in mean weights of adult fish have been examined over several years (Tilley 1983). Mean weights for five species of fish tended to be somewhat higher in the discharge embayment than in stations elsewhere, as did the ratio of predators to prey based on weights. It was concluded that species composition in the reservoir had not reached equilibrium in the 15 years after impoundment, and it was considered unlikely to do so in the future. The species composition in the vicinity of the discharge is, however, not significantly different from that in other sample areas (Tilley 1983).

F.4.1.2 Entrainment and Impingement

The potential for entrainment at ANO is not negligible. At full power operation, the plant withdraws 48 m^3/s (765,000 gal/min) of water. If the reservoir is viewed as a closed system, this is 0.5 percent of the reservoir volume per day. Viewing the reservoir as an open system, the intake is 5 percent of the mean flow through the reservoir; much larger percentages can be calculated during periods of low flow. Although these percentages do not represent estimates of entrainment or impingement, they may be large enough to result in significant impacts.

An assessment of entrainment at ANO has been conducted by AP&L (1990). Summary data are presented for 1977–1982 for fish larvae from meter net samples in the Illinois Bayou in the vicinity of the entrance to the intake canal and in the intake canal itself. Clupeid larvae represented 79–97 percent of all larvae captured in the entrainment samples, depending on the year. Although clupeids were the most frequently entrained larvae, these species have been able to reestablish themselves in the intake area and the reservoir each year. AP&L does not regard entrainment at ANO as having a significant impact on these or other species of fish in the lake (AP&L 1990).

Impingement samples have been taken from at least 1974 through 1982. Impingement has been substantial. In the FES for Unit 2, NRC staff reported that from June 10, 1974, through July 19, 1975, 34 species had been impinged at Unit 1; estimated impingement was 27.5 million fish weighing 213,000 kg (470,000 lb), of which 99.6 percent by number and 99.3 percent by weight were threadfin or gizzard shad (NUREG-0254). These fish were predominantly young-of-year and presumably stressed by low water temperatures (Zweiacker et al. 1977). Ten million fish weighing 97,900 kg (215,900 lb) were impinged during the first year of operation, compared with an average impingement of 2 million fish weighing 13,000 to 30,000 kg (29,000 to 66,000 lb) in ensuing years [AP&L, response to NUMARC survey (NUMARC 1990)]. Also during 1974–1975, an air bubble curtain was evaluated as a possible means of reducing impingement. It was considered ineffective. Impingement levels were found to be inversely correlated with temperature (Zweiacker et al. 1977).

An indication of the magnitude of ongoing impingement can be obtained by comparing estimated impingement of fish with estimated reservoir standing crops. These estimates were provided for 1981 for some of the more important commercial and sport fish and forage fish in the reservoir. Impingement in 1981 represented less than 3 percent of the estimated gizzard shad population and less than 13 percent of the estimated threadfin shad population, either by numbers or by weight. For the 11 other species, the fraction was 1 percent or less and usually less than 0.1 percent. Impingement rates of the magnitude estimated for threadfin shad could have a significant effect on the population, although demonstrating (i.e., measuring) the effect would probably be impossible given the limited preoperational data and the natural variability inherent in fish populations (Van Winkle et al. 1981). Loar et al. (1978) studied impingement of threadfin shad at 32 southeastern power plants, including ANO. The impingement rate of shad [number impinged per million cubic meters (2.6×10^8 gal) of water withdrawn] at ANO was more than 4 times that of the second highest plant in their study and more than 10 times higher than rates at the other nuclear power plants. Loar et al. concluded that the characteristic of peak winter impingement of threadfin shad was widespread for southeastern U.S. power plants between 33° and 37° N latitude (ANO is near 35° N latitude) and that impingement rates were higher in reservoirs than on rivers. They could not firmly relate the rates to type of intake structure or to plant operational parameters (e.g., flow rates; velocity near the intake screens).

F.4.1.3 Summary of Impacts

Information about preoperational (1969–72) and postoperational (1975–84, except for 1979) standing crops of fish from Lake Dardanelle are available in one of the National Reservoir Research Data Bases. Four multivariate analyses of variance, or MANOVAs, of the Lake Dardanelle data were conducted. These compared preoperational status of fish communities in the reservoir with postoperational status based on standing crops for selected important commercial, sport, or forage species within four groups of fish: clupeids (threadfin shad, gizzard shad, and skipjack herring); catfishes (channel catfish, flathead catfish, and blue catfish); basses (largemouth bass, striped bass, and white bass); and crappies and sunfishes (black crappie, white crappie, bluegill, and longear sunfish). A significant ($p < 0.05$) difference was found only with the basses. The individual univariate analyses of variance, or ANOVAs, for individual bass species showed a significant decrease in largemouth bass. However, a nonparametric test using the Mann-Whitney U statistic showed, in addition, a significant increase in striped bass (which had not been caught at all in the preoperational period). Whether these changes are related primarily to operation of ANO, to natural changes in Dardanelle Reservoir as it ages, or to other anthropogenic factors is not clear. Because entrainment and impingement of largemouth bass are low, substantial effects of ANO on this species would only be expected as an indirect consequence of effects on one of their food sources, clupeids; such effects on clupeids were not detected.

The combined effects of thermal discharges and entrainment and impingement stresses are likely greatest on the threadfin and gizzard shad populations. Quantifying the level of stress would require extensive additional analyses, far beyond the scope of this GEIS. Evaluating the consequences of these effects and stresses at the fish population level presents additional difficulties, due in large part to uncertainty about biological compensatory mechanisms (EPRI EA-5200s). However, as AP&L points out, threadfin and gizzard shad are able to reestablish themselves in the intake area and the reservoir each year [AP&L, response to NUMARC survey (NUMARC 1990)]. Effects of changes in zooplankton dominance and high annual levels of shad impingement are not apparent. In addition, state and federal regulatory agencies have not expressed concern about operation of ANO.

F.4.2 William B. McGuire Nuclear Station

The William B. McGuire Nuclear Station is a 2-unit, 2360-MW(e) plant located on Lake Norman, the largest impoundment in North Carolina. Both units use a once-through cooling system, drawing a combination of surface water from a manmade embayment and deep water from an intake located near the base of Cowan's Ford Dam. The near-shore discharge is channeled through a canal 1 km (0.6 mile) long. The Δ-T (change in temperature) at full load ranges from 8.6° C

(15.5°F) in the summer to 13.7°C (24.7°F) in the winter (Duke Power Company 1985).

Concerns about McGuire's impacts to aquatic resources have focused mainly on effects of heated water discharges on recreational fisheries (DUKE PWR/82-02), although entrainment and impingement are also of potential concern for aquatic life. Water use has also been identified as an issue.

Lake Norman was impounded in 1963 primarily for power generation. The Marshall Steam Station (coal-fired) also uses the lake for cooling water; with both facilities operating, the lake has the highest thermal loading from the discharge of once-through condenser cooling water of any lake of comparable size in the United States (DUKE PWR/82-02). Several sport fish species have been successfully introduced to the reservoir. Largemouth bass, crappie, striped bass, and white bass dominated the fishery in the early 1980s (DUKE PWR/82-02).

The following sections discuss the major potential sources of impacts from the McGuire plant.

F.4.2.1 Thermal Discharges

Extensive attention has been devoted to evaluating the thermal effects on Lake Norman of discharges from both Marshall and McGuire. Postoperational versus preoperational comparisons of fish standing crops based on cove rotenone sampling show fluctuations, but the only documented trend is a decline in gizzard shad standing stocks near the discharge since operation [Duke Power Company, response to NUMARC survey (NUMARC 1990)]. Minor sporadic die-offs of striped bass and yellow perch have been observed before and after operation of McGuire. These have been attributed to a loss of oxygenated cool-water habitat. The original NPDES permit for McGuire specified a maximum discharge temperature of 35°C (95°F). A new permit, issued in 1990, increases this limit to 37°C (99°F) during July to September. The new higher limit can be attained with a lower proportion of cool, deep (hypolimnetic) water from the lower-level intake structure. This in turn is expected to reduce the depletion of habitat for cool-water fish species (primarily adult striped bass and yellow perch).

Avoidance of the discharge area by fish during summer, which varies depending on the level of operation, has been documented and will probably increase with the new thermal limit. Because areas of Lake Norman water affected by thermal discharges will be increased only by approximately 1 percent as a result of the changed limits (Duke Power Company 1988), the loss of summer aquatic habitat should have negligible effects on fish populations. Attraction of fish to the discharge area during cooler months has occurred in the past and will probably continue. The likelihood of mortalities due to cold shock is substantially reduced with two units operating. No incidences have been reported of fish mortalities resulting from thermal shock in the first few years of operation (Carter 1990).

Gas bubble disease (GBD), which sometimes leads to mortality, has regularly been observed in the discharge of the Marshall plant (McInerny 1990). Duke Power (1985) projected only low incidences of GBD for the McGuire station, based on operating data from Marshall and the Δ-Ts expected for McGuire. In the limited postoperational data provided, the incidence of GBD was low. Incidence of disease and parasitism was also low, both in preoperational and operational years (Duke Power Company 1985).

F.4.2.2 Entrainment and Impingement

The only report currently available about entrainment and impingement is from a preoperational, predictive study (Duke Power Company 1978). Threadfin shad were expected to be the fish species most subject to both entrainment and impingement. A formal 316(b) demonstration has not been required at McGuire, and no extensive studies of fish entrainment and impingement have been conducted (Carter 1990).

F.4.2.3 Cumulative Impacts

Combined effects of the Marshall and McGuire plants on fisheries are difficult to document. This difficulty is typical of situations where not only power plants but also other external factors are operating on the system. Despite the potential for entrainment, impingement, and thermal effects, the overall fish populations of Lake Norman appear to be healthy and to support an increasing amount of recreational activity. In responses from federal and state agencies, the North Carolina Wildlife Resources Commission expressed a concern about mortalities of large striped bass in Lake Norman but also indicated that it was uncertain whether these are related to operation of McGuire (Hamilton 1990).

Consideration of impacts to aquatic resources in Lake Norman is an ongoing cooperative effort between Duke Power Company and the resource and regulatory agencies (Lewis 1990). This is evidenced by the recent modification of maximum discharge temperatures of the McGuire station to protect cool-water fish habitat.

F.4.3 D. C. Cook Nuclear Power Plant

The D. C. Cook Nuclear Power Plant is a 2-unit, 2130-MW(e) plant located on the southeastern shore of Lake Michigan. The plant uses a once-through cooling system for both units, drawing water from three intake cribs located 680 m (2231 ft) offshore in 7.3 m (24 ft) of water (Thurber and Jude 1984). Cooling water is also discharged offshore through two slot-jet discharge structures located 366 m (1200 ft) offshore in 5.5 m (18 ft) of water. The maximum temperature to which discharged water is heated above ambient temperatures (i.e., the Δ-T) is variously reported as 10°C (18°F) (Evans et al. 1977; Evans 1984; Chang and Rossman 1985) or 21°C (38°F) (Thurber and Jude 1984). A riprap bed of crushed limestone was deposited around the intake and discharge structures during construction to prevent erosion and scour.

Concerns about D. C. Cook impacts to aquatic resources have focused on effects of entrainment, impingement, and heated water discharges on recreational and commercial fisheries. The most frequently impinged and entrained fish species in Lake Michigan are alewife, yellow perch, and rainbow smelt (Jensen et al. 1982). All three species support small commercial fisheries, and yellow perch and rainbow smelt are also important to sport fishermen. In addition, there are important cold-water sport fishes (e.g., lake trout and various other stocked salmonids) that could be affected by thermal discharges.

Chang and Rossman (1985) report that the plant no longer requires biofouling control and that chlorination did not occur during their study period. The spread of the fouling organisms *Corbicula* and the zebra mussel in the Great Lakes in recent years may once again require the use of some type of biocide. In any case, D. C. Cook would be unlikely to cause biocide impacts because it discharges treated water through a diffuser (to ensure rapid mixing and dilution) into a large body of water. Chemical effluents would be rapidly diluted and are unlikely to accumulate in the system.

F.4.3.1 Thermal Discharges

The rapid mixing of heated water and discharge into a large body of cold water is unlikely to result in significant adverse impacts. Evans studied benthic communities in the vicinity of the discharge structure and found few or no differences between the thermal plume and control areas in abundances of bottom-dwelling organisms; the few differences that were detected were limited to small areas within a few hundred meters of the intake and discharge structures.

Spigarelli et al. (1983) studied movements of a cold-water sport fish, the brown trout, near the thermal plume of a Lake Michigan power plant similar to D. C. Cook [essentially the same discharge rate and Δ-T (change in temperature)]. The trout took up residence in the thermal plume instead of avoiding it, especially during the winter months when ambient temperatures are lower than those preferred by the fish. In Lake Michigan, fish can easily avoid thermal plumes, but some species (brown trout, rainbow trout, alewife, carp, and salmon) frequently occupy these gradients (Spigarelli et al. 1983).

F.4.3.2 Entrainment and Impingement

Because of the large volumes of water withdrawn for condenser cooling of the two units and the large numbers of important fishes in the vicinity, D. C. Cook has been studied for entrainment and impingement impacts. Studies before and during operation of the plant sought changes that could be attributed to operation. Few significant effects were detected from the entrainment of phytoplankton (Chang and Rossman 1985) or zooplankton (Evans et al. 1977), and even these effects were considered inconsequential or highly localized.

Madenjian et al. (1986) used two statistical procedures to assess D. C. Cook impacts. They compared catches of alewives and yellow perch before operation (1973–74) and during operation (1975–82). Both analyses disclosed no significant power plant impacts. State and federal resource agencies contacted for this document did not express concerns about the continuing operation of D. C. Cook (Madenjian et al. 1986).

F.4.4 Lake Michigan Nuclear Power Plants

Six nuclear generating stations are located on Lake Michigan. Except for the Palisades Nuclear Plant, they all use once-through cooling. Listed with the number of units, they are Big Rock Point Nuclear Plant (1), D. C. Cook Nuclear Power Plant (2), Kewaunee Nuclear Power Plant (1), Palisades Nuclear Plant (1), Point Beach Nuclear Plant (2), and Zion Nuclear Plant (2). The near-field aquatic effects of one of these, the D. C. Cook plant, have been considered separately in this section. In addition, EPA, the Illinois Environmental Protection Agency, and the Illinois Department of Conservation all specifically identified entrainment and impingement of fish at the Zion Nuclear Plant as issues of concern; and studies of potential mitigative measures have been requested. In terms of the far-field, long-term effects, it is appropriate to consider these plants as a group and to examine their cumulative impacts, considering also other sources of impact (including fossil-fuel power plants) on Lake Michigan as a whole. This approach has been taken in several publications that consider the cumulative effects of entrainment and impingement of fish.

Kelso and Milburn (1979) evaluated cumulative entrainment and impingement during 1975 or 1976 at 89 power plants using once-through cooling systems located on all five of the Great Lakes. The combined capacity of these plants was 54,118 MW(e). Consideration was also given to an additional 17 plants with once-through cooling systems not yet operational at that time but expected to be operational by 1982, with 30,705 MW(e) additional capacity. Of these, 25 existing and 3 planned plants, with 14,932 and 4,969 MW(e) capacities, respectively, were located on Lake Michigan.

Impingement information was available from 43 percent of the existing power plants. Impingement in Lake Michigan was second highest (after Lake Ontario), with a broad peak from May to July. Entrainment information was more limited, available from only 24 percent of the plants. Regression equations were developed for annual impingement and annual entrainment as functions of power plant size (apparently, with all units combined within plants); these were used to extrapolate to plants lacking adequate data. Based on these equations, annual impingement at existing Lake Michigan plants was estimated to be about 15.4 million fish; the proposed plants were projected to increase this by 755,000 fish. The corresponding estimates for entrainment of larvae were about 196 million and 10 million, respectively.

Kelso and Milburn (1979) estimated annual impingement in the Great Lakes by these power plants of approximately 100 million fish. Calculating an average weight of an impinged fish at about 75 g (2.6 oz), they estimated that the "harvest" by power plants through impingement was at least 7500 metric tons (8300 tons), or 15 percent of the total commercial landings (about 50,000 metric tons (55,000 tons), obtained from references dated 1970 and before). Because they considered their impingement figures to be low, they estimated that impingement losses were in excess of 25 percent of the total annual commercial fish harvest. Kelso and Milburn (1979) estimated an annual entrainment in the Great Lakes of about 1.2 billion larval fish, but because of inadequate information they did not try to relate these losses to the size of the commercial catch.

Scott-Wasilk et al. (1981) believed that Kelso and Milburn's (1979) comparison of the loss estimates with commercial catch data overstated the impact. They noted that 85 percent of the impingement and entrainment was of "ecologically less desirable, but very abundant species" that are increasingly dominant in the commercial catch. Alewife and smelt stocks fluctuate substantially but have shown no consistent trends in abundance in Lake Michigan, despite the entrainment and impingement and a steadily increasing commercial catch of alewives. They considered standing crops to be a more appropriate basis for comparison. Viewed this way for Lakes Michigan and Ontario and the western basin of Lake Erie, annual impingement losses (expressed variously as numbers or as weights) typically constituted less than 1 percent of total stocks. Scott-Wasilk et al. (1981) also felt that the probable effect of power plants on sport and commercial landings was negligible and that (biological) compensatory reserves for impacted stocks, although unquantified, were probably sufficient to minimize the impact of these losses.

Kelso and Milburn (1981), in their response, noted that although losses of alewife and smelt may be small in Lake Michigan, such losses might constitute a significant reduction in the forage base for trout and salmon. The concern was also expressed that discrete stocks and local populations might be depleted by clustering power plants with once-through cooling systems in areas including the southern basin of Lake Michigan.

A different approach, involving the adaptation and use of conventional fishery stock assessment models, was taken by Jensen et al. (1982) to estimate the effects of 15 power plants on Lake Michigan. All of the nuclear plants except Big Rock Point were included. Both the surplus-production and the dynamic- pool models were applied to estimate the proportions of the Lake Michigan standing stocks of alewife, yellow perch, and rainbow smelt impinged and the proportions of eggs and larvae entrained.

The impingement proportions should be reasonably comparable to those calculated by Scott-Wasilk et al. (1981) for 17 Lake Michigan power plants. Although all of the impingement estimates calculated in either paper for Lake Michigan were less than 1 percent, the estimates of Jensen et al. (1982) for alewife (0.25 percent and 0.21 percent, depending on the model used) were substantially smaller than the 0.77 percent estimated by Scott-Wasilk et al. (1981). Conversely, the Jensen et al. (1982) estimates for rainbow smelt of 0.15 percent (both models) were more than double the Scott-Wasilk et al. estimates.

Referring to the type of analysis conducted by Kelso and Milburn (1979), Jensen et al. (1982) also presented estimates of biomass impinged as a percentage of 1975 commercial catch statistics. They estimated that impingement amounted to 10 percent of the commercial catch of alewife, 3.6 percent that of yellow perch, and 3.1 percent that of rainbow smelt which, given the recent predominance of alewife in the commercial catches, compare reasonably well with Kelso and Milburn's (1979) calculation of 15 percent of total commercial landings (all species), based on older catch data.

The main advantage of the approach taken by Jensen et al. (1982) is that, rather than just ratios, the *effects* of entrainment and impingement can be estimated on standing stocks and on maximum sustainable yields. Using the full-flow scenario, but including entrainment and impingement, they estimated reductions of standing crops (biomass) of 2.86 percent for alewife, 0.28 percent for yellow perch, and 0.76 percent for rainbow smelt. Corresponding reductions in the maximum sustainable fishery yield are larger: 4 percent for alewife, 0.5 percent for yellow perch, and 1.2 percent for rainbow smelt. Using "maximum" entrainment and impingement coefficients, there is about a 10 percent decrease in biomass (species not specified). They concluded, "Although large numbers of alewife, rainbow smelt, and yellow perch are killed by entrainment and impingement, the proportions of the populations affected are relatively small. Still, the loss of fish biomass is not negligible, and entrainment and impingement impacts need to be considered in the design of new intake facilities" (Jensen et al. 1982).

The main lesson to be learned from these analyses of entrainment and impingement impacts on fisheries in Lake Michigan is that it may not be sufficient to evaluate the significance of these types of impacts one power plant at a time. The main effects of concern are not local but relate to the entire lake (or at least to entire basins). The issue is one of resource management, and the logical level for management is at the level of the resource: cumulative impacts of all plants (and other water uses) in an area or on a lake.

F.4.5 Hudson River Power Plants

Seven power stations (including two nuclear stations, Indian Point 2 and 3), with a total net rated capacity of 5798 MW(e), are located along the Hudson River estuary between river kilometers 8 and 228 (Hutchison 1988). The most extensive consideration of entrainment and impingement impacts on the aquatic environment ever undertaken centered on these facilities. During the late 1970s, the studies, analyses, and hearings involved four federal agencies, five utilities, and numerous other parties and drew on the cumulative efforts of nearly 2000 technical personnel. The results of these studies have recently been integrated and summarized as a case study (Barnthouse et al. 1988b) that is the best available evaluation of what can and what cannot be determined about these kinds of impacts.

The greatest attention focused on the population-level effects of entrainment and impingement of fish at the three largest plants: the Indian Point Nuclear Generating Station (Units 2 and 3) and the Bowline Point and Roseton fossil-fuel plants. In particular, the final EPA hearing that ended with the 1980 settlement agreement (Barnthouse et al. 1988a) focused on whether reducing entrainment and impingement effects by retrofitting closed-cycle cooling systems to the six active units at these three facilities was necessary. However, most of the later analyses included the effects of five power plants by adding Lovett and Danskammer, two smaller fossil-fuel stations. The other two plants were near each end of the estuary beyond the region for which data were available but also outside of the main spawning and nursery areas of key fish species. Therefore, analyses assessed the cumulative impact of steam-electric power generation on the Hudson River estuary. Impacts on striped bass received greatest attention, but white perch, Atlantic tomcod, American shad, alewife, blueback herring, and bay anchovy were also considered.

Numerous mathematical models have been developed to evaluate the extent and effects of entrainment and impingement (Christensen and Englert 1988; Barnthouse and Van Winkle 1988). The Hudson River approaches differ from those used for Lake Michigan, in which the numbers entrained or impinged were related to numbers or weights of fish in the lake or caught in the fishery. Interpreting such comparisons is very difficult because (1) the entrained (and probably also impinged) fish are younger and less valuable than those in the fishable stock and (2) impingement needs to be considered in relation to the life-cycle of the fish, not just on an annual basis. In the Hudson River, these issues were moot because estimates of the absolute size of stock standing crops or fishery yields were not available, in part because of the open nature of the estuary. Rather, emphasis was placed on the conditional entrainment and impingement mortality rates (Ricker 1975) (the fraction of an initial population that would be killed during the year if no other sources of mortality operated) imposed on each year class and on the resulting projected percentage reduction of the standing stock.

