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U.S. NUCLEAR REGULATORY COMMISSION

Docket No.: 50-341

Mr. J. K. Bryan
Vice President - Nuclear
Union Electric Company
Post Office Box 149
St. Louis, Missouri 63166

Dear Mr. Bryan:

Subject: Issuance of the Draft Environmental Statement for the Callaway Plant, Unit No. 1

Two copies of the Draft Environmental Statement related to operation of the Callaway Plant, Unit No. 1 are enclosed for your use. An additional twenty copies will be forwarded when they have returned from our printer-contractor.

Sincerely,
Original signed by:
B J. Youngblood

B. J. Youngblood, Chief
Licensing Branch No. 1
Division of Licensing

Enclosure:
NUREG-0813 (2 copies)

cc: See next page

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NUREG-0813
September 1981

DRAFT ENVIRONMENTAL STATEMENT

related to the operation of

CALLAWAY PLANT UNIT 1

UNION ELECTRIC COMPANY

Docket No. 50-483

U.S. Nuclear Regulatory Commission
Office of Nuclear Reactor Regulation

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ABSTRACT

This draft environmental statement contains the second assessment of the environmental impact associated with operation of Callaway Plant Unit 1, pursuant to the National Environmental Policy Act of 1969 (NEPA) and 10 CFR Part 51, as amended, of the NRC's regulations. This statement examines: the purpose and need for the Callaway project, alternatives to the project, the affected environment, environmental consequences and mitigating actions, and environmental and economic benefits and costs. No water-use impacts are expected from cooling-tower makeup withdrawn from, or blowdown discharged into, the Missouri River. Land-use and terrestrial- and aquatic-ecological impacts will be small. Air-quality impacts from cooling-tower drift and other emissions and dust will also be small. Impacts to historic and prehistoric sites will be negligible with the development and implementation of the applicant's cultural-resources management plan. No significant impacts are anticipated from normal operational releases of radioactivity. The risk associated with accidental radiation exposure is very low. Contentions accepted during the operating-license environmental hearing as issues in controversy are related to radiological releases to the hydrosphere and atmosphere. The net socioeconomic effects of the project will be beneficial. The action called for is the issuance of an operating license for Unit 1 of the Callaway Plant.

Comments should be filed no later than 45 days after the date on which the Environmental Protection Agency notice of availability of this draft environmental statement is published in the "Federal Register."

Further information may be obtained from:

Gordon E. Edison, Licensing Project Manager
Licensing Branch 1
U.S. Nuclear Regulatory Commission
Washington, DC 20555
301/492-8563

SUMMARY AND CONCLUSIONS

This draft environmental statement, operating-license stage, was prepared by the U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation (the staff).

1. This action is administrative.

2. The proposed action is the issuance of an operating license to the Union Electric Company (UE) for the startup and operation of Unit 1 of the Callaway Plant (Docket No. STN 50-483) located in Callaway County, Missouri, on the Missouri River about 16 km (10 mi) southeast of Fulton and 130 km (80 mi) west of St. Louis.

   The plant will employ one pressurized-water reactor to produce 3425 megawatts thermal (MWt). A steam turbine-generator will use this heat to produce a nominal net output of 1120 megawatts electric (MWe). The maximum design thermal output of the unit is 3579 MWt, with a corresponding maximum calculated electrical output of 1160 MWe. The exhaust steam will be condensed by cooling water circulated through a natural-draft cooling tower; makeup and blowdown water (i.e. water to replace that lost by evaporation and water to control the buildup of dissolved solids, respectively) will be taken from and discharged to the Missouri River.

3. The evaluation in this environmental statement represents the second assessment of the environmental impact associated with the Callaway Plant pursuant to the guidelines of the National Environmental Policy Act of 1969 (NEPA) and 10 CFR Part 51 of the Commission's regulations. After receiving an application in April 1974 to construct Units 1 and 2 of the Callaway Plant, the staff carried out a review of impact that would occur during construction and operation. This evaluation was issued in March 1975 as a final environmental statement - construction phase. After this environmental review, a safety review, an evaluation by the Advisory Committee on Reactor Safeguards, and public hearings in Fulton and St. Louis, Missouri, the U.S. Atomic Energy Commission (now U.S. Nuclear Regulatory Commission) issued permit Nos. CPPR-139 and CPPR-140 on 16 April 1976 for construction of Units 1 and 2 of the Callaway Plant. As of 1 July 1981, the construction of Unit 1 was about 77% complete and Unit 2 was about 1% complete. The applicant has applied for a license to operate Unit 1 and has submitted (October 1979) the required safety and environmental reports in support of the application. The applicant estimates a fuel-loading date of October 1982 for Unit 1. Further action on Unit 2, for which the applicant currently estimates a fuel-loading date in the fourth quarter of 1987, has been deferred by the applicant. While the environmental impacts of both units are considered, this environmental statement applies to Unit 1 only.

4. On 21 April 1981, the Atomic Safety and Licensing Board issued a Special Prehearing Conference Order specifying the intervenors' contentions accepted during the operating-license hearing as issues in controversy. The issues are related to the radiological environmental impacts of operation of the Callaway Plant and are as follows:

   a. Inadequate assessment and prediction of radioactive discharges to the Missouri River, or the dilution to be afforded by the river;

   b. Impact of radioactive releases on drinking water from the Missouri River: inadequate analysis of the liquid-pathway dosage through fish;

   c. Resuspension of sediment radionuclides leading to high levels of contamination;

   d. Inadequate assessment and prediction of radioactive releases to the atmosphere; inaccurate prediction of the dispersion and fallout rate of such materials due to meteorological considerations;

   e. Inadequate monitoring of radioactive releases (particularly tritium, noble gases, and alpha, beta, and gamma emitters) when in quantities below the level of detection by commercial monitoring equipment or during accidental releases; and

   f. Inadequate estimates of annual radiological emissions by not taking into account releases from the spent-fuel pool, increased releases as the plant gets older, and decontamination procedures.

   It is not certain whether the above issues actually will be litigated during the operating-license hearing because, under the summary disposition procedures in the NRC Rules of Practice (10 CFR 2.749), matters of controversy to which there is no genuine issue of material fact can be determined by the Atomic Safety and Licensing Board rather than by conducting an evidentiary hearing.

5. The staff has reviewed the activities associated with the proposed operation of Unit 1. The potential impacts, both beneficial and adverse, may be summarized as follows:

   a. The additional generating capacity provided by operation of Unit 1 of the Callaway Plant will meet the increasing load demand of the UE system (which would otherwise reduce the UE reserve margin below the value UE is contractually obligated to provide for the Illinois-Missouri Power Pool to which it belongs), increase the system reliability, promote fuel diversification, and be less expensive than any other generation alternative (Sec. 2).

   b. A total land area of 2926 ha (7230 acres) has been purchased for the Callaway Plant. About 92 ha (228 acres) will be removed from use as farmland or terrestrial habitat by the presence and operation of the plant; the remainder will be available for a combination of uses (terrestrial habitat, recreation, farming, research), consistent with the requirements of plant operation and safety, under a land-management plan developed in cooperation with the State of Missouri. The land-use impacts will be small (Secs. 4.2.2 and 5.2).

c. All the water used for operating the plant will come from the Missouri River. The average net use by Unit 1 will be 760 L/s (12,000 gpm), which is about 0.05% of the average regulated flow and about 1% of the lowest recorded flow; therefore, no water-use impacts are expected (Sec. 5.3.1).

d. The chemical, thermal, and other waste discharges into the Missouri River will be rapidly assimilated; hence, no adverse impacts on downstream water users or aquatic biota are expected (Secs. 5.3.2 and 5.5.2). The staff expects that applicable standards, which are stated in the NPDES permit (App. B), will be met (Sec. 5.3.2.1).

e. The effect on the 100-year flood level upstream of the site due to the construction of the Callaway Plant is considered to be negligible. Since construction of the intake structure, discharge outlet, and docking facilities already had been started at the time Executive Order 11988, Floodplain Management, was signed in May 1977, it is the staff's conclusion that further consideration of alternative locations for those structures identified as being the floodplain is neither required nor practicable (Sec. 5.3.3).

f. There will be a visible plume, usually shorter than about 1200 m (4000 ft), extending from the cooling tower most of the time; however, the ground-level fogging and icing caused by this plume will be negligible (Sec. 5.4.1). Air-quality impacts from cooling-tower drift and other plant emissions and dust will be small (Sec. 5.4.2).

g. The potential for impacts on the terrestrial ecosystem, which could be caused by operation of the sludge lagoons, cooling-tower emissions, bird impaction, noise, or transmission-line effects, have been examined and found to be very small (Sec. 5.5.1).

h. The potential for impacts on the aquatic ecosystem, which could be caused by impingement or entrainment, thermal discharges, or discharges of chemical and sanitary wastes, have been examined and are expected to be small. The staff believes that the losses of aquatic biota will be small; however, the need for further mitigation of intake-related impacts must await the results of the monitoring studies required by the NPDES permit and a 316(b) determination by the State of Missouri (Sec. 5.5.2).

i. Operation of the plant will not have an adverse effect on any rare, endangered, or threatened species (Sec. 5.6).

j. A well-designed cultural-resources management plan will avoid preventable operational impacts and will assure preservation of information where disruption is unavoidable. The applicant is preparing a final research design for the completion of a cultural-resource survey that will include an assessment of identified sites and a cultural-resource management plan, which will be done in consultation with the Missouri Department of Natural Resources, Division of Parks and Historic Preservation (Sec. 5.7).

k. The staff concludes that socioeconomic benefits from the creation of direct and indirect jobs and the increase in tax benefits outweigh the small adverse impacts from land use and increased demand for community services; hence, the net socioeconomic effect will be beneficial. Noise impacts will be negligible (Sec. 5.8).

l. No significant environmental impacts are anticipated from normal operational releases of radioactive materials. The estimated maximum individual dose for a member of the public subject to the maximum exposure will be very small compared to natural-background doses (about 100 millirems per year). As a result, the staff concludes that there should be no measurable radiological impact on members of the public from routine operation of the plant (Sec. 5.9.3).

m. The staff concludes that the risk to nuclear-plant workers from plant operation is comparable to the risks associated with other occupations (Sec. 5.9.3).

n. The staff concludes that the risk associated with radiation exposure due to postulated accidents is very low, and that there are no special or unique features about the Callaway site and environs that would warrant special mitigation measures for the Callaway Plant (Sec. 5.9.4).

6. The personnel that participated in the preparation of this environmental statement and their qualifications are listed in Section 7.

7. This draft environmental statement is being made available to the agencies and organizations specified in Section 8 and to the public.

8. On the basis of the analysis and evaluation set forth in this environmental statement, and after weighing the environmental, economic, technical, and other benefits against environmental, socioeconomic, and economic costs and after considering available alternatives at the operating-license stage, it is concluded that the action called for under NEPA and 10 CFR Part 51 is the issuance of an operating license for Unit 1 of the Callaway Plant, subject to the following conditions recommended by the staff for the protection of the environment:

   a. Before engaging in additional construction or operational activities that may result in a significant adverse environmental impact that was not evaluated or that is significantly greater than that evaluated in this environmental statement, the applicant shall provide written notification of its intentions to engage in such activities to the Director of the Office of Nuclear Reactor Regulation and shall receive written approval before proceeding with such activities.

   b. The applicant shall carry out the environmental monitoring programs outlined in this environmental statement as modified and approved by the staff and implemented in the environmental protection plan and the technical specifications incorporated in the operating license for Unit 1 of the Callaway Plant (Secs. 5.4.3, 5.5.1.6, 5.5.2.4, and 5.9.3.4).

   c. If harmful effects or evidence of irreversible damage are detected during the operating life of the plant, the applicant shall provide the staff with an analysis of the problem and a proposed course of action to alleviate it.

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FOREWORD

This draft environmental statement was prepared by the U.S. Nuclear Regulatory Commission (NRC), Office of Nuclear Reactor Regulation (the staff), in accordance with the Commission's regulation, 10 CFR 51, which implements the requirements of the National Environmental Policy Act of 1969 (NEPA). It reviews the impacts of operation of the Callaway Plant Unit 1. Assessments that are found in this statement augment those described in the Final Environmental Statement - Construction Stage (FES-CP) that was published in March 1975 in support of issuance of construction permits (CP) for Callaway Plant Units 1 and 2. This review is concerned only with Unit 1, although the analyses take into account the environmental impacts of both units.

The information in the various sections of this statement updates the FES-CP in four ways: (1) by evaluating changes in plant design and operation that will result in different environmental effects of operation (including those that would enhance as well as degrade the environment) than those projected during the preconstruction review; (2) by reporting the results of relevant new information that has become available subsequent to issuance of the FES-CP; (3) by factoring into the statement new environmental policies and statutes that have a bearing on the licensing action, and factoring the results of the applicant's preoperational monitoring program into the design of an operational surveillance program and into the development of environmental technical specifications and an environmental protection plan; and (4) by identifying unresolved environmental issues or surveillance needs that are to be resolved by means of license conditions. (No unresolved environmental issues or surveillance needs have been identified in this statement for the case of the Callaway Plant Unit 1.)

The staff recognizes the difficulty a reader would encounter in trying to establish the conformance of this review with the requirements of NEPA with only updating information. Therefore, introductory résumés in appropriate sections summarize both the extent of updating the FES-CP (NUREG-75/011) and the degree to which the staff considers the subject to be adequately reviewed.

Copies of this environmental statement are available for inspection at the Commission's Public Document Room, 1717 H Street NW, Washington, DC, and at the Callaway County Public Library, Fulton, MO. Single copies may be obtained by writing to:

Division of Technical Information
Document Control Office
U.S. Nuclear Regulatory Commission
Washington, DC 20555

1. INTRODUCTION

The proposed action is the issuance of an operating license to Union Electric Company (UE) of St. Louis, Missouri, for startup and operation of the Callaway Plant Unit 1 (CAL-1) on a 1290-ha (3188-acre) site in Callaway County 16 km (10 mi) southeast of Fulton, Missouri, and 8 km (5 mi) north of the Missouri River. The generating unit consists of one pressurized-water reactor, four steam generators, one steam turbine-generator, a heat-dissipation system, and associated auxiliary and engineered safeguards. Waste heat wi ' be dissipated to the atmosphere from a natural-draft cooling tower. Makeup water will come from the Missouri River; blowdown (i.e. water released to control the buildup of dissolved solids) will go into the Missouri River downstream from the intake. The unit is designed to operate at a nominal/design-maximum thermal level of 3425/3579 MWt and to produce a nominal/design-maximum net electrical output of 1120/1160 MWe (ER-OL,* Sec. 3.2; FES-CP, Sec. 1.1). The plant is being constructed for UE, the lead applicant and agent for itself and its subsidiaries: Missouri Power and Light Company, Missouri Utilities Company, and Missouri Edison Company. UE prepared the ER-OL and will operate the plant.

1.1 ADMINISTRATIVE HISTORY

On 30 April 1974, UE (the applicant) filed an application with the Atomic Energy Commission, now Nuclear Regulatory Commission (NRC), for a permit to construct the Callaway Plant Units 1 and 2. Construction permits Nos. CPPR-139 and CPPR-140 were issued on 16 April 1976 following reviews by the Commission's regulatory staff and its Advisory Committee on Reactor Safeguards, as well as public hearings before an Atomic Safety and Licensing Board in Fulton and St. Louis, Missouri, between 8 April 1975 and 29 January 1976. The conclusions resulting from the staff's environmental review were issued as a final environmental statement for a construction permit in March 1975.

As of 1 July 1981, construction of CAL-1 was about 77% complete. UE estimates that CAL-1 will be ready for fuel loading in October 1982 (Ref. 1) and for commercial operation in April 1983 (ER-OL, Rev. 1, Sec. 1.1). At present,

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*"Callaway Plant Environmental Report, Operating License Stage," Vols. I-III, Union Electric Company, 19 October 1979. Hereinafter this document is cited in the body of the text as ER-OL, followed by a specific section or page, figure, or table number. Similar citation is made to ER-OL, Revision 1, 6 February 1981 and to ER-OL, Revision 2, Response to Questions, 6 February, 10 March, and 31 March 1981. Likewise, "Callaway Plant Units 1 and 2 Environmental Report," Vols. I-IV, Union Electric Company, 30 April 1974, which was prepared for the construction-permit evaluation, is cited as ER-CP. The "Final Environmental Statement Related to the Proposed Callaway Plant Units 1 and 2," NUREG-75/011, published in March 1975, is referred to as FES-CP.

construction of Unit-2 has been deferred by UE (about 1% of the construction work has been completed).

On 19 October 1979, UE submitted an application including a Final Safety Analysis Report (FSAR) and Environmental Report (ER-OL) requesting issuance of an operating license for CAL-1 and stating that additional information related to environmental matters for Unit 2 will be filed at a later date consistent with its scheduled completion. Thus, this environmental statement is applicable only to CAL-1. (Most of the environmental information provided by the applicant was for operation of both units. Therefore, most of the analyses presented herein have been provided for the impacts of both units. These analyses are also applicable to the operation of a single unit, because all of the two-unit impacts are greater than the corresponding one-unit impacts. However, the conclusions in this statement are applicable only to the operation of CAL-1.) The FSAR and ER-OL were docketed on 8 August 1980 and 26 November 1980, respectively. Operational safety and environmental reviews were then initiated for CAL-1.

1.2 PERMITS AND LICENSES

The applicant has provided a status listing, as of 6 February 1981, of environmentally related permits, approvals, licenses, etc. required from Federal, state, regional, and local agencies in connection with the proposed project (ER-OL, Rev. 1, Table 12.1-1). The staff has reviewed the listing and is not aware of any potential non-NRC licensing difficulties that would significantly delay or preclude the proposed operation of CAL-1. The issuance of a water-quality certification pursuant to Section 401 of the Clean Water Act of 1977 by the Missouri Department of Natural Resources is a necessary prerequisite for the issuance of an operating license by NRC. The State of Missouri has issued National Pollutant Discharge Elimination System (NPDES) Permit No. MO-0098001; it is reproduced in Appendix B.

Reference

1. Atomic Safety and Licensing Board, Special Prehearing Conference, Docket No. STN-50-483-OL, p. 21, 21 April 1981.

2. PURPOSE AND NEED FOR THE ACTION

2.1 RÉSUMÉ

The proposed action for which this environmental statement has been written is the issuance of an operating license for the Callaway Plant Unit 1 (CAL-1). CAL-1 is a pressurized water reactor and steam electric system with a design electrical rating of 1150 MW. It is wholly owned by Union Electric Company (UE), the applicant, and its subsidiaries, which are given on p. 1-1 of Section 1.

When the FES-CP was issued in March 1975, UE scheduled CAL-1 for initial operation in 1981. The applicant's current schedule calls for CAL-1 to begin operating commercially in April 1983 (ER-OL, Rev. 1, Sec. 1.1). The original date for commercial operation was predicated on an expected growth rate in electrical-energy use in the UE system of 7.2%/yr between 1975 and 1985. Projections made by the applicant in 1980 show that the average annual rate of growth (AARG) of electrical-energy use would be 3.2% between 1980 and 1985. The applicant also indicates, and the staff agrees, that this decreasing trend in demand for electrical energy will continue. The AARG of electrical-energy consumption in the United States has steadily declined from 6.1% in 1976 to 1.1% in 1980.

The staff has studied the decline in expected growth rate of electrical-energy use, and finds that it is not unique to the UE service area; it is representative of a national trend, attributable in part to higher prices for electricity, conservation, and slower economic growth than predictions for the 1980s, which were made in the late 1970s, had assumed (Ref. 1). It is within this context that the applicant has delayed commercial operation of CAL-1 until late 1983.

In this section, the staff evaluates the purpose and need for operation of CAL-1 within the context of (1) overall system production costs for generating electricity, (2) availability of alternative fuels, and (3) reliability of the power supply for the UE service area. The conclusions drawn from this review will be factored into the staff's decision regarding the issuance of an operating license for CAL-1.

2.2 PRODUCTION COSTS

CAL-1 is a pressurized water reactor and steam electric system that was constructed to provide an economical source of baseload energy. Because the substantial capital costs and environmental costs associated with construction have already been incurred, the only economic factors that are relevant for consideration now are system fuel costs and operation and maintenance (O&M) costs, because these expenses will be affected by whether or not CAL-1 operates. (Capital costs are discussed in Sec. 3.) A comparison of system production costs with and without CAL-1 available to the system shows strong economic reasons why an operating license should be issued and operating plans should proceed as scheduled.

In the staff's analysis of projected production costs, according to an economic-dispatch logic, the annual projected fuel costs for the UE system are estimated on the basis of a specified mix of generating capacity and projected energy requirements (ER-OL, Rev. 1, Sec. 1). Analyses of production costs were performed for the years 1983 through 1987, with and without CAL-1 in service. The values reported in Table 2.1 represent the staff's estimate of the annual savings in system fuel costs by having CAL-1 online per schedule versus costs that will be incurred if it is not allowed to operate. The analyses assume that if CAL-1 were to be in commercial operation in 1984, it will have performed at an average capacity factor of 65%. The analyses also assume that the energy that would have been generated by CAL-1 will be replaced by coal-fired generation (84%) and purchased energy (15%). The 1% balance is oil fueled (peaking requirements only) and would be used whether or not CAL-1 operates. If the applicant's forecast is realized, some supplemental energy from outside the UE system would be required in 1983. This energy is assumed by the staff (and the applicant) to cost 20 mill/kWh in 1983. The applicant estimates savings for 1984, the first year in which CAL-1 would operate at the normal capacity factor (65%), to be $85 million (ER-OL, Rev. 1, Sec. 1.3); the staff estimate is $90 million for that year (Table 2.1). The staff believes these numbers to be in reasonable agreement.

On the basis of previous studies (Ref. 2), the staff assumes that the capacity factor, averaged over the lifetime of the plant, will be at least as high as 60%. An average 60% lifetime capacity factor would provide an increase of 6 billion kWh/yr of baseload electrical energy for the UE system.

The analysis in Table 2.1 includes the differential in variable O&M costs between CAL-1 and the units that would provide the replacement energy.

In addition, a decision to operate CAL-1 will necessitate a decommissioning expense once it is retired from service. For a large PWR unit (such as CAL-1) the decommissioning cost is estimated by the applicant to be in the range of $59 million to $73 million in 1983 dollars, depending on the decommissioning alternative selected (ER-OL, Sec. 5.8). The applicant's estimates of decommissioning costs are based on the methodology developed in NUREG/CR-0130, "Technology, Safety, and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station" (Ref. 3). This document is also the source for the cost-estimate methodology for PWR decommissioning used in NUREG-0586, "Draft Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities" (Ref. 4) (Sec. 5.11). The staff has reviewed the applicant's decommissioning-cost estimates and finds them reasonable.

In the FES-CP (March 1975) both applicant and staff estimated production costs of electrical energy that are much lower than the current estimates presented here. The staff believes the lower cost estimate was due to underestimates of the effect of the OPEC oil embargo and subsequent general fuel-price increases, and the dramatic escalation of all fuel prices that resulted. The effects of inflation were also underestimated by both staff and applicant at the time the FES-CP was written.

Table 2.1. Projected Annual Production-Cost Savings Resulting from Operation of CAL-1[1] (nominal dollars)

Category	1983		1984		1985		1986		1987	
Capacity factor[2] (%)	40		65		70		70		70	
Energy generated by CAL-1[2] (10^9 kWh)	4		6.5		7		7		7	
Costs:	($ million)	(mill/kWh)	($ million)	(mill/kWh)	($ million)	(mill/kWh)	($ million)	(mill/kWh)	($ million)	(mill/kWh)
CAL-1 production cost										
Fuel[3]	30	7.5	53	8.2	62	8.8	67	9.6	73	10.4
O&M[4]	13	3.2	22.6	3.5	24	3.4	25.6	3.6	27.5	3.9
Total	43	10.7	75.6	11.7	86	12.2	92.6	13.2	100.5	14.3
Fuel and O&M cost for replacement energy[4][5]										
Blended coal	40	22.7	73	25.5	79	25.6	90	29.3	102	33.2
Low-sulfur coal	36	22.5	67	25.7	71	25.2	81	28.7	91	32.5
Oil (peaking)	1	25	2	30.8	2	34	2	37	2	40
Purchased energy[6]	13	26	24	24.6	26	25	30	28	33	31
Total	90		166		178		203		228	
Weighted average		22.5		25.5		28		29		32.6
Savings with CAL-1 operation	47		90		92		110		128	
Production cost										
With CAL-1		10.7		11.7		12.2		13.2		14.3
Without CAL-1		22.5		25.5		28		29		32.6

[1] From the ER-OL (Rev. 1, Sec. 1.3), except as otherwise indicated.

[2] From J.G. Roberts, S.M. Davis, and D.A. Nash, "Coal and Nuclear: A Comparison of the Cost of Generating Baseload Electricity by Region," U.S. Nuclear Regulatory Commission, NUREG-0480, p. D-4, December 1978.

[3] From Data Resources, Inc., @ eng/E11/80/VARS; nuclear-fuel cost escalated at 8.6%/yr (1980-1990).

[4] O&M cost escalated at 7%/yr for both nuclear and fossil fuels. Includes variable O&M cost only.

[5] From "Energy Review," Vol. 4, No. 4, Table A-47, Data Resources, Inc., Winter 1980-81; coal cost escalated at 13.4%/yr (1980-1990). Mix is 44% blended coal, 40% low-sulfur coal, 1% oil, and 15% purchased energy.

[6] Assumed to escalate at the same rate (13.4%/yr) as coal-fired energy cost in the UE system.

In conclusion, the staff agrees with the applicant's assessment of potential savings resulting from operation of CAL-1. These savings would not be significantly altered if the demand for electricity grows at a lower rate than assumed, because UE's marginal energy source would continue to be coal. Table 2.1 shows savings for the years 1983 through 1987; in actuality, large savings in generating costs would continue as long as CAL-1 is capable of operating--about 30 years.

2.3 DIVERSITY OF SUPPLY

It is to the advantage of a public utility to have diverse sources of power available. Any number of problems could arise regarding the availability of fuel to generate electricity. If imported oil were not available, if further limits were placed on the use of natural gas as a boiler fuel, if coal piles were to freeze, if mining or railroad strikes occurred, or if shortages of enrichment facilities were to develop, too much reliance on one or two fuels --especially for baseload operation--could necessitate cutbacks to the power-supply grid. Currently, about 99% of UE's generating capacity is fueled by coal (ER-OL, Rev. 1, Sec. 1.3). With CAL-1 in commercial operation in 1983, this dependence on coal will be reduced to about 80%, and UE will be better prepared to meet unexpected changes in the supply and price of coal. The staff concludes that operation of CAL-1 will result in a large improvement in the diversity of fuel supply for the service area and is an important factor in support of issuing an operating license.

2.4 RELIABILITY ANALYSIS

Between 1969 and 1979, UE's electrical-energy output and peak-load demand grew at AARGs of 3.5% and 4.0%, respectively. During 1973 through 1980, these rates have slowed to 2.7% and 2.5%, respectively.

Current projections by the applicant for the UE system call for AARGs of 2.6% for peak-load demand and 3.2% for net-energy-for-area load from 1980 to 1985 (ER-OL, Rev. 1, Table 1.1-2).

Table 2.2 shows UE reserve margins, both historical and projected with and without CAL-1 in operation, through 1985. The peak-load-responsibility values reported here reflect UE's forecast for system-maximum hourly load. System capacity reflects capacity owned by UE. The projected adjusted capacity is based on the assumption that CAL-1 will start operating in 1983 at its design electrical rating of 1150 MWe. This will result in an increase of 17% in the adjusted capacity of the UE system.

