Table 3.9 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.
Source: ICRP 1991.

3.8.1.4 Baseline Gaseous and Liquid Effluents

Public radiation exposures from gaseous and liquid effluents resulting from refurbishment can be evaluated on the basis of effluent data from the replacement of steam generators and recirculation piping. The projections are based on large refurbishment efforts that have already been performed. Among the past refurbishment efforts, steam generator replacement has been the largest operation at U.S. PWRs. Replacement of the recirculating coolant piping probably represents the largest single effort at BWRs. During the replacement of steam generators and recirculation piping, releases of effluents have taken place under controlled conditions and in accordance with ALARA principles. Similar refurbishment efforts that may occur as part of the license renewal process would also take place under controlled conditions and in accordance with ALARA principles.

For the first several plants to replace steam generators, environmental reports were prepared that estimated amounts of radioactivity expected to occur in liquid and gaseous effluents as a result of the repair (NUREG/CR-3540). Actual effluent measurements were performed in several cases. The values are presented in Table 3.10, along with a summary of the same actual effluent types from BWRs and PWRs for 1986. It should be noted that steam generator repairs took less than a year, typically 6 to 9 months. The 1986 data are used because they represent a mid-level year between the early, post–Three Mile Island (TMI) backfitting and the more recent years that reflect a protracted emphasis on ALARA as well as the completion of the post-TMI backfits. The expected or measured releases from the refurbishments were also compared with (1) the normal operational effluents as predicted in the final environmental statements for the affected plants and (2) measured releases from the normal operation of these few reactors and for all reactors for 1986 as reported in NUREG/CR-2907. For each effluent type, when effluents associated with steam generator replacement are compared with those for normal operation as predicted in the final environmental statements, measured at the specific sites or measured at all LWR sites, they are found to be of the same order as or much less than effluents from normal operation for a year. The replacement of a steam generator

Table 3.10 Radioactive effluent source terms for steam generator replacements compared with typical 1986 effluent data for boiling-water reactors (BWRs) and pressurized-water reactors (PWRs)

Radioactive effluent	Surry[a] measurement (Ci) Unit 1	Surry[a] measurement (Ci) Unit 2	Turkey Point[a] measurement (Ci) Unit 3	Turkey Point[a] measurement (Ci) Unit 4	Point Beach[b] estimate (Ci/unit)	H. B. Robinson[c] estimate (Ci/unit)	BWRs[d,e] (1986)	PWRs[e] (1986)	BWRs (1990)	PWRs (1990)
Gaseous										
Noble gases	510	101	—	875	Negligible	140	53%, 1000[e]	57%, 1000	25%, 1000	23%, 1000
Iodine	0.0033	0.69	—	0.039	0.000007	0.00004	63%, 0.01	26%, 0.01	42%, 0.01[g]	49%, 0.01[g]
Particulates	0.0027	0.0013	0.00021	0.0012	0.00015	0.00009	63%, 0.01	26%, 0.01	—	—
Tritium	4.2	—	—	0.027	Negligible	0.7	—	—	—	—
Liquid										
Mixed fission and activation products (excluding tritium)	0.52	0.26	0.12	0.078	0.23	0.0013	50%, 0.1	30%, 1.0	47%, 0.1	39%, 1.0
Tritium	8.5[f]	—	—	47	125	14	26%, 10	85%, 100	37%, 100	90%, 100

[a]NUREG/CR-3540.
[b]NUREG-1011.
[c]NUREG-1003.
[d]Adapted from NUREG/CR-2907.
[e]Read as: 53% of the BWR nuclear power reactor sites released annually at least 1000 Ci of noble gases per reactor unit in 1986 (1 Ci = 3.7 × 10^{10} Bq).
[f]Estimated value from NUREG-0692.
[g]Data for the most recent years reported combine iodine and particulates.

does not change a plant's technical specifications relative to accident risk; thus, based on 10 CFR Part 50.59 an environmental assessment is not required. This point, coupled with past experience resulting in small environmental releases associated with steam generator changeouts, suggests that National Environmental Policy Act documents are not likely for future steam generator replacements.

Documents comparable to NUREG/CR-2907 estimating anticipated releases to the environment were not identified for BWR recirculation piping replacement, reflecting relatively less concern on the staff's part for effluents from recirculation piping replacement compared with initial concern for steam generator replacement. However, data of a similar nature are obtained from the two series of NRC summary documents, *Radioactive Materials Released from Nuclear Power Plants* (NUREG/CR-2907) and *Population Dose Commitments Due to Radioactive Releases from Nuclear Power Plant Sites* (NUREG/CR-2850). Annual release and dose commitment information for five reactor sites—Cooper, Monticello, Nine Mile Point-1, Peach Bottom-2, and Vermont Yankee—is presented in Table 3.11. Data presented in Table 3.11 demonstrate that releases of radioactive materials during recirculation piping replacement and consequent radiation doses to the public are similar to or less than those resulting from normal operation of the same plants. (Note that Peach Bottom Units 2 and 3 are reported together.) Releases from Peach Bottom Units 2 and 3 are typically larger than those at many other BWRs, although the releases still result in very small radiation doses to the public. This site has the largest releases during recirculation piping replacement. Given that data of Table 3.11 are representative of early technology for the recirculation piping replacement procedure, similar procedures during refurbishment of BWRs related to license renewal are not anticipated to result in significantly larger effluent releases or consequent radiation doses to the public.

Trends for dose reduction in the LWR industry (as seen in Table 4.6) suggest that dose reduction measures are working.

3.8.1.5 Dose to the Public from Radiological Effluents

Section 2.6 and Appendix B consider the scenario and types of potential refurbishment activities that may take place for license renewal. Only the period of major refurbishment is examined here because the potential for release of radioactive materials is greater for the single major refurbishment than for refurbishment in each of the four current term outages.

Detailed estimates of effluents associated with major refurbishment are not available at this time; however, there is a significant data base upon which to assess expected impacts. Major refurbishment efforts have taken place at PWRs and BWRs; associated data are presented in Tables 3.10 and 3.11. Within these tables, it is seen that effluents and dose impacts do not differ significantly from normal operation when a major refurbishment is performed. It is expected that, during the 9-month outage, a greater amount of work will be performed and some of the effluents, especially atmospheric particulates and possibly some liquid effluents associated with decontamination, may be slightly greater than were found during the steam

Table 3.11 **Radioactive effluent releases and radiation doses to the public for boiling-water reactors (BWRs) that have had recirculation piping replaced**

			Liquid releases			Air releases		
Year	Net electrical energy (10^6 MWh)	Total outage dates	Tritium (Ci)	Fission and activation products (Ci)	Population dose (person-rem)	I-131 and particulates (Ci)	Fission and activation products (Ci)	Population dose (person-rem)
				Cooper				
1979	5.0		6.6E	<2.5	0.01	<0.18	30000	0.3400
1980	3.8		8.8E	<11	0.02	<0.15	5000	0.0470
1981	3.9		<8.4E	<3.6	0.012	<0.011	2500	0.0540
1982	3.3		<9.1E	<5.4	0.03	<0.16	14000	0.1400
1983	5.3		<7.6E	<12	0.09	<0.023	1500	0.0100
1984	3.5	9/84	<7.2E	<6.3	0.06	<0.012	<1400	0.0100
1985	1.1	8/85	<5.1E	<13	0.06	<0.023	<1400	0.0100
1986	4.1		<5.6E	<7.4	0.03	<0.012	<1700	0.0100
1987	5.5		5.0E	<2.3	0.0081	0.027	1200	0.0003
1988	4.20		4.17	2.3	0.0068	0.0204	1810	0.0049
1989	4.79		5.45	2.19	0.007	0.00526	344	0.0014
1990	5.11		5.07	2.04	0.0029	0.000353	187	0.0012
				Monticello				
1979	4.4		ND[a]	ND	0	0.034	4000	0.1400
1980	3.5		ND	ND	0	0.028	3800	0.1600
1981	3.3		0.0042	0.0000031	0	0.035	3700	0.1800
1982	2.4		0.000027	0.00000058	0	0.089	7200	0.1900
1983	4.2		ND	ND	0	0.041	3200	0.1000
1984	2.6	2/84	ND	ND	0	0.029	520	0.0500
1985	4.3	1/85	ND	ND	0	0.10	2700	0.1400
1986	3.4		ND	ND	0	0.069	2500	0.1000
1987	3.5		ND	ND	0	0.17	4000	0.1700
1988	4.57		ND	ND	0	0.079	5880	0.18
1989	2.65		ND	ND	0	0.114	3980	0.21
1990	4.51		ND	ND	0	0.0434	2960	0.20
				Nine Mile Point 1				
1979	3.0		6.8	1.9	140	0.047	1000	0.0800
1980	4.5		ND	ND	0	0.026	590	0.0400
1981	3.3		5.1	5.4	4.9	0.015	610	0.2500
1982	1.1	8/82	5.8	0.0025	0.01	0.027	51	0.0100
1983	2.8	7/83	7.9	0.011	0.01	0.011	270	0.0400
1984	3.6		ND	ND	0	0.018	1000	0.0300
1985	4.9		ND					

Table 3.11 (continued)

Year	Net electrical energy (10^6 MWh)	Total outage dates	Liquid releases: Tritium (Ci)	Liquid releases: Fission and activation products (Ci)	Liquid releases: Population dose (person-rem)	Air releases: I-131 and particulates (Ci)	Air releases: Fission and activation products (Ci)	Air releases: Population dose (person-rem)
1986	3.2		2.2	<6.7E-4	0.0013	0.018	490	0.0200
1987	4.6		ND	ND	0.49[b]	0.016	200	0.0160
1988	0.0		ND	ND	0.21	0.00189	18	0.0044
1989	0.0		ND	ND	0.026	0.00302	0.000152	0.0067
1990	1.28		1.41	1.95E-3	0.007	0.00272	ND	0.016
Peach Bottom 2[c]								
1979	15		43.0	2.0E1	16	0.26	190000	14.0000
1980	4.3		37.0	1.9E0	3	0.029	15000	1.7000
1981	6.6		37.0	2.0E0	0.84	<0.042	16000	1.9000
1982	4.8		24.0	9.3E0	3.1	0.039	13000	2.2000
1983	4.5		20.0	2.2E0	1.1	0.046	35000	8.6000
1984	2.4	4/84	36.0	6.2E0	1.1	0.10	81000	8.5000
1985	2.3	6/85	50.0	2.2E0	1.2	0.069	130000	15.0000
1986	6.9		45.0	4.6E-1	0.61	0.052	28000	4.1000
1987	1.6		46.0	3.3E-1	0.47	0.020	12000	1.6000
1988	0.0		9.69	2.02E-1	0.32	0.00150	0.0019	0.014
1989	4.05		20.0	1.13E-1	0.2	0.00345	2640	0.13
1990	14.2		23.5	1.36E-2	0.076	0.0182	11200	0.77
Vermont Yankee								
1979	3.5		4.0	2.4E-4	0.0021	0.44	<8100	0.4600
1980	3.0		ND	ND	0	0.017	1600	0.0600
1981	3.6		37.0	1.0E-2	0.49	0.0045	<3200	0.1100
1982	4.2		ND	ND	0	0.0015	<3100	0.0600
1983	2.9		ND	ND	0	0.0041	<3100	0.1100
1984	3.3		ND	ND	0	0.0069	<3200	0.1000
1985	3.0	9/85	ND	ND	0	<0.0059	<3400	0.1000
1986	2.1	5/86	ND	ND	0	<0.0013	<1600	0.1200
1987	3.5		ND	ND	0	0.013	ND	0.0160
1988	4.11		ND	ND	0	0.00658	ND	0.059
1989	3.61		ND	ND	0	0.00892	10300	0.69
1990	3.62		ND	ND	0	0.0724	50700	0.16

[a]ND—not detected.
[b]Nine Mile Point—2 began operation in 1987. Radioactive releases are reported separately for units 1 and 2 in NUREG/CR-2907; doses reported are combined for units 1 and 2 in NUREG/CR-2850.
[c]Data for Peach Bottom includes units 2 and 3.
Sources: NUREG/CR-4494; NUREG/CR-2907-V8; NUREG/CR-2850.

generator changeouts or recirculation piping replacements. However, because of their origins (other effluents, for example), the noble gases and tritium gaseous emissions, which constitute the largest proportion of the total body dose from gaseous effluents to the maximally exposed individual, are not expected to increase beyond levels experienced for the already performed major refurbishments.

The resultant potential impacts on members of the public can be gauged with respect to impacts already experienced. Data tabulated in Appendix E on the maximally exposed individual from routine airborne emissions suggest that from 1985 through 1987, approximately 5 percent of the 47 plants for which data have been tabulated caused in any year annual total body doses of 1 mrem or greater, and approximately 10 percent caused thyroid doses of 1 mrem or greater. Because effluents and doses during periods of accomplished major refurbishment (Tables 3.10 and 3.11) have not been seen to differ significantly from normal operation, gaseous effluents and liquid discharges occurring during the 9-month refurbishment are not expected to result in maximum individual doses exceeding the design objectives of Appendix I to 10 CFR Part 50 or the allowable EPA limits of 40 CFR Part 190.

Within an 80-km (50-mile) radius, the average individual dose, considering all licensed LWRs, for 1985 to 1987 was between 0.001 and 0.002 mrem. If these values were increased a few percent, they would still be small. The average collective dose within an 80-km (50-mile) radius is between 1.0 and 2.0 person-rem (NUREG/CR-2850). For the assumed 9-month period of major refurbishment, these values might be raised slightly. In order to provide a point of comparison, the NCRP estimates that the effective dose equivalent from natural background sources to an individual in the United States is approximately 300 mrem annually. Typically, about 1 million persons are within an 80-km (50-mile) radius of a nuclear facility; this population will annually collect approximately 300,000 person-rem from natural background radiation.

Radiobiologists and epidemiologists generally agree that the collective dose to a population would have to be much larger than current doses from nuclear power plants before health effects would become a realistic concern. In its 1988 report (paragraph 251), the United Nations Scientific Committee on the Effects of Atomic Radiation 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 (10,000 person-rem). If the collective dose is only a few man-Sv, the most likely outcome is zero deaths.

In BEIR-V (1990) (p. 181), the National Academy of Sciences' Advisory Committee on the Biological Effects of Ionizing Radiation stated:

> Moreover, epidemiologic data cannot rigorously exclude the existence of the threshold in the millisievert [1 mSv is equivalent to 100 mrem] 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.

In the event that small annual radiation doses (i.e., 0.001 mrem/year) contribute to cancer risks, the "best estimate" of cancer risk would be 5×10^{-10}/year. EPA considers that a risk level of 1×10^{-6} to the public provides an ample margin of safety and is an acceptable risk.

3.8.1.6 Dose to the Public from On-Site Storage of Radioactive Materials

Steam generator assemblies, recirculation piping, and other large assemblies may be stored on- site in shielded buildings. Potential doses from such storage can be estimated from information gained by previous experience with steam generators. Each steam generator will contain approximately 300 Ci of fixed gamma emitters at the time it is removed from the containment (NUREG-1003). In past steam generator replacements, storage buildings that housed the removed steam generators and associated equipment provided sufficient shielding to limit the dose rate to less than 1 mrem/h outside the building. Shielding of a similar nature for buildings that may contain more than one steam generator or recirculation piping is anticipated for future refurbishment efforts because of the need to minimize occupational doses. If one of these buildings were 275 m (1500 ft), a typical distance, from the nearest site boundary, the estimated additional dose rate at the site boundary would be less than 0.00001 mrem/h from on-site storage of the steam generators and other equipment. An individual who lived at this location for 1 year would receive less than 0.1 mrem from this source. This dose rate would decrease rapidly during the first 2 years of storage because short-lived radionuclides would decay; thereafter, the dose would decrease by a factor of two every 5 years as the remaining ^{60}Co decayed. The staff concludes that radiation doses to the public from on-site storage of steam generators, recirculation piping, and other assemblies removed during refurbishment would be very small and insignificant.

3.8.1.7 Cumulative Impacts

A perspective on the addition of a radiation burden to members of the U.S. population can be gained from the data presented in Table 3.12. A total average annual effective dose equivalent of 360 mrem/year to members of the U.S. population is contributed by two primary sources: naturally occurring radiation and artificial sources (including human enhancement of natural sources) of radiation. Natural radiation sources other than radon result in 27 percent of the typical radiation dose received. The larger source of radiation dose (55 percent) is from radon, particularly because of homes and other buildings that entrap radon and significantly enhance its dose contribution over open-air living. The remaining 18 percent of the average annual effective dose equivalent consists of radiation from medical procedures (x-ray diagnosis, 11 percent, and nuclear medicine, 4 percent) and from consumer products (3 percent). For consumer products, the chief contributor is radon in domestic water supplies, building materials, mining, and agricultural products, as well as coal burning. (Smokers are additionally exposed to the natural radionuclide ^{210}Po in tobacco, resulting in the irradiation of a small region of the bronchial epithelium to up to 16,000 mrem/year. Tobacco products are the dominant contributor to individual

Table 3.12. Average annual effective dose equivalent of ionizing radiations to a member of the U.S. population

Source	Effective dose equivalent	
	mrem	Percent of total
Natural		
Cosmic	27	8.0
Terrestrial	28	8.0
Internal	39	11
Total natural	94	27
Artificial		
Radon (human enhanced)	200	55
Medical		
X-ray diagnosis	39	11
Nuclear medicine	14	4
Consumer products	11	3
Other		
Occupational	0.9	< 0.3
Nuclear fuel cycle	< 1.0	< 0.03
Fallout	< 1.0	< 0.03
Miscellaneous	< 1.0	< 0.03
Total artificial	266	73
Total natural and artificial	360	100

Source: Adapted from NCRP (1987).

body organ doses, but the conversion of the organ dose to effective dose equivalent is too uncertain for NCRP to include it in its tables. However, NCRP used a weighting factor of 0.08 and estimated effective dose equivalents to an average smoker of 1,300 mrem/year and to an average member of the U.S. population of 280 mrem/year (NCRP, Report No. 95, 1987). Radiation exposures from occupational activities, nuclear fuel cycle, and miscellaneous environmental sources (including nuclear weapons testing fallout) contribute very insignificantly to the total average effective dose equivalent.

Activities at nuclear power stations can be considered to contribute to the cumulative radiation burden. During the major period of refurbishment, radiation dose to members of the public within a 50-mile radius are not expected to change significantly from the current-term conditions which were between 0.001 and 0.002 mrem/year during 1985–1987, and even lower in the most recent reporting year. In 1990, the average dose was 0.0005 mrem/year. During refurbishment, the average dose to the public will remain very small, probably unchanged from current operation which, according to the most recent year analyzed, is less than 0.001 mrem/year. Therefore, cumulative impacts of radiation dose to members of the public should remain a very small part (less than 0.0003 percent) of the ionizing radiation dose to an average member of the U.S. population.

3.8.1.8 Mitigation

Radiation exposures to the public have been examined for potential mitigation, based on findings of impacts during the refurbishment effort. Adequate mitigation is already in place and properly functioning: the preceding sections demonstrate that public radiation doses have been steadily decreasing over nearly two decades.

The basis for current mitigation is found in the Code of Federal Regulations governing nuclear power plants. For example, in 10 CFR Part 20.1101 (radiation protection programs), specific requirements are detailed:

(a) Each licensee shall develop, document, and implement a radiation protection program commensurate with the scope and extent of licensed activities and sufficient to ensure compliance with the provisions of this part (see Section 20.2102 for recordkeeping requirements relating to these programs).
(b) The licensee shall use, to the extent practicable, procedures and engineering controls based upon sound radiation protection principles to achieve occupational doses and doses to members of the public that are ALARA.
(c) The licensee shall periodically (at least annually) review the radiation protection program content and implementation.

Regulations under which licensees of nuclear power plants operate explicitly require that attention be made to reducing public radiation exposures. Evidence is provided in Tables 3.10 and 3.11 as well as in the text of Sections 2 and 3 and in Appendices B and E to demonstrate that major refurbishment efforts taken during the current term of operation have operated under ALARA principles. Refurbishment activities that will take place in anticipation of license renewal can also be expected to comply with federal regulations in minimizing radiation dose.

Because of the existing federal regulations requiring operation under ALARA principles, and the historical record demonstrating that the regulations are being followed and are effective, ample evidence is provided that adequate mitigation for radiation exposure is already in place for major refurbishment activities and additional mitigation requirements are not warranted.

3.8.1.9 Conclusions

Off-site doses to the public attributable to refurbishment have been examined for both the maximally exposed individual and the typical or average individual. Because the focus of the analysis is on annual dose, only the results based on the assumed 9-month refurbishment outage were examined. In each instance, impacts were found to be small. To date, effluents and doses during periods of major refurbishments have not been seen to differ significantly from normal operation. Consequently, gaseous effluents and liquid discharges occurring during the 9-month refurbishment are not expected to result in maximum individual doses exceeding the design objectives of Appendix I to 10 CFR Part 50 or the allowable EPA limits of 40

CFR Part 190. Both the average individual dose and the 80-km (50-mile) radius collective doses will remain approximately 100,000 times less than the dose from natural background radiation. The evaluation of off-site radiation doses attributable to refurbishment determined that their significance is small for all nuclear plants. Radiation impacts to the public are considered to be of small significance because public exposures are within regulatory limits. It should also be noted that the estimated cancer risk is to the average member of the public is much less than 1×10^{-6}. Because current mitigation practices are properly functioning, cumulative impacts would not be significantly increased by refurbishment. Because current mitigation practices have resulted in declining public radiation doses for nearly two decades, additional mitigation is not warranted. The impact on human health is a Category 1 issue.

3.8.2 Occupational Dose

To determine the significance of the estimated occupational dose for refurbishment, the staff has compared dose projections for refurbishment with the historical (baseline) doses experienced at PWRs and BWRs. The dose estimates are based on detailed investigations of major refurbishment or replacement activities. Projected doses were used as the basis for estimates of cancer and genetic risk. Finally, the staff has compared the estimated risk to nuclear power plant workers with the risks to those workers from exposure to naturally occurring radiation and with published risks for other occupations. For the purpose of assessing radiological impacts to workers, the Commission has concluded that impacts are of small significance if doses and releases do not exceed permissible levels in the Commission's regulations. The standards for acceptable dose limits are given in 10 CFR Part 20.

Throughout the nuclear power industry, construction-type activities have continued at each operating plant but at greatly reduced levels compared with the original plant construction. These construction activities have included a broad range of plant modifications and additions made in response to a number of NRC requirements and industry initiatives, including post-TMI upgrades, radioactive waste system modifications, and spent fuel storage upgrades. In addition, several nuclear power plants have experienced major refurbishment efforts such as PWR steam generator replacement and the replacement of coolant recirculation piping in BWRs. These activities had significant potential for occupational exposure. Thus, occupational exposure histories accumulated to date are reflective of normal operation plus modifications and additions to existing systems. This information forms the basis for the evaluation of occupational doses resulting from refurbishment associated with license renewal.

3.8.2.1 Baseline Occupational Exposure

Table 3.13 shows the occupational dose history for PWRs and BWRs. Average collective occupational dose information and average annual individual worker doses are presented for those plants operating between 1974 and 1992. The year 1974 was chosen as a starting date because the dose data for years before 1974 are primarily from reactors with average rated capacities below 500 MW(e). Since the early 1980s, when the majority of post-TMI plant modifications were completed, there has been a decreasing trend in the average

Table 3.13 Annual average occupational dose for U.S. licensed light-water reactors

	Reported collective occupational dose (person-rem)						Annual average whole-body dose (rem)	
	BWR[a]			PWR[b]				
Year	Low	Average	High	Low	Average	High	BWR	PWR
1974	139	507	1430	18	345	1225	0.81	0.70
1975	114	701	2022	21	318	1142	0.86	0.76
1976	105	559	2468	58	460	1583	0.74	0.79
1977	198	828	3142	87	396	1153	0.89	0.65
1978	158	611	1327	48	424	1621	0.75	0.64
1979	157	733	1793	30	516	1792	0.73	0.56
1980	218	1136	3626	154	578	2387	0.87	0.52
1981	123	980	1836	58	652	3223	0.73	0.61
1982	205	940	1896	101	578	1426	0.76	0.53
1983	121	1056	2257	68	592	1881	0.82	0.56
1984	155	1004	4082	49	552	2880	0.66	0.49
1985	119	709	1677	36	424	1581	0.54	0.41
1986	84	645	2436	23	384	1567	0.51	0.37
1987	103	622	1579	47	370	1217	0.40	0.38
1988	53	529	1504	27	335	917	0.45	0.36
1989	177	432	910	18	287	1436	0.35	0.32
1990	83	426	884	13	285	1678	0.38	0.31
1991	103	324	1185	21	223	1468	0.31	0.27
1992	81	360	710	19	219	1280	0.32	0.26

[a]BWR = boiling-water reactor.
[b]PWR = pressurized-water reactor.
Source: NUREG-0713.

collective occupational dose. The average collective doses, however, are based on widely varying yearly doses. For example, between 1974 and 1992, annual collective doses for operating PWRs have ranged from 13 to 3223 person-rem; for operating BWRs, the figures range from 53 to 4083 person-rem. A decreasing trend in the highest annual collective dose is somewhat apparent, as is that for the average collective dose. In addition to decreases in collective dose, the average annual dose per nuclear plant worker has been reduced during this period from somewhat more than 0.8 rem to about 0.3 rem for BWRs and from around 0.7 rem to less than 0.3 rem for PWRs. A breakdown of the number of individual workers receiving doses in different ranges for 1992 is provided in Table E.8. These data demonstrate that 94 percent of plant radiation workers received less than 1 rem, and no worker received more than 4 rem. Overall data presented in Table 3.13 and in Appendix E provide ample evidence that doses to nearly all radiation workers are far below the worker dose limit established by 10 CFR Part 20 and that the continuing efforts to maintain doses at ALARA levels have been successful. A portion of the total work force can be defined as "transient." These individuals are usually employed for special functions and may be employed at multiple reactor sites during a given year. Data for individual reactors described earlier include these people, but only for each power plant. Thus some people are counted more than once and some people receive greater annual doses than are reported by individual plants. In 1993 there were approximately 13,000 of these people (NUREG-0713 1995). Over the years, doses to transient workers have been decreasing in the same way as doses to more permanent workers at nuclear power plants, going from an average of 1.04 rem in 1984 to 0.49 rem in 1993 (NUREG-0713 1995). In 1993 four transient workers received whole body doses between 4 and 5 rem, and no individuals received more than 5 rem (NUREG-0713 1995).

The wide range of annual collective doses experienced at LWRs in the United States results from a number of factors such as the reactor design, the amount of required maintenance, and the amount of reactor operations and in-plant surveillance. Because these factors can vary widely and unpredictably, it is impossible to determine in advance a specific year-to-year annual occupational radiation dose for a particular plant throughout its operating lifetime. On occasion, there may be a need for relatively high collective occupational doses compared with the average annual collective dose, even at plants with radiation protection programs designed to ensure that occupational doses will be kept to ALARA levels.

3.8.2.2 Projected Doses During Refurbishment

Many nuclear power plant operators have accrued considerable experience with the types of refurbishment activities that will be associated with license renewal. On the average, utilities have spent approximately $140 million per plant in modifications, and experience in retrofitting and modifying operating reactors has been gained. The level of effort required to support large construction activities such as a steam generator replacement has involved, for example, from 200,000 to 900,000 person-hours. The duration of shutdown has lasted from about 8 months to 2 years. Less complex modifications have required fewer person-hours and less plant downtime. Personnel who perform the modifications have often worked in relatively high radiation fields. Component surface exposure rates range from a few hundred mrem per hour to several rem per hour. The resulting cumulative radiation exposure to the work force has ranged from about 300 to 3500 person-rem for large, complex modifications and from 2 to 100 person-rem for smaller ones.

Throughout the process of plant modifications, it has been routine industrial practice to conduct ALARA reviews and studies on projects that may involve significant personnel exposures. Such evaluations are intended to assist the engineering of systems or implement radiological work practices that will reduce personnel exposures. Nonetheless, it is anticipated that each refurbishment program will result in occupational radiation doses in addition to those expected from normal operation during that time period.

Two scenarios were developed to estimate the occupational radiation doses caused by refurbishment activities: (1) a typical scenario that is expected in most situations and (2) a conservative scenario that is intended to capture additional work that might occur for those outlier plants whose impacts will be considerably greater than what is typical of the reactor population as a whole (see Section 2.6 and Appendix B). Care was taken to ensure that the dose estimates were conservative. The scenarios include work done in support of refurbishment during four current-term outages plus a single period of major refurbishment. Dose estimates for activities during each of the four current-term refurbishment outages are 11 and 10 person-rem for PWRs and BWRs respectively for the typical case and 200 and 191 person-rem respectively for the conservative case (see Tables 2.8 and 2.11). Dose estimates for the assumed single periods of major refurbishment are 79 and 153 person-rem for PWRs and BWRs respectively for the typical case and 1380 and 1561 for person-rem respectively for the conservative case.

3.8.2.3 Analysis of Occupational Exposures

According to the scenario developed in Appendix B, refurbishment efforts expended during the current licensing term are to take place during four outages plus a single large outage devoted to major items. Doses to power plant workers will, accordingly, take place during five time periods. Under the conservative scenario, the projected 200 to 191 person-rem for each of the four current term outages could increase the average annual collective dose during that period (based on 1992 numbers; see Table 3.13) from the range of 219 to 360 person-rem to the range of 419 to 551 person-rem for PWRs and BWRs respectively. These doses are similar to the average collective dose that was experienced by all LWRs during the second half of the 1980s. Under the typical scenario, the occupational doses would increase by less than 5 percent for both reactor types.

The single large outage effort in the conservative refurbishment scenario is estimated to result in a single-year increase in collective occupational dose (based on 1992 numbers) from 219 to 1599 person-rem for PWRs and from 360 to 1921 person-rem for BWRs. These levels are above the average of all reactors for any given year during the 1980s but are well below the levels for the highest single years for most BWRs and some PWRs (NUREG-0713). Thus the anticipated collective occupational doses attributable to refurbishment under the conservative scenario are in the range of doses already experienced by a large portion of the nuclear power plant industry. Under the typical scenario, the single large outage would add less than 7 percent to the current annual occupational doses.

During the large refurbishment outage, even in the conservative case, it is anticipated that average individual occupational doses will be maintained at acceptable levels. Experience during the early 1980s, when considerable backfitting was being performed within the industry, has shown that average worker doses could be kept to about 0.8 rem (NUREG-0713). Average worker doses are now in the 0.3–0.4 rem range. Because many activities in the 1980s were the same or similar to those expected to be performed in the refurbishment related to license renewal, it is estimated that such work can be performed while maintaining radiation protection to the degree achieved during the 1980s. On that basis, the NRC staff has compared the risks associated with the range of 0.4–0.8 rem to published risks associated with other occupations (Table 3.14). In this table, only nuclear plant workers are given the added chronic risk resulting from occupational exposures. Thus the risk for this category of workers is inflated by the theoretical calculations. There are three entries in Table 3.14 for nuclear power plant workers: using an annual average dose of 0.8 rem in conjunction with the "best estimate" cancer risk estimator; using an annual average dose of 0.4 rem in conjunction with the "best estimate" cancer risk estimator; and using the lower limit risk cancer estimator for both 0.8 and 0.4 rem.

During the 1980s, the average annual worker doses were reduced by a factor of two, from 0.8 to 0.4 rem (Table 3.13). Part of the reduction has resulted from the completion of backfitting work and part has resulted from improvements in radiation protection (ALARA) programs. The precise average annual worker doses that will accompany refurbishment are not known at present but are anticipated to be between 0.8 and 0.4 rem. This dose range puts nuclear power plant workers in the mid-range of job-related mortality incidence (Table 3.14). The actual cancer incidence as a result of radiation exposures at such low rates (i.e., two to three times natural background radiation) may be zero (NAS 1990). As a consequence, the actual occupational risk for nuclear plant workers may be in the lower part of the mortality incidence table. On the basis of these comparisons, the staff concludes that the risk to nuclear plant workers from refurbishment efforts associated with license renewal is comparable to the risks associated with other occupations.

The staff has examined the cumulative effects of occupational exposures during refurbishment activities under the conservative scenario. These effects are based on the dose estimate for BWRs (Appendix B) as an upper bound. A total of 2000–4000 persons are expected to compose the refurbishment work force if average annual individual doses are maintained at 0.4 to 0.8 rem. The risk of potentially fatal cancers in the exposed refurbishment work force population at a typical site and the risk of potential genetic disorders in all future generations of this refurbishment work force are estimated as follows: multiplying the estimated cumulative dose of 2325 person-rem (4 × 191 person-rem + 1561 person-rem) by the limit of the risk coefficients described earlier (Section 3.8.1.3 and Table 3.9), the staff estimates that between zero and one additional cancer death could occur in the total exposed refurbishment population for a given power plant. The magnitude of this risk estimate can be understood by comparing it with the current incidence of cancer deaths. Multiplying the estimated exposed worker population of 2000 to 4000 persons by the current incidence of actual cancer fatalities (20 percent), about 400 to 800 cancer deaths are expected in this population from causes other than occupational radiation exposure (American Cancer Society 1994).

The risk estimate of 0.1 genetic disorder to the progeny of the exposed refurbishment work-force population is roughly 5 million times less than the risk estimates of natural incidence of actual genetic ill health of about 500,000 expected for the same progeny. Because the risk is borne by the progeny of the entire population, it is thus properly considered as part of the risk to the general public. BEIR-III (1980) indicates that the mean persistence of the

Table 3.14 Incidence of job-related mortalities[a]

Occupational group	Mortality rates (premature deaths per 10^5 person-years)
Underground metal miners[b]	~1300
Uranium workers[b]	420
Smelter workers[b]	190
Nuclear-plant workers (early 1980s)[d]	44
Agriculture, forestry, and fisheries[c]	35
Mining, quarrying[c]	33
Nuclear-plant workers (1992)[e]	24
Construction[c]	22
Transportation and public utilities[c]	20
Nuclear-plant workers[f]	12
Government[c]	11
Wholesale and retail trade[c]	5
Manufacturing[c]	4
Services[c]	3

[a]Mortality incidences in this table do not include occupational diseases except for the hypothetical cancer incidence in nuclear plant workers.
[b]U.S. Department of Health, Education, and Welfare 1972.
[c]*Accident Facts* 1994 Edition, National Safety Council.
[d]The nuclear-plant worker's risk is equal to the sum of the radiation-related risk and the non-radiation-related risk. The estimated occupational risk associated with an average radiation dose of 0.8 rem is about 32 potential premature deaths per 10^5 person-years resulting from cancer, based on the ICRP 60 "best estimate" risk estimator of 4×10^{-4}/rem (ICRP 1991). The average non-radiation-related risk for seven U.S. electrical utilities during the 1970–79 period was about 12 actual premature deaths per 10^5 person-years, as shown in Figure 5 of Wilson and Koehl. (Note that the estimate of 32 radiation-related premature cancer deaths describes potential risk rather than an observed statistic. The lower confidence limit is zero.)
[e]The average worker dose in 1992 was approximately 0.3 rem. Using the "best estimate" risk estimator, about 12 premature deaths per 10^5 person-years are expected. Also, 12 actual premature deaths are caused by nonradiological causes typical of electrical utilities (see footnote *c*). The lower confidence limit is zero.
[f]Using the lower confidence limit for the risk estimate, no deaths from occupational radiation exposures are anticipated and the mortality incidence results totally from nonradiological causes typical of electrical utilities.
Source: Adapted from Wilson and Koehl (1980).

two major types of genetic disorders are about five generations and ten generations respectively. The risk of potential genetic disorders from refurbishment is conservatively compared with the risk of actual genetic ill health in the first five generations, rather than the first ten generations. Multiplying an assumed population of 1 million persons in the vicinity of the plant by the current incidence of actual genetic ill health in each generation (11 percent) yields an estimate that about 500,000 genetic abnormalities are expected in the first five generations of this population.

3.8.2.4 Cumulative Impacts

Currently, occupational radiation doses are on the order of 0.4 rem/year in addition to the 0.36 rem/year received by the typical U.S. resident. The cumulative impact of the estimated exposures due to refurbishment would be to increase average occupational radiation exposures for those involved from 0.76 rem to 0.79 rem for the year that includes the 9-month refurbishment period.

3.8.2.5 Conclusions

Occupational doses from refurbishment activities associated with license renewal (including current-term outages and the assumed single large outage) are estimated to be less than 1 percent of regulatory dose limits. The average individual exposures for refurbishment are expected to remain roughly the same as they have been during the last decade, within the middle zone of the occupations examined. The "best estimate" cancer risk due to refurbishment, 1×10^{-5}, is less than 10 percent of the ongoing annual occupational risk of 1.6×10^{-4} and less than 1 percent of the lifetime accumulation of occupational risk of 4.8×10^{-3}. Occupational radiation exposure during refurbishment meets the standard of small significance. Because the ALARA program continues to reduce occupational doses, no additional mitigation program is warranted. This is a Category 1 issue.

3.9 THREATENED AND ENDANGERED SPECIES

Potential impacts of refurbishment on federal- or state-listed threatened and endangered species, and species proposed to be listed as threatened or endangered, cannot be assessed generically because the status of many species is being reviewed and it is impossible to know what species that are threatened with extinction may be identified that could be affected by refurbishment activities. In accordance with the Endangered Species Act of 1973 (Pub. L. 93-205), the appropriate federal agency (either the U.S. Fish and Wildlife Service or the National Marine Fisheries Service) must be consulted about the presence of threatened or endangered species. At that time, it will be determined whether such species could be affected by refurbishment activities and whether formal consultation will be required to address the impacts. Each state should be consulted about its own procedures for considering impacts to state-listed species. Because compliance with the Endangered Species Act cannot be assessed without site-specific consideration of potential effects on threatened and endangered species, it is not possible to determine generically the significance of potential impacts to threatened and endangered species. This is a Category 2 issue.

3.10 SUMMARY OF IMPACTS OF REFURBISHMENT

The following conclusions have been drawn with regard to the impacts of refurbishment.

On-Site Land Use

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

Air Quality

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

Surface Water Quality and Use

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

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

Groundwater

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

Aquatic Ecology

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

Terrestrial Ecology

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

Socioeconomics

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

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

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

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

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

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

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

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

Radiological Impacts

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

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

Threatened and Endangered Species

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

3.11 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. The BWR conservative and typical work force numbers used in this analysis are 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.

3.12 REFERENCES

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4. ENVIRONMENTAL IMPACTS OF OPERATION

4.1 INTRODUCTION

Nuclear power plant operations during the license renewal term will result in a continuation of most of the impacts that were occurring prior to license renewal. Some operational procedures will change, however, in response to efficiency, reliability, and safety goals. These new procedures may result in a new baseline of plant-induced impacts that will continue throughout the license renewal term. In addition, the environmental receptors such as air, water, population, and biotic communities may be changing. These receptor changes in turn will influence the significance of any plant-induced impacts. Therefore, this chapter defines the prelicense-renewal baseline for plant-induced impacts and additional impacts due to a changing environment, refurbishment, and changes in plant operation.

It is the intent of this chapter to discuss all substantive issues of concern that were identified in the scoping process (Section 1.3). This chapter is organized according to the major modes by which nuclear power plants affect the environment. Because the cooling system is a major mode of interaction with the environment and because the three types of cooling systems have substantially different effects, the first three sections address the impacts of operation for each of the three cooling system types. Transmission lines have distinctly different effects from cooling systems, so they are discussed separately in Section 4.5. Operation of nuclear power plants also has potential human health, socioeconomic, and groundwater effects that are not closely related to either the cooling system or the transmission lines. These effects are discussed in Sections 4.6, 4.7, and 4.8.

The issue of impacts to threatened or endangered species is potentially relevant to all cooling system types and to transmission lines. Review of power plant operations has shown that neither current cooling system operations nor electric power transmission lines associated with nuclear power plants are having significant adverse impacts on any threatened or endangered species. However, widespread conversion of natural habitats and other human activities continues to cause the decline of native plants and animals. As biologists review the status of species, additional species threatened with extinction are being identified; consequently, it is not possible to ensure that future power plant operations will not be found to adversely affect some currently unrecognized threatened or endangered species. In addition, future endangered species recovery efforts may require modifications of power plant operations. Similarly, operations-related land-disturbing activities (e.g., spent fuel and low-level waste storage facilities) could affect endangered species. As noted in Section 3.2, without site-specific and project-specific information, the magnitude or significance of impacts on threatened and endangered species cannot be assessed. For these reasons, the nature and significance of nuclear power plant operations on as yet unrecognized endangered species cannot be predicted; and no generic conclusion on the significance of potential impacts on endangered species can be reached. The impact on threatened and endangered species, therefore, is a Category 2 issue and will not be discussed further in this chapter.

4.2 ONCE-THROUGH COOLING SYSTEMS

A once-through cooling system can affect the environment by withdrawing a large amount of water, heating it, adding biocides, and discharging it back to the receiving body. The main issues associated with plants using such a system are (1) effects on aquatic organisms due to changes in water quality, entrainment, and impingement; (2) water-use conflicts; and (3) effects on groundwater quality, hydrology, and use. These issues as they relate to license renewal are addressed in this section.

The following sections discuss the potential effects of operation of once-through condenser cooling systems on surface water quality, hydrology, and use (Section 4.2.1) and aquatic ecology (Section 4.2.2). Section 4.2.2.2 summarizes the conclusions for each of these issues.

4.2.1 Surface Water Quality, Hydrology, and Use

This section considers how once-through cooling systems may alter surface water quality, hydrology, and quantity; the consequent biological effects of such changes and the methodology used to arrive at conclusions are described in Section 4.2.2. Each issue is described and, as appropriate, illustrated with examples from operating nuclear power plants. Any ongoing effects will probably continue into the license renewal term, assuming that the cooling system design and operation will not change for any plant under the requirements for license renewal. Judgments about the significance of these issues during the license renewal term are based on published information, agency consultation, and information provided by the utilities (Appendix F) on every nuclear power plant in the United States. The conclusions reached in Section 4.2.1 apply to all nuclear power plants with once-through cooling systems.