A reasonable consensus was eventually achieved about the magnitude of entrainment impact (Englert and Boreman 1988; Barnthouse et al. 1988a). Estimates of conditional entrainment mortality based on historical and projected once-through cooling operations at the five power plants ranged from 5 to 7 percent for Atlantic tomcod to 35 to 79 percent for bay anchovy (Englert and Boreman 1988). For most species, the impact of entrainment was considered more important than that for impingement. For white perch, however, the estimates of conditional impingement mortality were relatively large, ranging from 10 to 59 percent (Barnthouse and Van Winkle 1988).

The Hudson River studies were relatively unsuccessful in meeting the broader objective of extending these direct impact estimates to determine the percentage reduction of the corresponding fish populations in the estuary (Klauda et al. 1988; Barnthouse et al. 1988c). Out-of-court negotiations among many of the parties involved began in August of 1979 (Barnthouse et al. 1988a) in an effort to end the stalemate that was increasingly apparent, especially concerning the long-term effects of the conditional mortality rates attributable to the power plants. These conditional entrainment and impingement mortality rates became the measures used to assess the impacts of existing operation. The successful result of these negotiations is summarized in Barnthouse et al. (1988a p. 269): "On December 19, 1980, the historic settlement agreement was signed by all parties. For the 10-year duration of the settlement, no cooling towers would be required. As an alternative, the utilities agreed to a variety of technical and operational changes intended to reduce entrainment and impingement. In addition, they agreed to supplement the production of striped bass in the Hudson River by means of a hatchery, to conduct a biological monitoring program, and to fund an independent research foundation for study of Hudson River environmental problems." The remainder of Barnthouse et al. (1988a) provides details of these elements of the settlement agreement.

The settlement agreement is expiring, and it is not certain what administrative procedures will occur in its aftermath. In responses to requests to federal and state agencies, NMFS mentioned that the Indian Point plant is "famous for entraining striped bass eggs and larvae" (Gorski 1990). The NMFS indicated that the attempt at mitigation by means of a striped bass hatchery has never been acceptable to the resource agencies, who have asked for closed-cycle cooling. The New York State Department of Environmental Conservation (NYSDEC) is the agency responsible for NPDES permits. It has expressed concerns about entrainment, impingement, and thermal discharge effects at Indian Point (Wich 1990). At present, entrainment and impingement effects at Indian Point are active issues; whether they will still be issues at the time of license renewal will be determined by the course of events that cannot now be predicted.

F.4.6 San Onofre Nuclear Generating Station

SONGS is a three-unit nuclear facility located on the coast of Southern California, roughly midway between Los Angeles and San Diego. All three units use once-through cooling systems, withdrawing water from the Pacific Ocean through submerged velocity-capped intake structures located at distances between approximately 900 and 980 m (3000 and 3200 ft) from shore in about 9 m (30 ft) of water. During normal operation, Unit 1 [436 MW(e)] withdraws water at a rate of 22 m^3/s (350,000 gal/min) and increases its temperature about 10°C (18°F) during passage through the plant. Units 2 and 3 are each rated at 1070

MW(e), and each withdraws approximately 50 m^3/s (800,000 gal/min), with a temperature increase of about 11°C (20°F). The Unit 1 discharge is through a single vertical pipe in 7.6 m (25 ft) of water about 762 m (2500 ft) from shore. Discharge of the larger units (2 and 3) is through 760-m (2500-ft) diffusers offset from one another and positioned more or less in sequence; for Units 2 and 3, they terminate 2500 m (8200 ft) and 1800 m (5900 ft) offshore, respectively.

Extensive studies of the effects of SONGS on aquatic biota have been conducted by the Marine Review Committee (MRC), appointed by the California Coastal Commission, over the period 1975–1989. These studies have recently been summarized and interpreted in a report of the MRC (MRC Document 89-02) supported by many other technical reports, databases, and other reports. Most of the conclusions are based on both near-field and far-field sampling before and after startup of Units 2 and 3. In the summary report, the extent of biological effects is estimated quantitatively. Adverse impacts are estimated to the kelp community (kelp, some fish, and kelp-bed invertebrates), to local populations of midwater fish species, and to far-field populations of fish in the Southern California Bight (the area between Point Conception and Cabo Colnett in northern Baja California). Besides quantifying these adverse impacts and identifying other biological effects, the report considers several distinct mitigative techniques, a combination of which is considered capable of providing complete mitigation (MRC Document 89-02). Note that the three-member MRC was not always unanimous in its judgments. In particular, one member felt that some of the conclusions understated the severity or extent of plant impact and that cooling towers should be installed as a mitigative measure.

Local adverse effects were measured on the kelp community in the San Onofre kelp bed (SOK), including giant kelp, kelp-bed fish, and large benthic kelp-bed invertebrates. The best estimate of reduction in the area covered by moderate- to high-density kelp in the SOK is 80 ha (200 acres). Fish living near the bottom in the SOK (e.g., sheephead, barred sandbass, and black surfperch) were estimated to be reduced by 70 percent [roughly 200,000 fish weighing about 25.4 metric tons (28 tons)] below the abundance expected in the absence of SONGS. The abundance of 13 species of snails and of the white sea urchin was estimated to have been reduced substantially (30–90 percent) below the levels expected without SONGS; other kelp-bed invertebrate species too rare to permit accurate sampling were also thought to have declined. According to the report, "these effects, although local, are deemed substantial because kelp is a valuable and limited habitat." These kelp-bed effects were attributed mainly to changes in the physical environment in the SOK as a result of the sometimes turbid discharge plume. These key environmental changes were (1) reduction in light levels reaching the bottom, (2) increases in the flow and the rates of particles near the bottom, and (3) modification of currents near the plant.

Two kinds of additional adverse impacts were attributed mainly to losses because of entrainment or impingement (see also Helvey 1985). First, reductions in the local abundance of some midwater fish populations were measured. The local abundance of queenfish (a forage fish) was reduced by an estimated 30 to 70 percent, depending on the location, out to a distance of 1.9 to 3.1 km (1.2 to 1.9 miles) from

SONGS. The estimated reduction for white croaker (a sport fish) was similar in magnitude, but over a smaller area. Several other species were believed to have experienced smaller reductions. Loss in the intake, predominantly due to impingement, was considered capable of explaining the loss of croaker and some of the loss of queenfish, but the operation of some other factor (such as plume turbidity) would also be required to explain some of the effects.

The second adverse entrainment/impingement impact concerns far-field effects. Consistent with the evaluation of such far-field effects in other plant-specific analyses (see, for example, the Hudson River power plants), the MRC report also recognizes that "even a major effect will be so diluted that the change will be indistinguishable from natural variation." For these effects, the MRC relied on inferred reductions rather than on attempts to measure effects. An "equivalent adult losses" method was used to estimate losses in recruitment due to measured (interpolated for young juveniles too small to be impinged) entrainment and impingement, and assumptions were made about the effect of biological compensation. Reductions "probably between one and ten percent" in the standing stocks of several midwater fish populations in the Southern California Bight were inferred. Because these latter entrainment/impingement effects could occur over large populations, they were considered by MRC to be substantial.

In contrast to these particular groups of organisms for which adverse plant impacts were measured or inferred, other groups of organisms showed no change or increased locally in abundance. With the exception of meroplankton (benthic larvae), which increased, other plankton was largely unaffected by operation of SONGS. Also, although entrainment of fish larvae, which are concentrated inshore at about the depths of the intakes, is considered an important contributor to reductions in adult stocks, there is no clear pattern of decreases in the abundance of fish larvae near SONGS. Differences between local and more distant sand crab populations are also felt to be unrelated to plant operation. General patterns of increases were seen among local benthic fish populations, soft-bodied benthic invertebrates, and mysids (semi- planktonic shrimp-like crustaceans).

Besides quantifying the biological effects of the operation of SONGS, the MRC report made recommendations concerning two sets of potential mitigative options. The first set concerned structural changes to the power plant. A majority of the MRC was opposed to backfitting cooling towers, and the MRC also discouraged moving the discharge diffusers. The second set of options would involve implementation of three to five mitigative techniques, selected from more than 30 that were considered. Finally, the MRC recommended increased monitoring as part of the changes to the NPDES program to determine the value of mitigative measures.

F.4.6.1 Cumulative Impacts

The MRC report (MRC Document 89-02) does not explicitly consider SONGS in the context of other power plants, of which there are at least six in the Southern California Bight (Helvey 1985). However, the fact that entrainment and impingement at these plants also contributes to impacts is recognized, and reduction of these impacts at other nearby plants is an optional part of one mitigative measure recommended by the MRC. In fact, noting studies at SONGS indicating that the thermal effluent from the plant is of little environmental concern, the

MRC states that "the greatest environmental protection might result from a waiver of thermal standards at Southern California Electric's coastal power plants, because this would minimize the volume of water pumped through the plants" (MRC Document 89-02, pp. 297–298).

As of late 1990, the California Coastal Commission had not acted on the MRC's recommendations (personal communication, R. F. Ambrose, Marine Science Institute, University of California, Santa Barbara, to S. W. Christensen, ORNL, Oak Ridge, Tennessee, October 5, 1990). The final MRC report initially gives the impression of considerable confidence in the conclusions of impact and in the ability of the recommended mitigative measures to achieve complete mitigation. Further reading reveals the importance of many estimates and assumptions made in reaching the conclusions and an explicit discussion of uncertainties. Whether the report's conclusions are contested or not remains to be seen. Nonetheless, the report demonstrates the ability of a focused, long-term project, applying consistent sampling and study techniques, to reach meaningful conclusions about the impacts of a power plant on aquatic organisms and about ways to mitigate these impacts.

F.4.7 Crystal River Nuclear Plant

The Crystal River Power Station consists of five units that withdraw cooling water from the Gulf of Mexico. Only one of the units, Unit 3, is nuclear powered; the other units are coal-fired. Two of the coal-fired units use closed-cycle cooling; the remaining units are once-through. All units use a common 5.5-km- (3.4-mile-) long intake canal and a 2.6-km- (1.6-mile-) long discharge canal (FPC 1985). Unit 3 discharges heated water into Crystal Bay at a rate of 43 m^3/s (680,000 gal/min) (Table 2.1); the total discharge of the three once-through units is approximately 83 m^3/s (1,318,000 gal/min) (FPC 1985). The change in temperature of the Unit 3 condensers is 9.5°C (17.1°F) (Table 2.3).

Important aquatic resources of Crystal Bay include a diverse benthic macroinvertebrate community, submerged macrophytes (seagrasses), coastal salt marshes, oyster reef communities, and a variety of finfish (e.g., bay anchovy, batfish, seatrout, red drum, spot, striped mullet) and shellfish (e.g., squid, shrimp, stone crab, blue crab) (FPC 1985).

Concerns about the impacts of the Crystal River Power Station on aquatic resources focus on thermal discharges and entrainment (Gardner 1990; Smallwood 1990). Based on data collected for the plant's 316(a) demonstration (FPC 1985), thermal effluents from the multiunit power station were considered by the Florida Department of Environmental Regulation (DER) to have substantially damaged the benthic macroinvertebrate and seagrass communities in a 1100-ha (2700-acre) mixing zone around the discharge canal (Olsen 1986). The DER also expressed concern about the entrainment by Crystal River Units 1, 2, and 3 of bay anchovies, crab larvae, and penaeid shrimp larvae. Conversely, DER agreed with the Florida Power Commission (FPC) conclusions that thermal discharges from Crystal River Units 1, 2, and 3 had enhanced productivity in the nearby salt marshes and increased the growth rates of oysters in areas moderately affected by heat.

Impacts to aquatic resources continue to be examined at this site as part of NPDES permit renewals. The Crystal River Station has recently been required by EPA to reduce total condenser cooling water withdrawals during a portion of the year [FPC, response to NUMARC survey (NUMARC)]. This flow reduction scheme would reduce the number of entrained organisms but would not reduce thermal effects. Installation of helper cooling towers would reduce thermal discharges from the Crystal River site (Charles Kaplan, Region 4 EPA, personal communication to G. F. Cada, ORNL, Oak Ridge, Tennessee, November 12, 1990).

F.5 SUMMARY

A detailed consideration of these once-through nuclear power plants indicates that many of the aquatic resources issues evaluated in the licensing stage have not materialized as significant problems. Even at facilities where impact potential is considered to be greatest, these impacts have been difficult to quantify. For example, while localized effects of phytoplankton entrainment or scouring of bottom sediments near the discharge structure have been demonstrated in some instances, such impacts have not precluded the maintenance of balanced, indigenous populations of shellfish, fish, and wildlife; and the regulatory agencies regard these effects as acceptable.

Conversely, these examples illustrate that the entrainment and impingement of fish and the discharge of heated effluents from once-through power plants continue to concern some regulatory and resource agencies. In some instances, the NPDES permit and 316(a) and (b) review processes have not been completed, and the acceptability of impacts or the need for mitigation are still under consideration. As noted in Section 4.2, those aquatic resources issues that have not been resolved to the satisfaction of EPA or the state water quality permitting agency as part of the discharge permitting process will need to be considered in the license renewal application.

F.6 ENDNOTES

1. The discrepancy between the estimates in the FES and the estimates provided by AP&L are probably explained in large part by one or both of two possibilities. First, comparison of information in Zweiacker et al. (1977) with AP&L's estimate suggests that AP&L's estimate may consist of actual collections of impinged fish during sampling that covered 6 days per week during 6 weeks per quarter, without scaling up to estimate impingement during periods not sampled. Second, the first year of operation represented by AP&L's estimates may not correspond exactly to the period for which estimates were made in the FES.

2. The National Reservoir Research Data Bases are available from Southeastern Wildlife and Fisheries Statistics Project, Institute of Statistics, North Carolina State University, Box 8203, Raleigh, NC 27605–8203. Documentation describing the data is not currently available. In addition, other caveats apply: serial correlation is possible and may interfere with the analysis, and other assumptions (e.g., equality of the within-group covariance matrices) sometimes were not satisfied or could not be tested.

3. The (calculated) estimates for both entrainment and impingement at the proposed plants appear to be too low by at least a factor of 8 in relation to the regression equations and the stated number and capacity of the new plants.

The reason for this apparent discrepancy cannot be determined from the information available (John Kelso, Great Lakes Biolimnology Laboratory, personal communication to S. W. Christensen, ORNL, Oak Ridge, Tennessee, January 28, 1991).

4. The staff presents these results from Jensen et al. but notes that it is not able to reproduce approximately the estimates of percentages impinged, even though seemingly sufficient information is provided in the paper. Insufficient information is provided to try to reproduce the estimates of percentages entrained.

5. The staff noted that the commercial catch estimates presented and used by Jensen et al. for alewife in Lake Michigan, but not for smelt, differ typically by a factor of 2 to 4—depending on the year—from those given by Scott-Wasilk et al. These differences result from the exclusion from the Scott-Wasilk et al. table of commercial catch data for alewife in Green Bay.

6. The source of the variation in the entrainment and impingement coefficients is not clear, but it may be derived from year-to-year variation in biomass in the models.

F.7 REFERENCES

AEC Docket 50-313, *Final Environmental Impact Statement Related to the Arkansas Nuclear One, Unit 1*, U.S. Atomic Energy Commission, February 1973.

AP&L (Arkansas Power and Light Company), *Arkansas Nuclear One Generating Station, Dardanelle Reservoir Environmental Monitoring Program, Summary Report of Environmental Impact of Thermal Discharge*, October 30, 1984.

AP&L. *Summary of Entrainment at Arkansas Nuclear One from 1977 through 1982*, undated report with responses to the NUMARC survey, 1990.

Barnthouse, L. W., and W. Van Winkle, "Analysis of Impingement Impacts on Hudson River Fish Populations," *American Fisheries Society Monograph*, **4**, 182–90, 1988.

Barnthouse, L. W., et al., "Hudson River Settlement Agreement: Technical Rationale and Cost Considerations," *American Fisheries Society Monograph*, **4**, 267–73, 1988a.

Barnthouse, L. W., et al., "Science, Law, and Hudson River Power Plants: A Case Study in Environmental Impact Assessment," *American Fisheries Society Monograph*, **4**, 1988b.

Barnthouse, L. W., et al., "What We Didn't Learn About the Hudson River, Why, and What It Means for Environmental Assessment," *American Fisheries Society Monograph*, **4**, 329–35, 1988c.

Carter, J. S., Duke Power Company, letter to S. W. Christensen, ORNL, Oak Ridge, Tennessee, September 4, 1990.

Chang, W. Y. B., and R. Rossman, "Effects of Power Plant Entrainment on Phytoplankton Response," *Verhandlungen Internationale Vereinigung Limnologie*, **22**, 2493–97, 1985.

Christensen, S. W., and T. L. Englert, "Historical Development of Entrainment Models for Hudson River Striped Bass," *American Fisheries Society Monograph*, **4**, 133–42, 1988.

CONF-740820 (STI/PUB/378, IAEA-SM-187/48), J. W. McMahon and A. E. Docherty, "Effects of Heat Enrichment on Species Succession and Primary Production in Fresh-Water Plankton," pp. 529–46 in *Proceedings of* *a Symposium on the Environmental Effects of Cooling Systems at Nuclear Power Plants*, 1975.

Duke Power Company, *McGuire Nuclear Station, 316(b) Predictive Study of Impingement and Entrainment*, Charlotte, North Carolina, 1978.

Duke Power Company, *McGuire Nuclear Station, 316(a) Demonstration*, Charlotte, North Carolina, 1985.

Duke Power Company, *McGuire Nuclear Station, Summary of Ecological Impacts, and Plan of Continuing Study: Supporting Documentation for Modification of NPDES Permit No. NC0024392*, Charlotte, North Carolina, 1988.

DUKE PWR/82-02, J. E. Hogan and W. D. Adair, eds., *Lake Norman Summary*, Vols. 1 and 2, Duke Power Company, Production Environmental Services, Huntersville, North Carolina, 1982.

Englert, T. L., and J. Boreman, "Historical Review of Entrainment Impact Estimates and the Factors Influencing Them," *American Fisheries Society Monograph*, 4, 143–51, 1988.

EPRI EA-5200s, *Compensatory Mechanisms in Fish Populations: Literature Reviews*, Vols. 1–3, Electric Power Research Institute, Palo Alto, California, 1987.

Evans, M. S., "Benthic and Epibenthic (*Microcrustaceans, Macrobenthos*) Community Structure in the Vicinity of a Power Plant, Southeastern Lake Michigan," *Verhandlungen Internationale Vereinigung Limnologie*, 22, 488–94, 1984.

Evans, M. S., et al., "Effects of the Donald C. Cook Nuclear Power Plant on Zooplankton of Southeastern Lake Michigan," pp. 125–39 in L. D. Jensen, ed., *Fourth National Workshop on Entrainment and Impingement*, EA Communications, Melville, New York, 1977.

FPC (Florida Power Corporation), *Final Report—Crystal River*, 316 Studies, Florida Power Corp., January 15, 1985.

Gardner, T., Florida Department of Natural Resources, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, May 30, 1990.

Geo-Marine, Inc., *The Distribution of Temperature and Dissolved Oxygen in the Vicinity of Arkansas Nuclear One, Final Report*, Vol. 1, conducted for Arkansas Power and Light Company, 1976.

Gorski, S. W., NMFS, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, July 18, 1990.

Hamilton, R. B., North Carolina Wildlife Resources Commission, conversation with S. W. Christensen, ORNL, Oak Ridge, Tennessee, August 31, 1990, clarifying a letter from R. B. Hamilton to G. F. Cada, ORNL, Oak Ridge, Tennessee, dated June 20, 1990.

Helvey, M., "Behavioral Factors Influencing Fish Entrapment at Offshore Cooling-Water Intake Structures in Southern California," *Marine Fisheries Review*, 47(1), 18–26, 1985.

Hutchison, J. B., Jr., "Technical Descriptions of Hudson River Electricity Generating Stations," *American Fisheries Society Monograph*, 4, 113–20, 1988.

Jensen, A. L., et al., "Use of Conventional Fishery Models to Assess Entrainment and Impingement of Three Lake Michigan Fish Species," *Transactions of the American Fisheries Society*, 111, 21–34, 1982.

Kelso, J. R. M., and G. S. Milburn, "Entrainment and Impingement of Fish by Power Plants in the Great Lakes Which Use the Once-Through Cooling Process," *Journal of Great Lakes Research*, 5, 182–94, 1979.

Kelso, J. R. M., and G. S. Milburn, "Response to Comment by J. Scott-Wasilk et al.," *Journal of Great Lakes Research*, 7, 495–97, 1981.

Klauda, R. J., et al., "What We Learned About the Hudson River: Journey Toward an Elusive Destination," *American Fisheries Society Monograph*, 4, 316–28, 1988.

Lewis, R. E., "Opportunity for Management of Natural Resources Through Utility and Regulatory Cooperation," *Presentations at the 120th Annual Meeting of the American Fisheries Society*, Pittsburgh, Pennsylvania, 1990.

Loar, J. M., et al. "An Analysis of Factors Influencing the Impingement of Threadfin Shad at Power Plants in the Southeastern U.S.," pp. 245–55 in L. D. Jensen, ed., *Fourth National Workshop on Entrainment and Impingement*, Chicago, Illinois, December 5, 1977, EA Communications, Inc., Melville, New York, 1978.

Madenjian, C. P., et al., "Intervention Analysis of Power Plant Impact on Fish Populations," *Canadian Journal of Fisheries and Aquatic Sciences*, 43, 819–29, 1986.

McInerny, M. C., "Gas-Bubble Disease in Three Fish Species Inhabiting the Heated Discharge of a Steam-Electric Station Using Hypolimnetic Cooling Water," *Water, Air, and Soil Pollution*, 49, 7–15, 1990.

MRC Document 89–02, W. W. Murdoch, et al., *Final Report of the Marine Review Committee to the California Coastal Commission*, California Coastal Commission, Marine Review Committee, San Francisco, 1989.

NUMARC (Nuclear Management and 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-0254, *Final Environmental Statement Related to Operation of Arkansas Nuclear One, Unit 2*, U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, 1977.

NUREG-CONF-002, S. W. Christensen, et al., "Defining and Determining the Significance of Impacts: Concepts and Methods," pp. 191-219 in R. K. Sharma et al., eds., *The Biological Significance of Environmental Impacts*, U.S. Nuclear Regulatory Commission, 1976.