UE is a member of the Mid-America Interpool Network (MAIN) and the Illinois-Missouri Power Pool (Ill-Mo). UE is contractually obligated to adhere to the Ill-Mo guidelines, which require each member to provide capacity for its own load plus a reserve of at least 15% of the member's highest demand (ER-OL, Rev. 1, Sec. 1.1.2.1.4). Based on UE's current load forecast and capacity plans (as shown in Table 2.2), if CAL-1 is not added as scheduled, UE reserve margins will be below 15% in 1983 and beyond because no other additions are planned before 1990.

A regional econometric forecasting model has been developed by Data Resources, Inc. (DRI) (Ref. 1). This model suggests that the growth of demand for electrical energy in states participating in the same power pools served by UE

Table 2.2. Historical and Projected Capacity Demand and Energy Output for Union Electric Company and Subsidiaries†[1]

Year	Adjusted Demand†[2] (MW)	Adjusted Demand†[2] AARG†[3] (%)	Adjusted Capacity†[4] (MW)	Reserve (%)	Union Electric Company Net Output (million MWh)	Union Electric Company Net Output AARG (%)
			Historical			
1969	3673		4159	13.2	17.8	
1970	3720		4548	22.3	18.6	
1971	4350		5074	16.6	19.5	
1972	4743		5680	19.8	20.6	
1973	4798		6325	31.8	21.7	
1969-73		6.9				
1974	5046		6029	19.5	21.7	
1975	5006		5924	18.3	22.6	
1976	5131		6473	26.2	23.1	
1977	5344		6444	20.6	24.8	
1978	5459		6417	17.5	25.3	
1979	5456		6969	27.7	25.1	
1980	5698†[5]		7015	23.1	26.2	
1973-80		2.4				3.1
			Projected			
1981	5772	1.2	7000	21.3	27.1	3.0
1982	5912	2.4	6845	15.8	28.0	3.3
1983	6039	2.1	7995†[6]	32.4†[6] 13.3†[7]	28.8	2.8
1984	6206	2.8	7995†[6]	28.8†[6] 10.2†[7]	29.8	3.4
1985	6481	4.4	7995†[6]	23.4†[6] 5.6†[7]	30.8	3.3
1980-85		2.6				3.2

†[1] Modified from the ER-OL (Rev. 1, Tables 1.1-1 and 1.1-2).

†[2] Demand adjusted for reserved purchases, reserved sales, interruptible load, and expected extreme weather. Prior to 1976, the adjusted demand is based on a "company" temperature-adjusted demand and has subsidiary generation at the time of system peak added to it. Starting in 1976, the historical adjusted demands are based on a "system" temperature-adjusted demand, which includes the generation of the subsidiaries.

†[3] Average annual rate of growth.

†[4] Capacity adjusted for unreserved purchases and sales. Values after 1979 are subject to change, pending the outcome of proposed changes in existing environmental standards.

†[5] As of October 1980. This value has an adjustment made for economic conditions.

†[6] With CAL-1.

†[7] Without CAL-1.

will probably be slightly less than the growth projected by UE; the model results project an AARG of 2.9% for 1980 to 1990 versus 3.2% as projected by UE.

The staff's reliability assessment could be altered by unavoidable slippages in, or decisions to delay, any of these subsequent additions, or by the uncertainty associated with UE reliance on outside purchases for needed power. Finally, it must be stressed that because the DRI econometric model is aggregated at the regional level and because UE serves only parts of the states within the region, the findings based on the DRI model are valid only if the growth rate in each of the service areas is the same as the growth rate for the respective region as a whole.

The staff concludes that there will be a reliability problem by 1983 for UE if CAL-1 does not come online as scheduled; hence, it concludes that operation of CAL-1 will lead to a large benefit in system reliability at that time.

2.5 CONCLUSIONS

The results of the staff's assessment of purpose and need for CAL-1 support a decision to issue an operating license for the unit in accordance with the schedule proposed by the applicant. The matter of overriding importance is that the addition of CAL-1 to the UE system is expected to result in significant savings in system production costs. Furthermore, the operation of this unit will decrease UE's dependence on coal fuel supplies, and will provide the added capacity needed to maintain minimum reserve-margin requirements.

The operation of CAL-1 will result also in increased environmental costs and limited increased risk. These issues are addressed in Section 5, and summarized in Section 6, of this environmental statement. The staff consistently finds the costs and risks to be small to moderate. Moreover, if CAL-1 does not operate, replacement energy will have to be generated. This increased use of other power-generation facilities will incur environmental costs and risks. Although decommissioning is identified as an incremental cost of operating CAL-1, it should be noted that this cost represents about 3% of the projected lifetime production-cost savings resulting from CAL-1 operation.

References

1. "Energy Review." Vol. 4, No. 2, Data Resources, Inc., Lexington, MA, Spring 1980.

2. J.O. Roberts, S.M. Davis, and D.A. Nash. "Coal and Nuclear: A Comparison of the Cost of Generating Baseload Electricity by Region." U.S. Nuclear Regulatory Commission, NUREG-0480, December 1978.

3. "Technology, Safety, and Costs of Decommissioning a Reference Pressurized Water Reactor Power Station." NUREG/CR-0130, U.S. Nuclear Regulatory Commission, June 1978.

4. "Draft Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities." NUREG-0586, U.S. Nuclear Regulatory Commission, January 1981.

3. ALTERNATIVES TO THE PROPOSED ACTION

3.1 RÉSUMÉ

During the construction-permit stage of the licensing process, the staff analyzed a wide range of alternatives including the alternative of not adding new production capacity. Based on this alternative analysis and a benefit-cost analysis, the staff determined that additional capacity was needed, that a nuclear-fueled plant would be an environmentally acceptable means of providing the capacity, and that Callaway Unit 1 (CAL-1), at a specified site and of a specified design, was acceptable from an environmental perspective. Since that time, CAL-1 has been substantially constructed; the economic and environmental costs associated with the construction of the plant have already been realized and must be viewed as "sunk costs" in any prospective assessment.

3.2 ALTERNATIVES

At the operating-license stage it is not reasonable to consider extensive plant modifications, or the construction of new and different energy sources as alternatives to the existing nuclear plant, unless a compelling environmental or safety concern that was not evident during the construction-permit review has been discovered. No such concern has emerged.

The environmental costs associated with any of these alternatives, which were considered and foreclosed at the construction-permit stage, would now be prohibitive when compared to the incremental costs of operating the completed plant. These alternatives would require significant environmental and capital commitments, in addition to their costs of operation. Furthermore, the delays caused by any proposed change in plans would necessitate an assessment of the cost of providing the energy that would have been produced by CAL-1 versus the cost of energy from replacement-energy sources during the delay period.

Therefore, the staff concludes that, at this time, the only logical alternative to CAL-1 operation is to deny its operation. In the absence of any significant environmental or safety objection, the decision is an economic one. If operation is denied, the most conservative (least costly) assumption is that existing capacity in the applicant's system is available to replace the energy that could have been provided by CAL-1. If, under this scenario, it can be demonstrated that significant production-cost savings are made available by operation of CAL-1 then the operating alternative is preferable. The staff evaluates these cost savings in Section 2.2 and finds that savings of about $90 million for CAL-1 would be realized during the initial full year of operation. Comparable savings would be expected during subsequent years.

After weighing these options, the staff concludes that the preferred alternative is operation of CAL-1.

4. PROJECT DESCRIPTION AND AFFECTED ENVIRONMENT

4.1 RÉSUMÉ

This résumé highlights changes in the design of, and operating procedures for, the Callaway Plant and new information on the local environment gained since the FES-CP was issued in 1975.

The major operational change was the deferring of construction of the second unit by UE; consequently, the proposed action for which this environmental statement has been prepared is issuance of an operating license for a single unit. The facility descriptions have been provided for two units because the data pertaining to environmental impacts in the ER-OL are for two units. Some facility descriptions and the descriptions of the affected environment are the same for operation of one or two units. Where applicable, the differences between one-unit and two-unit operation are pointed out.

Other changes are listed below.

Sludge lagoons (required by the State of Missouri), a technical-support center, an emergency-operations facility, and a few service facilities have now been added to the plant design. Information on land use has been updated, and information on soil types has been provided. A plan for managing the land owned by Union Electric Company (UE) that has not been preempted by plant facilities has been developed and is being implemented in cooperation with the Missouri Department of Conservation. Minor adjustments have been made in water flow rates, and the intake and discharge structures have been modified. The staff assessment of radioactive-waste systems has been revised. The amounts of nonradioactive wastes generated and discharged have been reestimated and estimates of the concentrations of dissolved solids in the river water have been updated.

Water-quality data have been updated from measurements made during 1976 to 1978, and surface-water and groundwater descriptions have been updated. Air-quality information has been updated, and ecological descriptions have been updated using recent data provided by the applicant. The description of historic and archeological sites has been updated with new information. Population-distribution estimates have been revised, and population projections within an 80-km (50-mi) radius of the site have been increased.

4.2 FACILITY DESCRIPTION

4.2.1 External Appearance and Plant Layout

There have been minor changes in the design and layout of the Callaway Plant (Fig. 4.1) since the FES-CP was issued in March 1975 (ER-OL, Sec. 3; ER-OL, Revs. 1 and 2). The cooling-tower height has been increased from 150 m (500 ft)

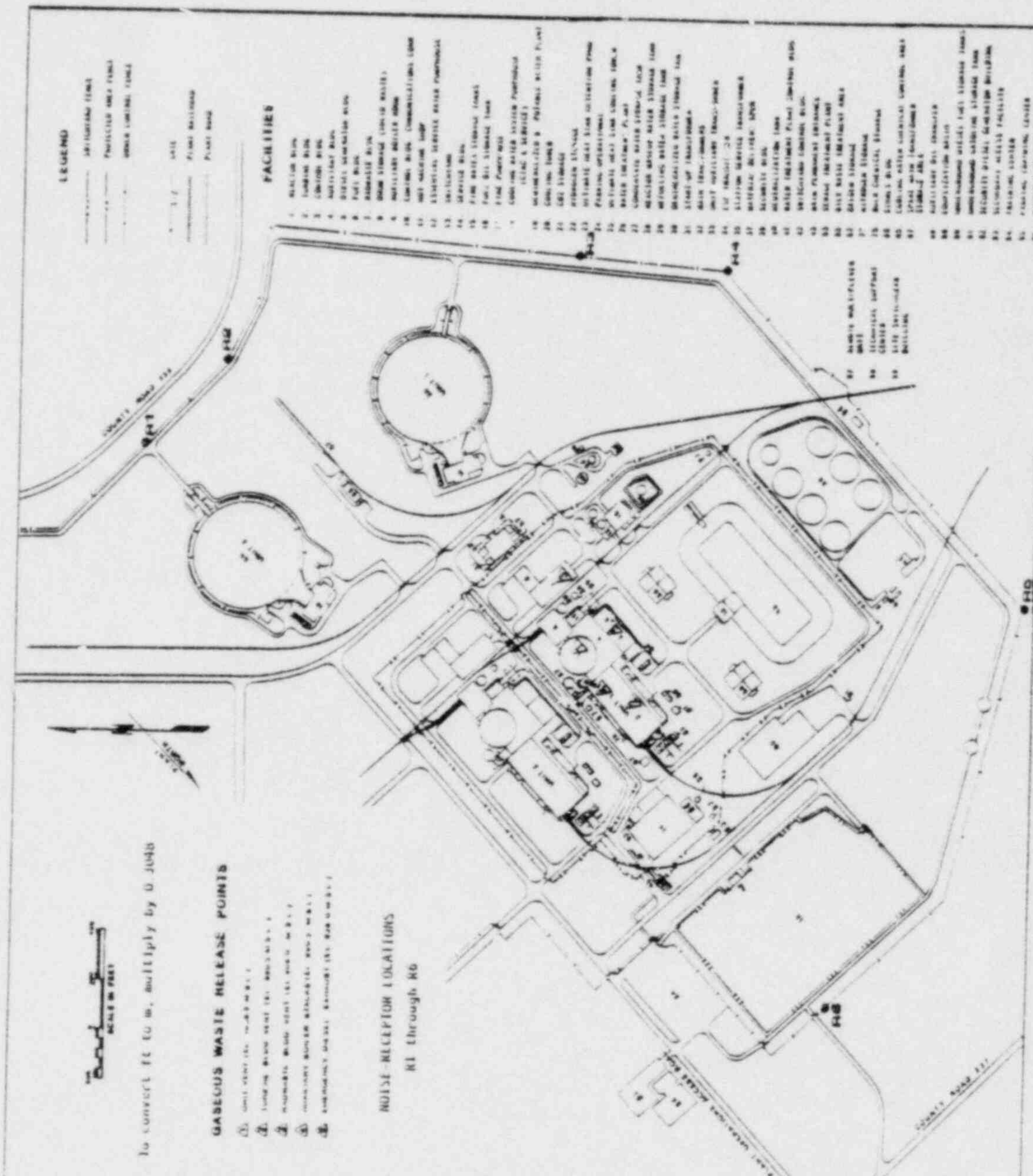


Figure 4.1. Plant Layout. (Adapted from the ER-OL, Rev. 1, Fig. 2.1-4)

to 169 m (555 ft), with minor and inconsequential adjustments in other dimensions. Sludge lagoons (retention ponds for sediment removed from the Missouri River with the intake water) have also been added. The sludge lagoons, each of which covers an area of about 3.5 ha (9 acres), are surrounded by low berms that blend into the terrain when viewed from points outside the site boundary. Three lagoons are being constructed initially; as many as 13 more will be constructed as needed to accommodate Unit 1 as well as Unit 2 at a future date (Fig. 4.2). Excavation work and some of the foundation work for the cooling tower and reactor-containment and turbine buildings for Unit 2 have been carried out. Until construction work is resumed on the structures for Unit 2, only Unit 1 structures and common facilities will be visible.

The applicant plans to construct emergency-preparedness facilities to meet the Commission's upgraded emergency-planning requirements contained in Appendix E to 10 CFR Part 50, "Emergency Planning and Preparedness for Production and Utilization Facilities." A technical-support center will be located adjacent to the service building and will accommodate 25 personnel (Fig. 4.1, item 98). There will be an emergency-operations facility (EOF) located at the southwest corner of the intersection of Highway CC and County Road 337 (Fig. 4.2). A backup EOF will be provided about 50 km (30 mi) from the site. In addition, a secondary-access facility will be located adjacent to the security fence between the switchyard and service building (Fig. 4.1, item 93). A few other service facilities (items 94 through 97 and 99 in Fig. 4.1) have also been added. The buildings added are small in comparison to the major structures (cooling towers and reactor, turbine, and auxiliary buildings).

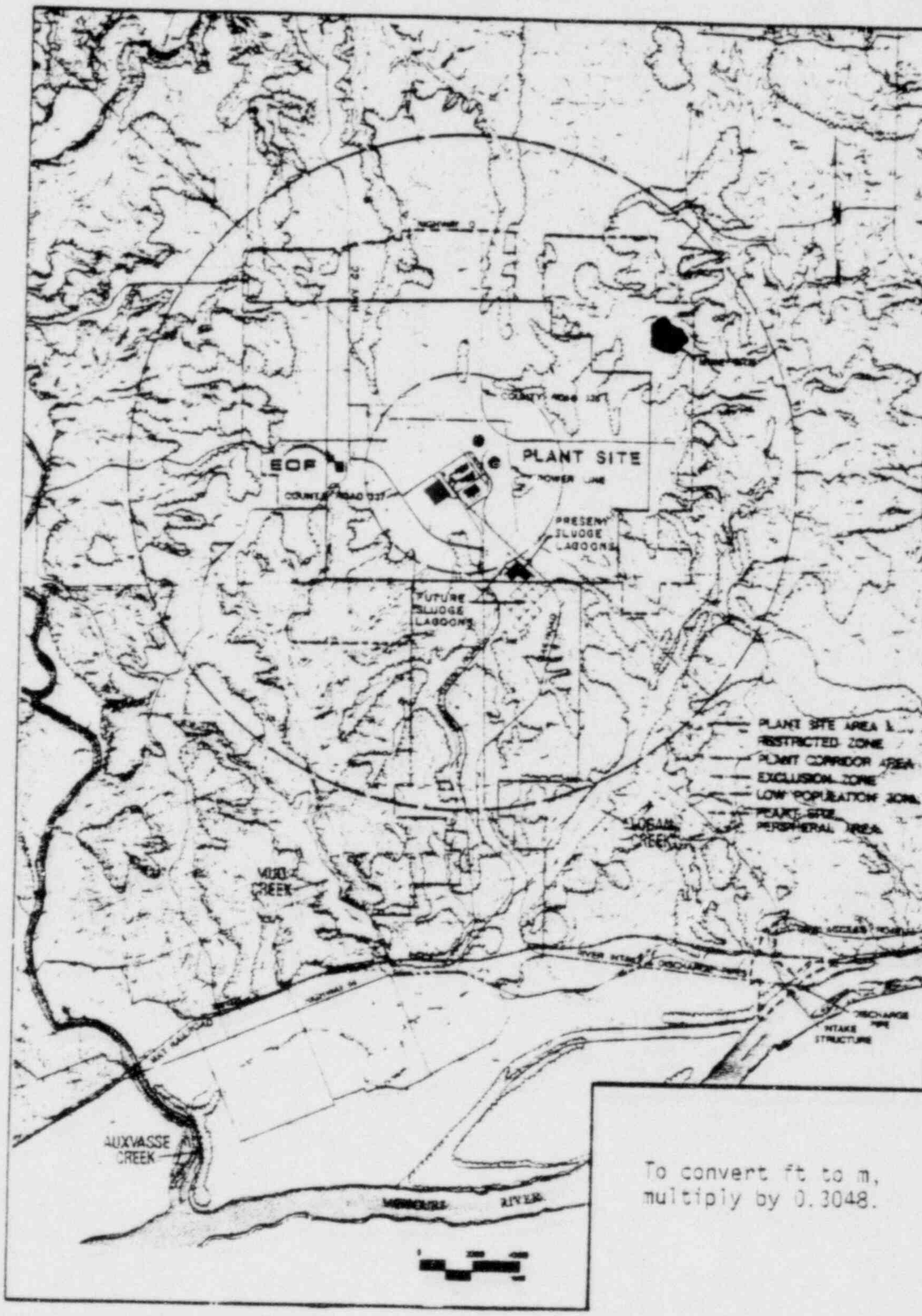
The construction of these additional onsite facilities will not significantly disturb the area relative to previous disturbances for construction of the plant. The offsite alternate EOF is expected to be in a conventional building that meets applicable building and zoning requirements and, therefore, is not expected to adversely impact the area.

The external appearance and layout of the plant is otherwise the same as described previously (FES-CP, Sec. 3.1 and Fig. 3.1).

4.2.2 <u>Land Use</u>

There have been some changes in plant design that affect land use, and additional information characterizing the affected land has been obtained since the FES-CP was issued. This information, which supplements the information in the FES-CP (Sec. 4.2.1) is provided below. Land-use impacts for one-unit operation will be the same as for two-unit operation.

Prior to construction, the principal land-use types for the 2926 ha (7230 acres) of land for the Callaway Plant owned by UE were agriculture and forest. The 1290-ha (3188 acre) plant-site area was about two-thirds agricultural and one-third forest, the 826-ha (2040-acre) peripheral area was about half agricultural and half woodland, and the 810-ha (2002-acre) corridor area was predominantly woodland (ER-OL, Sec. 2.1.3.3). Nine soil-series types occur on the land above the floodplain. Six of these (the Mexico, Putnam, Calwoods, Midco, Crider, and Nodaway series) constitute prime farmland; the other three (Winfred-Menfro, Goss, and Gasconade) are not prime farmland (Refs. 1 and 2). The soils of the Missouri River floodplain vary considerably from place to place and are probably prime farmland, but no official classification is



To convert ft to m, multiply by 0.3048.

Figure 4.2. Site Layout. (From the ER-OL, Rev. 1, Fig. 2.1-3; and Rev. 2, pp. 290.12-1 and -3)

available. About 270 ha (666 acres) of the land owned by UE have been converted to plant-facilities use (including 57 ha or 140 acres for the sludge lagoons), of which 244 ha (603 acres) were classified as prime farmland (ER-OL, Rev. 2, p. 290.15-2). An additional area of about 52 ha (128 acres) was used for construction-related activities (settlement ponds and a rock quarry), of which about 32 ha (78 acres) were prime farmland (Refs. 3 and 4). Details of the amounts of land required for each of the different kinds of facilities and the amounts and types of different soils removed from production have been provided by the applicant (ER-OL, Rev. 2, pp. 290.15-1 to -9).

Most of the 2656 ha (6564 acres) of land owned by UE but not preempted by the plant facilities (and also the transmission-line ROW, discussed separately below) will be available for agriculture, recreation, or wildlife habitat, insofar as these uses are not inconsistent with the safety and security requirements of plant operation. A total of 1038 ha (2564 acres) of the UE-owned land was used for agricultural production in 1980.

A plan for the use of land owned by UE and not needed for plant-operation activities (residual land) has been developed in cooperation with the Missouri Department of Conservation (Ref. 1), and in 1977 UE and the Missouri Conservation Commission entered into an agreement for an initial five-year management plan (ER-OL, Sec. 2.1.3.3.4). The area involved in the plan includes the exclusion zone (except for the fenced-in protected zone in which most of the facilities are located), as well as immediately adjacent land surrounding the plant in all directions. Public use will not be authorized in a residual land area of about 800 ha (2000 acres). This area includes most of the exclusion zone, which extends 1200 m (3937 ft) from the center of the protected zone, and about two-thirds of the corridor area (ER-OL, Fig. 2.1-34). Public use is also not authorized in an area surrounding the discharge structure, which is not included in the plan. The plan is self-supporting and intended to include a land- and water-conservation program for wildlife enhancement and species enrichment, an agricultural land-management program, a forest-management plan, outdoor recreational activities, and special preserves for ecological observation and study (ER-OL, Sec. 11.1.2.4). The applicant states and the staff agrees that, as of 1980, the plan has been working well and appeared to be successful. The plan is flexible and can be modified to accommodate additional priorities (ER-OL, Sec. 2.1.3.3).

Changes in land use due to transmission-line construction are primarily caused by the clearing of land along the ROW. The ROW for the two 345-kV lines that go northeast to the Montgomery Substation covers about 194 ha (480 acres) of forest, cropland, and pasture. The ROW for the two 345-kV lines that go southeast to the Bland Substation, which has been moved about 3 km (2 mi) north and 8 km (5 mi) east of the original location, covers about 267 ha (660 acres) of forest, cropland, and pasture. The terrain crossed by the ROW is similar to that on the plant site and is likely to have the same ecosystems as found on cropland, pastureland, and in areas onsite that are influenced by the edge effect where pasture and cropland meet the woods. The species that will occupy the new habitat of the ROW will undoubtedly be the same as in the contiguous similar habitats. Therefore, the species of flora and fauna would be the same as were described for similar habitats at the site (FES-CP, Sec. 2.7.2; ER-OL, Sec. 2.2.3).

4.2.3 Water Use

The flow diagrams and rates for the plant water-use system, including the cooling system, are shown in the FES-CP (Figs. 3.3 and 3.4). The only important change is that the coagulated river sediment and polyelectrolyte (sludge) from the water-treatment plant will be pumped to a series of onsite sludge lagoons instead of the river, and the supernatant from the sludge lagoons will be returned to the intake stream. There have also been some small changes in the applicant's estimates of the water flow rates for one or two units: a 4% decrease in the intake, makeup, circulating, and blowdown flows; a 9% increase in the service-water flow; a 10% decrease in the steady plant discharge and a 1% decrease in the net water use (intake less discharge) (ER-OL, Fig. 3.3-1). These changes, which have been reviewed by the staff and found to be reasonable, are too small to be significant in estimating water-use impacts; hence, the values given in the FES-CP still provide an adequate basis for estimating these impacts. The flow rates for a single unit will be half the values for two units given in the FES-CP. The updated estimates of the maximum intake and discharge flow rates for single-unit operation are 1240 L/s (19,600 gpm) and 300 L/s (4700 gpm), respectively. The average flow rates are expected to be about 80% of the maximum flow rates (ER-OL, Rev. 2, p. 291.6-1).

4.2.4 Cooling System

The cooling system and related component structures for two-unit operation were discussed in the FES-CP (Sec. 3.4). There have been some design changes in the component structures since the construction review; these are discussed below.

4.2.4.1 Intake Structure

The intake-structure design described in the FES-CP (Sec. 3.4.2 and Fig. 3.5) consisted of four bays with fish-escape openings that were about 7.4 m (24 ft) high, extending to 154 m (506 ft) MSL. This structure has been altered to a three-bay three-pump system. The new design incorporates slightly longer and wider forebays (ER-OL, Fig. 3.4-2; cf. ER-CP, Fig. 3.4-2) and 3-m (10-ft) high fish-escape openings, topping at 151 m (496 ft) MSL (ER-OL, p. 3.4-4).

The intake-structure depth has also been changed (ER-OL, Fig. 3.4-3; cf. ER-CP, Fig. 3.4-3). This is based on a corrected calculation of the 1-day 30-year low-flow river level of 151 m (495 ft) MSL (ER-OL, Sec. 3.4.4.3, p. 3.4-5). The previous estimate was 149 m (489 ft) MSL (FES-CP, p. 3-5). The floor of the intake is now at 148 m (486 ft) MSL rather than at the earlier design elevation of 147 m (482 ft) MSL (ER-CP, Question C-4). The height of the structure remains unchanged.

Provisions have been made to return excess water from the intake flow directly to the river when cooling-tower demand is low. A three-chamber arrangement in a box-like structure located on the downstream side of the intake structure is used for this purpose. The three chambers are connected by a common pipe that discharges the excess water directly back into the Missouri River. The frequency of discharge depends on various plant-operating and environmental conditions.

The applicant planned to return the fish and debris from the trash racks and screen washings to the river (FES-CP, Sec. 5.1.1.1). This plan will be implemented by discharging the debris into the river via a trash-rack trough (ER-OL, Sec. 3.4.4.3.2).

The maximum water velocity into the screens for two-unit operation is now estimated by the applicant to be 0.18 m/s (0.6 ft/s) at the 1-day 30-year low flow (151 m or 495 ft MSL, 155 m^3/s or 5500 cfs) (ER-OL, p. 3.4-5), which is lower than the previous maximum estimate of 0.24 m/s (0.8 ft/s) (FES-CP, p. 3-5; ER-CP, p. 3.4-4). Maximum velocity at the screens during the minimum river navigational flow (153 m or 501 ft MSL, 990 m^3/s or 35,000 cfs) will be about 0.09 m/s (0.3 ft/s). For one-unit operation, these intake velocities would be about one-half the stated values for two-unit operation.

In other respects, the design and operation of the intake structure are as described previously (FES-CP, Sec. 3.4.2).

4.2.4.2 Cooling Towers

The design, dimensions, and performance of the cooling towers are as previously described (FES-CP, Sec. 3.4.1 and Table 3.1), except for the following minor changes: the dimensions of the height, base, throat, and outlet have been changed by +11%, -13%, +15%, and +15%, respectively; the heat rejection rate is 6% less than previously estimated; the total water flow rate (circulating and service water) is 3% less; the blowdown and evaporation rates are 4% less; and the drift rate is 12% greater (ER-OL, Sec. 3.4). Data for the ambient conditions that affect cooling-tower performance have been updated by the applicant (ER-OL, Table 3.4-1); the changes are inconsequential with respect to environmental impacts.