Seventy nuclear power plants have a once-through cooling system (see Table 2.2). The operation of once-through cooling systems alters water quality primarily through the discharge of heat and chemicals to a receiving body of water. The largest volumes of discharge are associated with the main condenser cooling system, but there are other sources of liquid effluents (e.g., the service water system and sanitary wastes). Because the volumes of water discharged from other systems are relatively small compared with those of the once-through condenser cooling system (typically around 10 percent), concern about water quality impacts of discharges has generally focused on the condenser cooling system. The amounts of heated effluent from such a system can be large; a nuclear power plant with once-through cooling discharges water at about 46 m^3/s (736,000 gal/min) per 1000 MW(e) with a temperature increase of 10°C (18°F).

4.2.1.1 Regulation of Condenser Cooling System Effluents

The U.S. Nuclear Regulatory Commission (NRC) considered the costs and benefits of alternative condenser cooling systems (including potential impacts on water quality and aquatic ecology) in the environmental statements associated with issuance of construction permits and operating licenses. Once a plant is operating, however, the continuing regulation of nonradiological impacts on water quality and aquatic ecology is primarily the responsibility of the U.S. Environmental Protection Agency (EPA) or the applicable state permitting agency. This section describes the environmental statutes that underlie the regulation of impacts on aquatic resources from operating nuclear power plants. An understanding of the requirements of these statutes and the procedures under which aquatic resources effects are controlled by the permitting agencies is important to the interpretation of the issue categories.

As with other industries, discharges from steam-electric power plants are regulated under the Clean Water Act (CWA). Because power plants discharge wastewater into surface bodies of water, they must obtain a National Pollutant Discharge Elimination System (NPDES) permit under Section 402 of the CWA (33 USC 1342). The NPDES permit specifies the discharge standards and monitoring requirements that the facility must achieve for each point of discharge or outfall. NPDES permits must be renewed every 5 years, and during the renewal process, the plant must certify that no changes have been made to the facility that would alter aquatic impacts and no significant adverse impacts on aquatic resources have been observed. An NPDES permit is issued by EPA or, more commonly, a designated state water quality agency.

Under Section 316(a) of the CWA [33 U.S.C. 1326(a)], state-established thermal effluent limitations in the NPDES permit may be modified to a less stringent level if it can be shown that the less stringent level (i.e., higher temperatures) is sufficient to "ensure the protection and propagation of a balanced, indigenous population of shellfish, fish, and wildlife" (Bugbee 1978). The regulatory agency's decision to allow alternative thermal discharge limitations is based on the utility's 316(a) demonstration, which may present considerable information about the actual or projected thermal impacts of the power plant discharge. Like the NPDES permit, the 316(a) "variance" must be renewed every 5 years, and the applicant must provide evidence to the permitting agency as to why the variance is still appropriate. A 316(a) determination is not necessary for those power plants that are able to meet state water temperature standards; this is the case for many nuclear power plants that use closed-cycle cooling systems (Appendix F). However, a biological assessment/study, similar to that which would be required by 316(a), may be required to ensure that the mixing zone meets water quality standards [Charles H. Kaplan, letter to G. F. Cada, Oak Ridge National Laboratory (ORNL), Oak Ridge, Tennessee November 19, 1990].

Section 316(b) of the CWA [33 USC 1326(b)] requires that "the location, design, construction, and capacity of cooling water intake structures reflect the best technology available for minimizing adverse environmental impact." Like NPDES permits and 316(a) determinations, 316(b) determinations are made by EPA or a state permitting agency based on data supplied in the applicant's 316(b) demonstration. The 316(b) determination need not be separated from the NPDES process. Although 316(b) determinations are usually one-time judgments that are not periodically reconsidered, a determination under CWA Section 316(b) is not permanently binding. Where circumstances have changed (e.g., fish population has changed, the initial determination was deemed inappropriate, or some adjustment in the operation of the intake structure is warranted), a full 316(b) demonstration could again be required by EPA during the license period.

The 316(a) and (b) demonstrations provide EPA (or a designated state permitting agency) a means for considering condenser cooling system effects on aquatic biota, not just on water quality per se. Other federal and state agencies with responsibilities for aquatic resources [e.g., the U.S. Fish and Wildlife Service (FWS), the National Marine Fisheries Service (NMFS), state fish and wildlife agencies] do not issue permits but are consulted in the development of NPDES permits and Section 316 determinations.

Under Section 401 of the CWA (33 USC 1341), an applicant for a federal license or permit (the utility in this case) must obtain a state water quality certification (i.e., the state must certify that the applicant's discharges will comply with state water quality standards). This requirement would apply, for example, to U.S. Army Corps of Engineers Section 404 permits for the disposal of dredged and fill material and to EPA-issued NPDES permits. Of course, issuance of an NPDES permit by a state water quality agency implies certification under Section 401.

Any pesticide must be registered under the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA) (7 USC 136 et seq.); this includes the various chlorine compounds, bromine compounds, and molluscicides used to control biofouling in power plants. Registration requires development of toxicity data. Under FIFRA, no one can use a biocide except in accordance with labeled instructions. Information about toxicity developed by the biocide manufacturer as a FIFRA requirement may be used to determine permissible power plant discharge concentrations for the NPDES permit.

Other potential aquatic resource issues are the subjects of particular legislation or executive orders (EOs) with specific requirements that cannot be limited or eliminated. For example, potential effects of plant modifications on floodplains and wetlands must be considered under EOs 11988 and 11990, respectively. Modifications that entail disposal of dredged material may require a permit from the U.S. Army Corps of Engineers under Section 404 of CWA (Pub. L. 92-500). Because the impacts could range from small to large depending on the details of the site and the proposed construction, the potential effect on floodplains or wetlands is a Category 2 issue.

4.2.1.2 Water Quality/Hydrology

The continued operation of once-through condenser cooling systems will allow continuation of associated hydrologic changes, including altered current patterns at intake and discharge structures, altered salinity gradients, and altered thermal stratification of lakes. Water quality effects considered in this section include temperature effects on sediment transport capacity, scouring, eutrophication, and the discharge of biocides, sanitary wastes, and heavy metals.

4.2.1.2.1 Current Patterns

Operation of the cooling system usually causes changes in water currents in the immediate vicinity of both the intake and the outfall. The extent of the changes depends on the design and siting of the intake and discharge and the nature of the body of water (Langford 1983). Because many nuclear plants are located on large rivers, lakes, reservoirs or on the seacoast, such localized altered current patterns are minor. However, plants sited near small bodies of water may have marked effects on current patterns. Operation of the cooling water system of Oyster Creek Nuclear Generating Station (NGS) changed the flows of the lower portions of Oyster Creek and South Branch Forked River from alternating flows typical of estuarine streams to unidirectional flows with constant salinity. The South Branch Forked River became an intake canal, with salt water continuously moving upstream toward the power plant. Oyster Creek, on the other hand, became a discharge canal, with heated salt water moving continuously away from the plant. Although substantial changes to the hydrology and water quality of these small streams have been documented, there have been only minor effects on nearby Barnegat Bay (Kennish et al. 1984). Changes to current patterns are of small significance if they are localized near the intake and discharge of the power plant and do not alter water use or hydrology in the wider area. Because once-through power plants are located near substantial bodies of water that are not subject to extreme changes in volume or flow rate, cooling water withdrawals and discharges do not have major effects on the hydrology of these large bodies of water. Impacts during the license renewal period are expected to be of small significance for all plants. Localized effects on current patterns would have been manifested during the initial stages of plant operation and would have been mitigated if necessary at that time. Based on a review of the published literature and operational monitoring reports, operation of the cooling system is expected to cause only small, localized changes to current patterns near the power plant and would not contribute to the cumulative impacts. Further, consultation with the utilities and regulatory agencies during preparation of the draft GEIS, as well as their comments on the draft GEIS, revealed no concerns about the individual or cumulative impacts of cooling system operations on current patterns. The impacts of altered current patterns will continue to be localized and of small significance. No change in operation of the cooling system is expected during the license renewal term, so no change in effects on current patterns is anticipated. The effects on current patterns could be reduced by changing to a closed-cycle cooling system or by reducing the plants' generation rate. However, these measures would be costly and are not reasonable in light of the small benefits that might be gained from their implementation. Hence, no additional mitigation measures to reduce the impact of cooling system operations on current patterns are necessary in the renewal period. For these reasons, the effect of once-through cooling system operation on current patterns is a Category 1 issue.

4.2.1.2.2 Salinity Gradients

Power plants operating near estuaries can also alter salinity gradients. As noted, the Oyster Creek NGS cooling system converted two brackish creeks to canals with unidirectional flows and increased salinity to an average of 17 parts per thousand, similar to Barnegat Bay (Tatham et al. 1978). The two creeks have become hydrologic extensions of the bay because of operation of the power plant, causing significant changes in the original water quality and aquatic communities in the creeks because water quality is now essentially the same as that of the bay

(Chizmadia et al. 1984). Effects do not appear to extend beyond these creeks, which are also affected by dredging and thermal and chemical discharges.

Chesapeake Bay has a large number of power plants (mostly fossil-fueled) within the mesohaline (estuarine) zone. The fact that power plant discharges can alter salinity regimes, which in turn can change the type and abundance of aquatic organisms at the discharge site, is considered in the development of NPDES permits for Maryland power plants (MDNR 1988). Although natural salinity patterns have been altered by the discharge of Chalk Point (a large fossil-fueled power plant) into a shallow mesohaline area of Chesapeake Bay, other plants in the area, including the Calvert Cliffs Nuclear Power Plant, have not had consistent discharge effects on salinity (MDNR 1988). Any localized effects on biota near these Maryland power plants are attributed to thermal and habitat changes, rather than to salinity. Changes to salinity gradients are of small significance if they are localized near the intake and discharge of the power plant and are within the normal tidal or seasonal movements of salinity gradients that characterize estuaries. Based on a review of the published literature and operational monitoring reports, operation of the cooling system is expected to cause only small, localized changes to salinity gradients near the power plant. Further, consultation with the utilities and regulatory agencies during preparation of the draft GEIS, as well as their comments on the draft GEIS, revealed no concerns about the individual or cumulative impacts of cooling system operations on salinity gradients. These organizations did not identify a need for additional mitigation of impacts associated with this issue. For example, operation of numerous once-through power plants in the Chesapeake Bay estuary has not caused significant changes in salinity gradients. The effects on salinity gradients could be reduced by changing to a closed-cycle cooling system or by reducing the plants' generation rate. However, these measures would be costly and are not reasonable in light of the small benefits that might be gained from their implementation. Hence, no additional mitigation measures to reduce the impact of cooling system operations on salinity gradients are necessary in the renewal period. For these reasons, the effects of once-through cooling system operation on salinity gradients are a Category 1 issue.

4.2.1.2.3 Thermal Effects

Discharges of heated effluents have the potential to affect water quality in five ways: (1) water temperature increases, including altered thermal stratification of lakes, (2) temperature effects on sediment transport capacity, (3) scouring, (4) lowered dissolved oxygen concentrations, and (5) eutrophication. Heated water discharges tend to remain at (or move toward) the surface of lakes and rivers. These discharges form a plume of warm water that dissipates with distance from the source by rejecting heat to the atmosphere or mixing with cooler ambient waters. Mixing tends to occur more rapidly in rivers than in lakes because of increased turbulence. Also because of turbulence, rivers do not naturally thermally stratify; as a result, alteration of temperature stratification in rivers by nuclear power plants is not an issue. Impacts of thermal discharges to water quality are of small significance if discharges are within thermal effluent limitations designed to ensure protection of water quality and if ongoing discharges have not resulted in adverse effects on the five attributes of water quality identified above.

Temperature-induced density stratification of lakes and reservoirs is a principal regulator of water quality and organism distribution in deep waters. Thermal stratification can be changed in two general ways by once-through cooling of power plants: by the discharge of heated water and by the altered circulation patterns generated by pumping cooling water into and out of the power station (Coutant 1981). Temperature elevation can intensify stratification (through surface discharge of heated water), whereas enhanced circulation may break down stratification. The relative importance of these two counteracting processes depends on the characteristics of the site and cooling system.

Destratification can increase dissolved oxygen concentrations in deeper waters and decrease the solubility of phosphorus (which contributes to eutrophication), and may be a net benefit to warm-water fisheries by expanding available habitat. For example, Larimore and McNurney compared two nearby lakes in Illinois—Lake Shelbyville, an unheated flood control reservoir, and Lake Sangchris, a cooling lake for a coal-fired power plant. In contrast with the unheated lake, Lake Sangchris did not stratify in the summer. Furthermore, largemouth bass had a longer growing season and greater annual growth in the cooling lake.

On the other hand, Coutant (1981) noted that the common practice of using cool hypolimnetic water from deep intakes for power station cooling, with surface discharge, may increase the size of the warm epilimnion and decrease the amount of habitat available to cool-water fish. For example, thermal discharges from the Oconee Nuclear Station have increased the annual heat load of Keowee Reservoir by one-third and lowered the thermocline (boundary between warm surface waters and cool bottom waters) from between 5 and 15 m to as low as 27 m (Oliver and Hudson 1987), although neither specified thermal limits nor lethal temperatures were exceeded [Oliver and Hudson 1987; Duke Power Company response to NUMARC survey (NUMARC 1990)].

The McGuire Nuclear Station withdraws cool hypolimnetic water from Lake Norman and discharges the heated water at the surface. As with Oconee, this has the effect of increasing the size of the upper layer of warm water and decreasing the habitat available for cool-water fishes (e.g., striped bass) in the hypolimnion of Lake Norman. Temperature modeling indicated that increasing the maximum upper discharge temperature from 95 to 99°F during July, August, and September would conserve cool-water fish habitat in the lake by allowing smaller withdrawal rates of hypolimnetic waters and would lower the average heat content of the lake by allowing more heat to be dissipated to the atmosphere from the warmer localized area (Duke Power Company 1988; Lewis 1990). The increased thermal limit is not expected to substantially affect water quality or aquatic biota in the mixing zone. Following consultation with the North Carolina Department of Health and Natural Resources, the NPDES permit has been modified to allow the higher temperatures [Duke Power Company response to NUMARC survey (NUMARC 1990)]. Modeling reservoir heat budgets allows effects of thermal discharges on stratification to be predicted and used by utilities and regulatory agencies to develop the best heat dissipation scheme. Altered thermal stratification has never been a problem at most plants. At other plants (i.e., McGuire and Oconee), the issue has been periodically re-examined during the initial license period and mitigated as needed by adjusting thermal discharges.

The effects of altered thermal stratification on water quality and distribution of aquatic organisms are monitored during plant operation and are mitigated if necessary through the NPDES permit renewal process. Based on a review of the published literature and operational monitoring reports, operation of the cooling system has not altered thermal stratification at most power plants with once-through cooling systems. At the small number of plants where changes in thermal stratification have occurred, monitoring and modeling studies have been used to adjust the thermal discharges, thereby mitigating adverse impacts. As appropriate, these models take into account other thermal inputs to the receiving waterbody and therefore consider cumulative as well as individual plant effects. Consultation with the utilities and regulatory agencies during preparation of the draft GEIS, as well as their comments on the draft GEIS, revealed no concerns about the individual or cumulative impacts of cooling system operations on thermal stratification. The impacts of altered thermal stratification will continue to be of small significance. No change in operation of the cooling system is expected during the license renewal term, so no change in effects on thermal stratification is anticipated. The effects of thermal stratification could be reduced by changing to a closed-cycle cooling system or by reducing the plants' generation rate. However, these measures would be costly and are not reasonable in light of the small benefits that might be gained from their implementation. Hence, no additional mitigation measures to reduce the impact of cooling system operations on thermal stratification are necessary in the renewal period. For these reasons, the effects of once-through cooling system operation on thermal stratification are a Category 1 issue.

Increased temperature and the resulting decreased viscosity have been hypothesized to change the sediment transport capacity of water, leading to potential sedimentation problems, altered turbidity of rivers, and changes in riverbed configuration. Coutant (1981) discussed the theoretical basis for such possible changes, as well as relevant field investigations, and concluded that there is no indication that this is a significant problem at operating power stations. Examples of altered sediment characteristics are more likely the result of power plant structures (e.g., jetties or canals) or current patterns near intakes and discharges; such alterations are readily mitigated.

Based on review of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and comments on the draft GEIS, there is no evidence that temperature effects on sediment transport capacity have caused adverse environmental effects at any existing nuclear power plant. Regulatory agencies have expressed no concerns regarding the cumulative impacts of temperature effects on sediment transport capacity. Furthermore, because of the small area near the plant affected by increased water temperature, it is not expected that plant operations would have a significant contribution to cumulative impacts. Effects are considered to be of small significance for all plants. No change in the operation of the cooling system is expected during the license renewal term so no change in effects on sediment transport capacity is anticipated. Effects on sediment transport could be reduced by changing to a closed-cycle cooling system or by reducing the plants' generation rate. However, because the effects on sediment transport capacity are considered to be impacts of small significance and because these measures would be costly, the staff does not consider the implementation of these potential mitigation measures to be warranted. This is a Category 1 issue.

Cooling water discharges have the potential for scouring sediments, especially near high-velocity discharge structures, and for changing patterns of sediment deposition. Changes in sediment composition have been observed near operating power plants; for example, the Calvert Cliffs Nuclear Power Plant (MDNR), the Haddam Neck (Connecticut Yankee) Plant (Merriman and Thorpe), and the San Onofre Nuclear Generating Station (MRC). Fine-grained materials near the power plant discharge structure may become suspended by the discharge plume, resulting in localized increases in turbidity and a coarser-grained composition of sediments near the discharge. Depending on site-specific circumstances, changes in sediment composition near the power plant discharge may be regarded as adverse (shading of kelp beds; MRC), beneficial (enhancement of the productivity of benthic animals; MDNR), or inconsequential (Merriman and Thorpe). In all cases, sediment changes are localized.

Review of literature and operational monitoring reports, consultation with utilities and regulatory agencies, and comments on the draft GEIS confirm that sediment scouring has not been a problem at most power plants and has caused only minor localized effects at three plants. The impacts of sediment scouring will continue to be localized and of small significance. Contributions to cumulative impacts are not expected because of the small area near the power plant affected by higher velocity cooling water discharges, and no concerns about cumulative impacts were expressed by the regulatory agencies. The effects of sediment scouring could be reduced by changing to a closed-cycle cooling system or by reducing the plants' generation rate. However, these measures would be costly and are not reasonable in light of the small benefits that might be gained from their implementation. Hence, no additional mitigation measures to reduce sediment scouring effects are necessary in the renewal period. Sediment scouring due to discharge of condenser cooling water is a Category 1 issue.

An early concern about thermal discharges from power plants was that the heat would stimulate biological productivity and speed the process of eutrophication of natural waters. Coutant (1981) examined the evidence for such changes and concluded that, because enhanced mineralization of organic matter by bacteria would offset any thermally induced increases in organic production, significant eutrophication from direct thermal effects at most plants was unlikely. On the other hand, Coutant (1981) hypothesized that power plants that withdraw hypolimnetic water from stratified reservoirs and discharge heated effluents at the surface may (1) lengthen the growing season and (2) transfer previously unavailable nutrients from bottom waters to the surface. A longer growing season and more nutrients in the surface layer could result in more biological production and more organic matter that would settle into the hypolimnion and thus decay and consume oxygen; all of these are symptoms of eutrophication. This chain of events is most likely to be seen in small lakes that were oligotrophic (relatively unproductive) and supported hypolimnetic fisheries. Long-term monitoring of the McGuire Nuclear Station on such a reservoir indicates that operations have not resulted in increased eutrophication (NPDES No. NC0024392, 1988; NPDES No. NC0024392, 1990). Similarly, the operation of Oconee Nuclear Station does not appear to be causing eutrophication in Lake Keowee; long-term studies indicate that nutrient levels in the lake are low and appear to be declining [Duke Power Company, response to NUMARC survey (NUMARC 1990)]. Review of literature and operational monitoring reports, consultation with utilities and regulatory agencies, and review of comments on the draft GEIS indicate that power-plant-induced eutrophication has not been a problem at any existing nuclear power plant. Monitoring studies have not revealed cumulative impacts, and no concerns about nuclear power plants contributing to eutrophication in a cumulative way were expressed by the regulatory agencies. Effects are considered to be of small significance for all plants. No change in operation of the cooling system is expected during the license renewal term, so no change in the effects on eutrophification is anticipated. The eutrophication effects could be reduced by changing to a closed-cycle cooling system or by reducing the plants' generation rate. However, these measures would be costly and are not reasonable in light of the small benefits that might be gained from their implementation. Hence, no additional mitigation measures to reduce eutrophication effects are necessary in the renewal period. Accelerated eutrophication due to discharge of condenser cooling water is a Category 1 issue.

4.2.1.2.4 Chemical Effects

Some of the water quality issues that have been raised are potential chemical effects resulting from discharges of chlorine or other biocides, small-volume discharges of sanitary and other liquid wastes (Chapter 2), chemical spills, and heavy metals leached from cooling system piping and condenser tubing. Impacts of chemical discharges to water quality are considered to be of small significance if discharges are within effluent limitations designed to ensure protection of water quality and if ongoing discharges have not resulted in adverse effects on aquatic biota.

The discharged chemicals, including chlorine and other biocides, are regulated by the NPDES permit of each nuclear power plant. Regulatory concern about toxic effects of chlorine and its combination products, as well as operating experience with control of biofouling, has led many plants to eliminate the use of chlorine or reduce the amount used below those levels that were originally anticipated in the environmental statements associated with issuing the construction permit and operating license. Some power plants use mechanical cleaning methods or, because of the abrasive properties of particulates in the intake water, do not have to clean the condenser cooling system at all. Other plants chlorinate the condenser cooling or service water systems but can isolate certain portions for treatment (e.g., a single unit of a multi-unit plant), thereby allowing dilution to reduce the concentration of chlorine in the discharge. Because of these refinements and the process for modifying NPDES permit conditions as needed, water quality degradation from existing biocide usage at once-through nuclear power plants is not a concern among the regulatory and resource agencies consulted for this GEIS. Based on review of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and comments on the draft GEIS, water quality effects of discharge of chlorine and other biocides are considered to be of small significance for all plants. Small quantities of biocides are readily dissipated and/or chemically altered in the receiving waterbody so that significant cumulative impacts to water quality would not be expected. No change in operation of the cooling system is expected during the license renewal term, so no change in the effects of biocide discharges on receiving water quality is anticipated. Effects of biocide discharges could be reduced by increasing the degree of discharge water treatment, reducing the concentration of biocides, or by treating only a portion of the plants' cooling and service water systems at one time. However, because the effects of biocide discharges on water quality are considered to be impacts of small significance, the staff does not consider the implementation of these potential mitigation measures to be warranted. Discharge of chlorine and other biocides is a Category 1 issue. Discharges of sanitary wastes are regulated by NPDES permit, and discharges that do not violate the permit limits are of small significance.

Minor chemical spills or temporary off-specification discharges from sanitary waste treatment systems and other low-volume effluents (e.g., excessive coliform counts or total suspended solids levels, pH outside of permitted range) were cited as common NPDES permit violations in the utility responses to the NUMARC survey (NUMARC 1990). Such NPDES noncompliances have been variable, random in occurrence, and readily amenable to correction. These minor discharges or spills do not constitute widespread, consistent water quality impacts. Water quality effects of minor chemical discharges and spills are of small significance and do not have significant effects on aquatic biota for all plants and have been mitigated as needed. Significant cumulative impacts to water quality would not be expected because the small amounts of chemicals released by these minor discharges or spills are readily dissipated in the receiving waterbody. Spills and off-specification discharges occur seldom enough that regulatory agencies express no concern about them for operating nuclear power plants. While there may be additional management practices or discharge control devices that could further reduce the frequency of accidental spills and off-specification discharges, they are not warranted because impacts are already small and occur at low frequency and because such mitigation would be costly. The water quality impacts of permitted sanitary waste water and minor, nonradiological chemical discharges and spills are a Category 1 issue.

Heavy metals (e.g., copper, zinc, chromium) may be leached from condenser tubing and other heat exchangers and discharged by power plants as small-volume waste streams or corrosion products. Although all are found in small quantities in natural waters (and many are essential micronutrients), concentrations in the power plant discharge are controlled in the NPDES permit because excessive concentrations of heavy metals can be toxic to aquatic organisms. Discharge of metals and other toxic contaminants may also be subject to individual control strategies developed by the states to control toxic pollutants under the 1987 Amendments to the CWA. These strategies for point source discharges of toxic pollutants are implemented through the NPDES permit program. Langford reviewed the literature concerning heavy metal discharges from power plants and concluded that, during normal operations, concentrations generally are below the levels of detection. However, plant shutdowns for testing and refueling keep stagnant water in contact with condenser tubes and other metal structures for extended periods and could allow abnormally large amounts of metals to be leached. For example, Harrison et al. (DOE/ER-0317) detected elevated copper concentrations in the discharge during startup of Diablo Canyon Nuclear Power Station. Abalone deaths in the discharge area of the Diablo Canyon were attributed to high copper concentrations in the effluent following a shutdown period (Martin et al. 1977).

The ability of aquatic organisms to bioaccumulate heavy metals even at low concentrations has led to concerns about toxicity both to the biota and to humans that consume contaminated fish and shellfish. For example, bioconcentration of copper discharged from the Chalk Point Plant (a fossil-fuel power plant on Chesapeake Bay) resulted in oyster "greening" (Roosenburg 1969). Bioaccumulation of copper released from the H. B. Robinson Plant resulted in malformations and decreased reproductive capacity among bluegill in the cooling reservoir (ASTM STP 854); see Section 4.4.3. In all three of these examples of excessive accumulation of copper (Diablo Canyon, Chalk Point, and H. B. Robinson), replacement of the copper alloy condenser tubes with another material (e.g., titanium) eliminated the problem.

Concentrations of heavy metals in the discharges of once-through nuclear power plants are normally within NPDES permit limits and are quickly diluted or flushed from the area by the large volumes of the receiving water. Discharge of metals and other toxic contaminants may also be subject to individual control strategies developed by the states to control toxic pollutants under the 1987 Amendments to the CWA. These strategies for point source discharges of toxic pollutants are implemented through the NPDES permit program. Excessive discharges of metals have been corrected at the two nuclear power plants (Diablo Canyon and H. B. Robinson) that experienced problems during the original license period. Impacts of heavy metal discharges are considered to be of small significance if water quality criteria (e.g., NPDES permits) are not violated and if aquatic organisms in the vicinity of the plant are not bioaccumulating the metals. Based on review of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and comments on the draft GEIS, discharge of heavy metals leached from the condenser cooling system has been a problem at only Diablo Canyon and H. B.Robinson nuclear power plants, and mitigation was effective in both cases. Although cumulative impacts could result from the long-term accumulation and bioaccumulation of heavy metals, mitigation for individual plant effects has also reduced the potential for contributions to cumulative effects. Monitoring has not revealed a continuing problem with accumulation of heavy metals. No change in operation of the cooling system is expected during the license renewal term, so no change in metal concentrations in the cooling water discharge is anticipated. Effects of elevted metal concentrations could be reduced by replacing condenser tubes with alloys that are less likely to corrode. However, because the effects of metal concentrations on cooling water discharges are considered to be impacts of small significance and because the potential mitigation measures would be costly, the staff does not consider the implementation of these potential mitigation measures to be warranted. Elevated heavy metal concentrations in the condenser cooling water discharge is a Category 1 issue.

4.2.1.3 Water Use/Water Availability

Water use in the United States, as measured by freshwater withdrawals in 1985, averaged 15 million m^3/s (338 billion gal/day) (Carr et al. 1990). Four million m^3/s (ninety-two billion gal/day), or 27 percent of the water withdrawn, was consumed (e.g., by evaporation) and thus was not directly returned to the body of water. The remainder of the withdrawals (73 percent) was return flow available for reuse. In 1985, freshwater withdrawals by steam-electric power plants were approximately 5.7 million m^3/s (132 billion gal/day), which was 39 percent of the total freshwater withdrawals for all uses (Carr et al. 1990). About 2.4 million m^3/s (56 billion gal/day) of saline water was used for cooling by thermoelectric plants in coastal areas. Nuclear power plants accounted for 22 percent of the total thermoelectric withdrawals and fossil-fueled plants for 78 percent.

Consumptive uses remove the water from a stream or river and may or may not impact in-stream and off-stream beneficial uses. Return flows that are discharged to a stream are available to other users; freshwater withdrawals discharged to an estuary are effectively lost to further freshwater use (Carr et al. 1990). On the average, out of 0.4 m^3 (100 gal) withdrawn from surface waters for cooling of steam electric utilities, over 0.37 m^3 (98 gal) is returned almost immediately to the source body of water; less than 0.008 m^3 (2 gal) is consumed through evaporation (Solley et al. 1983). The consumptive loss for once-through cooling systems [0.5 m^3/s (18 ft^3/s) per 1000 MW(e)] is somewhat smaller than that attributed to cooling tower evaporation, which has been estimated to average 0.9 m^3/s (30 ft^3/second) per 1000 MW(e) (Giusti and Meyer 1978).

In those areas experiencing water availability problems, nuclear plant consumption may conflict with either existing or potential downstream municipal water use as well as with in-stream water uses. A shift in human population distribution and associated changes in demand for water could have important implications for the continued supply of cooling water for power generating facilities.

Impacts of power plant water use are considered to be of small significance since conflicts with other offstream or instream water users have not occurred and are not anticipated. The nuclear power plants that use once-through condenser cooling systems are located on large lakes, reservoirs, estuaries, oceans, and rivers, and—except possibly during extended periods of drought—are unlikely to experience problems with the water supply. Because net water consumption by facilities using once-through cooling is negligible compared with the size of the body of water, such plants should have only a limited potential for impacts on water availability for downstream use. Should water-use conflicts arise during operation of existing power plants, local officials who are responsible for allocating water resources would have to weigh the use of water for power generation. Based on review of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and comments on the draft GEIS, water use conflicts are found to be of small significance for all plants and cumulative impacts are not of concern. Net water consumption by facilities using once-through cooling is negligible compared with the size of the body of water. Because of abundant water supply, consumptive water use will have impacts of only small significance on riparian plant and animal communities at sites that use once-through cooling systems. No change in operation of the cooling system is expected during the license renewal term, so no change in effects on consumptive water use or riparian communities is anticipated. Effects on consumptive water use and riparian communities could be reduced by changing to a closed cycle cooling system or by reducing the plant's generation rate. However, because such changes would be costly, and because the effects on consumptive water use and riparian communities are of small significance, the staff does not consider the implementation of these potential mitigation measures to be warranted in light of the small benefit that might be gained. Both of these are Category 1 issues.

4.2.2 Aquatic Ecology

As noted in Section 4.2.1, large amounts of water are withdrawn by once-through cooling systems, passed through the condenser tubes, and discharged back to the body of water with an added load of heat and chemical contaminants. A total of 70 nuclear plants use once-through cooling (see Table 2.2). Initial concerns about effects of thermal effluents on aquatic biota (e.g., Krenkel and Parker 1969) were soon accompanied by concerns about impacts of biocide discharges and losses due to intake effects (i.e., impingement and entrainment). All of these issues have received considerable attention and study from utility and regulatory agency scientists in the past two decades, as exemplified by the numerous books and symposia devoted to resolving them (CONF-750425; Saila 1975; Schubel and Marcy 1978; Jensen 1978, 1981; Barnthouse and Van Winkle 1988). The aquatic resources issues that are considered in this section are entrainment (of fish, shellfish, phytoplankton, and zooplankton), impingement of fish and shellfish, thermal effects (heat shock, cold shock, thermal plume barrier to migratory fish, premature emergence of aquatic insects, enhanced susceptibility to parasitism and disease, stimulation of nuisance organisms, gas bubble disease, lower dissolved oxygen), and chemical effects (biocides and accumulation of contaminants in biota).

The following sections review the past and ongoing impacts on aquatic biota of operation of once-through condenser cooling systems. Any ongoing impacts will probably continue throughout the license renewal term because the cooling system design and operation is not expected to change for most plants. Judgments about the significance of these issues during the license renewal term are based on published information, agency consultation, and information provided by the utilities (Appendix F). These sources represent every nuclear power plant in the United States. In addition, seven case studies (Arkansas, McGuire, Cook, San Onofre, Crystal River, and combined effects of power plants on Lake Michigan and the Hudson River) were evaluated in greater detail. These case studies are examples of large once-through condenser cooling systems that affect a variety of aquatic environments (i.e., large lakes and reservoirs, oceans, and estuaries). Published information about these plants was reviewed to determine whether operation has resulted in demonstrable entrainment, impingement, or thermal impacts. For some of the case studies in Appendix F, cumulative effects of the operation of nuclear power plants in conjunction with other sources of stress to aquatic resources are considered.

4.2.2.1 Analysis of Issues

4.2.2.1.1 Entrainment of Phytoplankton and Zooplankton

As discussed in Section 2.3.5, water that is withdrawn for power plant cooling carries with it a variety of aquatic organisms. Those organisms that are small enough to pass through the debris screens in the intake pass through the entire cooling system and are exposed to heat, mechanical and pressure stresses, and possibly biocides before being discharged to the receiving water. This process, called entrainment, may affect phytoplankton, zooplankton, planktonic larval stages of benthic organisms such as shellfish (i.e., meroplankton), and fish eggs and larvae (ichthyoplankton). Most nuclear power plants have been required to monitor for entrainment effects during the initial years of operation. Entrainment impacts to phytoplankton and zooplankton are considered to be of small significance if there is no evidence of reductions of populations of phytoplankton or zooplankton.

Studies of the effects of entrainment at several nuclear power plants are reviewed in Appendix F. None of the agencies consulted expressed concern about entrainment of phytoplankton or zooplankton (Appendix F). Because of large numbers and short regeneration times of phytoplankton and zooplankton, impacts of entrainment on these organisms have rarely been documented outside the immediate vicinity of the plant and are considered to be of little consequence (Schubel and Marcy 1978; Hesse et al. 1982; Kennish et al. 1984; MDNR 1988; MRC 1989; EPRI EA-1038).

The effects of entrainment at nuclear plants are not expected to cause or contribute to cumulative impacts to populations of zooplankton or phytoplankton. The effects of phytoplankton and zooplankton entrainment are localized (i.e., the affected areas are smaller than the distances between power plants) and are not expected to contribute to cumulative impacts because generation times of plankton are rapid. Review of the literature and operational monitoring reports did not reveal evidence of cumulative impacts from entrainment of phytoplankton and zooplankton. Further, consultation with utilities and agencies during preparation of the draft GEIS, as well as their comments on the draft GEIS (NUREG-1529), revealed no concerns about cumulative impacts of phytoplankton and zooplankton entrainment.

Reviews of the literature, monitoring reports, and consultation with agencies and utilities did not reveal any evidence of mitigation measures that had been required to correct problems with entrainment of phytoplankton and zooplankton. Because cooling system operations are not expected to change during the license renewal term, additional mitigation is not expected to be warranted.

Entrainment of phytoplankton and zooplankton is expected to have a small impact on populations of these organisms in the source body of water at any plant. No change in operation of the cooling system is expected during the license renewal term, so no change in effects on entrainment of phytoplankton and zooplankton is anticipated. Effects on entrainment of phytoplankton and zooplankton could be reduced by changing to a closed cycle cooling system or by reducing the plant's generation rate. However, because the effects on entrainment of phytoplankton and zooplankton are considered to be impacts of small significance and because they would be costly to implement, the staff does not consider the implementation of these potential mitigation measures to be warranted. This is a Category 1 issue.

4.2.2.1.2 Entrainment of Fish and Shellfish

The effects of entrainment on aquatic resources were considered by NRC at the time of original licensing and are periodically reconsidered by EPA or state water quality permitting agencies in the development of NPDES permits and 316(b) demonstrations (Section 4.2.1.1.2). Although significant adverse entrainment effects have not been demonstrated at most facilities, the entrainment of fish and shellfish in early life stages remains an issue at some nuclear power plants with once-through cooling systems. Agencies consulted for this GEIS expressed concerns about the impacts of entrainment at Zion, Salem, Oyster Creek, Indian Point, Calvert Cliffs, Millstone, Yankee Rowe, and Surry. Several licensed nuclear power plants (e.g., Indian Point, Oyster Creek, Comanche Peak, Salem, and Zion) have unresolved 316(b) determinations. At some power plants, fish populations have been restored in the years since issuance of the original license and, as a result, more fish are now susceptible to entrainment. At other nuclear power plants (Beaver Valley, Susquehanna, Three Mile Island, and Peach Bottom), an agency expressed concern about future entrainment during the license renewal period as restoration efforts continue to increase fish populations (James Gillett, Deputy Regional Director, U.S. Fish and Wildlife Service, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, July 27, 1990).

The impacts of fish and shellfish entrainment are small at many plants, but they may be moderate or even large at a few plants with once-through cooling systems. Further, ongoing restoration efforts may increase the numbers of fish susceptible to intake effects during the license renewal period, so that entrainment studies conducted in support of the original license may no longer be valid. For these reasons, the entrainment of fish and shellfish is a Category 2 issue for plants with once-through cooling systems.

4.2.2.1.3 Impingement of Fish and Shellfish

Aquatic organisms that are drawn into the intake with the cooling water and are too large to pass through the debris screens may be impinged against the screens. Mortality of fish that are impinged is high at many plants because impinged organisms are eventually suffocated by being held against the screen mesh or are abraded, which can result in fatal infection. Impingement can affect large numbers of fish and invertebrates (crabs, shrimp, jellyfish, etc.). As with entrainment, operational monitoring and mitigative measures have allayed concerns about population-level effects at most plants, but impingement mortality continues to be an issue at others. Consultation with resource agencies (Appendix F) revealed that impingement is a frequent concern at once-through power plants, particularly where restoration of anadromous fish may be affected. In several cases, such as Oyster Creek, Salem, Surry, and Prairie Island, significant modifications were made to the intake structure to substantially reduce mortality due to impingement. Impingement is an intake-related effect that is considered by EPA or state water quality permitting agencies in the development of NPDES permits and 316(b) determinations. Appendix F examines studies of the effects of impingement of fish at several nuclear power plants. The impacts of impingement are small at many plants but may be moderate or even large at a few plants with once-through cooling systems. For this reason, the impingement of fish and shellfish is a Category 2 issue.

4.2.2.1.4 Thermal Discharge Effects

The heated effluents of steam-electric power plants can cause mortality among fish and other aquatic organisms from either thermal discharge effects or cold shock. Temperatures high enough to kill organisms are found in the cooling water systems, often in the area nearest the effluent discharge structure. Because thermal effects were among the earliest potential impacts identified for power plant operation, a great deal of research and regulatory effort has been aimed at understanding and controlling thermal discharges. Upper lethal temperatures (and various other expressions of temperature tolerance) have been determined for many important species and life stages. As a result, conditions that can lead to thermal discharge effects are relatively predictable.

Mitigative measures have been employed at many power plants to reduce the potential for thermal discharge effects. They can be minimized by lowering effluent temperature before discharge to natural waters (e.g., with cooling ponds) or by enhancing rapid mixing and heat dissipation (through high-velocity jet diffusers).

Each permitting state has developed mixing zone criteria and thermal discharge limits for steam-electric power plants. If the plant meets these criteria, no 316(a) determination is required. If the facility fails to meet the state temperature limits, the facility must submit data demonstrating that the discharge will ensure the protection and propagation of a balanced indigenous population of shellfish, fish, and wildlife [i.e., a 316(a) demonstration]. For plants within the state limits, the implicit assumption is made that a balanced indigenous population is ensured. The NPDES permit required for each power plant contains discharge temperature limits that are based on either state standards or site-specific studies of thermal effects [i.e., 316(a) demonstrations]. Nevertheless, thermal discharges continue to be an issue at some once-through nuclear power plants (see agency consultation, Appendix F). In some cases, the facility is being extensively modified to minimize thermal-discharge-related effects (e.g., installation of cooling towers at Crystal River). In others, the 316(a) determination has not been approved and is now under review. Studies of thermal discharge effects at selected nuclear power plants that employ once-through cooling systems are described in Appendix F.

Based on the research literature, monitoring reports, and agency consultations, the potential for thermal discharges to cause thermal discharge effect mortalities is considered small for most plants. However, impacts may be moderate or even large at a few plants with once-through cooling systems. For example, thermal discharges at the Crystal River Nuclear Plant are considered by the agencies to have damaged the benthic invertebrate and seagrass communities in the effluent mixing zone around the discharge canal; as a result, helper cooling towers have been installed to reduce the discharge temperatures (Appendix F.4.7). Conversely, at other plants it may become advantageous to increase the temperature of the discharge in order to reduce the volume of water pumped through the plants and thereby reduce entrainment and impingement effects (see discussion of San Onofre Nuclear Generating Station in Appendix F.4.6). Because of continuing concerns about thermal discharge effects and the possible need to modify thermal discharges in the future in response to changing environmental conditions, this is a Category 2 issue for plants with once-through cooling systems.

4.2.2.1.5 Cold Shock

Cold shock occurs when organisms that have been acclimated to warm water (e.g., in a discharge canal in winter) are exposed to sudden temperature decreases when artificial heating ceases. Such situations may occur when a single-unit power plant suddenly shuts down in winter (Coutant 1977) or when winds or currents shift a thermal plume that was occupied by fish or benthic invertebrates seeking warm water. As with heat effects, the conditions that can lead to cold shock are relatively well understood—it is a function of acclimation temperature, final (cold ambient) temperature, and exposure times—and therefore can be mitigated if needed. Cold shock mortalities have occurred, for example, at the Haddam Neck (Connecticut Yankee) plant (S. W. Gorski, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, July 18, 1990) and at the Prairie Island and Monticello nuclear generating plants (P. M. Bailey, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, July 3, 1990). Cold-shock mortalities are relatively rare and usually involve small numbers of fish. Population-level effects have not been demonstrated. Where necessary, the discharge structure or the plant operating procedures have been modified to reduce cold-shock effects. Structural modifications could include constructing a barrier to prevent fish from residing in the discharge canal or designing a high-velocity discharge to encourage rapid mixing and to discourage residence in the plume. Operational measures that could be used to reduce the risk of cold shock by gradually reducing the amount of warm water discharged in winter include gradual shutdowns or shutdowns of only one unit of a multi-unit power plant at a time.