Olsen, L. A., Florida Department of Environmental Regulation, interoffice memorandum to J. P. Subramani, Florida Department of Environmental Regulation, February 4, 1986.

Ricker, W. E., "Computation and Interpretation of Biological Statistics of Fish Populations," *Fisheries Research Board of Canada,* Bulletin 191, 1975.

Rickett, J. D., *Dardanelle Reservoir-Illinois Bayou Embayment Survey,* Progress Report Number 26, February 7, 1983.

Rickett, J. D., and Watson, R. L., "Phytoplankton Community Structure in Dardanelle Reservoir, Arkansas, 1975–1982," *Arkansas Academy of Science Proceedings*, 37, 70–73, 1983a.

Rickett, J. D., and Watson, R. L., "Zooplankton Community Structure in Dardanelle Reservoir, Arkansas, 1975–1982," *Arkansas Academy of Science Proceedings*, 37, 65–69, 1983b.

Rickett, J. D., and Watson, R. L., "Fluctuations and Relationships of Selected Physicochemical Parameters in Dardanelle Reservoir, Arkansas, 1975–1982," *Arkansas Academy of Science Proceedings*, 34, 98–102, 1985.

Scott-Wasilk, J., et al., "A Comment on the Paper by John R. M. Kelso and Gary S. Milburn, 'Entrainment and Impingement of Fish by Power Plants in the Great Lakes Which Use the Once-Through Cooling Process,'" [*J. Great Lakes Res.*, 5, 182–94 (1979)], *Journal of Great Lakes Research*, 7, 491–95, 1981.

Smallwood, S., Florida Department of Environmental Regulation, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, May 31, 1990.

Spigarelli, S. A., et al., "Selected Temperatures and Thermal Experience of Brown Trout, *Salmo Trutta*, in a Steep Thermal Gradient in Nature," *Env. Biol. Fish.*, 8(2), 137–49, 1983.

Thurber, N., and D. Jude, *Impingement Losses at the D. C. Cook Nuclear Plant During 1975–1979 with a Discussion of Factors Responsible and Relationships to Field Catches,* Special Report No. 104, Great Lakes Research Division, University of Michigan, Ann Arbor, Michigan, 1984.

Tilley, S., *A Summary of the Dardanelle Reservoir Fishery Survey Annual Reports*, Arkansas Power and Light, Environmental and Technical Services, 1983.

Van Winkle, W., et al., "An Analysis of the Ability to Detect Reductions in Year-Class Strength of the Hudson River White Perch (*Morone Americana*) Population," *Canadian Journal of Fisheries and Aquatic Sciences*, 38(6), 627–32, 1981.

Wich, K. F., NYSDEC, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, July 6, 1990.

Zweiacker, P. J., et al., "Evaluation of an Air-Bubble Curtain to Reduce Impingement at an Electric Generating Station," pp. 343–56 in *Proceedings of the 31st Annual Conference of the Southeastern Association of Fish and Wildlife Agencies*, Vol. 31, 1977.

APPENDIX G

POSTULATED ACCIDENTS

Postulated Accidents

G.1 STATISTICAL ANALYSIS

G.1.1 Introduction

For 28 nuclear plants, final environmental statement (FES) estimates of risk quantities exist: early fatality, normalized latent fatality, normalized total dose, and normalized expected cost. The last three estimates are normalized to a per 1000-MW(t) (thermal megawatts) basis. The estimates are made using the Calculation of Reactor Accident Consequences (CRAC) computer code for the middle year of the current licensing (MYL) period. The CRAC runs are costly and difficult, requiring expensive input data.

There are also 16-, 80-, and 240-km (10-, 50-, and 150-mile) exposure index projections for the MYL and for the middle year of the license renewal (MYR) period, usually either 2030 or 2050, for the 28 (FES) nuclear plants and 46 other (non-FES) plant sites. Exposure indices are population averages weighted by wind-direction frequency, as discussed in Chapter 5. The exposure index projections are relatively easy and inexpensive to compute. Thus, the FES data will be used to investigate the relationship between the calculated FES estimates of the four risk quantities and the exposure index and to derive a prediction equation with which we could (1) predict the MYR estimates as a function of exposure index and (2) place upper confidence bounds on the predictions.

Because of the basic design differences, a nuclear power plant's reactor type (pressurized water or boiling water) may be an important factor in the relationship between the risk quantity estimates and exposure index. Of the FES plants, 18 are pressurized-water reactors (PWRs) and 10 are boiling-water reactors (BWRs). BWRs can be further subgrouped based on the containment type (Mark I, Mark II, or Mark III), but among the FES plants there are only a few of each type. (For example, only two are Mark I containment plants.) Using a regression analysis that parallels the one to be described, tests were conducted for differences in regression parameters among the three boiling-water containment types, but none of significance for any risk estimate (i.e., $p > 0.05$ for all estimates) was found. Therefore, at the outset, all BWRs were identified simply as "B" and PWRs as "P."

Prediction equations are based on regression relations between risk estimates and exposure indices. Perhaps the most natural starting point is the straight-line model: estimate = $a + b$ (exposure index) + random error. Because there are two reactor types, two lines are considered simultaneously; that is,

$$\text{estimate} = a_{type} + b_{type}(\text{exposure index}) + e, \quad \text{(G.1)}$$

where e denotes a random error, and *type*, B or P, distinguishes BWRs from PWRs. The error term represents the lack of information that would be provided by other independent variables, if available, as well as the randomness of the 28 FES plants considered as a random sample of all plants. The CRAC estimate is deterministic in the sense that it is the output of a computer program but could also exhibit randomness associated with random input arguments. Eq. (G.1) has four parameters: two intercepts and two slopes.

Fitting the model gives least squares estimates of the a_{type} and b_{type}. Call them $\hat{a}_{type}$ and $\hat{b}_{type}$. For each plant in the observed data set, there are also predicted values, $\hat{a}_{type}$ + $\hat{b}_{type}$ (exposure index) and residuals, which are the estimates minus their predicted values. The residual for an observation may be thought of as an approximation to the error for that observation, because under fairly general conditions the difference approaches zero as the sample size increases.

The error component in a model like Eq. (G.1) is often assumed without justification to be normal. Perhaps this is because the parameter estimates do behave normally as the sample size increases (Huber 1981, Section 7-2). However, in applications involving prediction, it is known that the assumption of normality can lead to serious errors. This is because laws of large numbers, which apply to parameter estimates, do not apply to predictions of single new observations.

The objective is to obtain a strong regression relationship that will provide prediction confidence bounds and will allow inferences to be made regarding the regression parameters. To do this, a good regression must exhibit the following properties.

1. The distribution of residuals should be roughly normal—symmetric and without extreme outliers. This property ensures that the asymptotic (large-sample) normality of parameter estimates can be used as an adequate approximation in finite samples, which in turn is needed to make inferences about the parameters.

2. The residuals should show no trend in the predictor variable(s). The presence of a trend in the residuals suggests that additional (e.g., higher order) terms in the predictors might improve the fit significantly.

3. The residuals should be statistically stable in the predictor(s) (e.g., they should not fan out). If the residuals are not statistically stable, the error distribution probably changes with the predictors, so neither residuals nor errors can be lumped together for study, at least without other strong assumptions.

Properties 1, 2, and 3 can be assessed using residual plots.

The following discussion makes use of the R^2 statistic, known as "the squared multiple correlation coefficient" and "the proportion of explained variance." R^2 indicates how well data and model agree; it is 1 when the data fit perfectly. However, a higher R^2 does not automatically imply a better model. Additional predictor variables always increase R^2, regardless of whether there is any significant improvement, and the inclusion of insignificant terms in a model can inflate the standard errors of predictions based on it. Also, sometimes R^2 is quite high for models with severe outliers among the residuals. These factors were considered in the development of these models.

Now consider a new exposure index, say exposure index $'$, not necessarily in the original 28. A prediction of a new risk estimate (estimate$'$) at exposure index$'$ is obtained by simply plugging the new exposure index into the fitted regression model for the appropriate reactor type. According to the most common definition, an upper confidence bound U for estimate$'$ is a function of the observed data that satisfies the probability statement

$$P(estimate' \le U) = 1 - \alpha \quad (G.2)$$

for some specified level of confidence $1 - \alpha$. Often α is taken to be 0.05. The probability in Eq. (G.2) is with respect to an assumed statistical model, in our case Eq. (G.1), before (and not conditional upon) any of the observations. We have

$$estimate' = a_{type} + b_{type}\ (exposure\ index') + e' . \quad (G.3)$$

The random error components, e in Eq. (G.1) and e' in Eq. (G.3), affect the prediction problem in two ways. First, estimates $\hat{a}_{type}$ and $\hat{b}_{type}$ are uncertain. Second, even if a_{type} and b_{type} were known exactly, estimate$'$ would still not be known because of e'. As indicated above, assessing the errors $\hat{a}_{type}$ and $\hat{b}_{type}$ is fairly straightforward, although an asymptotic approximation is usually incurred. The difficulty is in estimating the distribution of e. Because our interest is in upper confidence bounds for predictions, there is special interest in the upper tail of the error distribution. Usually, many more observations are needed to estimate upper tails than for central quantities such as a mean.

Compounding the problem is that errors are not observed—they are only residuals. Although the residuals and errors converge as the sample size increases, the sample size is only 28. The residuals depend on $\hat{a}_{type}$ and $\hat{b}_{type}$. They do differ from the errors, and they are not statistically independent.

The "standard" approach to prediction confidence bounds is based on the assumption of normality of errors. When this assumption holds, the standard approach is optimal and valid in the sense of Eq. (G.2). When the assumption fails, Eq. (G.2) may be off considerably. This is discussed in further detail in Schmoyer (1990).

Coming up with small-sample regression prediction confidence bounds without making strong assumptions (e.g., normality of errors) is a difficult problem for which no good solution is currently known. Such confidence bounds would be considered "distribution free" or "nonparametric," because they require no parametric assumptions about the error distribution.

Schmoyer (1990) discusses asymptotically valid nonparametric prediction confidence bounds. For these bounds, under a few weak conditions, Eq. (G.2) holds in the limit as the sample size increases. Schmoyer discusses "bootstrap" (Stine 1985) and "cross-validation" (Butler and Rothman 1980) prediction bounds. The bootstrap bounds are computationally intensive and not exactly reproducible (i.e., they involve a Monte Carlo procedure). The cross-validation bounds were designed for symmetrically distributed data. However, Schmoyer considers an asymmetric analog. He also proposes new bounds and shows that they tend to be better than the cross-validation bounds in terms of approximating [Eq. (G.2)].

The asymptotically valid approach seems better than the standard approach, if normality is unsubstantiated. However, the former is still premised on a large-sample approximation. For this project, the prediction bounds proposed by Schmoyer were computed for comparison with the normal-theory approach. Disparity between the two suggests that the normal-theory bounds may be off. These bounds will here be referred to as the "distribution-free" bounds.

In Schmoyer, it is argued that distribution-free upper prediction bounds should not be calculated for levels of confidence higher than $1-1/(n + 1)$, where n is the sample size. This is related to the idea that the largest distribution-free upper prediction bound from a simple random sample of size n is the n^{th} (the largest) order statistic, and the probability that a new observation exceeds the n^{th} order statistic is $1/(n + 1)$.

If the assumption of normality is suspect, the same caveats would seem to apply even more strongly to the normal-theory bounds. One can formally use higher levels of confidence to obtain higher bounds. However, attaching an interpretation such as Eq. (G.2) to such bounds seems very tenuous.

As R^2 decreases from 1, the issue of statistical noise becomes more important and must be addressed. In particular, as R^2 decreases, the best predictions will tend to become considerably lower than their corresponding upper confidence bounds, whether normal or distribution free. For additional discussion of regression, residuals, prediction, and R^2, see Draper and Smith (1981).

G.1.2 Regressions

Individual regressions are discussed in the following paragraphs. For each regression, models such as Eq. (G.1) were fitted both without and with log-transforming the data. In the log case, logs of both estimates and exposure indices were used. In all cases, for the regressions without log transformations, the residuals have outliers and tend to fan out as the exposure index increases, whereas the residual plots look much better in the log case. This is illustrated in residual plots, which follow. Therefore, the no-log approach has not been pursued.

G.1.2.1 Early Fatality Caused by a Severe Accident

Because of a threshold dose phenomenon, it does not make sense to normalize early fatalities. Therefore, only the 22 plants with capacities greater than 3025 MW(t) (and consequently the largest source terms) were considered for this regression.

Of these, the Wolf Creek plant has an estimated early fatality that is (identically) zero and therefore had to be dropped when logs were taken. This leaves 21 plants for the early fatality regression. (Note that the zero expected early fatality estimate may be illogical in the sense that the expectation of a nonnegative quantity can only be zero if the quantity is itself zero with certainty.)

The FES consequence analyses found that most early fatalities occurred within 8 to 80 km (5 to 50 miles) of the plant. Therefore, early fatality was considered to be most highly related to the 16- or 80-km (10- or 50-mile) exposure indices. Consequently, the regression of early fatality on the 16- and 80-km (10- and 50-mile) indices was considered, first individually, then together in a multiple regression. R^2 values are 0.55 for the 16-km (10-mile) index, 0.32 for the 80-km (50-mile) index, and 0.68 for the multiple regression. Each of these regressions has a high overall significance ($p < 0.0001$). However, in the multiple case, the 16-km (10-mile) term is significant ($p = 0.0027$), whereas the 80-km (50-mile) term is not ($p = 0.93$). Therefore, only the 16-km (10-mile) exposure index and reactor type were selected for predicting early fatality.

Figure G.1 is a residual plot for the regression of early fatality on the 16-km (10-mile) exposure index and reactor type. This and all subsequent plots in this

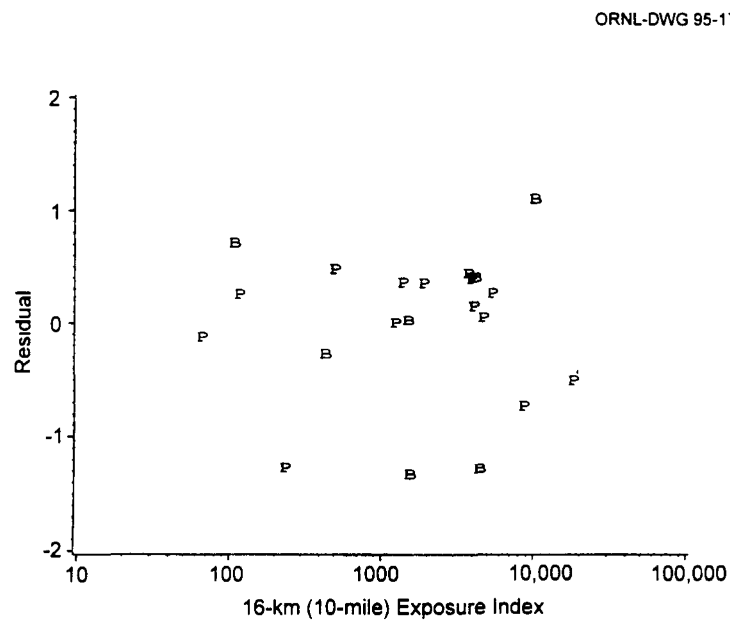

Figure G.1 Residuals from regression of the log of early fatality (average deaths per reactor year) on the log of 16-km (10-mile) exposure index of persons at risk. (Reactor type: B = boiling water, P = pressurized water.)

appendix are on base-10 log scales. Thus a difference of one unit in the residuals corresponds to a factor of 10 difference between the fitted and actual values on the original scale. It seems to satisfy properties 1 through 3, except perhaps for a tendency for the B residuals to be slightly more scattered. This could be because the B-types are not resolved into their three subclasses. The intercept and slope estimates (± standard error) for this regression are -7.81 ± 0.91 and 1.22 ± 0.28 for PWRs and -5.09 ± 1.40 and 0.42 ± 0.42 for BWRs.

Figure G.2 shows the log of acute fatalities within 16 km (10 miles) of 21 FES plants.

G.1.2.2 Normalized Latent Fatalities and Normalized Total Dose Resulting from a Postulated Severe Accident

Normalized latent fatalities and total dose are thought to be related to the 240-km (150-mile) exposure index. R^2 for the regression of either the normalized total dose or latent fatality on the 240-km (150-mile) index is 0.68. Both of these regressions are highly significant ($p < 0.0001$). Figures G.3 and G.4 are residual plots. In both cases, assumptions 1 through 3 seem to be met, except for (1) a tendency for the B residuals to be more dispersed, (2) a single P outlier, and (3) a slight suggestion that a quadratic term in the 240-km (150-mile) index might improve the fit. The significance levels for quadratic

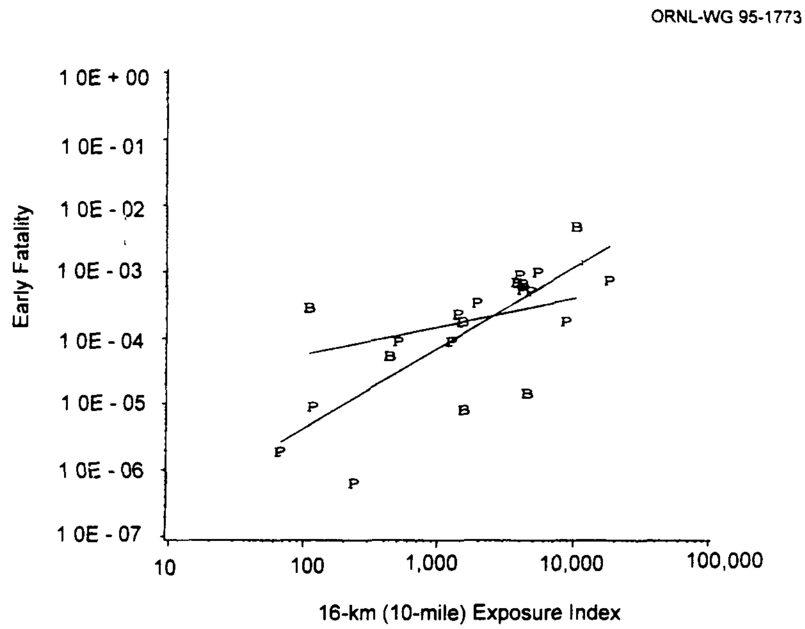

Figure G.2 **Log plot of early fatalities per reactor year within 16 km (10 miles) of 21 nuclear power plants [3300 MW(t) or greater], resulting from postulated accidents, regressed on log of exposure index (EI) for 16 km (10 miles).** (EI is the sum of the products of wind frequency in 22.5° quadrants and population in those sectors. P = pressurized-water reactors, B = boiling-water reactors.)

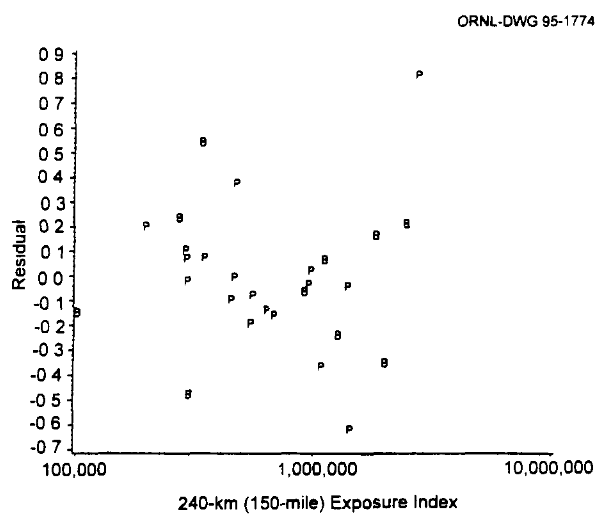

Figure G.3 **Residuals from regression of log of normalized latent fatality (average deaths per 1000-MW reactor-year) on the log of 240-km (150-mile) exposure index of persons at risk.** (Reactor type: B = boiling water, P = pressurized water.)

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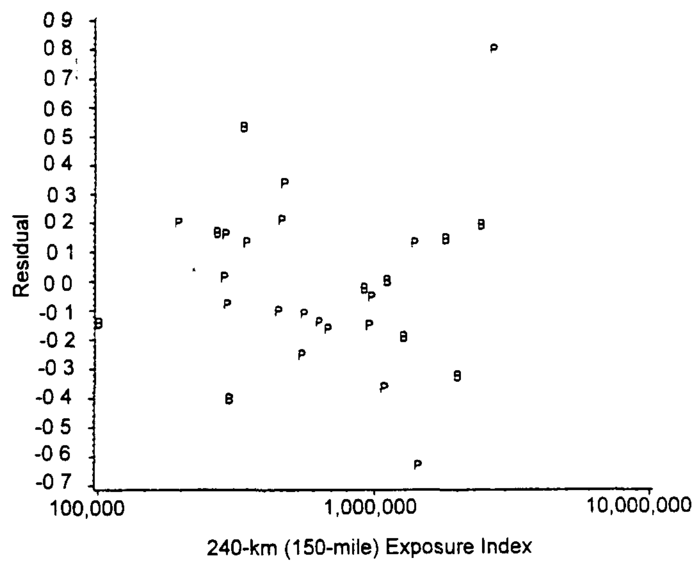

Figure G.4 Residuals from regression of the log of normalized total dose (rem per 1000-MW reactor-year) on the log of 240-km (150-mile) exposure index of persons at risk. (Reactor type: B = boiling water, P = pressurized water.)

terms, when included in the models, are 0.05 for normalized latent fatalities and 0.04 for normalized total dose. Fitting the quadratic terms does not improve the problem of the greater dispersion among B residuals. The outlier, which is Indian Point, is discussed further in Section G.1.3. Intercept and slope estimates are shown in Table G.1.

Figures G.5 and G.6 show the normalized latent fatalities and total dose, respectively, at 28 FES plants.

G.1.2.3 Normalized Expected Cost Resulting from a Postulated Severe Accident

Loss of property and other economic impacts caused by a postulated accident generally would be larger as population increased. Consequently, as with latent fatalities and fatal dose, it is reasonable to project the expected costs for an accident during the license renewal period using population or using the exposure index. Because the relationship of cost to the various candidate explanatory variables was less clear than in the fatality or dose cases, it was necessary to experiment with a greater variety of regression models. First considered were the regressions of normalized expected cost on 80-km (50-mile) radius population values; the 16-, 80-, and 240-km (10-, 50-, and 150-mile) exposure indices, and on each index in conjunction with population. Because only about half of the cost of an accident is expected to be incurred within 80 km (50 miles), the 240-km (150-mile) radius seems more appropriate.