4.2.4.3 Discharge Structure

Reinforced concrete with sheet piling has been used for stabilizing the embankment at the discharge conduit (Fig. 4.3) in place of the riprap called for in the original design (ER-CP, Fig. 3.4-4), and the location of the bottom surface of the 24-inch diameter discharge pipe has been placed at 150 m (493 ft) MSL (Fig. 4.3) rather than 148 m (487 ft) MSL because the recalculated 1-day 30-year low-flow river level of 151 m (495 ft) MSL is 1.8 m (6 ft) higher than the previously calculated value (ER-CP, Fig. 3.4-4). The discharge pipe is located so that it will be barely submerged when the river level drops to the 1-day 30-year low-flow level. Discharge is in the direction of river flow. The present predicted discharge velocity for two-unit operation is 2.1 m/s (7.0 ft/s) (ER-OL, p. 3.4-6), compared to the original predicted velocity of 2.3 m/s (7.4 ft/s) (FES-CP, Sec. 3.4.3, and ER-CP, p. 3.4-4). For one-unit operation the discharge velocity would be 1.05 m/s (3.5 ft/s).

4.2.5 Radioactive-Waste-Management System

Under requirements set by Part 50.34a of Title 10 of the Code of Federal Regulations, an application for a permit to construct a nuclear power reactor must include a preliminary design of equipment to keep levels of radioactive materials in effluents to unrestricted areas as low as is reasonably achievable (ALARA). The term ALARA takes into account the state of technology and the economics of improvements both in relation to benefits to the public health

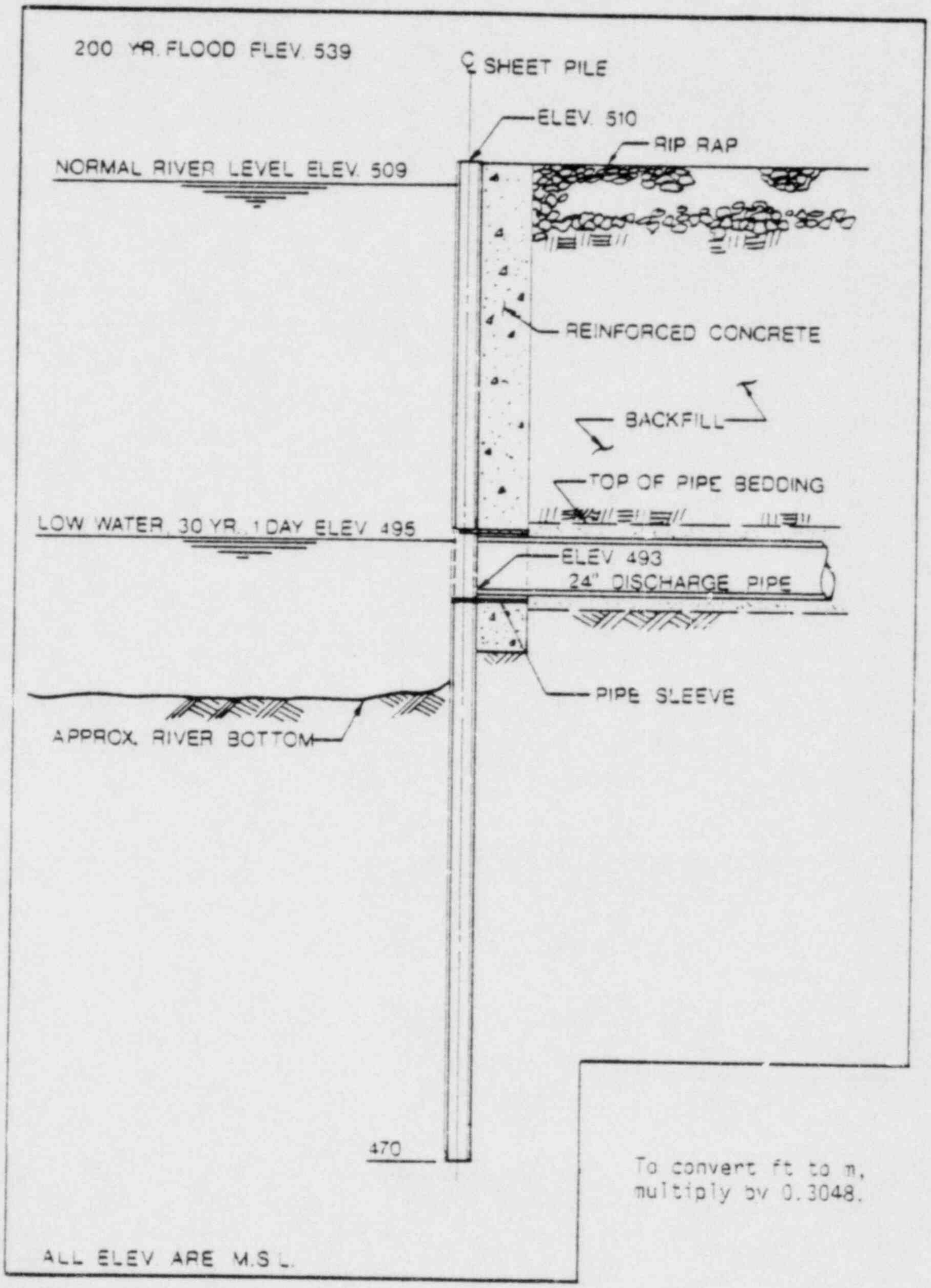


Figure 4.3. Discharge Structure. (From the ER-OL, Fig. 3.4-4)

and safety and other societal and socioeconomic considerations and in relation to the utilization of nuclear energy in the public interest. Appendix I to 10 CFR Part 50 provides numerical guidance on radiation-dose-design objectives for light-water-cooled nuclear power reactors to meet the requirement that radioactive materials in effluents released to unrestricted areas be kept ALARA.

To comply with the requirements of 10 CFR Part 50.34a, the applicant has provided the final designs of radwaste systems and effluent-control measures for keeping levels of radioactive materials in effluents ALARA within the requirements of Appendix I to 10 CFR Part 50. In addition, the applicant has provided an estimate of the quantity of each principal radionuclide expected to be released annually to unrestricted areas in liquid and gaseous effluents produced during normal operation, including anticipated operational occurrences.

The staff's detailed evaluation of the radwaste systems and the capability of these systems to meet the requirements of Appendix I will be presented in Chapter 11 of the staff's "Safety Evaluation Report - Callaway Plant Unit 1," which is to be issued in October 1981. The quantities of radioactive material that are now estimated by the staff to be released from the plant are presented in Appendix C of this environmental statement along with examples of the calculated doses to individual members of the public and to the general population that result from these effluent quantities.

As part of the operating license for this plant, the NRC will require technical specifications limiting release rates for radioactive material in liquid and gaseous effluents and requiring routine monitoring and measurement of all principal release points to ensure that the plant operates in conformance with the radiation-dose-design objectives of Appendix I to 10 CFR Part 50, as amended.

4.2.6 Nonradioactive-Waste-Management System

Nearly all the nonradioactive wastes will be discharged with the plant-effluent water into the Missouri River. The remainder will be discharged as gaseous effluents or cooling-tower drift or be removed by truck for reclamation or disposal in a sanitary landfill (FES-CP, Sec. 3.7). The nonradioactive-waste discharges were estimated prior to construction (FES-CP, Secs. 3.6 and 3.7). Changes in these estimates, which are due to changes in plant design, planned operating procedures, or new environmental data, are discussed below.

4.2.6.1 Makeup-Water-Treatment Wastes

Most of the wastes added to the plant effluent are chemicals used for the treatment of the makeup water. Prior to construction, estimates were made of the maximum amounts of these chemicals and the resulting increases in the plant-discharge concentrations (FES-CP, Table 3.7; ER-CP, Table E9-1). Updated estimates have been provided by the applicant (ER-OL, Rev. 1, Table 3.6-5) and reviewed by the staff, and are summarized in Table 4.1. The changes in the estimates of the amounts of chemicals added are: sulfate, +83%; sodium, +110%; phosphonates, -77%; copper and nickel, -64%; chloride, +410%; and total dissolved solids, +100%.

Table 4.1. Chemicals Added to Plant Discharge and Predicted Effluent Concentrations, Units 1 and 2†1

Chemical	Maximum Amount Added†2 (kg/d)	Addition to Plant-Effluent Concentration†3 (mg/L)
Organic phosphonates†4	500	12
Sodium†5	4,400	250/75†6
Sulfate†7	16,700	360/310†6
Copper and nickel†8	9	0.2
Chloride†9	4,900	120
Total dissolved solids†10	26,500	1,200/520†6

†1 Adapted from the ER-OL (Rev. 1, Table 3.6-5). The maximum amounts of chemicals added for operation of Unit 1 alone will be smaller by a factor of two. The additions to the plant-effluent concentrations that will occur when Unit 1 alone is operating are discussed in the text.

†2 Based on use for maximum-treatment rates.

†3 Quotient of the maximum amount added and the average effluent flow rate (4.2×10^7 L/d), except as noted.

†4 From the ER-OL (Rev. 2, p. 291.9-1).

†5 From caustic (NaOH) used for anion resin regeneration and rock salt (NaCl) used to generate sodium hypochlorite (NaOCl).

†6 Larger value applies during demineralizer regeneration (4 h/d); smaller value at other times (Sec. 4.2.6.1).

†7 From sulfuric acid (H_2SO_4) used for cation resin regeneration and pH adjustment of cooling-tower circulating water.

†8 From condenser-tube erosion (90% Cu and 10% Ni).

†9 From rock salt used to generate sodium hypochlorite. See Section 4.2.6.1 for a discussion of the free-chlorine concentration that will occur as a result of the sodium hypochlorite treatment.

†10 Total of listed chemicals.

Table 4.1 gives the added chemicals and effluent concentrations calculated for operating two units. For operation of a single unit, the amounts of chemicals added will be reduced by a factor of two, as will the effluent flow rate; hence, plant-effluent concentrations of all chemicals that are discharged continuously will remain the same. The sodium hydroxide and sulfuric acid used to regenerate the demineralizer are discharged intermittently, and will be different for operation of a single unit. The calculations for two units, each with its own demineralizer, are based on the assumption that the demineralizers would not be regenerated simultaneously. Hence, during the time (two hours) that a single demineralizer is being regenerated the amounts of sodium and sulfate released by regeneration would be the same whether or not the other unit was operating. For operation of a single unit, the plant-effluent flow rate would be reduced to one-half; hence, operation of a single unit rather than two units would increase the plant-effluent concentration of the sodium and sulfate released by regeneration by a factor of two. (The plant-effluent concentrations of chemicals used for pH control, scaling and corrosion control, or biocides would not be affected.) The total plant-effluent concentrations of sodium and sulfate during regeneration, listed in Table 4.1 for two units as 250 mg/L and 860 mg/L, respectively, increase to 420 mg/L and 1400 mg/L, respectively, for operation of a single unit, and the total concentration increases from about 1200 mg/L to about 2000 mg/L. However, the time during which the release of regeneration chemicals occurs is reduced from four hours to two hours.

The changes in plant design and operating conditions that affect the waste generated by treatment of the makeup water are discussed below.

Clarifying Treatment

Clarifying treatment will be used to remove suspended solids from the makeup water. Liquid polyelectrolyte will be added to the intake water to coagulate the suspended solids. The estimated amounts of polyelectrolyte that will be used have not changed since the FES-CP was issued (ER-CP, Table E9-1; FES-CP, Sec. 11.1.7 and Table 3.7; ER-OL, Table 3.6-2). The change is in the disposition of the coagulated solids. In the design considered in the FES-CP, the coagulated solids were to be returned to the river. In the current design they will be drawn off as sludge in the clarifier blowdown and deposited in onsite sludge lagoons. A large but unknown fraction of the polyelectrolyte will be adsorbed by the coagulated sediment and remain in the sludge lagoon. The supernatant from the sludge lagoons (except the portion that evaporates) will be returned to the water-treatment plant. In other respects, the polyelectrolyte treatment is as previously described (FES-CP, Sec. 11.1.7). This change in disposition of the coagulated solids is the result of a requirement in the NPDES permit that clarifier sludge not be discharged into the Missouri River.

Demineralization

Gravity sand filters, activated-carbon filters, and two ion-exchange demineralizer trains are used to produce high-quality makeup water. The applicant's estimate of the amounts of sulfuric acid and sodium hydroxide that will be used for regenerating the demineralizer resins have been reduced from previous estimates by 21% and 41%, respectively (ER-CP, Table E9-1; FES-CP, Table 3.7; ER-OL, Table 3.6-2).

Scaling and Corrosion Control

The makeup water for the circulating and service-water systems will require treatment with organic phosphonate dispersant to inhibit buildup of solid deposits (scale) in the cooling system. The dispersant will be Betz 403U, which consists of a water solution of methylenephosphonic acid. The water/acid ratio is proprietary information. The applicant's estimate of the average concentration of dispersant in the cooling water that will be needed to control the scale has been reduced by about 75% (FES-CP, Table 3.7; ER-OL, Rev. 2, p. 291.9-1). The methylenephosphonic acid may degrade to orthophosphate. The time for this degradation to occur depends on many factors and is not known.

The circulating and service water will be maintained at a proper pH level for scaling and corrosion control by adding sulfuric acid. The applicant's estimate of the maximum amount of sulfuric acid needed for this purpose is larger than the preconstruction estimate by a factor of about three (FES-CP, Table 3.7; ER-OL, Table 3.6-2). This increase is, in part, due to a revised estimate of the maximum alkalinity of the river (Sec. 4.2.6.2).

Biocide Treatment

The design of the biocide-treatment system has been changed. A solution of sodium hypochlorite will be used, rather than free chlorine, because the recent development of reliable onsite hypochlorite-generation systems makes sodium-hypochlorite treatment safer and more economical.

The sodium hypochlorite will be produced onsite using a packaged electrolytic generation system located in the cooling-water chemical-control system building. Rock salt will be used as a raw material to produce 0.8% sodium hypochlorite solution. At maximum capacity, 7900 kg/d (17,500 lb/d) of rock salt will be used. The output will correspond to 2300 kg/d (5000 lb/d) of equivalent available chlorine, which is about the same as the amount of gaseous chlorine that would have been used according to preconstruction plans (ER-CP, Table E9-1). Small amounts of dilute hydrochloric acid (up to about 300 L/mo or 80 gal/mo) will be used for cleaning the hypochlorite-generation cell.

Biocide treatment of the circulating water will require, for each unit, two 30- to 50-minute hypochlorite treatments each day. The applicant states that a maximum total-residual-chlorine concentration of 0.5 mg/L could be present in the blowdown entering the discharge line for short periods at the end of a treatment period, but that this would be reduced prior to discharge during the one-hour transit time in the discharge pipe due to an expected chlorine demand in the discharge water. The applicant estimates that the average total-residual-chlorine concentration reaching the Missouri River from treatment of the circulating-water system will be less than 0.2 mg/L during a maximum two-hour period each day for each unit. The staff estimated the chlorine concentration in the river due to plant discharge and found that even under conditions of maximum discharge flow rate for two units and a 1-day 30-year low-flow rate for the river it would be less than 0.005 mg/L.

4.2.6.2 Blowdown

About 75% of the makeup water taken from the Missouri River (which constitutes 98% of the intake water) will be dissipated into the air by evaporation from the cooling towers, but less than 3% of the dissolved solids in the river water will be removed by this means (as cooling-tower drift); hence, the concentration of these dissolved solids in the plant effluent will be about four times as large as the original concentration in the river water. New data on the maximum concentration of dissolved solids in the Missouri River, obtained by the applicant, is about 20% larger than preconstruction data (ER-CP, Table 3.6-1; ER-OL, Table 3.6-1); hence, there will be a corresponding increase in the concentration of dissolved solids from this source in the plant effluent. The chemicals in the blowdown will consist of the dissolved solids from the river that were present in the makeup water and the chemicals that were added for makeup-water treatment (Sec. 4.2.6.1). Updated values of the concentrations of dissolved solids in the Missouri River, and in the plant effluent, which consists primarily of blowdown but also includes wastes from demineralizer regeneration (Sec. 4.2.6.1), are given in Table 4.2.

4.2.6.3 Cooling-Tower Drift

Most of the dissolved solids present in the intake water and added for makeup-water treatment will be discharged with the cooling-tower blowdown into the river; however, about 3% of these solids will be discharged into the atmosphere as cooling-tower drift, which consists of small droplets of water and dissolved solids picked up by the air flowing through the cooling tower.

The preconstruction estimates of cooling-tower drift (FES-CP, Sec. 5.1.2.3) have been revised by the applicant (ER-OL, Sec. 5.1.4) and reviewed by the staff. The preconstruction estimate of the average rate of emission of solids contained in drift droplets from both cooling towers was 23 g/s (3 lb/min). The applicant's revised estimate for the average rate for two units was 26 g/s (3.4 lb/min) (ER-OL, Sec. 5.1.4.2). On the basis of updated data supplied by the applicant for river-water composition (ER-OL, Table 3.6-1), chemicals added to the cooling water (ER-OL, Table 3.6-2; ER-OL, Rev. 2, p. 291.9-1), effluent-discharge rate (ER-OL, Rev. 2, p. 291.6-1), and drift-emission rate of 14.3 L/s (227 gpm) (ER-OL, Sec. 5.1.4.2), the staff estimates that the average rate of emission of solids contained in drift droplets from both towers will be 30 g/s (4 lb/min). The rate of emission will be one-half this value when only one tower is operating.

Using data provided by the applicant (ER-OL, Tables 3.6-2 and 3.6-5 and App. 2D), the staff has recalculated the average composition of the solids dissolved in the cooling-tower drift and found it to be: 35% sulfate, 25% carbonate, 10% calcium, 10% sodium, 7% chloride, 5% silicate, 4% magnesium, 3% hexane solubles, 1% iron, 0.3% phosphates, and 0.2% nitrates, with trace amounts of other metals (Table 4.2). These values are within two percentage points of the values that may be inferred from data provided in the FES-CP (Table 3.2).

4.2.6.4 Sanitary and Other Wastes

Sanitary Wastes

The design and specifications for the sewage-treatment plant to be used during plant operation, after construction activities have been completed, are as previously described (FES-CP, Sec. 3.7.1; ER-CP, Sec. 3.7.1; and ER-OL, Sec. 3.7.1).

Table 4.2. Concentrations of Various Chemicals in the Plant Effluent and in the Missouri River, Units 1 and 2†[1] (mg/L except as indicated)

Parameter	Concentration: In Plant Effluent†[2]	Concentration: In River: Maximum Observed†[3]	Concentration: In River: After Mixing with Effluent†[4]	Maximum Level Not Harmful to Aquatic Life†[5]
Total dissolved solids	3620†[6]/ 2940†[7]	605 (D&M)	613	2000 mg/L
Total alkalinity ($CaCO_3$)	1182†[6]	319 (EE)	321	When caused almost entirely by bicarbonates, alkalinity does not seem to have any harmful effect on aquatic life
Total hardness ($CaCO_3$)	1400	350 (EE)	352	Hardness of itself has no biological significance in dealing with water quality and aquatic life
Turbidity (JTU)	Unknown†[9]	2400†[10] (CCW)	~ 2400†[9,10]	3000 JTU - determined for fish over a 10-day period
Suspended solids	60†[7]	3213†[10] (EE)	3206†[9]	90 mg/L - determined for fish
Specific conductance (µmho/cm)	3600	900 (MCWC)	906	2000 µmho at 25°C - maximum in 95% of U.S. waters with good mixed fish fauna
Nitrate (N)	25.8	5.45 (EE)	5.5	4.2 mg/L - maximum in 95% of U.S. waters with good fish fauna
Total iron	183.5	45.9 (EE)	46.2	0.7 mg/L - maximum in 95% of U.S. waters with good fish fauna
Sulfate	2608†[6]/ 2058†[7]	437 (EE)	443	90 mg/L - maximum in 95% of U.S. waters with good fish fauna
Chloride	388†[6]	57 (MCWC)	58	170 mg/L - maximum in 95% of U.S. waters with good fish fauna
Silica	160	40 (MCWC)	40	Unknown
Cadmium	0.088	0.022 (EE)	0.022	0.01-10 mg/L - maximum for fish, depending on species, type of water, temperature, and exposure time
Chromium	0.28	0.07 (EE)	0.07	0.05 mg/L
Sodium	594†[6]/ 419†[7]	86 (EE)	87	85 mg/L - maximum concentration of Na + K in 95% of U.S. waters with good fish fauna
Copper	0.76†[6]	0.14 (EE)	0.14	0.02 mg/L
Lead	1.12	0.28 (EE)	0.28	0.1 mg/L for fish
Manganese	2.0	0.5 (MCWC)	0.5	1.0 mg/L
Mercury	0.004	0.001 (EE)	0.001	0.004 mg/L for fish
Zinc	0.84	0.21 (EPA & USGS)	0.21	0.5 mg/L - determined for mixed warmwater fish
Hexane solubles	106.8	26.7 (EE)	26.9	Unknown
Arsenic	0.056	0.014 (D&M)	0.014	1.0 mg/L
Phosphorous†[11]	< 14.2†[6]	2.3 (EPA)	2.3	Unknown

†1 Adapted and modified by the staff from the ER-OL (Rev. 1, Table 3.6-5) and Table 4.1. For a single unit, river concentration after mixing will be reduced by one-half the difference between the two river-concentration values given.

†2 Four times maximum observed river concentration plus predicted effluent concentration of chemicals added.

†3 Obtained from James & Moore field surveys (D&M), Missouri Clean Water Commission (MCWC), U.S. Environmental Protection Agency (EPA), U.S. Geological Survey (USGS), Envirodyne Engineers field surveys (EE), and Capitol City Water Co., Jefferson City, Missouri (CCW).

†4 A mixing ratio (river/effluent flows) of 470 is used.

†5 From J.E. McKee and H.W. Wolf, "Water Quality Criteria," (2nd ed.), Publication No. 3-A, California State Water Resources Control Board, Sacramento, 1963.

†6 Increased by the maximum plant-effluent concentration listed in Table 4.1.

†7 Maximum concentration when demineralizers are not being regenerated.

†8 Decreased by about 34 mg/L due to aeration in cooling tower.

†9 Sludge from the water-treatment plant not discharged to the Missouri River.

†10 Artificially high because river ambient suspended-solids concentration during a low flow of 290,000 L/s would be considerably less than 3213 mg/L - as low as 30 mg/L has been recorded in low-flow periods.

†11 Phosphorous will be present in various forms, mostly phosphate (in the river) and organic phosphonate (less than 5 mg/L in the effluent), but not as elemental phosphorous. In general, phosphates are not toxic to fish and other aquatic life, and may be beneficial under certain circumstances by increasing algae and zooplankton. However, they may lead to eutrophication due to an overabundance of algae. The maximum concentrations of organic phosphonates that are not harmful to aquatic life are not known.

Oily-Wastewater Treatment

An oily-waste separator system will be used to remove most of the oil from the plant-wastewater effluent for storage and shipment to an offsite waste-reclamation plant. The specifications provided for the construction permit (FES-CP, Sec. 3.6.7) have not changed.

Gaseous Effluents

Gaseous effluents will be released from the auxiliary boilers and emergency diesel generators. These discharges will be small; there have been no changes affecting the release of gaseous effluents since the construction permit was issued (FES-CP, Sec. 3.7.3).

4.2.7 Power-Transmission Systems

Two transmission lines, each consisting of two 345-kV circuits, will connect the Callaway Plant to the UE grid. The ROWs for both lines have been established and cleared. The Callaway-Bland line was under construction, and construction of the Callaway-Montgomery line was nearly complete, as of December 1980. The discussion in the FES-CP is still applicable for both routes (FES-CP, Sec. 3.8 and Fig. 3.12).

4.3 PROJECT-RELATED ENVIRONMENTAL DESCRIPTIONS

4.3.1 Hydrology

4.3.1.1 Surface Water

The preconstruction description of the surface water (FES-CP, Sec. 2.5.1), supplemented by the following updated information, remains valid. A discussion of the hydrological effects of alterations in the floodplain, as required by Executive Order 11988, Floodplain Management, is given in Section 5.3.3.

Availability

The Callaway Plant is located on a plateau about 8 km (5 mi) north and 100 m (330 ft) above the normal water level of the Missouri River. The plateau is dissected by intermittent and perennial streams that flow into the Missouri River. The principal streams include Cow Creek, which drains the area to the north of the site; Logan Creek, which drains the area to the east of the site; Mud Creek, which drains the area to the south of the site; and Auxvasse Creek, which drains the area to the west of the site. The location of these streams relative to the site and an outline of their drainage areas is shown in Figure 4.4.

A revised cross section of the river at the location of the intake and discharge (RM 115.4) was provided by the applicant and is shown in Figure 4.5. This section was plotted from a hydrographic survey performed in October 1975, and shows the effect of dredging in front of the intake structure.

Users

There are no major municipal or industrial water users within 8 km (5 mi) of the site; however, local streams are used for irrigation and livestock watering.