Impacts of cold shock are considered to be of small significance if populations of aquatic organisms in the vicinity of the plant are not reduced. Based on review of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and comments on the draft GEIS, cold-shock-related mortalities of aquatic organisms have been a problem at few existing nuclear power plants. Operational and structural mitigation measures have been effective at the plants that experienced cold shock mortalities. Because mitigation has been effective in those few cases where cold shock has been a problem, effects are considered to be of small significance for all plants. Cold shock is not expected to contribute to cumulative impacts because the potential area of impact is so small and because mitigation to prevent cold shock mortalities at individual power plants also reduces the likelihood that thermal discharges would contribute to cumulative effects. No change in operation of the cooling system is expected during the license renewal term, so no change in potential for cold shock is anticipated. Effects of cold shock could be reduced by changing to a closed cycle cooling system or by reducing the plant's generation rate. However, because the effects of cold shock are considered to be impacts of small significance and these changes would be costly, the staff does not consider the implementation of these potential mitigation measures to be warranted. Cold shock is a Category 1 issue.

4.2.2.1.6 Effects of Movements and Distribution of Aquatic Organisms

Heated effluents can affect aquatic populations in more subtle ways by altering their distribution, growth, or movements. Changes in benthic community composition such as losses of seagrass or other macrophytes can alter the habitat available to aquatic animals. Warm water can increase the metabolic rates of aquatic biota, a method often used in aquaculture to achieve high growth and production rates. However, in the absence of adequate food supplies, elevated metabolic rates can lead to a poor condition of the fish inhabiting heated areas.

It had been suggested that thermal plumes could constitute a barrier to migrating fish if the mixing zone covered a substantial area and exceeded the fish avoidance temperatures. However, studies of effects of heated effluents on Columbia River salmon (Nakatani 1969) and anadromous fish in the Chesapeake Bay (e.g, shad and striped bass) (MDNR 1988) have concluded that fish migration routes were not blocked. Most migrating adult American shad move in the lower half of the water column (Witherell and Kynard 1990) and are therefore unlikely to be deterred by a thermal plume at the surface.

Impacts from potential thermal plume barriers are considered to be of small significance if fish migrations are not blocked and populations of aquatic organisms in the vicinity of the plant are not reduced. Based on review of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and comments on the draft GEIS, thermal plume barriers have not been a problem at any existing nuclear power plants. Heat is rapidly dissipated from power plant discharge plumes, so that effects would only be localized and therefore of small significance for all plants. These effects are not expected to contribute to cumulative impacts. No regulatory agency expressed concerns about cumulative impacts to migrations of aquatic organisms. No change in operation of the cooling system is expected during the license reneqal term, so no change in the potential for a thermal plume barrier to migrating fish is anticipated. Effects of a thermal plume barrier to migrating fish could be reduced by changing to a closed cycle cooling system or by reducing the plant's generation rate. However, because the effects of a thermal plume barrier to migrating fish are considered to be impacts of small significance and because the changes would be costly to implement, the staff does not consider the implementation of these potential mitigation measures to be warranted. Thus thermal plume barriers to migrating fish are a Category 1 issue.

The temperature regime of a body of water is an important component of habitat available to aquatic organisms. By altering the temperature regime, heated effluents can increase or decrease the amount of available habitat. For example, the abundance of coldwater species may be constrained near the southern limits of their distribution by thermal power plant effluents because the heated water exceeds the temperature tolerance of the species. By the same token, heated effluents can extend the northern range of warmwater species by providing thermal refuges during the winter. For example, Stauffer et al. found that blue tilapia, a tropical exotic fish species from Africa and southern Asia, were able to survive low winter water temperatures in the Susquehanna River, Pennsylvania, by congregating in thermal effluents. On a larger scale, the effects of global warming on water temperatures and on the distribution and productivity of aquatic organisms is being studied (Regier et al. 1990). At present, heated discharges from power plants influence a relatively small area of the affected bodies of water so that significant changes to the geographic distribution of a species are unlikely.

Impacts of thermal discharges on geographic distribution of aquatic organisms are considered to be of small significance if populations in the overall region are not reduced. Based on review of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and comments on the draft GEIS, thermal discharges have not been shown to constrain the regional geographic distribution of aquatic organisms at any existing nuclear power plants. Localized reductions in coldwater species or increases in warmwater species are possible, but the effects are limited to small areas and have not altered larger geographic distributions. Effects are considered to be of small significance for all plants. Heat is rapidly dissipated from power plant discharge plumes, and heated plumes are small relative to the size of the waterbody. Consequently, effects would only be localized, and cumulative impacts on geographic distribution would not be expected. No regulatory agency expressed concerns about cumulative impacts on geographic distribution of aquatic organisms. No change in operation of the cooling system is expected during the license renewal term, so no change in effects on geographic distribution of aquatic organisms is anticipated. Effects on geographic distribution of aquatic organisms could be reduced by changing to a closed cycle cooling system or by reducing the plant's generation rate. However, because the effects on geographic distribution of aquatic organisms are considered to be impacts of small significance and because these changes would be costly, the staff does not consider the implementation of these potential mitigation measures to be warranted. Effects of localized thermal discharges on geographic distribution of aquatic organisms are a Category 1 issue.

4.2.2.1.7 Premature Emergence of Aquatic Insects

Heated discharges from power plants can impact aquatic insects that inhabit the bottom areas influenced by the thermal plume. Impacts can range from direct mortality (e.g., when lethal temperatures are exceeded) to sublethal effects (e.g., increases in growth rates; decreases in development times; changes in body size and fecundity). Different species have different tolerances for altered temperature regimes, so that the benthic invertebrate community in the discharge area is rarely eliminated; but it may become dominated by a reduced number of taxa that are tolerant of higher temperatures. Because thermal plumes tend to be buoyant, often the bottom area of the receiving body of water that is affected by elevated temperatures is relatively small, and the effects on the benthic invertebrate community are localized.

Premature emergence of aquatic insects can result from heated effluents coming in contact with benthic habitats (e.g., in the discharge canal or along the shoreline near the discharge) and accelerating the development of immature forms. Adult insects emerge from the water before the normal seasonal cycle and may be unable to reproduce. Although this phenomenon has been observed near power plants, the area likely to be affected by thermal effluents would be a small part of the total lake or river bottom area available for production of aquatic insects. In addition, most aquatic insects have adult upstream migration flights that compensate for normal downstream drift of immature stages (Hynes), so that such localized effects on reproduction through this mechanism are inconsequential (Coutant 1981).

Effects of thermal discharges on premature emergence of aquatic insects are considered to be of small significance if changes are localized and populations in the receiving waterbody are not reduced. Based on reviews of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and comments on the draft GEIS, thermal discharges have not been shown to cause reductions in the overall populations of aquatic insects near any existing nuclear power plants. Localized mortalities among heat-intolerant insect species occur in the thermal mixing zone, but the effects are limited to small areas and do not alter insect communities in larger geographic areas. Because heat in the discharged water is readily dissipated to the atmosphere, effects from this and other heated effluents would not be expected to contribute to cumulative impacts. Effects are considered to be of small significance for all plants. No change in operation of the cooling system is expected during the license renewal term, so no change in effects on emergence of aquatic insects is anticipated. Effects on emergence of aquatic insects could be reduced by changing to a closed cycle cooling system or by reducing the plant's generation rate. However, because the effects on emergence of aquatic insects are considered to be impacts of small significance and because these changes would be costly, the staff does not consider the implementation of these potential mitigation measures to be warranted. Effects of thermal discharges on premature emergence of aquatic insects is a Category 1 issue.

4.2.2.1.8 Gas Bubble Disease

Rapid heating of water in the condenser cooling system decreases the solubility and increases saturation levels of dissolved gases. The supersaturation of nitrogen gas has led to incidents of "gas bubble disease" (GBD) in the discharge areas of steam-electric power plants. The mechanisms by which gas supersaturation and GBD occur at steam-electric power plants (as well as under other conditions such as in the tailwaters of hydroelectric power plants) have been described by Wolke et al. Discharge configurations that do not allow rapid mixing of the effluent with the receiving waters may allow organisms to reside in the supersaturated effluent for long periods (Coutant 1981). As a result of equilibrating with the effluent, the tissues of aquatic organisms become supersaturated as well. Eventually, this unstable condition breaks down, and bubbles form inside the animal, most obviously in the fins and the eyeball (Wolke et al.). Fish mortalities generally occur at gas supersaturation levels above 110 to 115 percent (EPA 440/5-86-001).

GBD in the discharge of a steam-electric power plant (the Marshall Steam Station on Lake Norman) was first reported by DeMont and Miller and has been observed at other power plants since that time. GBD at the Pilgrim Nuclear Power Station caused a loss of 43,000 Atlantic menhaden in 1973, and another 5,000 in 1976 [Boston Edison Company, response to NUMARC survey (NUMARC 1990)]. The problem appears to be greatest at power plants that have discharge canals where fish may reside for extended periods of time (i.e., long enough to equilibrate with supersaturated effluents). The reported incidences of GBD at the Waukegan Generating Station (a coal-fired plant on Lake Michigan; Otto), the Marshall Steam Station (a coal-fired plant on Lake Norman; DeMont and Miller), and the Pilgrim Nuclear Power Station all involved fish residing in discharge canals. Ensuring the rapid mixing of effluents with receiving waters (e.g., with a jet diffuser system) appears to prevent GBD mortalities by inhibiting residence in the thermal plume (Lee 1984). Alternatively, measures to prevent residence of fish in discharge canals may be effective. Emplacement of a barrier net to exclude fishes from the Pilgrim discharge canal has prevented GBD mortalities at that plant since 1976 [Boston Edison Company, response to NUMARC survey (NUMARC 1990)]. The GBD problem has been mitigated at the one nuclear power plant where large numbers of fish were affected.

Impacts of GBD are considered to be of small significance if populations of aquatic organisms in the vicinity of the plant are not reduced. Based on review of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and comments on the draft GEIS, GBD-related mortalities of aquatic organisms have not been a problem at most existing nuclear power plants; and operational and structural mitigation measures have been effective at those plants that experienced GBD mortalities during the initial license period. Effects are considered to be of small significance for all plants. Mitigation to prevent GBD mortalities at individual power plants also reduces the likelihood that thermal discharges would contribute to cumulative effects; no regulatory agency expressed concerns about the contribution of existing nuclear plants to cumulative impacts of GBD. No change in operation of the cooling system is expected during the license renewal term, so no change in effects on GBD is anticipated. Effects on GBD could be reduced by changing to a closed cycle cooling system or by reducing the plant's generation rate. However, because the effects on GBD are considered to be impacts of small significance and because such charges would be costly, the staff does not consider the implementation of these potential mitigation measures to be warranted. Gas bubble disease is a Category 1 issue.

4.2.2.1.9 Low Dissolved Oxygen in the Discharge

A power plant may aggravate the biological effects of low dissolved oxygen (DO) concentrations in the source water by adding a heat load to water with preexisting low DO levels. Aquatic biota below the discharge are then stressed by both higher temperatures (which increase the metabolic rate and the need for oxygen) and preexisting suboptimal oxygen levels. Concern about the effects of low DO concentrations in the heated discharge of the Sequoyah Nuclear Plant on downstream mussel beds and sauger reproduction has been expressed by the Tennessee Division of Water Pollution Control (Ann McGregor, Tennessee Division of Water Pollution Control, telephone interview with G. F. Cada, ORNL, Oak Ridge, Tennessee, May 30, 1990). Cool, hypolimnetic water released from Watts Bar reservoir, upstream from the Sequoyah Nuclear Plant, often had low DO concentrations. The temperature of the condenser cooling water rises approximately 14°C when both units are operating without cooling towers. As a result, a mean net decrease of 0.8 mg/L of DO concentration was measured in the cooling water, which under extreme low flow conditions could reduce the mean water column DO concentration in the Chickamauga reservoir near the Sequoyah Nuclear Plant by approximately 0.5 mg/L (TVA 1990). Water quality modeling indicated that increasing the DO of Watts Bar Dam releases by 2 mg/L would improve DO concentrations through Chickamauga Reservoir by about 1 mg/L. Recent changes in the release schedule of Watts Bar Dam appear to have reduced the stagnation of water near the Sequoyah Nuclear Plant and alleviated concern about low DO effects (Tom Roehm, Tennessee Division of Water Pollution Control, telephone interview with G. F. Cada, ORNL, Oak Ridge, Tennessee, November 16, 1992).

Impacts of low DO concentrations in the discharge are considered to be of small significance if populations of aquatic organisms in the vicinity of the plant are not reduced. Based on review of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and comments on the draft GEIS, low DO concentrations have not been a problem at most existing nuclear power plants, and operational mitigation measures have been effective at the one plant that experienced problems during the initial license period. Effects of low DO concentrations are considered to be of small significance for all plants. Water will be reaerated by turbulent diffusion and/or photosynthesis, so far-field effects are not expected. Mitigation to prevent low DO concentrations in the vicinity of the power plant will also reduce the likelihood of significant cumulative impacts; none of the resource agencies expressed an ongoing concern about the contribution of existing power plants to cumulative impacts of low DO concentrations. No change in operation of the cooling system is expected during the license renewal term, so no change in effects of low DO concentrations is anticipated. Effects of low DO concentrations could be reduced by changing to a closed cycle cooling system or by reducing the plant's generation rate. However, because the effects of low DO concentrations are considered to be impacts of small significance and because these changes would be costly, the staff does not consider the implementation of these potential mitigation measures to be warranted. Low DO concentrations in the thermal discharge are a Category 1 issue.

4.2.2.1.10 Losses from Parasitism, Predation, and Disease

Sublethal power plant stresses may alter predator-prey interactions in the receiving body of water. Aquatic organisms that are stunned but not killed by entrainment, impingement, or thermal effects may still suffer "indirect" mortality through increased susceptibility to predators. Numerous laboratory studies have been carried out to evaluate the level of indirect mortality that might occur following heat and cold shocks or entrainment (reviews in ORNL/TM-7801; Coutant 1981). These studies have commonly demonstrated increased susceptibility to predation, but field evidence of such effects is often limited to anecdotal information such as observations of enhanced feeding activity of seagulls and predatory fish near power plant outfalls. For example, Barkley and Perrin (1971), and CONF-730505 reported increased concentrations of predators feeding on forage fish attracted to thermal plumes. Neither quantification of the levels of stress needed to increase predation rates, nor prediction of the subsequent population- and community-level effects of such changes can be made easily in the field. It is likely that operation of once-through cooling systems will cause some changes in predator-prey relationships, but the best evidence for impacts (or lack of impacts) may come from long-term monitoring of fish populations. Neither the literature reviews nor consultations with agencies and utilities (Appendix F) have revealed studies that demonstrate population- or community-level effects from power-plant-induced alterations of predator-prey relationships.

Elevated water temperatures in power plant discharges have been hypothesized to increase the susceptibility of fish to diseases and parasites. Langford cites a number of factors that could contribute to such an effect, including the tendency for fish to congregate in the heated discharge area in greater than normal concentrations, increased stresses on fish in warmer water that makes them more prone to infection, and the ability of some diseases and parasites to develop faster at higher temperatures. Additionally, it has been suggested that stress and injury from entrainment and impingement contribute to increased susceptibility of fish to disease, parasites, and predation. Coutant (1981) noted that although some studies of increased disease and parasitism in heated waters have found localized effects, most were not adequately designed to determine the significance of the effects to the overall population. The greatest risks appear to be associated with changes in animal concentrations; crowding can occur among fish that are attracted to heated effluents in the winter or that avoid heated water in the summer by occupying limited cool-water refugia. Crowding increases the chances of exposure to infectious diseases and may also lead to other stresses (decreased food supply or reduced oxygen concentrations) that increase susceptibility to disease (Coutant 1987). Despite limited laboratory studies that confirm this phenomenon, population-level effects in the vicinity of plants have not been observed.

Effects of sublethal stresses on the susceptibility of aquatic organisms to predation, parasitism, and disease are considered to be of small significance if changes are localized and populations in the receiving waterbody are not reduced. Based on reviews of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and comments on the draft GEIS, these forms of indirect, power plant-induced mortality have not been shown to cause reductions in the overall populations near any existing nuclear power plants. Effects are considered to be of small significance for all plants. Although sublethal power plant stresses could contribute to cumulative impacts experienced by aquatic biota, monitoring has revealed no evidence for significant effects; the regulatory and resource agencies consulted in the preparation of this GEIS did not express concerns about the contribution of sublethal power plant stresses to cumulative impacts. No change in operation of the cooling system is expected during the license renewal term, so no change in effects of sublethal stresses is anticipated. Effects of sublethal stresses could be reduced by changing to a closed cycle cooling system or by reducing the plant's generation rate. However, because the effects of sublethal stresses are considered to be impacts of small significance and because the changes would be costly, the staff does not consider the implementation of these potential mitigation measures to be warranted. This is a Category 1 issue.

4.2.2.1.11 Stimulation of Nuisance Organisms

A variety of nuisance organisms or nonnative species may become established or proliferate as a result of power plant operations, including fouling organisms such as the Asiatic clam (*Corbicula* sp.) and the recently introduced zebra mussel, *Dreissena polymorpha*. Aspects of the operation of the power plants (e.g., warm temperatures or high flow rates that bring food to filter-feeding organisms) may be conducive to the growth and development of these organisms. *Corbicula* sp. and zebra mussels may become so abundant as to cause operational difficulties for the power plant and may out-compete native clams and mussels in thermally enriched waters. A population of tropical, non-native blue tilapia became established in the Susquehanna River in Pennsylvania by congregating in thermal effluents during the winter. Exposure to rapid temperature decreases (cold shock) killed these fish and eradicated the population from the vicinity of a steam-electric power plant (Stauffer et al.).

Langford (1983) reports a number of instances in which wood-boring crustaceans and mollusks, notably "shipworms," have caused concern in British waters. Although increased abundance of shipworms in the area influenced by heated power plant effluents caused substantial damage to wooden structures, replacement of old wood with concrete or metal structures eliminated the problem. Langford concluded that increased temperatures could enhance the activity and reproduction of wood-boring organisms in enclosed or limited areas but that elevated temperature patterns were not sufficiently stable to cause widespread effects.

In the United States, the influence of the operation of Oyster Creek Nuclear Generating Station on shipworm abundance and distribution has been extensively studied (see summary in Richards et al. 1984). Although numerous studies have varied somewhat in their conclusions, there is agreement that heated effluents from the plant increased the distribution and abundance of the nonnative, tropical-subtropical wood-boring species *Teredo bartschi* (Kennish et al. 1984). This species has not been found in Oyster Creek or Barnegat Bay since 1982, perhaps because of low water temperatures in Oyster Creek during a station outage in the winter of 1981–82 and the pathological effects of a parasite [GPU Nuclear Corporation response to NUMARC survey (NUMARC 1990)]. In addition, the removal of substantial amounts of driftwood and the replacement of untreated structural wood is thought to have contributed to reducing the populations of wood-boring organisms in Oyster Creek. No other concerns about nuisance organisms were cited by the regulatory or resource agencies contacted for this GEIS (Appendix F). Measures taken by licensees to control nuisance species (e.g., increased chlorination or use of molluskicides) may result in impacts on other species. This impact is addressed in Section 4.2.1 and is also controlled by the NPDES permitting procedures.

The effects of stimulating the growth of nuisance organisms are considered to be of small significance to aquatic resources if these organisms are restricted to the condenser cooling system (e.g., Asiatic clam; zebra mussel) or do not proliferate beyond the immediate vicinity of the plant. Based on review of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and comments on the draft GEIS, nuisance organisms such as Asiatic clam may be an operational problem, but they have not impacted aquatic resources near most existing nuclear power plants. Mitigation measures were effective at the one plant that experienced problems with nuisance organisms (shipworms). Effects are considered to be of small significance for all plants. The regulatory and resource agencies consulted in the preparation of this GEIS did not express concerns about the contribution of power plant operations to other activities that might encourage the growth of nuisance organisms (i.e., cumulative effects). No change in operation of the cooling system is expected during the license renewal term, so no change in the growth or distribution of nuisance organisms is anticipated. Effects on nuisance organisms could be reduced by changing to a closed cycle cooling system or by reducing the plant's generation rate. However, because the effects on the growth of nuisance organisms are considered to be impacts of small significance and because such changes would be costly, the staff does not consider the implementation of these potential mitigation measures to be warranted. The stimulation of nuisance aquatic organisms by operation of existing power plants is a Category 1 issue.

4.2.2.2 Summary

The issues and the need for these issues to be addressed in license renewal applications of existing nuclear power plants with once-through cooling systems are summarized in Table 4.1. The operational experience of existing nuclear power plants indicates that many early aquatic resource concerns have not materialized as problems at any facility. Neither the published literature nor the responses of regulatory and resource agencies have revealed concerns about such early issues as phytoplankton and zooplankton entrainment and premature emergence of aquatic insects living in thermal discharges. Although statistically significant localized effects of these stresses have occasionally been demonstrated, long-term or far-field impacts have not been documented. Other issues (e.g., lowered DO concentrations, discharge of heavy metals, cold shock, and stimulation of nuisance organisms) were problems at a few nuclear power plants with once-through cooling systems but have since been mitigated.

Table 4.1 Significance of aquatic resources impacts for license renewal of existing nuclear power plants that use once-through cooling systems

Issue	Impact significance[a]
Water quality, hydrology, and use issues	
Water use conflicts	1
Altered current patterns at intake and discharge structures	1
Altered salinity gradients	1
Temperature effects on sediment transport capacity	1
Altered thermal stratification of lakes	1
Scouring from discharged cooling water	1
Eutrophication	1
Discharge of chlorine or other biocides	1
Discharge of metals in waste water	1
Discharge of sanitary wastes and minor chemical spills	1
Effects of consumptive water use on riparian communities	1
Aquatic ecology	
Impingement of fish and shellfish	2
Entrainment of fish and shellfish early life stages	2
Entrainment of phytoplankton and zooplankton	1
Thermal discharge effects	2
Cold shock	1
Thermal plume barrier to migrating fish	1
Distribution of aquatic organisms	1
Premature emergence of aquatic insects	1
Stimulation of nuisance organisms (e.g., shipworms)	1
Losses from predation, parasitism, and disease among organisms exposed to sublethal stresses	1
Gas supersaturation (gas bubble disease)	1
Low dissolved oxygen in the discharge	1
Accumulation of contaminants in sediments or biota (Section 4.2.1 and 4.2.4)	1

[a]A 1 means impact significance expected to be small at all sites. A 2 means that the impact may be of moderate or large significance at some sites.

Some aquatic resource issues warrant further monitoring and, in some cases, mitigative measures to define and correct adverse impacts. The entrainment and impingement of fish and the discharge of large volumes of heated effluents into small or warm ambient waters were a source of concern at some nuclear power plants. Such issues were examined and resolved through either the NEPA process during the licensing of the facility or the mechanisms of NPDES permitting and associated 316(a) and (b) determinations. They either were found acceptable or mitigated. For some plants with once-through cooling systems, the large volumes of water withdrawn, heated, and discharged back to the receiving water may cause adverse effects to fish and shellfish populations during the license renewal term. Because impacts of entrainment of fish and shellfish, impingement, and thermal discharge effects could be small, moderate, or large, depending on the plant, these are Category 2 issues for plants with once-through cooling systems. These issues will need to be analyzed in the supplemental NEPA document at the time of license renewal.

4.3 COOLING TOWERS

This section introduces cooling towers and their emissions (Section 4.3.1) and then evaluates the impacts of the emissions on surface water and groundwater (Section 4.3.2), aquatic ecology (Section 4.3.3), agricultural crops (Section 4.3.4), terrestrial ecology (Section 4.3.5, which also includes bird collisions with cooling towers), and human health (Section 4.3.6). Impacts of cooling-tower noise are also addressed (Section 4.3.7). Each section that evaluates impacts (Sections 4.3.2–4.3.7) provides a conclusion that defines the significance of the impacts. These conclusions are based on reviews of cooling-tower data available for towers at specific nuclear plants as well as for other cooling towers (e.g., those at coal-fired plants).

4.3.1 Introduction

Mechanical- and natural-draft wet cooling towers transfer waste heat to the atmosphere primarily by evaporating water. Natural-draft towers are generally up to 160 m (520 ft) in height, whereas mechanical-draft towers are generally less than 30 m (100 ft) tall (Roffman and Van Vleck 1974). Because of the large cooling capacity of natural-draft towers, only one such tower is required for each reactor unit; but two or more mechanical-draft towers are required for equivalent cooling.

Most of the water lost from a cooling tower escapes to the atmosphere as water vapor in the exhaust flow. About 10 percent of the vapor recondenses after release, forming the visible part of the plume leaving the tower (Golay et al. 1986). Drift droplets of cooling water are also entrained in the air stream inside the tower and escape directly into the atmosphere. A particulate solid drift material remains after droplet evaporation. The drift contains varying amounts of salts, biocides, and microorganisms.

Natural-draft towers release drift and moisture high into the atmosphere where they are dispersed over long distances. Local impacts are more likely to occur with mechanical-draft towers because the plume is not dispersed over as great an area. The visible moisture plume from a natural-draft cooling tower may be 20 to 30 percent longer than that from comparable mechanical-draft towers (Roffman and Van Vleck 1974). Icing of vegetation and roads can occur near mechanical draft towers when fog is present and temperatures are below freezing. Much of the drift eventually deposits on the earth. The atmospheric transport of drift and the amount of deposition to the earth has been estimated for most nuclear plants through the use of computer models. Actual measurements of drift deposition have been collected at only a few nuclear plants. These measurements indicate that, beyond about 1.5 km (1 mile) from nuclear plant cooling towers, salt deposition is not significantly above natural background levels.

4.3.2 Surface Water Quality and Use

Sections 4.3.2 and 4.3.3 review the past and ongoing impacts on aquatic resources caused by the operation of nuclear power plants with cooling towers. Any ongoing impacts will probably continue into the license renewal term because the cooling system design and operation will not change as a result of license renewal. Judgments about the significance of these issues during the license renewal terms are based on published information, agency consultation, and information provided by the utilities (Appendix F) applicable to every nuclear power plant in the United States. The conclusions drawn in Sections 4.3.2 and 4.3.3 apply to all nuclear power plants with cooling towers.

4.3.2.1 Water Use

Two factors may cause water-use and water-availability issues to become important for some nuclear power plants that use cooling towers. First, the relatively small rates of cooling water withdrawal and discharge allowed some power plants with cooling towers to be located on small bodies of water that are susceptible to droughts or competing water uses. Second, closed-cycle cooling systems evaporate cooling water, and consumptive water losses may represent a substantial proportion of the flows in small rivers. Loss of a substantial portion of flow from a small stream as a result of evaporative losses from a cooling tower will reduce the amount of habitat for fish and aquatic invertebrates. Off-stream water uses, such as power plant consumption, must be regulated to ensure that important in-stream uses, such as habitat for aquatic organisms, boating, angling, and waste assimilation, are not compromised.

Consumptive water use can adversely impact riparian vegetation and associated animal communities by reducing the amount of water in the stream that is available for plant growth, maintenance, and reproduction. Riparian vegetation is defined as streamside vegetation that is structurally and floristically distinct from adjacent upland plant communities (Taylor 1982). Riparian vegetation has important ecological functions; and its importance as a resource has been widely recognized and reviewed (e.g., Brinson et al. 1981; Johnson et al. 1985). Briefly, riparian vegetation stabilizes stream channels and floodplains. It influences biogeochemical cycles, water temperature and quality, and the duration and magnitude of flooding. Riparian vegetation also provides diverse cover, food, water, reproductive habitat, and migration corridors for many aquatic and terrestrial animals. As a result, riparian zones often support a wide variety and high density of wildlife (deer, small mammals, songbirds, raptors, reptiles, and amphibians), especially in arid or urbanized areas. Riparian vegetation may be adversely affected by dewatering in a number of ways (Taylor 1982), including decreases in the width of the riparian corridor, changes in species and community diversity, increased susceptibility to flooding, changes in tree canopy cover, lower tree basal area, and lower seedling densities. Impacts to wildlife occur as a direct or indirect result of degradation of riparian habitats. Such dewatering effects are most apparent in the arid and semi-arid West; in the eastern United States, dewatering effects generally involve more subtle changes in community composition because of the higher precipitation, humidity, and soil moisture and the lower water stress conditions that prevail.

Limerick Generating Station, located on the Schuylkill River at Pottstown, Pennsylvania, is an example of a plant with a closed-cycle cooling system that is subject to water availability constraints because of in-stream-flow requirements in a smaller river, controversy over water use related to interbasin transfer, competing water uses, and water-related agreements between utilities. Aquatic resource issues identified include (1) water quality and low-flow problems in the Schuylkill River; (2) water availability conflicts with downstream water users; (3) increased in-stream flow requirements, particularly with respect to continuing efforts to improve the water quality of the Schuylkill River and to reintroduce American shad into the river; and (4) concerns over saltwater movement upstream in the Delaware River as the result of upstream water use (Margaret A. Reilly, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee May 24, 1990; D. T. Guise, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, July 3, 1990).

Limerick is in one of the fastest growing regions in Pennsylvania, which is experiencing heavy residential development and water demands for domestic, existing industrial, and developing industrial uses (Joseph Hoffman, letter to V. R. Tolbert, ORNL, Oak Ridge, Tennessee, August 27, 1990). Limerick is permitted to withdraw up to 13 percent of the minimum flow of the Schuylkill River and a major portion of the flow of Perkiomen Creek for cooling tower makeup. Only 5 percent of the 1.8–2.0 m^3/s (65–70 ft^3/s) withdrawn from the Schuylkill River when the flow is greater than 15 m^3/s (530 ft^3/s) is returned to the river. This loss of in-stream flow is viewed as a significant contribution to the water quality and low-flow problems in the Schuylkill River (Dennis T. Guise, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, July 3, 1990). This water-use issue may be exacerbated as efforts to reintroduce the American shad into the Schuylkill River continue. In addition to the water use from the Schuylkill River, 2 m^3/s (71 ft^3/s) of water is diverted from the Delaware River to the East Branch of Perkiomen Creek via the Point Pleasant Diversion at a rate of 2 m^3/s (71 ft^3/s); this interbasin transfer affects the achievement of the 85 m^3/s (3000 ft^3/s) minimum flow objective in the Delaware River at Trenton. The effects of the diversion are being debated through an NPDES permit appeal before the Pennsylvania Environmental Hearing Board (Dennis T. Guise, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, July 3, 1990).

The Palo Verde NGS offers another example of competing water uses that may affect continued operation of nuclear facilities that use cooling towers. Palo Verde currently uses treated effluent from the cities of Phoenix and Tolleson for cooling tower makeup water. The blowdown from the cooling towers discharges to on-site lined evaporation ponds [Arizona Public Service Company response to NUMARC survey (NUMARC 1990)]. In the absence of the power plant, part of the municipal effluent would be used for commercial purposes and the remainder discharged to the Gila River, where it would be used for groundwater recharge, irrigation, and support of riparian habitat (Jack Bale, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, May 31, 1990). According to the Arizona Game and Fish Department (Donald Turner, Arizona Game and Fish Department letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, June 29, 1990), if Palo Verde uses all of its allocation, the flow from the Gila River downstream to Gillespie Dam will be reduced, the water tables will drop significantly, and aquatic habitat and riparian vegetation will be destroyed. Sixty-nine percent of the water flowing in the Gila and Salt rivers downstream from the Ninety-First Avenue treatment plant is discharged by the treatment plant. Most if not all of the water produced by the treatment plant is committed to Palo Verde. When all three units of the plant were operating, flow in the river was significantly reduced, pools and ponds dried up, and numerous fish die-offs occurred (Donald Turner, Arizona Game and Fish Department, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, June 29, 1990).

Nuclear facilities on small bodies of water may experience water-use constraints related to availability. For example, during temporary drought periods, power plants with cooling towers may have to curtail operations if evaporative water losses exceed the capacity of small, multiple-use source bodies of water. Byron Station in Illinois withdraws water from the Rock River to supply natural-draft cooling towers. By agreement with the Illinois Department of Conservation, the withdrawal for makeup is limited to 3.5 m^3/s (125 ft^3/s) and net water consumption is limited to no more than 9 percent of the flow below 19 m^3/s (679 ft^3/s) [Commonwealth Edison Company response to NUMARC survey (NUMARC 1990)]. Duane Arnold Energy Center on the Cedar River in Iowa uses mechanical-draft cooling towers for condenser cooling and could also experience water availability constraints. The state of Iowa Department of Natural Resources currently has no water-use concerns with operation of Duane Arnold (Larry J. Wilson, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, May 22, 1990); however, the plant may possibly experience future constraints on the availability of water for consumptive use, because the surface water withdrawals within the state are projected to increase by 19 percent from 1985 to 2005 (Thamke 1990). Within Linn County, where Duane Arnold is located, water use is also projected to increase (Brian Tormee, telephone interview with V. R. Tolbert, ORNL, Oak Ridge, Tennessee, September 4, 1990).

Consultations with regulatory and resources agencies indicate that water use conflicts are already a concern at two closed-cycle nuclear power plants (Limerick and Palo Verde) and may be a problem in the future at Byron Station and the Duane Arnold Energy Center. Because water use conflicts may be small or moderate during the license renewal period, this is a Category 2 issue for nuclear plants with closed-cycle cooling systems. Related to this, the effects of consumptive water use on in-stream and riparian communities could also be small or moderate, depending on the plant, and is also a Category 2 issue.

4.3.2.2 Water Quality

Although cooling towers are considered to be closed-cycle cooling systems, concentration of dissolved salts in the makeup water—which results from evaporative water loss—requires the discharge of a certain percentage of the mineral-rich stream (blowdown) and its replacement with fresh water (makeup). The quantities of blowdown are relatively small compared with the discharges from once-through systems, typically on the order of 10 percent. Water quality impacts could occur from the elevated temperatures of the blowdown or from the concentration and discharge of chemicals added to the recirculating cooling water (to prevent corrosion and biofouling, regulate pH, etc.). A unit of water may reside in the cooling circuit for 3 to 20 cycles before being lost to evaporation or released in the blowdown stream (Coutant 1981). The concentration of total dissolved solids in the cooling tower blowdown averages 500 percent of that in the makeup water, a concentration factor that can be tolerated by most freshwater biota (ORNL/NUREG/TM-226). Dilution of the low-volume blowdown by the receiving water also reduces water quality impacts of heat and contaminants discharged from closed-cycle cooling systems.

Because of strict regulation of chemical discharges from steam-electric power plants (e.g., EPA regulations per 40 CFR Part 423), water treatment systems for cooling tower blowdown have been developed. Many of these systems recapture chemical additives for recycling in the cooling system (Coutant 1981). As noted in Section 4.2, all nuclear power plants are required to obtain an NPDES permit to discharge effluents. These permits are renewed every 5 years by the regulatory agency, either EPA or, more commonly, the state's water quality permitting agency. The periodic NPDES permit renewals provide the opportunity to require modification of power plant discharges or to alter discharge monitoring in response to water quality concerns. Utility responses to the NUMARC survey (Table F.2) indicate that such changes have been made during the plants' operation to correct water quality problems.

Impacts of cooling tower discharges are considered to be of small significance if water quality criteria (e.g., NPDES permits) are not consistently violated. In considering the effects of closed-cycle cooling systems on water quality, the staff evaluated the same issues that were evaluated for open-cycle systems (Table 4.1): altered current patterns, altered salinity gradients, temperature effects on sediment transport capacity, altered thermal stratification of lakes, scouring from discharged cooling water, eutrophication, discharge of chlorine and other biocides, discharge of other chemical contaminants, and discharge of sanitary wastes. Based on review of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and comments on the draft GEIS, discharge of cooling tower effluents has not been a problem at existing nuclear plants. Although occasional violations of NPDES permits have occurred at many plants (e.g., minor spills), water quality impacts have been localized and temporary. Effects are considered to be of small significance for all plants. Cumulative impacts to water quality would not be expected because the small amounts of chemicals released by these low-volume discharges are readily dissipated in the receiving waterbody. No change in operation of the cooling system is expected during the license renewal term, so no change in effects of cooling towers discharges on receiving water quality is anticipated. Effects of cooling tower discharges could be reduced by operating additional wastewater treatment systems, or by reducing the plant's generation rate. However, because the effects of cooling tower discharges on water quality are considered to be impacts of small significance and because the changes would be costly, the staff does not consider the implementation of these potential mitigation measures to be warranted. Effects of cooling tower discharges on water quality are all Category 1 issues.

4.3.3 Aquatic Ecology

Cooling towers have been suggested as mitigative measures to reduce known or predicted entrainment and impingement losses (see, for example, Barnthouse and Van Winkle 1988). The relatively small volumes of makeup and blowdown water needed for closed-cycle cooling systems result in concomitantly low entrainment, impingement, and discharge effects (see Section 4.2.2 for a more complete discussion of these effects regarding once-through cooling systems). Studies of intake and discharge effects of closed-cycle cooling systems have generally judged the impacts to be insignificant (NUREG/0720; NUREG/CR-2337). None of the resource agencies consulted for this GEIS (Appendix F) expressed concerns about the impacts of closed-cycle cooling towers on aquatic resources.

However, even low rates of entrainment and impingement at a closed-cycle cooling system can be a concern when an unusually important resource is affected. Such aquatic resources would include threatened or endangered species or anadromous fish that are undergoing restoration. For example, concern about potential impacts of the Washington Nuclear Project (WNP-2) on chinook salmon has been raised by the Washington Department of Fisheries (Cynthia A. Wilson, Washington Department of Fisheries, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, July 5, 1990). Although entrainment, impingement, and thermal discharges are not believed to be a problem at WNP-2, the importance of the Columbia River salmon stocks are such that the resource agency feels that monitoring should continue. Similarly, the Pennsylvania Fish Commission has expressed concern about future entrainment and impingement of American shad by the Limerick Generating Station, the Susquehanna Steam Electric Station, Three Mile Island Nuclear Station, and Peach Bottom Atomic Power Station (Dennis T. Guise, Pennsylvania Fish Commission, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, July 3, 1990). In all cases, losses of American shad at these power plants are minimal or nonexistent, but periodic monitoring has been recommended to ensure that no future problems occur as the anadromous fish restoration efforts continue.

It is unlikely that the small volumes of water withdrawn and discharged by closed-cycle cooling systems would interfere with the future restoration of aquatic biota or their habitats. Effects of operation of closed-cycle cooling systems on aquatic organisms are considered to be of small significance if changes are localized and populations in the receiving waterbody are not reduced. In considering the effects of closed-cycle cooling systems on aquatic ecology, the staff evaluated the same issues that were evaluated for open-cycle systems (Table 4.1): impingement of fish and shellfish, entrainment of fish and shellfish early life stages, entrainment of phytoplankton and zooplankton, thermal discharge effects, cold shock, effects on movement and distribution of aquatic biota, premature emergency of aquatic insects, stimulation of nuisance organisms, losses from predation, parasitism, and disease, gas supersaturation of low dissolved oxygen in the discharge, and accumulation of contaminants in sediments or biota. Based on reviews of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and comments on the draft GEIS, these potential effects have not been shown to cause reductions in the aquatic populations near any existing nuclear power plants. None of the regulatory and resource agencies expressed concerns about the cumulative effects on aquatic resources of closed cycle cooling system operations at this time, although some recommended continued monitoring in view of efforts to restore fish populations. Effects of all of these issues are considered to be of small significance for all plants. No change in operation of the cooling system is expected during the license renewal term, so no change in effects of cooling towers on aquatic biota is anticipated. Effects of entrainment, impingement, and discharges from closed-cycle cooling systems could be reduced by reducing the plant's generation rate, or by operating additional wastewater treatment systems. However, because the effects of cooling tower withdrawals and discharges on aquatic organisms are considered to be impacts of small significance and because the changes would be costly, the staff does not consider the implementation of these potential mitigation measures to be warranted. The effects of closed-cycle cooling system operation on aquatic biota are all Category 1 issues.

4.3.4 Agricultural Crops and Ornamental Vegetation

The issue addressed by this section is the extent to which the productivity of agricultural crops near nuclear plants may be reduced by exposure to salts or other effects (e.g., icing, increased humidity) resulting from cooling-tower operation. The approach to evaluating this issue was as follows: first, based on a literature review, potential impacts of salts in general (whether from cooling towers or other sources such as wind-blown salts near seashores) are described according to the rate of salt deposition to earth and the relative sensitivity of different types of crops (Section 4.3.4.1); then, the data generated by monitoring programs at a representative subset of specific nuclear plants were reviewed (Section 4.3.4.2). The subset includes 10 of the 11 nuclear power plants with mechanical-draft cooling towers. Mechanical-draft towers are the focus of this section because impacts of drift deposition and icing are more likely to occur near these towers than at natural-draft towers. Drift from natural-draft towers is released at greater heights, disperses more widely, and therefore deposits on earth at lower rates or concentrations. Data were also found and reviewed for 8 of the 17 plants with natural-draft cooling towers (Table 4.1). The coal-fired Chalk Point Plant was also included in the analysis because extensive monitoring of cooling-tower-drift effects has been conducted there and because this plant uses brackish water for cooling and represents a case with comparatively high potential for drift impacts from natural-draft towers. The only nuclear plant that has a natural-draft tower and uses brackish water for cooling is Hope Creek in New Jersey. It is included among the plants that were reviewed.

The following standard of significance is applied to the effects of cooling tower operation on agricultural crops and ornamental vegetation. The impact is of small significance if under expected operational conditions measurable productivity losses (either quantity or quality of yield) do not occur for agricultural crops; and measurable damage (either visual or to plant function) does not occur for ornamental vegetation.

4.3.4.1 Overview of Impacts

4.3.4.1.1 Ambient Salts and Cooling-Tower Drift

Agricultural crops can be affected by chemical salts and biocides in cooling tower drift and drift-induced or plume-induced ice formation. Increased fogging, cloud cover, and relative humidity resulting from cooling-tower operation have little potential to affect crops, and adverse effects have not been reported. Generally, drift from cooling towers using fresh water has low salt concentrations and, in the case of mechanical draft towers, falls mostly within the immediate vicinity of the towers (ANL/ES-53), representing little hazard to vegetation off-site. Typical amounts of salt or total dissolved solids in freshwater environments are around 1000 ppm (ANL/ES-53). In arid environments, competition for water resources can result in the use of relatively low-quality or saline water for cooling, and the potential for drift-induced damage to surrounding vegetation may be greater (McBrayer and Oakes 1982). For example, source water for cooling at Palo Verde in Arizona is withdrawn from an onsite reservoir containing treated sewage effluent of relatively high salinity. As a result, cooling tower basin water also had high salinity levels including 10,000 to 26,000 ppm total dissolved solids, 3,400 to 7,000 ppm Cl^-, and 2,700 to 8,600 ppm Na^+ (NUS-5241). High salt levels also occur at plants on the coasts or coastal bays. Brackish cooling water used by the Chalk Point coal-fired plant in Maryland contained 11,000 to 26,000 ppm total soluble salts and 6,600 to 18,000 ppm Cl^- (Mulchi and Armbruster 1983). Nuclear plants with cooling towers use fresh water, except for the Hope Creek Plant in New Jersey, which uses saline water. At the Crystal River Plant, Florida, which currently uses brackish water in once-through cooling, a helper cooling tower has been constructed to cool water in a canal that receives discharge from five fossil and one nuclear units.