Economic consequences were also benchmarked to the MELCOR Accident

Table G.1 Regression estimates (± standard error) for reactor plants

Dependent variable	Intercept	Slope
	Pressurized-water reactors	
Normalized latent fatalities	-11.35 ± 1.47	1.55 ± 0.25
Normalized total dose	-6.94 ± 1.45	1.51 ± 0.25
	Boiling-water reactors	
Normalized latent fatalities	-6.05 ± 1.32	0.67 ± 0.23
Normalized total dose	-1.78 ± 1.30	0.66 ± 0.25

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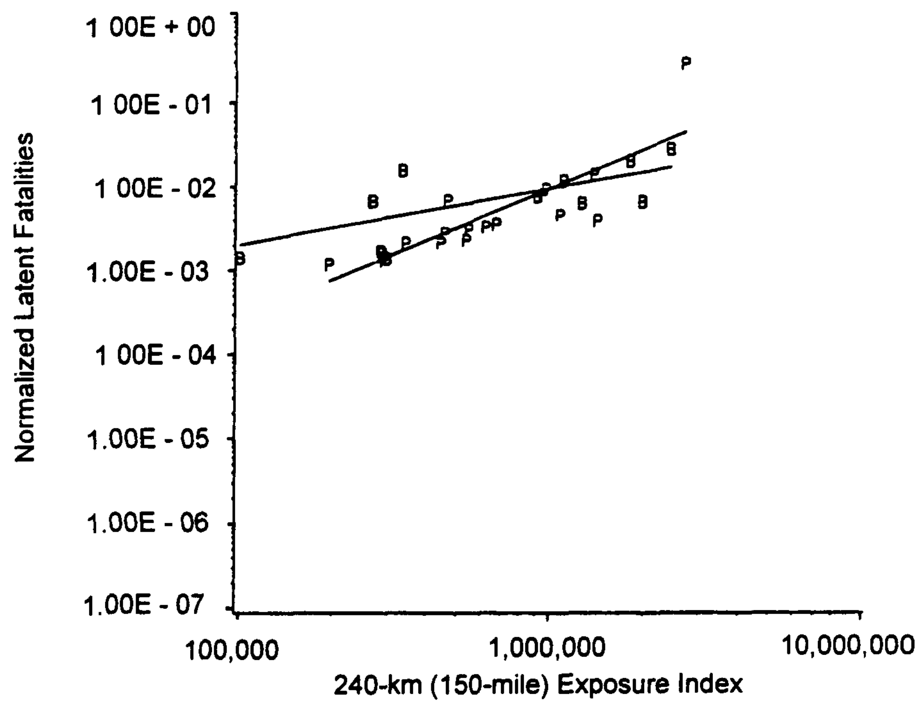

Figure G.5 Log plot of normalized latent fatalities per 1000 MW(t) per reactor-year of 28 nuclear power plants resulting from postulated accidents, regressed on log of exposure index (EI) at 240 km (150 miles). (EI is the sum of the products of wind frequency in 22.5° sectors and population in those sectors. P = pressurized-water reactors, B = boiling-water reactors.)

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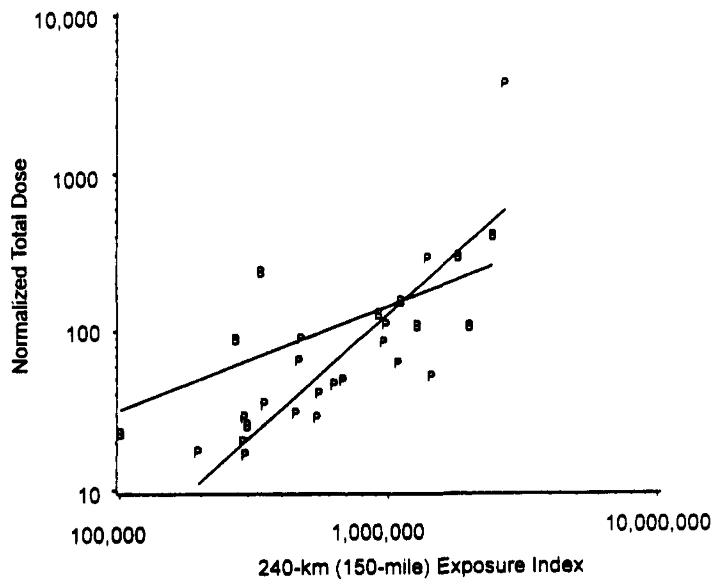

Figure G.6 **Log plot of normalized total dose in person-rem per 1000 MW(t) per reactor-year within 240 km (150 miles) of 28 nuclear power plants [3300 MW(t) or greater] resulting from postulated accidents, regressed on log of exposure index (EI).** (EI is the sum of the products of wind frequency in 22.5° sectors and population in those sectors. P = pressurized-water reactors, B = boiling-water reactors.)

Consequence Code System (MACCS) computer code to ensure the calculated values were based on the most current models and data. The benchmark computations indicated that the CRAC calculations used to estimate the economic impacts for the FES plants did not have a continuous linear relationship with population. Rather, the MACCS code predicted higher costs than did the CRAC code; low population sites were underpredicted by substantial margins. The differences were primarily due to the difference in the handling of decontamination costs in the two codes. Results from Tingle (1993) indicate that for the results to be comparable to results calculated from MACCS, the regression values should be adjusted through the use of population-dependent correction factors. Table 5.31 reflects average expected cost values that were derived from the regression and then corrected with the following factors:

- Sites with MYR 10 mile populations ≤ 10,000 multiply cost data by 40.
- Sites with MYR 10 mile populations > 10,000 and ≤ 50,000 multiply cost data by 25.
- Sites with MYR 10 mile populations > 50,000 multiply cost data by 15.

Also, the FES values were in 1980 dollars. To correct for this, the average expected cost values were inflated to 1994 dollars.

Because no expected cost data are available for Indian Point, these regressions are based on 27 observations. R^2 values for the regressions are listed in Table G.2.

All of these regressions are highly significant ($p < 0.0001$). However, in each of the multiple regressions, the regression terms associated with population, after adjusting for the exposure index, were insignificant ($p > 0.05$). Thus, the model based on reactor type and only the 240-km (150-mile) exposure index were selected for predicting normalized expected cost.

Figure G.7 is a residual plot for the regression of normalized expected cost on the 240-km (150-mile) exposure index. Assumptions 1 through 3 are supported, except that the residual dispersion is greater among the Bs than the Ps. The intercept and slope estimates for this regression are -4.12 ± 1.92 and 1.30 ± 0.33 for PWRs and -0.06 ± 1.45 and 0.62 ± 0.25 for BWRs. Figure G.8 shows the regression for normalized expected cost on the 150-mile exposure index.

G.1.2.4 Comments on the Regressions

The previous regression analyses have led to fairly simple straight-line models. There are problems with the models, however, particularly the greater dispersion among the B residuals. If separate B types (1, 2, 3) are considered, the B dispersion is much smaller—so small, in fact, that the B residuals should not be used for making predictions. This is because of the large number of parameters (i.e., slopes and intercepts) being used to accommodate the B data. In this case, the P residuals alone should be used to compute prediction intervals, even for the B data, and there are only 18 P residuals. According to our "1/(n+1)" rule, even 95 percent confidence levels would then be suspect. We could use 90 percent confidence intervals instead, but then the intervals would be shaky simply because 90 percent does not represent a very high level of confidence.

Table G.2 R^2 values for normalized expected cost regressions

Predictors	R^2 value
Reactor type and population	0.39
Reactor type and 16-km (10-mile) index	0.40
Reactor type and 80-km (50-mile) index	0.49
Reactor type and 240-km (150-mile) index	0.51
Reactor type, 16-km (10-mile) index, and population	0.45
Reactor type, 80-km (50-mile) index, and population	0.48
Reactor type, 240-km (150-mile) index, and population	0.56

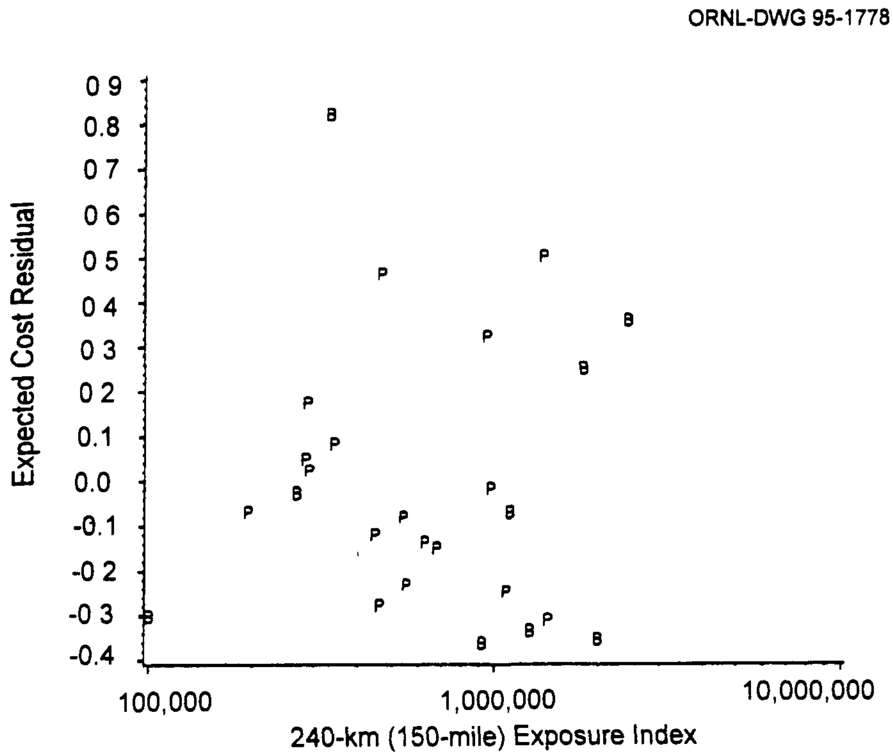

Figure G.7 **Residuals from regression of the log of normalized expected cost (dollars per 1000-MW reactor-year) on the log of 240-km (150-mile) exposure index of persons at risk.** (Reactor type: B = boiling water, P = pressurized water.)

Alternatively, separate regressions could be performed for the B and P data. However, because there are only ten B data points, the P predictions would still suffer from the small size and the B predictions even more so.

The best remedy for the problem of the greater B dispersion is to get more B data.

When the B residuals are numerous enough relative to the number of parameters being fitted to them, they can be used together with the P residuals to make predictions.

G.1.3 Predictions

Predictions are computed simply by plugging predictors into fitted regression equations. Collectively, they form the fitted regression line or curve. This is illustrated in Figures G.8 through G.16.

That the MYL exposure indices are representative of the MYR exposure indices is evident from the cumulative distribution functions in Figures G.17 and G.18. A cumulative distribution function of a set of data (here exposure indices) specifies for every number x the proportion of the set

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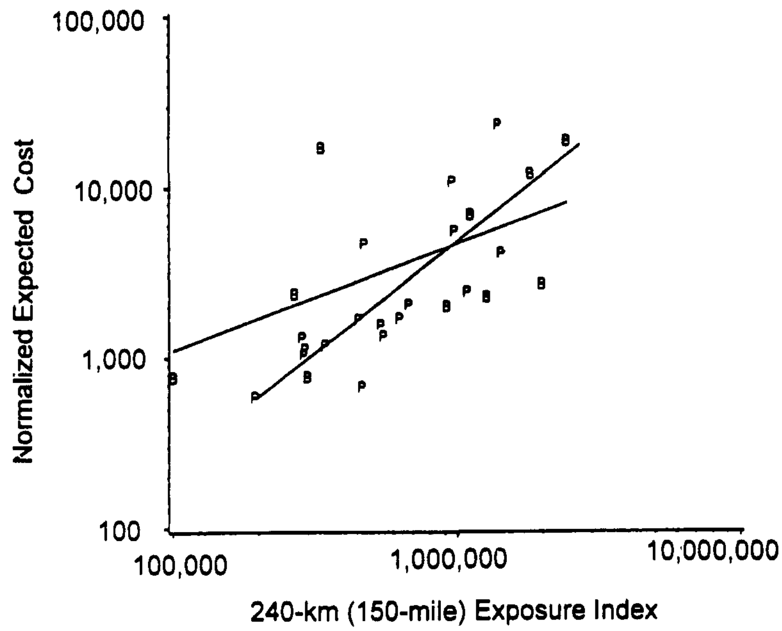

Figure G.8 **Log plot of normalized expected cost per 1000 MW(t) per reactor-year of 27 nuclear power plants [3300 MW(t) or greater] resulting from postulated accidents, regressed on the log of exposure index (EI).** (EI is the sum of the products of wind frequency in 22.5° sectors and population in those sectors. P = pressurized-water reactors, B = boiling-water reactors.)

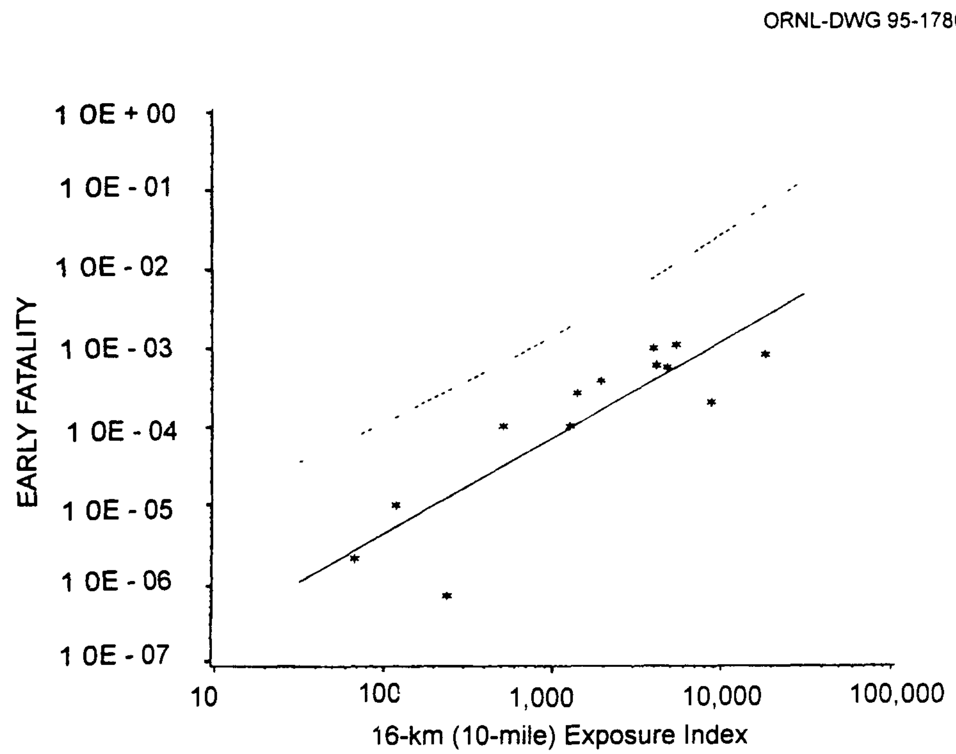

Figure G.9 **Log plot of early fatalities (average deaths per reactor-year) for final environmental statement pressurized-water reactor plants, fitted regression line, and 95 percent normal-theory upper prediction confidence bounds (dotted curve).**

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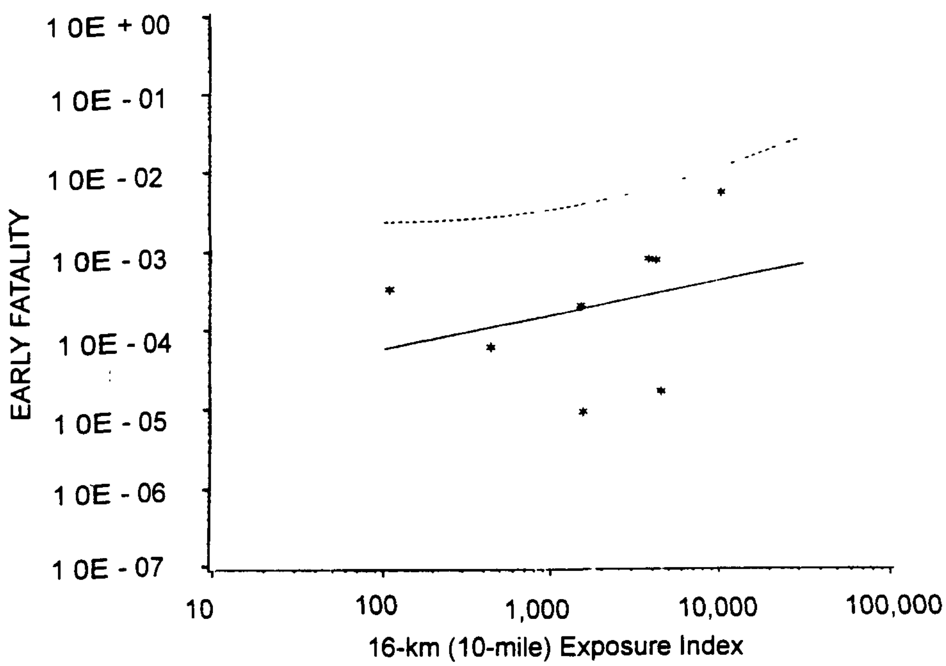

Figure G.10 **Log plot of early fatalities (average deaths per reactor-year) for final environmental statement boiling-water reactor plants, fitted regression line, and 95 percent normal-theory upper prediction confidence bounds (dotted curve.)**

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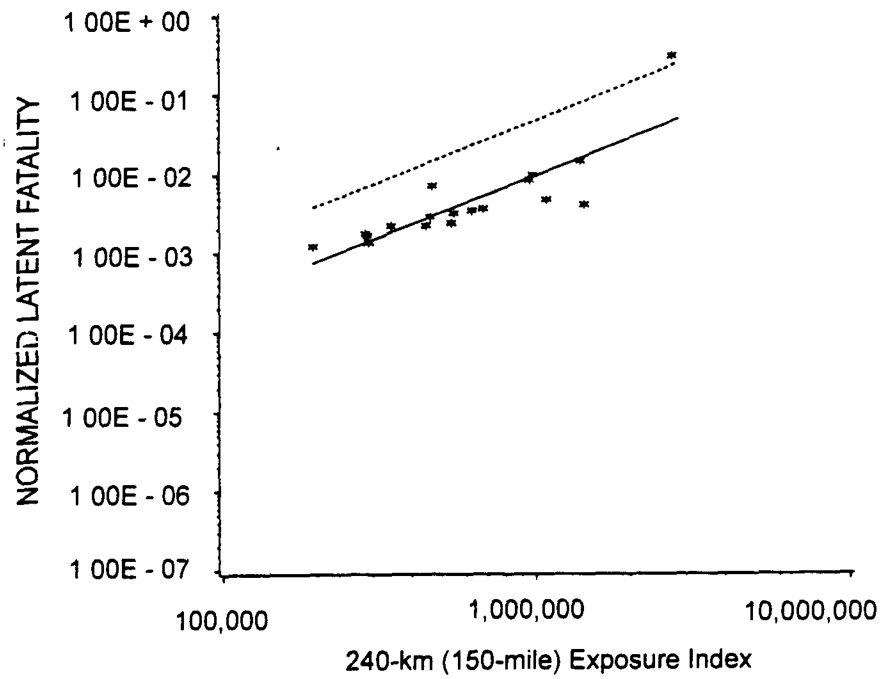

Figure G.11 **Log plot of normalized latent fatalities (average deaths per 1000-MW reactor-year) for final environmental statement pressurized-water reactor plants, fitted regression line, and 95 percent distribution-free upper prediction confidence bounds (dotted curve).**

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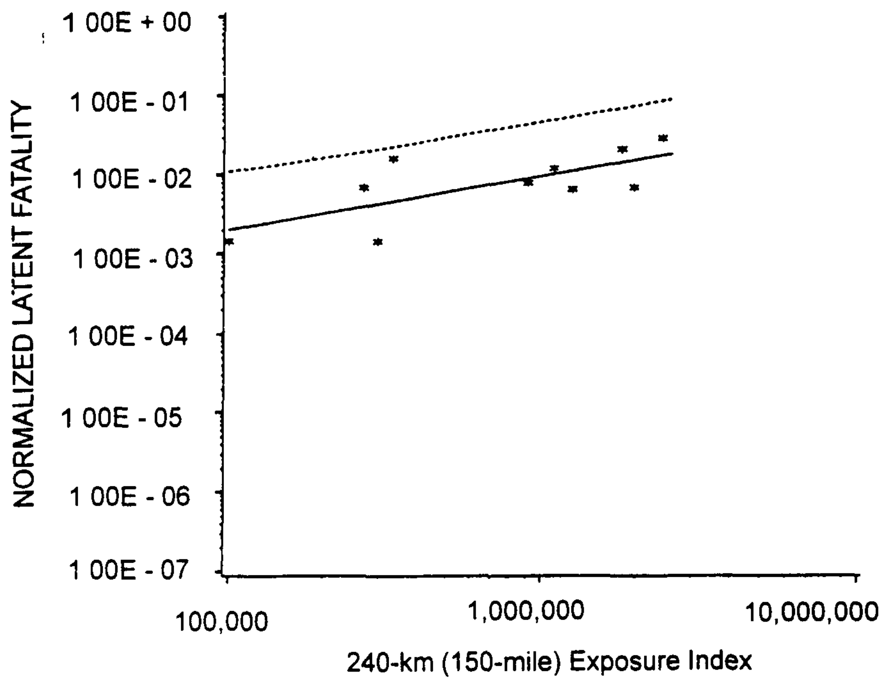

Figure G.12 **Log plot of normalized latent fatalities (average deaths per 1000-MW reactor-year) for final environmental statement boiling-water reactor plants, fitted regression line, and 95 percent distribution-free upper prediction confidence bounds (dotted curve).**