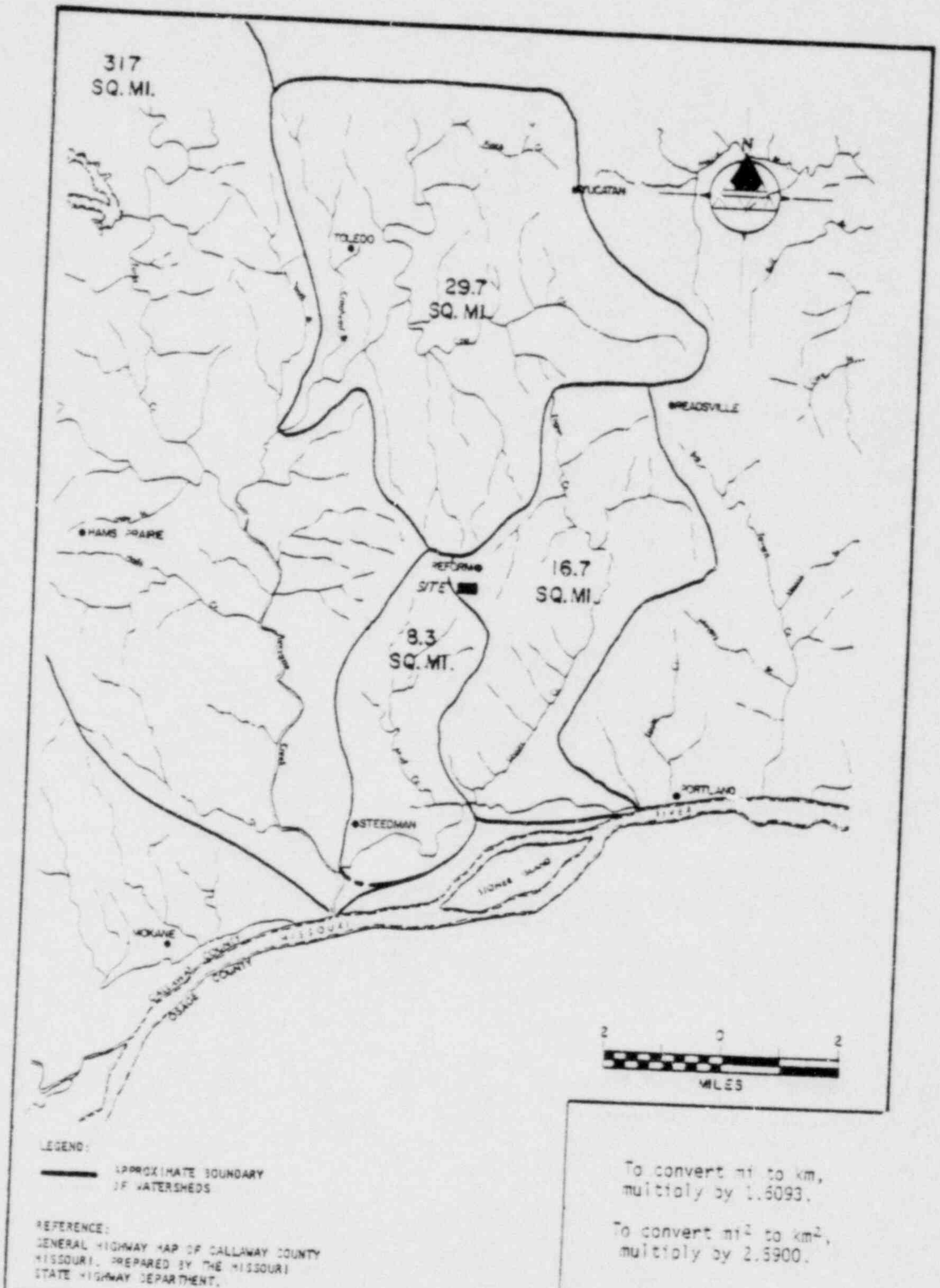


Figure 4.4. Local Surface-Water-Drainage Map. (From the ER-OL, Fig. 2.4-1)

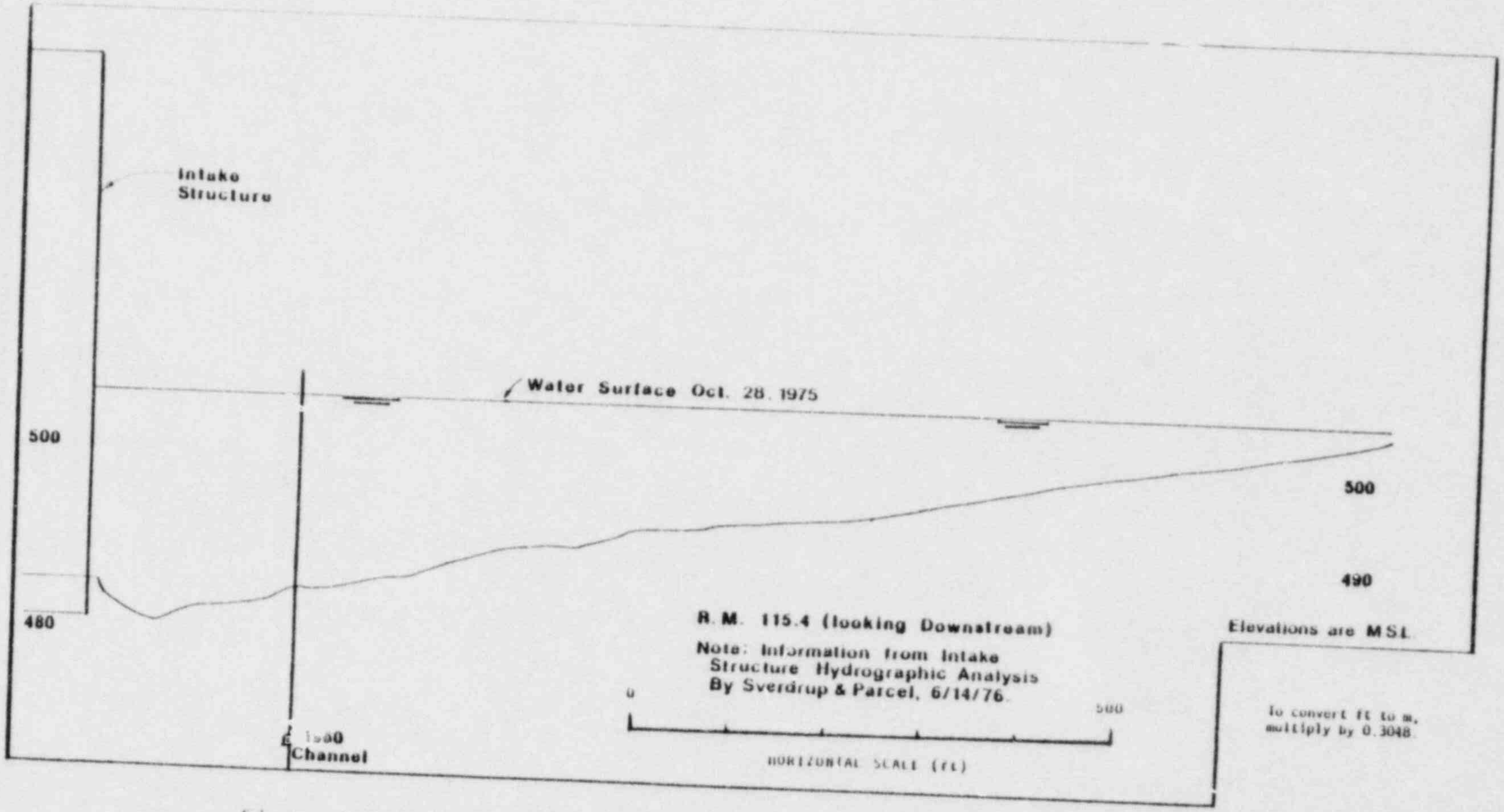


Figure 4.5. River Cross Section. (Adapted from the ER-OL, Fig. 3.4-7)

The predominant surface-water withdrawal from the Missouri River in the Callaway Plant site area is for the Central Electric Power Cooperative Chamois Plant. This plant, located about 3 km (2 mi) upstream from the Callaway intake, withdraws and discharges about 3100 L/s (110 cfs) for the purpose of power generation. A list of other significant users of Missouri River water and discharges from the mouth of the river to River Mile 226 has been provided by the applicant (ER-OL, Table 2.1-19).

A low-flow rate of 240,000 L/s (8500 cfs) was used in the FES-CP for calculating water-related impacts under low-flow conditions for the Missouri River near the intake structure. This is the 7-day 20-year low-flow rate at Missouri River Mile 115 (ER-OL, Table 2.4-6). The 7-day 10-year low-flow rate of 280,000 L/s (9900 cfs) (ER-OL, Table 2.4-6) is used in this environmental statement. The dilution factor under these low-flow conditions for a plant discharge flow from two units of 600 L/s will be (river flow)/(discharge flow) = 470. The dilution factor increases to 940 for one-unit operation. The measured average flow rate at Hermann, Missouri, over a 26-year period (1952-77) under regulated-flow conditions is 2.04×10^6 L/s (72,200 cfs); the average flow rate near the site is estimated by the applicant to be 1.95×10^6 L/s (69,000 cfs) (ER-OL, Sec. 2.4.1.1.5). The lowest flow on record at Hermann, Missouri, is 119,000 L/s (4200 cfs); the corresponding low flow near the site is estimated by the applicant to be 99,000 L/s (3500 cfs). These conditions occurred in January 1940 during a period of extensive river freezing (ER-OL, Sec. 2.4.1.2.2).

4.3.1.2 Groundwater

A very brief description of the groundwater was given in the preconstruction review (FES-CP, Sec. 2.5.2). This description is updated and supplemented below.

Availability

The local unconfined-aquifer system at the site consists of Quaternary deposits, including modified loess, accretion gley, and clayey glacial till. Infiltration rates through these units are very low, with permeabilities ranging from about 10^{-6} to 10^{-8} cm/s. Underneath the unconsolidated material lie layers of Graydon Chert conglomerate, Bushberg Sandstone, Snyder Creek Shale, and Callaway Limestone. The Graydon Chert is commonly saturated with water levels extending 0.5 to 1 m (1.5 to 3 ft) into the glacial till, about 5 to 10 m (15 to 30 ft) below the natural ground surface at the site.

Beneath the Callaway Limestone lies the Cotter-Jefferson City Formation, which is the top unit of the regional leaky-artesian-aquifer system. The Cotter-Jefferson City Formation is a fine- to medium-grained dolomite with typical yields to domestic and farm wells of 40 to 60 L/min (10 to 15 gpm). It is about 90 to 170 m (300 to 560 ft) thick in the site area. Other bedrock formations within the vicinity of the site include the following:

1. The Roubidoux formation, a fine- to coarse-grained sandstone with interbedded cherty dolomite, is a major aquifer with yields to municipal- and industrial-supply wells ranging from 95 to 1320 L/min (25 to 350 gpm). Its thickness ranges from 30 to 75 m (100 to 250 ft).

2. The Gasconade Dolomite and Gunter Sandstone, cherty dolomite (averaging 90 m or 300 ft thick) and medium-grained sandstone (averaging 8 to 10 m or 25 to 30 ft thick), respectively, are major aquifers with typical yields to municipal and industrial wells of 190 to 280 L/min (50 to 75 gpm). However, yields as high as 3800 L/min (1000 gpm) have been reported.

3. The Eminence Dolomite, a medium- to coarse-grained crystalline dolomite, is a minor aquifer with yields to domestic- and farm-supply wells of about 60 to 75 L/min (15 to 20 gpm). Its thickness ranges from 60 to 110 m (200 to 360 ft).

4. The Potosi Dolomite, a fine- to coarse-grained dolomite, is a major aquifer with yields of up to 1900 L/min (500 gpm) to municipal and industrial wells. Its average thickness ranges from 15 to 75 m (50 to 250 ft).

5. The Bonneterre Formation, a fine- to medium-grained dolomite, is a minor aquifer with yields to domestic and farm wells of from 75 to 95 L/min (20 to 25 gpm). This formation, along with the Derby-Doerun and Davis Formations, has a total thickness varying from 130 to 220 m (430 to 720 ft).

6. The Lamotte Sandstone, a fine- to coarse-grained well-cemented sandstone is a major aquifer with typical yields of about 250 L/min (65 gpm) to domestic-, municipal-, and industrial-supply wells. Its average thickness is about 60 m (200 ft).

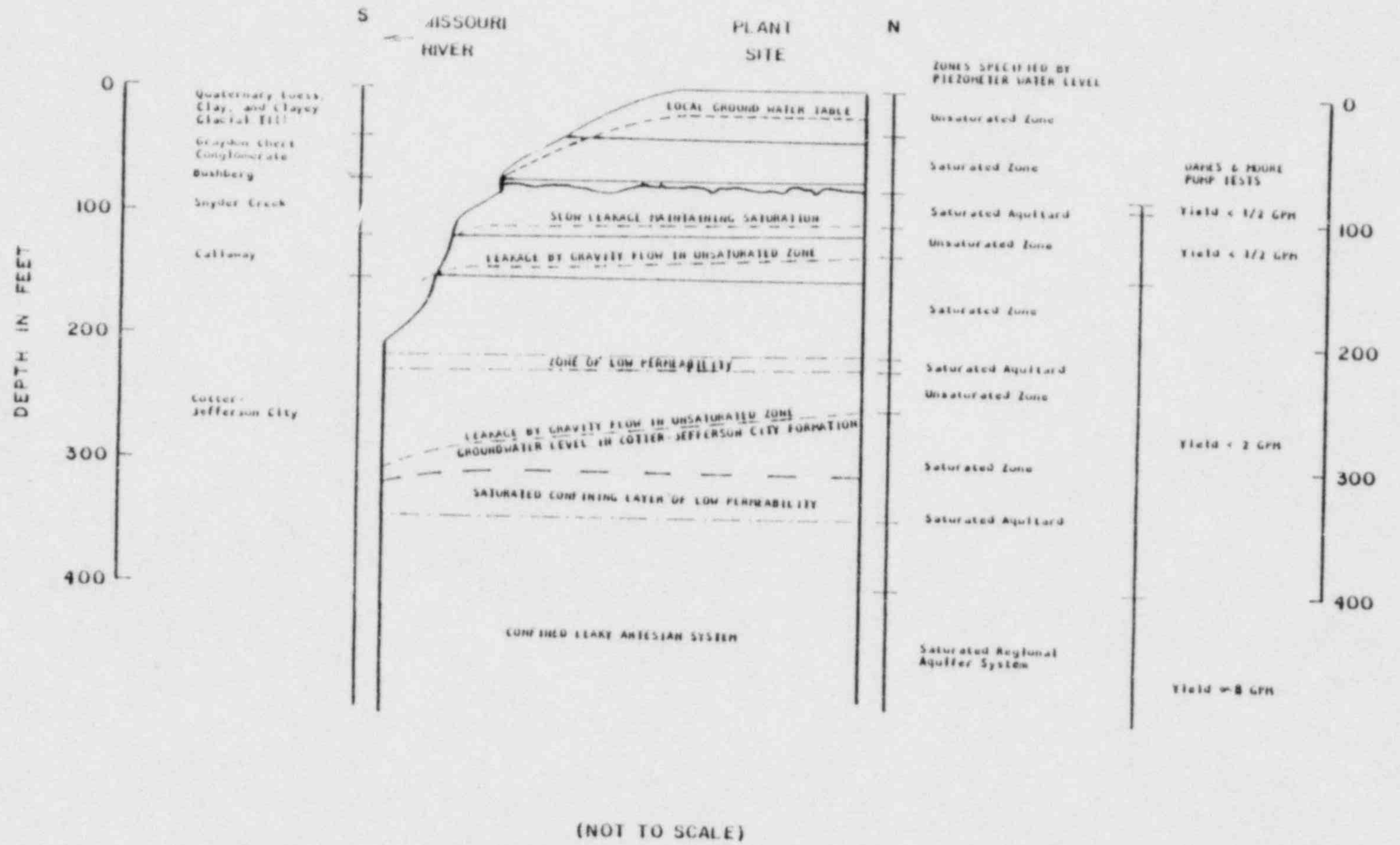
In addition to the Cotter-Jefferson City Formation, the Postosi, Bonneterre, and Lamotte Formations are probably present beneath the site. The presence of the Roubidoux, Gasconade-Gunter, and Eminence aquifers has been confirmed by the Missouri Geological Survey from drillers' logs and samples.

A generalized schematic diagram representing the site hydrogeologic environment is presented in Figure 4.6.

The regional deep-aquifer system is recharged by vertical leakage from the Cotter-Jefferson City Formation where the formation occurs as exposed bedrock in stream courses. In the site area, which is an upland area covered by thick deposits of soil with relatively low permeability, there is little recharge to the underlying formations (ER-OL, Sec. 2.4.2).

Users

According to a well survey performed by the applicant, there are 48 wells and 10 enclosed springs within 8 km (5 mi) of the plant site. Of the 48 wells, seven are dug wells ranging in depth from 3 to 20 m (10 to 70 ft) and supplying from 2 to 20 L/min (0.5 to 5 gpm). The total water use from these dug wells is about 9100 L/d (2400 gal/d). There are 39 wells drilled into the Cotter-Jefferson City Formation within 8 km of the site. They range in depth from about 30 to 150 m (100 to 500 ft) and yield from 35 to 115 L/min (9 to 30 gpm). The total use of water from these wells is about 64,000 L/d (17,000 gal/d). Of the remaining wells, one is drilled into the Roubidoux Formation to a depth of over 210 m (700 ft) and is capable of yielding up to 1100 L/min (300 gpm). The remaining well is a driven well that obtains water from the alluvial



To convert ft to m,
multiply by 0.3048.

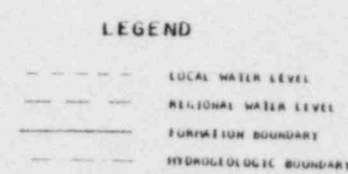


Figure 4.6. Site Hydrologic Environment, Generalized Schematic Diagram.
(From the ER-OL, Fig. 2.4-9)

deposits along the Missouri River. The average yield from the enclosed springs is less than 19 L/min (5 gpm).

Future use of groundwater for domestic and livestock purposes should remain relatively unchanged over the life of the plant.

4.3.2 Water Quality

Water from the Missouri River is the only water that will be used for plant operations or affected by water discharged as plant effluent. The quality of this water was discussed prior to construction (FES-CP, Sec. 2.5.1 and Table 2.2). This discussion was based on EPA STORET-System data taken prior to 1973 near Hermann, Missouri, about 32 km (20 mi) downstream from the plant. Later EPA data at the same site, up to 1979, indicate no significant change in water quality (ER-OL, Table 2.4-7). However, data obtained by the applicant from sampling stations closer to the plant during the preconstruction monitoring program (1974-75) and water analyses conducted from 1976 to early 1979 gave different results and appreciably higher maximum values (ER-OL, Sec. 2.2.2.2 and App. D). The maximum values from these data are reproduced in Table 4.2. The staff has reviewed these data and considers them to be valid if interpreted as maximum values that occur infrequently for short periods. The maximum values for hardness and alkalinity, which are 60% and 33% larger than the maximum values reported in the FES-CP, were observed only once at a sampling site 1.5 km (1 mi) downriver from the intake structure, and probably represent an infrequent local fluctuation.

Fecal-coliform counts observed during construction monitoring (June 1976 through December 1978) revealed a wide range of values: at the sampling station closest to the intake structure the range was between 1 and 7800 per 100 milliliters, with an average of about 1300 per 100 milliliters. Comparable values were observed downstream (ER-OL, App. 2D).

4.3.3 Meteorology and Air Quality

The discussion of the general climatology of the site and vicinity contained in the FES-CP remains unchanged. Since issuance of the FES-CP, information about the frequencies of thunderstorms and tornadoes has changed. A recent study by the National Climatic Center (Ref. 5) indicates that about 75 thunderstorms can be expected to occur each year in the vicinity of the site, being most frequent during May through July. The applicant has presented more recent information on tornado occurrences in the vicinity of the Callaway site for 1956 to 1971 based on data from Poultney (Ref. 6). For this period, the computed recurrence interval for a tornado at the plant site is about 830 years. The applicant has also determined that six tornadoes have occurred in the vicinity of the plant since 1971, slightly increasing the computed recurrence interval for a tornado at the plant site.

Since issuance of the FES-CP, two additional years of meteorological data have been collected at the plant site. For a composite three-year period of record (from 4 May 1973 to 3 May 1975 and from 16 March 1978 to 15 March 1979), data from the 10-m level indicated that winds from the southeast, south-southeast, and south each occurred about 10% of the time. Winds from the southeast clockwise through the southwest occurred about 45% of the time at the 10-m level for this period of record. The winds are calm only about 0.25% of the time. The mean wind speed is about 3 m/s (7 mph).

4.3.4 Ecology

4.3.4.1 Terrestrial

The terrestrial ecology of the area is essentially unchanged from the description prepared prior to construction (FES-CP, Sec. 2.7.2). Data obtained during 1973 baseline studies and a 1974-75 preconstruction survey commissioned by the applicant have been supplemented by a construction monitoring program that continued up to May 1981 (ER-OL, Sec. 6.1.4.3) (Refs. 7 and 8). The data obtained from the construction monitoring program (and preconstruction monitoring data not available when the FES-CP was prepared) did not yield results that would require changes in the description in the FES-CP. Most of the flora and fauna native to central Missouri may be found on the plant site. The site prior to construction is described in greater detail in a management plan prepared by the Missouri Department of Conservation (Ref. 1).

4.3.4.2 Aquatic

A two-year preconstruction monitoring program, which is an expansion of previous baseline studies (ER-CP, Sec. 2.7), and subsequent monitoring required by the construction permit have provided additional information on the aquatic communities at specified sampling stations on the Missouri River and Logan Creek. The creek, which drains the plant-site area and enters the Missouri River about 300 m (1000 ft) downstream from the discharge structure, is an important spawning area and source of plankton. The second year (1975) of the preconstruction program included studies to investigate and define spawning activities and juvenile development of fish in the Logan Creek area.

The expanded study of 1975 included the calculation of two indices that describe the phytoplankton community: an index of community diversity and an index of pollution-tolerant genera. Except for unusually great seasonal fluctuations in density and productivity, attributed to increased flooding (ER-OL, Sec. 2.2.2.8, p. 2.2-39), no major change in plankton populations has occurred. Methods of sampling benthic macroinvertebrates were modified: Ponar grab and material tow samples were employed at selected river stations; Ekman and Ponar grabs provided sediment samples of Logan Creek. Analyses of the new data did not indicate any major change in the species diversity of the Missouri River or Logan Creek. No pink mucket pearly mussels (<u>Lampsilis orbiculata orbiculata</u>), an endangered species, were collected.

With the update of the preconstruction monitoring, fish collections near the Callaway Plant site have yielded a total of 68 species. The more abundant species in the Missouri River are as previously reported (FES-CP, p. 2-6) with the addition of the emerald shiner (<u>Notropis atherinoides</u>), which dominated the river-backwater collections of 1974 (ER-CP, Sec. 2.2.2.8, p. 2.2-41). Several species of shiners are numerically dominant in lower Logan Creek; the bluntnose minnow (<u>Pimephales notatus</u>) is the prevalent species in upstream stations on the creek.

In addition to the monitoring programs discussed above, the applicant is in the process of conducting new studies. These additional studies were to cover June 1980 through May 1981 (Ref. 7). As of July 1981, the applicant had completed six months of sampling and analysis. Results and trends of these studies are similar to the earlier programs. Two additional species of fish have been collected in the Missouri River, the rainbow smelt (Osmerus mordax) and the blue sucker (Cycleptus elongatus). Neither species is threatened or endangered, although the blue sucker is considered scarce in Missouri (Ref. 9).

Thirty-one species of fish have been identified as potential spawners in Logan Creek. In late April 1975, when water temperatures and levels had risen, a fish-spawning survey of the creek yielded only six species in the reproductive state. However, since spawning can occur at other times, the absence does not confirm that other species do not occur in this area. Spawning adults and/or juveniles of 25 of the expected 31 species have been collected from Logan Creek since 1973. Although the presence of these fish in the creek is not necessarily a consequence of spawning activities, the data suggest that Logan Creek is moderately used as a spawning and nursery area.

A shallow cutoff channel, the Mollie Dozier Chute, is located directly upriver from the plant intake structure (ER-OL, Fig. 2.2-2). The significance of Mollie Dozier Chute as a contributor to the fish productivity of the Missouri River is unknown. This backwater area is not connected directly to the Missouri River and has been silted in by flooding and agricultural runoff. Mollie Dozier Chute is frequently dry, and access to the area by fish is limited to periods of sporadic and temporary flooding.

4.3.5 Endangered and Threatened Species

Rare and endangered species were discussed and listed in the FES-CP (Sec. 2.7.2.2 and Tables 2.3 and 2.4). No adverse impacts to any species listed were identified. In 1973, the U.S. Fish and Wildlife Service (FWS) dropped the category "rare", and now classifies species as either "endangered" or "threatened".

In compliance with Section 7(c) of the 1978 amendments to the Endangered Species Act, the NRC requested from the FWS (Ref. 10) a list of endangered and threatened species that may occur in the vicinity of the Callaway Plant and two transmission corridors in Callaway, Montgomery, Osage, and Gasconade Counties, Missouri. The FWS response (Ref. 11) stated that three species may be present in the area of concern: the bald eagle (Haliaeetus leucocephalus alascensis) in Callaway, Osage, and Gasconade Counties; the pink mucket pearly mussel (Lampsilis orbiculata orbiculata) in Osage and Gasconade Counties; and the peregrine falcon (Falco peregrinus) in Gasconade County. Bald eagles have been sighted along the Missouri River several kilometers from the Callaway site; they may be expected to be seen occasionally flying over the site, but do not nest in the area (ER-OL, Sec. 2.2.3.7) (Ref. 7). The pink mucket pearly mussel has been found in the Gasconade River, which enters the Missouri River about 16 km (10 mi) downstream from the intake structure, and the Osage River, which enters the Missouri River about 24 km (15 mi) upstream from the intake structure. It was also noted that the gray bat (Myotis grisescens) can be found in one cave in the southeastern part of Osage County. No Federally designated endangered or threatened plant species have been observed on the site (ER-OL, p. 2.2-81).

The Missouri Department of Conservation maintains its own list of rare and endangered species (Ref. 12). Two species of birds listed as endangered by the state have been observed near the Callaway Plant: the marsh hawk (Circus cyaneus) and the sharp-shinned hawk (Accipter striatus) (ER-OL, Sec. 2.2.3.7). One species of fish, one species of mammals, and two species of birds listed as rare by the state have been observed near the Callaway Plant: the brown bullhead (Ictalurus nebulosus), the long-tailed weasel (Mustela fenata), the bald eagle (Haliaeetus leucocephalus alascensis), and the ruffed grouse (Bonasa umbellus) (ER-OL, Secs. 2.2.2.7.1 and 2.2.3.3.3 and p. 2.2-82). The brown bullhead was collected once in the Missouri River and twice in Logan Creek (ER-OL, Tables 2.2-18 and 2.2-19). Only one state-designated species of rare and endangered plants has been found on the site: the American elm (Ulmus americana) (ER-OL, p. 2.2-80).

4.3.6 Historic and Archeological Sites

The region in which the Callaway Plant is located has a long and diverse cultural sequence, and numerous historic and prehistoric cultural-resource sites are known to exist. A description of the cultural history of the region was provided by the applicant (ER-OL, Sec. 2.6 and Apps. 2I, 2J, and 2K).

Two cultural-resource sites were located on the plant property prior to issuance of the FES-CP (FES-CP, Sec. 2.3). The applicant's archeological survey indicated that one of the sites might have cultural-scientific importance. It had been determined that this site, 23CY20, was potentially eligible for inclusion in the National Register of Historic Places. The site was nominated by the state, and the nomination was later returned by the Keeper of the National Register with a request for additional information (Ref. 13). The NRC staff will resubmit the site 23CY20 material to the Keeper. The applicant is taking appropriate measures to protect the site during the determination process.

During a site visit on 18-19 November 1980, the staff and the Missouri Department of Natural Resources, Division of Parks and Historic Preservation, observed some unrecorded sites and requested the applicant to conduct a survey of the area of potential environmental impact related to the operation and maintenance of the nuclear power plant and associated facilities (see App. H). The applicant is presently proceeding toward a final research design to undertake a survey and assessment of sites that may be identified.

4.3.7 Socioeconomic Characteristics

Socioeconomic characteristics include demography, governmental services, housing, land use, local economy, political and social structures, and recreation. The relevant attributes for the region around the Callaway Plant have been described (FES-CP, Secs. 2.2, 4.2, 4.5, and 5.6). Some changes have occurred since the FES-CP was issued; these are described below.

4.3.7.1 Demography

Population projections within an 80-km (50-mi) radius surrounding the site have been revised upward since publication of the FES-CP. Preconstruction data and current data provided by the applicant and reviewed by the staff are presented in Table 4.3. Population-distribution estimates for 1970 and 2030, within 16 km (10 mi) of the site, are shown in Figure 4.7.

Population fluctuations will occur seasonally within 8 km (5 mi) of the plant due to changes in the transient populations of the Reform Wildlife Management Area and Lost Canyon Lakes. The Reform Wildlife Management Area allows hunting, fishing, and trapping, but a ban against camping will prevent people from staying in the area. Lost Canyon Lakes is a recreational-vehicle and trailer-park development with about 200 people on an average weekday, 600 people on a typical weekend, and 1400 people on a holiday. As discussed in Section 4.3.7.2 Lost Canyon Lakes plans further development; should this occur, there will be an increase in the future transient population.

Table 4.3. Projected Population Within 80 Kilometers, 1970-2030

Year	Population Estimates	
	Preconstruction†[1]	Current†[2]
1970†[3]	305,411	305,338
1980	348,674	369,490
1990	391,374	421,180
2000	425,435	464,820
2010	465,591	492,190
2020	500,946	518,090
2030	-	553,370

†[1] From the ER-CP (Table 2.2-3).

†[2] From the ER-OL (Table 2.1-4).

†[3] The difference between the two 1970 values reflects the census-data update.

4.3.7.2 Settlement Patterns

Eight of the original 16 residences located on the land owned by UE still remain and are being rented to tenants by UE. When CAL-1 becomes operational, the one residence on the plant site will not be leased but will be used for various plant activities. UE plans to continue renting the other seven residences to tenants as long as it remains profitable.

The developer of Lost Canyon Lakes recently has offered 110 homesites in the area, each of about 1.2 ha (3 acres). Although the area is inhabited only by transients at this time, the composition of the population will change as these units are sold and developed.