Talbot (1979) has concluded that adequate estimates of natural background levels of atmospheric salt loading (naturally occurring drift) and rates of deposition thereof are not available for points remote from oceans. In field measurements at a wet cooling tower, A. Backhaus et al. (1988) estimated that up to 60 percent of the chemical contents in the sample came from atmospheric aerosols and not from the tower. Therefore, observed deposition is not all drift from cooling towers (Talbot 1979). Recent work (ORNL/TM-11121) has quantified background aerosol deposition for a dozen sites throughout the country, but deposition for most locations remains poorly known.

Salts from cooling towers are deposited on vegetation by (1) wind-driven impaction, (2) droplet and particulate fallout, and (3) rainfall (Talbot 1979; CONF-740302, 1975b). In high-salt environments such as a windy seashore, impaction is usually the most important process, delivering 10 times more salt to vegetation than does fallout. Increasing wind speeds and salt concentrations increase impaction, hence increasing vegetation injury (Talbot 1979). In most humid environments, rainwater will wash off salts deposited on vegetation (ANL/ES-53), but exposure can be significant during periods between rainfalls.

4.3.4.1.2 Effects of Salt Drift

Plants damaged by salt drift may have acute symptoms, including necrotic or discolored tissue, stunted growth, or deformities (Talbot 1979; Hoffman et al. 1987). Chronic effects are less obvious but may include some degree of chlorosis and reduced growth (Talbot 1979) or increased susceptibility to disease and insect damage (Hosker and Lindberg 1982).

Climatic conditions affect plants' ability to tolerate salt (Talbot 1979; Maas 1985). The degree of injury is related to the salt content in the leaves, but hot or dry weather conditions and water stress are critical in inducing injury (most crops can tolerate greater salt stress during relatively cool and humid weather) (Maas 1985).

Among the factors that affect the plant's foliar accumulation of salt are physical characteristics of the leaves (Maas 1985; CONF-740302, 1975d; Taylor 1980), type and concentration of salt, ambient temperature and humidity, and length of time the leaf remains wet (Maas 1985). Because salt on foliage is apparently absorbed from solution, high humidity, which retards evaporation, enhances salt uptake (CONF-740302, 1975d; McCune et al. 1977; Talbot 1979; Grattan et al. 1981). Because precipitation and dew affect salt deposition, uptake, and resultant injury, dose exposure is difficult to predict (Talbot 1979; Grattan et al. 1981; McCune et al. 1977; EPA-600/3-76-078).

Plant species and crop varieties vary significantly in their tolerance to drift deposition and to soil salinity (Talbot 1979; Maas 1985). In general, salt uptake, plant injury, and reduction in crop yield have been shown to increase with increasing levels of airborne salt or deposition and with time of exposure (CONF-740302, 1975b; Mulchi and Armbruster 1981; Maas; Grattan et al.; EPA-600/3-76-078). Some plants, however, have shown a slight increase in vegetative productivity [e.g., tobacco at < 4 kg/ha (3.6 lb/acre) per week (Mulchi and Armbruster 1983) and cotton at 8 kg/ha (7 lb/acre per week) (Hoffman et al. 1987)]. Based on experimental exposures, a yield reduction of 10 percent has been estimated for deposition levels as low as 4.7 kg/ha (4.2 lb/acre) per week to corn, a species sensitive to foliar salt injury (Mulchi and Armbruster 1981). Relationships between experimental levels of salt deposition, foliar concentrations of sodium and chloride, and corn yield show that yield may be slightly reduced even at rates as low as 2 kg/ha (1.8 lb/acre) per week (Mulchi and Armbruster 1981). Also, bush beans can have reduced yield depending on the age of plants, with older plants being most sensitive (EPA-600/3-76-078). Deposition rates near nuclear-plant towers, according to available deposition data (Section 4.3.5.1.2), appear to be generally below the rates that would affect sensitive agricultural crops.

Talbot (1979) tabulated salt deposition amounts known to induce acute toxicity symptoms in vegetation (Table 4.2). Corn was the most sensitive crop, showing injury above 1.8 kg/ha (1.6 lb/acre) per week; the least sensitive was pinto beans, showing injury above 253 kg/ha (226 lb/acre) per week. Armbruster and Mulchi (1984) showed that foliar salt deposition of 3.2 to 8.8 kg/ha (2.9 to 7.9 lb/acre) per week increased foliar chloride content and damaged foliage of corn, with the higher deposition reducing the yield of grain by as much as 11 percent. They found similar results for soybeans, with bean yields

Table 4.2 Estimates of salt-drift deposition rates estimated to cause acute injury to vegetation

Species	Deposition above which injury is expected (kg/ha/week)
Crops and ornamental plants	
Zea mays (corn)	1.82
Glycine hispida var York (soybean)	7.28
Gossypium hirsutum (cotton)	8.0
Medicago sativa (alfalfa)	15.7
Forsythia intermedia var spectabilis (forsythia)	189.6
Phaseolus vulgaris var Pinto (pinto bean)	252.8
Albizzia julibrissin rosea (mimosa)	379.2
Koelreutaria paniculata (golden rain tree)	568.8
Native species	
Cornus florida (flowering dogwood)	1.2 (in Maryland) 47.4 (in New York)
Fraxinus americana (white ash)	1.3 (in Maryland) 18.9 (in New York)
Tsuga canadensis (Canadian hemlock)	9.4
Pinus strobus (white pine)	189.6
Quercus prinus (chestnut oak)	379.2
Robinia pseudoacacia (black locust)	379.2
Acer rubrum (red maple)	474.0
Hammamelis virginiana (witch hazel)	1042.8

Source: Adapted from Talbot 1979 and Hoffman et al. 1987.
Note: To convert kg/ha to lb/acre, multiply by 0.8924.

reduced by as much as 7 percent at the highest deposition rate.

W. C. Hoffman et al. (1987) experimentally exposed cotton and cantaloupe in the arid environment near Palo Verde to foliar salt deposition rates of 8 to 415 kg/ha (7 to 370 lb/acre) per year total salt and alfalfa to depositions up to 829 kg/ha (740 lb/acre) per year. They found foliar injury in alfalfa only at the highest deposition level but no injury to cantaloupe or cotton despite increases in foliar Na^+ and Cl^-. Yields of cantaloupe and alfalfa were not reduced, but 415 kg/ha (370 lb/acre) per year reduced cotton boll production and seed cotton yield by approximately 25 percent.

The burning quality of tobacco is known to be adversely affected by elevated Cl^-. Experiments have shown that burning quality, or length of time the leaf will burn, is impaired by increasing experimental doses of salt deposition (Mulchi and Armbruster 1983). A 17 percent reduction in burning quality was estimated for a Cl^- deposition of 5 kg/ha (4.5 lb/acre) per week, based on regression relationships of deposition, leaf chloride concentration, and leaf burn (Mulchi and Armbruster 1983).

Field studies of the effects of salt drift have been conducted at the Turkey Point plant and the coal-fired Chalk Point plant. Hindawi et al. (EPA-440/5-86-001) investigated field exposures of bean and corn plants to saltwater drift from a test cooling tower and power spray module at the Turkey Point plant. Salt concentrations in tissues of bean and corn plants increased with time during three weeks of exposure and decreased exponentially with distance from the salt drift source. Some injury to leaves was visible at the site of greatest exposure.

The coal-fired Chalk Point plant has a relatively high potential impact from natural-draft cooling towers because brackish water is used for cooling. Other than the Hope Creek plant, all nuclear plants with natural-draft towers use fresh water for cooling. Deposition rates at Chalk Point were measured at 12 monitoring sites at distances of from 1.6 km to 9.6 km (1 to 6 miles) from the towers during their initial 5 years of operation (Mulchi et al. 1982). No increased deposition resulting from cooling-tower operation was detected at these distances. Deposition rates at the sites ranged from about 0.5 to 1.2 kg/ha (0.4 to 1 lb/acre) per month for NaCl, which comprises most of the solids in the brackish cooling water. Monitoring sites, which were established to study effects on agricultural crops, were not located in areas closer to the towers because no active cropland was in these areas and because the plant, located on a peninsula on the Patuxent River, is bounded by water except to the north and north-northwest. Most drift probably deposits in the river.

A study of tobacco plants 3 years after Chalk Point cooling towers began operating failed to find any increase in leaf salt content that could be attributed to drift (Mulchi and Armbruster 1983). Chloride levels in tobacco and chloride and sodium levels in corn and soybeans at 1.6 km (1 mile), the closest distance crops were grown to the Chalk Point towers, were within the range of preoperational values and were no higher than levels found up to 9.6 km (6 miles) from the towers (Mulchi et al. 1982; Mulchi and Armbruster 1983).

4.3.4.1.3 Effects on Soils

Drift deposition also has the potential to damage vegetation by soil salinization. Soil salinization does not usually occur in areas where rainfall is sufficient to leach salts from the soil profile. In arid regions, however, such as at Palo Verde, cooling tower drift has the potential to increase soil salinity and thus affect native and agricultural plants (McBrayer and Oakes 1982). Salinity of irrigated soils in arid regions may also be increased by drift, even though such soils already have a high salinity resulting from salts in irrigation water and high evaporation rates. Responses of crop plants to soil salinity appear to be poorly correlated to their tolerance to foliar-applied salts (Grattan et al. 1981; Maas 1985).

In an experiment in a more humid environment, salts were applied to soils to simulate drift deposition from the Chalk Point coal-fired plant with brackish water cooling towers. One-time applications of 14–112 kg/ha (13–100 lb/acre) NaCl affected leaf Cl^- in corn and soybeans but resulted in no visible damage or reduction in yield (Armbruster and Mulchi 1984). These soil salt treatments also increased soil pH and extractable cations (Armbruster and Mulchi 1984), but leaching by winter precipitation returned soil to pretreatment status.

In humid environments, effects of drift deposition on soils appear transitory if they can be detected at all. Field measurements of the effects of the operating cooling towers at Chalk Point showed no changes in soil chemical elements at distances of 1.6 to 9.6 km (1 to 6 miles) (Mulchi et al. 1982). In a study of five saltwater cooling towers near Galveston Bay, Texas, salt deposition up to 746 kg/ha/year was found within 100 m (328 ft) of the towers, with levels decreasing to <52 kg/ha (46 lb/acre) per year at 434 m (1424 ft) (Wiedenfeld et al. 1978). Weekly deposition ranged from 4.27 kg/ha (3.81 lb/acre) per week to 58.8 kg/ha (52.5 lb/acre) per week. In the survey, salt content of the soil at 104 m (341 ft) from the towers returned to previous levels when towers were shut down during the winter.

4.3.4.2 Plant-Specific Operational Data

Annual reports of environmental monitoring for vegetation damage at nuclear plants were reviewed. Vegetation monitoring included detailed measurements of vegetation structure and composition on permanent plots, aerial infrared photography with subsequent field surveys for vegetation injury, or general surveillance. Vegetation damage ranging from foliar chlorosis to defoliation can be identified on false-color infrared aerial photographs (NUREG/CR-1231). Vegetation monitoring for drift effects has been conducted at 18 nuclear plants. Most of the nuclear plants are not located close to agricultural areas, but six of the plants monitored crops, pasture, orchards, or ornamental vegetation. None reported visible damage to ornamental vegetation or reduction in crop yield (Table 4.3).

A detailed study at Palo Verde in Arizona showed that, after 6 years of operation, no change in agricultural soils attributable to cooling tower emissions occurred. Although significant increases or decreases occurred in some soil parameters at some monitoring locations, these changes appear unrelated to cooling-tower operation and were believed to have been caused by irrigation management, cropping, and fertilizer application. At the conclusion of the 6-year study, no significant effects on

Table 4.3 Results of nuclear facility monitoring for cooling-tower drift effects on terrestrial vegetation

Plant	Vegetation effects	Type of monitoring
	Natural draft	
Arkansas	No visible damage; no foliar chemical changes after one year	Aerial photography; foliar chemistry; orchard, native trees
Beaver Valley	No visible damage	Aerial photography; soil pH and conductivity; native vegetation
Byron	No visible damage	Aerial photography; crops; woody, ornamental, and native vegetation
Callaway	No visible damage	Aerial photography; permanent vegetation plots; native trees
Davis-Besse	No visible damage	Aerial photography; soil chemistry; native vegetation
Hope Creek	No visible damage after one year; no foliar chemical changes after one year	Ground survey; foliar chemistry; soil chemistry; native vegetation
Three Mile Island	No visible damage	Visual inspection; crops and native vegetation
Trojan	No visible damage	Aerial photography; pasture, ornamental and native vegetation
	Mechanical draft	
Catawba	Possible ice damage to loblolly pine < 61 m (200 ft) from towers	Aerial photography; ground survey; native trees
Duane Arnold	No visible damage	Visual inspection; native vegetation
Edwin I. Hatch	No visible damage	Aerial photography; permanent vegetation plots; native vegetation

Table 4.3 (continued)

Plant	Vegetation effects	Type of monitoring
Joseph Farley	No visible damage	Aerial photography; native vegetation
Palisades	Severe ice damage < 61 m (200 ft) from towers; some icing beyond 250 m (820 ft); sulfate injury < 150 m (492 ft) from towers; change in vegetation caused by damage to trees	Aerial photography; permanent vegetation plots; native vegetation
Palo Verde	No visible damage; foliar salt concentrations increased on site	Aerial photography; foliar chemistry; soil chemistry; crops and native vegetation
Prairie Island	Frequent ice damage to oaks adjacent to towers; change in canopy structure caused by ice damage; reduced viability in acorns from oaks near towers	Aerial photography; ground survey; acorn viability survey; native vegetation
River Bend	No visible damage	Aerial photography; permanent vegetation plots; native vegetation
Fort Saint Vrain	No visible damage	Aerial photography; crops; native vegetation
Washington	No foliar chemical changes	Foliar chemistry; soil chemistry; native vegetation

crops or native vegetation had been noted, and the study was discontinued (Halliburton NUS 1992).

At the Palisades plant in Michigan, concern was expressed by owners of nearby fruit orchards about possible effects of elevated humidity on the incidence of disease, particularly apple scab, in their orchards. The concern was that increased humidity could result in the need for increased applications of disease-control sprayings and thus increase orchard operating costs. NRC staff recommended a survey program to assess impacts of cooling-tower moisture on yield, quality, and frequency of disease-control sprayings (NRC 1978). Weather conditions encouraging apple scab are temperatures of 17 to 24°C (63 to 75°F) and

>85 percent relative humidity for 9 h or more. A study was conducted to determine these weather conditions near Palisades cooling towers and in more distant areas (Ryznar et al. 1980). Long-term weather records from weather stations outside the influence of the Palisades cooling towers were analyzed. In addition, a network of meteorological stations was established in the vicinity of the Palisades plant. No increase in weather occurrences favoring apple scab was observed that could be related to Palisades operation.

4.3.4.3 Conclusion

Monitoring results from the sample of nuclear plants and from the coal-fired Chalk Point plant, in conjunction with the literature review and information provided by the natural resource agencies and agricultural agencies in all states with nuclear power plants, have revealed no instances where cooling tower operation has resulted in measurable productivity losses in agricultural crops or measurable damage to ornamental vegetation. Because ongoing operational conditions of cooling towers would remain unchanged, it is expected that there would continue to be no measurable impacts on crops or ornamental vegetation as a result of license renewal. The impact of cooling towers on agricultural crops and ornamental vegetation will therefore be of small significance. Because there is no measurable impact, there is no need to consider mitigation. Cumulative impacts on crops and ornamental vegetation are not a consideration because deposition from cooling tower drift is a localized phenomenon and because of the distance between nuclear power plant sites and other facilities that may have large cooling towers. This is a Category 1 issue.

4.3.5 Terrestrial Ecology

This section addresses the impact of cooling tower drift on natural plant communities (Section 4.3.5.1) and the impact of bird mortality resulting from collisions with natural-draft cooling towers (Section 4.3.5.2).

4.3.5.1 Effects of Cooling-Tower Drift

This section addresses the extent to which natural plant communities near nuclear plants are affected by exposure to salts, icing, or other effects (e.g., fogging and increased humidity) caused by operation of cooling towers. The approach to evaluating this issue is the same as that used for evaluating the impact on agricultural crops in Section 4.3.4.

4.3.5.1.1 Overview of Impacts

The potential impacts of cooling tower operation on native vegetation are similar to those for agricultural crops, including salt-induced leaf damage, growth and seed yield reduction, and ice-induced damage (see Section 4.3.4). In addition, native vegetation may suffer changes in community structure (Talbot 1979) in response to ice damage or differences in species tolerances to drift. Increased fogging and relative humidity near cooling towers have little potential to affect native vegetation, and no such impacts have been reported.

The following standard of significance is applied to the effects of cooling tower operation on natural plant communities. The impact is of small significance if no measurable degradation (not including short-term, minor, and localized impacts) of natural plant communities results from cooling tower operation.

Species vary in their sensitivity to soil salinity and foliar salt deposition, and their tolerances of drift deposition are not well known. Curtis et al. (PPSP) determined that experimental exposure to saline cooling-tower drift for one growing season resulted in foliar damage to vegetation when leaf Cl^- levels were between 3145 and 9000 μg/g dry weight. These investigators also found that several species of trees growing under field conditions were not always as sensitive to salt deposition as they were under greenhouse conditions. Actual sensitivities of native trees may therefore be less than those shown in Table 4.2. Age of leaves also affects sensitivity to deposition. McCune et al. 1977 found that the youngest leaves of deciduous woody species and the year-old needles of conifers were more susceptible than leaves of other ages. Seasonal deposition, therefore, has the potential to affect these species groups differently. The most sensitive native species, flowering dogwood, shows injury from deposition above 1.2 kg/ha (1.1 lb/acre) per week, and the least sensitive species, witch hazel, shows injury above 1042.8 kg/ha (930.6 lb/acre) per week (Talbot 1979). Deposition rates near nuclear plant cooling towers, according to available deposition data, appear to be generally below the rate that would adversely affect dogwood.

Talbot (1979) reviewed studies of vegetation damage at nine industrial cooling tower installations. Three of the six installations having mechanical draft towers (one saltwater and two freshwater) produced some damage to native vegetation within 215 m (705 ft). Natural draft towers at three sites had no reported visible effects on vegetation. Natural draft cooling towers using brackish water at the coal-fired Chalk Point plant resulted in elevated chloride concentrations in vegetation after 1 year of tower operation (PPSP-CPCTP-18), but symptoms of salt toxicity in native trees had not been observed after 2 years of operation (Lauver et al. 1978), after which monitoring was terminated because of the absence of significant effects (C. L. Mulchi, University of Maryland, personal communication with H. Quarles, ORNL, Oak Ridge, Tennessee, March 15, 1995).

Impacts on native vegetation as a result of soil salinization (Section 4.3.4) are not expected except possibly in arid environments. Although according to McBrayer and Oakes (1982), the predicted annual salt deposition of 25 to 50 kg/ha (22 to 51 lb/acre) near the Palo Verde cooling towers could increase soil salinity enough to alter distribution of certain species because natural soil salinity is already close to their salt tolerances, a monitoring study conducted over the first 6 years of cooling tower operation showed no significant effects on native vegetation or crops (Halliburton NUS 1992).

4.3.5.1.2 Plant-Specific Operational Data

Vegetation monitoring at nuclear plants is described in Section 4.3.4. Of the 18 plants reviewed, visible vegetation damage resulting from cooling tower operation was reported for only the Catawba, Palisades, and Prairie Island plants, all with mechanical-draft towers (Table 4.3). At these facilities, damage has been reported primarily within 150 m of the towers. Although no vegetation damage was reported at Palo Verde, increased foliar salt concentrations were found on-site (Halliburton NUS 1992).

At the Catawba Plant a few loblolly pine trees adjacent to the cooling towers were apparently damaged by ice. Damage to the trees consisted of some browning of needles on trees nearest the towers.

At Palisades, monitoring conducted in response to observed vegetation damage included chloride and sulfate deposition and visual observation of damage. Vegetation damage resulted primarily from sulfate and was more extensive than at any other nuclear facility because, at Palisades' unique location, the tops of the cooling towers are lower than the tops of forested dunes on the site. This unique position of the cooling towers contributes to interception of cooling tower emissions by dune vegetation. Vegetation injury ranged from visible signs to severe necrosis of leaves to near-total defoliation in areas with maximum impact. In 1975, severe icing from drift interception also caused extensive damage by breaking branches as well as trunks of trees (Rochow 1978). Approximately 8 ha (20 acres) was affected by sulfates and icing, including about 6 ha (15 acres) of forest. Sulfate damage resulted from addition of sulfuric acid to the cooling water. However, this practice was discontinued, thus significantly reducing the impacts; and the severe icing in 1975 may have resulted from unusual weather conditions combined with a possible cooling tower malfunction (Ryznar et al. 1980).

Vegetation damage was found to correlate with elevated rates of sulfate deposition from the Palisades towers (Rochow 1978); chloride deposition, however, was less than 1.0 g/m^2/month in areas of extensive vegetation damage and did not correlate with the damage. Sulfate deposition rates were 0.61 g/m^2/month between 700 and 1609 m (2296 and 5278 ft) and 9.0 g/m^2/month within 50 m (164 ft) of the tower. About 75 percent of the sulfate fell out within 145 m (129 ft) of the towers (Rochow 1978). Heaviest damage to vegetation was in areas receiving more than 5 g/m^2/month sulfate, but areas receiving 2 to 5 g/m^2/month also were heavily damaged. Areas receiving 1 to 2 g/m^2/month were damaged primarily in the upper portions of trees.

Monitoring at Prairie Island included aerial photography, ground surveys of vegetation, and acorn viability monitoring. Viability of acorns collected from red oak trees located near the mechanical-draft towers was low, although acorn production appeared normal. Icing from plume downwash, which occurred frequently, may have damaged developing embryos in the acorns, which take 2 years to develop (Richardson 1976; Richardson 1978). Ice also damaged some of the trees growing adjacent to the towers. Because the towers at Prairie Island have not been used for cooling during the winter since 1984, icing damage has been eliminated.

Monitoring at Palo Verde included drift deposition, soil chemistry, salt concentrations in vegetation, and aerial photography. Drift deposition up to 95.6 kg/ha (85.3 lb/acre) per year has occurred on the site within 1.6 km (1 mile) of the cooling towers. Amounts of approximately 25 to 50 kg/ha (22 to 45 lb/acre) per year were predicted to alter soil salinity enough to affect vegetation over the long term (McBrayer and Oakes 1982). Increases in soil sodium, potassium, or chloride content have been reported, but increases also occurred in some sites that were distant from the towers (Halliburton NUS 1992). Observed changes in soil chemistry at Palo Verde appeared to be unrelated to cooling tower operation, and no effects on vegetation were reported.

4.3.5.1.3 Conclusion

Monitoring results from the sample of nuclear plants and from the Chalk Point plant, in conjunction with the literature review and information provided by the natural resource agency and agricultural agencies in all states with nuclear power plants, have revealed no instances where cooling tower operation has resulted in measurable degradation of the health of natural plant communities. Observed vegetation damage caused by icing and cooling-tower drift at mechanical draft towers usually is minor and localized in small ares (e.g., Catawba and Prairie Island). Damage to native vegetation has not occurred at Chalk Point coal plant and the Hope Creek nuclear plant, which use brackish water for cooling and represent a comparatively high probability of impact from operation of natural draft towers. Therefore, damage at other nuclear plants with natural draft towers is unlikely. Damage from operation of mechanical-draft towers at Palisades was more extensive than for the other nuclear plants, but was limited to about 8 ha (20 acres) on the site. The damage resulted from Palisades unique location, the addition of sulfuric acid to cooling water, and possibly from a cooling tower malfunction combined with unusual weather conditions. The use of sulfuric acid was discontinued, significantly reducing the impact. Cooling tower drift in the arid environment at Palo Verde has not affected native species through soil salinization: no actual damage was reported over a 6 year study of cooling tower operation (Halliburton NUS 1992). The only potential mitigation measures would be to change to another cooling system or to modify the cooling towers to reduce the amount of drift. Because the impacts of cooling tower drift on native plants are expected to be of small significance at all plants and because the potential mitigation measures would be costly, no mitigation measures beyond those implemented during the current term license would be warranted. Cumulative impacts on natural plant communities are not a consideration because of the distance between nuclear power plant sites and other facilities that may have large cooling towers. This is a Category 1 issue.

4.3.5.2 Bird Collisions with Cooling Towers

This section addresses the significance of avian mortality resulting from collisions of birds with natural-draft cooling towers at nuclear plants. Natural-draft towers, which are tall structures, cause some mortality, whereas mechanical-draft towers cause negligible mortality and are not addressed here. This issue was evaluated by reviewing the general literature for avian collision mortality associated with all types of man-made objects, as well as the monitoring studies conducted at six nuclear plants. The literature review is presented in Section 4.5.6.2. The significance of the mortality caused by cooling towers is determined by examining the actual numbers and species of birds killed and comparing this mortality with the total avian mortality resulting from other man-made objects and with the abundance of bird populations near the towers.

4.3.5.2.1 Overview of Impacts

Throughout the United States, millions of birds are killed annually when they collide with man-made objects, including radio and TV towers, windows, vehicles, smoke stacks, cooling towers, and numerous other objects. An overview of collision mortality for all types of man-made objects is included in the discussion of transmission lines in Section 4.5.6.2.

Avian mortality due to man-made structures is of concern if the stability of the local population of any bird species is threatened or if the reduction in the numbers within any bird population significantly impairs its function within the local ecosystem. Avian mortality resulting from collisions of birds with cooling towers is considered to be of small significance if the losses do not threaten the stability of local populations of any species and if there is no noticeable impairment of its function within the local ecosystem.

4.3.5.2.2 Plant-Specific Analysis

Monitoring of bird collisions has been done at several nuclear plants with natural draft cooling towers, including the Susquehanna plant near Berwick on the Susquehanna River in eastern Pennsylvania, the Davis-Besse plant on the shore of Lake Erie in north central Ohio, the Beaver Valley plant on the Ohio River in extreme western Pennsylvania, the Trojan Plant on the Columbia River in extreme northwestern Oregon, the Three Mile Island plant near Harrisburg in southeastern Pennsylvania, and the Arkansas Nuclear One plant on Dardanelle Lake in northwestern Arkansas. The following information was obtained from nuclear plant annual monitoring reports and from a few other sources, as cited.

At the Susquehanna plant, surveys were conducted on weekdays during spring and fall migration from 1978 through 1986. This plant's natural draft towers are 165 m (540 ft) tall and illuminated at the top with 480-V aircraft warning strobe lights. About 1500 dead birds (total for all survey years) of 63 species were found that had apparently collided with the cooling towers. Others were probably lost in the tower basin water during plant operation. Most of the birds were passerines (songbirds). Fewer collisions seemed to occur during plant operation, when cooling tower plumes and noise may have frightened birds away from the towers. From 1984 through 1986, eight dead bats were also found, including little brown myotis, red bat, and big brown bat.

At Davis-Besse, extensive surveys for dead birds were conducted from fall 1972 to fall 1979. Early morning surveys at the 152-m (499-ft-) tall cooling tower were made almost daily from mid-April to mid-June and from the first of September to late October. After the tower began operating in the fall of 1976, some dead birds were lost through the water outlets of the tower basin. A total of 1554 dead birds were found, an average of 196 per year. The dead birds included 1222 at the cooling tower, 222 around Unit 1 structures, and 110 at the meteorological tower. Most were night-migrating passerines, particularly warblers, vireos, and kinglets. Waterfowl that were abundant in nearby marshes and ponds suffered little collision mortality. Most collision mortalities at the cooling tower occurred during years when the cooling tower was not well illuminated (1974 to spring 1978). After completion of Unit 1 structures and the installation of many safety lights around the buildings in the fall of 1978, collision mortality was significantly reduced (average of 236 per year from 1974 through 1977, 135 in 1978, and 51 in 1979). Diffusion of light from these safety lights may illuminate the cooling tower in such a way that birds can see and avoid it. Lights at nuclear plants may not confuse birds to the extent sometimes caused by lights on radio or TV towers (Section 4.5.6.2). Lights illuminating the Pilgrim Nuclear Station in Massachusetts apparently were not a problem to migrating birds, which were monitored by radar. The orientation, flight speed, and altitude of these birds appeared unaffected by the lights, although on one of nine nights, flight direction at the station was different from that in a control area and flight altitude was higher (Marsden et al. 1980).

At Beaver Valley, surveys were conducted in spring and fall from 1974 through 1978 at the natural draft tower. A total of 27 dead birds were found. At the Trojan Plant, surveys were conducted weekly in 1984 and 1988 at the 152-m 499-ft-) tall cooling tower, meteorological tower, switch yard, and generation building. No dead birds were found. At the 113-m (371-ft-) tall cooling towers at Three Mile Island, a total of 66 dead birds were found from 1973 through 1975 (Temme and Jackson 1979). No dead birds were found at Arkansas Nuclear One, where monitoring at the natural-draft tower was done twice weekly from October 15 through April 15 in 1978–79 and 1979–80.

4.3.5.2.3 Conclusion

Existing data on cooling-tower collision mortality suggest that cooling towers cause only a very small fraction of the total bird collision mortality (see Section 4.5.6.2 for a review of this mortality). The relatively few nuclear plants having natural-draft towers in the United States (approximately 32 units), combined with the relatively low bird mortality at individual natural draft towers, shows that (1) these nuclear plant towers are not greatly affecting bird populations (see Section 4.5.6.2.1) and (2) their contribution to the cumulative effects of bird collision mortalities is very small. Mechanical-draft cooling towers, which are not nearly as tall as natural-draft towers, and other facilities pose little risk to migrating birds.

Local bird populations are apparently not being significantly affected by collision with cooling towers. Waterfowl and other birds that are commonly present as permanent or summer residents around nuclear plants do not frequently collide with the towers. Instead, a very high percentage of the collision mortalities occur during the spring and fall bird migration periods and involve primarily birds migrating at night. Studies that have been conducted at six nuclear plants, in conjunction with literature reporting total collision mortality (Section 4.5.6.2), show that (1) avian mortality associated with cooling towers is a very small part of the total mortality and (2) local bird populations are not being significantly reduced. Data on collision mortality were found for only 6 of the 20 nuclear plants with natural-draft cooling towers. Collision mortality at one or more of these plants may be greater than at the plants where surveys were conducted.

Avian mortality resulting from collisions of birds with cooling towers involves sufficiently small numbers for any species that it is unlikely that the losses would threaten the stability of local populations or result in a noticeable impairment of the function of a species within local ecosystems. There is no reason to believe that the annual mortality rate resulting from collision of birds with any cooling tower would be different during the license renewal term. Thus, avian mortality resulting from collision with cooling towers is of small significance. A potential method of mitigating avian morality would be to illuminate natural draft cooling towers at night. Because it is unlikely that the numbers of birds killed from collision with cooling towers are large enough to affect local population stability or impair the function of a species within the local ecosystem, consideration of further mitigation is not necessary. Because any contributions of cooling tower collisions to overall bird mortality have already been expressed in species populations, it is not expected that there will be any incremental or cumulative impact on bird populations from cooling tower collision mortality due to relicensing of current nuclear plants. The cumulative effect of bird mortality is further considered with transmission lines in Section 4.5.6.2. Avian mortality resulting from collision with cooling towers is a Category 1 issue.

4.3.6 Human Health

Some microorganisms associated with cooling towers and thermal discharges can have deleterious impacts on human health. Their presence can be enhanced by thermal additions. These microorganisms include the enteric pathogens *Salmonella* sp. and *Shigella* sp. as well as *Pseudomonas aeruginosa* and the thermophilic fungi (Appendix D). Tests for these pathogens are well established, and factors germane to their presence in aquatic environs are known and in some cases controllable. Other aquatic microorganisms normally present in surface waters have only recently been recognized as pathogenic for humans. Among these are Legionnaires' disease bacteria (*Legionella* sp.) and free-living amoebae of the genera *Naegleria* and *Acanthamoeba*, the causative agents of various, although rare, human infections. Factors affecting the distribution of *Legionella* sp. and pathogenic free-living amoebae are not well understood. Simple, rapid tests for their detection and procedures for their control are not yet available. The impacts of nuclear plant cooling towers and thermal discharges are considered of small significance if they do not enhance the presence of microorganisms that are detrimental to water and public health.

Potential adverse health effects on workers due to enhancement of microorganisms are an issue for steam-electric plants that use cooling towers. Potential adverse health effects on the public from thermally enhanced microorganisms is an issue for the nuclear plants that use cooling ponds, lakes, or canals and that discharge to small rivers. These plants are all combined in the category of small river (average flow less than 2830 m^3/s (100,000 ft^3/s) in Tables 5.18 and 5.19. These issues were evaluated by reviewing what is known about the organisms that are potentially enhanced by operation of the steam-electric plants.

Because of the reported cases of fatal *Naegleria* infections associated with cooling towers, the distribution of these two pathogens in the power plant environs was studied in some detail (Tyndall et al. 1983; see also Appendix D). In response to these various studies (Appendix D), many electric utilities require respiratory protection for workers when cleaning cooling towers and condensers. However, no Occupational Safety and Health Administration (OSHA) or other legal standards for exposure to microorganisms exist at present. Also, for worker protection, one plant with high concentrations of *Naegleria fowleri* in the circulating water successfully controlled the pathogen through chlorination before its yearly downtime operation (Tyndall et al. 1983).

Changes in the microbial population and in the use of bodies of water may occur after the operating license is issued and the application for license renewal is filed. Ancillary factors may also change, including average temperature of water resulting from climatic conditions. Finally, the long-term presence of a power plant may change the natural dynamics of harmful microorganisms within a body of water by raising the level of *N. fowleri*, which are indigenous to the soils. Increased populations of *N. fowleri* may have significant adverse impacts. On entry into the nasal passage of a susceptible individual, *N. fowleri* will penetrate the nasal mucosa. The ensuing infection results in a rapidly fatal form of encephalitis. Fortunately, humans in general are resistant to infection with *N. fowleri*. Hallenbeck and Brenniman (1989) have estimated individual annual risks for primary amebic meningoencephalitis caused by the free living *N. fowleri* to swimmers in fresh water, to be approximately 4×10^{-6}. Heavily used lakes and other fresh bodies of water may merit special attention and possibly routine monitoring for *N. fowleri*.

Thermophilic organisms may or may not be influenced by the operation of nuclear power plants. The issue is largely unstudied. However, NRC recognizes a potential health problem stemming from heated effluents. Occupational health questions are currently resolved using proven industrial hygiene principles to minimize worker exposures to these organisms in mists of cooling towers. NRC anticipates that all plants will continue to employ proven industrial hygiene principles so that adverse occupational health effects associated with microorganisms will be of small significance at all sites, and no mitigation measures beyond those implemented during the current term license would be warranted. Aside from continued application of accepted industrial hygiene procedures, no additional mitigation measures are expected to be warranted as a result of license renewal. This is a Category 1 issue.

Public health questions require additional consideration for the 25 plants using cooling ponds, lakes, canals, or small rivers (all under the small river category in Tables 5.18 and 5.19) because the operation of these plants may significantly enhance the presence of thermophilic organisms. The data for these sites are not now at hand and it is impossible to predict the level of thermophilic organism enhancement at any given site with current knowledge. Thus the impacts are not known and are site-specific. Therefore, the magnitude of the potential public health impacts associated with thermal enhancement of *N. fowleri* cannot be determined generically. This is a Category 2 issue.

4.3.7 Noise Impacts

When noise levels are below the levels that result in hearing loss, impacts have been judged primarily in terms of adverse public reactions to the noise. Generally, power plant sites do not result in off-site levels more than 10 dB(A) above background. However, some sites have calculated impacts to critical receptors at this level and above. Noise level increases larger than 10 dB(a) would be expected to lead to interference with outdoor speech communication, particularly in rural areas or low-population areas where the day-night background noise level is in the range of 45–55 dB(A). Generally, surveys around major sources of noise such as large highways and airports have found that, when the day-night level increases beyond 60 to 65 dB(A) (FICN 1992), noise complaints increase significantly. Noise levels below 60 to 65 dB(A) are considered to be of small significance.

The principal sources of noise from plant operations are natural-draft and mechanical-draft cooling towers, transformers, and loudspeakers. Other occasional noise sources may include auxiliary equipment such as pumps to supply cooling water from a remote reservoir. Generally, these noise sources are not perceived by a large number of people off-site.

In most cases, the sources of noise are sufficiently distant from critical receptors outside the plant boundaries that the noise is attenuated to nearly ambient levels and is scarcely noticeable. However, during the original license application process, some of the sites identified critical receptors near plant boundaries that would experience noise levels greater than 10 dB above ambient. Those levels would increase the difficulty in outdoor speech communication. (The noise would require that people speak louder to communicate.) In no case is the off-site noise level from a plant sufficient to cause hearing loss.

Natural-draft and mechanical-draft cooling towers emit noise of a broadband nature, whereas transformers emit noise of a specific tonal nature at harmonics of the 60-Hz primary frequency. The frequencies with important intensities are 120, 240, 360, and 480 Hz. Loudspeakers emit noise at audible frequencies, generally below 5000 Hz. Because of the broadband character of the cooling towers, the noise associated with them is largely indistinguishable and less obtrusive than transformer noise or loudspeaker noise. Transformer noise is distinct because of its specific low frequencies. These low frequencies are not attenuated with distance and intervening materials as much as higher frequencies are; thus, low frequencies are more noticeable and obtrusive. However, at most sites employing cooling towers, transformer noise is masked by the broadband cooling tower noise. Loudspeakers would be a more intermittent source of noise.

Cooling tower and transformer noises do not change appreciably with time. No change in noise levels or their attendant impacts would be expected during the license renewal term.

License renewal does not add to the extent of noise impacts, either in frequency distribution or in intensity. No major changes in the noise profile of power plants is anticipated. The only possible source of added impacts would be the result of additional people who build homes near enough to the site that they are affected by noise. At the noise levels anticipated, no cumulative biological impacts are expected.

During the license renewal term, noise impacts will be the same as during the initial license term. These impacts were found to be generally not noticed by the public, thus noise impacts are of small significance. Consideration was given to mitigating these noise impacts. Because the principal sources of noise are cooling towers, transformers, and loudspeakers, these sources would be the focus of noise reduction efforts. Reduction in loudspeaker noise could be accomplished by restricting such use to emergencies only and using personal electronic pagers to contact personnel. Mitigation of the low-frequency noise from cooling towers or transformers is much more difficult and would require shielding by massive concrete structures or earthen berms.

Because these noise reduction methods would be costly and given that there have been few complaints and the noise impacts are so small, no additional mitigation measures are warranted for license renewal. This is a Category 1 issue.

4.4 COOLING PONDS

4.4.1 Introduction

Power plants that use cooling ponds compose a unique subset of closed-cycle systems in that they operate as once-through power plants [i.e., large condenser flow rates (Table 2.1)] that withdraw from and discharge to relatively small bodies of water created for the plant. Cooling ponds reduce the heat load to natural bodies of water from power plant operations without the construction and operational expenses of cooling towers. The natural body of water is not relied on for heat dissipation but is used as a source of makeup water to replace that lost to evaporation and as a receiving stream for discharges from the cooling pond.

4.4.1.1 Types of Cooling Ponds

The range of power plants that use cooling ponds or lakes represents a gradation from closed-cycle power plants sited on small cooling ponds to once-through power plants sited on large, multipurpose reservoirs. For the purpose of this section, a cooling pond will be defined as "a man-made impoundment that does not impede the flow of a navigable system and that is used primarily to remove waste heat from condenser water prior to recirculating the water back to the main condenser" (ORNL/NUREG/TM-226). Under this definition, nine nuclear power plants use cooling ponds: Braidwood, Clinton, Dresden, La Salle, H. B. Robinson, South Texas, Virgil C. Summer, Wolf Creek, and Turkey Point (actually an extensive system of canals for recirculating water). Effects of other power plants located on large, multipurpose reservoirs (e.g., Comanche Peak and William B. McGuire) are included in the analysis of once-through cooling systems in Section 4.2.

The surface areas of the cooling ponds associated with these nine plants range from 629 to 2924 ha (1573 to 7310 acres). Braidwood, Clinton, Dresden, La Salle, and South Texas all use large cooling ponds that rely on nearby rivers for makeup water. Both H. B. Robinson and Clinton recycle their heated effluent in cooling ponds that are impoundments of relatively small creeks. The Virgil C. Summer plant dissipates waste heat to Monticello Reservoir, which in turn receives makeup water from Parr Reservoir. Wolf Creek recycles its condenser cooling water through a cooling pond that receives its makeup water from nearby John Redmond Reservoir. Turkey Point recirculates condenser cooling water through a complex series of canals.

4.4.1.2 Cooling Pond Emissions and Effluents

Power plants sited on cooling ponds do not have unique effluents or emissions. The examples considered in this section represent open-cycle condenser cooling systems that use the man-made pond to recirculate cooling water. Discharges to natural waters are used primarily to control the buildup of dissolved solids, analogous to blowdown from cooling towers, and may or may not have elevated temperatures. The types of emissions and effluents are the same as those considered for once-through cooling systems in Section 4.2.

Also, intake and discharge effects are regulated in the same way as for once-through cooling systems [i.e., through NPDES permits and, if needed, CWA Section 316(a) and (b) determinations (see Section 4.2 for a discussion of these regulatory mechanisms)].

Accelerated evaporation of water from a cooling pond produced by thermal loading from the power plant increases the concentration of total dissolved solids (TDS). Concentrations of TDS in cooling reservoirs average about 1.8 times those in the makeup waters (ORNL/NUREG/TM-226). Contaminants may also accumulate in the pond water and sediments. Accumulation of such water quality constituents as metals (copper or zinc) and chlorinated organic compounds in water, sediments, and aquatic biota has been cited as a potential issue for power plants located on cooling ponds.