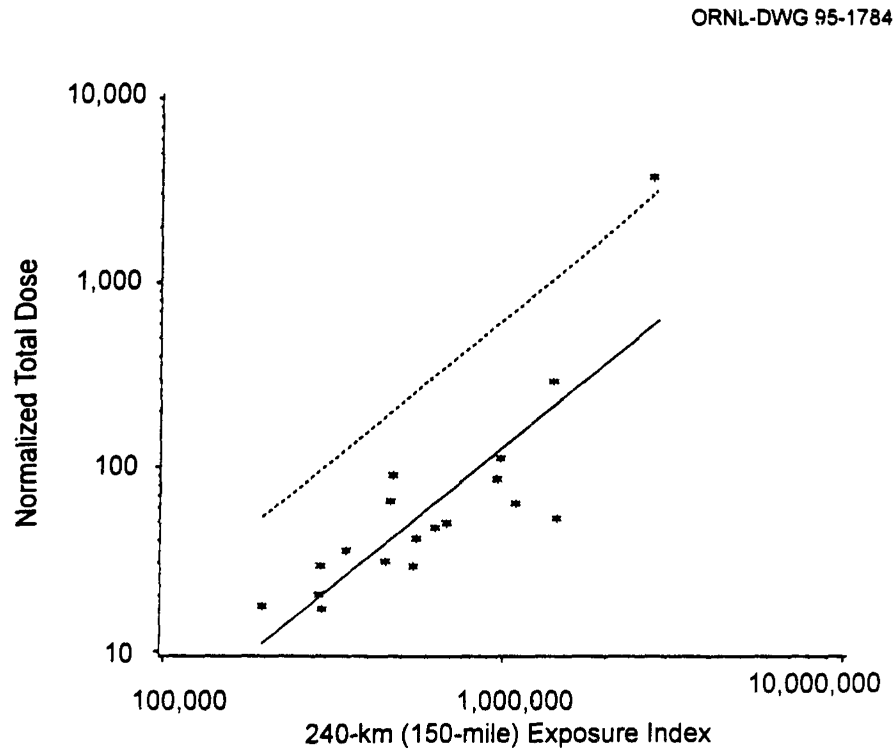

Figure G.13 **Log plot of normalized total dose (person-rem per 1000-MW reactor-year) for final environmental statement pressurized-water reactor plants, fitted regression line, and 95 percent distribution-free upper prediction confidence bounds (dotted curve).**

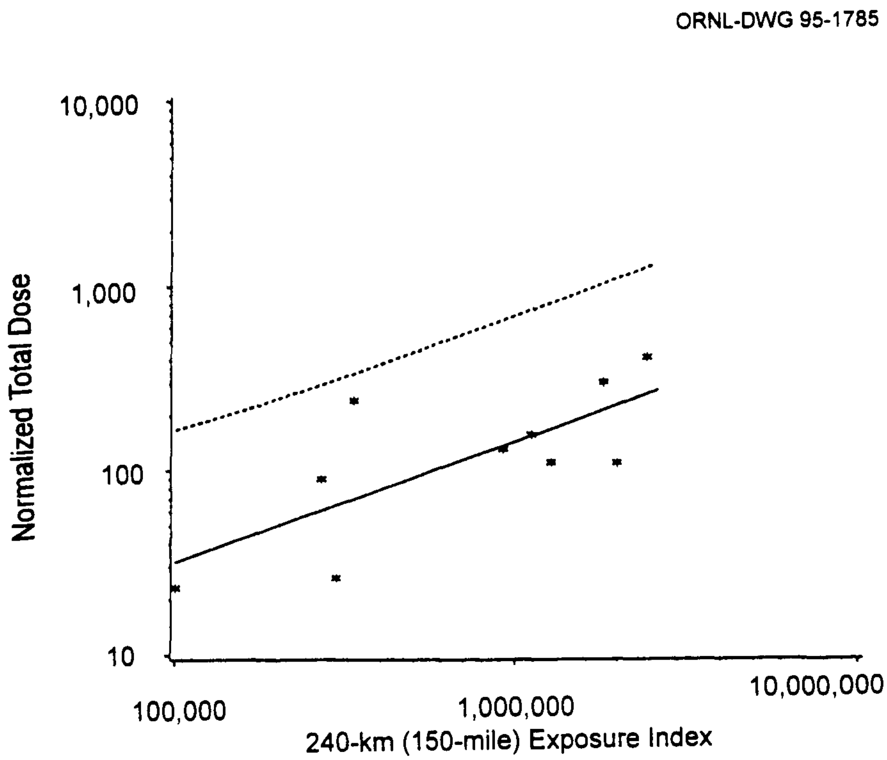

Figure G.14 **Log plot of normalized total dose (person-rem per 1000-MW reactor-year) for final environmental statement boiling-water reactor plants, fitted regression line, and 95 percent distribution-free upper prediction confidence bounds (dotted curve).**

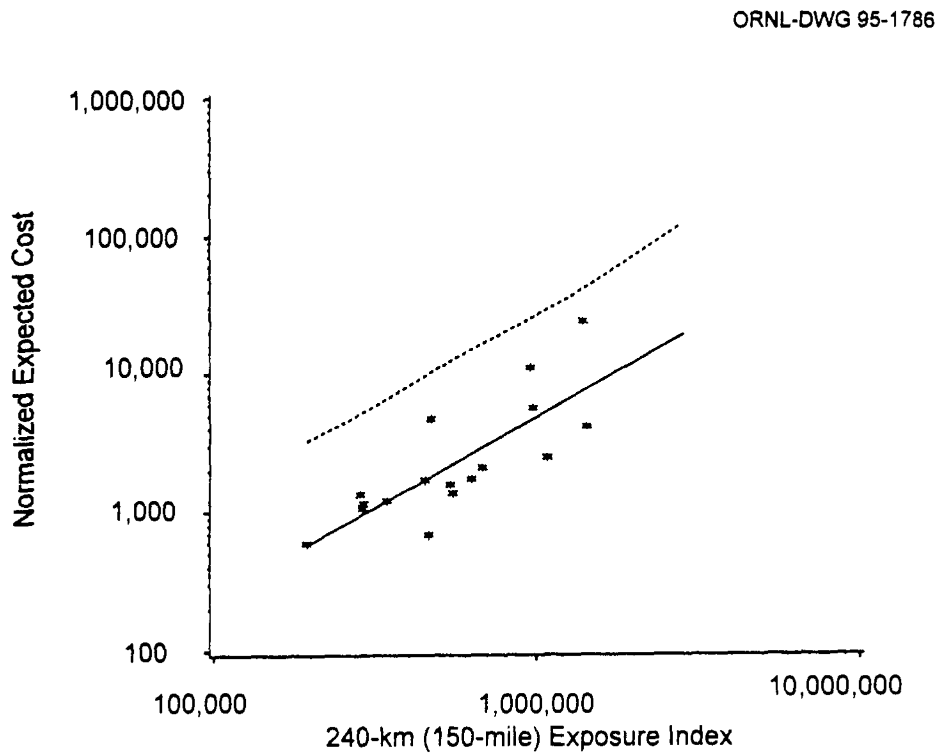

Figure G.15 **Log plot of normalized expected cost (dollars per 1000-MW reactor-year) for final environmental statement pressurized-water reactor plants, fitted regression line, and 95 percent distribution-free upper prediction confidence bounds (dotted curve).**

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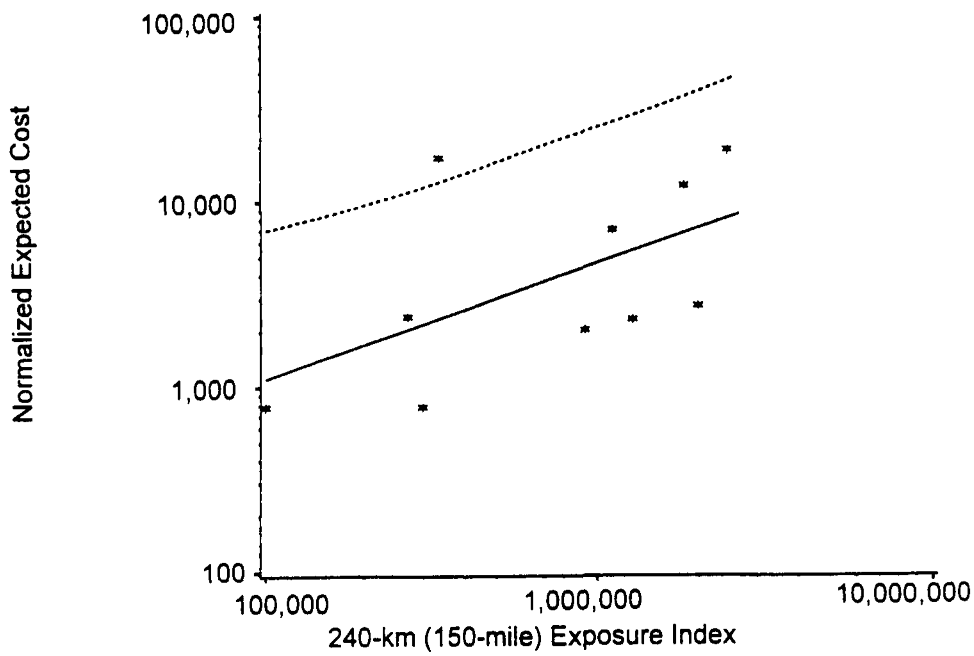

Figure G.16 **Log plot of normalized expected cost (dollars per 1000-MW reactor-year) for final environmental statement boiling-water reactor plants, fitted regression line, and 95 percent distribution-free upper prediction confidence bounds (dotted curve).**

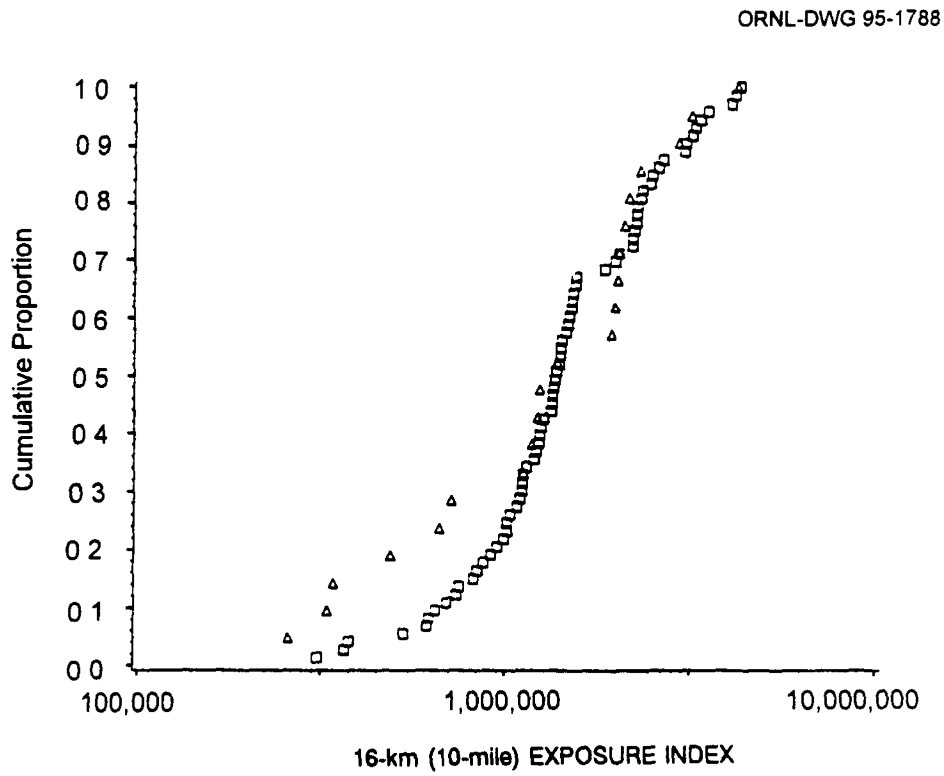

Figure G.17 **Cumulative proportions of the midyear license date for 16-km (10-mile) exposure index of persons at risk for final environmental statement plants and all other plants.** [Year: △ = middle year of license (MYL), □ = middle year of license renewal (MYR).]

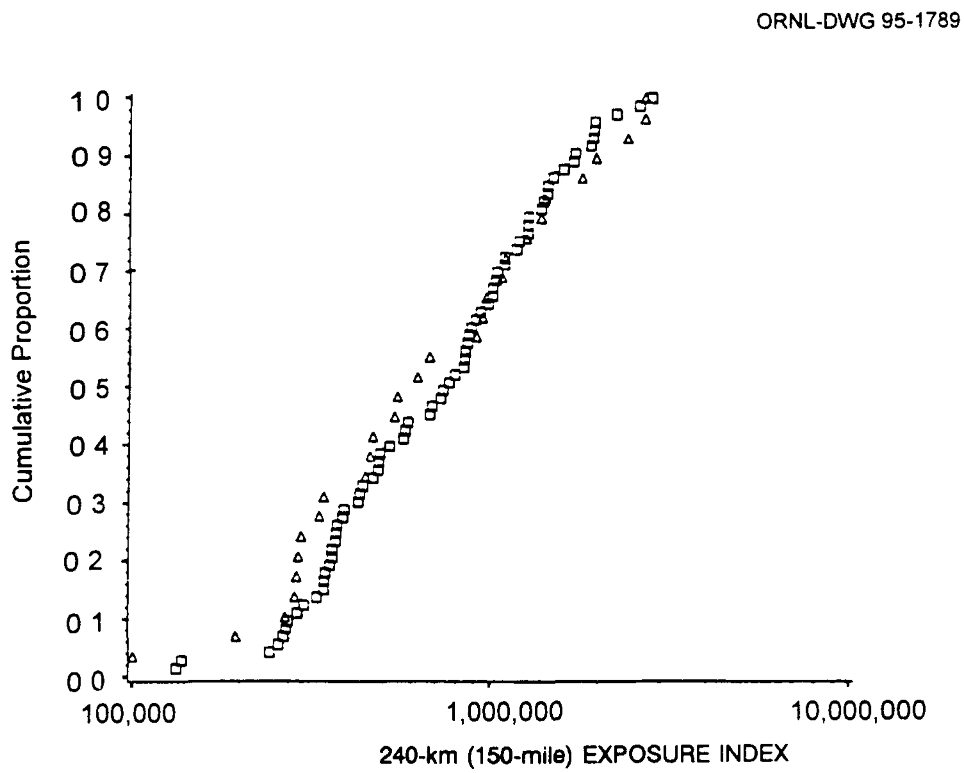

Figure G.18 Cumulative proportions of the midyear license date for 240-km (150-mile) exposure index of persons at risk for final environmental statement plants and all other plants. [Year: △ = middle year of license (MYL), □ = middle year of license renewal (MYR).]

having value no greater than *x*. In the figures, the MYL and MYR cumulative distribution functions are similar, indicating that the two populations are similar. Plots for individual reactor types are similar.

Representativeness is an advantage in several ways, one of which is that it implies that the predictions are not extrapolations. Extrapolation itself does not violate the assumptions of prediction interval theory, but it is known to exacerbate the effect of violating them.

When the assumption of normality of errors fails, normal-theory prediction confidence bounds can be far from valid. Testing the normal assumption in regression is a difficult problem. If regression errors were observable (rather than just residuals), a goodness-of-fit test for normality would be straightforward. Unfortunately, goodness-of-fit tests must be based on residuals, which depend on parameter estimates and are statistically dependent.

Even if errors were observable, it is essentially impractical to determine the practical importance of accepting or rejecting with a goodness-of-fit test. The test may be so lacking in power that an important deviation from normality would most likely go undetected. In that case, goodness-of-fit tests would likely also accept many non-normal distributions, some of which would imply considerably different prediction confidence limits. It can also happen that a goodness-of-fit test is so powerful that even unimportant deviations from normality would most likely be detected with high statistical significance.

In spite of the above caveats, a Shapiro-Wilks goodness-of-fit test for normality was performed on the regression residuals for the four models selected. Significance levels are $p = 0.04$ for acute fatalities, 0.55 for normalized total dose, 0.53 for normalized latent fatalities, and 0.21 for normalized expected cost. Thus, at least in the case of acute fatality, the normal assumption is immediately suspect. The outlying P residual in the normalized latent fatality and normalized total dose residual plots (Figures G.3 and G.4) casts doubt on the normal assumption for these variables as well, in spite of the acceptance of the goodness-of-fit test ($p > 0.05$).

Figures G.9 through G.16 contain the observed MYL data; the fitted regression lines; and normal-theory 95 percent (in the sense of Equation G.2) upper prediction confidence bounds for the fatality, dose, and cost variables. In our application, the sample size n is either 21, 27, or 28. [FES early fatalities could not be normalized, so only plants with MWT(t) > 3000 (21 out of 28 FES plants) were used to develop the correlation for early fatalities.]

The $n/(n+1)$ upper limit for a suitable level of confidence for prediction bounds is thus either 0.95, 0.96, or 0.97. Because 0.95 is a standard level, it is used for all prediction bounds.

The acute fatality regression is based only on plants of more than 3025 MW(t). These plants should tend to have greater expected acute fatality estimates than plants of less than 3025 MW(t). Therefore, acute fatality predictions based on the fitted regression for plants with less than 3025 MW(t) should tend to be high and thus conservative.Also computed for comparison were 95 percent distribution-free upper bounds, discussed in the introduction of this appendix and in Schmoyer. Tables G.3 through G.6 contain predictions and normal and distribution-free upper 95 percent prediction confidence bounds for the variables. Although the best fitted lines for both B and P reactors are determined solely by their own respective data, it is important to note that all (i.e., both B and P) residuals affect the upper prediction bounds, whether normal or distribution free. The MYR predictions are based on a projection of the exposure index for those time points (usually 2030 or 2050). The MYL actual estimates, when available, are included for reference.

In comparing the normal theory and distribution-free predictions bounds, the normal bounds can be either higher or lower. In the case of acute fatalities, they are higher, in the other cases, they are lower. In all cases they are clearly different. What the difference means in terms of practical importance is critical here, but it is not a statistical issue.

Table G.3 Middle year of the license renewal (MYR) early fatality predictions

Power plant	Reactor type[a]	16-km (10-mile) exposure index	MYL[b] early fatality estimate × 1000	MYR early fatality prediction × 1000	Normal theory 95 percent UCB[c] × 1000	Distribution free 95 percent UCB × 1000
Arkansas	P	1993		0.17	3.3	2.1
Beaver Valley	P	9535	2.0	1.1	25	17
Bellefonte	P	2317		0.20	4.0	2.5
Big Rock Point	B	476		0.11	2.7	1.9
Braidwood	P	2126	0.38	0.18	3.6	2.3
Browns Ferry	B	2019		0.20	4.3	2.8
Brunswick	B	1195		0.16	3.5	2.2
Byron	P	1468	0.26	0.11	2.3	1.4
Callaway	P	541	0.10	0.034	0.69	0.44
Calvert Cliffs	P	1232		0.093	1.8	1.2
Catawba	P	7219	1.1	0.80	17	11
Clinton	B	760	0.0090	0.13	3.0	2.0
Commanche Peak	P	1518	0.10	0.12	2.3	1.5
Cooper	B	411		0.10	2.6	1.8
Crystal River	P	1064		0.077	1.5	0.98
DC Cook	P	4163		0.41	8.4	5.4
Davis Besse	P	979		0.070	1.4	0.89
Diablo Canyon	P	1020		0.073	1.5	0.93
Dresden	B	2345		0.22	4.6	3.0
Duane Arnold	B	6283		0.33	8.0	5.6
Farley	P	1021		0.074	1.5	0.93
Fermi 2	B	4919	0.74	0.30	6.8	4.6
Fitzpatrick	B	1532		0.18	3.8	2.5
Fort Calhoun	P	1155		0.086	1.7	1.1
Ginna	P	2291		0.20	3.9	2.5
Grand Gulf	B	562	0.060	0.12	2.8	1.9
Haddam Neck	P	5476		0.57	12	7.7

See footnotes at end of table

Table G.3 (continued)

Power plant	Reactor type[a]	16-km (10-mile) exposure index	MYL[b] early fatality estimate × 1000	MYR early fatality prediction × 1000	Normal theory 95 percent UCB[c] × 1000	Distribution free 95 percent UCB × 1000
Hatch	B	372		0.099	2.6	1.8
Hope Creek	B	1807	0.0090	0.19	4.1	2.6
Indian Point 2						
Indian Point 3			0.83			
Kewanee	P	671		0.044	0.89	0.57
La Salle	B	1307		0.17	3.6	2.3
Limerick	B	10709	5.4	0.41	11	8.7
Maine Yankee	P	1246		0.094	1.8	1.2
McGuire	P	4919		0.50	10	6.7
Millstone 3	P	9420	0.20	1.1	25	16
Monticello	B	1832		0.19	4.1	2.6
Nine Mile Point	B	1568	0.20	0.18	3.8	2.5
North Anna	P	704		0.047	0.94	0.60
Oconee	P	5184		0.53	11	7.2
Oyster Creek	B	5584		0.31	7.4	5.1
Palisades	P	2421		0.21	4.2	2.7
Palo Verde	P	96	0.0021	0.0041	0.11	0.078
Peach Bottom	B	1972		0.20	4.2	2 7
Perry	B	5020	0 016	0.30	6.9	4.7
Pilgrim	B	1435		0.18	3.7	2.4
Point Beach	P	1612		0.13	2.5	1.6
Prarie Island	P	2188		0.19	3 7	2.4
Quad Cities	B	2228		0.21	4.5	2.9
Rancho Seco	P	835		0.058	1.1	0.73
River Bend	B	1857	0.40	0 20	4.1	2.7
Robinson	P	1889		0.16	3.1	2 0
Salem	P	1808		0.15	2.9	1 9

See footnotes at end of table

Table G.3 (continued)

Power plant	Reactor type[a]	16-km (10-mile) exposure index	MYL[b] early fatality estimate × 1000	MYR early fatality prediction × 1000	Normal theory 95 percent UCB[c] × 1000	Distribution free 95 percent UCB × 1000
San Onofre	P	5179	1.0	0.53	11	7.2
Seabrook	P	5234	0.60	0.54	11	7.3
Sequoyah	P	3471		0.33	6.6	4.2
Sheron Harris	P	1773	0.18	0.14	2.8	1.8
Shoreham	B	5915		0.32	7.7	5.3
South Texas	P	278	0 00070	0.15	0.33	0.22
St. Lucie	P	11447	0.070	1.4	32	22
Summer	P	902	0.17	0.063	1.3	0.80
Surry	P	6796		0.74	16	10
Susquehanna	B	3976	0.77	0.27	6.0	4.0
TMI	P	10327		1.2	28	19
Trojan	P	12556		1.6	37	25
Turkey Point	P	17852		2.4	60	42
Vermont Yankee	B	2408		0.22	4.6	3.0
Vogtle	P	141	0.010	0.0066	0.16	0.11
WNP-2	B	134	0.32	0.064	2.3	2.0
Waterford	P	6163	0.57	0.66	14	9.1
Watts Bar	P	1241		0.093	1.8	1.2
Wolf Creek	P	381		0.022	0.47	0.30
Yankee Rowe	P	1998		0.17	3.3	2.1
Zion	P	16913		2.3	56	39

[a]P = pressurized-water reactor; B = boiling-water reactor.
[b]MYL = middle year of license.
[c]UCB = upper confidence bound.