The staff expects that the area within 16 km (10 mi) of the site will experience a slow growth rate and continue its rural character during the operation of CAL-1. The location and availability of land around Jefferson City will not require the community to grow toward the site. Also, inasmuch as the

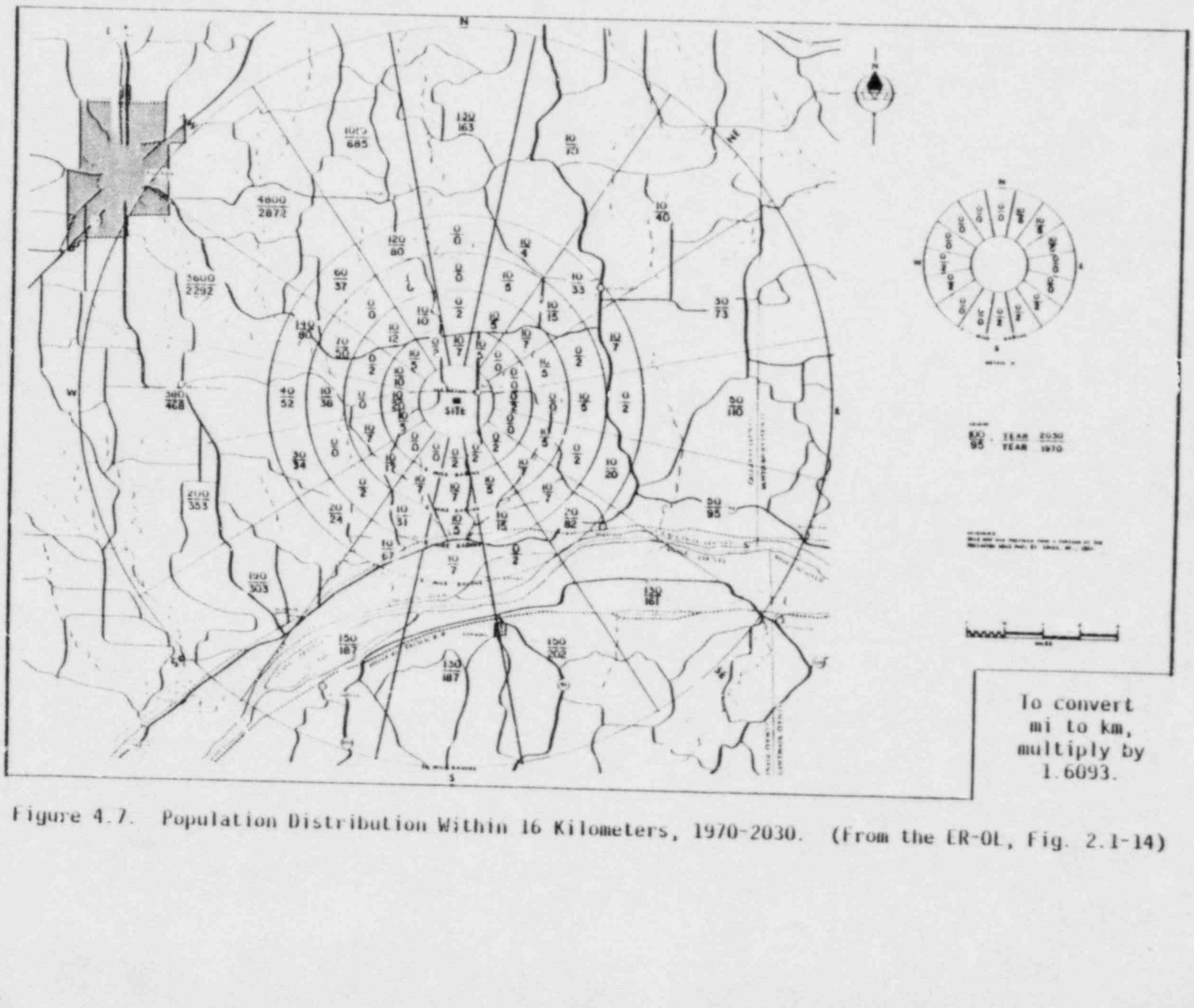


Figure 4.7. Population Distribution Within 16 Kilometers, 1970-2030. (From the ER-OL, Fig. 2.1-14)

site is not within commuting distance (130 km or 80 mi) of St. Louis, the development of suburban communities near the site is not anticipated.

4.3.7.3 Commercial and Recreational Fishing

Commercial- and recreational-fishing activities were covered very briefly in the FES-CP (Sec. 2.7.1). Updated estimates of commercial and recreational fish harvests within an 80-km (50-mi) radius of the plant were provided by the applicant (ER-OL, Sec. 6.1.4.2.1.2.2). Commercial and recreational fishing on the Missouri River between the Callaway Plant and the Mississippi River were examined by the staff because of their importance for assessing the potential impacts from accidental releases of radioactive effluents (Sec. 5.9.4).

The commercial harvest from the Missouri River in Missouri was about 150,000 kg (330,000 lb) in 1978 and about 114,000 kg (250,000 lb) in 1979, mostly species of carp, catfish, and buffalo (Refs. 14 and 15). The combined harvest of the nine downstream counties potentially affected by operation of CAL-1 (from the plant to the Mississippi River) was 24% of the total for 1978 and 29% of the total for 1979. County agents of the Missouri Department of Conservation have stated that commercial fishing in this area is limited by lack of access points, seasonally poor river conditions, and low local-market demands. Commercial fishing, determined by license checks on the Missouri River, is fairly heavy during the summer months in the vicinity of St. Louis and St. Charles Counties.

There are no current data available related to recreational fishing in Missouri. County agents in the area extending from the Callaway Plant to the Mississippi River report that bank fishing is more prevalent than boat fishing, and is usually confined to areas with road access. The few public-access boat ramps in the area are located upstream from the plant at Mokane and Chamois, and downstream in St. Louis County. Recreational-fishing pressure is greatest in the areas near cities and towns. Catfish, carp, and buffalo are the most abundantly caught recreational species.

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5. ENVIRONMENTAL CONSEQUENCES AND MITIGATING ACTIONS

5.1 RÉSUMÉ

This résumé highlights changes in the staff's evaluation of environmental effects of operating the Callaway Plant in the light of information gained since the FES-CP was issued in 1975. No discussion is provided of those impacts for which there has been no new information or change since the construction review.

The major change is a consequence of the decision to defer construction of Unit 2. Analyses and conclusions in the FES-CP regarding environmental impacts applied to two units. The analyses in this section (except as noted) also are for two units; however, the conclusions pertain only to the operation of CAL-1. Conclusions for operation of CAL-1 alone can be drawn from the two-unit analyses because the one-unit impacts do not exceed the two-unit impacts. Other changes are relatively minor, and are summarized below.

Changes in land-use impacts due to operation of the sludge lagoons and revised estimates prompted by updated information are discussed. Water-use and hydrological impacts are reexamined and updated to reflect changes in plant design and operation and more recent environmental data. Air-quality impacts are reexamined using onsite meteorological data collected after 1975. Terrestrial- and aquatic-ecology impacts are reviewed and updated. Historic and archeological sites are reviewed in the light of new information gained during the site visit. Socioeconomic impacts are reviewed and updated. Information on radiological impacts of normal operation has been revised to reflect updated knowledge gained since the FES-CP was issued. The material on plant accidents now contains information that has been revised and updated to include Class 9 accidents and the lessons learned from the accident at Three Mile Island, Unit 2. The latest information on environmental effects of the uranium fuel cycle and decommissioning is provided.

Operational monitoring programs are to be conducted in accordance with the Environmental Protection Plan (EPP) to be issued by NRC as part of the operating license. The EPP will require the applicant, as licensee, to (1) notify NRC if changes in plant design or operation occur, or if tests or experiments affecting the environment are performed, provided that such changes, tests, or experiments involve an unreviewed environmental question; (2) maintain specific environmentally related records; (3) report violations of conditions stated in the NPDES permit or state certification pursuant to Section 401 of the Clean Water Act; and (4) report unusual or important environmental events.

5.2 LAND USE

Much of the discussion in the FES-CP of operational impacts on land use (FES-CP, Secs. 5.3.4, 5.4.4, 5.5.4, and 5.6.1) remains valid. The following analyses of potential land-use impacts are provided to take into consideration the addition of sludge lagoons, other plant-design changes, and new information gained since the FES-CP was issued.

Of the 2926 ha (7230 acres) constituting the plant site, peripheral land, corridor area, and land committed to the plant by UE ownership, about 92 ha (228 acres), of which 90% was prime farmland, will be used in the operation of the Callaway Plant (ER-OL, Sec. 5.7.1.3). An additional area of 800 ha (2000 acres) will be unavailable for public use during the operational lifetime of the plant. It includes 300 ha (750 acres) of prime farmland (ER-OL, Fig. 2.1-34).

Recovery for subsequent use as terrestrial habitat is expected on about half the area impacted by construction. Recovery of terrestrial habitat lost to settlement ponds (36 ha or 88 acres) and the initial three sludge lagoons (11 ha or 26 acres) should take place during the operational lifetime of the plant. Temporary destruction of an additional 46 ha (114 acres) of terrestrial habitat will occur as a result of the construction and use of 13 additional sludge lagoons. All the land committed to use for sludge lagoons will become terrestrial habitat or be available for agriculture at the end of the operational lifetime of the plant. Other changes in plant design, discussed in Section 4.2.1, will have a negligible effect on land use.

Land use for the period 1977-1982 has been guided by an initial land-management plan developed in cooperation with the State of Missouri (Sec. 4.2.2). The staff believes that this cooperative plan will minimize adverse land-use impacts and probably lead to beneficial effects because it provides expert planning and advice that was not made available for the plant site and adjacent areas prior to 1977, and recommends that it be continued with whatever improvements may be indicated by experience gained during the initial period.

The land-use impacts due to operation of CAL-1 alone will not be very different from those due to operation of two units (the major difference being that fewer sludge lagoons will be needed), but they will be less.

The staff concludes that land-use impacts due to operation of CAL-1 will not exceed estimates given in the FES-CP. There will be some recovery from land-use impacts that have already occurred as a consequence of construction of the plant, and some of the operational impacts will be temporary. The land-use impacts may be summarily characterized as small.

5.3 WATER

5.3.1 Use

The average/maximum net water use (intake less discharge) for operation of two units at the Callaway Plant would be about 1500/1900 L/s (24,000/30,000 gpm) (Sec. 4.2.3). All the water for operating the plant would be taken from the Missouri River, and would amount to about 0.1% of the average flow, about 0.7% of the 7-day 10-year low flow, and about 2% of the lowest recorded flow

(Sec. 4.3.1.1). No groundwater will be used for Callaway Plant operations. Water use for a single unit will be about one-half the use for two units, or about 750/950 L/s (12,000/15,000 gpm) for average/maximum net water use. On the basis of these data, the staff concludes that the water-resource commitment for operation of CAL-1 will be small and that this water use will have no impact on surface-water supplies downstream or on organisms inhabiting the river.

5.3.2 Quality

Water-quality impacts will be caused by chemical and other wastes in the plant effluent discharging into the Missouri River. They were examined by the staff during the construction review (FES-CP, Secs. 5.3.1 and 5.4.1). There have been changes in concentrations of wastes in the plant effluent due to changes in plant design, operating procedures, and environmental data (Secs. 4.2.6 and 4.3.2). The consequent changes in surface-water-quality impacts are examined below.

5.3.2.1 Surface Water

The revised estimates of the chemical wastes in the plant effluent that are discharged into the Missouri River are given in Table 4.2. The values in the table are for two operating units; the changes needed to make them applicable to one unit are described in the first footnote to the table and in Section 4.2.6.1.

The major change in the plant effluent is due to the addition of sludge lagoons to collect most of the sediment from the makeup water. As a consequence, the concentration of suspended solids in the river downstream from the discharge point will be decreased rather than increased. In addition, most of the polyelectrolyte, which is adsorbed by the suspended particles, will remain in the sludge lagoons with the sediment instead of being discharged to the river.

Other changes that affect the quality of the river water below the discharge point are as follows.

A new estimate of the amount of organic phosphonate dispersant needed for scaling control, provided by the applicant, is smaller by a factor of four and leads to a corresponding reduction in the estimate of the effluent phosphonate concentration by a factor of four. Gaseous chlorine will be replaced by sodium hypochlorite for biocide control, but this does not appreciably change the applicant's estimated discharge of residual chlorine. The free available chlorine at the outfall from cooling-tower blowdown will still be within the limits of 0.5 mg/L for the daily maximum and 0.2 mg/L for the monthly average for operation of either one or two units (Sec. 4.2.6.1). The estimated concentrations of sodium, sulfate, copper, and total dissolved solids in the plant effluent, based on the applicant's data and reviewed by the staff, have increased by 18%, 51%, 46%, and 8%, respectively. These and other changes in the estimated chemical-discharge concentrations given in Table 4.2 are not large enough to alter any of the conclusions stated in the FES-CP (Sec. 5.3) regarding water-quality impacts. The concentrations of dissolved copper and nickel (less than 0.8 mg/L each) in the plant effluent are within the NPDES limits (Tables 4.1 and 4.2 and App. B). Changes in the concentrations of dissolved solids in the river after mixing are mostly due to the use of updated values of the maximum measured concentrations in the river prior to mixing (Sec. 4.3.2).

Under 7-day 10-year low-flow conditions (280,000 L/s or 9900 cfs), the concentration of all dissolved substances present in the Missouri River would be increased up to about 0.7% as a consequence of the loss of up to 1900 L/s (66 cfs) of water by evaporation, nearly all in the cooling towers. (This increase is for operation of two units; CAL-1 alone would cause an increase of less than about 0.4%.) This increase is not expected to produce observable adverse impacts on the downstream water quality.

The number of fecal-coliform bacteria already present in the Missouri River water was found to exceed state water-quality standards (ER-OL, p. 2.2-5). Operation of the plant will probably have a very small but favorable impact on the number of bacteria; the biocide treatment will kill a large fraction of the bacteria in the cooling water, and treatment of sanitary wastes should be sufficient so that the number of bacteria returned to the river in the discharge should be less than the number removed from the river in the intake.

The applicant asserts that the Callaway Plant will be in compliance with all applicable state and Federal regulations regarding plant effluents (ER-OL, Rev. 2, Sec. 3.6.10). EPA standards for existing sources are applicable (ER-OL, App. 5B). The applicable standards are stated in NPDES Permit No. MO-0098001 issued to the applicant by the State of Missouri (App. B). The staff concurs with the applicant's assertion and concludes, on the basis of the foregoing analysis and review of data submitted by the applicant and of the analysis and review in the FES-CP, that the surface-water-quality impacts caused by operation of CAL-1 will be small.

5.3.2.2 Groundwater

No plant use of groundwater is projected during the operational stages of Callaway Units 1 and 2. Liquid effluent from the plant will be discharged into the Missouri River after suitable treatment. There will be no releases to the groundwater as a result of normal plant operation.

The staff concludes that operation of the Callaway Plant will have no effect on groundwater use in the area.

5.3.3 Floodplain Aspects

Construction of the intake structures and discharge outlet had already begun at the time Executive Order 11988, Floodplain Management, was signed in May 1977. Therefore, it is the staff's conclusion that consideration of alternative locations for those structures identified as being in the floodplain is neither required nor practicable.

For the Missouri River in the vicinity of the plant intake and discharge structures and docking facility, the 1% chance (100-year) flood discharge is 17.3×10^6 L/s (610,000 cfs). The rating curve for the river at this location shows the water level corresponding to this discharge as elevation 162 m (533 ft) MSL. Portions of these structures are, by design, located below this elevation. However, the intake structure is designed to remain functional during the 200-year flood (water elevation 164 m or 539 ft MSL). In addition, the plant can be safely shut down using the onsite cooling towers, which are unaffected by Missouri River floods.

The 100-year floodplain of the Missouri River is about 3000 m (10,000 ft) wide at the location of the intake and discharge outlet. These structures, along with an access road running from State Highway 94, extend about 600 m (2000 ft) into the 100-year floodplain on the north side of the river. However, a preexisting levee system, although overtopped by the 100-year flood, greatly reduces the conveyance that would otherwise exist in the affected overbank area. The additional reduction in channel conveyance caused by the road and structures is considered to be minor, and upstream effects on 100-year flood-water level will be negligible. The 100-year floodplain of the Missouri River at the site and the location of floodplain structures is shown in Figure 5.1.

The Callaway Plant is located on the high point of a plateau; therefore, there will be no interaction between plant structures and the floodplains of streams draining the plant area.

In conclusion, the effect on the 100-year flood levels of any streams in the vicinity of the site due to the construction or operation of the Callaway Plant will be negligible.

5.4 AIR QUALITY

5.4.1 Fog and Ice

The only significant source of fog and ice from plant operations will be from the cooling towers. Contributions from other plant sources, such as the ultimate heat sink, are expected by the staff to be smaller. The fogging and icing impacts from the cooling towers were examined by the staff during the construction review (FES-CP, Sec. 5.1.2.3); they have been reexamined in the light of new data provided by the applicant on drift-emission rates and plume characteristics (ER-OL, Sec. 5.1).

The generation of visible plumes, which remain aloft sometimes for extended distances, is the most apparent atmospheric effect of natural-draft cooling-tower operation. An analysis of the visible plumes generated by two towers, based on three years of onsite meteorological data as model input rather than the more limited offsite data used in the preconstruction analysis, has been provided by the applicant (ER-OL, Sec. 5.1.4.1). The applicant predicted that the plumes from both towers will extend less than 1200 m (4000 ft) 43% of the time, more than 3000 m (10,000 ft) 23% of the time, and greater than 6000 m (20,000 ft) 8% of the time (ER-OL, Table 5.1-1). The staff has reviewed this analysis and concludes that it is reasonable. These results cannot be compared directly with the single-tower calculations because plume effects for two towers are not additive; however, they do provide loose upper limits for plume lengths from a single tower.

Ground-level fogging in areas of level terrain can result when the cooling-tower plume descends to the surface. If this occurs when surface temperatures are below freezing, icing can result. The revised analysis by the applicant predicts two additional hours per year of ground fogging (but no icing) from two towers operating at maximum capacity (ER-OL, Sec. 5.1.4.1 and Table 5.1-2). These predictions are supported by published reports which state that natural-

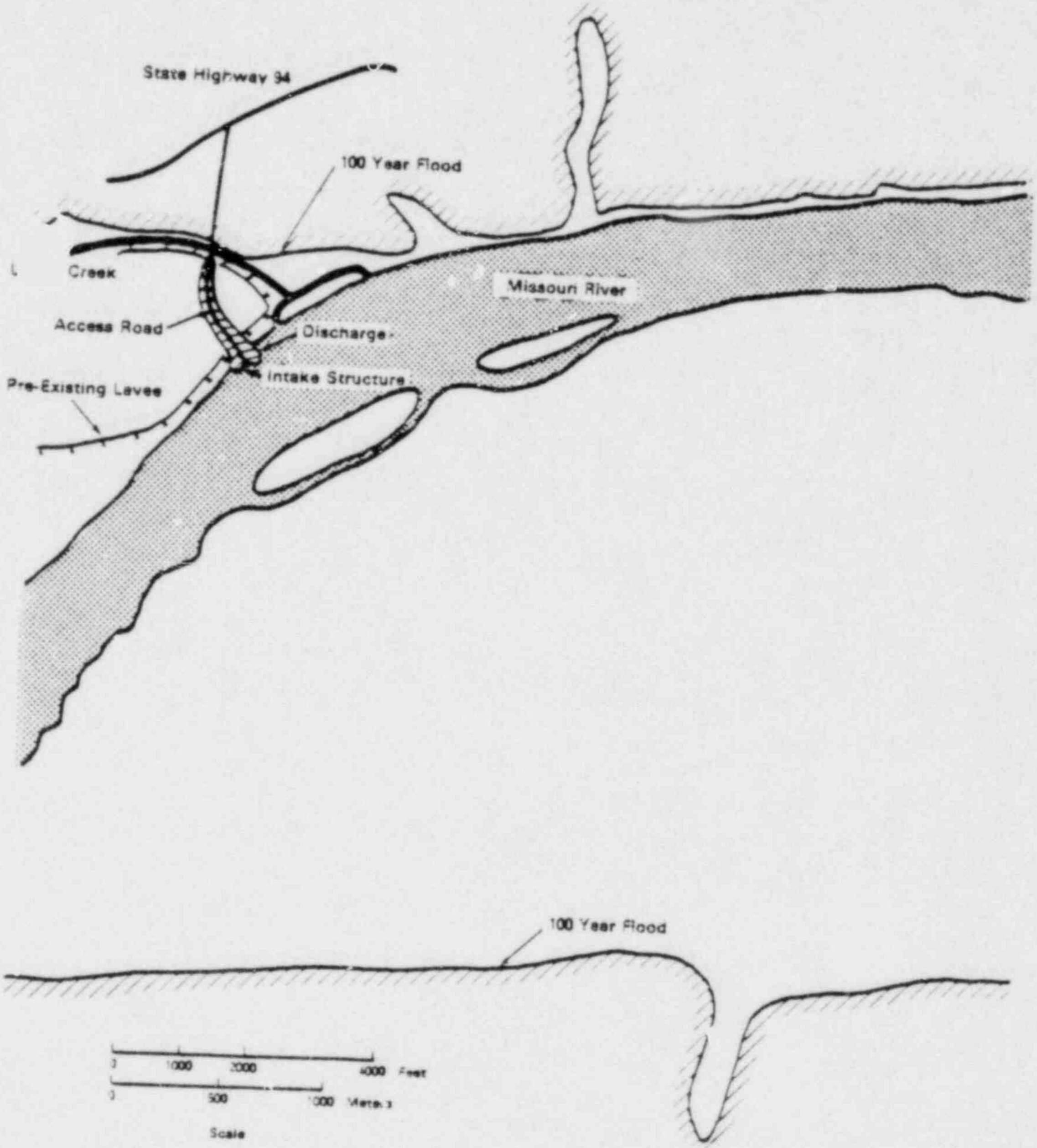

Figure 5.1. Floodplain-Location Map.

draft cooling towers rarely induce ground fogging or icing (Refs. 1 and 2). Therefore, ground-level fogging and icing due to cooling-tower operation are not expected to be frequent occurrences at or near the Callaway site.

The possibility of increased ground-level humidity due to the moisture emitted from the cooling tower has been examined by the applicant (ER-OL, Sec. 5.1.4.1). The findings indicate that, over a three-year period, such increases are expected to occur less than 1% of the time, primarily because the large tower height and great heat flux from the tower result in elevated plumes that rarely reach the ground.

The visible plume from a natural-draft cooling tower will reduce the amount of sunshine reaching the ground below. Studies have indicated that reductions in sunshine of up to 20 min/d can occur in the immediate vicinity of such towers. At distances of about 10 km (6 mi) such reductions drop to 1 min/d. Thus, it is reasonable to expect plume-shadowing effects of a similar magnitude in the vicinity of the Callaway site.

It was assumed at the time the FES-CP was issued, on the basis of information from published studies, that the vertical extent of the plume should neither create cumulus clouds nor produce precipitation (primarily snow in winter) downwind from the site. Such phenomena have subsequently been observed at other natural-draft cooling towers, although they occur relatively infrequently (Refs. 1 and 2). The staff considers such a small and infrequent increase in precipitation and creation of cumulus clouds to be generally neutral or benign impacts and, therefore, does not consider this new information to be sufficient basis for revising its conclusions regarding cooling-tower impacts.

The staff concludes, on the basis of the foregoing considerations, that the contributions to fogging and icing from operation of the CAL-1 natural-draft cooling tower will be negligible.

5.4.2 Emissions and Dust

5.4.2.1 Cooling-Tower Drift

Estimates of the total rate of emission of solids in the cooling-tower drift from both towers (30 g/s or 4 lb/min) and of the composition of these solids (mostly calcium, sodium and magnesium sulfates, carbonates, chlorides, and silicates) were reviewed and updated by the staff (Sec. 4.2.6.3) on the basis of new data provided by the applicant. The emission rate is 30% higher than preconstruction estimates. The revised estimate is still within the expected range for natural-draft cooling towers, for which the observed drift effects are small and limited to the immediate vicinity of one cooling tower (Ref. 2). Hence, the staff does not consider this increase to be sufficient to alter conclusions stated in the FES-CP regarding air-quality impacts from cooling-tower drift, and concludes that those due to operation of CAL-1 will be small. Terrestrial impacts from drift fallout are considered in Section 5.5.1.2.

5.4.2.2 Other Emissions and Dust

As stated in the FES-CP, nonradioactive atmospheric pollutants (e.g. oxides of nitrogen and SO_2) produced by operation of auxiliary boilers and diesels should not have a significant impact on air quality in the vicinity of the plant.

5.4.3 Monitoring

The operational phase of the onsite meteorological measurements program will be essentially the same as the preoperational program described in the FES-CP. Because of the increased emphasis on real-time assessments of atmospheric-dispersion conditions during plant operation, the following information will be monitored in the control room:

1. Wind speed and direction at the 10-, 60-, and 90-m levels,
2. Vertical temperature difference between 10 m and 60 m and between 10 m and 90 m,
3. Dry-bulb and dew-point temperatures at 10 m, and
4. Precipitation near the ground.

Procedures to improve data recovery during the operational program should be implemented by the applicant.

5.5 ECOLOGY

5.5.1 Terrestrial

The terrestrial-ecology impacts that were expected to be caused by operation of the plant were assessed during the construction-permit review (FES-CP, Secs. 5.3.3, 5.4.3, and 5.5.3). Additional impacts that are expected to occur during operation, but were not considered previously, and impacts that were reevaluated in the light of changes in plant design, operating procedures, or new meteorological data, are considered below. The permanent loss of terrestrial habitat from the presence and operation of the Callaway Plant is about 92 ha (228 acres) (Sec. 5.2); other temporary losses related to plant operation are described below.

5.5.1.1 Sludge Lagoons

There will be a temporary loss of about 57 ha (140 acres) of terrestrial habitat, mostly pasture and old farmland, to excavation of the sludge lagoons (Fig. 4.2) as they are used for plant operations (Refs. 3 and 4). The loss of 11 ha (26 acres) has already occurred; the loss of up to 46 ha (114 acres) could occur during the operational lifetime of the plant (Units 1 and 2). Most of the suspended solids in the makeup water from the river, and the polyelectrolyte added to the makeup water to coagulate the suspended solids, will be deposited in the sludge lagoons instead of being returned to the river as originally planned. After each sludge lagoon is filled with sediment removed from the Missouri River water, the area will be fertilized and reseeded with a mixture of grasses and other ground cover to restore it to a state where native plants are sufficiently established to maintain a natural cover. The staff concludes that, if the foregoing plans are implemented, the sludge lagoons and rock quarry will have a small and temporary, but not permanent, negative impact on the terrestrial ecology.

The topography of the plant site and the location of the plant facilities are such that no accelerated erosion will occur as a consequence of the existence or operation of the plant, after construction activities and final landscaping have been completed.

The sludge lagoons might occasionally serve as a resting place for waterfowl, but they will be less attractive than the settling ponds and nearby natural bodies of water. They provide no food and are more susceptible to interference by man. They will not act as potential sites for algal blooms because their high levels of suspended solids will inhibit algal growth. On the basis of the foregoing considerations, the staff concludes that the sludge lagoons do not pose a hazard to the ecosystem.

5.5.1.2 Cooling-Tower Emissions

Terrestrial impacts resulting from cooling-tower emissions were reexamined by the staff in the light of new data provided by the applicant on emission rates, drift composition, plume characteristics, and drift-fallout distribution (Secs. 4.2.6.3, 5.4.1, and 5.4.2.1). This information is used to update the preconstruction discussion of terrestrial impacts from cooling-tower emissions (FES-CP, Sec. 5.1.2.3).

Fog and Ice

The fogging and icing that might result from cooling-tower emissions and other plant sources are examined in Section 5.4.1 and found to be negligible; hence, the staff concludes that there will be no terrestrial impacts from fogging and icing as a consequence of operation of CAL-1.