4.4.2 Surface Water Use and Quality

This section and Section 4.4.4 review the past and ongoing impacts on aquatic resources of operation of nuclear power plants with cooling ponds. Any ongoing impacts will probably continue into the license renewal term because the cooling system design and operation are not expected to change. Judgments about the significance of these issues during the license renewal term are based on published information, agency consultation, and information provided by the utilities (Appendix F) applicable to every nuclear power plant in the United States. The conclusions reached in these sections apply to all nuclear power plants with cooling ponds.

4.4.2.1 Water Use

Nine nuclear power plants use off-stream ponds or lakes as cooling devices. Although these off-stream bodies of water were specifically designed to serve as cooling systems for temperature reduction before discharge into a river or reservoir, some (e.g., La Salle County Nuclear Station) provide recreational fishing opportunities in addition to cooling. The water-use issue associated with operation of cooling ponds is the availability of adequate streamflows to provide makeup water, particularly during droughts or in the context of increasing in-stream and off-stream uses. Two nuclear power plants, the Braidwood Station and the Wolf Creek Generating Station, have already experienced water-use conflicts.

Braidwood, which withdraws makeup water for its cooling pond from the Kankakee River, will face future water availability conflicts as Joliet, Illinois, becomes a potential downstream water user. Potential use of water upstream for irrigation may also affect the Kankakee River flow and the availability of water for the Braidwood facility. In response to other water-use demands, Braidwood, La Salle County, Dresden, and other nuclear facilities using cooling ponds or lakes, particularly those on the same river system as other thermoelectric generating facilities, may have to reevaluate their overall water requirements and tolerances to drought conditions. For example, Braidwood was forced to cease withdrawal from the Kankakee River during much of July and August 1988 because the flow of the river was below the level at which makeup withdrawals were permitted [Commonwealth Edison Company response to NUMARC survey (NUMARC 1990); Gary Clark, telephone interview with V. R.

Tolbert, ORNL, Oak Ridge, Tennessee, July 5, 1990]. These plants could increase the sizes of their cooling ponds or adopt other measures to compensate for an inability to withdraw makeup water during low flows or because of competing water uses (Gary Clark, Illinois Division of Water Resources, personal communication to V. R. Tolbert, ORNL, Oak Ridge, Tennessee, July 5, 1990).

Probably the most important change in the consideration of water-use impacts since the initial licensing of most of the nuclear generating facilities has been the increased emphasis on in-stream flow for preservation of aquatic habitat, riparian (streamside) habitat, and associated biota. An example of potential water-use conflicts is associated with the withdrawal of makeup water by the Wolf Creek Generating Station in Kansas. Water for the Wolf Creek cooling lake is withdrawn from the Neosho River downstream of John Redmond Reservoir. Riffle (shallow water) areas of this river serve as habitat for a threatened fish species, the Neosho madtom. Makeup water withdrawals during severe drought conditions could affect the riffle habitat of this species (Harold Spiker, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, June 28, 1990).

Nuclear power plants that withdraw makeup water for cooling ponds from small bodies of water may need to curtail operations during drought periods or may experience future conflicts with other water users (including increasing emphasis on in-stream uses). This potential issue affects only a small number of existing plants, and mechanisms exist for resolving these conflicts (e.g., through derating the plant during temporary drought periods or, if longer-term solutions are required, by the periodic renewals of the plants' NPDES permits). Consultations with regulatory agencies indicate that water use conflicts are already a concern at two of the nine nuclear power plants with cooling ponds (Braidwood and Wolf Creek). Because water use conflicts may be of small or moderate significance during the license renewal period, this is a Category 2 issue for nuclear plants with cooling systems that utilize cooling ponds. The effects of consumptive water use on in-stream and riparian communities could also be of small or moderate significance, depending on the plant, and also are a Category 2 issue.

4.4.2.2 Water Quality

An issue associated with the operation of a cooling pond is potential alteration of the quality of both pond and natural receiving waters as a result of the addition and concentration of a variety of chemicals. As with all other types of condenser cooling systems, chemicals (e.g., chlorine) may be added to control biofouling and to inhibit scaling and corrosion in the condenser tubing. In addition, corrosion products are leached into the circulating water flow and may be concentrated in the recirculating system.

Discharges of heat and chemical contaminants are controlled by the NPDES permits that are issued and periodically renewed for each power plant (Section 4.2). Whereas the volume of water that is discharged to a natural body of water from a cooling pond may be comparable to that discharged as blowdown from a cooling tower, the concentration of dissolved solids is less. In ORNL/NUREG/TM-226, Parkhurst and McLain estimate that the average concentration of TDS is about 400 percent above ambient in the blowdown from cooling towers and about 180 percent above ambient in the discharge from cooling reservoirs. Greater quantities of biocides may also be needed for cooling towers than for cooling ponds because of the additional need to control biofouling on the cooling tower surfaces.

Larimore and McNurney (EPRI EA-1148) compared the water quality of a power plant cooling lake (Lake Sangchris in Illinois) with that of a nearby lake unaffected by power plant discharges. The most obvious differences resulted from the heat input and power-plant-induced circulation, which prevented seasonal thermal stratification in the cooling lake. With the exception of temperature, no water quality differences between the two lakes were attributed to power plant operations.

Becker et al. (EPRI EA-1054) examined available data from 14 cooling impoundments (all associated with fossil-fuel power plants) to identify water quality and ecological effects. These 14 cooling impoundments were selected from a population of 135 steam-electric power plant cooling ponds across the United States as those most likely to provide "worst-case" conditions for identifying impacts from power plant operation. Selection was based on load ratio, that is, impoundment surface area divided by rated plant generating capacity in megawatt (electrical). The authors assumed that cooling impoundments with low load ratios (relatively little dilution of power plant discharges) would be most likely to exhibit discharge-related water quality and ecosystem effects. Neither low DO concentration nor supersaturation of other dissolved gases was a problem, although oxygen deficits occurred in deeper waters of those cooling ponds that stratified. There was no indication that plant chlorination increased the chloride concentration of closed impoundments. Evaporation from a completely closed pond (no blowdown) resulted in gradual, long-term concentration of inorganic constituents, but levels did not exceed those commonly tolerated by aquatic life.

Potentially more important than the overall increase in TDS is the concentration of specific constituents—for example, heavy metals. The accumulation of heavy metals in cooling ponds via evaporation and bioconcentration has not been identified as a concern by the utilities or regulatory agencies, although specific studies appear to be uncommon. In a survey of 14 cooling impoundments, Becker et al. (EPRI EA-1054) found data on metals for only one. Trace metal concentrations were measured at North Lake, a cooling impoundment in Texas with one of the lowest load ratios in the study. North Lake is a completely enclosed system with essentially no drainage. As a result of high evaporative water losses, water levels cannot be maintained solely by precipitation, so makeup water must be pumped from the nearby Trinity River. In 15 years of operation, the cooling impoundment was refilled about 5.5 times, a situation that should lead to relatively high concentrations of water quality constituents. The North Lake data indicated that trace metals (copper, chromium, iron, lead, manganese, and zinc) were not accumulating in the impoundment, and the levels were too low to be toxic to the ecosystem (Sams 1976). On the other hand, a study of copper concentrations at eight nuclear power plants indicated that the highest chronically elevated concentrations in the discharge waters occurred at the H. B. Robinson Steam Electric Plant Unit 2, a plant with a cooling impoundment (ASTM STP 854). Examination of a variety of factors, including influent water quality and copper specification, led Harrison (ASTM STP 854) to conclude that elevated levels of copper in the H. B. Robinson plant effluent could be attributed to the low-pH water in the region, which caused relatively high leaching of copper from the condenser tubes. The naturally high corrosivity of the water appeared to be the cause of elevated copper concentrations at this plant. The copper-containing tubing was subsequently replaced because of high leakage, eliminating copper loading to the cooling pond [Carolina Power & Light Company response to NUMARC survey (NUMARC 1990)].

Although power plant chlorination may result in the presence of chlorinated organic compounds, the potential accumulation of these materials appears to have been studied rarely. Sams (1976) investigated the possible buildup of total chlorinated organic compounds in the closed cooling impoundment of a fossil-fueled power plant but detected no quantitative differences between the pond and its makeup water source.

The Illinois Department of Conservation has expressed concern about the adverse influence of discharges from the Dresden Nuclear Power Station cooling pond on the temperature and water quality of the Kankakee River (Mark Frech, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, July 2, 1990). EPA has also pointed out that Dresden may have difficulty meeting temperature limits in the future as water quality improves and standards become more stringent (Robert Springer, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, June 29, 1990). With this exception, the effect of operation on water quality is not a concern at the nine nuclear power plants that use cooling ponds as part of their condenser cooling systems. In all cases, the NPDES permits and 316(a) determinations that limit the discharge of heat and other pollutants are periodically reevaluated and renewed by the EPA or state water quality permitting agencies, allowing existing or future water quality issues to be resolved in a timely manner.

The impacts of condenser cooling system discharges on water quality of cooling ponds are considered to be of small significance if water quality criteria (e.g., as contained in NPDES permits) are not violated and if aquatic organisms in the vicinity of the plant are not bioaccumulating metals or other contaminants. Based on review of literature and operational monitoring reports, consultations with utilities and regulatory agencies, and comments on the draft GEIS, degradation of water quality in cooling ponds has not been a problem at most existing nuclear power plants. Mitigation was effective at the one plant that experienced elevated metal levels during the current license period. Effects are considered to be of small significance for all plants. Heat is rapidly dissipated in the vicinity of the power plant so that far-field, cumulative effects would not be expected. No evidence of existing, significant accumulation of contaminants in or near cooling ponds was found in the literature or provided by regulatory agencies. No change in operation of the cooling system is expected during the license renewal term, so no change in effects of discharges on water quality of cooling ponds is anticipated. Effects of discharges to cooling ponds could be reduced by operating additional water treatment systems, greater flushing of the cooling pond/reservoir, or by reducing the plant's generation rate. However, because the effects of discharges on water quality of cooling ponds are considered to be impacts of small significance and because these changes would be costly, the staff does not consider the implementation of these potential mitigation measures to be warranted. Effects of condenser cooling water discharges on water quality of cooling ponds are a Category 1 issue.

4.4.3 Aquatic Ecology

As noted in Section 4.4.2, the concentrations of TDS in cooling ponds averages less than three times that in the makeup water. Such concentrations of most water quality constituents are unlikely to affect aquatic biota. However, elevated levels of particular constituents may be of greater concern. For example, formerly elevated copper concentrations in the effluent from the H. B. Robinson plant (Section 4.4.2) were implicated in increased deformities and reduced reproductive capacity in the bluegill population residing in the cooling pond (NUREG/CR-2822; ASTM STP 854). Harrison and Lam (NUREG/CR-2822) concluded that these sublethal effects were the result of leaching of copper from the condenser tubes by the low-pH water in the pond. Although the highest concentrations of copper in fish tissue were found in bluegills collected in the discharge area, tissue concentrations were also elevated in the intake site compared with an upstream control site. Following replacement of the copper-alloy condenser tubing, fish populations recovered and skeletal deformities disappeared [Carolina Power & Light Company response to NUMARC survey (NUMARC 1990)].

In addition to potential effects from water quality degradation, aquatic biota of cooling ponds may be affected by impingement, entrainment, and thermal discharges. These effects are the same as those considered for once-through cooling systems (Section 4.2.2), except that they mainly influence aquatic communities that did not exist before creation of the cooling pond; natural communities are affected to a lesser extent by the relatively small withdrawals and discharges associated with makeup water and blowdown. In a review of impacts of cooling impoundments of fossil-fuel power plants, Becker et al. (EPRI EA-1054) detected no major detrimental impacts on fish populations from power plant operation. The qualitative effects observed included earlier seasonal spawning and faster growth rates, which the authors attributed to elevated water temperatures. Information was not adequate to determine quantitative power plant effects on fish populations in the 14 impoundments studied. Larimore and McNurney (EPRI EA-1148) compared fish populations of a cooling lake and a nearby noncooling lake. Largemouth bass in the cooling lake spawned earlier, grew faster, were more accessible to anglers in the winter, and had lower rates of parasitic infestation. Parkhurst and McLain (ORNL/NUREG/TM-226) reviewed effects of cooling reservoirs on fish populations. They concluded that (1) effects on game fish populations are generally insignificant or positive but rarely negative, (2) growth rates are generally similar to those of fish from other waters, (3) some species may spawn earlier in the heated environment, (4) many species are attracted to the heated areas during the winter and avoid those areas in the summer, and (5) the thermal tolerances of species inhabiting heated waters are often higher than those for the same species inhabiting ambient-temperature waters.

Consultations with regulatory agencies and nuclear utilities that operate cooling ponds have revealed some site-specific concerns. For example, the Virgil C. Summer Nuclear Station has experienced thermal-discharge-effect-related fish kills in recent summers in and around the heated water discharge bay (James A. Timmerman, Jr., letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, July 2, 1990). These fish kills were localized; they do not appear to have had any adverse effect on the cooling pond population. The utility is investigating the specific causes of the fish kills to implement corrective actions [South Carolina Electric & Gas Company response to NUMARC survey (NUMARC 1990)]. Concerns about biological effects of inadequate in-stream flows below the Wolf Creek Generating Station, particularly during drought years, have been raised (Harold L. Spiker, letter to G. F. Cada, ORNL, Oak Ridge, Tennessee, June 28, 1990). This water-use issue is discussed in Section 4.4.2.1.

The operating experience of nuclear power plants using cooling ponds indicates that impacts on aquatic resources appear to be a function of unique characteristics of the plant or the environment and not generally the result of the cooling system technology. Water-use conflicts (Braidwood, Wolf Creek) and hot weather fish kills (Virgil Summer) could occasionally develop at many fossil-fuel and nuclear power plants. Elevated concentrations of trace metals, which should be most apparent in recirculating cooling ponds, were a concern at only one plant. In this example, elevated copper concentrations in the effluent are believed to have resulted from the leaching of copper from condenser tubing by naturally acidic water; the extent to which buildup of copper in the pond by the recirculation of cooling water also contributed to the subsequent biological effects was not determined. Because effects on the bluegill population have been eliminated by the replacement of the condenser tubing with noncopper alloys, recirculation of residual copper in the cooling pond does not appear to be a problem.

Water quality and aquatic ecology issues for nuclear power plants that use cooling ponds, are summarized in Table 4.4. As noted for power plants with once-through cooling systems in Section 4.2.3.2, operational experience indicates that most early aquatic resource concerns have been found to be of small significance at all sites, and no mitigation measures beyond those implemented during the current term license would be warranted. For the reasons given in Section 4.2.2, these are Category 1 issues. However, entrainment and impingement of fish and thermal discharge effects are of sufficient concern on large cooling ponds that support valued aquatic resources that they continue to be examined in detail as part of CWA Section 316(a) and (b) demonstrations. Section 316(a) or (b) determinations are pending for two of the nine nuclear power plants with cooling ponds (Braidwood and Clinton). Further, changes in aquatic communities of either the cooling ponds or source bodies of water could warrant reexamination of entrainment, impingement, or heat shock effects at any of the plants before the time of license renewal. For some plants, the large volumes of water withdrawn, heated, and discharged back to the receiving water may cause adverse effects to fish populations during the license renewal term. Because impacts of fish entrainment and

Table 4.4 Significance of aquatic resources impacts for license renewal of existing nuclear power plants that use cooling ponds

Issue	Impact significance[a]
Water quality, hydrology, and use	
Water-use conflicts	2
Altered current patterns at intake and discharge structures	1
Altered salinity gradients	1
Temperature effects on sediment transport capacity	1
Altered thermal stratification of lakes	1
Scouring due to discharged cooling water	1
Eutrophication	1
Discharge of chlorine or other biocides	1
Discharge of metals in waste water	1
Discharge of sanitary wastes and minor chemical spills	1
Effects of consumptive water use and riparian communities	2
Aquatic ecology	
Impingement of fish	2
Entrainment of fish, early life stages	2
Entrainment of phytoplankton and zooplankton	1
Thermal discharge effects	2
Cold shock	1
Thermal plume barrier to migrating fish	1
Distribution of aquatic organisms	1
Premature emergence of aquatic insects	1
Stimulation of nuisance organisms (e.g., shipworms)	1
Losses from predation, parasitism, and disease among organisms exposed to sublethal stresses	1
Gas supersaturation (gas bubble disease)	1
Low dissolved oxygen in the discharge	1
Accumulation of contaminants in sediments or biota	1

[a]A 1 means that the impact is expected to be of small significance at all sites. A 2 means that the impact may be of moderate or large significance at some sites.

impingement and of thermal discharge effects could be small, moderate, or large, depending on the plant, these are Category 2 issues for nuclear plants that use cooling ponds.

4.4.4 Terrestrial Ecology

The issue evaluated in this section is the extent to which vegetation and wildlife are affected by increased fogging, humidity, and icing near cooling ponds and by water contaminants that may be present in the ponds. The primary impacts of cooling ponds on terrestrial ecological resources occurred when the ponds were constructed and filled, resulting in flooding and loss of terrestrial plant and animal communities. Potential impacts during plant operation include exposure of terrestrial habitats near the ponds to increased levels of humidity, icing, and fog. Also, waterfowl and other wildlife that use the ponds may be exposed to increased levels of dissolved solids and other contaminants released from the power plant. Fogging, humidity, icing, and the presence of dissolved solids and other contaminants that might be present in or at cooling ponds are of concern if they are present at levels that threaten the stability of local wildlife populations or vegetation communities in the vicinity of the cooling ponds. If there is no threat to the stability of local wildlife populations or vegetation communities, then any impact is considered of small significance.

These potential impacts apparently have not been a problem at any plant with cooling ponds. No significant damage to or loss of vegetation has been reported to result from increased humidity, fog, or icing. Without damage to vegetation, wildlife populations should not be affected. Water quality in the ponds is not being degraded to the extent that aquatic life is adversely affected (Sections 4.4.2 and 4.4.4). Therefore, wildlife using these ponds should not be significantly affected by changes in water quality or by loss of aquatic food or prey. Bioaccumulation of contaminants in the bodies of wildlife predators feeding on aquatic biota is not expected to be a problem because of the very low concentrations of contaminants. Because no threat to the stability of local wildlife populations or vegetation communities is found for any cooling pond, the impacts are found to be of small significance. Potential mitigation measures would include excluding wildlife (e.g., birds) from contaminated ponds, converting to a dry cooling system, or reducing plant output during fogging or icing conditions, the impacts are found to be so minor that consideration of additional mitigation measures is not warranted. These effects of cooling ponds are so minor and so localized that cumulative impacts are not a concern. This is a Category 1 issue.

4.5 TRANSMISSION LINES

Impacts of transmission lines result from their maintenance, electromagnetic fields, corona, and rights-of-way (ROW). Their impacts on air quality (Section 4.5.2), land use (Section 4.5.3), human health (Section 4.5.4), surface water quality and aquatic ecology (Section 4.5.5), terrestrial ecology (Section 4.5.6), floodplains and wetlands (Section 4.5.7), and historic and aesthetic resources (Section 4.5.8) are assessed in this section. As at the construction permit stage, the transmission corridor of concern is that which was constructed between the plant switchyard to its connection with the existing transmission system. No new transmission line construction is planned in existing or new corridors. The types of impacts of transmission lines during the license renewal period will be the same as those during the first 40 years of operation.

4.5.1 Introduction

Transmission lines use voltages of about 115 or 138 kV and higher. In contrast, local or area distribution lines use voltages below 115 or 138 kV. Only transmission lines are discussed in this document. Extra-high-voltage transmission lines operate at 345 to 800 kV, whereas ultra-high-voltage (UHV) lines operate at 1000 kV and above. Lines up to 765 kV, a voltage occurring primarily in the eastern United States, are in commercial operation, whereas UHV lines are still in the testing stage of development. The principal advantage of higher-voltage lines is that they can transmit proportionately more power than can lower-voltage lines.

Detailed descriptions of transmission lines and basic electrical concepts are provided by ORNL-6165, DOE/BP-945, and BNWL-1774. Typical transmission line structures, shown in Figure 4.1, range in height from about 20 to 52 m (65 to 170 ft) and provide average spans (the distance between structures) of about 106 to 350 m (350 to 1150 ft). The structures support a three-phase system of conductors and two ground wires above the conductors. The ground wires intercept lightning strikes to prevent the strikes from hitting the conductors and adversely affecting power system operation. The most common structure types are the H-frame and lattice; single-pole and guyed-Y types are less common. The H-frame is usually made of wood and is used for lower-voltage lines. The metal lattice structure is capable of bearing more weight than the H-frame, allowing greater span length, higher-voltage lines, and more circuits for a given width of ROW.

Transmission lines must be inspected periodically to detect any deterioration of or damage to line components. This inspection can be done from the ground but is often done from a helicopter. Maintenance or repairs of power lines may require that vehicles gain access to the lines.

Electric and magnetic fields, collectively referred to as electromagnetic field or EMF, are produced by operating transmission lines. EMF strength at ground level varies greatly under these lines, generally being stronger for higher-voltage lines, a flat configuration of conductors (as opposed to, for example, the delta configuration), relatively flat terrain, terrain with no shielding obstructions (e.g., trees or shrubs), and a closer approach of the lines to the ground. At locations where field strength is maximum, measured values under 500-kV lines often average about 4 kV/m, but sometimes exceed 6 kV/m. Maximum electric field strengths at ground level are 9 kV/m for 500-kV lines and 12 kV/m for 765-kV lines (DOE/BP-945).

Measured magnetic field strengths at the location of maximum values beneath 500-kV lines often average about 70 mG (milligauss). During peak electricity use, when line current is high, the field strength may peak at 140 mG (about 1 percent or less of the time) (DOE/BP-945).

The term "corona" generally refers to the electrical discharges occurring in air subjected to the strong electric fields adjacent to phase conductors. Corona generally is not a problem at voltages below 345 kV. Corona results in audible noise, radio and TV interference, energy losses, and the production of ozone and oxides of nitrogen.

An ROW must be acquired by the utility to prevent certain land uses and vegetation growth from interfering with transmission line operation. To ensure power system reliability, the growth of tall vegetation under the lines must be prevented (by cutting or herbicides) to avoid physical interference with lines or the potential for

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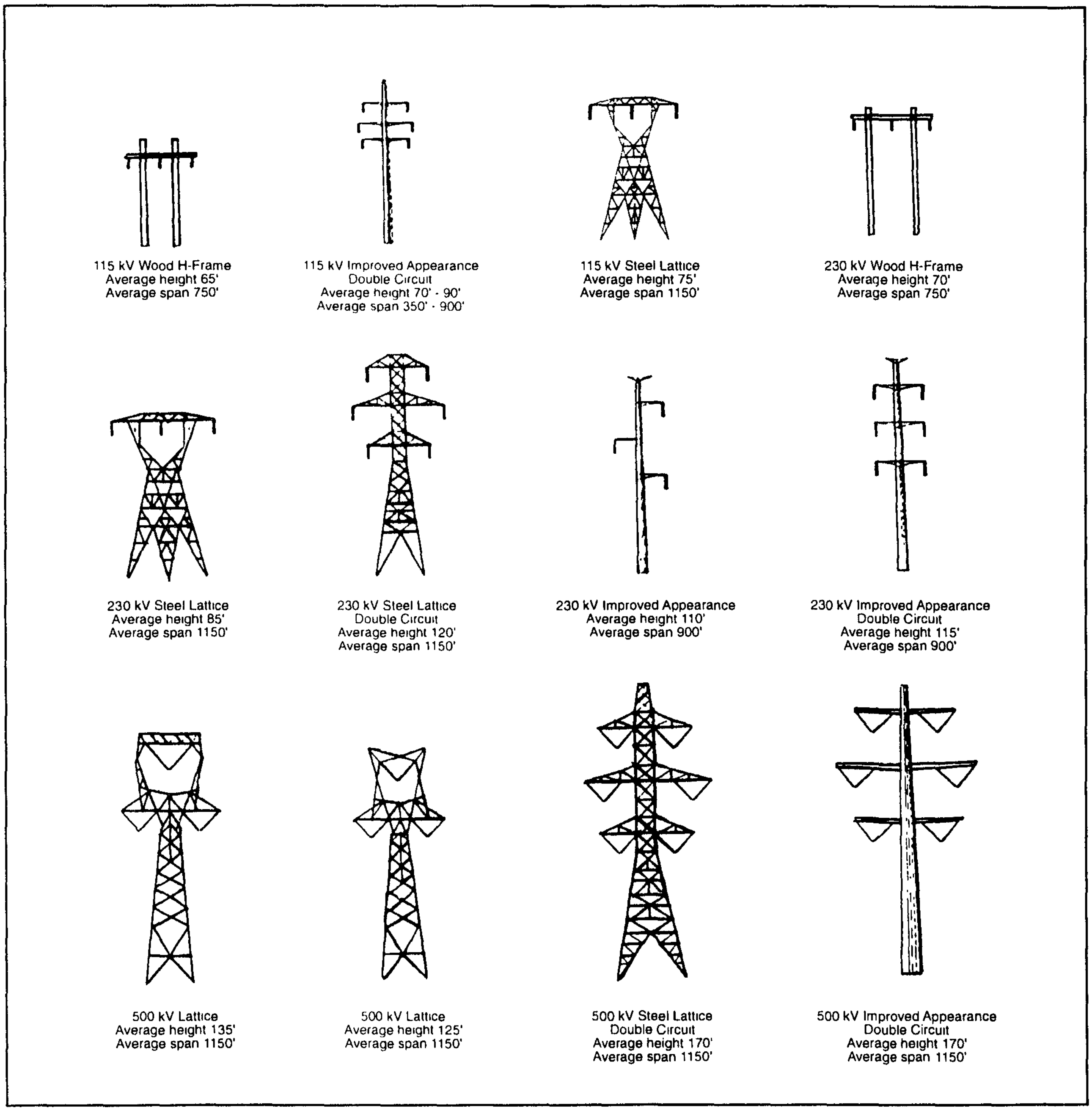

Figure 4.1 Examples of typical transmission line towers. *Source:* DOE/BP-945.

short-circuiting from the line to the vegetation. At the edge of ROW, trees that could topple onto the lines must be removed.

ROW maintenance is described in greater detail by FWS/OBS-79/22, ORNL-6165, BNWL-1774, and Byrnes and Holt (1987).

4.5.2 Air Quality

Small amounts of ozone and substantially smaller amounts of oxides of nitrogen are produced by transmission lines during corona, a phenomenon that occurs when air ionizes near isolated irregularities on the conductor surface such as abrasions, dust particles, raindrops, and insects. Several studies have quantified the amount of ozone generated and concluded that the amount produced by even the largest lines in operation (765 kV) is insignificant (SNYPSC 1978; Scott-Walton et al. 1979; Janes 1980; Varfalvy et al. 1985). Monitoring of ozone levels for 2 years near a Bonneville Power Administration 1200-kV prototype line revealed no increase in ambient ozone levels caused by the line (Bracken and Gabriel 1981; DOE/BP-945). Ozone concentrations generated by transmission lines are therefore too low to cause any significant effects. The minute amounts of oxides of nitrogen produced are similarly insignificant. A finding of small significance is supported by the evidence that production of ozone and oxides of nitrogen are insignificant and does not measurably contribute to ambient levels of those gases. Potential mitigation measures (e.g., burying transmission lines) would be very costly and would not be warranted. This is a Category 1 issue.

4.5.3 Land Use

4.5.3.1 Overview of Impacts

The concerns addressed by this section involve the extent to which license renewal and up to an additional 20 years of plant operation will preclude alternative uses of the transmission line corridor and the relative value that should be placed on such alternative uses. At the time of a license renewal application the transmission corridor and lines will have been in place for well over 20 years, having been initially constructed to furnish power to the site for construction of the plant. Even after cessation of plant operation the transmission line to the site would continue to be used to bring power in to the site during decommissioning. It is likely that a utility would locate new generating capacity on a site and utilize the existing transmission corridor. The site and transmission corridor are valuable assets for the utility. Therefore, the most likely scenario is that regardless of whether a license is renewed it should be anticipated that a transmission corridor will continue in use for the transmission of power indefinitely.

The issue addressed by this section is the extent to which existing transmission lines will, after relicensing, continue to preclude productive use of land or interfere with land uses (e.g., cultivation). Impacts are expected to be no different from those that have occurred during past power line operation. Impacts are described and assessed by reviewing the published literature reporting monitoring data on this topic. No monitoring data on land-use impacts were found that deal with transmission lines specifically associated with nuclear plants. However, because transmission lines associated with nuclear plants are no different from lines associated with other types of generating facilities, literature on any type of transmission line is applicable to the analysis in this section.

The impact of transmission lines on land use resulting from license renewal is considered of small significance if there is no increase in the amount of land committed to the corridor right-of-way and if there are no major changes in the use patterns of the corridor resulting from renewal of the operating license. Alterations in the corridor path could result in impacts of moderate to large significance. Relocating the transmission corridor could result in large land use impacts. There is no basis to believe that any alteration in a transmission corridor would be made in conjunction with license renewal.

The presence of a transmission line and its ROW precludes certain land uses on the ROW that could bring economic gain to the landowner and decreases the profits of forestry, agricultural, orchard, and vineyard operations. However, the landowner has been compensated to some extent for these economic losses by the initial purchase of the ROW easement or, in some cases, by purchase of the land itself.

The construction of buildings or any other permanent structures that could interfere with transmission line operation is usually prohibited on a power line ROW. In contrast, several land uses can occur on ROW without endangering line operation and are usually not restricted by the ROW easement, including hiking, hunting, off-road vehicle use, grazing, agricultural cultivation, irrigation, and roads. Power-line corridors on private property may sometimes increase the frequency of trespassing.

In rural areas, the primary impact on land use is continuing interference with agricultural cultivation, orchards, vineyards, spraying, and irrigation. Some mobile irrigation facilities are very long and may cover an entire field or a large part of the field in one operation (Varner and Patel 1984). The presence of a transmission line structure in such a field may require that the irrigation facility be segmented into two or more independent pieces. Such segmentation increases the labor requirements and the costs of the irrigation facility. Aerial spraying of an agricultural field is restricted by transmission lines; spraying costs may be increased, and the extra maneuvers that the aircraft pilot must make to avoid the lines may lessen the effectiveness of the pesticide coverage.

Impacts on crop production that may have been caused by transmission line interference with aerial spraying have been reported by one field study of cotton, rice, and soybean fields crossed by a 500-kV line in eastern Arkansas (Parsch and Norman 1986). This study hypothesized that crop yields could be reduced either by EMFs (see Section 4.5.6.3) or by inadequate aerial spraying directly under the power lines. Only cotton yields were found to be reduced: 15 percent less lint was produced under the lines than 150 ft from the lines. The resulting loss of income from cotton was estimated as $85.25 per year for an 1100-ft (335-m) span of the lines, based on a 15 percent yield reduction and an average lint yield of 480 lb/acre. The field sampling and statistical analyses were extensive; the observed yield reduction appeared to be real rather than a sampling error. However, the study could not determine whether the EMF or line interference with aerial spraying caused the yield reduction.

The presence of a transmission line structure in any agricultural field, irrigated or not, will continue to exclude land from production and increase the time and money required to perform weed control, cultivation, and harvesting. The major (e.g., 70–90 percent) economic cost results from the exclusion of otherwise productive land from cultivation. The amount of land area affected depends on the structure type and size, the type of crop, and the agricultural practices involved (Grumstrup et al. 1982; EPRI WS-78-141). For lattice-type structures 8 to 9.8 m^2 (26 to 32 ft^2) at the base, the exclusion of productive land varies from about 488 to 976 m^2 (1600 to 3200 ft^2) for each structure. Operations for cultivating some types of crops can be conducted beneath structure bases if the structure is large enough, thus minimizing losses. The presence of guy wires significantly increases the area of land excluded from production, while non-guyed single-pole and H-frame structures have about half as much impact as lattice structures (Grumstrup et al. 1982). Minor additional costs result from the maneuvering necessary for farm machinery to avoid tower legs. Lattice structures and guyed structures interfere more with farming practices than do pole-type structures.

Costs also depend on the relative locations of transmission line structures within fields (Table 4.5). A study of corn, soybean, wheat, oats, buckwheat, and hay fields in Ontario found that the amount of land excluded from production increased in the following order of structure locations: (1) straddling a fence row (minimal impact); (2) adjacent to a fence row; (3) adjoining the headland (the end of the field where the tractor turns) but in the main part of the field; (4) midfield; and (5) within the headland, near, but not adjacent to, a fence row (maximum impact) (EPRI WS-78-141). In tobacco fields, equipment operations differed from those in grain fields, and structures in midfield obstructed cultivation on about twice as much land area as did structures in the headland (Scott 1982). For a variety of grain crops, the economic losses caused by power lines were accounted for by the following factors: time lost—about 30 percent of the costs; land excluded from production—about 60 percent; damaged crop costs—about 2 percent; and material loss—about 8 percent (EPRI WS-78-141). In vineyards, orchards, and tobacco fields, about 75 to 95 percent of the total costs resulted from the continuing exclusion of land from production (EPRI WS-78-141; Scott 1982). In general, the economic losses associated with transmission line structures are closely related to the value of the affected crop, and the percentage of total economic loss resulting from land lost to cultivation is proportionately higher for higher value crops (Scott 1982). Tobacco, orchard, and vineyard crops have relatively high value per acre; grain crops have lower value.

Utilities sometimes locate transmission lines in agricultural areas rather than wooded areas to minimize maintenance costs. Although utilities pay a higher price for ROW on agricultural land, overall costs are minimized by avoiding the higher long-term costs of ROW vegetation maintenance that would be necessary in wooded areas (EPRI WS-78-141).

The potential impact of transmission lines on land use differs among nuclear plants in different geographic regions because land

Table 4.5 Estimated losses in crop profits caused by a lattice structure[a]

Crop	Structure location: Midfield	Structure location: Headland
Tobacco	$356	$132
Peach orchard[b]	95	84
Vineyard[b]	117	53
Wheat	15	—
Soybeans	18	—
Grain corn	25	—
Silage corn	30	—

[a]The currency is the Canadian dollar 1977–1980. The structure is 8.5 × 8.5 m (28 by 28 ft) at the base and its orientation is square to the crop rows as opposed to diagonal to crop rows.
[b]The midfield value is based on not being able to drive equipment under structures and is an average of several midfield variations of structure positioning.
Sources: EPRI WS-78-141; Scott.

uses (e.g., different types of agricultural crops) are different in different regions. The type and extent of the impacts of power lines on land use are relatively well known, and no monitoring of land-use impacts has been done for any specific nuclear plant.

4.5.3.2 Conclusion

There is no basis to believe that the renewal of any operating license will change existing land use in the transmission line corridor either in terms of the amount of land committed or activities taking place within or adjacent to the corridor. For this reason, the staff finds that the impacts of transmission lines on land use attributable to license renewal is of small significance. Ongoing land use impacts would be expected to continue, e.g., constraints on agricultural activity. Although transmission line towers prevent some land from being cultivated or grazed, the amount of land area involved represents only a very small fraction of existing cropland and pasture in the vicinity of transmission lines. Therefore, the reduction in total harvest or livestock production typically has no significant impact on individual farm production or on overall production in larger regions such as townships or counties. The interference with aerial spraying caused by transmission lines can affect an area that is larger than that of the tower site, but the yield in this larger area would not be expected to be reduced by more than a small fraction (e.g., a 15 percent yield reduction in cotton).

The presence of transmission lines does not cause additional permanent loss of farmland (in the sense that farmland is lost, for example, to parking lots and buildings during urban development). Any restrictions on land use within the corridor right-of-way would have been imposed and compensated for as necessary years earlier.

Additional mitigation might require removal of wires, towers, and tower bases so that the entire area previously occupied by towers could be used for farming. Because such mitigation would be costly and would provide little environmental benefit, further consideration of mitigation is not warranted. The significance of any impacts is so minor and localized that cumulative impacts are not an issue. This is a Category 1 issue.

4.5.4 Human Health

The two human health issues related to transmission lines are the acute effect, shock hazard, and the potential for chronic effects from exposure to electric and magnetic fields. As stated previously, the transmission line of concern is that between the plant switchyard and the intertie to the transmission system. Transmission lines are necessary to transfer energy from all types of electrical generating facilities to consumers. Therefore, these issues are generic to the 118 nuclear power plants. Issues are evaluated by referral to the National Electric Safety Code [NESC (1981)] for the shock hazard issue and a review of relevant literature for the issue of potential chronic effects from exposure to the electric and magnetic fields surrounding transmission lines.

EMFs resulting from 60-Hz power transmission lines fall under the category of nonionizing radiation. An example of ionizing radiation is the X-ray. Much of the general population has been exposed to power line fields since near the turn of the century. However, except for the concern about electrical shock from insulated conductors such as fences, there was little concern about health effects from such exposures until the 1960s. A series of events during the 1960s and 1970s heightened public interest in the possibility of non–shock-related health effects from nonionizing radiation exposures and resulted in increased scientific investigation in this area (Wilson et al. 1990). Then, in 1979, results of an epidemiological study suggested a correlation between proximity to high-current wiring configurations and incidence of childhood leukemia (Wertheimer and Leeper 1979). This report resulted in additional interest and scientific research; however, no consistent evidence linking harmful effects with 60-Hz exposures has been presented.

4.5.4.1 Acute Effects (Shock Hazard)

Primary shock currents are produced mainly through direct contact with conductors and have effects ranging from a mild tingling sensation to death by electrocution. Tower designs preclude direct public access to the conductors. Secondary shock currents are produced when humans make contact with (1) capacitively charged bodies such as a vehicle parked near a transmission line or (2) magnetically linked metallic structures such as fences near transmission lines. A person who contacts such an object could receive a shock and experience a painful sensation at the point of contact. The intensity of the shock depends on the EMF strength, the size of the object, and how well the object and the person are insulated from ground.

Design criteria that limit hazards from steady state currents are based on the NESC (1981), adherence to which requires that utility companies design transmission lines so that the short-circuit current to ground, produced from the largest anticipated vehicle or object, is limited to less than 5 mA. In practice, this limits the electric field near roadways to about 7–8 kV/m. No similar code exists for the limitation of the magnetic fields of transmission lines; however, because of concerns about the safety of magnetic fields, several states have created their own regulations. See Nair et al. (1989) for a review of these regulations.)

With respect to shock safety issues and license renewal, three points must be made. First, in the licensing process for the earlier licensed nuclear plants, the issue of electrical shock safety was not addressed. Second, some plants that received operating licenses with a stated transmission line voltage may have chosen to upgrade the line voltage for reasons of efficiency, possibly without reanalysis of induction effects. Third, since the initial NEPA review for those utilities that evaluated potential shock situations under the provision of the NESC, land use may have changed, resulting in the need for a reevaluation of this issue.

The electrical shock issue, which is generic to all types of electrical generating stations, including nuclear plants, is of small significance for transmission lines that are operated in adherence with the NESC. Without review of each nuclear plant transmission line conformance with NESC criteria, it is not possible to determine the significance of the electrical shock potential. This is a Category 2 issue.

4.5.4.2 Chronic Effects

4.5.4.2.1 Results of Ongoing Research

Substantial scientific evidence from laboratory studies funded primarily by DOE and EPRI indicates that extremely low-frequency (ELF) electric and magnetic fields can, under certain conditions, cause biological effects (Wilson et al. 1990; Polk and Postow 1986; Adey and Lawrence 1984; Chiabrera et al. 1985; EPA/600/6-90/005A; Carpenter and Ayraptyan 1994). The importance of these effects for humans who are exposed to transmission line fields is not clear. Perhaps the greatest deficiency in understanding at this time is the lack of a mechanistic theory capable of predicting biological effects from low-level EMF exposures (EPA/600/6-90/005A). Without an understanding of how these EMF fields are interacting with biological functions, the knowledge gained from scientific studies is of limited value both in evaluating the importance of the study results and in devising rational protection strategies for the public and for utility workers.

At exposure levels capable of producing relatively high current densities (10 to 100 mA/m^2), a substantial body of evidence has been accumulated indicating that EMF fields may influence biological function (IRPA/INIRC 1990). Such exposures have been suggested to induce chromosome aberrations, alter the distribution in molecular weights during protein synthesis, inhibit production of melatonin, alter calcium binding in brain tissue, influence RNA transcription, and produce a variety of other effects (OTA-BPA-53 1989). Questions concerning the potential carcinogenic effects of EMF field exposure have been raised as a result of suggestive epidemiological findings and some laboratory experiments. Two currently accepted models of cancer are the initiation-promotion paradigm (Easterly 1981; Stevens et al. 1990). Currently, most investigators conclude that EMF fields are not likely to act as initiators because they have not been shown to cause genetic damage (Aldrich and Easterly 1987). EMF effects on RNA transcription, however, could imply increased reduction of oncogene products, and some investigators consider such data to be indicative of genetic effects (Goodman et al. 1983; Goodman et al. 1987; Goodman and Henderson 1986, 1988). Work is in progress on an attempt to replicate the studies suggesting modification of transcription by EMF. However, attempts thus far have been unsuccessful. Moreover, it has not been shown that EMF fields are cancer promoters, but the presence of some reported EMF bioeffects reveals the need for further study of this issue (Byus et al. 1987; Cain et al. 1986).

The EMF epidemiologic literature has been reviewed extensively (Aldrich and Easterly 1987; Ahlbom; Coleman and Beral 1988; EPA/600/6-90/005A; NRPB 1992). The strongest evidence of an association between certain forms of cancer and exposure to magnetic fields comes from the studies of childhood cancers, namely leukemia, cancer of the central nervous system (CNS), and lymphoma.[1] Several studies have found somewhat elevated, statistically significant risks and elevated nonsignificant risks for these three site-specific cancers in children for whom magnetic fields either have been estimated by the types of wires near their homes or have been measured at 2 mG (0.2 μT) or more. However, there are contradictory results within these same studies, and dose-response relationships could not be substantiated, except in Savitz et al. (1988), based upon limited information on wiring codes. [Savitz and Kaune (1993) have offered an improved analysis of this work.] Furthermore, little information exists on personal exposure and length of residency in the EMFs. Additional but weaker evidence of an association between leukemia, cancer of the CNS, and perhaps cancer of other sites comes from the occupational studies of EMF exposure.

The studies of residential adult exposures to EMFs also provide mixed evidence of a risk of leukemia, mainly because of lack of power or low exposure to levels of EMFs that are hypothesized as being associated with cancer. For the same reasons, these studies cannot be used as support for denying that such an association exists. However, the case control study of cancer in Colorado residents (Wertheimer and Leeper 1982) does support an association with CNS cancer and lymphoma if proximity to high-current electrical wiring configurations is assumed to be an adequate surrogate for exposure.