Table G.4 Middle year of the license renewal (MYR) normalized latent fatality (NLF) predictions

Power plant	Reactor type[a]	240-km (150-mile) exposure index	MYL[b] NLF estimate × 1000	MYR NLF prediction × 1000	Normal theory 95 percent UCB[c] × 1000	Distribution free 95 percent UCB × 1000
Arkansas	P	265479		1.2	4.5	6.0
Beaver Valley	P	1021547	8.3	9.8	35	49
Bellefonte	P	678549		5.2	18	26
Big Rock Point	B	136942		2.5	11	13
Braidwood	P	1615088	4.0	20	76	100
Browns Ferry	B	491751		6.0	22	30
Brunswick	B	256923		3.8	15	19
Byron	P	1214624	4.7	13	47	64
Callaway	P	373564	2.2	2.1	7.4	10
Calvert Cliffs	P	1459323		17	64	86
Catawba	P	914688	3.6	8.2	30	42
Clinton	B	1418383	6.6	12	45	61
Commanche Peak	P	353530	1.3	2.0	7.1	9.9
Cooper	B	428471		5.4	20	27
Crystal River	P	573211		4.0	14	20
DC Cook	P	1051654		10	37	51
Davis Besse	P	1104797		11	40	55
Diablo Canyon	P	302887		1.5	5.4	7.4
Dresden	B	1193394		11	40	54
Duane Arnold	B	329426		4.5	17	23
Farley	P	344405		1.8	6.6	9.1
Fermi 2	B	1287935	12	11	42	57
Fitzpatrick	B	270532		4.0	15	20
Fort Calhoun	P	242370		1.0	3.9	5.3
Ginna	P	357773		1.9	6.9	9.6
Grand Gulf	B	388245	1.4	5.1	19	25

See footnotes at end of table.

Table G.4 (continued)

Power plant	Reactor type[a]	240-km (150-mile) exposure index	MYL[b] NLF estimate × 1000	MYR NLF prediction × 1000	Normal theory 95 percent UCB[c] × 1000	Distribution free 95 percent UCB × 1000
Haddam Neck	P	1722399		22	85	110
Hatch	B	347873		4.7	18	24
Hope Creek	B	1955878	21	15	58	76
Indian Point	P	2863844		49	200	260
Indian Point 2			300			
Indian Point 3						
Kewanee	P	440217		2.6	9.4	13
La Salle	B	1396350		12	45	60
Limerick	B	2647224	29	18	74	95
Maine Yankee	P	391929		2.2	7.9	11
McGuire	P	890305		7.9	28	40
Millstone 3	P	1510698	15	18	68	90
Monticello	B	487606		5.9	22	30
Nine Mile Point	B	273322	6.9	4 0	15	20
North Anna	P	876587		7.7	28	39
Oconee	P	867675		7.6	27	38
Oyster Creek	B	1970098		15	58	77
Palisades	P	1041961		10	37	51
Palo Verde	P	290395	1.2	1.4	5.1	6.9
Peach Bottom	B	1453860		12	46	62
Perry	B	1021049	8.0	9.7	36	49
Pilgrim	B	486154		5.9	22	30
Point Beach	P	469985		2.9	10	15
Prarie Island	P	375227		2.1	7.4	10
Quad Cities	B	854803		8 6	31	43
Rancho Seco	P	992605		9 4	34	47
River Bend	B	432680	16	5.5	20	27

See footnotes at end of table.

Table G.4 (continued)

Power plant	Reactor type[a]	240-km (150-mile) exposure index	MYL[b] NLF estimate × 1000	MYR NLF prediction × 1000	Normal theory 95 percent UCB[c] × 1000	Distribution free 95 percent UCB × 1000
Robinson	P	738770		5.9	21	30
Salem	P	1979840		27	110	140
San Onofre	P	1284282	9.7	14	52	70
Seabrook	P	523715	2.2	3.5	12	18
Sequoyah	P	769140		6.3	22	32
Sheron Harris	P	688554	3.2	5.3	19	27
Shoreham	B					
South Texas	P	579617	2.8	4.1	14	21
St. Lucie	P	727763	2.4	5.8	21	29
Summer	P	852405	3.4	7.4	26	37
Surry	P	846246		7.3	26	37
Susquehanna	B	2279528	6.9	17	66	85
TMI	P	1928285		26	100	130
Trojan	P	944628		8.7	31	44
Turkey Point	P	345115		1.8	6.6	9.1
Vermont Yankee	B	1286085		11	42	57
Vogtle	P	590283	7.0	4.2	15	21
WNP-2	B	132195	1.5	2.5	10	13
Waterford	P	370569	1.7	2.0	7.3	10
Watts Bar	P	798733		6.7	24	34
Wolf Creek	P	363380	1.6	2.0	7.1	9.9
Yankee Rowe	P	1739663		22	86	110
Zion	P	1107448		11	40	56

[a]P = pressurized-water reactor; B = boiling-water reactor
[b]MYL = middle year of license.
[c]UCB = upper confidence bound.

Table G.5 Middle year of the license renewal (MYR) normalized total dose (NTD) predictions

Power plant	Reactor type[a]	240-km (150-mile) exposure index	MYL[b] NTD estimate	MYR NTD prediction	Normal theory 95 percent UCB[c]	Distribution free 95 percent UCB
Arkansas	P	265479		18	64	85
Beaver Valley	P	1021547	87	130	480	650
Bellefonte	P	678549		72	250	360
Big Rock Point	B	136942		39	160	200
Braidwood	P	1615088	53	270	1000	1300
Browns Ferry	B	491751		91	330	440
Brunswick	B	256923		59	220	290
Byron	P	1214624	64	170	630	840
Callaway	P	373564	35	29	100	140
Calvert Cliffs	P	1459323		230	840	1100
Catawba	P	914688	50	110	400	550
Clinton	B	1418383	110	180	670	880
Commanche Peak	P	363530	17	28	100	140
Cooper	B	428471		83	300	400
Crystal River	P	573211		56	200	280
DC Cook	P	1051654		140	500	680
Davis Besse	P	1104797		150	540	730
Diablo Canyon	P	302887		21	77	100
Dresden	B	1193394		160	590	790
Duane Arnold	B	329426		70	260	340
Farley	P	344405		26	93	130
Fermi 2	B	1287935	160	170	620	830
Fitzpatrick	B	270532		61	230	300
Fort Calhoun	P	242370		15	57	74
Ginna	P	357773		27	98	130
Grand Gulf	B	388245	26	78	280	380
Haddam Neck	P	1722399		290	1100	1400

See footnotes at end of table.

Table G.5 (continued)

Power plant	Reactor type[a]	240-km (150-mile) exposure index	MYL[b] NTD estimate	MYR NTD prediction	Normal theory 95 percent UCB[c]	Distribution free 95 percent UCB
Hatch	B	347873		72	270	350
Hope Creek	B	1955878	300	220	850	1100
Indian Point	P	2863844		630	2600	3200
Indian Point 2			3800			
Indian Point 3						
Kewanee	P	440217		38	130	180
La Salle	B	1396350		180	660	870
Limerick	B	2647224	410	270	1100	1400
Maine Yankee	P	391929		32	110	150
McGuire	P	890305		110	380	530
Millstone 3	P	1510698	290	240	890	1200
Monticello	B	487606		90	330	440
Nine Mile Point	B	273322	90	62	230	300
North Anna	P	876587		110	370	520
Oconee	P	867675		100	370	510
Oyster Creek	B	1970098		230	860	1100
Palisades	P	1041961		140	490	670
Palo Verde	P	290395	18	20	73	97
Peach Bottom	B	1453860		190	680	900
Perry	B	1021049	130	150	530	710
Pilgrim	B	486154		90	330	440
Point Beach	P	469985		41	150	200
Prarie Island	P	375227		30	100	140
Quad Cities	B	854803		130	470	630
Rancho Seco	P	992605		130	450	620
River Bend	B	432680	240	84	300	400
Robinson	P	738770		82	290	400
Salem	P	1979840		360	1400	1800

See footnotes at end of table

Table G.5 (continued)

Power plant	Reactor type[a]	240-km (150-mile) exposure index	MYL[b] NTD estimate	MYR NTD prediction	Normal theory 95 percent UCB[c]	Distribution free 95 percent UCB
San Onofre	P	1284282	110	190	690	910
Seabrook	P	523715	31	49	170	240
Sequoyah	P	769140		87	310	430
Sheron Harris	P	688554	41	74	260	360
Shoreham	B					
South Texas	P	579617	66	57	200	280
St. Lucie	P	727763	29	80	280	390
Summer	P	852405	47	100	360	500
Surry	P	846246		100	350	490
Susquehanna	B	2279528	110	250	960	1200
TMI	P	1928285		350	1300	1700
Trojan	P	944628		120	420	580
Turkey Point	P	345115		26	93	130
Vermont Yankee	B	1286085		170	620	830
Vogtle	P	590283	91	59	200	290
WNP-2	B	132195	23	38	160	200
Waterford	P	370569	20	29	100	140
Watts Bar	P	798733		92	320	450
Wolf Creek	P	363380	29	28	100	140
Yankee Rowe	P	1739663		300	1100	1500
Zion	P	1107448		150	540	730

[a]P = pressurized-water reactor; B = boiling-water reactor.
[b]MYL = middle year of license
[c]UCB = upper confidence bound.

Table G.6 Middle year of the license renewal (MYR) normalized expected cost (NEC) predictions

Power plant	Reactor type[a]	240-km (150-mile) exposure index	MYL[b] NEC NLF[c] estimate	MYR NEC prediction	Normal theory 95 percent UCB[d]	Distribution free 95 percent UCB
Arkansas	P	265479		850	3600	4700
Beaver Valley	P	1021547	11000	4900	21000	27000
Bellefonte	P	678549		2900	12000	16000
Big Rock Point	B	136942		1300	6500	8100
Braidwood	P	1615088	4100	8900	41000	51000
Browns Ferry	B	491751		3000	12000	16000
Brunswick	B	256923		2000	8800	11000
Byron	P	1214624	2500	6200	27000	34000
Callaway	P	373564	1200	1300	5400	7400
Calvert Cliffs	P	1459323		7800	35000	44000
Catawba	P	914688	2100	4300	18000	23000
Clinton	B	1418383	2300	5800	24000	31000
Commanche Peak	P	363530	1100	1300	5300	7100
Cooper	B	428471		2700	11000	15000
Crystal River	P	573211		2300	9300	13000
DC Cook	P	1051654		5100	22000	28000
Davis Besse	P	1104797		5400	23000	30000
Diablo Canyon	P	302887		1000	4200	5500
Dresden	B	1193394		5200	22000	28000
Duane Arnold	B	329426		2300	9900	13000
Farley	P	344405		1200	4900	6600
Fermi 2	B	1287935	7000	5400	23000	30000
Fitzpatrick	B	270532		2100	9000	11000
Fort Calhoun	P	242370		760	3300	4200
Ginna	P	357773		1300	5200	6900
Grand Gulf	B	388245	780	2600	11000	14000
Haddam Neck	P	1722399		9700	45000	56000

See footnotes at end of table.

Table G.6 (continued)

Power plant	Reactor type[a]	240-km (150-mile) exposure index	MYL[b] NEC NLF[c] estimate	MYR NEC prediction	Normal theory 95 percent UCB[d]	Distribution free 95 percent UCB
Hatch	B	347873		2400	10000	13000
Hope Creek	B	1955878	12000	7000	31000	39000
Indian Point	P	2863844		19000	100000	120000
Indian Point 2						
Indian Point 3						
Kewanee	P	440217		1600	6600	9300
La Salle	B	1396350		5700	24000	31000
Limerick	B	2647224	19000	8500	39000	48000
Maine Yankee	P	391929		1400	5800	7900
McGuire	P	890305		4100	17000	23000
Millstone 3	P	1510698	23000	8200	37000	46000
Monticello	B	487606		3000	12000	16000
Nine Mile Point	B	273322	2400	2100	9000	11000
North Anna	P	876587		4000	17000	22000
Oconee	P	867675		4000	16000	22000
Oyster Creek	B	1970098		7100	31000	39000
Palisades	P	1041961		5000	21000	28000
Palo Verde	P	290395	590	960	4000	5200
Peach Bottom	B	1453860		5800	25000	32000
Perry	B	1021049	2000	4700	20000	26000
Pilgrim	B	486154		3000	12000	16000
Point Beach	P	469985		1800	7200	10000
Prarie Island	P	375227		1300	5500	7400
Quad Cities	B	854803		4200	17000	23000
Rancho Seco	P	992605		4700	20000	26000
River Bend	B	432680	17000	2800	12000	15000
Robinson	P	738770		3200	13000	18000
Salem	P	1979840		12000	56000	69000

See footnotes at end of table

Table G.6 (continued)

Power plant	Reactor type[a]	240-km (150-mile) exposure index	MYL[b] NEC NLF[c] estimate	MYR NEC prediction	Normal theory 95 percent UCB[d]	Distribution free 95 percent UCB
San Onofre	P	1284282	5600	6600	29000	37000
Seabrook	P	523715	1700	2100	8300	12000
Sequoyah	P	769140		3400	14000	19000
Sheron Harris	P	688554	1400	2900	12000	17000
Shoreham	B					
South Texas	P	579617	680	2400	9500	14000
St. Lucie	P	727763	1600	3200	13000	18000
Summer	P	852405	1700	3900	16000	21000
Surry	P	846246		3800	16000	21000
Susquehanna	B	2279528	2700	7700	35000	43000
TMI	P	1928285		11000	54000	66000
Trojan	P	944628		4400	18000	24000
Turkey Point	P	345115		1200	4900	6600
Vermont Yankee	B	1286085		5400	23000	30000
Vogtle	P	590283	4700	2400	9700	14000
WNP-2	B	132195	780	1300	6400	7900
Waterford	P	370569	1300	1300	5400	7300
Watts Bar	P	798733		3600	15000	20000
Wolf Creek	P	363380	1100	1300	5300	7100
Yankee Rowe	P	1739663		9800	46000	57000
Zion	P	1107448		5500	23000	30000

[a]P = pressurized-water reactor; B = boiling-water reactor
[b]MYL = middle year of license.
[c]NLF = normalized latent fatality
[d]UCB = upper confidence bound

G.2 ENDNOTES

1. Current evidence indicates that, for BWRs, the type of containment may significantly influence the public risk compared with PWR containments, and the degree of influence may vary between the different BWR containment types. This variation of risk influence among containment types does not seem to be as prevalent for PWR containments.

G.3 REFERENCES

Butler, R., and E. D. Rothman, "Predictive Intervals Based on Reuse of the Sample," *Journal of the American Statistical Association*, **75**, 881–89, 1980.

Draper, N., and H. Smith, *Applied Regression Analysis, Second Addition*, Wiley, New York, 1981.

Huber, P. J., *Robust Statistics*, Wiley, New York, 1981.

Schmoyer, R. L., "Asymptotically Valid Prediction Intervals for Linear Models," *Technometrics* (submitted), 1990.

Stine, R. A., "Bootstrap Prediction Intervals for Regression," *Journal of the American Statistical Association* **80**, 1026–31, 1985.

Tingle, A., *CRAC2S-MACCS Comparison of Exposure Index Calculations*, Brookhaven National Laboratory, Upton, N.Y., February 1993.

APPENDIX H

ENVIRONMENTAL STATUTES AND REGULATIONS AFFECTING LICENSE RENEWAL ACTIVITIES

Environmental Statutes and Regulations Affecting License Renewal Activities

H.1 INTRODUCTION

This appendix summarizes the statutes and executive orders that may affect license renewal applications for nuclear power plants. The summary builds on the information in Section 2.3, "Plant Interaction With the Environment," and addresses the following topics: land use, water use, water quality, air quality, aquatic resources, terrestrial resources, radiological impacts, solid waste, chemical impacts, and socioeconomic factors.

The federal and state statutes and the executive orders presented in this part include

(1) statutes and executive orders that could require the Nuclear Regulatory Commission (NRC) or the applicant to undergo a *new* authorization or consultation process with federal or state agencies outside the NRC; or

(2) statutes and executive orders that could require the NRC or the applicant to *renew* authorizations currently granted or hold additional consultations with federal or state agencies outside the NRC.

This summary is provided as a general overview to assist the applicant in identifying environmental and natural resources laws that may affect the license renewal process. The summary is not intended as a complete and final list, and the applicant is reminded that a variety of additional local and regional requirements may exist for the specific plant site.

H.2 FEDERAL STATUTES AND EXECUTIVE ORDERS

H.2.1 Land Use

Coastal Zone Management Act of 1972, as amended, Title 16 U.S.C. 1451, et seq.

Congress enacted the *Coastal Zone Management Act* (CZMA) in 1972 to address the increasing pressures of over-development upon the nation's coastal resources. The National Oceanic and Atmospheric Administration administers the Act. The CZMA encourages states to preserve, protect, develop, and, where possible, restore or enhance valuable natural coastal resources such as wetlands, floodplains, estuaries, beaches, dunes, barrier islands, and coral reefs, as well as the fish and wildlife using those habitats. Participation by states is voluntary. To encourage states to participate, the CZMA makes federal financial assistance available to any coastal state or territory, including those on the Great Lakes, that is willing to develop and implement a comprehensive coastal management program.

H.2.2 Water Use

Water use law is dominated by state regulation rather than federal regulation.

H.2.3 Water Quality

(a) Clean Water Act, as amended, Title 33 U.S.C. 1251, et seq.

The *Clean Water Act* (CWA), formerly known as the Federal Water Pollution Control Act, is intended to "... restore and maintain the chemical, physical, and biological integrity of the Nation's water" (Section 101). The CWA has five elements: (1) a system of minimum national effluent standards for each industry, (2) water quality standards, (3) a discharge permit program that translates these standards into enforceable limits, (4) provisions for special problems such as toxic chemicals and oil spills, and (5) a revolving construction loan program (formerly a grant program) for publicly-owned treatment works.

The CWA requires the Environmental Protection Agency (EPA) to establish effluent limitations for the amounts of specific pollutants that may be discharged by municipal sewage plants and industrial facilities. The two-step approach to setting the standards includes (1) establishing a nationwide base-level treatment through an assessment of what is technologically and economically achievable for a particular industry and (2) requiring more stringent levels of treatment for specific plants if necessary to achieve water quality objectives for the particular body of water into which that plant discharges. For example, EPA sets limits based on water quality to control pollution in waters designated by the states for drinking, swimming, or fishing.

The primary method by which the CWA imposes limitations on pollutant discharges is the nationwide permit program established under Section 402 and referred to as the National Pollutant Discharge Elimination System (NPDES). Under the NPDES program, any person responsible for the discharge of a pollutant or pollutants into any waters of the United States from any point source must apply for and obtain a permit.

Section 502(6) of the CWA defines the term *pollutant* to include radioactive materials. In its implementing regulations (40 CFR 122 in particular), however, EPA refined the definition of *pollutant* to exclude radioactive materials regulated under the Atomic Energy Act of 1954 (AEA), as amended. Thus, although the CWA and its implementing regulations clearly apply to naturally occurring (e.g., radium) and accelerator-produced radioisotopes, they do not apply to source, byproduct, or special nuclear materials as defined by the AEA.

Note that, quite apart from the CWA, states may under certain circumstances exercise a limited role in the regulation of these materials. Until Section 274 was added to the AEA in 1959, states had no role in the licensing and regulation of source, byproduct, or special nuclear materials. Section 274, however, provided a statutory basis by which states could assume from NRC a measure of authority over the regulation of byproduct and source materials and special nuclear materials in quantities not sufficient to form a critical mass. To effect this transfer of authority, (1) NRC must find that the state's radiation control program is compatible with NRC's and that it is adequate to protect public health and safety, (2) the state must establish its authority to enter into an agreement with NRC, and (3) NRC must enter into an agreement with the governor of the state desiring such authority. Thus far, 29 states have entered into such agreements with NRC. Even in agreement states, however, NRC retains regulatory authority over several important areas, including construction and operation of production and utilization facilities and disposal of certain source, byproduct, and special nuclear materials [AEA, Section 274(c)].

Section 404 enables the Corps of Engineers in the Department of the Army to issue permits for the discharge of dredged or fill materials into waters of the United States at specific sites. The Corps specifies a site by applying guidelines promulgated by EPA (40 CFR 230). Further, any proposal to dump dredged or fill material into the ocean must comply with the dumping criteria set forth in Section 227.13 of the Marine Protection, Research, and Sanctuaries Act (MPRSA) regulations. Under Subsection 404(c) of the CWA, EPA can prohibit (or limit the use of) a proposed disposal site or withdraw an already designated site, under regulations codified at 40 CFR 231. This determination may occur if EPA foresees unacceptable impacts on municipal water supplies, shellfish beds, fishery areas, or wildlife and recreational areas. However, such a determination must be made after consultation with the Corps and the permit applicant.

A significant feature of Section 404 is that the Corps may issue general permits on a state, regional, or nationwide basis for dredging or fill activities that are similar in nature and cause only minimal individual and cumulative adverse impacts. General permits are granted for a period not to exceed 5 years. The Corps issues individual permits for actions that have a potential for significant environmental impacts.

(b) Marine Protection, Research, and Sanctuaries Act of 1972, Title 16 U.S.C. 1431, et seq.

The MPRSA (Pub.L. 92-532) regulates ocean dumping of waste, provides for a research program on ocean dumping, and provides for the designation and regulation of marine sanctuaries. Also known as the Ocean Dumping Act, the Act regulates the ocean dumping of all material beyond the territorial limit or 3 miles from shore and prevents or strictly limits dumping material that "would adversely affect human health, welfare, or amenities, or the marine environment, ecological systems, or economic potentialities." "Material" includes (but is not limited to) dredged material, solid waste, incinerator residue, garbage, sewage, sewage sludge, munitions, chemical and biological warfare agents, radioactive materials, chemicals, biological and laboratory waste, wrecked or discarded equipment, rock, sand, excavation debris, and industrial, municipal, agricultural, and other waste. The term does not include sewage from vessels or oil, unless the oil is transported via a vessel or aircraft for the purpose of dumping. Disposal by means of a pipe, regardless of how far at sea the discharge occurs, is regulated by the CWA, through the NPDES permit process.

Some of the waste material as defined above may be transported to and dumped into the ocean under conditions stipulated in a permit issued by EPA or the Corps of Engineers, depending upon the type of waste involved. Ocean dumping, however, is only possible if no other reasonable alternatives, such as landfilling, are available.