Drift Fallout

The preconstruction calculation of the geographical distribution of drift fallout for two units (FES-CP, Table 5.6) has been revised by the applicant using more recent meteorological data and providing more detail (ER-OL, Rev. 2, Table 5.1-6). The staff has reviewed the applicant's calculation and concludes that it is reasonable. It should be noted that the applicant's modeling results are very conservative in that they neglect evaporation of drift droplets and, hence, overestimate the number of droplets (i.e. the amounts of solids) that do, in fact, reach the ground. The estimated maximum deposition rate of 4.5 g/m^2 per year (1.1 ton/mi^2 per month), which will occur at a location about 2500 m (8200 ft) directly north of the cooling towers (ER-OL, Rev. 2, Table 5.1-6, corrected for revised estimate of total emission rate), is well below the standard of 15 ton/mi^2 per month for settleable particulates established by the State of Missouri (ER-OL, Sec. 3.6.11). Deposition rates for operation of CAL-1 alone will be one-half the rates stated above, which are for both units. The composition of the drift will be as described in Section 4.2.6.3. Natural rainfall will prevent a buildup of salt deposits in the soil. A review of experience with freshwater cooling towers, both in this country and abroad, has failed to provide any findings of an environmental effect beyond the immediate vicinity of the cooling towers (Ref. 2). Therefore, the staff concludes that terrestrial impacts due to cooling-tower-drift fallout resulting from operation of CAL-1 will be small.

5.5.1.3 Bird Impaction

Bird kills by collision with cooling towers have been studied and reviewed (Refs. 5 and 6). The hazard is greatest on overcast nights during migration. There are no data for estimating the extent of bird kills that might be expected at the Callaway Plant, but all lighting on the towers should be intermittent, high-intensity strobe lights. This type of lighting will serve adequately for aircraft warning, and it will not attract birds as do nonblinking lights (Ref. 7). This mode of illumination should decrease the number of birds killed by collision with the towers. The staff expects that, with such precautions, the number of birds killed will be small relative to their populations.

5.5.1.4 Noise

The noises of operation produced by the power plant and the cooling towers will be less than 70 dBA at the fence (Sec. 5.8.6). This is within EPA-recommended limits for the sound power level for unpopulated land. The sound will return to ambient levels at 1700 m (5600 ft) from the cooling towers. The major source of noise, the cooling towers, resembles the noise of small waterfalls and, consequently, will not disturb resident wildlife.

5.5.1.5 Transmission Lines

The ROWs for both transmission lines have already been built. Selective cutting was used throughout; where streams were crossed, vegetation on the banks was not disturbed; and where foundations have been or will be dug, contouring, reseeding, and fertilization of the disturbed area are being undertaken to prevent erosion (ER-OL, App. 4A). The cleared tree trunks have been windrowed along the edge of the ROW; branches and limbs have been removed. The amount of forest that has been removed (270 ha or 670 acres) is a small fraction of the forestland that exists in the area. Where the ROWs go through the forest, ecotone communities will develop along the edges. The staff believes that new flora and fauna will be the same as in the contiguous similar communities that will serve as the source of new immigrants.

Potential operational hazards of high-voltage transmission lines, such as ozone, noise, shock hazards, and low-level electric fields, have been studied. The effects of these operational by-products on terrestrial ecosystems was thoroughly reviewed for a 500-kV transmission line (Ref. 8) and none of these potential hazards was found to have a measurable impact. The Callaway Plant will use lower-voltage 345-kV lines; therefore, the staff concludes that it is unlikely these factors will have any measurable impact on terrestrial ecology.

Bird collisions with the transmission lines are most likely to occur with birds that fly in flocks, such as starlings, blackbirds, and grackles; the estimated death rate due to such collisions is less than five birds per line-mile per year (Ref. 9). The impact of these deaths on the population of these ubiquitous species would not be detectable.

The towers will provide new roosts for raptors along the length of the ROW. The effects of predator-prey relationships will be in favor of the raptors. This is desirable because acceptable raptor habitat is lost with most of man's new construction projects.

The Callaway-Bland transmission line crosses the Gasconade River at one point. The Gasconade River has been inc uded, in its entirety, in the first Nationwide River Inventory listing of rivers that might qualify for designation in the National Wild and Scenic Rivers System (Ref. 10). The Callaway-Bland line uses an existing ROW for about half the length, including the Gasconade River crossing. The river banks are not distrubed at the crossing and the closest towers are set far back; a screen of willows on one bank and a high bank on the other side block any view of the towers from small boats on the river. The staff concludes that the impact of the ROW crossing has been minimized as much as is reasonably possible, and that there will be no adverse effect that could preclude inclusion of the Gasconade River in the National Wild and Scenic Rivers System or alter its potential classification within it.

On the basis of the foregoing considerations and information provided in the FES-CP, the staff concludes that terrestrial-ecology impacts of the transmission lines during operation of CAL-1 will be small.

5.5.1.6 Monitoring

A recommendation in the FES-CP (Secs. 6.1.4.2 and 6.2.4.2) was that the applicant's postconstruction monitoring should include an analysis of the chemical composition of the soil and leaf litter. This was to ensure verification of the prediction that the cooling-tower drift would not adversely affect the soil chemistry and, therefore, any plants growing in the soil. On the basis of the considerations discussed above, the staff concludes that the potential for damage to the surrounding ecosystem caused by the water and chemicals in drift expected to come from the CAL-1 cooling tower will be small. Nevertheless, the staff believes it is prudent to undertake a limited-term inspection program because a margin of uncertainty exists in the foregoing conclusion. An acceptable monitoring program is best accomplished by means of infrared aerial photography with accompanying ground truth. A program to accomplish this will be specified in an environmental-protection plan that will be included as Appendix B of the operating license. This plan also will include requirements for prompt reporting by the licensee of any occurrence of important events that potentially could result in significant environmental impact causally related to plant operation. Examples of such events are excessive bird destruction due to collision with plant facilities, onsite plant- or animal-disease outbreaks, and mortality of any species protected by the Endangered Species Act of 1973 as amended.

5.5.2 Aquatic

The aquatic-ecology impacts that were expected to be caused by operation of the plant (both units) were assessed during the construction review (FES-CP, Secs. 4.4.1, 5.1.1, 5.1.2, 5.3.1, 5.4.1, and 5.5.1). Changes in plant design and planned operating procedures that have occurred since the FES-CP was issued and that might affect aquatic-ecology impacts are described in Sections 4.2.1, 4.2.3, 4.2.4, and 4.3.4.2. Consequent changes in aquatic-ecology impacts are discussed below.

5.5.2.1 Impingement and Entrainment

The redesign of the intake structure (Sec. 4.2.4.1) has increased the size of the individual embayments, and thus reduced maximum water velocity through the screens (now estimated at 0.18 m/s or 0.6 ft/s). These new conditions will slightly lessen the potential for impingement and entrainment. The relocation of the intake-structure base and gates will not affect the number of organisms that might enter the opening and, therefore, should not alter the losses of aquatic biota due to impingement and/or entrainment, as compared with the losses assessed in the FES-CP.

Because optimal operation of the intake-structure pumps is at a fixed pumping rate chosen for efficient overall operation, more water will be withdrawn from the river at certain times of the year than is necessary for cooling-tower operation. This excess water will be discharged directly back into the Missouri River through the common discharge pipe (Sec. 4.2.4.1). Periods of excess water withdrawal will coincide with high or normal river flows; therefore, scour associated with discharging this excess water will be minimal.

The closed-cycle cooling design with low makeup volume and intake velocity will minimize entrainment and impingement losses. The conclusion stated in the FES-CP was that the impacts would be minor and insignificant to the river fish populations. This conclusion remains valid. Limited fisheries of the river in the site vicinity (Sec. 4.3.7.3) further reduce the likelihood of socioeconomic impacts from intake losses of fish. Results of the 316(b) monitoring studies, as required by the NPDES permit, will indicate if additional mitigative measures are needed (Sec. 5.5.2.4).

5.5.2.2 Thermal Discharge

The thermal-discharge effects associated with the thermal plume created by discharge of the blowdown into the Missouri River were analyzed during the construction review (FES-CP, Sec. 5.1.2.1). The staff has updated that analysis to take into account the following changes that have been introduced since the construction review: (1) a correction in the value used for the 7-day 10-year low flow for the river; (2) new data for the maximum ambient river temperature; (3) repositioning of the discharge pipe; and (4) the decision to defer construction of the second unit. An analysis of the effect of these changes on the thermal-discharge impacts is given below.

Missouri water-temperature standards for the Missouri River, as amended through 10 July 1980, are unchanged from those considered in the FES-CP. These standards require that effluents not elevate or depress stream temperatures more than 2.8°C (5°F) or cause the stream temperature to exceed 32°C (90°F) outside the mixing zone. As a guideline for the design of outfalls, no more than 25% of the cross-sectional area or volume of a stream shall be allowed as a mixing zone (Ref. 11). The only additional requirement, as specified in the NPDES Permit No. MO-0098001 (App. B), is that the discharge be controlled, limited to a maximum discharge temperature of 35°C (95°F), and monitored continuously on a 24-hour recorder.

Thermal-plume analyses were performed by the applicant and verified by the staff (FES-CP, Sec. 5.1.2.1). The two conditions investigated were:

1. Extreme January low river flow (the 7-day 10-year low flow) and extreme outfall-temperature difference (ΔT) above ambient river temperature and

2. Highest ambient river temperature ever recorded, the lowest legal flow maintained by the Corps of Engineers for the period of the year most likely to have the high temperature, and discharge flow and temperature values higher than ever expected.

The thermal plumes for these two cases are shown in the FES-CP (Fig. 5.1).

For Case 1, the 7-day 10-year low flow of 280,000 L/s (9900 cfs, ER-OL, Table 2.4-6) is larger than the value used for the original thermal-discharge calculation (240,000 L/s or 8500 cfs, FES-CP, Sec. 5.1.2.1). The discharge temperature used in the analysis was about 4°C (7°F) higher than the expected discharge temperature; hence, the maximum difference, ΔT, between the temperature of the effluent and the river at the point of discharge will be less than the assumed value. Thus, the thermal plume is expected to be smaller than predicted in the FES-CP, and the water temperature standards will be satisfied.

For Case 2, it was shown that an extreme discharge temperature of 35°C (95°F) and a maximum ambient river temperature of 30°C (87°F) will satisfy water-quality standards. However, an ambient temperature of 32°C (90°F) has been observed at Boonville, Missouri, in both July and August (ER-OL, Table 3.4-4). The maximum discharge temperatures are estimated to be 34.4°C (94°F) and 33.9°C (93°F) in these two months, respectively. Thus, the ΔT for two operating units will be smaller and the plume will be smaller than previously estimated (FES-CP, Fig. 5.1). Although the environmental effects of this extreme case are even less than previously predicted, no mixing zone of any size will reduce the stream temperature to 32°C (90°F) or below outside the mixing zone. The state water-quality standards do not address themselves to this possibility; therefore, no definite conclusion as to compliance or violation of the standards can be made. However, it can be stated that, under this condition, the discharge will increase the river temperature by an undetectable amount within a short distance from the discharge structure.

The repositioning of the discharge pipe from 148 m (487 ft) MSL to 150 m (493 ft) MSL (Sec. 4.2.4.3 and Fig. 4.3; cf. ER-CP, Fig. 3.4-4) will not affect the results of the thermal-plume analysis because a two-dimensional model was used for the analysis (ER-CP, App. 5A). Repositioning could introduce small changes that are not taken into account in the two-dimensional model; the stresses introduced by these changes will either be the same or smaller (e.g. there will be a reduction in the flow velocity and thermal gradient at the river bottom). Therefore, the conclusion that losses of aquatic biota due to thermal-plume effects will not be significant (FES-CP, Sec. 5.1.2.1) is still valid. The spatial separation between the fish-escape portal and the discharge plume is still sufficient to avoid thermal stress to organisms leaving the intake structure by this route, and the plume still allows sufficient bypass for other organisms in the river. Impacts to benthic invertebrates from river-bottom scouring and thermal stress were considered in the construction review and found to be acceptable (FES-CP, Sec. 5.1.2.2); repositioning will decrease these impacts, because the discharge flow or current will be farther from the river bottom.

The difference in temperature between the river water and the plant effluent, averaged over each month, is expected to vary from 4°C (7°F) in August to 16°C (29°F) in January, with a yearly average of 10°C (18°F). The average rate at which heat would be discharged into the river if both units operated continuously is 1.0×10^7 J/s, as calculated from the average monthly river-effluent temperature difference and average monthly effluent flow and averaged over one year (ER-OL, Table 3.4-4; ER-OL, Rev. 1, Table 3.4-2).

The analyses that led to the results summarized above were based on the operation of two units. The areal extent of the plume for the operation of CAL-1 alone will be less, although not necessarily half the value listed, because the area of the plume will not be directly proportional to the flow rate.

The environmental consequences of thermal discharge to the river were examined previously and found to be small and in compliance with water-quality standards of the State of Missouri, including those stated in NPDES Permit No. MO-0098001 (App. B) for two-unit operation under the expected extreme conditions (FES-CP, Sec. 5.1.2.1).

Inasmuch as one-unit operation will have a lesser potential for aquatic impacts due to thermal effects, the staff concludes that the environmental consequences of thermal discharge to the river will still be small and that the thermal discharge will still be in compliance with the requirements of the State of Missouri.

5.5.2.3 Chemical Discharges

Aquatic impacts from chemical (including biocidal) discharges and other nonradioactive wastes were examined during the construction review (FES-CP, Secs. 5.3.1 and 5.4.1). Changes in discharges of chemical and other nonradioactive-waste materials that have occurred since the construction review are discussed in Sections 4.2.6 and 4.3.2. The consequent changes in water quality are discussed in Section 5.3.2. The aquatic-ecology impacts that may occur as a consequence of the water-quality changes are considered below.

Table 4.2, which provides a list of the revised estimates of the chemical wastes discharged to the Missouri River, includes a list of annotations provided by the applicant that gives a summary indication of the maximum levels of chemicals and other water-quality attributes that have been found not to be harmful to aquatic life.

The maximum observed ambient river concentrations of several substances are already above the maximum levels not harmful to aquatic life (Table 4.2). Ambient concentrations of copper and cadmium that may be toxic to aquatic organisms were found (ER-OL, p. 2.2-5). These concentrations will be further increased by operation of the Callaway Plant, but the predicted increases will be small compared to natural fluctuations and within the NPDES limits (Sec. 5.3.2.1). The staff believes that aquatic-ecology impacts due to chemicals added to the river by plant operations will be small, because the aquatic species that are present in the Missouri River have adapted to the ambient levels of dissolved and suspended substances.

The number of fecal-coliform bacteria already present in the Missouri River water was found to exceed state water-quality standards (ER-OL, p. 2.2-5). Operation of the plant will probably have a very small but favorable impact on the number of bacteria; the biocide treatment will kill a large fraction of the bacteria in the cooling water so that very few of the bacteria removed in the makeup water will be returned in the discharge.

On the basis of the foregoing analysis and review of data submitted by the applicant and of the analysis and review in the FES-CP, the staff concludes that the impacts due to discharge of chemical and other nonradioactive wastes on the [illegible] tic ecology caused by operation of both units would be comparable to o[illegible] those presented in the FES-CP. The overall nonradioactive-waste [illegible] impacts from operation of CAL-1 alone will be smaller by a factor [illegible] two.

5.5.2.4 Monitoring

Since issuance of the construction permits for the Callaway Plant in 1976, it has been concluded in a number of decisions interpreting Section 511 of the Clean Water Act that the NRC does not have responsibility for imposing operational monitoring conditions for protection of the aquatic environment, inasmuch as the act placed that responsibility on the USEPA or agreement states. The certifications and permits required under the Clean Water Act provide the mechanisms for protection of water quality and aquatic biota. Operational monitoring of plant effluents will be required by the NPDES permit issued by the State of Missouri (App. B). A fish-impingement and -entrainment monitoring program, as required under Section 316(b) of the Clean Water Act, has been reviewed and approved by the Missouri Department of Natural Resources. That program has been defined in the NPDES permit and will provide information necessary for the state to determine if further mitigation of intake losses is necessary. NRC will rely on the decision made by the Missouri Department of Natural Resources, under the authority of the Clean Water Act, for any requirement for intake-design changes, should they be necessary.

5.6 ENDANGERED AND THREATENED SPECIES

The only Federally listed endangered terrestrial species that has been reported in Callaway County is the bald eagle (Haliaeetus leucocephalus) (Sec. 4.3.5). The Callaway Plant and its transmission-line ROWs will not disturb any known nesting or feeding areas; hence, the operation of CAL-1 will have no impact on this species. Two other Federally listed endangered or threatened terrestrial species, the peregrine falcon (Falco peregrinus) and gray bat (Myotis grisescens), have been observed in neighboring counties (Osage and Gasconade) (Sec. 4.3.5). The plant site is too distant to have any impact on these species; the cave in which the gray bat was found is not close to the ROW, and the impacts of transmission-line operation on the peregrine falcon would be negligible even if the ROW went through the territory in which it was observed, hence, the staff concludes that operation of CAL-1 will not affect these species.

The only Federally listed endangered aquatic species that has been reported for the area of concern is the pink mucket pearly mussel (Lampsilis orbiculata orbiculata), which has been found in the Gasconade and Osage Rivers (Sec. 4.3.5). Sand and gravel are the preferred habitat, although mud may also be acceptable. Turbid waters such as those of the Missouri River are unlikely habitats; in fact, the Missouri River is considered a natural barrier (Ref. 12). Therefore, the staff concludes that operation of CAL-1 will not have an impact on the pink mucket pearly mussel.

The staff has also considered the impacts of CAL-1 operation on rare and endangered animal and plant species from the state list that have been observed near the plant (Sec. 4.3.5). They are the marsh hawk (Circus cyaneus), sharp-shinned hawk (Accipter striatus), brown bullhead (Ictalurus nebulosus), long-tailed weasel (Mustela fenata), bald eagle (Haliaeetus leucocephalus alascensis), ruffed grouse (Bonasa umbellus), and American elm (Ulmus americana) (Sec. 4.3.5).

The Callaway Plant site is not critical habitat for any of the listed species. Habitat loss is small and has already occurred (Sec. 5.2). Further impacts due to plant operations will be very small; traffic and the number of workers will be less than during construction, and operational impacts due to cooling-tower operation and waste discharges have been examined and found to be negligible or small (Secs. 5.3.2, 5.4, and 5.5). Therefore, the staff concludes that operation of CAL-1 will not have an adverse impact on any of the rare or endangered species.

5.7 HISTORIC AND ARCHEOLOGICAL SITES

At the request of the NRC and the Missouri Department of Natural Resources, Division of Parks and Historic Preservation, the applicant will undertake a survey of the area of potential environmental impact related to the operation and maintenance of the nuclear power plant and associated facilities. The applicant is preparing a final reearch design for the completion of the cultural-resources survey, which will include an assessment of identified sites and a cultural-resources management plan, which will be done in consultation with the Missouri Department of Natural Resources, Division of Parks and Historic Preservation. For sites that may subsequently be identified and considered potentially eligible for the National Register of Historic Places, determination-of-eligibility requests will be prepared and sent to the Keeper of the National Register, with the applicant taking appropriate measures to protect such sites during the process. A well-designed cultural-resources management plan will avoid preventable operational impacts and will assure the preservation of information where disruption is unavoidable.

5.8 SOCIOECONOMICS

The expected socioeconomic impacts due to operation of the Callaway Plant were considered prior to the start of construction (FES-CP, Sec. 5.6). New data has become available for some of the impacts; these have been reexamined and the predictions have been updated using the most-recent data available. The relevant results are presented below. On the basis of these results, the staff concludes that the overall socioeconomic impacts of operating CAL-1 will be beneficial.

5.8.1 Local Economy

UE estimates that CAL-1 will require 281 operating and maintenance employees, with a payroll of $8.1 million in 1982 (ER-OL, Rev. 2, Table 8.1-9). Certain positions at the plant will require people of unique skills that may not reside in the local area. The applicant has estimated that about 85 people will move into the area to fill these jobs (ER-OL, Rev. 2, p. 310.6-1 and Table 8.1-8), and that these employees and their families will add about 280 people to the local population. The applicant has projected that about 50% of these people will reside in Fulton, 25% in Jefferson City, 10% in Columbia, and the remainder in other locations (ER-OL, p. 8.1-5). The staff estimates that the number of operating and maintenance employees required will be approximately 60% greater than estimated by the applicant. Projections resulting from this higher staff estimate will be increased at the same ratio.

Indirect jobs (those created locally for supplying the site) and induced jobs (those created by the increase of consumer spending) will be created by the operation of CAL-1. Based on an appropriate employment multiplier, UE has estimated that 117 support service jobs will be added as a result of CAL-1 operation (ER-OL, Rev. 2, p. 310.6-1 and Table 8.1-8). The staff concurs that this level of secondary employment could be achieved. Many of these positions will be filled by local residents, attracting only a few people to move into the area for these jobs.

The transition from construction to operation will result in a net loss of payroll income. The construction payroll reached a maximum of about 2000 workers with a gross annual payroll of about $80 million per year during 1979 to 1981, and will drop rapidly to about 100 construction workers and $3 million per year in 1983 (ER-CP, Sec. 8.1.3.1.1). The operating work force started with an initial contingent of 40 workers and an estimated payroll income of $1 million in 1979, and is projected by the applicant to reach 281 workers with an estimated payroll income (in current dollars) of about $8 million in 1982 (ER-OL, Rev. 2, Table 8.1-9) The staff believes that this loss will be mitigated by the gradual nature of the transition from construction to operation, the greater stability of the operating work force and a tendency for the operating workers to invest and spend a greater fraction of their income locally, the increased taxes paid by the applicant to local agencies (Sec. 5.8.2), and the fact that the operational-payroll income will extend over a longer period.

The applicant estimates that retail purchases by plant operating employees will be about $2.7 million in 1982 (ER-OL, Rev. 2, Table 8.1-11).

Indirect benefits to the local economy will arise from the purchase of materials and supplies. Income spent by operating workers residing in the area will provide a benefit to local businessmen involved in selling commodities and services. However, because of the small number of new operating-worker households, the staff concludes that the local benefit would be small and not necessarily contribute to an increase in local employment or expansion of local businesses.

Purchases of local materials and supplies by the applicant will be limited to commonly available items. Hardware, clerical goods, and consumable bulk supplies will constitute some of these types of local purchases, and the applicant has estimated a 1982 expenditure of $700,000 for these types of supplies and materials. Essential components for the facility will be supplied directly by the original manufacturers (ER-OL, Sec. 8.1.2.2.1). The staff anticipates that the local purchases, which represent a small percentage of the CAL-1 operating budget, will have a minor impact on the regional economy.

5.8.2 Tax Benefits

UE, which is a privately owned utility, has begun to pay large tax revenues to the local area and the state. The property taxes collected from UE for CAL-1 amounted to $3.25 million in 1980 (ER-OL, Rev. 2, Table 8.1-14). Callaway County, with its increased tax base, is making improvements in public services (e.g. its school system). UE's tax payments will be substantial when CAL-1 begins to operate, and these payments can stabilize and/or reduce tax rates. The applicant estimates that property taxes for CAL-1 will amount to $4.4,

$5.4, and $6.1 million in 1981, 1982, and 1983, respectively (ER-OL, Rev. 2, Table 8.1-15). The long-term effect of enlarging the tax base has been studied at other nuclear-host communities (Ref. 13), and it was found that services were increased and functions were added to local government. The staff believes that this expansion will occur around the Callaway Plant, also.

5.8.3 Settlement Patterns

Because the housing requirements of construction workers (e.g. trailers, apartments, and other temporary housing) are different from those of most operational workers (e.g. single-family homes), there has begun a search by operational employees for permanent housing near the site. The staff conferred with local realtors and found that the supply of single-family homes close to the site was limited, whereas demand has begun to increase. New housing construction may occur in the local area if interest rates decline and money becomes more available for borrowing.

5.8.4 Recreation

Use of the Reform Wildlife Management Area (Sec. 4.2.2) should increase after construction of the Callaway Plant is complete. The numbers of trucks and heavy equipment and passenger cars will decline, decreasing the number of noise sources and lowering noise levels. This decline will favorably affect the hunting and trapping in the area and may encourage other people to visit it. The setting is such that the visual intrusion of the plant, as observed and inferred by the staff during a visit to the site on 18-19 November 1980, is small.

5.8.5 Community Services and Institutions

As the construction labor force declines with the completion of the plant, various resources and community facilities will become available. The small number of operation employees moving into the area will make use of these resources and facilities and have an insignificant effect on regional supplies. In addition, the migration of these people into the area over a three- to four-year period allows for a mild, rather than stressful, absorption of them into the local community structure.

5.8.6 Noise

Operating-noise levels were discussed briefly in qualitative terms in the construction review (FES-CP, Sec. 5.6.5), but no quantitative data were provided. Therefore, the staff has reexamined the noise impacts on the basis of quantitative calculations. Sound pressure levels that will result from operation of the plant have been calculated by the staff at six receptor locations on the owner control fence, as shown in Figure 4.1, and at the location of the nearest residence. The calculations were based on the methodology described in the "Electric Power Plant Environmental Noise Guide" (Ref. 14) and on the assumption that the plant will operate continuously at full power. The three principal noise sources considered in this analysis are the two natural-draft cooling towers and the switchyard. The nearest residence is located about 1700 m (5600 ft) from the cooling towers and 2200 m (7200 ft) from the switchyard (ER-OL, Rev. 2, p. 290.6-1).

Ambient sound pressure levels were not measured in the vicinity of the site. The applicant has estimated the ambient day-night sound level to be 35-40 dB (ER-OL, Rev. 2, p. 290.7-1), using a report by the National Academy of Sciences (Ref. 15) for undeveloped rural areas. In its own calculations, the staff has assumed a standard ambient spectrum slightly higher than this range, but within the quoted uncertainty of ± 10 dBA. The resulting calculated sound pressure levels at the receptor sites and at the nearest residence are listed in Table 5.1. However, the values listed are expected to be conservative (high) because effects of ground cover, barriers, and terrain are not included. An additional uncertainty is introduced because sound power levels of the sources are uncertain within a few dB.

Table 5.1. Noise Levels at Receptor Locations Onsite and at the Nearest Residence

Receptor Location†1	Sound Pressure Level (dBA)	
	Overall	Day-Night
R1	61	68
R2	59	66
R3	60	67
R4	53	60
R5	52	58
R6	55	61
Nearest residence†2	42	43

†1 See Figure 4.1 for locations.

†2 These values are essentially the assumed ambient levels. The contributions due to the plant are 29 dBA to the overall sound level and 36 dBA to the day-night sound level and, when added logarithmically, contribute a negligible amount.

The State of Missouri has no noise regulations that apply to the operation of the Callaway Plant. However, the EPA noise guidelines (Ref. 16) have been used by the staff as a standard to which noise levels it has calculated can be compared.

EPA recommends a limit of 70 dBA for the sound power level for farmland and generally unpopulated land. This is primarily for protection from hearing loss. From Table 5.1, it is apparent that this level is already satisfied at the owner control fence (receptor locations R1 through R6 in Fig. 4.1); the sound level beyond the fence continues to decrease inversely with the square of the distance from the source. For farm residences and residential areas with outside space, the recommendations for the day-night sound power level are 55 dBA outdoors and 45 dBA indoors. The calculated sound levels at the nearest residence during operation of CAL-1 will be essentially ambient, and the contribution from plant operation is negligible.

The staff concludes, on the basis of the foregoing considerations, that noise produced by operation of the plant will be well below EPA recommendations for protection of the public health and welfare, and that there will be no adverse noise impacts.

5.9 RADIOLOGICAL

5.9.1 Regulatory Requirements

Nuclear power reactors in the United States must comply with certain regulatory requirements and guidance in order to operate. The permissible levels of radiation in unrestricted areas and the radioactivity in effluents to unrestricted areas are spelled out in 10 CFR Part 20, "Standards for Protection Against Radiation" (Ref. 17). These regulations specify limits on levels of radiation and limits on concentration in effluent releases of radionuclides in air and water (above natural background) under which the reactor must operate. These regulations state that no member of the general public in unrestricted areas shall receive a radiation dose of more than 0.5 rem per year (or 2 millirems per hour or 100 millirems per 7 days) to the total body. These radiation-dose limits are established to be consistent with considerations of the health and safety of the public.