A careful review of the epidemiological studies involving leukemia, lymphoma, and cancer of the CNS shows a pattern of response that suggests, but does not prove the possibility of, a causal link. Evidence from a large number of biological test systems shows that these fields induce some biological responses in laboratory settings. However, the explanation of which biological processes are involved and the way in which these processes could causally relate to each other and to the induction of malignant tumors is not understood.

4.5.4.2.2 Transmission Line Exposures Relative to Domestic Exposures

An important question regarding regulations is whether transmission line exposures contribute significantly to total EMF field exposures. In most cases, fields produced inside the home by appliances and electrical wiring exceed contributions from transmission line fields. Exceptions to this rule are individuals living adjacent to high-voltage transmission line ROW. Also relevant is the fact that exposures to transmission line fields are considered more continuous than those to appliance fields because transmission line fields permeate large areas (e.g., an entire home). Fields generated by appliances are generally more localized, resulting in intermittent exposures as individuals move around and as the appliances are turned on and off.

Some comparisons (of induced currents) among transmission line exposures, domestic exposures, and exposures used in bioeffects experiments can be made using induced current density as an exposure metric. According to data provided in OTA-BPA-53, field strengths on the ROW of a 500-kV line induce body currents that are higher than those induced by domestic exposures produced by typical electrical appliances. Comparison with bioeffects experiments (OTA-BPA-53) shows that while current densities in many bioeffects experiments are higher than those typically induced by household exposures, some are significantly less. These comparisons are based, however, on average current densities predicted in humans, because EMF dosimetry has not advanced to the point of determining specific current densities in various tissues and organs. Nor has mechanistic understanding identified what field characteristics are important biologically.

4.5.4.2.3 Conclusion

Potential chronic effects are unquantified at this time. Subsequent to the 1992 National Energy Policy Act, a sequence of events relative to ELF research took place. The National Institute of Environmental Health Sciences (NIEHS) was made responsible for directing the EMF biological research funded through the Department of Energy. To oversee policy and general direction of this research, a National EMF Advisory Committee was assembled. Both the EPA and the National Institute for Occupational Safety and Health now maintain EMF hotlines, yet NIEHS has taken the position that the NIEHS has the sole responsibility for declaring whether a hazard exists and the magnitude of that hazard. Federal regulations are not anticipated in the near future, but some states have developed and other states are in the process of developing pertinent ambient field levels at ROW boundaries.

A careful review of the biological and physical studies of 60-Hz EMFs has failed at this time to uncover consistent evidence linking harmful effects with field exposures. EMF fields are unlike other agents that have a toxic effect (e.g., toxic chemicals and ionizing radiation) in that dramatic acute effects cannot be forced and longer-term effects, if real, are subtle. Nonetheless, a wide range of biological responses have been reported to be affected by EMF fields.

Even if clear adverse effects were apparent in the epidemiology literature or with some biological assay, considerable additional work would be required to determine how and what to mitigate, because evidence suggests that some EMF bioeffects do not follow the typical "more intensity is worse" relationship. Furthermore, there may be a subtle relationship between the intensity of the local geomagnetic field and the appearance of effects for some intensities of 60-Hz fields. This complicating evidence points to the fact that, while much experimental and epidemiological evidence has been accrued, the pieces still do not fit together very well.

Because of inconclusive scientific evidence, the chronic effects of EMF could not be categorized as either a Category 1 or 2 issue. NRC will continue to monitor the research initiatives, those within the national EMF program and others internationally, to evaluate the potential carcinogenicity of EMF fields as well as other progress in the EMF study disciplines. If NRC finds that a consensus has been reached by appropriate federal health agencies that there are adverse health effects, all license renewal applicants will have to address the health effects in the license renewal process.

4.5.5 Surface Water Quality and Aquatic Ecology

A basic concern with right-of-way and service road maintenance is the effect that such maintenance activities may have on the health of nearby aquatic ecosystems. The effects are considered of small significance if there is no measurable change in species diversity, abundance or health within the aquatic ecosystem. An effect of moderate significance is defined as one resulting in reduced abundance or health of one or several species that may eventually lead to the demise of the species. An effect of large significance is defined as one resulting in the loss of any species on which a high recreational or commercial value is placed or the collapse of the existing ecosystem.

Potential effects of transmission lines on aquatic resources would arise mainly from water quality impacts associated with maintaining power line ROW and service roads. Where roads cross or border on surface waters, soil erosion could cause elevated turbidity and sedimentation. Appropriate control techniques (e.g., grassed or wooded buffer strips between the road and the body of water) will minimize impacts. Because ROW are normally maintained by mowing or selective application of herbicides (Section 4.5.1.4), soil erosion from power line corridors should not normally be a problem. Potential toxic effects of herbicides that are applied to power line ROW and subsequently transported to surface waters should be considered in the maintenance program. By using herbicides approved for ROW use in accordance with FIFRA, significant adverse effects of herbicides are avoided. Mowing and other activities needed to maintain transmission line corridors are readily controllable to minimize impacts to aquatic resources. These activities are not expected to change during the license renewal term.

Changes in any affected aquatic ecosystem due to construction and maintenance practices will have taken place long before consideration of license renewal. Ongoing management practices with respect to controlling soil erosion and the proper application of herbicides will continue over the term of a renewed license. The aquatic ecosystem is expected to be unaffected by license renewal with no measurable change in species diversity, abundance or health. The effect of transmission lines on surface water quality and aquatic ecology is then of small significance. The continued use of proper management practices with respect to soil erosion and application of herbicides is expected. Impacts of any transmission lines on aquatic ecosystems over a larger geographic area or over time will be stable and not cumulative. The effect of transmission line right-of-way maintenance on surface water quality and aquatic ecology is a Category 1 issue.

4.5.6 Terrestrial Ecology

This section evaluates the impacts of ROW management on wildlife (Section 4.5.6.1); the impacts of bird collisions with transmission lines (Section 4.5.6.2); and the impacts of EMFs on plants, wildlife, and livestock (Section 4.5.6.3).

4.5.6.1 Impacts of ROW Management on Wildlife

The extent to which wildlife populations are affected by vegetation control on transmission line ROW is the issue evaluated by this section. The effects of ROW management in the transmission corridor during the license renewal term are considered of small significance if habitat diversity remains the same as that of the surrounding area, or is increased, while species population declines (if any) in the surrounding habitat are small. The significance of the impact is evaluated by a review of the voluminous published literature on this topic. Numerous scientific papers published mainly during the late 1970s and the 1980s were reviewed for this analysis. Data are not available for lines associated specifically with nuclear plants, but the literature applies to such lines because the same methods for ROW management are used for transmission lines associated with any type of generating facility. This issue was addressed by NRC environmental impact statements for the construction permit stage and the operating license stage.

Most data on the impacts of power line corridors on wildlife are for relatively moist areas of the United States where vegetation growth is rapid and vegetation must be controlled to prevent its interference with the transmission lines. In arid regions, little or no vegetation control is required, and the potential effects on wildlife are small. Potential effects are also small where lines cross croplands, because no vegetation management is required. The following discussion is therefore applicable primarily to forested regions where the utility must conduct vegetation control on transmission line ROW.

Broadcast spraying of herbicides and mowing of the entire corridor have greater periodic impacts on wildlife than do selective cutting or selective application of herbicides. Mowing reduces the vegetation on the ROW to a low stubble, and the remaining vegetation or the regrowth the first year after cutting provides little food or cover for wildlife. As a result of the reduced vegetation, populations of the primary species of birds that nest on a transmission line ROW have been shown to be reduced. Mammal populations may also be reduced, although few data have been collected to show such an impact. Resprouting and regrowth of vegetation on the ROW is usually rapid after cutting. If the vegetation is cut only once every 4 years rather than annually, it usually develops into a dense mixed growth of shrubs, shrub patches, saplings, forbs, and grasses. Bird populations increase along with the vegetation until the next mowing, when the cycle begins again (de Waal Malefyt 1984; Everett et al. 1981; Kroodsma 1982).

Broadcast spraying of herbicides is also done on a periodic basis and causes a cyclic effect on wildlife. However, spraying often kills entire plants, and resprouting is less common. Therefore, after a number of spraying cycles, some plant species are greatly reduced in abundance on the ROW. The resulting plant community consists of herbicide-resistant species and is often not very diverse. Grasses, ferns, and relatively few species of shrubs are usually the dominant vegetation. Correspondingly, the wildlife community has relatively few species and low population densities, and bird-nesting success in grass and forb areas on ROW has been observed to be low. Therefore, from the wildlife perspective, broadcast spraying is usually considered the least desirable vegetation maintenance technique. Annual mowing could have an effect similar to broadcast spraying but is seldom if ever used as a routine management technique for transmission line ROW (Cavanagh et al. 1976; Chasko and Gates 1981, 1982; de Waal Malefyt 1984; Hartley et al. 1984). Broadcast spraying of herbicides on some ROW that currently is mowed may become necessary if woody vegetation becomes too dense, as in ROW through mesophytic forests where forest regeneration is rapid (Luken et al. 1991).

Selective cutting or spraying of vegetation has less impact on wildlife because low-growing shrubs and other vegetation are left undisturbed and provide good wildlife habitat. Selective techniques are labor-intensive and thus may be more expensive than broadcast spraying or mowing. A primary goal of these selective techniques is to eliminate undesirable plant species from the ROW while keeping those that provide good wildlife habitat and that will not interfere with the power lines. Cutting and spraying are often combined because cut stems must often be sprayed to prevent resprouting and thus eliminate the plant. As the desirable plant species begin to dominate the ROW, they gain a competitive advantage and help to prevent the reestablishment of undesirable plants; thus, the long-term vegetation maintenance costs may be reduced (FWS/OBS-79/22, Luken et al. 1994).

Herbicides are generally not highly toxic to wildlife when they are properly applied for ROW management. Therefore, toxic effects of herbicides on wildlife are generally of little concern to wildlife biologists or wildlife managers. Of the many papers reviewed for this analysis, none expressed serious concern for toxic effects.[2] Rather, herbicide effects on wildlife have been shown to result from the vegetation changes that occurred as a result of herbicide application.[3] Changes in vegetation on an ROW or in any other habitat always cause changes in the wildlife community, whether the vegetation is cut or modified by herbicides. As in the case of cutting, herbicide effects on vegetation are usually beneficial to some wildlife species and detrimental to others. The literature referenced above shows that, as long as a diverse plant community remains on herbicide-treated ROW, a diverse wildlife community will also be present.

The maintenance of ROW vegetation as a low-growing plant community results in an ROW wildlife community that is characteristic of such vegetation. This wildlife community has some species of small mammals and birds that are not present in the natural plant communities bounding the ROW. Therefore, the presence of the ROW vegetation adds to the number of wildlife species found in the area. In addition, the ROW provides food and cover for many species of animals that were already present before line construction.[4] Forest edge along the ROW as well as along other open areas may provide some benefit to wildlife, but benefits of such an edge appear to have been overrated (Chasko and Gates 1982; Kroodsma 1984a, 1984b, 1987; Reese and Ratti 1988; Small and Hunter 1989).

The presence of the transmission line and its cleared corridor is apparently not a great disturbance to any wildlife species. Based on all of the literature reviewed, no wildlife species is known to have disappeared from habitats adjoining the corridors after line construction. Some species, however, are less abundant in the forest near the corridor than in the deeper forest, indicating avoidance of the transmission lines and/or the corridor (Kroodsma 1984b, 1984c). Because these species also appear to avoid other types of clearings (e.g., croplands or pasture), the openness of the corridor appears to be the feature being avoided, not the line itself. Predation on eggs and nestlings of forest birds has been observed to be greater near the forest/corridor edge than in the deeper forest and may be one factor responsible for some species appearing to avoid or to be less dense near the corridor (Chasko and Gates 1981, 1982).

The overall effect on wildlife of a transmission line corridor located within a forest appears to be an increase in the number of species present in the total corridor and forest area, while some populations of forest species are slightly lower as a result of the corresponding decrease in amount of forest habitat. Some bird and mammal species that inhabit grassy or brushy habitats are added to the area and are responsible for the increase in the number of species. At the same time, all other forest species remain in the area, and some find improved cover or food resources in the ROW. Population declines in forest species are usually small because the ROW is narrow and occupies only a small fraction of a forested area.

A current concern among ornithologists is the high degree to which forested habitats are being fragmented into smaller and smaller areas as a result of clearing for agriculture and urbanization. This fragmentation appears to be at least partly responsible for significant declines in the populations of many migrant bird species (Small and Hunter 1988; Yahner and Scott 1988). Transmission line corridors, probably because of their narrowness, have not been noted as a significant factor in forest fragmentation impacts on birds.

Where corridors cross particularly important wildlife habitats, impacts may be of greater concern. Impacts on winter habitats of certain big game animals were a particular concern. However, impact studies done for deer wintering yards in the northeastern United States and southeastern Canada (Jackson 1980; Willey and Marion 1980; Doucet et al., 1983, 1987), deer in winter habitats in the Northwest (Loft and Menke 1984), and elk winter habitats in the West (Nelson 1986) showed no significant impact.

Although animal population density is cyclic in response to vegetation changes in ROW, over the long term (i.e., over many cycles) the populations appear relatively stable, with no species being significantly affected. The overall impact of transmission line corridors, based on an extensive literature, appears to be neither significantly adverse nor significantly beneficial. The consensus among wildlife biologists appears to be that cleared transmission line corridors and their maintenance do not have significant adverse impacts and that corridors provide valuable wildlife habitats if properly managed. Of the papers reviewed for this GEIS, none was found that identified any impact of transmission line corridors on wildlife that was of great concern to the authors. The evidence supports a conclusion that continued ROW management during the license renewal term will not lower habitat diversity or cause significant changes in species populations in the surrounding habitat. Thus the impacts are of small significance. The only potential mitigation measure would be relocation of the transmission lines to less sensitive areas, but this would not be warranted due to the small benefit and high capital cost of such actions. No mitigation measures beyond those implemented during the current term license would be warranted and little potential for cumulative impacts is indicated. This is a Category 1 issue.

4.5.6.2 Avian Mortality Resulting from Collisions With Transmission Lines

Numerous studies have been published of avian mortality resulting from collisions with transmission lines and other man-made objects. The issue is whether collision mortality is large enough to cause long-term reductions in bird populations. The analysis of this issue is based on published literature addressing bird collisions with all types of man-made objects and applies to all transmission lines regardless of the type of generating facility. Monitoring data collected at one nuclear plant, Prairie Island, are also summarized.

Avian mortality resulting from collisions with transmission lines is of concern if stability of local populations of any bird species is threatened or if the reduction in the numbers within any bird population significantly impairs its function within the ecosystem. Avian mortality resulting from collisions of birds with transmission lines is considered to be of small significance if there is no threat to the stability of local populations of any species and if there is no noticeable impairment of its functioning within the local ecosystem.

Many millions of birds die each year from natural causes, and millions are killed each year in the United States as a result of colliding with windows of houses and other buildings, radio and TV towers, vehicles, transmission and distribution lines, telephone lines, cooling towers, smokestacks, and many other man-made objects. Numerous papers have reported the more noticeable, sometimes spectacular, kills that have occurred at radio and TV towers and at transmission lines located near lakes or wetlands where birds are concentrated.[5] Large bird kills at radio and TV towers occur at night during spring and fall bird migration and involve primarily passerine birds (songbirds) that appear to be confused by tower lights (Crawford 1981; Larkin 1988; Maehr et al. 1983; Taylor and Kershner 1986). These lights, during conditions of low clouds or fog, create a surrounding area of diffuse light that flying birds are reluctant to leave, with the result that the birds fly in circles around the towers. Thus, these birds run a high risk of colliding with the towers' guy wires. In contrast, kills along transmission lines involve a greater fraction of heavier, less agile birds such as waterfowl and cranes. Inclement weather is often a contributing factor in transmission line kills; lights are not a contributing factor, because they generally are not used to mark transmission lines.

It is unknown to what extent avian populations decline as a result of collision mortality of all types or mortality associated specifically with transmission lines. Several authors have concluded that the mortality caused by transmission lines in their studies did not cause a significant reduction in the bird populations located in their study areas. However, some of these authors expressed concern for cumulative impacts (Beaulaurier et al. 1984; Faanes

1987; Meyer and Lee 1981). Cumulative impacts would accrue as migratory birds such as waterfowl migrate to different areas and are exposed to additional lines, whereupon more collisions occur and total mortality continues to increase.

A few authors have also pointed out that bird mortality along the many thousands of miles of transmission and communication lines in the United States is probably of greater significance than the more noticeable kills in certain transmission line locations where birds are concentrated (Avery 1981; Willard and Willard 1978). The amount of bird mortality in nonwetland areas or in areas of average bird numbers has received little study because the individual bird kills are spread out over long distances and are hard to find. Therefore, accurate estimates of the total bird mortality caused by transmission lines do not exist, and the significance of transmission line collision mortality with regard to long-term population effects cannot be accurately assessed.

Overall, relatively little concern about bird collision mortality has been expressed in the literature. Generally, collision mortality has appeared to be only a small fraction of total mortality and therefore has not been considered to have significant population impacts. Banks (1979) estimated that human activity and bird collisions with man-made structures resulted in the deaths of about 196 million birds per year or 1.9 percent of the total bird mortality (about 10 billion per year) in the continental United States. About 63 million of the estimated 10 billion annual bird deaths (i.e., 0.63 percent) resulted from collision with all types of man-made structures. The transmission line impact would be a fraction of this estimate. Stout and Cornwell (1976) reported on waterfowl mortality. They estimated that about 0.07 percent of the nonhunting waterfowl mortality resulted from collisions with lines, including transmission, distribution, and telephone lines. These estimates, which are essentially all that is available in the literature, suggest that transmission lines do not pose a serious threat to avian populations. Banks (1979) states that most of the human-related mortality is accounted for by relatively few species and that these species maintain large, harvestable populations. This, as Banks pointed out, suggests that human activities do not significantly affect most bird species. Banks concluded that "activities of man that do not necessarily result in the death of birds but rather reduce reproductive potential, such as habitat alteration and environmental contamination, are much more likely to have long-term effects on avian populations."

More recent literature on bird collision mortality has not raised strong concerns that the Banks (1979) and Stout and Cornwell (1976) estimates are too low. However, Avery (1981) pointed out that collision mortality may be significantly higher than Banks' estimate of 63 million. He states that the primary source of collision mortality appears to involve the millions of miles of transmission and communication lines and the billions of glass windows throughout the country. He cites collision mortality estimates higher than Banks' estimates (e.g., 80 million bird deaths annually from collision with windows), but a lack of information prevented him from estimating mortality resulting from collisions with transmission lines. No study reviewed for this GEIS has suggested that collision mortality is a significant factor in reducing the populations of common bird species.

Several reports have suggested that rare species sometimes could be significantly affected by transmission and communication lines, particularly if the lines passed through an area where such species were concentrated (Faanes 1987; ORAU-142, 1978c; Meyer and Lee 1981; Willard and Willard 1978). For example, A. J. Crivelli et al. (1988) surveyed Dalmatian pelican mortality resulting from collision with a line through a pelican wintering area. They concluded that this mortality would result in a 1.3 to 3.5 percent reduction in the number of pelican breeding pairs in Greece and Bulgaria. Whooping cranes, an endangered species in the United States, have collided with power lines on at least 10 occasions according to Faanes (1987). The principal known cause of death for wild fledged whooping cranes is collision with power lines (Morkill and Anderson 1991). Several papers reviewed by Kroodsma (ORAU-142, 1978b) reported that 10 percent of the known mortality of bald eagles from 1960 to 1972 apparently resulted from collisions with some object, frequently a transmission line. Willard and Willard (1978) reported that 4 out of 200 nesting female white pelicans in a small Oregon population died from collisions with transmission lines and considered this mortality to be a significant impact on a small, threatened population.

Several studies have reported on relatively large collision kills where transmission lines crossed wetland areas being used by large concentrations of birds (Anderson 1978; Beaulaurier et al. 1984; Faanes 1987; ORAU-142, 1978c; Malcolm 1982; Meyer and Lee 1981; Rusz et al. 1986). Although the authors were concerned about the mortality, most of them reported that the data indicated the mortality was a small fraction of the number of birds present and that the local bird population was not significantly affected. The case reported by Malcolm (1982) appears to involve the greatest collision mortality.

Two additional studies reported collision-caused deaths of sandhill and whooping cranes, two species that appear particularly susceptible to collision with transmission lines. In the San Luis Valley, Colorado, 78 sandhill cranes and 3 whooping cranes collided with lines during the fall and spring in 1983 and 1984, as reported by W. M. Brown et al. (1985). Whooping cranes were the most frequent casualty in proportion to their abundance (13 to 29 birds observed at various times). These authors also reported that at least eight other whooping cranes in the Rocky Mountain population struck transmission lines from 1977 to 1985. In Idaho, in an area where nine pairs of sandhill cranes were observed nesting, three sandhill cranes and one whooping crane collided with lines during the first year after line construction (Howard et al. 1985).

Sandhill crane mortality in general from 1978 through 1985 was reviewed by Windingstad (1988). Known mortality was as follows: toxins (e.g., from moldy corn and waste peanuts)— approximately 5550 cranes; hail storm (1 occurrence)—600; avian botulism—150; avian cholera— 125; lightning (1 occurrence)—90; collision with transmission lines—5 occurrences reported, the worst resulting in 51 carcasses at a line crossing the Platte River near a crane roost site (numbers in the other four occurrences were not reported); unknown cause—8; lead poisoning—4, avian tuberculosis—1; and predators—1. Despite this extensive mortality in sandhill cranes, their midcontinent population has increased dramatically during the past few decades.

Modification of existing transmission lines has been investigated to reduce collision mortality in localities where relatively large kills occur. The most promising modifications include removal of the ground wires in the most critical locations or placing markers on the ground wires to make them more visible to birds. Such markers include black-and-white ribbons, orange aviation marker balls, plastic spirals, and spiral vibration dampers (Alonso et al. 1994; Brown et al. 1985; Faanes 1987; Morkill and Anderson 1991; ORAU-142, 1978d). For example, Alonso et al. found that colored PVC spirals installed on groundwires reduced bird collisions by 60 percent, and Morkill and Anderson found that yellow aviation balls installed on groundwires reduced sandhill crane collisions by 56 percent.

No relatively high collision mortality is known to occur along transmission lines associated with nuclear power plants in the United States other than the Prairie Island plant in Minnesota. This plant is located on the Mississippi River southeast of Minneapolis and may be the only nuclear plant where surveys were done to find birds that collided with off-site lines. The plant's 1978 annual report presented a 5-year study of bird collisions with transmission lines near the river. Counts were conducted by walking several transects, usually on a weekly basis from April 22 through May 27 from 1974 through 1978. A total of 453 birds were found over the entire 5-year period of observation, primarily passerines (songbirds), mourning doves, ring-necked pheasants, and American coots. Waterbirds included 11 sora rails, 8 wood ducks, 3 mallards, 2 black ducks, 1 great blue heron, 1 ruddy duck, and 1 hooded merganser. No raptors were found. Most collisions apparently occurred during inclement weather. Scavengers probably removed many bird carcasses before they could be found.

Available literature on transmission line collision mortality is insufficient to determine conclusively whether bird populations are being significantly affected. Rather, existing data suggest that transmission lines associated with nuclear plants are probably responsible for only a small fraction of total collision mortality for transmission and distribution lines in general. Also, existing literature suggests that total collision mortality (cumulative impacts) associated with all types of man-made objects is not reducing bird populations significantly.

Based on (1) the fact that existing literature does not show significant impacts of collision mortality on overall species populations and (2) the lack of known instances where nuclear-plant lines are affecting large numbers of individuals in local areas, the staff concludes that the mortality resulting from bird collisions with transmission lines associated with license renewal and an additional 20 years of operation will not cause long-term reduction in bird populations and thus will be of small significance. Further, little potential for significance due to cumulative impacts is indicated. Finally, the modification of transmission lines would not be warranted because the impact is so small and such mitigation measures would be costly. This is a Category 1 issue.

4.5.6.3 Impacts of Electromagnetic Fields on Flora and Fauna

The effects of electromagnetic fields on terrestrial biota are considered to be of small significance if the overall health, productivity and reproduction of individual species appears unaffected.

The EMFs produced by operating transmission lines up to 1100 kV have not been reported to have any biologically or economically significant impact on plants, wildlife, agricultural crops, or livestock (DOE/BP-945; Miller 1983). Areas under and in the vicinity of the lines have been studied numerous times. Vegetation, foliar damage due to EMF-induced corona at leaf margins, agricultural crop production, wildlife population abundance, livestock production, and potential livestock avoidance of the lines have been investigated. Also, many laboratory experiments with plants and laboratory animals have been conducted, often using electric fields much stronger than those occurring under transmission lines.

4.5.6.3.1 Plants

Studies have shown that minor damage to plant foliage and buds can occur in the vicinity of strong electric fields. For example, tree foliage and buds that are close to transmission lines can be damaged and upward or outward growth of branches can be reduced. Damage typically occurs only to the tips and margins of leaves in the uppermost plant parts that are the closest to the lines. The damage in the form of a leaf burn is most prevalent on small pointed leaves and is similar to leaf damage that might occur as a result of drought or other environmental stresses. The damage generally does not interfere with overall plant growth (Miller 1983).

The damage is thought to result from heating caused by induced corona at the leaf tips and margins. The electric field is greatly focused by leaf points or marginal teeth, thus increasing its strength to the point that corona (Section 4.5.1.3) occurs. Night-vision instruments have shown this corona as a glow of light concentrated at leaf tips and margins. The damage apparently does not extend to lower levels of the plant because the electric field weakens with distance from the lines and because the upper plant parts shield the lower parts from the electric field.

In one experiment under an 1100-kV prototype line, the upward growth of alder and Douglas fir trees was reduced by this damage, with the result that the crowns of the trees became somewhat flattened on top and the overall crown developed a broader appearance than usual (Rogers et al. 1984). The growth of the lower parts of the trees and of lower-growing plants such as pasture grass, barley, and peas appeared unaffected (Rogers and Hinds 1983). In another experiment, 50-kV/m fields had no apparent effect on corn germination or the growth of corn seedlings; and the growth of corn, bluegrass, and alfalfa apparently was not affected by fields of 25–50 kV even though minor damage occurred to the outer fringes of the uppermost leaves (Bankoske et al. 1976). Germination of sunflower seeds in a 5-kV/m electric field was reduced by about 5 percent in some cases [4 out of 11 replicates (Marino et al. 1983)]. An experiment with several species of agricultural plants found that a maximum of about 1 percent of the total plant tissue was damaged by exposing the plants to 50-kV/m fields (Poznaniak and Reed 1978).

Lee (DOE/BP-945) reviewed several papers reporting studies in Indiana, Tennessee, and Arkansas. The productivity of corn and other crop plants was not affected by electric fields of 12 to 16 kV/m under a 765-kV line and a UHV test line in Indiana, although plants under the larger line suffered some leaf tip damage from induced corona. Corn production in Tennessee may have been reduced by electric fields up to 8.5 kV/m, but the authors indicated the results were inconclusive. An Arkansas study found normal yields of rice and soybeans but a 15 percent reduced yield of cotton beneath a 500-kV line (see Section 4.5.3). The researchers could not determine whether the reduced cotton yield resulted from electric field or ineffective aerial application of agricultural chemicals beneath the line.

4.5.6.3.2 Honeybees

Several studies have shown that honeybees in hives under transmission lines are affected by EMF (EA-4218; Rogers and Hinds 1983; Warren et al. 1981). Adverse effects include increased propolis (a reddish resinous cement) production, reduced growth, greater irritability, and increased mortality. These effects can be greatly reduced by shielding the hives with a grounded metal screen or by moving the hives away from the lines (Rogers and Hinds 1983; Lee 1980). V. P. Bindokas et al. (1988) showed that these impacts were not caused by direct effects of the electric fields on the bees but by voltage buildup and electric currents within the hives and the resultant shocks to bees. Bees kept in moisture-free nonconductive conditions were not adversely affected, even in electric fields as strong as 100 kV/m.

4.5.6.3.3 Wildlife and Livestock

Chronic exposure to EMF is experienced by small birds and mammals that primarily inhabit ROW corridors and by birds (primarily raptors) that nest in transmission line towers. EMF exposures to larger animals and livestock are usually relatively brief because these animals inhabit relatively large areas instead of small areas beneath the lines. Exposures occur as these larger animals pass beneath the lines or as birds fly by the lines.

The voluminous literature on population studies of small bird and mammal species in transmission line corridors (Section 4.5.6.1) has expressed virtually no concern for possible impacts of EMF. These species apparently thrive underneath the lines, where their abundance appears to depend on habitat quality rather than on the strength of the electric fields to which they are exposed or the size of the line. For example, the density of breeding birds under 500-kV lines in eastern Tennessee is greater than that in adjacent forests (Kroodsma 1984c, 1987) and appears to be greater than bird density in most grassland habitats or agricultural fields. Also, the density of small mammal populations near these lines appears to depend on habitat type rather than on the presence of the lines (Schreiber et al. 1976). A Minnesota study of a 500-kV line found little evidence of either a positive or negative effect of the power line on bird populations (Niemi and Hanowski 1984). Bird and small mammal populations under an 1100-kV line in Oregon were also apparently unaffected by line operations (Rogers and Hinds 1983). Habitat use by elk in western Montana was apparently unaffected by operation of a 500-kV line, as the elk used habitats along the power line in proportion to their availability (DOE/BP-1136).

Raptors, ravens, and some water bird species frequently nest and perch on transmission line towers, particularly in grassland areas where other suitable nest sites are lacking.[6] Thus, the birds are able to use habitats without suitable nest sites—habitats that they otherwise would not have used (Gilmer and Stewart 1983; Williams and Colson 1989). On high-voltage lines supported by metal lattice towers, the birds usually nest on the top (bridge) of the tower where the strength of the electric field is minimal (e.g., 5 kV/m or less) (Lee 1980). Lee found 80 percent of 110 nests on towers to be located on the tower bridge and cited previous studies that showed similar results.

The success of these tower nests in producing young appears to be no different from nests located in areas not exposed to EMF. In central North Dakota, 113 ferruginous hawk nests in high-voltage transmission line towers (18 percent of a total of 628 nests found) had a higher success rate (87 percent) than nests in other locations (however, a hail storm that missed the lines reduced the success of some other nests). The number of fledglings per occupied nest was 2.8 for ground nests (which were larger than tower or tree nests), 2.6 for tower nests, 2.3 for haystack nests, and 2.0 for tree nests (Gilmer and Stewart 1983). In Idaho, Steenhof et al. (1993) studied nesting success of ravens and raptors on a 576-km (370-mile) segment of 500-kV transmission line constructed in 1981. From 1981 through 1989 (the last year reported by Steenhof et al.), the numbers of these species nesting on transmission towers increased to 133 pairs, including roughly 64 percent common ravens, 21 percent red-tailed hawks, 9 percent ferruginous hawks, 6 percent golden eagles, and 0.3 percent great horned owls. Nesting success of these birds averaged 65 percent to 86 percent and was similar to or better than that of the same species nesting on other substrates. Lee (1980) reported finding 110 hawk and raven nests on 260 miles of 230-kV and 500-kV lines of the Bonneville Power Administration. Although the success of these nests was not monitored, the author reported that, based on a literature review, it was unlikely that nesting would be adversely affected by EMF found in most locations in transmission line towers.

Livestock in both field and laboratory studies have shown no significant impacts when exposed to EMF. In DOE/BP-945, J. M. Lee reviewed about 10 reports on effects of transmission lines on livestock in the United States and Sweden. These studies found no evidence that the growth, production, or behavior of beef and dairy cattle, sheep, hogs, or horses were affected by EMF. The studies involved 11 farms along a 765-kV line in Indiana, 55 dairy farms near 765-kV lines in Ohio, 36 herds of cattle near 400-kV lines in Sweden, a mail survey of 106 farms in Sweden, a study of fertility of 58 cows under a 400-kV line in Sweden compared with 58 in a control area, 30 swine raised beneath a 345-kV line in Iowa compared with 30 raised in a control area, and cattle behavior under an 1100-kV prototype line in Oregon. Cattle under the 1100-kV test line in Oregon were startled by the first occurrence of corona noise when the line was reenergized after a shutdown period (Rogers and Hinds 1983). From 1977 through 1981, grazing of cattle in pasture under the line appeared to be unaffected by line operation. In 1980–81, the cattle spent more time near the line during periods when it was deenergized than when it was operating, but spent an increasing amount of time under the line when it was operating as the growing season progressed (Rogers and Hind 1983).

In the Indiana study (Amstutz and Miller 1980), performance of livestock frequently under a 765-kV line on 11 farms was studied during a 2-year period (1977–1979; 9 farms participated for the full 2 years). Animals included 10 horses, 55 sheep, 149 beef cattle, 337 hogs, and 429 dairy cattle. Maximum field voltage levels recorded near ground level were about 9.1 kV/m. General health, behavior, and performance of the animals were not affected by the transmission line EMF.

In the Swedish study of cow fertility, 58 heifers were exposed to a 400-kV, 50-Hz transmission line from June to mid-October 1985 (Algers and Hultgren 1987). The length of exposure was 15 to 20 times longer than the average exposure per year for Swedish dairy herds exposed to 400-kV lines. No effects were observed on the frequency of malformations, the length or variation of the estrous cycle, the midcycle plasma progesterone level, the intensity of estrus, the number of inseminations per pregnancy, the overall conception rate, or the fetal viability. Previous studies of cattle showed no significant effects of EMF on reproduction.

4.5.6.3.4 Conclusion

No significant impacts of EMF on terrestrial biota have been identified. Although foliage very close to lines can be damaged, the overall productivity and reproduction of native and agricultural plants appear unaffected. Also, no evidence suggests significant impacts on individual animals or wildlife populations that are chronically exposed to EMF under transmission lines or in the towers. Livestock behavior and production also appear unaffected by line operation. Therefore, the potential impact of EMF on terrestrial biota is expected to be of small significance for all plants. The only potential mitigation would be to exclude plants and animals from the right of way, a measure with very severe impacts of its own. However, because the impact is of small significance and because mitigation measures could create additional environmental impacts and would be costly, no mitigation measures beyond those implemented during the current term license would be warranted. This is a Category 1 issue.

4.5.7 Floodplains and Wetlands

Transmission lines pass through floodplains and wetlands in many areas. This section evaluates the impacts on floodplains and wetlands that may result from periodic cutting or herbicide treatment of woody vegetation and the occasional use of heavy equipment for line repair. The analysis in this section is based on a literature review and applies to all power lines regardless of the type of generating facility.

Vegetation control is normally required only in forested areas where trees could grow tall enough to interfere with line operation. Marshes, ponds, or other types of wetlands lacking trees generally should not be subjected to vegetation control and thus should not be affected. In forested wetlands, most of which are on floodplains, vegetation may be cut by hand or with a tractor with a rotary blade or may be controlled by herbicides (Section 4.5.1.4). Impacts are generally restricted to the ROW and should have no significant impact on the functions and values that have been identified for floodplains, including storage and slow release of floodwaters, water quality maintenance, groundwater recharge, and support of wildlife populations (Greeson et al. 1979). Herbicides that are often used in prairie wetlands to improve habitat for waterfowl do not appear to have toxic effects on aquatic biota (Solberg and Higgins 1993).

Repair of transmission lines may require access by heavy equipment to tower sites in floodplains or wetlands. This access would damage vegetation and disturb wildlife, having the same types of impacts that occurred during construction of the line. Overall impacts are expected to be relatively minor because (1) line repairs at any one location are rarely required, (2) impacts would be temporary and restricted to relatively small areas, and (3) tower sites often avoid wetlands. Repairs made during winter would generally have less impact than repairs in summer, but often there may be no choice of season because of the necessity for immediate repair.

Studies in Massachusetts indicate that transmission lines and their ROW can be constructed and maintained through wetlands without significant impact (Nickerson and Dobberteen 1987; Thibodeau and Nickerson 1986). The studies were conducted in several areas where 345-kV lines were constructed through cattail marsh, wooded swamp, and shrub swamp/bog. Preconstruction studies were done in 1975 and 1976, and postconstruction studies were done from 1977 to 1982 and again in 1987. The cattail marsh was affected by the placement of heavy oak mats that were required so that heavy construction equipment could enter the marsh. This was done during the winter when the marsh was frozen and aerial parts of plants were dead. The marsh recovered to its original condition in 1 year. Line maintenance or repair using heavy equipment, if required, could be conducted during winter with no greater harm to a marsh.

In a bog, although vegetation was damaged by placement of oak mats and had not fully recovered after 10 years, the number of plant species in affected areas did not differ significantly from that in control areas. The authors recommended that line construction avoid bogs because of their extremely slow recovery.

Wooded swamp dominated by red maple showed significant change in vegetation structure because trees had to be removed from the ROW. After construction, the number of species and individuals returned to normal after 1 year, and a shrub layer became the dominant vegetation. After 10 years, the number of plant species in the ROW was greater than that in undisturbed swamp, even though the ROW vegetation had been mowed once (at a level of 3 ft) 6 years after construction. Because of the rapidity of swamp recovery after construction and the stability of the maintained ROW vegetation, the authors concluded that there was no substantial negative impact on wetland functioning. On swamp ROW cleared for lines from 1936 through 1939, selective cutting and herbicide treatment of cut stumps had been conducted. The numbers of species and individuals were similar to those in adjacent forest, and the ROW showed little evidence of disturbance except where trees had recently been cut (Nickerson and Dobberteen 1987; Thibodeau and Nickerson 1986).

No transmission line associated with a nuclear plant has been identified as being a significant impact on the functions and values of a wetland or floodplain. Only minor impacts of small significance are expected from ROW maintenance or line repair. Because the impact is of small significance and mitigation measures would be costly to implement, none of the mitigation measures identified above (i.e., placement of oak mats in affected areas and avoidance of maintenance during the growing season) would be warranted. This is a Category 1 issue.

4.5.8 Aesthetic Resources

This section evaluates the issue of transmission-line-induced impacts of continued operation of nuclear power plants on historic and aesthetic resources. Transmission lines are probably the most frequently seen equipment associated with power plants, particularly plants such as D. C. Cook or Diablo Canyon that are well hidden from public view. Transmission lines are the least novel in appearance when compared with highly visible nuclear power plant components such as cooling towers and containment vessels. Therefore, they are perceived with less bias than other components of the nuclear power plant complex. People may not even realize that some transmission lines are associated with a particular power plant, especially a nuclear plant.

The definitions of insignificant, noticeable, and significant levels of impact are the same as those described in Section 3.7.8.

The evaluation of past and projected future impacts of transmission lines on aesthetic resources involved staff examination of the experience at the seven selected case study sites, a brief survey of the projected and realized aesthetic impacts at the other operating nuclear power plants, a survey of the professional literature, and a search of recent newspaper and magazine accounts related to these issues.

Nuclear power plants are frequently sited near bodies of water for access to cooling water; their associated transmission lines often intrude into recreation, historic, or scenic areas. Most of the adverse impacts to date from transmission lines center on such incompatibility. Notable examples include Brunswick, Diablo Canyon, Millstone, Nine Mile Point, St. Lucie, and Vogtle. Crossings of major rivers, wetlands, wildlife areas, roads, lakes, cemeteries, and battlefields are the source of the disputes that have arisen. Various design, engineering, siting, construction, and metallic surface treatments have been made available to mitigate these conflicts.

In general, during the license renewal term, continued use of transmission lines and ROW is projected to cause little or no additional impacts beyond those that have already occurred. Some habituation to lines is likely to occur or continue. The problem of erosion of access roads under transmission lines at Diablo Canyon represents a type of impact that could worsen over time if mitigation is not effectively implemented. Proper maintenance of the t ransmission line corridor will help prevent aesthetic degradation. Additional mitigation measures such as replacement of towers or burying the transmission line would be excessively costly and would have additional environmental impacts.

The aesthetic impacts associated with continued operation of transmission lines are of small significance for all plants, and no mitigation measures beyond those implemented during the current term license would be warranted. This is a Category 1 issue.

4.6 RADIOLOGICAL IMPACTS OF NORMAL OPERATION

This section provides an evaluation of the radiological impacts on occupational personnel and members of the public during normal operation following license renewal. This evaluation extends to all 118 nuclear power reactors. Radiation exposures occurring after license renewal are projected based on present levels of exposures. Estimates of additional maintenance, testing, and inspections as a result of a variety of age-related changes in operational procedures were made based on the anticipated changes to current operation and are detailed in Section 2.6 and Appendix B. Added maintenance, testing, and inspection will be accompanied by increased exposure time to members of the work force but are not expected to significantly influence dose to members of the public. Regulatory requirements under which nuclear reactors presently operate are discussed in Section 3.8.1.1.

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

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

4.6.1 Public Exposure

During normal operations after license renewal, small quantities of radioactivity (fission, corrosion, and activation products) will continue to be released to the environment in a manner similar to present operation. Analyses of historic effluent data presented in Appendix E have pointed to a systematic reduction in effluents (primarily airborne). While there is no empirical evidence of a leveling off, there will be a practical lower limit of effluent release.

Radioactive-waste management systems are incorporated into each plant and are designed to remove most of the fission-product radioactivity that leaks from the fuel, as well as most of the activation- and corrosion-product radioactivity produced by neutrons in the vicinity of the reactor core (Section 2.2). Improved fuel integrity in the 1980s was an important factor in reducing effluents. In addition, the effectiveness of the gaseous and liquid treatment equipment has increased significantly over the past two decades, as is evidenced by the continuously decreasing levels of effluents (NUREG/CR-2907). The amounts of radioactivity released through vents and discharge points to areas outside the plant boundaries are recorded and published semiannually in the radioactive effluent release reports for each facility. A discussion of the environmental pathways for radioactive effluent releases to the air and water was presented in Section 3.8.1.2. This section will focus on issues more unique to license renewal.

4.6.1.1 Radionuclide Deposition

The concentration of radioactive materials in soils and sediments builds up to an equilibrium value that depends on the rate of deposition and the rate of removal. Removal can take place through radioactive decay or through chemical, biological, or physical processes. For a given rate of release, the concentrations of longer-lived radionuclides and consequently the dose rates attributable to them would continue to increase if license renewal were granted.