(c) Safe Drinking Water Act, as amended, Title 42 U.S.C. 300 F., et seq.

In 1974 Congress enacted the *Safe Drinking Water Act* (SDWA) to manage potential contamination threats to groundwater. The act instructed EPA to establish a national program to prevent underground injections that would endanger drinking water sources. Primary drinking water standards promulgated under the SDWA apply to drinking water "at the tap" as delivered by public water supply systems.

Section 1447 of the SDWA states that each federal agency having jurisdiction over a federally owned or maintained public water system must comply with all federal, state, and local requirements, administrative authorities, and processes and sanctions regarding the provision of safe drinking water. Sections 1412, 1414, and 1445(a) of the SDWA provide drinking water regulations and specific operating procedures for public water systems.

Public water systems, as defined in 40 CFR 141.2, provide piped water for human consumption and have at least 15 connections or regularly serve at least 25 people. Public water systems are either

(1) community water systems, that is, public water systems that serve at least 15 connections used by year-round residents or regularly serve at least 25 year-round residents; or

(2) non-community water systems, all other water systems (e.g., campgrounds and gas stations).

On July 8, 1987 (FR 52, 25690), EPA amended 40 CFR 141.2 to add a definition of a "non-transient non-community water system" as a public water system that is *not* a community water system but that regularly serves at least the same 25 people for 6 months per year (e.g., work places and hospitals).

The SDWA requires EPA to establish primary water regulations for contaminants that may cause adverse public health effects. The regulations include both mandatory levels (maximum contaminant levels) and nonenforceable health goals [maximum contaminant level goals (MCLGs)] for each included contaminant.

MCLGs have extra significance because they can be used under the *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) as amended by the *Superfund Amendments and Reauthorization Act* (SARA) as applicable or relevant and appropriate requirements in national priorities list cleanups.

H.2.4 Air Quality

Clean Air Act, as amended, Title 42 U.S.C. 7401, et seq.

On November 15, 1990, President Bush signed into law sweeping revisions of the *Clean Air Act* (CAA). The new law contains titles that

- strengthen measures for attaining air quality standards (Title 1),
- set forth provisions relating to mobile sources (Title II),
- expand the regulation of hazardous air pollutants (Title III),

- require substantial reductions in power plant emissions for control of acid rain (Title IV),
- establish operating permits for all major sources of air pollution (Title V),
- establish provisions for stratospheric ozone protection (Title VI), and
- expand enforcement powers and penalties (Title VII).

The CAA Amendments will have far-reaching effects not only on environmental activities at federal facilities, but also on procurement, maintenance, and motor vehicle operation activities.

The original 1970 CAA authorized EPA to establish National Ambient Air Quality Standards (NAAQS) to limit levels of pollutants in the air. EPA has promulgated NAAQS for six criteria pollutants: sulfur dioxide, nitrogen dioxide, carbon monoxide (CO), ozone, lead, and particulate matter. All areas of the United States must maintain ambient levels of these pollutants below the ceilings established by the NAAQS; any area that does not meet these standards is a "nonattainment" area (NAA).

The 1990 Amendments require that the boundaries of serious, severe, or extreme ozone or CO NAAs located within metropolitan statistical areas (MSAs) or consolidated metropolitan statistical areas (CMSAs) be expanded to include the entire MSA or CMSA unless the governor makes certain findings and the administrator of EPA concurs. Consequently, all urban counties included in an affected MSA or CMSA, regardless of their attainment status, will become part of the NAA.

Under previous law "major sources" were those with the potential to emit more than 100 tons per year (tpy). The CAA Amendments reduced the size of plants subject to permitting and stringent retrofitting or offsetting requirements. In *serious* ozone NAAs, "major sources" include those with the potential to emit more than 50 tpy of volatile organic compounds. In *severe* ozone NAAs, "major sources" include those that emit 25 tpy or, in extreme areas, 10 tpy. For serious CO NAAs, a "major source" is now one that emits 50 tpy. For serious particulate matter NAAs, a "major source" is now one that emits 70 tpy.

The new source performance standards (NSPS) set minimum nationwide emission limitations for classes of facilities. The NSPS are set at levels that reflect the degree of control achievable through the application of the best system of continuous emission reduction that has been adequately demonstrated for that category of sources. The NSPS must take into consideration the cost of achieving such emissions reductions and any non-air-quality health and environmental impacts and energy requirements.

The National Emissions Standards for Hazardous Air Pollutants aim to control pollutants that may reasonably be anticipated to result in either an increase in mortality or an increase in serious irreversible or incapacitating, but reversible, illness. Since 1970 EPA has listed only eight hazardous air pollutants and has established standards for only seven. The 1990 Amendments directed EPA to establish technology-based standards for 189 hazardous substances based on the use of "maximum achievable control technology."

Title V of the CAA Amendments established a federal permitting program, similar to the CWA permitting program, which is to be administered by the states. Title V declared that after the effective date of any approved or promulgated permit program, it will be unlawful to operate a major source, affected source, or any other source (including an area source) subject to regulation under the CAA unless the source complies with all air quality requirements and has an operating permit. Under previous federal law, construction permits were required only for new sources; existing sources were left largely unpermitted, unless the state elected to require an operating permit. The CAA Amendments eliminated the distinction between new and existing sources; all major sources are now required to have an operating permit.

The new permit program will be fee-based, and federal facilities are explicitly required to pay a fee or charge imposed by a state or local agency to defray the costs of its air pollution regulatory program. The statute sets minimum rates for such fees at $25 per ton of each regulated pollutant, up to 4000 tpy. The EPA administrator may set other amounts to adequately reflect reasonable costs of the permit program. The following sources must have a permit to operate:

- major hazardous air pollutant sources,
- major sources under NAAQS,
- all affected sources under Title IV, and
- all sources subject to NSPS.

H.2.5 Aquatic Resources

(a) Fish and Wildlife Coordination Act, as amended, Title 16 U.S.C. 661–664, et seq.

The *Fish and Wildlife Coordination Act* (FWCA), as amended, proposes to ensure that fish and wildlife resources receive equal consideration with other values during the planning of water resources development projects. The act was passed because the goals of water-related projects (e.g., flood control, irrigation, navigation, and hydroelectric power) may conflict with the goal of conserving fish and wildlife resources. Conversely, developers can design water development projects to enhance the quality and enjoyment of fish and wildlife resources if such goals are incorporated into project plans.

The act authorizes the Secretary of the Department of the Interior (DOI) to provide assistance to and cooperate with federal, state, and public or private agencies and organizations in the development and protection of wildlife resources and habitat; make surveys and investigations of the wildlife in the public domain; and accept donations of land and funds that will further the purposes of the act.

The act requires consultation with the head of the state agency that administers wildlife resources in the affected state. The purpose of this process is to promote conservation of wildlife resources by preventing loss of and damage to such resources and to provide for the development and improvement of wildlife resources in connection with the agency action.

Although the recommendations of the Secretary of the Interior and state officials are not binding, the federal agency must give them full consideration. Furthermore, any reports and recommendations made by those officials become an integral part of any report prepared by the responsible federal agency when seeking authorization for the water-resource development project. Such a report must also include an estimate of the wildlife benefits or losses to be derived from the proposed project and a description of the conservation measures the agency finds should be adopted to obtain maximum overall project benefits.

The FWCA authorizes federal agencies to acquire lands in connection with water development projects for use in activities designed to conserve and enhance wildlife resources. These activities should be conducted in accordance with plans approved by the federal agency, the Secretary of the Interior, and the head of the applicable state agency. The report that accompanies the authorization request should describe the probable extent of land acquisition.

In other conservation provisions the FWCA authorizes the Secretary of DOI [through the Fish and Wildlife Service (FWS) and the Bureau of Mines] to investigate and report to Congress on the effects of domestic sewage; mine, petroleum, and industrial wastes; erosion silt; and other pollutants on wildlife and to make recommendations for alleviating their effects. It also directs the Corps of Engineers to consider fish and wildlife resource and habitat in its management of water levels in the upper Mississippi River.

Two general types of activities exempt from the act are (1) water impoundments with a surface area of less than 4 ha (10 acres) and (2) programs for land management and use carried out by federal agencies on land under their jurisdiction.

(b) Fish and Wildlife Conservation Act of 1980, Title 16 U.S.C. 2901, et seq.

The *Fish and Wildlife Conservation Act* provides federal technical and financial assistance to states for the development of conservation plans and programs for nongame fish and wildlife. The act also encourages federal agencies to conserve and promote the conservation of nongame fish and wildlife and their habitats. Conservation plans are required to identify appropriate nongame fish and wildlife species and significant problems that may adversely affect these species and their habitats. The conservation plan must also determine the actions that should be taken to conserve the nongame fish and wildlife species. The designated state agencies are expected to consult with the appropriate federal agencies during the development, revision, and implementation of the plan.

H.2.6 Terrestrial Resources

Endangered Species Act of 1973, as amended, Title 16 U.S.C. 1531, et seq.

The *Endangered Species Act* (ESA) originally passed in 1973. It provides for the designation and protection of invertebrates, wildlife, fish, and plant species that are in danger of becoming extinct and conserves the ecosystems on which such species depend.

The act defines an endangered species as any species that is in danger of becoming extinct throughout all or a significant portion of its range (the act excludes recognized insect pests from this definition). A threatened species is one that is likely to become endangered in the foreseeable future. The act makes it illegal for any individual to kill, collect, remove, harass, import, or export an endangered or threatened species without a permit from the Secretary of DOI. DOI's FWS performs most administrative and regulatory actions under the act. The National Marine Fisheries Service in the

U.S. Department of Commerce deals with actions affecting marine species.

To be protected, a species must be listed by the Secretary of the Interior as endangered or threatened. The listing process generally begins with a petition to the Secretary. Consultation with affected states is required prior to listing, but the Secretary makes the final decision. Whenever possible, a designation of critical habitat accompanies the listing of an endangered or threatened species. The Secretary must publish and periodically update the lists and develop and implement "recovery plans" for the conservation and survival of endangered and threatened species. Recently, the American bald eagle has been removed from the list because of FWS recovery plans.

The act directs the Secretaries of Interior and Commerce to establish programs to conserve fish, wildlife, and plants, including endangered and threatened species. Also, the Department of Agriculture oversees the import and export of endangered and threatened species. Implementation of such programs usually includes acquisition of lands under the act itself and under the FWCA of 1958, as amended; the *Fish and Wildlife Act* of 1956, as amended; and the *Migratory Bird Conservation Act* of 1929, as amended.

The act mandates cooperation between the U.S. federal, state, and foreign governments. The Secretary of the Interior must cooperate with the states to acquire and manage land and has authority to enter into cooperative agreements to provide assistance to those states that establish programs for the conservation of endangered and threatened species. The President and the Secretary of the Interior may provide financial and technical assistance to foreign countries to encourage conservation of fish, wildlife, and plants. The Secretaries of the Interior and Commerce must also carry out obligations under two international agreements: the *Convention on International Trade in Endangered Species of Wild Fauna and Flora* and the *Convention on Nature Protection and Wildlife Preservation in the Western Hemisphere.*

All federal agencies must utilize their authorities to carry out programs for the conservation of endangered and threatened species. Regulations promulgated under Section 7 of the act define the process whereby proposed federal actions that may affect threatened or endangered species are approved, disapproved, and appealed. In particular, "Each Federal agency shall, in consultation with and with the assistance of the Secretary [of DOI], ensure that any action authorized, funded, or carried out by such agency ... is not likely to jeopardize the continued existence of any endangered species or threatened species or result in the destruction or adverse modification of habitat of such species which is determined by the Secretary ... to be critical ... [Endangered Species Act Section 7(a)(2)]."

H.2.7 Radiological Impacts

Occupational Safety and Health Act

The Occupational Safety and Health Administration (OSHA) of the Department of Labor is responsible for the implementation of the *Occupational and Safety Health Act.* The act establishes safe and healthful workplace standards. Employers who fail to comply with OSHA standards can be penalized by the federal government. The act allows states to develop and enforce OSHA standards if such programs have been approved by the Secretary of Labor.

H.2.8 Solid Waste

Resource Conservation and Recovery Act of 1976, as amended, Title 42 U.S.C. 6901, et seq.

In 1976 Congress remodeled the *Solid Waste Disposal Act,* which dealt with the disposal of nonhazardous waste, into a major new program on hazardous waste. The *Resource Conservation and Recovery Act* (RCRA) outlines the framework for national programs to achieve environmentally sound management of both hazardous and nonhazardous wastes. RCRA also promotes resource recovery techniques and methods to reduce the generation of waste. The *Hazardous and Solid Waste Amendments* of 1984 (HSWA) both expanded the scope of RCRA and increased the level of detail in many of its provisions.

RCRA, as amended, contains ten subtitles. Subtitle C, "Hazardous Waste Management"; Subtitle D, "State and Regional Solid Waste Plans"; Subtitle I, "Regulation of Underground Storage Tanks"; and Subtitle J, "Demonstration Medical Waste Tracking Program," constitute the regulatory portion of the law. The other subtitles provide the legal and administrative structure for achieving the objectives of the law.

EPA, the Department of Commerce, the Department of Energy, and DOI all have specific responsibilities under RCRA. EPA issues guidelines and regulations for proper management of solid wastes, oversees and approves the development of state waste management plans, and provides financial aid to agencies and firms performing research on solid waste. The Department of Commerce encourages greater commercialization of proven resource recovery technologies. The Department of Energy oversees activities involving research and development of new techniques for producing energy from wastes. DOI oversees mineral waste problems, including recovery of metals and minerals and methods for stabilizing mining wastes.

Generators of hazardous waste must notify EPA that the wastes exist and require management in compliance with RCRA. Proper identification and initial management of hazardous wastes promote the success of the "cradle-to-grave" program. Generators must determine if the wastes are hazardous. If so, they notify EPA that they are managing a hazardous waste; obtain an EPA identification number for the generating facility; and verify that the transportation, treatment, storage, and disposal of the waste is conducted only by others with EPA numbers.

Generators must also prepare a Uniform Hazardous Waste Manifest to accompany shipments of hazardous waste. The manifest includes the name and EPA identification number of persons authorized to manage the waste and serves as a document of accountability to prevent improper disposal. The manifest system promotes self-enforcement of RCRA's requirements.

Under RCRA, no material can be a hazardous waste without first being a solid waste. RCRA defines a *solid waste as* "... any garbage, refuse, sludge from a waste treatment plant, water supply treatment plant, or air pollution control facility and other discarded material, including solid, liquid, semisolid, or contained gaseous material resulting from industrial, commercial or mining and agricultural operations, and from community activities ... [excluding] ... solid or dissolved materials in domestic sewage, or solid or dissolved materials in irrigation return flows, or industrial discharges which are point sources subject to permits under Section 402 of the Federal Water Pollution Control Act .... or source, special nuclear, or byproduct material as defined by the Atomic Energy Act [AEA] of 1954 ... [Section 1004(27)]."

RCRA then defines a *hazardous waste* as "a solid waste, or combination of solid wastes, which because of its quantity, concentration, or physical, chemical, or infectious characteristics may ... cause, or significantly contribute to an increase in mortality or an increase in serious irreversible, or incapacitating reversible, illness; or ... pose a substantial present or potential hazard to human health or the environment when improperly treated, stored, transported, or disposed of, or otherwise managed [Section 1004(5)]."

The 1984 HSWA addressed Congressional concern that inadequate or improper controls for management of hazardous waste would increase risks to human health and the environment. HSWA introduced three major changes in RCRA.

First, Congress restricted land disposal of untreated hazardous waste unless it could be demonstrated that there will be no migration of hazardous constituents from the disposal unit for as long as the wastes remain hazardous [Section 3004(d)(1)]. Second, facilities were required to adopt "minimum technical requirements" for landfills and surface impoundments to keep hazardous constituents from migrating into groundwater and to permit detection if migration occurs. Third, EPA was granted the authority to require corrective action for releases of hazardous constituents from any solid waste disposal unit at a facility seeking a RCRA

Subtitle I (implemented at 40 CFR Part 280), added by HSWA, established a program to regulate the three to five million underground storage tanks in the United States and to prevent their leaking. Under this subtitle RCRA regulates the storage of a product (e.g., petroleum products), rather than hazardous waste. In addition the substances regulated under Subtitle I include all the hazardous substances (except those regulated as a hazardous waste under Subtitle C of RCRA) defined under CERCLA. *Hazardous substances* under CERCLA encompass a wide variety of items regulated under other federal statutes including the CWA, CAA, and *Toxic Substances Control Act* (TSCA). (Radionuclides, which are specifically excluded under RCRA's definition of *solid waste,* are regulated under CERCLA because they are defined as *hazardous air pollutants* under the CAA.) Subtitle I of RCRA regulates underground storage tanks containing radioactive materials unless they are "mixed" with hazardous waste, in which case they are regulated under Subtitle C.

Federal agencies and departments that own or operate underground storage tanks are subject to and must comply with all applicable federal, state, interstate, and local requirements, except when the President determines that exemption of specific tanks from these requirements is in the "paramount" interest of the United States.

Section 3006 of RCRA authorizes states to develop and enforce their own hazardous waste programs in place of the federal program administered by EPA. Before administering any of the provisions of HSWA, authorized states must again go through the state program approval process.

H.2.9 Chemical Impurities

Federal Insecticide, Fungicide, and Rodenticide Act, as amended, Title 7 U.S.C. 135, et seq.

The *Federal Insecticide, Fungicide, and Rodenticide Act* as amended by the Federal Environmental Pesticide Control Act and subsequent amendments, requires the registration of all new pesticides with EPA before they are used in the United States. Manufacturers are required to develop toxicity data for their pesticide products. Toxicity data may be used to determine permissible discharge concentrations for an NPDES permit.

H.2.10 Socioeconomic Factors

Historic Preservation Requirements

Five laws, one executive order, and a Presidential memorandum have been passed during the last 75 years to help protect and preserve the nation's archaeological and historic resources.

The Antiquities Act of 1906 provided for the protection of historic and prehistoric remains and monuments on federal lands. It established a permit system for conducting scientific archaeological investigations, which could only be conducted by recognized institutions that would report results and maintain all collections for the public.

In 1935 Congress passed the *Historic Sites Act* that declared it was a national policy "to preserve for public use historic sites, buildings, and objects of national significance." This act extended protection to sites on both federal and non-federal lands by giving the Secretary of the Interior the authority to survey, document, evaluate, acquire, and preserve archaeological and historical sites throughout the country. It led to the creation of the Historic Sites Surveys, the Historic American Buildings Survey, and the Historic American Engineering Record (now the National Architectural and Engineering Record).

The Archaeological Recovery Act of 1960 gave DOI the major responsibility for preserving archaeological data that might be lost through federal dam construction. The *Archaeological and Historic Preservation Act* of 1974 amended and significantly expanded the scope of the 1960 Act by requiring preservation of archaeological data affected as a result of any federal or federally related land modification activities.

The act made the Secretary of the Interior responsible for coordinating and administering a nationwide program for the recovery, protection, and preservation of scientific, prehistoric, historic, and archaeological data that would otherwise be damaged or destroyed through federal action. This act, also referred to as the *Archaeological Salvage Act* or the *Moss-Bennett Act,* for the first time authorized up to 1 percent of the cost of a project to be transferred to the Secretary of the Interior for preserving archaeological data on federal construction projects, other than dam construction. The 1 percent limitation can be waived by federal agencies after obtaining concurrence from DOI and then notifying Congress.

The most comprehensive national policy on historic preservation was established by Congress with the passage of the *National Historic Preservation Act* of 1966 (NHPA). In this act historic preservation was defined to include "the protection, rehabilitation, restoration and reconstruction of districts, sites, buildings, structures, and objects significant in American history, architecture, archaeology, or culture." The act led to the creation of the National Register of Historic Places, a file of cultural resources of national, regional, state, and local significance. The act also established the Advisory Council on Historic Preservation (the Council), an independent federal agency responsible for administering the protective provisions of the act.

Two of the major provisions of the NHPA for federal agencies are Sections 106 and I 10. Both sections aim to ensure that historic properties are appropriately considered in planning federal initiatives and actions. Section 106 is a specific, issue-related mandate to which federal agencies must adhere. It is a reactive mechanism that is driven by a federal action. Section I 10, in contrast, sets out broad federal agency responsibilities with respect to historic properties. It is a proactive mechanism with emphasis on ongoing management of historic preservation sites and activities at federal facilities.

Section 106 requires that the head of any federal agency having direct or indirect jurisdiction over a proposed federal or federally assisted undertaking in any state, and the head of any federal department or independent agency having authority to license any such undertaking, must ensure that the provisions of the NHPA are administered. Section 106 also mandates consultation during such federal actions. It compels federal agencies to "take into account" the effect of their projects on historical and archaeological resources and to give the Council the opportunity to comment on such effects.

Section 110(a) of the NHPA and Executive Order (E.O.) 11593 (which was substantially incorporated into the NHPA amendments of 1980) require agencies to provide leadership in preserving, restoring, and maintaining the historic and cultural environment of the nation. The 1980 NHPA amendments expanded the NHPA of 1966 by making federal agencies responsible for identifying, preserving, and nominating to DOI all sites, buildings, districts, and objects under their jurisdiction or control that appear to qualify for listing on the National Register of Historic Places. It also required DOI to develop criteria and procedures for federal agencies to use in these reviews and nominations. As a result, both Section 110(a) and E.O. 11593 require each federal agency, in cooperation with the state historic preservation officer in the state involved, to "establish a program to locate, inventory, and nominate to the Secretary (DOI) all properties under the agency's ownership or control by the agency, that appear to qualify for inclusion on the National Register in accordance with the regulations promulgated under Section 101(a)(2)(A)."

Amendments to NHPA in 1980 also provided additional guidance and clarification to the historic preservation program. Congress gave DOI the authority to waive the 1-percent limitation on the use of project funds to defray the costs of data recovery, increased the role of the state historic preservation officer in the administration of the National Historic Preservation Program, and clarified federal agency responsibilities under E.O. 11593.

The *Archaeological Resources Protection Act of 1979* was enacted to provide a comprehensive framework for protecting and regulating the use of archaeological resources on public and Indian lands protected by the *Antiquities Act* of 1906. The act requires that a permit be received from the federal land manager for the excavation and removal of archaeological resources on public land.

The President's 1978 *Memorandum on Environmental Quality and Water Resources Management* directed the Council to issue final regulations under the NHPA and directed federal agencies with water resource responsibilities and programs to publish procedures implementing the NHPA within 3 months after promulgation of the final Council regulations.