In addition to the radiation-protection standards of 10 CFR Part 20, license requirements are spelled out in 10 CFR Part 50.36a (Ref. 18) that are to be imposed on licensees in the form of technical specifications on effluents from nuclear power reactors to keep releases of radioactive materials to unrestricted areas during normal reactor operations, including expected operational occurrences, as low as is reasonably achievable (ALARA). Appendix I to 10 CFR Part 50 provides numerical guidance on design objectives and limiting conditions for operation for LWRs to meet this ALARA requirement. Applicants for permits to construct and licenses to operate an LWR shall provide reasonable assurance that the following dose-design objectives will be met: 3 millirems per year to the total body or 10 millirems per year to any organ from liquid effluents; 10 millirads per year gamma radiation or 20 millirads per year beta radiation from gaseous effluents--and/or 5 millirems per year to the total body or 15 millirems per year to the skin from gaseous effluents; and 15 millirems per year to any organ from the airborne effluents that include the rad oiodines, carbon-14, tritium, and particulates.

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

In addition to the impact created by radioactive effluents from LWRs discussed above there are, within the NRC policy and procedures for environmental protection spelled out in 10 CFR Part 51, generic treatments of environmental effects of all aspects of the uranium fuel cycle. These environmental data are discussed and tabulated in Section 5.10. In the same manner, data regarding the environmental impact of transportation of fuel and waste to and from an LWR are discussed and tabulated in Section 5.9.3.

Recently, an additional operational requirement for uranium-fuel-cycle facilities including nuclear power plants has been established by the EPA in 40 CFR Part 190 (Ref. 19). This standard specifies annual dose limits (excluding radon and daughters) for members of the public of 25 millirems total body, 75 millirems thyroid, and 25 millirems other organs from all fuel-cycle-facility contributions that may impact a specific individual in the public.

5.9.2 Operational Overview

During normal operations of CAL-1, small quantities of fission products and induced radioactivity will be released to the environment. In partial fulfill-ment of NEPA requirements, the staff has determined the estimated dose to members of the public outside the plant boundary due to the radiation from these radioisotope releases and relative to natural-background-radiation dose levels.

These very small environmental doses are the result of a series of successive, conscious efforts to contain and control all radioactive emissions and effluents from the plant. As mentioned above, highly efficient radioactive-waste-management systems are incorporated in the nuclear-plant design and are specified in detail in the operating technical specifications for the plant. The effectiveness of these systems is measured by process and effluent radiological-monitoring systems that permanently record the amounts of radioactive constitutents remaining in the various airborne and waterborne process and effluent streams. The amounts of radioactivity released through vents and discharge points to be further dispersed and diluted to points outside the plant boundary are recorded and published semiannually in the Radioactive-Effluent-Release Reports of each facility.

The small amounts of airborne effluents that are released diffuse in the atmosphere in a fashion determined by the prevalent meteorological conditions and, thus, are much dispersed and diluted by the time they reach unrestricted areas that are open to the public. Similarly, the small amounts of waterborne effluents that are released are diluted with plant wastewater and then are further diluted as they are discharged into the Missouri River beyond the plant boundary.

Any radioisotopes originating in CAL-1 that finally enter unrestricted areas will produce dose effects through their radiations on members of the general public similar to the effects from background radiations (i.e. cosmic/terrestrial and internal radiations), which also include radiation from nuclear-weapons fallout. These radiation-dose effects can be calculated for the many potential radiological-exposure pathways specific to the environment outside the plant boundary such as direct-radiation doses from airborne or waterborne effluent streams or internal radiation-dose commitments from radioactive contaminants deposited on vegetation, in meat and fish products, in drinking water, or in cows' milk.

These doses, calculated for the "maximally exposed" individual (i.e. the hypothetical individual potentially subject to maximum exposure), form the basis of staff evaluation of impacts. Actually, these estimates are for a fictitious person because assumptions are made that tend to overestimate the dose that would actually accrue to members of the public outside the plant boundary. For example, for the maximally exposed individual to receive the dose calculated at the plant boundary, he would have to remain physically at that boundary for 70% of the year, an unlikely occurrence.

Site-specific values for the various parameters involved in each dose pathway are used in the calculations. These include calculated or observed values for the amounts of radioisotopes released in the gaseous and liquid effluents, meteorological information (e.g. wind speed and direction) specific to the site topography and effluent-release points, and hydrological information relative to dilution and "flushing" of the liquid effluents as they are discharged.

A periodic land census, required by the radiological technical specifications, will be made. As use of the land surrounding the site boundary changes, revised calculations will be made to ensure that the dose estimate for gaseous effluents always represents the highest dose for any individual member of the public for each applicable pathway. For example, the estimate considers where people live, vegetable gardens are located, cows are pastured, etc.

For CAL-1, in addition to the direct effluent monitoring, measurements will be made on a number of types of samples from the surrounding area to determine the possible presence of radioactive contaminants that, for example, might have been deposited on vegetation, be present in drinking water outside the plant, or be incorporated in cows' milk at nearby farms.

5.9.3 Routine Operation

5.9.3.1 Exposure Pathways: Dose Commitments

There are many environmental pathways through which persons may be exposed to radiation originating in a nuclear power reactor. All of the potentially meaningful exposure pathways are shown schematically in Figure 5.2. When an individual is exposed through one of these pathways, his dose is determined, in part, by the amount of time he is in the vicinity of the source or the amount of time the radioactivity is retained in his body. The actual effect of the radiation or radioactivity is determined by calculating the dose commitment. This dose commitment represents the total dose that would be received over a 50-year period following the intake of radioactivity for one year under the conditions existing 15 years after the plant begins operation (i.e. the midpoint of plant operation).

There are a number of possible exposure pathways to man that can be studied to determine whether routine releases at the CAL-1 site are likely to have any significant impact on members of the general public living and working outside the site boundary, and whether the releases will in fact meet regulatory requirements. A detailed listing of these possibilities would include external radiation exposure from gaseous effluents, inhalation of iodines and particulate contaminants in the air, drinking milk from a cow or eating meat from an animal that feeds on open pasture near the site on which iodines or particulates may have deposited, eating vegetables from a garden near the site that

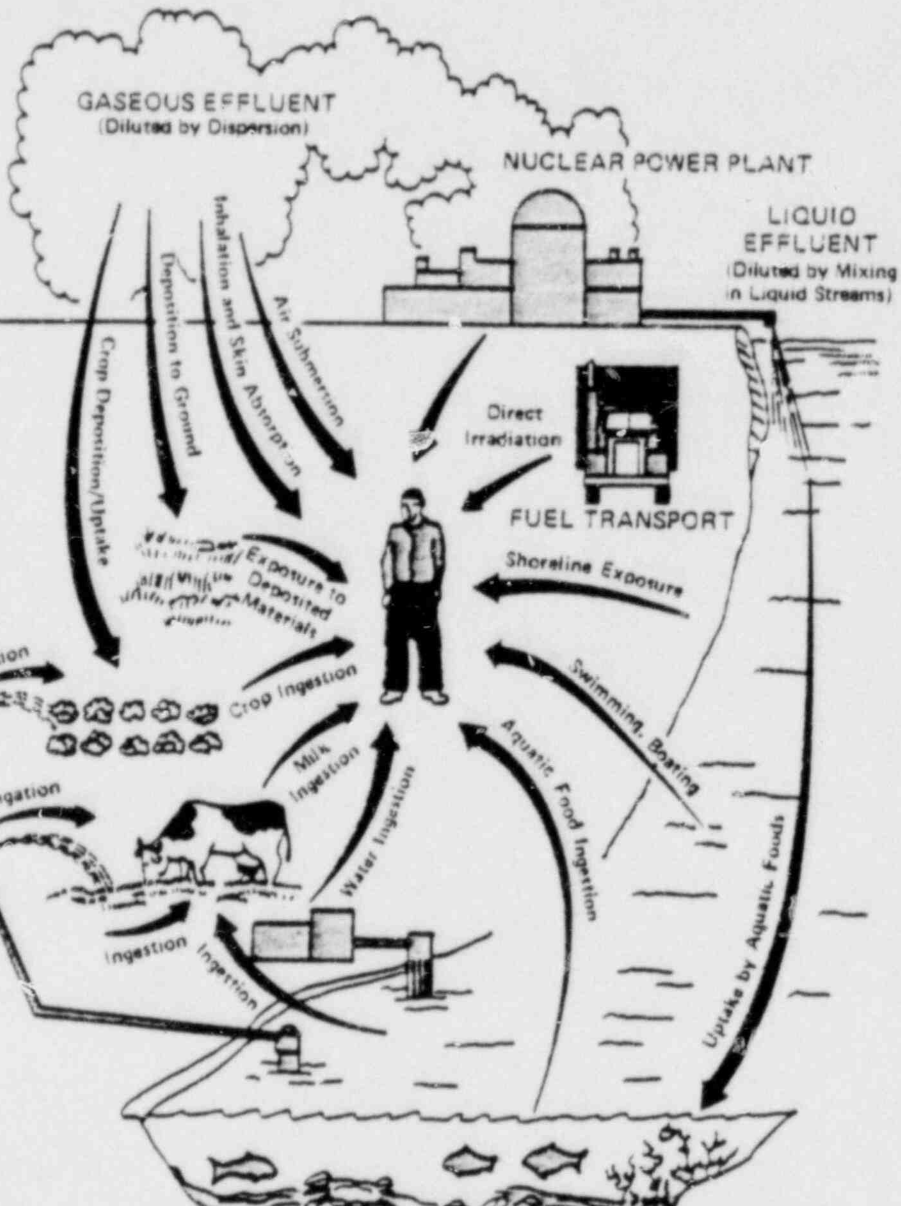

Figure 5.2. Potentially Meaningful Exposure Pathways to Man.

may be contaminated by similar deposits, and eating fish caught near the point of discharge of liquid effluents.

Other less significant pathways include: external irradiation from radionuclides deposited on the ground surface, eating animals and food crops raised near the site using irrigation water that may contain liquid effluents, shoreline activities near lakes or streams that may be contaminated by effluents, and direct radiation from within the plant itself. Note that for the CAL-1 site there is no drinking-water pathway of concern because the first drinking-water intake is 125 km (about 80 mi) downstream of the plant and dilution makes the effect completely negligible. Calculations of the effects for most pathways are limited to a radius of 80 km (50 mi). This limitation is based on several facts. Experience has shown that all significant dose commitments (greater than 0.1 millirem per year) for radioactive effluents are accounted for within an 80-km (50-mi) radius of the plant. Beyond that radius the doses are smaller than 0.1 millirem per year, which is far below natural-background doses, and are subject to substantial uncertainty because of limitations of predictive mathematical models.

The staff has made a detailed study of all the significant pathways and has evaluated the radiation-dose commitments both to the plant workers and the general public for these pathways resulting from routine operation of CAL-1. Discussions of these evaluations follow:

Occupational Radiation Exposure

The dose to nuclear-plant workers varies from reactor to reactor and can be projected for environmental-impact purposes by using the experience to date with modern PWRs. Most of the dose to nuclear-plant workers is due to external exposure to radiation from radioactive materials outside the body rather than internal exposure from inhaled or ingested radioactive materials. Recently licensed 1000-MWe PWRs are designed and operated in a manner consistent with new (post-1975) regulatory requirements and guidelines. These new requirements and guidelines place increased emphasis on maintaining occupational exposure at nuclear power plants ALARA, and are outlined in 10 CFR Part 20 (Ref. 17); "Standard Review Plan," Chapter 12 (Ref. 20); and Regulatory Guide 8.8 (Ref. 21). The applicant's proposed implementation of these requirements and guidelines is reviewed by the staff at the construction-permit stage, the operating-license stage, and during actual operation. Approval is granted only after the review indicates that an ALARA program can actually be implemented.

Based on actual operating experience, it has been observed that occupational dose has varied considerably from plant to plant, and from year to year. Average collective occupational-dose information from 239 PWR-years of operation is available for those plants operating between 1974 and 1980. (The year 1974 was chosen as a starting date for these data because the total average rated capacity for reactors for years prior to 1974 was below 500 MWe.) These data indicate that the average reactor annual dose at PWRs has been about 440 person-rems, with particular plants experiencing an average lifetime annual dose to date as high as 1300 person-rems (Ref. 22). These dose averages are based on widely varying yearly doses at PWRs. For example, annual collective doses for PWRs have ranged from 18 to 5262 person-rems per reactor, and the average annual dose per nuclear-plant worker has been about 0.8 rem (Refs. 22 and 23).

The wide range of annual doses (18 to 5262 person-rems) experienced at PWRs in the United States is dependent on a number of factors such as the amount of required routine and special maintenance and the degree of reactor operations and in-plant surveillance. Because these factors can vary in an unpredictable manner, it is impossible to determine in advance a specific year-to-year or average annual occupational radiation dose for a particular plant over its operating lifetime. The need to accept high doses can occur, even at plants with radiation-protection programs that have been developed to assure that occupational radiation doses will be kept at levels that are ALARA.

In recognition of the factors mentioned above, staff occupational-dose estimates for environmental-impact purposes for CAL-1 are based on the assumption that the plant will experience the annual average occupational dose for PWRs to date. Thus, the staff has projected that the occupational dose for CAL-1 will be 440 person-rems per year, but could average as much as three to four times this value over the life of the plant.

The risks of various occupations, including nuclear-plant workers, are given in Table 5.2. References and supporting text for this table are given in NUREG-0743 (Ref. 24). Based on the comparisons in the table, the staff concludes that the risk to nuclear-plant workers from plant operation is comparable to the risks associated with other occupations.

Table 5.2. Incidence of Job-Related Fatalities

Occupational Group	Fatality Incidence Rates (premature deaths per 10^5 man-years)
Underground metal miners	1275
Uranium miners	422
Smelter workers	194
Mining	61
Agriculture, forestry, and fisheries	35
Contract construction	33
Transportation and public utilities	24
Nuclear-plant workers	23
Manufacturing	7
Wholesale and retail trade	6
Finance, insurance, and real estate	3
Services	3
Total, private sector	10

Public Radiation Exposure

Transportation of Radioactive Materials. The transportation of "cold" nuclear fuel to the reactor, of irradiated fuel from the reactor to a fuel reprocessing plant, and of solid radioactive wastes from the reactor to waste-burial grounds is considered in 10 CFR Part 51.20, Paragraph g (Ref. 18). The contribution of the environmental effects of such transportation to the environmental costs of licensing the nuclear power reactor is set forth in Summary Table S-4 from 10 CFR Part 51.20, reproduced herein as Table 5.3. The cumulative dose to the exposed population as summarized in Table S-4 is very small when compared to the annual dose of 26,000,000 person-rems to this same population from background radiation.

Table 5.3. (Summary Table S-4) Environmental Impact of Transportation of Fuel and Waste to and from One Light-Water-Cooled Nuclear Power Reactor[1]

NORMAL CONDITIONS OF TRANSPORT

	Environmental impact
Heat (per irradiated fuel cask in transit)	250,000 Btu/hr.
Weight (governed by Federal or State restrictions)	73,000 lbs. per truck; 100 tons per cask per rail car.
Traffic density:	
Truck	Less than 1 per day.
Rail	Less than 3 per month.

Exposed population	Estimated number of persons exposed	Range of doses to exposed individuals[2] (per reactor year)	Cumulative dose to exposed population (per reactor year)[3]
Transportation workers	200	0.01 to 300 millirem	4 man-rem.
General public:			
Onlookers	1 00	0.003 to 1.3 millirem	3 man-rem.
Along Route	600,000	0.0001 to 0.06 millirem	

ACCIDENTS IN TRANSPORT

	Environmental risk
Radiological effects	Small[4]
Common (nonradiological) causes	1 fatal injury in 100 reactor years; 1 nonfatal injury in 10 reactor years; $475 property damage per reactor year.

[1] Data supporting this table are given in the Commission's "Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants," WASH-1238, December 1972, and Supp. I, NUREG-75/038 April 1975. Both documents are available for inspection and copying at the Commission's Public Document Room, 1717 H St. NW., Washington, D.C., and may be obtained from National Technical Information Service, Springfield, Va. 22161. WASH-1238 is available from NTIS at a cost of $5.45 (microfiche, $2.25) and NUREG-75/038 is available at a cost of $3.25 (microfiche, $2.25).

[2] The Federal Radiation Council has recommended that the radiation doses from all sources of radiation other than natural background and medical exposures should be limited to 5,000 millirem per year for individuals as a result of occupational exposure and should be limited to 500 millirem per year for individuals in the general population. The dose to individuals due to average natural background radiation is about 130 millirem per year.

[3] Man-rem is an expression for the summation of whole body doses to individuals in a group. Thus, if each member of a population group of 1,000 people were to receive a dose of 0.001 rem (1 millirem), or if 2 people were to receive a dose of 0.5 rem (500 millirem) each, the total man-rem dose in each case would be 1 man-rem.

[4] Although the environmental risk of radiological effects stemming from transportation accidents is currently incapable of being numerically quantified, the risk remains small regardless of whether it is being applied to a single reactor or a multireactor site.

Direct Radiation. Radiation fields are produced around nuclear plants as a result of radioactivity within the reactor and its associated components, as well as of radioactive-effluent releases. Direct radiation from sources within the plant are due primarily to nitrogen-16, a radionuclide produced in the reactor core. Because the primary coolant of a PWR is contained in a heavily shielded area, dose rates in the vicinity of PWRs are generally undetectable (less than 5 millirems per year).

Low-level radioactivity storage containers outside the plant are .imated to make a dose contribution at the site boundary of less than 1% of that due to the direct radiation from the plant.

Radioactive Eff'uent Releases: Air and Water. As pointed out earlier, all effluents from CAL-1 will be subject to extensive decontamination, but small controlled quantities of radioactive effluents will be released to the atmosphere and to the hydrosphere during normal operations. Estimates of site-specific radioisotope-release values have been developed on the basis of the descriptions of operational and radwaste systems in the applicant's ER and FSAR and by using the calculational model and parameters developed in NUREG-0017 (Ref. 25). This has been supplemented by extensive use of the applicant's site and environmental data in the ER, and in subsequent answers to staff questions, to obtain a complete picture of airborne and waterborne releases from CAL-1.

These small amounts of effluents are then highly diluted by the air and water into which they are released before they reach areas in which they interact with activities of the general public.

Radioactive effluents can be divided into several groups. Among the airborne effluents, the radioisotopes of the noble gases--krypton, xenon, and argon--do not deposit on the ground or interact with living organisms; therefore, the noble-gas effluents act primarily as a source of external radiation emanating directly from the effluent plume. Dose calculations are performed for the site boundary where the highest external-radiation doses to a member of the public as a result of gaseous effluents have been estimated to occur; these include the annual beta and gamma air doses as well as the total-body and skin doses from the plume at that boundary location.

Another group of airborne effluents--the radioiodines, carbon-14, and tritium--are also gaseous but tend to be deposited on the ground and/or absorbed into the body during inhalation. For this class of effluents, estimates of direct external-radiation doses from deposits on the ground, and of internal-radiation doses to total body, thyroid, bone, and other organs from inhalation and from vegetable, milk, and meat consumption are made. Concentrations of iodine in the thyroid and of carbon-14 in bone are of particular significance here.

A third group of airborne effluents, consisting of particulates that remain after filtration of the effluents, could include fission products such as cesium and barium and corrosion products such as cobalt and chromium. The calculational model determines for these contaminants the direct external-radiation dose and the internal-radiation doses through the same pathways as described above for the radioiodines, carbon-14, and tritium. Doses from the particulates are combined with those of the radioiodines, carbon-14, and tritium for comparison to one of the design objectives of Appendix I to 10 CFR Part 50.

The waterborne radioactive-effluent constituents could include fission products such as strontium and iodine, corrosion and activation products such as sodium and manganese, and tritium as tritiated water. Calculations estimate the internal doses (if any) from fish consumption, water ingestion (as drinking water), and eating of meat or vegetables raised near the site on irrigation water, as well as any external radiation from recreational use of the water past the point of discharge.

The release values for each group of effluents, along with site-specific meteorological and hydrological data, serve as input to computerized radiation-dose models that estimate the maximum radiation dose that would be received outside the facility via a number of pathways for individual members of the public and for the general public as a whole. These models and the radiation dose calculations are discussed in Regulatory Guide 1.109 (Ref. 26) and in Appendix D of this environmental statement.

Examples of site-specific dose-assessment calculations and discussions of parameters involved are given in Appendix C. Doses from all airborne effluents except the noble gases are calculated for the location (e.g. site boundary, garden, residence, milk cow, meat animal) where the highest radiation dose to a member of the public from all applicable pathways has been established. Only those pathways associated with airborne effluents that are known to exist at a single location are combined to calculate the total maximum exposure to an exposed individual. Pathways associated with liquid effluents are combined without regard to location, but they are assumed to be associated with maximum exposure to an individual other than through gaseous-effluent pathways.

5.9.3.2 Radiological Impact on Man

Although the doses calculated in Appendix C are based on radioactive-waste-treatment system capability, the actual radiological impact associated with the operation of CAL-1 will depend, in part, on the manner in which the radioactive-waste-treatment system is operated. Based on its evaluation of the potential performance of the ventilation and radwaste-treatment systems, the staff has concluded that the systems as now proposed are capable of controlling effluent releases to meet the dose-design objectives of Appendix I to 10 CFR Part 50 (Ref. 18).

Plant operation will be governed by radiological-effluent technical specifications that will be based on the dose-design objectives of Appendix I. Because these design-objective values were chosen to permit flexibility of operation while still ensuring that plant operations are ALARA, the actual radiological impact of plant operation may result in doses close to the dose-design objectives. Even if this situation exists, the individual doses for the member of the public subject to maximum exposure will still be very small when compared to natural-background doses (about 100 millirems per year) or the dose limits specified in 10 CFR Part 20 (500 millirems per year, whole body). As a result, the staff concludes that there will be no measurable radiological impact on members of the public from routine operation of the plant.

Since 1 December 1979, the licensee has also been regulated according to 40 CFR Part 190, the Environmental Protection Agency's "Environmental Radiation Protection Standards for Nuclear Power Operations" (Ref. 19). These operating standards specify that the annual dose equivalent must not exceed 25 millirems to the whole body, 75 millirems to the thyroid, and 25 millirems to any other organ of any member of the public as the result of exposures to planned discharges of radioactive materials (radon and its daughters excepted) to the general environment from all uranium-fuel-cycle operations and radiation from these operations that can be expected to affect a given individual. The staff further concludes that, under normal operations, CAL-1 is capable of operating within these guidelines.

The radiological effects of a nuclear power plant are well known and documented. Accurate measurements of radiation and radioactive contaminants can be made with very high sensitivity so that much smaller amounts of radioisotopes can be recorded than can be associated with any possible known ill effects. Furthermore, the effects of radiation on living systems have for decades been subject to intensive investigation and consideration by individual scientists as well as by select committees occasionally constituted to objectively and independently assess radiation-dose effects. Although, as in the case of chemical contaminants, there is debate about the exact extent of the effects of very low levels of radiation, the limits of deleterious effects are well established and amenable to standard methods of risk analysis. Thus, the risks to the maximally exposed member of the public outside the site boundary can be readily quantified. Furthermore, the impacts on, and risks to, the total population outside the boundary can also be readily calculated and recorded.

5.9.3.3 Radiological Impact on Biota Other than Man

Depending on the pathway and the radiation source, terrestrial and aquatic biota will receive about the same or somewhat higher doses than man receives. Although guidelines have not been established for acceptable limits for radiation exposure to species other than man, it is generally agreed that the limits established for man are also conservative for other species. Experience has shown that it is the maintenance of population stability that is crucial to the survival of a species, and species in most ecosystems suffer rather high mortality rates from natural causes.

Although the existence of extremely radiosensitive biota is possible and increased radiosensitivity in organisms may result from environmental interactions with other stresses (e.g. heat, biocides), no biota have yet been discovered that show a sensitivity (in terms of increased morbidity or mortality) to radiation exposures as low as those expected in the area surrounding CAL-1. Furthermore, at all the plants where radiation exposure to biota other than man has been analyzed (Ref. 27), there have been no cases of exposure that can be considered significant in terms of harm to the species, or that approach the exposure limits to members of the public permitted by 10 CFR Part 20 (Ref. 17). Inasmuch as the 1972 BEIR Report (Ref. 28) concluded that evidence indicated no other living organisms are very much more radiosensitive than man, no measurable radiological impact on populations of biota is expected as a result of the routine operation of this plant.

5.9.3.4 Radiological Monitoring

Radiological environmental-monitoring programs are established to provide data on measurable levels of radiation and radioactive materials in the site environs. Such monitoring programs are conducted to verify the effectiveness of in-plant systems used to control the release of radioactive materials and to ensure that unanticipated buildups of radioactivity will not occur in the environment. Secondarily, the monitoring programs could identify the highly unlikely existence of unmonitored releases of radioactivity. A surveillance (land-census) program is established to identify changes in the use of unrestricted areas to provide a basis for modifications of the monitoring programs.

These programs are discussed in greater detail in Regulatory Guide 4.1, Rev. 1, "Programs for Monitoring Radioactivity in the Environs of Nuclear Power Plants" (Ref. 29), and the Radiological Assessment Branch Technical Position, Rev. 1, "An Acceptable Radiological Environmental Monitoring Program" (Ref. 30).

Preoperational

The preoperational phase of the monitoring program should provide for the measurement of background levels of radioactivity and radiation and their variations along the anticipated important pathways in the areas surrounding the plant, the training of personnel, and the evaluation of procedures, equipment, and techniques. In the ER, the applicant proposed a radiological environmental-monitoring program to meet these objectives, and it was discussed in the FES-CP. This early program has been updated and expanded; it is presented in the ER-OL (Sec. 6.1.5) and is summarized here in Table 5.4.

The applicant initiated a baseline preoperational program in the summer of 1973 and continued it through December 1974. One year prior to fuel loading, the program will be resumed to provide two full years of preoperational data.

The staff has reviewed the applicant's preoperational environmental-monitoring plan and finds that it is acceptable as presented.

Operational

The operational offsite radiological-monitoring program is conducted to measure radiation levels and radioactivity in plant environs. It assists and provides backup support to the effluent-monitoring program as recommended in 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" (Ref. 31).

The applicant states that the operational program will in essence be a continuation of the preoperational program described above, providing adequate sampling of specific indicator organisms and selected media to confirm that levels of radioactivity in the environment stemming from CAL-1 remain ALARA. The proposed operational program will be reviewed prior to plant operation. Modification will be based on anomalies and/or exposure-pathway variations observed during the preoperational program.

The final operational-monitoring program proposed by the applicant will be reviewed in detail by the staff, and the specifics of the required monitoring program will be incorporated into the radiological technical specifications for the operating license.