In Regulatory Guide 1.109, explicit guidance is provided for calculation of dose for nearly all conceivable pathways. To account for the buildup of radioactive materials, buildup factors of the form $(1 - e^{-\lambda t})$ in the calculations are included, where λ is the radionuclide decay constant, and t is the midpoint of a facility's operational life. Hence, only radioactive decay is used in the removal term. Initially, most of the calculations for construction and operating stage permits used 15 years as the approximate midpoint of facility operating life. This value is now more often taken to be 20 years. The potential license renewal term is an additional 20 years; thus, the effective midlife is 30 years.

At present, most of the radiation dose commitments to the population resulting from atmospheric emissions are from the noble gases (NUREG/CR-2850 1993). The noble gases do not build up in the environment. Iodine-131, of interest because it has the ability to concentrate in the thyroid, achieves equilibrium within weeks. Tritium, cobalt, and cesium normally account for the greatest proportion of the dose from liquid effluents. Tritium is not known to concentrate in sediments or solids and hence does not build up. To determine whether the added period of operation following license renewal would, by virtue of buildup, result in significant (double) added dose, the ratios of buildup factors for midlives of 30 to midlives of 20 years were evaluated. These ratios amount to a 35 percent increase for ^{137}Cs and a 6 percent increase for ^{60}Co. This added increase due to buildup will not significantly change the total dose to members of the public.

One remaining topic about buildup in the environment warrants discussion. Buildup is not explicitly accounted for in the aquatic food pathway (i.e., fish, shellfish, etc.) This pathway relies on the use of bioconcentration factors. A bioconcentration factor for a nuclide is the ratio of the concentration in biota to the radionuclide concentration in water. In certain cases, the bioaccumulation factors may require reexamination. These principally involve fish (in the human food chain) that are bottom feeders. Bottom feeders may ingest worms and other biota that may remobilize radioactive materials accumulated in the sediments.

Accumulation of radioactive materials in the environment is of concern not only to license renewal, but also to operation under present licenses. NRC reporting rules require that pathways that may arise as a result of unique conditions at a specific site considered in licensees' evaluations of radiation exposures. If an exposure pathway is likely to contribute significantly to total dose (10 percent or more to the total dose from all pathways), it must be routinely monitored and evaluated. Environmental monitoring programs are in place at all sites to provide a backup to the calculated doses based on effluent release measurements. Since these programs are ongoing for the duration of the license, locations where unique situations give rise to significant pathways not detailed in NRC Regulatory Guide 1.109 will be identified if and when they become significant. If such pathways result in doses at a plant exceeding the design objectives of Appendix I to 10 CFR Part 50, action will be required.

4.6.1.2 Direct Radiation

Radiation fields are produced around nuclear plants as a result of radioactivity within the reactor and its associated components, low-level storage containers, and components such as steam generators that have been removed from the reactor (as described in Section 3.8). Direct radiation from sources within a light water reactor plant is due primarily to ^{16}N, a radionuclide produced in the reactor core by neutron activation of ^{16}O from the water. Because the primary coolant of an LWR is contained in a heavily shielded area, dose rates in the vicinity of light water reactors are generally undetectable and are less than 1 mrem/year at the site boundary. Some plants [mostly boiling water reactors (BWRs)] do not have completely shielded secondary systems and may contribute some measurable off-site dose. These sources of direct radiation will be unaffected by license renewal.

Original impact statements were reviewed for estimates of off-site dose from radioactive storage containers at both boiling-water reactors and pressurized-water reactors. These estimates suggested small dose contributions at site boundaries (Section 3.8.1.6). Nothing is anticipated to occur during license renewal to significantly change this estimate.

4.6.1.3 Transportation-Related Radiation Doses

The transportation of "cold" (unirradiated) nuclear fuel to the reactor, of spent irradiated fuel from the reactor, and of solid radioactive wastes from the reactor to a waste burial ground represents a source of exposure considered in 10 CFR Part 51.52. The contribution of the environmental effects of such transportation to the environmental costs of license renewal of the nuclear power reactor is set forth in Summary Table S-4 from 10 CFR 51.52. This issue is discussed in Section 6.4.

4.6.1.4 Radiological Monitoring

Background measurements at all sites were obtained during the preoperational phase of the monitoring program. Thus, each facility has characterized the background levels of radioactivity and radiation and their variations among the anticipated important pathways in the areas surrounding the facilities. The operational, off-site radiological monitoring program is conducted to provide data on measurable levels of radiation and radioactive materials in the site environs in accordance with 10 CFR Parts 20 and 50. The program assists and provides backup support to the effluent-monitoring program recommended in NRC Regulatory Guide 1.21, *Measuring, Evaluating, and Reporting Radioactivity in Solid Wastes and Releases of Radioactive Materials in Liquid and Gaseous Effluents from Light-Water-Cooled Nuclear Power Plants*. Such environmental monitoring programs are conducted to augment dose calculations and to ensure that unanticipated buildups of radioactivity will not occur in the environment.

The environmental monitoring programs also identify the existence of effluents from unmonitored release points. An annual survey (land census) identifies changes in the use of unrestricted areas to provide a basis for modifying the monitoring programs.

4.6.2 Public Radiation Doses

Doses to the public during the license renewal term were estimated using current (baseline) levels and trends. For the period after license renewal, two measures of impact are appropriate. They are the dose to the maximally exposed individuals and the population dose. The latter is the average individual dose as a function of distance and sector location multiplied by the population in that sector at that distance.

4.6.2.1 Maximally Exposed Individual

Table 4.6 presents the dose to the maximally exposed individual resulting from airborne effluents as tabulated by NUMARC (1989) for the years 1985 to 1987. Under most circumstances, the dose calculations, made by the reporting utilities, result in an overestimate of dose because of conservative assumptions. The table shows that the greatest dose value for the maximally exposed individual from atmospheric releases (between 1985 and 1987) is 4.3 mrem.[7] On the average, about 5 percent of the sites report an annual dose of 1 mrem or greater to the maximally exposed individual. NRC has recently begun to estimate individual doses for comparison with 10 CFR Part 50, Appendix I objectives (NUREG/CR-2850 1994). Combining air and liquid pathways for calendar year 1990, operation at about 5 percent of the sites resulted in annual

Table 4.6 Calculated total body dose to the maximally exposed individual from routine airborne effluents (mrem)

Plant	1985	1986	1987
Arkansas, Unit 1	—	0.0017	0.0023
Arkansas, Unit 2		0.006	0.0044
Beaver Valley	—	0.023	0.0014
Brunswick	—	—	0.028
Catawba	0.88	2.2	0.89
D. C. Cook	0.057	0.02	0.024
Cooper	0.57	0.4	0.018
Crystal River	0.022	0.21	0.2
Davis-Besse	0.0081	0.00064	0.12
J. M. Farley	0.13	0.12	0.081
Grand Gulf	0.09	0.068	0.34
Haddam Neck	1.0	0.39	0.66
Oconee	0.15	0.087	—
Oyster Creek	1.4	4.3	0.17
Peach Bottom	0.041	0.12	0.015
Pilgrim	0.49	0.027	—
Quad-Cities, Unit 1	0.002	—	0.0025
Quad-Cities, Unit 2	0.002	—	0.0021
Rancho Seco	0.17	—	—
H. B. Robinson	—	0.016	0.068
Shearon Harris	—	—	0.022
E. I. Hatch	0.093	0.004	0.13
Indian Point	0.00078	0.00049	—
Kewaunee	—	0.12	0.00001
Limerick	—	0.00079	0.00022
McGuire, Unit 1	—	0.15	0.081
McGuire, Unit 2	1.8	—	0.0036

Table 4.6 (continued)

Plant	1985	1986	1987
Salem	0.016	0.028	0.047
Sequoyah	0.19	0.002	—
St. Lucie, Unit 1	0.013	0.011	0.0023
St. Lucie, Unit 2	0.0062	0.0021	0.0028
V. C. Summer	—	0.00051	0.000001
Susquehanna	0.1	0.0069	0.011
Three Mile Island	—	0.019	0.0028
Trojan	0.069	—	—
Turkey Point, Unit 1	—	0.0038	0.0087
Turkey Point, Unit 2	—	0.0042	0.0088
Waterford	—	—	0.66
Washington	—	0.013	0.024
Zion	0.044	0.092	0.00047

Source: NUMARC 1989.
Note: To convert millirem to millisievert, multiply by 0.01.

doses of 1–3 mrem to the total body; 32 percent of the sites, 0.1–1.0 mrem; and 63 percent of the sites, less than 0.1 mrem. A comparison of the data from Table 4.6 and from NUREG/CR-2850 (1994) with the design objective doses of Appendix I to 10 CFR Part 50 and the EPA dose limits (Section 3.8.1) shows that existing plants are operating far below allowable limits with respect to effluent control.

Given the conservative nature of the calculations leading to the doses of Table 4.6, the impact on maximally exposed persons around nuclear generating facilities is clearly very small.

4.6.2.2 Average Individual Dose and Population Dose Commitment

4.6.2.2.1 Recent Data

Trends for average individual doses for persons living around nuclear power plants reflect the small radiation dose levels seen in the maximally exposed individuals. Each year, NRC issues a report entitled *Population Dose Commitments Due to Radioactive Releases from Nuclear Power Plant Sites*. The latest publication is for the calendar year 1989 (NUREG/CR-2850, Vol. 11). Methods used in this series are described in Section 3.8.1. The prescribed calculational methods include several basic assumptions to ensure that the results are conservative. Table 4.7 (adapted from

Table 4.7 Summary of population and occupational doses (person-rem) for all operating nuclear power plants combined

	Population			
Year	Liquid	Air	Total	Occupational
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.

NUREG/CR-2850 and NUREG-0713) presents results obtained for a 15-year period ending in 1989. The numerical entries are person-rem received by those who live within a 50-mile radius of a site; data for individual sites also appear in these reports. The person-rem number is obtained by adding together the individual doses received by this population. For 1988, the cumulative person-rem varied from a low of 0.0015 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 4.8. (Information presented in Tables 4.8 and 4.9 was derived from NUREG/CR-2850, Vol. 10,

Table 4.8 Highest public dose data from nuclear power plant effluents, 1988

Plant	Population dose (person-rem)	Population within 50 miles (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, Vol. 10.
Note: To convert rem to sievert, or mrem to millisievert, multiply by 0.01.

Table 4.9 Individual public dose data from power plant effluents, 1988

Individual dose range (mrem)	Percentage of total	Cumulative percentage
0 to 0.000001	6 percent	6 percent
0.000001 to 0.00001	4 percent	10 percent
0.00001 to 0.00003	18 percent	28 percent
0.00003 to 0.0001	30 percent	58 percent
0.0001 to 0.0003	21 percent	79 percent
0.0003 to 0.001	13 percent	92 percent
0.001 to 0.003	5 percent	97 percent
0.003 to 0.01	< 2 percent	99 percent
0.01 to 0.03	< 1 percent	100 percent

Source: NUREG/CR-2850, Vol. 10.
Note: To convert mrem to millisievert, multiply by 0.01.

the most recent volume which presents data summaries with average individual doses.) The arithmetic mean annual radiation dose to people who lived in the vicinity of a U.S. nuclear power plant in 1988 was about 0.0005 mrem. The overall median for 1988 was less than 0.0003 mrem. A histogram shown in Figure 4.1 of NUREG/CR-2850 provided the information shown in Table 4.9.

Note that 97 percent of the individuals received 0.003 mrem or less during 1988. The most recent NCRPM report on this subject gives 300 mrem/year as the U.S. average dose from natural background radiation (NCRPM 1987). The addition of 0.018 mrem at the Hatch site as a result of plant operation is well within and indistinguishable from variations in natural background radiation (see Dudney et al. 1990).

According to the National Council on Radiation Protection and Measurements report, if a person moves from the coast to the Rocky Mountains, the natural annual doses can be increased by as much as 70 mrem. This 70-mrem addition to natural background which occurred because of a personal relocation is 7690 times greater than the average dose from operation of the McGuire nuclear facility during 1988.

4.6.2.2.2 Analysis of Current Trends

Projections into the future can be made on the basis of current trends. On that basis, average individual dose commitments were analyzed. The first objective of the analysis was to determine to what extent known information about all sites could be used to predict what the dose commitment values for each site were for the years 1979–1987. The second objective, if current dose commitments could be predicted adequately, was to use the models to predict future dose commitments for U.S. sites by extrapolating the characteristics used in the model and the population projections for the sites into future years (see Section E.3.2 for more details of this analysis).

A linear model was fitted to the dose data using combinations of independent variables. The independent variables that proved to be most predictive of the log (dose) values included calendar year, year of startup, size in megawatts, vendor (or manufacturer), and status (up or down). The linear model for estimation of air doses resulted in the following conclusions. The manufacturer with the highest air doses is Babcock-Wilcox (B-W) (but highly variable); the next highest is GE; and the lowest is Combustion Engineering (C-E). Air doses are decreasing with calendar year (for 1979 to 87) for all reactor types. The rate of decrease is fastest for GE reactors. The rate of decrease is much smaller for C-E reactors than for others, partly because these are lower to begin with. With the exception of C-E, all types have higher air doses from older reactors. For C-E, newer reactors have higher doses. Larger reactors had higher air doses. This relationship was strong and was a major contributor to the prediction of dose for each reactor site; it 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 for Westinghouse reactors. The overall model accounts for approximately 42 percent of the variation in the air dose values. For all reactor types (manufacturers), air doses decrease significantly when the reactor is operating below 25 percent capacity. This is not necessarily true for doses from liquid sources.
The linear model for estimating liquid dose resulted in the following conclusions: B-W

reactors have significantly higher liquid doses than do reactors of other manufacturers, and GE reactors are next highest. Mixed sites (those with multiple reactors and different vendors) have the lowest liquid doses. GE and mixed sites have higher doses from liquid sources when they are operating below 25 percent of theoretical maximum output. Many mixed sites are partly GE reactors. All other manufacturers, all of which are pressurized-water reactors, have lower doses when they are operating below 25 percent capacity. Liquid doses are higher in older reactors only for GE reactors. For others, there is not a significant trend with reactor age. For GE reactors and for Westinghouse reactors, the larger reactors had higher liquid doses. The increase in liquid dose with megawatt capacity was much higher for GE reactors than for the other types. Liquid doses are overall much less predictable than air doses, and the resulting model fit for the liquid doses reflects this unpredictability. For liquid doses, the best-fitting model accounted for only about 20 percent of the overall variability in the model.

Liquid effluents 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 decrease and for doses from liquid sources to decrease less rapidly. The decreasing trend in total dose commitment results mostly from the lower air dose estimates.

On the basis of the coefficients estimated with this analysis, it is apparent that the dose commitments are being systematically lowered. Results of the analysis were used to plot historical data against predicted doses (see sample figures in Section E.3). These figures portray how each sample reactor has performed with respect to other reactors in its class (i.e., age, size, vendor). Again, the dominant theme is the decline in dose commitment, which is almost universally observed. Even if there were a sudden cessation of the decline in dose to the public, levels are sufficiently low to represent an insignificant impact to humans.

4.6.2.3 Projected Doses for License Renewal

On the basis of information presented in the preceding section, radiation doses to members of the public can be projected into the license renewal period. The three factors upon which judgments can be made are the maximally exposed individual, the average exposed individual, and the cumulative exposure of a population. At present, each of these measures meets the design objectives and regulations. No aspect of future operation was identified that would substantially alter this situation. Rather, evidence presented above suggests that radioactive effluents and hence doses to the public are decreasing.

Maximum individual doses are reported in semiannual effluent release reports, and when these doses exceed Appendix I design objectives, the staff pursues remedial action. Thus these issues are handled on a case-by-case basis. A review of the atmospheric release data sources suggests that, in any given year, up to 5 percent of the power plants produce radiation doses of approximately 20 percent of the Appendix I design objectives (NUMARC 1989). No aging phenomenon has been identified which is expected to increase public radiation doses. Since the design objective provides a point of reference for visibility to the NRC staff, normally operating reactors are not expected to reach regulatory dose limits more often in the period after license renewal than they do at present. For these reasons, impacts to maximally exposed individuals in the public during future operation under license renewal are judged to be radiologically unchanged from present operations.

Similarly, radiation exposure to the average individual and collective dose to the population around a nuclear power plant are not anticipated to increase from present levels in the period after license renewal. Analysis of all available pertinent information suggests that, if anything, radiation doses to the public are decreasing.

Ninety-nine percent of the population within 50 miles of any plant received a dose of 0.003 mrem or less from nuclear power plant effluents in 1988 (Table 4.9). In 1990, the average dose to persons living within an 80-km (50-mile) distance from nuclear power plants was less than 0.001 mrem (NUREG/CR-2850 v. 12). If all 150 million people living within 80 km (50 miles) of nuclear plants receive 0.001 mrem/year for 70 years, the collective dose will be 10,500 person-rem. Using a risk coefficient of 5×10^{-4} cancer fatalities per person-rem, approximately 5 fatalities can be hypothesized. Among the 150 million people, about 30 million will die of spontaneous cancer. Hence, the added risk of cancer fatality is less than 1 in 6 million national cancer fatalities.

From a different perspective, the population of 150 million people would accumulate 45,000,000 person-rem/year from natural background radiation. The annual collective dose from operation of all 118 nuclear power plants, assuming an annual average individual dose as high as 0.002 mrem per person, is 300 person-rem. This is 150,000 times less than the collective dose from naturally occurring radiation. From this perspective, the contribution of nuclear power plants to the radiation dose to members of the public is not significant. Future increases in populations will result in proportional increases in population doses; that is, a doubling of the population around the 118 plants would result in a 600 person-rem annual collective dose. However, the population increase would not change the fact that the collective dose from plant operation is still 150,000 times less than that from naturally occurring radiation.

Cumulative impacts to average individual members of the public can be viewed from the same perspective presented in Section 3.8.1.7. During operation under license renewal, the average annual dose to the public from nuclear power plant operations will remain very small, less than 0.001 mrem/year. Cumulative radiation doses to members of the public will remain about 360 mrem/year and nuclear power plant operation will remain a very small part (less than 0.0003 percent) of the ionizing radiation dose to an average member of the U.S. population.

4.6.2.4 Mitigation

In addition to the regulations within 10 CFR Part 20.1101 (see Section 3.8.1.8) which speak directly to required operation under ALARA principles, 10 CFR Part 50.36a imposes conditions on licensees in the form of technical specifications on effluents from nuclear power reactors. These specifications are intended to keep releases of radioactive materials to unrestricted areas during operations to ALARA levels. Appendix I to 10 CFR Part 50 provides numerical guidance on dose-design objectives and limiting conditions for operation of LWRs to meet the ALARA requirements. These regulations will remain in effect during the period of license renewal.

Evidence presented in Section 3.6, Appendix E, and this section demonstrates that the ALARA process has been effective at controlling and reducing radiation doses to the public. Radiation doses to the public are declining both for average and total doses (Table 4.7) and for individual doses (Tables 4.10 and 4.11). No changes in the operation of power plants under license renewal are expected to increase radiation doses to the public compared with current operation. Because effective mitigation procedures are already in place, there is no need to consider additional mitigation during the period of license renewal.

4.6.2.5 Conclusion

Radiation doses to members of the public from current operation of nuclear power plants have been examined from a variety of perspectives and the impacts were found to be well within design objectives and regulations in each instance. No effect of aging that would significantly affect the radioactive effluents has been identified. Both maximum individual and average doses are expected to remain well within design objectives and regulations. In about 5 percent of the plants, maximum individual doses are approximately 20 percent of the Appendix I design objective. All other plants are operating far below this level.

Because no reason was identified to expect effluents to increase in the period after license renewal, continued operation well within regulatory limits is anticipated. The staff concludes that the significance of radiation exposures to the public attributable to operation after license renewal will be small at all sites. It should also be noted that the estimated cancer risk to the average individual due to plant operations is much less than 1×10^{-6}. No mitigation measures beyond those implemented during the current term license would be warranted because current mitigation practices have resulted in declining public radiation doses and are expected to continue to do so. This is a Category 1 issue.

4.6.3 Occupational Radiation Dose

To determine the significance of the estimated occupational dose during the license renewal term, the staff has examined the baseline trends in cumulative annual occupational dose at pressurized-water reactors and boiling-water reactors and the projected increments to occupational dose due to extended plant operation. These projections were compared with the occupational dose limit requirements of 10 CFR Part 20 and with dose levels now being experienced and were also used as the basis for estimates of cancer risk, which were compared with the spontaneous cancer rate.

4.6.3.1 Baseline Occupational Dose

Occupational radiation protection programs in place at nuclear power plants have maintained an annual average individual dose of only 0.28 rem during 1992 (Table 4.10), compared with an exposure limit of 5 rem. Furthermore, the distribution of individual dose (Table 4.11) indicates that only 3 people received doses at the highest reported level of between 4 and 5 rem and less than 0.5 percent of the workers received doses in excess of 2 rem. (Other supportive historical data can be found in Appendix E.)

Table 4.10 Light-water reactor (LWR) occupational whole-body dose data for boiling-water reactors (BWRs) and pressurized-water reactors (PWRs)

Year	Annual average whole-body dose (rem)		
	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 millirem to millisievert, multiply by 0.01.

Table 4.11 Number of workers at boiling-water reactor (BWRs), pressurized-water reactor (PWRs), and light-water reactor (LWRs) 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, 1993.
Note: To convert millirem to millisievert, multiply by 0.01.

As plants age, there will be slight increases in radioactive inventories, resulting in slight increases in occupational radiation doses.

4.6.3.2 Projected Doses for License Renewal

During the license renewal term, the greatest increment to occupational dose over present doses would occur during a 10-year in-service inspection refueling (Table 2.8). The average dose increment related to the 10-year in-service inspection refueling would raise boiling-water reactor averages from a present 360 person-rem (Table 3.12) by 91 person-rem (10-year in-service inspection refueling, Table 2.8) to 451 person-rem and raise pressurized-water reactors from 219 person-rem by 51 person-rem to 270 person-rem. Under the conservative scenario (Table 2.11) these dose increments would add 108 person-rem to BWRs and 66 person-rem to PWRs. These increased levels for a single year are similar to the levels experienced at some plants during the past 2 two reporting years (Table 3.13). After the period of refurbishment, routine operating conditions are expected to cause, industry wide, approximately 32,000 person-rem/year exposure to plant personnel [i.e., 5 percent increase over the currently experienced 30,000 person-mrem/year (Appendix B)]. With the conservative scenario, there is about an 8 percent increase in radiation dose over current operating experience (Tables 2.8 and 2.11).

Within the radiation bioeffects community, one school of thought holds that any radiation exposure is accompanied by a risk of cancer. The other perspective is that below a certain dose and dose rate, no cancer risk is involved. The lowest statistically significant dose associated with excess cancer fatalities among the atomic bomb survivors is considered by ICRP 60 (1991) to be 20 rad. The collective dose to the U.S. population from natural background radiation is approximately 75 million person-rem/year; while not declaring itself on one side or the other on the risk issue, the 1990 BEIR-V report states that there may be no risk from this natural background radiation. If there is no risk from natural background radiation, the annual 32,000 person-rem dose may be of little concern. At the other extreme, if it is assumed that individual doses of less than 20 rem may be included in the collective dose without causing an exaggerated result, the full 32,000 person-rem dose to all workers at nuclear power plants for the typical case may be multiplied by the best estimate risk coefficient for workers (4×10^{-4}); this risk coefficient leads to an annual total of 13 deaths. Of these, 12 would be expected because of normal present-day operation and 1 would be expected to result from aging- and refurbishment-related changes in operation.

This analysis of typically expected conditions provides a range of 0 to 13 deaths induced per year as a result of license renewal, with one of these fatalities resulting from added dose due to aging; very little difference is estimated under the conservative scenario. Thus, radiation doses attributable to plant aging accumulated during the license renewal term might result in a 5 percent increase in the calculated cancer incidence to plant workers, but there may be no increase. The significance of the possible increase depends altogether on the degree of credibility assigned to the risk coefficient derived at high dose and dose rate and applied for low dose and dose rate. In any case, the risk associated with occupational radiation exposures after license renewal is not expected to be significantly different from that during the initial license term.

Currently, occupational radiation doses are on the order of 0.4 rem/year in addition to the 0.36 rem/year received by the typical U.S. resident. If occupational exposure increases by 8 percent as estimated for the conservative scenario, cumulative occupational radiation doses will increase from about 0.76 rem/year to 0.79 rem/year for those working at nuclear plants that operate after the initial license term. Under the typical scenario, occupational doses would increase approximately 5 percent over the currently experienced levels increasing average exposures to 0.78 rem/year.

4.6.3.3 Conclusion

Occupational doses attributable to normal operation during the license renewal term have been examined from several different perspectives. First, projected occupational doses during the period of maximum added dose, the 10-year in-service inspection refueling, are within the range of doses experienced during the past 2 reporting years. Second, the average dose increase of 5 to 8 percent to the typical plant worker would still maintain doses well below regulatory limits. Therefore, occupational radiation exposure during the term of the renewed license meets the standard of small significance. No mitigation measures beyond those implemented during the current term license would be warranted because the ALARA process continues to be effective in reducing radiation doses. This is a Category 1 issue.

4.7 SOCIOECONOMIC IMPACTS

This section reports on the socioeconomic impacts associated with nuclear power plant operations during the license renewal term. The staff reviewed the following socioeconomic issues: (1) changes to local housing caused by plant-induced population growth; (2) the magnitude of all nuclear plant tax payments in relation to total revenues in host communities; (3) disruptions to local public services (i.e., education, transportation, public safety, social services, public utilities, and tourism/recreation); (4) changes to local land use and development patterns resulting from plant-induced population growth and all tax payments; (5) the effects of plant operations on local employment and income levels; (6) plant-related disturbances to historic resources at and around the plant site; and (7) plant-related disturbances to aesthetic resources. Of these socioeconomic impacts only those directly affecting the natural and built environment are carried forward to the decision whether to renew an operating license. The regional economic impact including income, employment, and taxes are not considered in the license renewal decision. As in Chapter 3, plant-induced population growth was studied as a potential influence on a number of the impacts listed above.

The methodological techniques used to evaluate impacts are described briefly in Section 3.7.1 and are detailed in Section C.1; a brief summary of these methods is provided here. For this chapter, past impacts related to plant operations were studied so that the impacts of future operations could be predicted. The impacts projected for the case study sites represent the range of potential impacts at existing nuclear plants because the sample plants were selected to represent the range of nuclear plant sites nationwide. A detailed discussion of site-specific findings is presented in Sections C.4.1 through C.4.7 of Appendix C.

The size of the work force required during the license renewal term is an important determinant of population growth. The permanent license renewal term work force is expected to include those personnel who were on-site during the initial license term, up to 60 additional permanent operations workers per unit, and temporary refueling and maintenance workers during periodic plant outages. 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.

In addition to those workers previously required during operations-period outages, another 30 workers will be needed for periodic outages during the license renewal term. Potential impacts associated with the presence of periodic outage workers were not systematically evaluated because the duration of these outages will be short (typically 3–4 months). However, evidence about past effects resulting from the temporary influx of refueling/maintenance workers was collected and used in the analysis to predict the impacts of refueling/maintenance during the license renewal term.

The site-specific projections presented here are based on the assumption that no other major construction projects will occur at the same time as refueling and maintenance activities. The potential cumulative population-related impacts during license-renewal-term refueling and maintenance activities would result from the combined populations associated with refueling/maintenance and other concurrent construction activities (not necessarily related to the power plant). Analyses of various refurbishment scenarios (see Appendix C and Chapter 3) suggest the potential magnitude of cumulative impacts resulting from different work force sizes. For example, about 800 refueling/maintenance workers (i.e., about the mean number of workers involved in regularly scheduled outages) combined with another construction work force of about 200, for a total of 1000 workers, would have only small adverse impacts at all but the most remote and sparsely populated sites (e.g., Wolf Creek). Combined work forces of 2,300 could induce large impacts to housing, education, and transportation at some sites. A sensitivity analysis indicates that impact magnitudes would not be increased by a work force as large as 3,400.

The population growth that has resulted from operations at the case study plants has been small, ranging from less than 0.1 percent to 13 percent of a local area's total population (see Table 4.12 and Appendix C). As discussed in Section 3.7.1, the staff believes that Indian Point and Wolf Creek serve as the lower and upper bounds, respectively, of operations-related growth as a percentage of a study area's total population. Thus, population growth that has resulted from worker in-migration is estimated to range at all plants from less than 0.1 percent to 13 percent.

Certain characteristics of the license renewal term work force (e.g., percentage residing in the study area, percentage moving into the study area, percentage of in-migrants accompanied by families) were assumed to be similar to those of the current plant staff and were used to make projections concerning population growth. Information about the impacts that have resulted from population growth during a plant's operation was used to estimate the population-driven impacts that would occur during the plant's license renewal term.

Based on predictions for the case studies, new plant-related population growth resulting from the license renewal term at any nuclear plant would be much smaller than the growth that has resulted from operations thus far. Growth related to increased employment during the license renewal term is expected to represent between less than 0.1 percent and 0.8 percent of the local area's total population for all plants. Because the number of additional permanent workers required at any plant would be relatively small (up to 60 per unit) and because the communities around the plants have already accommodated the existing work force during operations, it is likely that license renewal terms would result in only minimal long-term plant-related population increases for most plants. Therefore, new (incremental) population-driven impacts generally would be minimal, and impacts

Table 4.12 Impact area population growth associated with current and additional permanent plant staff at seven plants in the case study[a]

Plant	Current number of permanent plant staff	Population increase from current staff	Population growth from current staff as a percentage of study area's total population	Projected population increase from additional permanent staff	Population growth from additional staff as a percentage of study area's total population
Arkansas Nuclear One	2205	3418	7.4%	189	0.3%
D. C. Cook					
Bridgman/Lake Township	1252	141	3.0%	15	0.3%
Berrien County		1109	0.7%	104	< 0.1%
Diablo Canyon	1300	2149	1.0%	199	< 0.1%
Indian Point					
Dutchess County	1335	415	0.2%	39	< 0.1%
Westchester County		316	< 0.1%	32	< 0.1%
Oconee	2300	504	0.9%	41	< 0.1%
Three Mile Island	1086	246	1.7%	13	< 0.1%
Wolf Creek	1044	1137	13.3%	68	0.8%

[a]Includes both direct and indirect workers and their families.
Source: Staff computations.

already occurring during current operations would continue with only slight increases during the license renewal term.

4.7.1 Housing

Two types of housing impacts related to workers' demand for housing may occur during license renewal term operations: (1) new housing impacts resulting from the in-migration of additional plant operations workers and (2) the continuing impacts arising from the housing demands of workers involved in periodic plant outages for refueling and maintenance. A third type of impact, unrelated to workers' demands, is the continuing impact of the plant on housing value and marketability.

4.7.1.1 Definition of Significance Levels

Detailed definitions of significance levels of impacts that result from increased housing demand are provided in Section 3.7.2. In summary, small impacts result when no discernible change in housing availability occurs, changes in rental rates and housing values are similar to those occurring statewide, and no housing construction or conversion occurs. Moderate impacts result when there is a discernable reduction in housing availability, rental rates and housing values exceed the inflation rate elsewhere in the state, and minor housing conversions or temporary additions occur. Large impacts occur when project-related demand results in very limited housing availability, considerable increases in rental rates and housing values, and substantial conversion of housing units.

Definitions of the significance of the plant's impacts on the desirability of housing located close to the plant follow. A small impact on housing desirability results when very few or no instances of outmigration occur because of the operation of the nuclear power plant. Also, very few cases of prospective home buyers refusing a home because of its proximity to the plant would occur. Under normal plant operations, housing values should remain within the range of regional fair market prices. Moderate impacts on housing desirability include occasional difficulty in finding a buyer for a house because of its proximity to a nuclear plant. Impacts are also moderate if the proximity of the nuclear plant is cited as a reason for discounting the sale price of the housing units. Impacts on housing desirability are considered large if substantial migration from houses in the vicinity of the plant occurs or if realtors find it difficult or impossible to sell homes in the area. A large impact may also result if a sustained and substantial drop in housing value occurs because of the house's proximity to the plant. Such impacts may be evidenced by a gradual increase in housing value with increasing distance from the plant.

4.7.1.2 Analysis

Housing Demand

The in-migration of plant personnel associated with current operations at each of the seven case study sites has had small impacts on housing. The number of operations workers required at the plants is small relative to original construction work force size, and the operations workers have been introduced gradually to the site so that housing demand has also increased gradually. The demand for housing by refueling workers was found to have a large impact at only one site (Wolf Creek). In that case, approximately 640 additional workers were on-site during the plant outage.

Based on impacts associated with current term operations, population-driven housing impacts resulting from additional permanent workers in the license renewal term would be small at all case study sites. The housing demand resulting from an additional 60 workers per unit would not be large enough to strain the housing markets of communities in which the plants are located and would result in a small impact even in areas where little growth in housing is expected.

Impacts related to the demand for housing resulting from the in-migration of refueling workers are projected to continue to be the same as those currently being experienced—with slight exacerbation due to the additional 30 temporary refueling workers (Section 4.7.1). Thus large impacts may continue at one case study site, Wolf Creek. At other case study plants, these continuing housing impacts associated with in-migrating refueling workers would remain small to moderate.

Housing Marketability

The prevailing belief of realtors and planners in communities surrounding the case study plants is that the plants have had little if any effect on the marketability or value of homes in the vicinity. Housing choices of local residents are rarely affected by the presence of the plant. However, buyers from outside the community are occasionally averse to purchasing properties close to a nuclear power plant. Housing markets have not been affected by this situation because of its infrequency. The value of housing units in close proximity to the plants has experienced only small impacts. A slight negative impact did result because of the accident at Three Mile Island Unit 2; the price of houses in two small subdivisions close to the plant dropped slightly below fair market value after the accident and stayed that way for a brief period following it. At some sites, housing values have increased slightly because of amenities such as sewer systems and improved school systems that were made possible because of tax payments by the nuclear plant.

The license renewal term of the plants will be very much like the original operations period but will include additional safety and maintenance activities. Thus, impacts on housing marketability and values that have occurred during operations will continue during the license renewal term. At all case study sites, only small impacts on housing value and marketability are projected to continue.

4.7.1.3 Conclusion

No demand-related impacts are expected during regular operations, and only small impacts to housing value and marketability are projected. During continuing periodic refueling/maintenance outages, housing demand impacts during refueling/maintenance may range from small to large at various sites. The observed relationship between demographic characteristics and projected housing impacts at the case study sites suggests that large impacts are possible when a work force exceeding 600 persons is required at a site located in a low-population area or in an area that has or recently has had growth control measures that limit housing development. This is a Category 2 issue.

4.7.2 Taxes

This section describes the importance of nuclear plant tax payments as a source of local government revenue. These payments may be made directly to local government jurisdictions or indirectly to local government jurisdictions through state tax and revenue-sharing programs. The tax impacts of operations during the license renewal term were projected based on the current magnitude of tax payments by nuclear plants in relation to total revenues in their local areas (Section C.4.1.3).

4.7.2.1 Definition of Significance Levels

Significance levels during license term renewal operations are considered small if new tax payments are < 10 percent of the taxing jurisdiction's revenue, moderate if payments are 10 to 20 percent, and large if payments represent > 20 percent of revenue. A detailed description of these significance categories is in Section 3.7.3.1. However, the tax payments used to calculate impacts during the license renewal term are all property taxes paid by the nuclear plant, not just the increment due to refurbishment-related improvements.

4.7.2.2 Analysis

The primary taxing authorities for most of the case study plants are the county and city in which the plant is sited and the local school district. The tax-related impacts experienced by those jurisdictions vary widely, depending on the relative size of the taxing jurisdictions and the taxing structure of the state in which the case study is located. The magnitude of current nuclear plant tax payments relative to total local revenues and the associated impact levels is shown in Table 4.13.

The primary tax-related impact expected to occur during the license renewal term at the seven case study plants would be the continuation of tax revenues paid by utilities to local taxing authorities. An additional new tax impact would result from the increase in each plant's assessed value because of refurbishment-based improvements and the associated increase in tax payments. The magnitude of this increase is unknown and may depend on the state's (or other assessing authority's) method of assessment and previous agreements or laws that limit increases in assessed valuation. Generally, the relative importance of tax payments to local jurisdictions during the license renewal term would be similar to that of payments during the current term, although the size of the payments is projected to increase somewhat (see Table 4.13).

4.7.2.3 Conclusion

Tax-related impacts from the continued operation of nuclear plants would range from small to large, as at the case study sites. Tax impacts would consist of the continued effect of direct and indirect tax payments to local jurisdictions, which began before license renewal, in combination with the increase in payments because of refurbishment-related improvements. Impacts of this kind are judged to be beneficial.

4.7.3 Public Services

The approach used to determine past impacts of plant operations and project future public service impacts during the license renewal term is discussed in the introduction to Section 3.7 (also see Section C.4.1.3). For most public services, future impacts were determined based on the projected number of in-migrating workers. To project impacts to local educational systems, however, the number of workers accompanied by their families and the associated family size were also important.

The levels of significance for impacts to public services are the same as those discussed under refurbishment: (1) education, Section 3.7.4.1; (2) transportation, Section 3.7.4.2; (3) public safety, Section 3.7.4.3; (4) social services, Section 3.7.4.4; (5) public utilities, Section 3.7.4.5; and (6) tourism and recreation, Section 3.7.4.6. In general, impacts are small if the existing infrastructure (facilities, programs, and staff) could accommodate any plant-related demand without a noticeable effect on the level of service. Moderate impacts arise when the demand for service or use of the infrastructure is sizeable and would noticeably decrease the level of service or require additional resources to maintain the level of service. Large impacts would result when new programs, upgraded or new facilities, or substantial additional staff are required because of plant-related demand (see Section 3.7.4).

Table 4.13 Current property taxes as percent of total revenues for taxing jurisdiction at seven nuclear power plants in the case study

Plant	Local taxing jurisdiction	Percentage of revenue	Magnitude of beneficial effect
Arkansas Nuclear One	Pope County (study area)	26	Large
	Russellville School District	42	Large
D. C. Cook	Berrien County (study area)	14	Moderate
	Lake Township (study area)	88	Large
	Bridgman School District	81	Large
Diablo Canyon	San Luis Obispo Co. (study area)	11	Moderate
	San Luis Coastal Unified School District	39	Large
Indian Point	Westchester County (study area)	0	Small
	Town of Cortlandt	33	Large
	Hudson School District	37	Large
	Village of Buchannan	49	Large
Oconee	Oconee County (study area)	14	Moderate
	Oconee School District	14	Moderate
Three Mile Island	Londonderry Township (study area)	< 1	Small
	Middletown Borough (study area)	< 1	Small
	Royalton Borough (study area)		
	Lower Dauphin School District	< 1	Small
		< 1	Small
Wolf Creek	Coffey County (study area)	45	Large
	Burlington School District	63	Large

Source: Staff computations.

4.7.3.1 Education

Few if any operations-related impacts on education were found at the case study sites. Communities had no substantial problems assimilating the children of the plant staff into local school systems. Educational impacts during the license renewal term would be small at all case-study sites, as has been the case during past operations. The number of new students would be low relative to the size of current school systems. This small impact could be mitigated by hiring additional staff members for the schools, building new educational facilities, or adding modular classrooms to existing facilities. However, because the impact is so small and implementation of these measures would be costly, such measures would not be warranted.

Based on the case-study analysis, educational impacts are projected to be of small significance at all plants. Because no additional teaching staff or classroom space would be needed, no mitigation measures beyond those implemented during the current term license would be warranted. This is a Category 1 issue.

4.7.3.2 Transportation

Transportation impacts related to current operations have been small at most sites but small to moderate at Three Mile Island and Wolf Creek during refueling and maintenance outages. Impacts to transportation during the license renewal term would be similar to those experienced during current operations and would be driven mainly by the workers involved in current plant operations. The 60 additional permanent workers expected during the license renewal term would represent only a small incremental addition to the continuing impacts from past normal operations, while the 30 incremental workers required during periodic refueling/maintenance outages would represent only a small increase in the number of workers typically involved in periodic outages under the original term of the license.

Based on past and projected impacts at the case study sites, transportation impacts would continue to be of small significance at all sites during operations and would be of small or moderate significance during scheduled refueling and maintenance outages. Because impacts are determined primarily by road conditions existing at the time of the project and cannot be easily forecast, a site specific review will be necessary to determine whether impacts are likely to be small or moderate and whether mitigation measures may be warranted.This is a Category 2 issue.

4.7.3.3 Public Safety

Overall, no serious disruptions of services occurred at the case study sites during the operations period. Existing services were adequate to handle the influx of plant staff. Impacts during license renewal would be largely the same as those that occurred during past operations. There would be little or no need for additional police or fire personnel. For this reason impacts would be of small significance at all sites. This small impact could be mitigated by hiring additional police or fire personnel, purchasing additional fire or police vehicles, building police or fire stations, or making improvements and additions to existing facilities. However, because existing services are projected to be adequate to handle plant-related demands and because mitigative measures would be costly, no mitigation measures beyond those implemented during the current term license would be warranted. This is a Category 1 issue.

4.7.3.4 Social Services

Information from case study sites and the literature support a determination of only small impacts on local social services associated with past operations. Impacts to social services during license renewal would be essentially the same as those that have occurred during past operations and would be of small significance at all sites. These impacts could be mitigated by hiring additional staff to administer existing social service programs or establishing new social service programs. However, because no change in the level of services is anticipated and because mitigative measures would be costly, no mitigation measures beyond those implemented during the current term license would be warranted. This is a Category 1 issue.

4.7.3.5 Public Utilities

Overall, there have been minimal impacts to public utilities as a result of plant operations. The existing capacity of public utilities was sufficient to accommodate the small influx of plant staff, and some locales experienced a noticeable decrease in the level of demand for services with the completion of original plant construction. Although impacts to public utilities during license renewal would be very similar to those that occurred during past operations, an increased problem with water availability may occur in conjunction with plant demand and plant-related population growth as a result of current water shortages in some areas. These shortages may result in moderate impacts to public water supplies at sites with limited water availability. This is a Category 2 issue.