Federal agencies should coordinate National Environmental Policy Act (NEPA) compliance with the responsibilities of the NHPA to ensure that historic and cultural properties are given proper consideration in the preparation of environmental assessments (EAs) and environmental impact statements (EISs). However, agency obligations under NHPA are independent from NEPA and must be complied with even when an EA or EIS is not required. That is, for proposed projects that are not classified as major federal actions with significant environmental impacts, federal agencies must still consider impacts to historic properties and sites. Where both NEPA and the NHPA are applicable, draft EISs must integrate NHPA considerations along with other environmental impact analyses and studies. (See 40 CFR Part 1502.25.)

To coordinate the independent responsibilities of the two acts (NEPA and NHPA), federal agencies should undertake compliance with NHPA regulations as soon as it is determined that a National Register listed or eligible property may be affected by a proposed project or program.

H.2.11 Other

(a) Emergency Planning and Community Right-to-Know Act of 1986, Title 42 U.S.C. I 1001, et seq.

The *Emergency Planning and Community Right-to-Know Act* (EPCRA), enacted on October 17, 1986, represents a significant first step toward a major federal role in areas previously regulated by state and local government. EPCRA was enacted by Congress as a stand-alone provision, Title III, of SARA.

Title III was passed in response to concerns regarding the environmental and safety hazards posed by the storage and handling of toxic chemicals. The disaster in Bhopal, India, in which more than 2000 people suffered death or serious injury from the accidental release of methyl isocyanate, triggered this concern. To reduce the likelihood of such a disaster in the United States, Congress imposed requirements on both states and regulated facilities. Facilities must notify the local emergency planning districts regarding materials and releases at sites.

The emergency planning aspect requires local communities to prepare plans to deal with emergencies relating to hazardous substances. The community right-to-know aspect creates new rights for members of the public and local governments to obtain information concerning potential threats in their neighborhoods involving hazardous substances. EPCRA provides the tools for local governments and members of the community to make their own decisions regarding hazardous materials in their communities.

EPCRA contains three subtitles. Subtitle A, "Emergency Planning and Notification," establishes mechanisms to enable states and communities to prepare to respond to unplanned releases of hazardous substances.

Subtitle B, "Reporting Requirements," contains three distinct reporting provisions concerning two different groups of chemical substances. The first two sets of reports require submission of inventory-related data on *hazardous chemicals* (i.e., those substances for which a material safety data sheet is mandated under the hazard communication regulations of OSHA). The third reporting provision requires annual reports to the EPA and to the state in which the reporting facility is located of environmental releases of listed *toxic chemicals* manufactured, processed, or otherwise used at the facility in excess of specified threshold quantities.

Subtitle C, "General Provision," contains a variety of general provisions, including, but not limited to, civil, criminal, and administrative penalties for violations of the statute's reporting requirements; enforcement actions that can be brought by citizens, states, and emergency planning and response entities; and restrictions on an owner's or operator's rights to make trade secrecy claims in the reports required by EPCRA.

(b) National Electric Safety Code

The *National Electric Safety Code* provides a comprehensive listing of criteria regarding electrical safety.

(c) Executive Order 11990, Protection of Wetlands

Executive Order 11990 was issued to avoid direct or indirect support of new construction on wetlands wherever there is a practicable alternative. Federal agencies are required to evaluate the potential effects of any actions they may take on wetlands when carrying out their responsibilities (e.g., planning, regulating, and licensing activities). However, this executive order does not apply to the issuance by federal agencies of permits, licenses, or allocations to private parties for activities involving wetlands on nonfederal property.

(d) Pollution Prevention Act of 1990

This legislation focuses on treating and disposing of waste rather than on meeting source reduction limits. The millions of tons of pollution generated each year could be reduced in a cost-effective manner through changes in production, operation, and types of raw materials used in industry. The technique of source reduction is considered fundamentally different from and more desirable than waste management and pollution control. EPA is to carry out the responsibilities set forth in this act.

(e) The Bald and Golden Eagle Protection Act

The *Bald and Golden Eagle Protection Act* prohibits knowingly (or with disregard for the consequences of one's actions) taking, possessing, selling, transporting, importing, or exporting the American or golden eagle, dead or alive, without a permit.

(f) The American Indian Religious Freedom Act

The *American Indian Religious Freedom Act* (AIRFA) clarifies U.S. policy pertaining to the protection of Native Americans' religious freedom. The special nature of Native American religions has frequently resulted in conflicts between federal laws and policies and religious freedom. Some federal laws, such as those protecting wilderness areas or endangered species, have inadvertently given rise to problems such as denial of access to sacred sites or prohibitions on possession of animal-derived sacred objects by Native Americans.

AIRFA, passed in 1978, acknowledged prior infringement on the right of freedom of religion for Native Americans. Furthermore, it stated in a clear, comprehensive, and consistent fashion the federal policy that laws passed for other purposes were not meant to restrict the rights of Native Americans. The act established a policy of protecting and preserving the inherent right of individual Native Americans (including American Indians, Eskimos, Aleuts, and Native Hawaiians) to believe, express, and exercise their traditional religions.

AIRFA is primarily a policy statement. Approximately half of the brief statute is devoted to Congressional findings. Following the Congressional findings, the act makes a general policy statement regarding American Indian religious freedom: "... henceforth it shall be the policy of the United States to protect and preserve for American Indians their inherent right to freedom to believe, express, and exercise the traditional religions of the American Indian, Eskimo, Aleut, and Native Hawaiians, including but not limited to access to sites, use and possession of sacred objects, and the freedom to worship through ceremonial and traditional rites (42 U.S.C. 1996)."

The final section of the act requires the President to order agencies to review their policies and procedures in consultation with traditional native religious leaders.

(g) Native American Graves Protection and Repatriation Act

The *Native American Graves Protection and Repatriation Act*, enacted on November 16, 1990, established a means for American Indians, including members of Indian tribes, Native Hawaiian organizations, and Native Alaskan villages and corporations, to request the return or "repatriation" of human remains and other cultural items presently held by federal agencies or federally assisted museums or institutions.

The act also contains provisions regarding the intentional excavation and removal of, inadvertent discovery of, and illegal trafficking in Native American human remains and cultural items.

All federal agencies that manage land and/or are responsible for archaeological collections from their lands or generated by their activities must comply with the Native American Graves Protection and Repatriation Act.

(h) Marine Mammal Protection Act

The *Marine Mammal Protection Act* (MMPA) was enacted in 1972 to protect and manage marine mammals and their products (e.g., the use of hides and meat). The primary authority for implementing the act belongs to the FWS and National Marine Fisheries Service. The FWS manages walruses, polar bears, sea otters, dugongs, marine otters, and West Indian, Amazonian, and West African manatees. The National Marine Fisheries Service manages whales, porpoises, seals, and sea lions. The two agencies may issue permits under MMPA Section 104 (16 U.S.C.

1374) to persons, including federal agencies, that authorize the taking or importing of specific species of marine mammals.

After the Secretary of the Interior or the Secretary of Commerce approves a state's program, the state can take over responsibility for managing one or more marine mammals. Regulations governing the transfer of responsibility were published in May 1983. Although certain states actively participate in the management of marine mammals, as of August 9, 1994, no state has fully taken on this duty.

The MMPA established a Marine Mammal Commission whose duties include reviewing laws and international conventions relating to marine mammals, studying the condition of these mammals, and recommending steps to federal officials (e.g., listing a species as endangered) that should be taken to protect marine mammals. Federal agencies are directed by MMPA Section 205 (16 U.S.C. 1405) to cooperate with the commission by permitting it to use their facilities or services.

(i) Executive Order 11988,. Floodplain Management

Executive Order 11988 was issued to avoid direct or indirect support of floodplain development whenever there is a practicable alternative. A federal agency is required to evaluate the potential effects of any actions it may take in a floodplain. Federal agencies are also required to encourage and provide appropriate guidance to applicants to evaluate the effects of their proposals on floodplains prior to submitting applications for federal licenses, permits, loans, or grants.

(j) Low-Level Radioactive Waste Policy Act, Title 42 U.S.C. 2021b, et seq..

The *Low-Level Radioactive Waste Policy Act* is designed to improve the procedures for the implementation of compacts providing for the establishment and operation of regional low-level radioactive waste disposal facilities. It also allows for Congress to grant consent for certain interstate compacts. The amended act sets forth the responsibilities for disposal of low-level waste by states or interstate compacts. The act states the amount of waste that certain low-level waste recipients can receive over a set time period. The amount of low-level radioactive waste generated from both pressurized and boiling water reactor types is allocated over a transition period until a local waste facility is operational.

(k) Nuclear Waste Policy Act of 1982, Title 42 U.S.C. 10101, et seq.

The *Nuclear Waste Policy Act of 1982* provides for the research and development of repositories for the disposal of high-level radioactive waste, spent nuclear fuel, and low-level radioactive waste. The act consists of three titles and several subtitles. Title I includes the provisions for the disposal and storage of high-level radioactive waste and spent nuclear fuel. Subtitle A of Title I delineates the requirements for site characterization and construction of the repository and the participation of states and other local governments in the selection process. Subtitles B,C, and D of Title I deal with the specific issues for interim storage, monitored retrievable storage, and low-level radioactive waste.

(l) Toxic Substances Control Act

Congress enacted TSCA in 1976, to become effective January 1, 1977. The act authorizes EPA to secure information on all new and existing chemical substances and to control any of these substances determined to cause an unreasonable risk to public health or the environment.

Under earlier laws EPA had authority to control toxic substances only after damage occurred. The earlier laws did not require the screening of toxic substances before they entered the marketplace. TSCA closed the gap in the earlier laws by requiring that the health and environmental effects of all new chemicals be reviewed before they are manufactured for commercial purposes.

Determinations regarding compliance with TSCA must be made on a case-by-case basis if an activity involves the manufacture, processing, distribution in commerce, use, and/or disposal of a new or existing chemical substance or mixture that may present an unreasonable risk of injury to health or the environment. Although the definition of "chemical substances" explicitly excludes from its scope several materials that might otherwise meet the definition, including those that are regulated under other federal statues, TSCA is potentially applicable to all "chemical substances" and "mixtures" that are manufactured, imported, processed, used, distributed, and/or disposed of in the United States. By definition, TSCA-regulated chemical substances and mixtures do not include "... any source material, special nuclear material, or byproduct material (as such terms are defined in the Atomic Energy Act of 1954 and regulations issued under such Act) ...." [TSCA, Section 3(2)(B)(iv)]. Although TSCA excludes nuclear material, the TSCA-regulated portion of a mixed nuclear and regulated waste must comply with TSCA requirements. Materials that are not chemical substances or mixtures are not subject to the various requirements of TSCA.

The TSCA program is run by EPA and is not delegated to any state agency.

(m) National Environmental Policy Act

NEPA of 1969 as implemented by E.O. 11514 and E.O. 11991 established national policies and goals for the protection of the environment. NEPA aims to encourage harmony between people and the environment, to promote efforts to prevent or eliminate damage to the environment and the biosphere, and to enrich the understanding of ecological systems and natural resources important to the country.

NEPA is divided into two titles. Title I outlines a basic national charter for protection of the environment. Title II establishes the Council on Environmental Quality (CEQ). CEQ monitors the progress made toward achieving the goals set forth in Section 101 of NEPA. CEQ's duties include advising the president on environmental issues and providing guidance to other federal agencies on compliance with NEPA. Accordingly, CEQ promulgated regulations (amended in 1986) governing the NEPA process for all federal agencies.

Section 102(2) of NEPA contains "action-forcing" provisions that ensure federal agencies act according to the letter and the spirit of the law. These procedural requirements direct all federal agencies to give appropriate consideration to the environmental effects of their decision making and to prepare detailed environmental statements on recommendations or reports on proposals for legislation and other major federal actions significantly affecting the quality of the environment.

Agencies must establish specific criteria for classes of action that (1) usually require an EIS, (2) normally require an EA but do not necessarily require an EIS, and (3) require neither an EA nor an EIS (the "categorical exclusions").

If the action requires an EIS, the agency must publish a notice of intent and begin the scoping process. Then the agency prepares the draft EIS, solicits comments from affected parties and various governmental entities, and drafts the final EIS after considering the comments received. The contents of the final EIS must be considered when making a decision on the proposed action. The agency must prepare a record of decision, a concise statement of its decision discussing its choice among alternatives and the means that will be employed to mitigate or minimize environmental harm.

If the agency action does not fall within the category of actions designated as categorical exclusions or as requiring an EIS, the agency must prepare an EA. The EA determines whether an EIS is needed. If the EA determines that an EIS is not needed, the agency must issue a finding of no significant impact that briefly explains why the agency's action will not have a significant impact on the environment.

Although NEPA requires agencies to take what is known as a "hard look" at the environmental consequences of their actions, it does not force them to take the most environmentally sound alterative.

(n) Comprehensive Environmental Response, Compensation, and Liability Act

Congress passed CERCLA of 1980, also known as "Superfund" in response to a growing national concern about the release of hazardous substances to the environment. SARA, signed by President Reagan on October 17, 1986, amended many provisions of CERCLA. SARA has been the only major revision of CERCLA since its enactment in 1980.

CERCLA provides for liability, compensation, cleanup, and emergency response for hazardous substances released into the environment and for the cleanup of inactive hazardous waste disposal sites. CERCLA [Section 101 (14)] defines *hazardous substances* as

> (A) any substance designated pursuant to Section 311(b)(2)(A) of the Federal Water Pollution Control Act, (B) any element, compound, mixture, solution, or substance designated pursuant to Section 102 of this act, (C) any hazardous waste having the characteristics identified under or listed pursuant to Section 3001 of the Solid Waste Disposal Act (but not including any waste the regulation of which under the

Solid Waste Disposal Act has been suspended by act of Congress), (D) any toxic pollutant listed under Section 307(a) of the Federal Water Pollution Control Act, (E) any hazardous air pollutant listed under Section 112 of the Clean Air Act, and (F) any imminently hazardous chemical substance or mixture with respect to which the Administrator has taken action pursuant to Section 7 of the Toxic Substances Control Act.

Releases of source, byproduct, or special nuclear material from a nuclear incident are excluded from CERCLA requirements if the releases are subject to the financial protection requirements of the AEA. Releases of source, special nuclear, or byproduct materials from a processing site designated by the *Uranium Mill Tailings Radiation Control Act* of 1978 are also excluded [CERCLA Section 101(22)].

CERCLA intends to provide for response to, and cleanup of, environmental problems that are not covered adequately by the permit programs of the many other environmental laws, including the CAA, CWA, SDWA, MPRSA, RCRA, and AEA. In general, if a release to the environment constitutes a "federally permitted release," as defined by Section 101(10) of CERCLA, the release is not subject to CERCLA reporting requirements. However, if the release exceeds the permitted limit for a specific substance by the reportable quantity of that substance or more, results from startup or shutdown of a process, or occurs more frequently than the permit stipulates, it is subject to CERCLA reporting requirements. Future regulations may exempt federally permitted facilities and continuous-release facilities on a case-by-case basis. Permits do not cover abandoned waste disposal sites, and these sites are clearly subject to CERCLA.

CERCLA, as amended by SARA, provides for a fund, called the Superfund, that EPA or state and local governments can use to pay for the cleanup of hazardous waste sites listed on the national priorities list (NPL). The NPL, compiled by EPA, lists those sites, including federally owned facilities, that appear to pose the most serious threats to public health or the environment. EPA determines whether to place a site on the NPL by using the hazard ranking system (HRS).

Under the HRS, pertinent data about a site are evaluated and "scored." A site may receive scores for items such as waste volume, waste toxicity, proximity to population, and distance to underground drinking water. The cleanup of sites must conform to EPA's National Contingency Plan, the operating rules for Superfund cleanups promulgated by EPA under Section 105(a)(8)(B) of CERCLA. The NPL is dynamic. As HRS studies are performed, releases and waste sites may be removed from or added to the list. As of May 31, 1994, the NPL included 1,286 final sites (150 in the federal section) and 54 proposed sites (six of which are federal sites).

If liability for the release of a hazardous substance can be firmly established, the liable or "potentially responsible party" must pay for the cost of remedial responses. Generally, funds from the Superfund do not go toward paying for the cleanup of releases from federally owned facilities [Section 111(e)(3)] except to provide alternative water supplies in cases involving groundwater contamination outside the boundaries of a federally owned facility if the federally owned facility is not the only potentially responsible party.

Under Section 120 of CERCLA, each department, agency, and instrumentality of the United States is subject to, and must comply with, CERCLA in the same manner as any nongovernmental entity (except for requirements for bonding, insurance, financial responsibility, or applicable time period).

The Superfund process includes the following steps:

Preliminary assessment—EPA performs a preliminary assessment of a site (often a review of data without an actual site visit) to determine if further study is necessary.

Site inspection—A site inspection is an on-site investigation conducted to find out whether there is a release or potential release and to determine the nature of the associated threats.

Remedial investigation—A remedial investigation, conducted by the lead agency, determines the nature and extent of the problem presented by the release.

Feasibility study—The lead agency undertakes a feasibility study to develop and evaluate options for remedial action. The remedial investigation and feasibility study are collectively referred to as the "RI/FS."

Record of decision—After completing the RI/FS, EPA selects the appropriate cleanup option and publishes it in a public document known as the record of decision.

Remedial design—The remedial design includes the technical analysis and procedures that follow the selection of a remedy for a site.

Remedial action—The remedial action involves the actual construction or implementation of a cleanup.

In general the proposed remedy for a site must meet two threshold criteria: (1) to protect human health and the environment and (2) to comply with "applicable or relevant and appropriate requirements". Federal and/or state requirements are considered "applicable" if they are "... based upon an objective determination of whether the requirement specifically addresses a hazardous substance, pollutant, contaminant, remedial action, location, or other circumstance found at a CERCLA site" [40 CFR Part 300 (9)(1)].

CERCLA, if not reauthorized by Congress, will expire in 1995. Referred to as the Superfund Reform Act of 1994 (The Act), HR-3800 and S-1834 have emerged as the primary amending statutes on Superfund law. The major features of these bills are intended to enhance EPA's information-gathering activities; sharply limit joint and several liability as it applies to de minimis parties; limit the liability of lenders; create more flexibility within the remedy selection process; and increase opportunities for public participation in the decision-making process and incorporate environmental justice concerns within the CERCLA process. This list is not exhaustive; however, it gives a general overview of the scope of CERCLA reform.

Appendix I

NRC Procedures for the Submission of Petitions for Rulemaking

NRC Procedures for the Submission of Petitions for Rulemaking

This appendix contains NRC's procedural requirements for the submission of petitions for rulemaking. Individuals seeking a change to the findings in Appendix B (Table B-1) of Subpart A of 10 CFR Part 51 should follow these procedures. Petitions for rulemaking may be filed at any time.

10 CFR § 2.802 Petition for Rulemaking

(a) Any interested person may petition the Commission to issue, amend or rescind any regulation. The petition should be addressed to the Secretary, U.S. Nuclear Regulatory Commission, Washington, DC 20555, Attention: Chief, Docketing and Service Branch.

(b) A prospective petitioner may consult with the NRC before filing a petition for rulemaking by writing the Director, Freedom of Information and Publications Services, Office of Administration, U.S. Nuclear Regulatory Commission, Washington, DC 20555, Attention: Chief, Rules Review and Directives Branch. A prospective petitioner may also telephone the Rules Review and Directives Branch on (301)415-7158 or toll free on (800) 368-5642.

(1) In any consultation prior to the filing of a petition for rulemaking, the assistance that may be provided by the NRC staff is limited to-

(i) Describing the procedure and process for filing and responding to a petition for rulemaking;

(ii) Clarifying an existing NRC regulation and the basis for the regulation; and

(iii) Assisting the prospective petitioner to clarify a potential petition so that the Commission is able to understand the nature of the issues of concern to the petitioner.

(2) In any consultation prior to the filing of a petition for rulemaking, in providing the assistance permitted in paragraph (b)(1) of this section, the NRC staff will not draft or develop text or alternative approaches to address matters in the prospective petition for rulemaking.

(c) Each petition filed under this section shall:

(1) Set forth a general solution to the problem or the substance or text of any proposed regulation or amendment, or specify the regulation which is to be revoked or amended;

(2) State clearly and concisely the petitioner's grounds for and interest in the action requested;

(3) Include a statement in support of the petition which shall set forth the specific issues involved, the petitioner's views or arguments with respect to those issues, relevant technical, scientific or other data involved which is reasonably available

to the petitioner, and such other pertinent information as the petitioner deems necessary to support the action sought. In support of its petition, petitioner should note any specific cases of which petitioner is aware where the current rule is unduly burdensome, deficient, or needs to be strengthened.

(d) The petitioner may request the Commission to suspend all or any part of any licensing proceeding to which the petitioner is a party pending disposition of the petition for rulemaking.

(e) If it is determined that the petition includes the information required by paragraph (c) of this section and is complete, the Director, Division of Freedom of Information and Publications Services, or designee, will assign a docket number to the petition, will cause the petition to be formally docketed, and will deposit a copy of the docketed petition in the Commission's Public Document Room. Public comment may be requested by publication of a notice of the docketing of the petition in the FEDERAL REGISTER, or, in appropriate cases, may be invited for the first time upon publication in the FEDERAL REGISTER of a proposed rule developed in response to the petition. Publication will be limited by the requirements of section 181 of the Atomic Energy Act of 1954, as amended, and may be limited by order of the Commission.

(f) If it is determined by the Executive Director for Operations that the petition does not include the information required by paragraph (c) of this section and is incomplete, the petitioner will be notified of that determination and the respects in which the petition is deficient and will be accorded an opportunity to submit additional data. Ordinarily this determination will be made within 30 days from the date of receipt of the petition by the Office of the Secretary of the Commission. If the petitioner does not submit additional data to correct the deficiency within 90 days from the date of notification to the petitioner that the petition is incomplete, the petition may be returned to the petitioner without prejudice to the right of the petitioner to file a new petition.

(g) The Director, Division of Freedom of Information and Publications Services, Office of Administration, will prepare on a semiannual basis a summary of petitions for rulemaking before the Commission, including the status of each petition. A copy of the report will be available for public inspection and copying for a fee in the Commission's Public Document Room, 2120 L Street, NW., Washington, DC.

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10 SUPPLEMENTARY NOTES

11 ABSTRACT *(200 words or less)*

THE 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 PART 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 POWER REACTORS FOR EACH TYPE OF ENVIRONMENTAL IMPACT THE GEIS ATTEMPTS TO ESTABLISH GENERIC FINDINGS COVERING AS MANY PLANTS AS POSSIBLE. 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 INDENTIFY 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

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