4.7.3.6 Tourism and Recreation

Impacts to recreation and tourism during the license renewal term would be largely the same as those that have occurred during operations in the current term. Few or no adverse effects have occurred during current operations at the case-study sites, and some positive effects have resulted because taxes paid by the plants have allowed some municipalities to improve their recreational facilities and programs. Some plants have also increased local tourism. Based on the case study analysis, it is projected that any adverse impacts would be small at all plants and would primarily be the continuation of impacts of past operations. Some positive impact to tourism and recreation also may continue. These impacts could be mitigated by improving existing recreation facilities or adding recreation areas to meet the expanded demand. Because current facilities would be adequate to accommodate local demand and adding new facilities would be costly, no mitigation measures beyond those implemented during the current term license would be warranted. This is a Category 1 issue.

4.7.4 Off-Site Land Use

This section evaluates the impact of plant-induced changes on local land-use and development patterns produced by plant operation during the license renewal term. Detailed definitions of the three magnitudes of land-use change are provided in Section 3.7.5.1. The magnitude of change to off-site land use is considered small if very little new development and minimal changes to an area's land-use pattern result. Moderate change results if considerable new development and some changes to the land-use pattern occur. The magnitude of change is large if large-scale new development and major changes in the land use pattern occur. During the renewal term, new land-use impacts could result from plant-related population growth or from the use by local governments of the plants' tax payments to provide public services that encourage development. This analysis examines the land-use changes associated with past operations to project the potential new impacts of operations during the license renewal term. Conflicts between off-site land use and nuclear plant operations are not expected because federal regulations (10 CFR Part 54) require each licensee to ensure that its nuclear plant remains appropriately protected from any site-related hazards (e.g., airplanes, toxic gases), new or existing at the time the plant was licensed.

4.7.4.1 Analysis

In most cases, the land-use changes that have resulted from operations at the case study plants have been moderate (see Table 4.14 and Appendix C). However, local property tax payments that the utility makes on its nuclear plants have stimulated large indirect land-use changes in one study area because the local jurisdictions has been able to provide the public services (e.g., sewer and water lines, roads) necessary to support substantial industrial development.

For population-driven land-use impacts, the impact predictors are the same as those discussed for refurbishment (Section 3.7.5). The assessment of new tax-driven land-use impacts considered (1) the size of the plant's tax payments relative to the community's total revenues, (2) the nature of the community's existing land-use pattern, and (3) the extent to which the community already has public services in place to support and guide development. In general, if the plant's tax payments are projected to be small relative to the community's total revenue, new tax-driven land-use changes during the plant's license renewal term would be small, especially where the community has preestablished patterns of development and has provided adequate public services to support and guide development. If the plant's tax payments are projected to be medium to large relative to the community's total revenue, new tax-driven land-use changes would be moderate. This is most likely to be true where the community has no preestablished patterns of development (i.e., land use plans or controls) or has not provided adequate public services to support and guide development in the past, especially infrastructure that would allow industrial development. If the plant's tax payments are projected to be a dominant source of the community's total revenue, new tax-driven land-use changes would be large. This would be especially true where the community has no preestablished pattern of development or has not provided adequate public services to support and guide development in the past.

It is projected that population growth related to worker in-migration in the license renewal term would result in small land-use impacts for all of the socioeconomic case study areas (see Appendix C). In contrast, it is projected that new tax-driven land-use impacts would be large at one case study site and moderate at the others during the license renewal term.

4.7.4.2 Conclusion

Based on predictions for the case study plants, it is projected that all new population-driven land-use changes during the license renewal term at all nuclear plants will be small because population growth caused by license renewal will represent a much smaller percentage of the

Table 4.14 Levels of operations-related land-use change at seven case study sites

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

[a]Change due to tax-related impacts.
Source: The staff.

local area's total population than has operations-related growth. Also, any conflicts between offsite land use and nuclear plant operations are expected to be small. In contrast, it is projected that new *tax-driven* land-use changes may be moderate at a number of sites and large at some others. Because land use changes may be perceived by some community members as adverse and by others as beneficial, the staff is unable to assess generically the potential significance of site-specific off-site land use impacts. This is a Category 2 issue.

4.7.5 Economic Structure

The effects of plant operations during the license renewal term on local employment are predicted by comparing the projected number of direct and indirect jobs created during the license renewal term at a plant with projected total employment for the appropriate study area. Relatively few *new* plant-related jobs would be created 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.

4.7.5.1 Definition of Significance Levels

A detailed explanation of levels of impact significance is in Section 3.7.6.1. Economic effects are small if plant-related employment accounts for <5 percent of total study area employment, moderate if it accounts for 5 to 10 percent, and large if it accounts for more than 10 percent of total study area employment. In summary, the relevant workers are those involved in plant operation, including both new and existing workers. Also, if the magnitude of plant-related employment relative to total study area employment is close to the upper bound for a particular significance level, the impact should be placed in the next higher significance category if the site is remotely located and has a low population density. A site is considered remote if, within a distance of 80 km (50 miles), there is no city with more than 100,000 persons. Low population density is less than 50 persons per 2.6 km^2 (1 square mile). This adjustment factor is necessary to determine the importance of plant employment to the local area in light of its proximity to other areas with competing employment opportunities.

4.7.5.2 Analysis

The economic impacts that have resulted from operating the case study plants range from small to large (see Table 4.15 and Appendix C). Plant-related employment ranges from less than 1 percent to 18 percent of total employment in the communities near the case study plants.

The economic impacts projected to occur during the license renewal term would be primarily a continuation of impacts that already have occurred. At most case study sites, the share of total local employment represented by plant-related employment will be the same as or slightly less than that during current operations (Table 4.15).

4.7.5.3 Conclusion

Based on the findings for the case study sites, economic impacts would be beneficial at all nuclear plant sites. These beneficial impacts would range from small to large.

Table 4.15 Current and projected employment effects of plant operation for the sites in the case study[a]

	Current operations		License renewal term operations	
Plant	Percentage of study area employment[b]	Magnitude of impact	Percentage of study employment[b]	Magnitude of impact
Arkansas Nuclear One	12	Large	8.9	Large
D. C. Cook				
Bridgman/Lake Township	8	Moderate	8.1	Moderate
Berrien Co.	2	Small	1.8	Small
Diablo Canyon	2	Small	1.2	Small
Indian Point	< 1	Small	< 1.0	Small
Oconee	7	Moderate	3.6	Small
Three Mile Island	13	Large	9.8	Large
Wolf Creek	18	Large	7.1	Moderate

[a]Includes the effect of direct *and* indirect jobs and income created by plant operations.
[b]By place of residence.
Source: Appendix C.

4.7.6 Aesthetic Resources

This section evaluates the impacts on aesthetic resources from continued operation during an extended license renewal period. Significance levels of impacts are the same as those described in Section 3.7.8. The analysis of aesthetic impacts focuses on the visibility and perception of the plants' buildings, particularly containment structures and cooling towers and their associated water vapor plumes. These site features are often visible from neighborhoods, roads, and recreation-based water bodies over a wide area. However, no new visual changes are expected during the renewal term, and impacts primarily would be those that currently exist and would change only as the public's perceptions changed or as new information about affected resources arose.

The evaluation of impacts of past power plant operations and projected future impacts on aesthetic resources involved the following: (1) staff examination of local perceptions at the seven case study sites, as reported by key informants; (2) a brief survey of the original and eventually realized aesthetic impacts at other operating nuclear power plants; (3) a survey of relevant academic literature; and (4) a review of recent newspaper and magazine articles related to these issues. In addition, the staff reviewed several final environmental impact statements prepared by NRC for plants located in areas where aesthetic impacts were perceived to be an important issue: the Indian Point Nuclear Power Plant, located in the lower Hudson River Valley in New York (NUREG-0042, NUREG-0574, Jones and Jones 1975); the Greene County Nuclear Plant in the mid-Hudson River Valley (NUREG-0512); the Montague Nuclear Plant, in north Central Massachusetts (NUREG-0084); and Floating Nuclear Plant, an offshore location (NUREG-0394). Finally, the staff reviewed research sponsored by NRC that developed an econometric model for explaining and predicting visual aesthetic impacts.

4.7.6.1 Analysis

Nuclear power plants—particularly those with natural draft cooling towers—stand out starkly from their backgrounds both physically and symbolically. Their containment buildings and, when present, their hyperbolic cooling towers mark these industrial facilities as decidedly different, although their novelty typically appears to wear off for people who view them repeatedly.

Nuclear plants are usually situated in open areas near bodies of water, rendering cooling towers even more visible. Although they are visible from as far away as 10 miles, the structures are typically partially obscured by trees, buildings, or even slight changes in topography. There are few environments where such structures are perceived as well integrated with surrounding landscapes. Additionally, the visible vapor plumes associated with cooling towers can rise more than 5000 ft above the towers and extend as far as 9 miles downwind. Such a presence, although visible only part of the time under certain meteorological and seasonal conditions, extends the plant-related viewshed considerably beyond that of a tower alone.

At Indian Point, opposition to the plant is difficult to separate from opposition to its effect on aesthetic values, which, according to critics, have been diminished by the plant (K. Kennedy; D. Samson; N. Castro; D. Clyde; L. Gobrecht; K. Sauer telephone interviews with James Saulsbury, June 22, 1990). However, based on a viewshed analysis by landscape architects, the plant is either not visible from or is only insignificantly visible from historical sites in the area (Jones and Jones 1975). The plant is visible from the Peekskill Waterfront, from the Stoney Point Marina, from several established areas in Buchanan and Peekskill, and from approaches on the Hudson River (NUREG-0574). Although opposition to a nuclear facility and aesthetic concerns may both be issues in Westchester County, New York, it appears to be far from the situation in South Carolina (Oconee) and Kansas (Wolf Creek). Structures of the D. C. Cook plant (Michigan) and the Diablo Canyon plant (California) are sufficiently hidden or integrated into the existing landscapes that it is difficult to generalize about the public's attitude toward effects on aesthetic resources. The surrounding community seems generally well accustomed to the Arkansas Nuclear One plant in rural Arkansas and has some reservations only about the cooling tower and plume. The 1979 accident at the Three Mile Island plant (Pennsylvania) illustrates how attitudes seem to have directly affected aesthetic preferences (see Appendix C).

From the analysis of the case study plants (summarized in Table 4.16), perceptions of adverse impacts on aesthetic resources from the continued operation of nuclear power plants are probable in limited circumstances. Such circumstances would include areas that have concentrated aesthetic resources within a plant's viewshed or areas where past associations with a plant could diminish one's enjoyment of the physical environment. But even in these circumstances, the staff has not found clear and widespread evidence of adverse consequences to community institutions and functions that would justify characterizing a site as having a large impact.

Among the case study sites, Wolf Creek, Three Mile Island, Oconee, and Diablo Canyon all have had some impacts on prehistoric sites. At Wolf Creek, the presence of the nuclear power plant was credited as a positive force in local preservation efforts because (1) it brought new people into the area, who in turn influenced local citizens regarding the value and benefits that support of historic preservation could bring to a community, and (2) the increased incomes and expanded work force resulted in some neglected structures becoming occupied and repaired (M. Sirico; M. Reams telephone interviews with James Saulsbury, June 22, 1990).

Historic and archaeological resources can vary widely from site to site. Furthermore, they may have been identified only recently (e.g., an archaeological site) or their historic significance only recently established (e.g., a historic building). For these and other reasons, the National Historic Preservation Act of 1966 requires that the agency undertaking a major action consult with the State Historic Preservation Office to determine whether historic resources exist on or near the site and whether they will be affected by the proposed action.

4.7.6.2 Conclusion

The staff believes that the case studies and the other sources of information consulted have bounded the impacts of continued operation of nuclear power plants on aesthetic resources. Under the proposed provisions of license renewal, no applicant is expected to alter the existing visual intrusiveness of any plant. Certainly, the staff expects that some individuals at nuclear plant sites would perceive the plant structures and vapor plumes negatively. These perceptions will be based on purely

Table 4.16 Summary of past and projected impacts on aesthetic resources from operation of seven nuclear power plants in the case study

Impact predictors	Arkansas Nuclear One	D. C. Cook	Diablo Canyon	Indian Point	Oconee	Three Mile Island	Wolf Creek
Plant located near physical or environmental contexts memorialized in popular or professional media	No	No	No	Yes	No	No	No
Plant viewed as decidedly obtrusive into existing landscape	Somewhat	No	No	Yes	No	Yes	No
Active, widely shared, organized opposition to plant's operation because of plant's decided obtrusiveness	None	None	None	None	None	None	None
Measurable socioeconomic impact resulting from decreased aesthetic enjoyment of environment	No	No	No	Limited	No	Limited	No
Significance of past and projected impacts[a]	Insignificant	Insignificant	Insignificant	Moderate	Insignificant	Moderate	Insignificant

[a]Impacts during the license renewal term are expected to be the same as those experienced during past operations unless new information arises or there is a change in the context in which the plant operates.

Source: Appendix C.

aesthetic considerations (for instance, that the plant is out of character or scale with the community), on environmental and safety concerns, or on an anti-nuclear orientation. Whatever the consideration, the staff believes that these individuals' enjoyment of the environment will be depreciated. However, because license renewal will not alter the visual intrusiveness of any plant, the number of individuals having negative perceptions would probably remain constant. The number of such individuals has not been sufficient to measurably impact community institutions and functions in the past, so the staff believes that the impacts on aesthetic resources would be small in the future. For these individuals, mitigation through the use of nonreflective surfaces and tree plantings would be impractical from both efficiency and cost-benefit perspectives; therefore, no mitigation measures beyond those implemented during the current term license would be warranted. The impact on aesthetic resources is a Category 1 issue.

4.7.7 Historic and Archaeological Resources

This section evaluates potential impacts of license renewal term operations to historic and archaeological resources.

4.7.7.1 Definition of Significance Levels

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

4.7.7.2 Analysis

Impacts to historic and archaeological resources during the license-renewal term would be largely the same as those occurring during the current operations period. At the case-study sites, only small impacts are known to occur. However, any construction activity during the license renewal term, such as building a new waste storage facility or a new access road to a transmission corridor, could induce new impacts. Also, it is possible that previously unknown historic and archaeological resources will be identified or their historic significance will be established in the future. As discussed at length in Section 3.7.7, a determination of impact to historic and archaeological resources must be made through consultation with the SHPO as mandated by the National Historic Preservation Act.

4.7.7.3 Conclusions

Although it is unlikely that historic or archaeological impacts of moderate or large significance would occur during the license-renewal term, determinations of impacts to historic and archaeological resources are site-specific in nature and must be made through consultation with the SHPO. Any mitigation measures must likewise be determined on a case-by-case basis. Because site-specific and activity-specific information is needed to assess the significance of impacts to historic and archaeological resources, this is a Category 2 issue.

4.8 GROUNDWATER USE AND QUALITY

4.8.1 Groundwater Use

Those nuclear plants that use groundwater may affect the utility of groundwater to neighbors. This impact could occur as a direct effect of pumping groundwater, thereby either lowering the water table and reducing the availability or inducing infiltration of water of lesser quality into the ground. Neighboring groundwater users could also be affected indirectly if construction or operation of the power plant were to disrupt the normal recharge of the groundwater aquifer. The impact to neighboring groundwater users is likely to be most significant at a site where water resources are limited. Groundwater usage impact may be important at those sites where a power plant's usage rate exceeds 0.0063 m^3/s (100 gpm). Lower usage rates are not expected to impact sole source or other aquifers significantly.

Groundwater is not used at all nuclear power plants, and where it is used, the rate of usage varies greatly among users. Only Grand Gulf uses groundwater as a source of makeup to the condenser cooling system. This largest user employs a Ranney well collection system to draw groundwater from the Mississippi River alluvial aquifer. Other plants use lesser amounts of groundwater for service water systems or for potable water. Some licensed plants intentionally lower the groundwater table, either by pumping or by a system of drains, in the vicinity of building foundations.

The groundwater-use issue was evaluated by examining the groundwater requirements of appropriate subsets of nuclear power plants. Four subsets were established to encompass the entire scope of groundwater-use issues as described above. One subset consists of sites in regions where the water table or artesian water levels historically have been falling for a number of years (Atlantic and Gulf coastal plains, upper Midwest, Arizona, and California). A second subset consists of sites on both high ground and low-lying areas adjacent to the Great Lakes, the Atlantic and Gulf coasts, and the lower Mississippi River where extensive operational dewatering systems may have been installed. A third subset consists of plants with cooling towers adjacent to small rivers. The fourth subset consists of the only plant using groundwater for cooling tower makeup water.

Data were taken from appropriate final safety analysis reports (FSARs) and final environmental statements (FESs) pertaining to operation of nuclear power plants, and sites having potential groundwater-use conflicts were identified. Appropriate state water-use permitting agency representatives and U.S. Geological Survey (USGS) personnel were interviewed by telephone for additional information. Evaluations and conclusions for each of these groundwater-use scenarios are presented separately in the following discussion.

4.8.1.1 Potable and Service Water

Only one of the upper Midwest sites examined withdraws more than 0.0063 m^3/s (100 gal/min) of groundwater for potable and service water systems [Duane Arnold is permitted to withdraw 0.19 m^3/s (3000 gal/min) by the Water Supply Section, Environmental Protection Division, Iowa Department of Natural Resources]. Other plants (Braidwood, Cook, Dresden, Kewaunee, La Salle, Point Beach, and Zion) in the upper Midwest withdraw small amounts 19×10^{-5} to 536×10^{-5} m^3s (3 to 85 gal/min) of groundwater for potable water systems, or none at all. Except for Duane Arnold, all service water systems are supplied by alternative resources (municipal water systems, lakes, or rivers).

Several Atlantic and Gulf coastal plain sites that are not near municipal water suppliers withdraw larger amounts of groundwater than the upper Midwest sites for potable and service water systems. Withdrawals for these sites (Calvert Cliffs, Crystal River, Hope Creek, Salem, and River Bend) range from 0.025 to 0.050 m^3/s (400 to 800 gal/min). Other coastal sites (Turkey Point, St. Lucie, and Waterford) obtain potable and service water from municipal suppliers.

Only one of the two western sites withdraws groundwater for potable and service water systems. The Palo Verde site in Arizona withdraws 0.063 m^3/s (1000 gal/min) from a confined aquifer.

Many plants use groundwater only for potable water systems and require less than 0.0063 m^3/s (100 gal/min). The cones of depression around such wells generally remain within the plant boundary (typically the case for upper Midwest sites). Where the cone of depression does not extend beyond the site boundary, the plant groundwater use is not expected to contribute to cumulative impacts on groundwater supply. For sites having plant wells that produce more than 0.0063 m^3/s (100 gal/min) (sites that draw both service and potable water from wells), cones of depression may extend beyond the plant boundary. For these sites, a reasonable likelihood exists that off-site private wells will be impacted. The staff considers plant contributions to groundwater use to be of small significance where the plant groundwater consumption is less than 0.0063 m^3/s (100 gal/min).

The effect of groundwater usage on neighboring groundwater users will depend on the rate of usage and the distance to the neighboring well. A neighboring well close to the well field of a plant using a large amount of groundwater could experience some decline in yield. The power plants using groundwater are generally remotely located, and groundwater is not thought to be a limited resource. Conflicts that do arise should be resolvable by taking steps to restore yield of the affected water supply, such as deepening the affected wells.

In conclusion, this is a Category 1 issue for those plants using less than 0.0063 m^3/s (100 gal/min) of groundwater for potable and service water. At this usage rate, there would be no significant depletion of the groundwater supply which could impact other users. Because the cone of depression would not extend beyond the site boundary, mitigation is not warranted. However, if use exceeds 0.0063 m^3/s (100 gal/min), there is a possibility of moderate or large adverse effects, and mitigation may be warranted. Therefore, this is a Category 2 issue for those plants using more than 0.0063 m^3/s (100 gal/min) of groundwater.

4.8.1.2 Operational Dewatering Systems

Operational dewatering systems are in place at the Perry site (on a bluff overlooking Lake Erie) and the Calvert Cliffs site (on a bluff overlooking Chesapeake Bay). The Perry site is actively dewatered by pumping wells, and the water table is depressed by more than 15 m (50 ft). During construction dewatering, the cone of depression extended outward about 150 m (500 ft) (it remained inside the site boundary). Less vigorous pumping is required during operational dewatering, and the cone of depression is reduced. If pumping were discontinued, the water table would rise approximately 6 m (20 ft), groundwater would continue to drain passively through a gravity drain system, and the cone of depression would continue to shrink. The Calvert Cliffs site is passively dewatered by an underdrain system (natural gravity flow). The base of the reactor containment structure at Calvert Cliffs is more than 6 m (20 ft) below sea level, whereas the water table is maintained several feet above sea level. There is no impact to neighboring groundwater users at either of these sites.

None of the sites in low-lying areas of the Atlantic coastal plain had operational dewatering systems (i.e., Hope Creek, Millstone, Oyster Creek, St. Lucie, and Turkey Point). At St. Lucie, a construction site dewatering system [pumped at 0.80 m^3/s (13,000 gal/min)] was decommissioned before the plant was placed in operation. The St. Lucie construction/ operation case history is typical of plants in low-lying areas.

For other sites using active dewatering systems (systems in which groundwater is pumped from the aquifer), the same bounding conditions apply as for groundwater use in potable and service water systems. That is, for operational dewatering systems that do not exceed 0.0063 m^3/s (100 gal/min), impacts would be of only small significance. Because the cone of depression would not extend beyond the site boundaries, no mitigation measures beyond those implemented during the current term license would be warranted. For plants that withdraw more than 0.0063 m^3/s (100 gal/min), the significance of the groundwater withdrawal cannot be determined generically. Groundwater use through operational dewatering is a Category 2 issue.

4.8.1.3 Surface Water Withdrawals for Cooling Towers

Many plants located on small rivers have cooling towers. Rivers often supply alluvial aquifers, and large-scale withdrawals of makeup water for evaporative loss could impact an alluvial aquifer during periods of low flow. However, withdrawal from the river is regulated by local or state agencies.

For example, the withdrawal of water at Duane Arnold is restricted at low flow (Water Use Permit). Under normal flow conditions, Duane Arnold withdraws 1.6 m^3/s (27,000 gal/min) from the Cedar River as cooling tower makeup water. This plant continues to operate, at least temporarily, during low flow by withdrawing water from a standby reservoir on a tributary to Cedar River. This reservoir is used only during emergencies when low-flow conditions exist on the Cedar River.

Indirect groundwater-use conflict resulting from surface water withdrawal from a small river for use in cooling towers is a potentially important concern. Because the significance of these conflicts cannot be determined at this time, this is a Category 2 issue.

4.8.1.4 Use of Groundwater for Cooling Tower Makeup

The Ranney wells at Grand Gulf withdraw groundwater from Mississippi River alluvium at a rate of 1.5 m^3/s [24,000 gal/min (34 million gal/day)] for use as cooling tower makeup water to avoid the aquatic effects of a surface water intake. Groundwater in Mississippi River alluvium is used primarily for irrigation and catfish farming (Jamie Crawford, Mississippi Bureau of Land and Water Resources, telephone interview with W. P. Staub, ORNL, Oak Ridge, Tennessee, December 3, 1990). Generally, groundwater from the alluvial aquifer is too high is iron content to be used for municipal water supplies.

The impact of cooling water intake on groundwater at the Grand Gulf plant (the only plant employing Ranney wells) does not conflict with other groundwater uses in the area. However, conflicts could develop if other uses develop (e.g., additional catfish farms). Because it is not possible to predict whether conflicts will occur at Grand Gulf or the significance of impacts associated with Ranney well use at other plants (if they were to adopt their use), it is not possible to determine the significance of Ranney well use at this time. This is a Category 2 issue.

4.8.2 Groundwater Quality

Impairment of groundwater quality could occur at estuary and ocean site facilities that withdraw groundwater for any purpose (e.g., potable and service water systems, operational dewatering). Long-term pumping of groundwater from coastal plain aquifers by industrial and municipal facilities has contributed to saltwater intrusion in some areas of nearly every Atlantic and Gulf Coast state (USGS 1990). The saltwater intrusion issue was evaluated by examining groundwater use at selected nuclear power plants sited on estuaries and oceanic coastlines. Operational dewatering is not taking place at any of the estuaries or coastal sites.

Groundwater quality could also be impaired at inland sites where groundwater may be replaced by poorer quality river water through induced infiltration (NUREG-0777). Potential impairment of groundwater quality at facilities that have large cooling ponds is discussed in Section 4.8.3.

At this time, no licensed plant is located on a sole-source aquifer (i.e., sole or primary source of water supply for an area). If a site occupied by one of the licensed nuclear plants were in an area designated as a sole-source aquifer, NRC would cooperate with responsible agencies in making required information available. Under the provisions of the SDWA, states must establish demonstration programs for protection of critical aquifers.

Slightly elevated concentrations of tritium have been observed in groundwater adjacent to the Prairie Island plant on the Mississippi River in southern Minnesota (Minnesota Environmental Quality Board 1991; Minnesota Department of Public Service 1992). These elevated concentrations have not altered the current use of groundwater near the site. One off-site privately owned well has reported tritium concentrations ranging between 800 and 1000 pCi/L (dates of measurements are uncertain, but they are no more recent than 1991). By comparison, tritium concentrations in North American streams were about 10 pCi/L prior to the beginning of the nuclear age and about 4000 pCi/L at the end of large-scale atmospheric testing of nuclear weapons in 1963. Radioactive decay of tritium between 1963 and 1992 would produce a concentration of about 715 pCi/L (DOE 1992). If tritium concentrations at Prairie Island were as high as 1000 pCi/L in 1992, then perhaps one-third of the tritium contamination found in local groundwater might be attributable to the Prairie Island plant and the balance would be attributable to atmospheric testing. Future radioactive decay of tritium would further reduce its overall concentration in groundwater. Natural decay and tritium release to the environment at Prairie Island might be expected to reach equilibrium eventually at around 300 pCi/L. This compares with a regulatory limit of 20,000 pCi/L in drinking water.

Data were taken from appropriate FSARs and FESs pertaining to the operation of nuclear power plants. Sites having a potential impact on groundwater quality were identified; appropriate state water-use permitting agency representatives and USGS personnel were interviewed by telephone for additional information. Groundwater quality impacts are considered to be of small significance when the plant does not contribute to changes in groundwater quality that would preclude current and future uses of the groundwater. Hence, the contribution of plant operations (during the license renewal period) to the cumulative impacts of major activities on groundwater quality would be relatively small.

4.8.2.1 Potable and Service Water

Groundwater withdrawals in estuary and oceanic areas can cause saltwater intrusion into freshwater aquifers. Saltwater intrusion, where it occurs, is the cumulative effect of groundwater consumption by users in the affected region and therefore could have a cumulative impact on groundwater quality. Estuary and oceanic sites located in rural areas withdraw groundwater from confined aquifers at rates between 0.025 and 0.063 m^3/s (400 and 1000 gal/min) (e.g., for Calvert Cliffs, Crystal River, and Hope Creek–Salem). In contrast, sites located near urban areas purchase water for their potable and service water systems from municipal suppliers (e.g., Millstone, St. Lucie, and Turkey Point), which themselves use groundwater resources. Directly or indirectly, all nuclear power plants in Florida derive their potable and service water supply from groundwater. The staff considers nuclear plant contributions to saltwater intrusion to have small significance on groundwater quality where the plant's groundwater consumption is less than 10 percent of the regional total.

Withdrawal of potable and service water at nuclear power plants represents a small percentage of county-wide water supplies derived from groundwater in both urban and rural counties of Florida. According to Marella (1988, data for 1985), 2.98 and 21.3 m^3/s (68 and 486 million gal/day) of groundwater were withdrawn for all uses in semi-urban St. Lucie and urban Dade Counties where the St. Lucie and Turkey Point plants are located, respectively. Both of these plants purchase about 0.063 m^3/s [1.4 million gal/day (1000 gal/min)] from municipal sources in these counties. About 1.09 m^3/s (25 million gal/day) of groundwater were withdrawn in rural Citrus County, compared with

1.4 million gal/day withdrawn by Crystal River plant wells in that county. Nuclear plant groundwater consumption at its current rate would not contribute significantly to any future saltwater intrusion that might occur.

Ken Miller (Maryland Water Resources Administration, Water Rights Division, telephone interview with W. P. Staub, ORNL, Oak Ridge, Tennessee, November 28, 1990) believes that saltwater intrusion of the Aquia aquifer, which serves the Calvert Cliffs plant, is unlikely. He bases his conclusion on the fact that this aquifer is confined and changes to an aquitard on its downdip (seaward) side as illustrated in USGS (1988) and Chapelle and Drummond (1983).

Geologic conditions as described above are site specific. The USGS (1988) states that the Raritan-Magothy aquifer in New Jersey is susceptible to saltwater intrusion and is already contaminated in some places. However, based on data for Florida, power plant groundwater consumption ranges from about 0.3 percent to 6 percent of the total in urban and rural regions, respectively. Saltwater intrusion is more likely to occur in urban regions because of the greater demand for water, and electric power generation would be a small contributor.

The potential for inducing saltwater intrusion is considered to be of small significance at all sites because groundwater consumption from confined aquifers for potable and service water uses by nuclear power plants is a small fraction of groundwater use in all cases. Where saltwater intrusion has been a problem, the large uses have been agricultural (irrigation) and municipal groundwater consumption. Mitigation for saltwater intrusion, if needed, would likely take the form of groundwater withdrawal curtailments. Because nuclear plant water consumption represents a small fraction of total consumption, consumption curtailments of large groundwater users (i.e., municipal or agricultural users) are more likely. Consequently, groundwater use curtailments are not expected to be warranted for nuclear plants to mitigate saltwater intrusion impacts. However, even if pro-rata curtailments of groundwater consumption were required of all users, nuclear plants could accommodate most conceivable reductions without adversely affecting their operations. Therefore, this is a Category 1 issue.

4.8.2.2 Groundwater Withdrawal at Inland Sites

Grand Gulf uses large quantities of groundwater from an alluvial aquifer as described in Section 4.8.1.4. Geohydrologic modeling has predicted that groundwater would be replaced by river water of lesser quality by induced infiltration (NUREG-0777). A groundwater monitoring system is currently being installed at Grand Gulf, but no data are currently available to validate the model. Nevertheless, the model's prediction is reasonable.

The net flow of the infiltrating river water will be into the Grand Gulf Ranney well collectors. Thus, water quality change will be largely confined to the plant. Any other users of groundwater from the same formation would induce infiltration in a similar manner. The quality of Mississippi River water would not preclude the current uses of the groundwater from the alluvium. Long-term use of Ranney wells may cause groundwater quality to approach the water quality of the adjoining river. Therefore, the change in water quality resulting from use of Ranney wells would be of small significance at any site. The only possible mitigation for a plant using Ranney wells would be to construct and operate a water intake structure in the nearby water body. However, because the change in groundwater quality would not preclude current and future uses and because building a surface water intake structure would be costly and have adverse environmental effects of its own (Sect. 4.8.1.4), no mitigation measures beyond those implemented during the current term license would be warranted. This is a Category 1 issue. Because groundwater quality level would never be lower than that of the nearby Mississippi River, groundwater withdrawal for Grand Gulf's use would not contribute significantly to the cumulative impacts of water infiltration into the aquifer.

4.8.3 Groundwater Quality Impacts of Cooling Ponds

Alteration of groundwater quality in shallow, unconfined aquifers may occur at the nine nuclear power plant sites that use cooling ponds (Section 4.4.1). Irrigation and private domestic water supplies are the principal off-site uses of these groundwater resources. This issue was evaluated by examining off-site land uses and potential for shallow groundwater utilization at all nine sites. The impact on private uses of groundwater was subdivided into two sets based on current land use: (1) sites surrounded by undeveloped land, including saltwater marshes, and (2) sites adjacent to farmland. Short- and long-term potential for utilization of shallow groundwater resources depends on current land use.

Four plant sites are surrounded by undeveloped land or have large exclusion areas around them. These plants are Clinton (large exclusion area), Dresden (surrounded by undeveloped woodlands), South Texas, and Turkey Point (surrounded by saltwater marshes). Although off-site groundwater is not being used currently near these sites, its long-term use is not necessarily precluded.

The remaining five sites have relatively small exclusion areas and are adjacent to farmland. These plants are Braidwood, La Salle, Robinson, Summer, and Wolf Creek. A limited amount of off-site groundwater is being used currently or could potentially be used at these sites in the near term.

All of the cooling ponds are unlined and have surface areas that range from 637 to 2960 ha (1573 to 7310 acres). Cooling pond water has higher concentrations (than makeup water) of total dissolved solids due to evaporation, heavy metals due to contact of cooling water with plant equipment, and chlorinated organic compounds used to prevent biofouling of equipment. The average concentration of total dissolved solids in continuously recycled cooling pond water is about 2.8 times as large as that in makeup water.

Water seeping from these ponds commingles with underlying shallow groundwater and produces a groundwater mound. Groundwater spreads laterally away from this mound. The commingled groundwater will eventually reach off-site areas. At this point, groundwater quality will be between that of the cooling pond water and the quality of the naturally occurring groundwater. These groundwater contaminant plumes are not expected to alter current groundwater-use categories (as defined by various state regulatory agencies) because contaminant concentrations are not expected to rise significantly. However, groundwater quality is not routinely monitored for contaminants specific to cooling ponds.

Depending on groundwater velocity and adsorption characteristics, some contaminants (diluted by dispersion in natural groundwater) may reach off-site areas during the initial term of the license. As plant operation continues, groundwater quality at points near the site may approach the quality of the cooling pond water. If necessary, mitigation of groundwater contamination due to cooling pond operations might take the form of lining the ponds to reduce infiltration or cleaning groundwater by pumping and treating, both of which would be costly.

The extent of groundwater contamination by cooling ponds has not been documented at this time. Off-site groundwater monitoring is not standard practice at these sites, and there are no data with which to characterize the significance of potential off-site groundwater contamination. For those plants with cooling ponds located in a salt marsh (South Texas and Turkey Point), groundwater quality is not a significant concern because groundwater quality beneath salt marshes is too poor for human use. Because continued infiltration into the shallow aquifer will not change its groundwater use category (which is already restricted to industrial uses only) and because potential mitigation measures would be costly, no mitigation measures beyond those implemented during the current term license would be warranted. Therefore, for plants with cooling ponds located in salt marshes, this is a Category 1 issue. Groundwater in salt marshes is already restricted to industrial use, and there is no mechanism by which cooling pond water infiltrating into the groundwater would change its use category. The impact on groundwater quality for plants with cooling ponds that are not located in salt marshes is a Category 2 issue.

4.9 SUMMARY OF IMPACTS OF OPERATION

The conclusions about the environmental impacts of nuclear power plant operation during a license renewal term are summarized below.

Threatened and Endangered Species

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

Surface Water Quality, Hydrology, and Use

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

- The staff found no potential for water use conflicts or riperian plant and animal community impacts of moderate or large significance for plants with open-cycle cooling systems because they are used on large water bodies. Because the potential mitigation measures are costly and because the potential benefits are small, the staff does not consider mitigation to be warranted. These are Category 1 issues.
- The staff found that water use conflicts and the effects of consumptive water use on in-stream aquatic and riparian terrestrial communities could be of moderate significance at some plants that employ cooling-tower or cooling-pond systems because they are often located near smaller water bodies. For plants with these cooling systems, these are Category 2 issues.

Aquatic Ecology

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

Groundwater Use and Quality

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

- Cooling system makeup water consumption may cause groundwater use conflicts. During times of low flow, surface water withdrawals for cooling tower makeup from small rivers can reduce groundwater recharge. Because the significance of such impacts cannot be determined generically, this is a Category 2 issue.
- Groundwater withdrawals could cause adverse effects on groundwater quality by inducing intrusion of lower-quality groundwater into the aquifer. The staff found that the significance of these potential impacts are of small significance in all cases. Because all plants except Grand Gulf use relatively small quantities of groundwater and surface water intrusion at Grand Gulf would not preclude current water uses, the staff found that mitigation was not warranted. This is a Category 1 issue.
- Cooling ponds leak an undetermined quantity of water through the pond bottom. Because the water in cooling ponds is elevated in salts and metals, such leakage may contaminate groundwater. The staff found that groundwater quality impacts of ponds located in salt marshes would be of small significance in all cases because salt marshes already have poor water quality. This is a Category 1 issue. Cooling ponds that are not located in salt marshes may have groundwater quality impacts of small, moderate, or large significance. This is a Category 2 issue.

Air Quality

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

Terrestrial Ecology

- The potential impact of cooling tower drift on crops and ornamental vegetation arising from operations during the license renewal term is expected to be of small significance for all nuclear plants. No mitigation measures beyond those implemented during the current license term are warranted because there have been no measurable effects on crops or ornamental vegetation from cooling tower drift. This is a Category 1 issue.
- The impact of cooling towers on natural plant communities would continue to be unmeasurable as a result of license renewal and will therefore be of small significance. Because the impacts of cooling tower drift on native plants are expected to be small and because potential mitigation measures would be costly, no mitigation measures beyond those during the current term license would be warranted. This is a Category 1 issue.

- Bird mortality from collision with power lines associated with nuclear plants is of small significance for all plants because bird mortality is expected to remain a small fraction of total collision mortality associated with all types of man-made objects. Because the numbers of birds killed from collision with cooling towers are not large enough to affect population stability or the ecosystem, consideration of further mitigation is not warranted. Both bird collosion with power lines and bird collision with cooling towers are Category 1 issues.
- Because no threat to the stability of local wildlife populations or vegetation communities is found for any cooling pond, the impacts are found to be of small significance. Potential mitigation measures would include excluding wildlife (e.g., birds) from contaminated ponds, converting to a dry cooling system, or reducing plant output during fogging or icing conditions. The impacts are found to be so minor that consideration of additional mitigation measures is not warranted. These effects of cooling ponds are so minor and so localized that cumulative impacts are not a concern. This is a Category 1 issue.
- Maintaining power-line ROWs causes fluctuations in wildlife populations, but the long-term effects are of small significance. The staff found that bird collision with transmission lines are of small significance. Also, transmission line maintenance and repair would have impacts of only small significance on floodplains and wetlands. In each case, the staff found that potential mitigation measures beyond those implemented during the current license term would be costly and provide little environmental benefit, and thus are not warranted. These are Category 1 issues.
- Wildlife, livestock, and plants residing in power-line EMF apparently grow, survive, and reproduce as well as expected in the absence of EMF. The potential impact of EMF on terrestrial resources during the license renewal term is considered to be of small significance for all plants. Because the impact is of small significance and because mitigation measures could create additional environmental impacts and would be costly, no mitigation measures beyond those implemented during the current term license would be warranted. This is a Category 1 issue.

Land Use

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

Human Health

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

- Among the 150 million people who live within 50 miles of a U.S. nuclear power plant, about 30 million will die of spontaneous cancer unrelated to radiation exposure from nuclear power plants. This number is compared with approximately 5 calculated fatalities associated with potential nuclear-power-plant-induced cancer. The estimated annual cancer risk to the average individual is less than 1×10^{-6}. Public exposure to radiation during the license renewal term is of small significance at all sites, and no mitigation measures beyond those implemented during the current license term are warranted because current mitigation practices have resulted in declining public radiation doses and are expected to continue to do so. This is a Category 1 issue.
- The significance of potential for electrical shock from charges induced by transmission lines that may occur during the license renewal term cannot be evaluated generically because no NESC review was performed for some of the earlier licensed plants. For those that underwent an NESC review, a change in the transmission line voltage may have been made since issuance of the initial operating license, or changes in land use since issuance of the original license could have occurred. This is a Category 2 issue.
- There is no consensus among scientists on whether 60-Hz electromagnetic fields have a measurable human health impact. Because of inconclusive scientific evidence, the chronic effects of electromagnetic fields would be not be categorized as either a Category 1 or 2 issue. If NRC finds that a consensus has been reached that there are adverse health effects, all license renewal applicants will have to address it in the license renewal process.
- Occupational health questions related to thermophilic organisms, like *Legionella* sp., are currently resolved using proven industrial hygiene principles to minimize worker exposures to these organisms in mists of cooling towers. Adverse occupational health effects associated with microorganisms are expected to be of small significance at all sites. Aside from continued application of accepted industrial hygiene procedures, no additional mitigation measures beyond those implemented during the current license term are warranted. This is a Category 1 issue.
- Thermophilic organisms may or may not be influenced by operation of nuclear power plants. The issue is largely unstudied. However, NRC recognizes a potential health problem stemming from heated effluents. Public health questions require additional consideration for the 25 plants using cooling ponds, lakes, canals, or small rivers because the operation of these plants may significantly enhance the presence of thermophilic organisms. The data for these sites is not now at hand and it is impossible with current knowledge to predict the level of thermophilic organism enhancement at any given

site. Thus, the impacts are not known and are site specific. Therefore, the magnitude of the potential public health impacts associated with thermal enhancement of *N. fowleri* cannot be determined generically. This is a Category 2 issue.

Noise

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

Socioeconomics

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

4.10 ENDNOTES

1. For example, Coleman et al. 1989; Fulton et al. 1980; Savitz et al. 1988; Spitz and Johnson 1985; Tomenius 1986; Wertheimer and Leeper 1979; Wilkins and Koutras 1988; Feychting and Ahlbom 1993; Petridow et al. 1993.
2. Anthony and Morrison 1985; Beason et al. 1982; Bunyan and Stanley 1983; Campbell et al. 1983; Castrale 1987; Wildlife No. 235; Connor and McMillan 1988; D'Anieri et al. 1987; DeFazio et al. 1988; de Waal Malefyt 1987; Freedman et al. 1988; FWS/OBS-79/22; Gangstad and Hesser 1989; Gangstad and Phillips 1989; Ghassemi and Quinlivan 1982; Hill and Camardese 1986; Hoffman and Albers 1984; Hoffman et al. 1990; Holechek 1981; Hudson et al. 1984; Kennedy and Jordan 1985; Kirkland 1978; Lautenschlager 1986; Linder and Richman 1990; Lochmiller et al. 1991; Mayer 1976; McComb and Rumsey 1982, 1983a, 1983b; Moore 1983; Morrison and Meslow 1984a, 1984b; Newton and Knight 1981; Rands 1986; Risebrough 1986; Roberts and Dorough 1984; Santillo et al., 1989a, 1989b; Savidge 1978; Schulz et al. 1992a, 1992b; Solberg and Higgins 1993; Steele 1984; Sullivan and Sullivan 1981, 1982; Thompson et al. 1991; Voorhees 1984; Walker 1983; Warren et al. 1984; White et al. 1981.
3. Anthony and Morrison 1985; Beason et al. 1988; Bunyan and Stanley 1983; Lautenschlager 1986; McComb and Rumsey 1983a; Moore 1983; Morrison