Table 5.4. Preoperational Radiological-Monitoring Program[a]

CRITICAL PATHWAYS/GROUPS	SAMPLE METHOD	PARAMETERS MEASURED	SAMPLE FREQUENCY
COMMUNITIES Fulton Portland Chamois	TLD samples from dosimeters 1 mile or less from community and within 10-mile radius of facility	Gross gamma analysis	Half monthly; half annually
	Air particulate samples from samplers 1 mile or less from community and within 10-mile radius of facility	Gamma isotopic, gross alpha, gross beta analyses	Monthly composites Weekly
	Iodine particulate samples from cartridge filters 1 mile or less from community and within 10-mile radius of facility	Radioiodine	Monthly
SOILS	One 3.5-kilogram sample from each of 4 locations immediately surrounding the facility	Gross alpha, gross beta, gamma isotopic analyses	Annually in 1973 and 1974
GROUNDWATER	Two 3.5-liter samples from each of 2 on-site wells	Gamma isotopic, alpha, gross beta, tritium analyses	Fall of 1973, approximately monthly during 1974
DRINKING WATER	Three 2.5-liter samples from public water supply closest downstream from facility	Same as for groundwater	Fall of 1973, approximately monthly during 1974
SURFACE WATER	One 2.5-liter sample from each of 2 locations, one upstream from proposed discharge outfall, one downstream	Same as for groundwater and drinking water	Bimonthly for 4 periods, monthly for final 7 periods
BOTTOM SEDIMENTS	One 3.5-kilogram sample from each of 3 locations in proposed discharge area	Gross alpha, gross beta, gamma isotopic analyses	Three collections annually (7/73, 9/73, 9/74)
FISH and SHELLFISH	One 3.5-kilogram sample of each of 5 species of edible fresh fish from each of 3 locations in proposed discharge area	Gross alpha, gross beta, gamma isotopic analyses	Four collections annually

Table 5.4. (Continued)

CRITICAL PATHWAYS/GROUPS	SAMPLE METHOD	PARAMETERS MEASURED	SAMPLE FREQUENCY
MILK	One 3.5-liter sample from 2 commercial dairies near Fulton	Comprehensive analysis for individual radionuclides I-131, Cs-134, Cs-137, Sr-89, Sr-90, Ba-140, K-40, Zn-65, Cr-51	Monthly during pasture season; bi-monthly during winter months when cows feed on stored grain
FRUITS and VEGETABLES	One 3.5-kilogram sample of edible portions	Gross alpha, beta, and gamma isotopic analyses	Annually at harvest
MEAT and POULTRY	One 3.5-kilogram sample of edible portions of animals fed on feed grown in area	Gross alpha, beta, and gamma isotopic analyses	Two samples each of beef and pork; one sample each of mutton and chicken
PREDICTED HIGHEST POINTS OF RADIONUCLIDE CONCENTRATIONS	For method refer to USEPA ORP/SID, Figure 3	Gross gamma, gross alpha, gross beta, radioiodine, gamma isotopic analyses	TLD, monthly and annually; air particulate, weekly and monthly composites; I-131, monthly

a Adapted from the ER-OL (Table 6.1-5).

5.9.4 Postulated Accidents

On 13 June 1980 the Commission published in the "Federal Register" a statement of interim policy regarding accident considerations (Ref. 32). This statement withdrew the proposed Annex to Appendix D of 10 CFR Part 50 and suspended the rulemaking proceedings associated with it. It also put forth the Commission's interim policy that: "...Environmental Impact Statements shall include considerations of the site-specific accident sequences that lead to releases of radiation and/or radioactive materials, including sequences that can result in inadequate cooling of reactor fuel and to melting of the reactor core. In this regard, attention shall be given both to the probability of occurrence of such releases and to the environmental consequences of such releases." This section presents an analysis of accidents, including those commonly referred to as Class 9 accidents.

The staff has considered the potential radiological impacts on the environment of possible accidents at the Callaway Plant Units 1 and 2 in accordance with the statement of interim policy. The following discussion reflects these considerations and conclusions.

The first section deals with general characteristics of nuclear power plant accidents including a brief summary of safety measures to minimize the probability of their occurrence and to mitigate their consequences if they should occur. Also described are the important properties of radioactive materials and the pathways by which they could be transported to become environmental hazards. Potential adverse health effects and impacts on society associated with actions to avoid such health effects are also identified.

Next, actual experience with nuclear power plant accidents and their observed health effects and other societal impacts are then described. This is followed by a summary review of safety features of the facilities of Callaway Units 1 and 2 and of the site that act to mitigate the consequences of accidents.

The results of calculations of the potential consequences of accidents that have been postulated in the design basis are then given. Also described are the results of calculations for the Callaway site using probabilistic methods to estimate the possible impacts and the risks associated with severe accident sequences of exceedingly low probability of occurrence.

5.9.4.1 General Characteristics of Accidents

The term accident, as used in this section, refers to any unintentional event not addressed in Section 5.9.3 that results in a release of radioactive materials into the environment. Therefore, the predominant focus is on events that can lead to releases substantially in excess of permissible limits for normal operation. Such limits are specified in the Commission's regulations at 10 CFR Part 20 and 10 CFR Part 50, Appendix I.

There are several features that combine to reduce the risk associated with accidents at nuclear power plants. Safety features in the design, construction, and operation comprising the first line of defense are to a very large extent devoted to the prevention of the release of these radioactive materials from their normal places of confinement within the plant. There are also a number of additional lines of defense that are designed to mitigate the consequences of failures in the first line. Descriptions of these features for Callaway Units 1 and 2 may be found in the applicant's Final Safety Analysis Report (Ref. 33), and in the staff's forthcoming Safety Evaluation Report. The most important mitigative features are described in Section 5.9.4.3 Design Features.

These safety features are designed taking into consideration the specific locations of radioactive materials within the plant, their amounts, their nuclear, physical, and chemical properties, and their relative tendency to be transported into, and for creating biological hazards in, the environment.

Fission-Product Characteristics

By far the largest inventory of radioactive material in a nuclear power plant is produced as a by-product of the fission process and is located in the uranium oxide fuel pellets in the the reactor core in the form of fission products. During periodic refueling shutdowns, the assemblies containing these fuel pellets are transferred to a spent fuel storage pool so that the second largest inventory of radioactive material is located in this storage area. Much smaller inventories of radioactive materials are also normally present in the water that circulates in the reactor coolant system and in the systems used to process gaseous and liquid radioactive wastes in the plant.

These radioactive materials exist in a variety of physical and chemical forms. Their potential for dispersion into the environment is dependent not only on mechanical forces that might physically transport them, but also on their inherent properties, particularly their volatility. The majority of these materials exist as nonvolatile solids over a wide range of temperatures. However, some are relatively volatile solids and a few are gaseous in nature. These characteristics have a significant bearing on the assessment of the environmental radiological impact of accidents.

The gaseous materials include radioactive forms of the chemically inert noble gases krypton and xenon. These have the highest potential for release into the atmosphere. If a reactor accident were to occur involving degradation of the fuel cladding, the release of substantial quantities of these radioactive gases from the fuel is a virtual certainty. Such accidents are very low frequency but credible events (cf. Sec. 5.9.4.2). It is for this reason that the safety analysis of each nuclear power plant analyzes a hypothetical design-basis accident that postulates the release of the entire contained inventory of radioactive noble gases from the fuel into the containment system. If further released to the environment as a possible result of failure of safety features, the hazard to individuals from these noble gases would arise predominantly through the external gamma radiation from the airborne plume. The reactor containment system is designed to minimize this type of release.

Radioactive forms of iodine are formed in substantial quantities in the fuel by the fission process and, in some chemical forms, may be quite volatile. For this reason, they have traditionally been regarded as having a relatively high potential for release from the fuel. However, the chemical forms in which the fission product radioiodines are found are generally solid materials at room temperature, so that they have a strong tendency to condense (or "plate out") onto cooler surfaces. In addition, most of the iodine compounds are quite soluble in, or chemically reactive with, water. Although these properties do not prevent the release of radioiodines from degraded fuel, they do act to mitigate the release from containment systems that have large internal surface areas and that contain large quantities of water as a result of an accident. The same properties affect the behavior of radioiodines that may "escape" into the atmosphere. Thus, if rainfall occurs during a release, or if there is moisture on exposed surfaces, e.g. dew, the radioiodines will show a strong tendency to be absorbed by the moisture. Because of radioiodine's distinct radiological hazard, its potential for release to the atmosphere has also been reduced by the use of special filter systems and/or containment spray systems. If released to the environment, the principal radiological hazard associated with the radioiodines is ingestion into the human body and subsequent concentration in the thyroid gland.

Other radioactive materials formed during the operation of a nuclear power plant have lower volatilities and, therefore, by comparison with the noble gases and iodine, a much smaller tendency to escape from degraded fuel unless the temperature of the fuel becomes quite high. By the same token, such materials, if they escape by volatilization from the fuel, tend to condense quite rapidly to solid form again when transported to a lower temperature region and/or dissolve in water when present. The former mechanism can have the result of producing some solid particles of sufficiently small size to be carried some distance by a moving stream of gas or air. If such particulate materials are dispersed into the atmosphere as a result of failure of the containment barrier, they will tend to be carried downwind and deposit on surface features by gravitational settling or by precipitation (fallout), where they will become "contamination" hazards in the environment.

All of these radioactive materials exhibit the property of radioactive decay with characteristic half-lives ranging from fractions of a second to many days or years (see Table 5.5). Many of them decay through sequence or chain-of-decay processes and all eventually become stable (nonradioactive) materials. The radiation emitted during these decay processes is the reason that they are hazardous materials.

Exposure Pathways

The radiation exposure (hazard) to individuals is determined by their proximity to the radioactive material, the duration of exposure, and factors that act to shield the individual from the radiation. Pathways for the transport of radiation and radioactive materials that lead to radiation exposure hazards to humans are generally the same for accidental as for "normal" releases. These are depicted in Figure 5.2. There are two additional possible pathways that could be significant for accidental releases that are not shown in that figure. One of these is the fallout onto open bodies of water of radioactivity initially carried in the air. The second would be unique to an accident that results in temperatures inside the reactor core sufficiently high to cause melting and subsequent penetration of the basemat underlying the reactor by the molten core debris. This creates the potential for the release of radioactive material into the hydrosphere through contact with groundwater. These pathways may lead to external exposure to radiation, and to internal exposures if radioactivity is inhaled or ingested from contaminated food or water.

It is characteristic of these pathways that during the transport of radioactive material by wind or by water, the material tends to spread and disperse, like a plume of smoke from a smokestack, becoming less concentrated in larger volumes of air or water. The result of these natural processes is to lessen the intensity of exposure to individuals downwind or downstream of the point of release, but they also tend to increase the number of individuals who may be exposed. For a release into the atmosphere, the degree to which dispersion reduces the concentration in the plume at any downwind point is governed by the turbulence characteristics of the atmosphere, which vary considerably with time and from place to place. This fact, taken in conjunction with the variability of wind direction and the presence or absence of precipitation, means that accident consequences are very much dependent on the weather conditions existing at the time.

Health Effects

The cause-and-effect relationships between radiation exposure and adverse health effects are quite complex (Ref. 34, pp. 517-534, and Ref. 35), but

Table 5.5. Activity of Radionuclides in a Callaway Reactor Core at 3636 MWt

Radionuclide	Radioactive Inventory (million Ci)	Half-Life (days)
Noble Gases		
Kr-85	0.64	3,950
Kr-85m	27.5	0.183
Kr-87	53	0.0528
Kr-88	77	0.117
Xe-133	194	5.28
Xe-135	39	0.384
Iodines		
I-131	97	8.05
I-132	133	0.0958
I-133	194	0.875
I-134	214	0.0366
I-135	173	0.280
Alkali Metals		
Rb-86	0.03	18.7
Cs-134	8.5	750
Cs-136	3.4	13.0
Cs-137	5.3	11,000
Tellurium-Antimony		
Te-127	6.7	0.391
Te-127m	1.2	109
Te-129	34.7	0.048
Te-129m	6.0	34.0
Te-131m	14.3	1.25
Te-132	133	3.25
Sb-127	6.9	3.88
Sb-129	37.7	0.179
Alkaline Earths		
Sr-89	102	52.1
Sr-90	4.2	11,030
Sr-91	122	0.403
Ba-140	184	12.8
Cobalt and Noble Metals		
Co-58	0.89	71.0
Co-60	0.33	1,920
Mo-99	184	2.8
Tc-99m	163	0.25
Ru-103	122	39.5
Ru-105	82	0.185
Ru-106	29	366
Rh-105	56	1.50
Rare Earths, Refractory Oxides, and Transuranics		
Y-90	4.4	2.67
Y-91	133	59.0
Zr-95	173	5.2
Zr-97	173	0.71
Nb-95	173	35.0
La-140	184	1.67
Ce-141	173	32.3
Ce-143	153	1.38
Ce-144	97	284
Pr-143	153	13.7
Nd-147	68	11.1
Np-239	1,836	2.35
Pu-238	0.064	32,500
Pu-239	0.023	8,900,000
Pu-240	0.023	2,400,000
Pu-241	3.9	5,350
Am-241	0.0019	150,000
Cm-242	0.57	163
Cm-244	0.027	6,630

they have been more exhaustively studied than any other environmental contaminant.

Whole-body radiation exposure resulting in a dose greater than about 10 rems for a few persons and about 25 rems for nearly all people over a short period of time (hours) is necessary before any physiological effects to an individual are clinically detectable. Doses about 10 to 20 times larger, also received over a relatively short period of time (hours to a few days), can be expected to cause some fatal injuries. At the severe but extremely low probability end of the accident spectrum, exposures of these magnitudes are theoretically possible for persons in the proximity of such accidents if measures are not or cannot be taken to provide protection, e.g. by sheltering or evacuation.

Lower levels of exposures may also constitute a health risk, but the ability to define a direct cause-and-effect relationship between any given health effect and a known exposure to radiation is difficult given the backdrop of the many other possible reasons why a particular effect is observed in a specific individual. For this reason, it is necessary to assess such effects on a statistical basis. Such effects include cancer in the exposed population and genetic changes in future generations after exposure of a prospective parent. Cancer in the exposed population may begin to develop only after a lapse of 2 to 15 years (latent period) from the time of exposure and then continue over a period of about 30 years (plateau period). However, in the case of exposure of fetuses (in utero), cancer may begin to develop at birth (no latent period) and end at age 10 (i.e. the plateau period is 10 years). The health-consequences model currently being used is based on the 1972 BEIR Report of the National Academy of Sciences (Ref. 28).

Most authorities are in agreement that a reasonable and probably conservative estimate of the statistical relationship between low levels of radiation exposure to a large number of people is within the range of about 10 to 500 potential cancer deaths (although zero is not excluded by the data) per million person-rems. The range comes from the latest NAS BEIR III Report (1980) which also indicates a probable value of about 150. This value is virtually identical to the value of about 140 used in the current NRC health-effects models. In addition, about 220 genetic changes per million person-rems would be projected by BEIR III over succeeding generations. That also compares well with the value of about 260 per million person-rems currently used by the NRC staff.

Health-Effects Avoidance

Radiation hazards in the environment tend to disappear by the natural process of radioactive decay. However, where the decay process is a slow one, and where the material becomes relatively fixed in its location as an environmental contaminant (e.g. in soil), the hazard can continue to exist for a relatively long period of time--months, years, or even decades. Thus, a possible consequential environmental societal impact of severe accidents is the avoidance of the health hazard rather than the health hazard itself, by restrictions on the use of the contaminated property or contaminated foodstuffs, milk, and drinking water. The potential economic impacts that this can cause are discussed below.

5.9.4.2 Accident Experience and Observed Impacts

The evidence of accident frequency and impacts in the past is a useful indicator of future probabilities and impacts. As of mid-1981, there were 73 commercial nuclear power reactor units licensed for operation in the United States at 51 sites with power-generating capacities ranging from 50 to 1130 megawatts electric (MWe). (The Callaway Units 1 and 2 are designed for 1188 MWe each.) The combined experience with these units represents about 500 reactor years of operation over an elapsed time of about 20 years. Accidents have occurred at several of these facilities (Refs. 36 and 37). Some of these have resulted in releases of radioactive material to the environment, ranging from very small fractions of a curie to a few million curies. None is known to have caused any radiation injury or fatality to any member of the public, any significant individual or collective public radiation exposure, or any significant contamination of the environment. This experience base is not large enough to permit a reliable quantitative statistical inference. However, it does suggest that significant environmental impacts due to accidents are very unlikely to occur over time periods of a few decades.

Melting or severe degradation of reactor fuel has occurred in only one of these units, during the accident at Three Mile Island - Unit 2 (TMI-2) on 28 March 1979. In addition to the release of a few million curies of xenon-133, it has been estimated that a release of about 15 curies of radioiodine to the environment occurred at TMI-2 (Ref. 38). This amount represents an extremely minute fraction of the total radioiodine inventory present in the reactor at the time of the accident. No other radioactive fission products were released in measurable quantity.

It has been estimated that the maximum cumulative offsite radiation dose to an individual was less than 100 millirems (Refs. 38 and 39). The total population exposure has been estimated to be in the range of about 1000 to 3000 person-rems. This exposure could produce between zero and one additional fatal cancer over the lifetime of the population. The same population receives each year from natural-background radiation about 240,000 person-rems, and about a half-million cancers are expected to develop in this group over its lifetime, primarily from causes other than radiation (Refs. 38 and 39). Trace quantities (barely above the limit of detectability) of radioiodine were found in a few samples of milk produced in the area. No other food or water supplies were impacted.

Accidents at nuclear power plants have also caused occupational injuries and a few fatalities, but none attributed to radiation exposure. Individual worker exposures have ranged up to about 4 rems as a direct consequence of accidents, but the collective worker-exposure levels (person-rems) are a small fraction of the exposures experienced during normal routine operations that average about 410 person-rems per reactor year.

Accidents have also occurred at other nuclear reactor facilities in the United States and in other countries (Refs. 36 and 37). Due to inherent differences in design, construction, operation, and purpose of most of these other facilities, their accident records have only indirect relevance to current nuclear power plants. Melting of reactor fuel occurred in at least seven of these accidents, including the one in 1966 at the Enrico Fermi Atomic Power Plant Unit 1. This was a sodium-cooled fast breeder demonstration reactor designed to generate 61 MWe. The damages were repaired and the reactor reached full power in four years following the accident. It operated successfully and completed its mission in 1973. This accident did not release any radioactivity to the environment.

A reactor accident in 1957 at Windscale, England, released a significant quantity of radioiodine, about 20,000 curies, to the environment. This reactor, which was not operated to generate electricity, used air rather than water to cool the uranium fuel. During a special operation to heat the large amount of graphite in this reactor, the fuel overheated and radioiodine and noble gases were released directly to the atmosphere from a 123-m (405-ft) stack. Milk produced in a 520-km^2 (200-mi^2) area around the facility was impounded for up to 44 days. However, this kind of accident cannot occur in a water-cooled reactor like that at Callaway.

5.9.4.3 Mitigation of Accident Consequences

Pursuant to the Atomic Energy Act of 1954, the Nuclear Regulatory Commission is conducting a safety evaluation of the application to operate Callaway Units 1 and 2. Although this evaluation will contain more detailed information on plant design, the principal design features are presented in the following section.

Design Features

Callaway Units 1 and 2 are essentially identical units. Each contains features designed to prevent accidental release of radioactive fission products from the fuel and to lessen the consequences should such a release occur. Many of the design and operating specifications of these features are derived from the analysis of postulated events known as design-basis accidents. These accident-preventive and mitigative features are collectively referred to as engineered safety features (ESF). The possibilities or probabilities of failure of these systems are incorporated in the assessments discussed in Section 5.9.4.4.

Each steel-lined concrete containment building is a passive mitigating system that is designed to minimize accidental radioactivity releases to the environment. Safety injection systems are incorporated to provide cooling water to the reactor core during an accident to prevent or minimize fuel damage. The containment spray system is designed to spray cool water into the containment atmosphere. The operation of the spray system after a loss-of-coolant accident (LOCA) would prevent containment-system overpressure by quenching the steam generated as a result of reactor coolant flashing into the containment atmosphere. The spray water also contains an additive (sodium hydroxide) that will chemically react with any airborne radioiodine to remove it from the containment atmosphere and prevent its release to the environment.

The mechanical systems mentioned above are supplied with emergency power from onsite diesel generators in the event that normal offsite station power is interrupted.

The fuel-handling area located in the fuel building also has accident mitigating systems. The ventilation system contains both charcoal and high efficiency particulate filters. This ventilation system is also designed to keep the area around the spent-fuel pool below the prevailing barometric pressure during fuel-handling operations so as to prevent exfiltration through building openings. If radioactivity were to be released from the building, it would be drawn through the ventilation system and most of the radioactive iodine and particulate fission products would be removed from the flow stream before exhausting to the environment.

There are features of the plant that are necessary for its power-generation function that can also play a role in mitigating certain accident consequences. For example, the main condenser, although not classified as an ESF, can act to mitigate the consequences of accidents involving leakage from the primary to the secondary side of the steam generators (such as steam generator tube ruptures).

If normal offsite power is maintained, the ability of the plant to send contaminated steam to the condenser instead of releasing it through the safety valves or power-operated relief valves can significantly reduce the amount of radioactivity released to the environment. In this case, the fission-product-removal capability of the normally operating water-processing system would come into play.

Much more extensive discussions of the safety features and characteristics of the Callaway Plant may be found in the applicant's Final Safety Analysis Report (Ref. 33). The staff evaluation of these features will be addressed in a forthcoming Safety Evaluation Report. In addition, the implementation of the lessons learned from the TMI-2 accident, in the form of improvements in design, and procedures and operator training, will significantly reduce the likelihood of a degraded core accident that could result in large releases of fission products to the containment. Specifically, the applicant is expected to follow the guidance on TMI-related matters specified in NUREG-0737. As noted in Section 5.9.4.4 Uncertainties, no credit has been taken for these actions and improvements in establishing the radiological risk of accidents in this environmental statement.

Site Features

In the process of considering the suitability of the site of Callaway Units 1 and 2, pursuant to NRC's reactor-site criteria in 10 CFR Part 100, consideration was given to certain factors that tend to minimize the risk and the potential impact of accidents. First, the site has an exclusion area as provided in 10 CFR Part 100. The exclusion area of the 1290-ha (3188-acre) site has a minimum exclusion distance of 1200 m (3937 ft) from the midpoint between the reactor buildings, and lies entirely within the plant site. The applicant owns all the surface rights within the exclusion area, including the mineral rights. The authority of the applicant to determine all activities within the exclusion area, which is required by Part 100, has been established by right of ownership.

Activities within the exclusion area that are unrelated to plant operation are limited to agricultural activities. There are no industrial, recreational, or residential structures within the plant area. The applicant has negotiated with the Callaway County Court with respect to traffic control on County Roads 335 and 337 traversing the exclusion area. The applicant states that it has received assurances that traffic on these roads in the exclusion area can be controlled adequately in case of emergency. The staff has determined that these activities will not interfere with normal plant operation, as required by Part 100.

Second, beyond and surrounding the exclusion area is a low-population zone (LPZ), also required by 10 CFR Part 100. This is a circular area with a radius of 4 km (2.5 mi). Within this zone the applicant must assure that there is a reasonable probability that appropriate and effective measures could be taken on behalf of the residents and other members of the public in the event of a serious accident.

Third, Part 100 also requires that the nearest population center of about 25,000 or more persons be no closer than one and one-third times the outer radius of the LPZ. The purpose of this criterion is a recognition that, although accidents of greater potential hazards than those commonly postulated as representing an upper limit are conceivable, but highly improbable, it was considered desirable to add the population-center distance requirement to provide for protection against excessive doses to people in large centers.

No commercial or industrial facilities are located within the LPZ. In 1970, 116 residents lived within it, and the 1980 population has been estimated at 76. There are no sources of seasonal population in the LPZ with the exception of Lost Canyon Lake (a trailer park used seasonally), and the Reform Wildlife Management Area, which attracts hunters and fishermen. There is no working-day concentration that would create a significant transient population. The nearest population center is Jefferson City, Missouri, located about 40 km (25 mi) west-southwest of the plant. The City of Fulton, Missouri, located about 16 km (10 mi) southeast of the plant, had a 1970 population of 12,248. Fulton is not expected to reach a population of 25,000 by 2020. The population-center distance is more than one and one-third times the LPZ, as required by Part 100.

The safety evaluation of the Callaway site has also included a review of potential external hazards, i.e. activities offsite that might adversely affect the operation of the plant and cause an accident. This review encompassed nearby industrial, transportation, and military facilities that might create explosive, missile, toxic gas, or similar hazards. The staff has concluded that the hazards from nearby industrial and military facilities, pipelines, air transportation, waterways, and railways are acceptably low. A more detailed discussion of the site features will be included in the staff's safety evaluation report.

Emergency Preparedness

Emergency-preparedness plans including protective-action measures for the Callaway Plant and environs are in an advanced, but not yet fully completed, stage. In accordance with the provisions of 10 CFR Section 50.47, effective 3 November 1980, an operating license will not be issued to the applicant unless a finding is made by the NRC that the state of onsite and offsite emergency preparedness provides reasonable assurance that adequate protective measures can and will be taken in the event of a radiological emergency. Among the standards that must be met by these plans are provisions for two Emergency Planning Zones (EPZ). A plume-exposure-pathway EPZ of about 16 km (10 mi) in radius and an ingestion-exposure-pathway EPZ of about 80 km (50 mi) in radius are required. Other standards include appropriate ranges of protective actions for each of these EPZs, provisions for dissemination to the public of basic emergency-planning information, provisions for rapid notification of the public during a serious reactor emergency, and methods, systems, and equipment for assessing and monitoring actual or potential offsite consequences in the EPZs of radiological-emergency conditions.

The NRC findings will be based on a review of the Federal Emergency Management Agency findings and determinations as to whether state and local government emergency plans are adequate and capable of being implemented, and on the NRC assessment as to whether the applicant's onsite plans are adequate and capable of being implemented. Although the presence of adequate and tested emergency plans cannot prevent the occurrence of an accident, it is the judgment of the staff that they can and will substantially mitigate the consequences to the public should one occur.

5.9.4.4 Accident Risk and Impact Assessment

Design-Basis Accidents

As a means of assuring that certain features of the Callaway Units 1 and 2 meet acceptable design and performance criteria, both the applicant and the staff have analyzed the potential consequences of a number of postulated accidents. Some of these could lead to significant releases of radioactive materials to the environment, and calculations have been performed to estimate the potential radiological consequences to persons offsite. For each postulated initiating event, the potential radiological consequences cover a considerable range of values depending on the particular course taken by the accident and the conditions, including wind direction and weather, prevalent during the accident.

In the safety analysis and evaluation of Callaway Units 1 and 2, three categories of accidents have been considered by the applicant and the staff. These categories are based upon their probability of occurrence and include (1) incidents of moderate frequency, i.e. events that can reasonably be expected to occur during any year of operation; (2) infrequent accidents, i.e. events that might occur once during the lifetime of the plant; and (3) limiting faults, i.e. accidents not expected to occur but that have the potential for significant releases of radioactivity. The radiological consequences of incidents in the first category, also called anticipated operational occurrences, are discussed in Section 5.9.3. Initiating events postulated in the second and third categories for the Callaway Units 1 and 2 are shown in Table 5.6. These are designated design-basis accidents in that specific design and operating features as described in Section 5.9.4.3 Design Features are provided to limit their potential radiological consequences. Approximate radiation doses that might be received by a person at the most adverse location along the site boundary (1200 m or 3900 ft from the plant) are also shown in the table, along with a characterization of the time duration of the releases. The staff has used conservative models for calculations to estimate the potential upper bounds for individual exposures summarized in Table 5.6 for the purpose of implementing the provisions of 10 CFR Part 100, "Reactor Site Criteria." For these calculations, pessimistic (conservative or worst case) assumptions are made as to the course taken by the accident and the prevailing conditions. These assumptions include much larger than expected amounts of radioactive material released by the initiating events, additional single failures in equipment, operation of ESFs in a degraded mode,* and very poor meteorological-dispersion conditions.

Table 5.6. Approximate Radiation Doses from Design-Basis Accidents at the Callaway Plant[a]

Design-Basis Accidents	Dose at 1200 m[b] (rems)	
	Thyroid	Whole Body
Infrequent Accidents		
Rod-ejection accident	43.0	0.1
Steam generator tube rupture	72.0	1.0
Fuel-handling accident	4.0	1.0
Limiting Faults		
Main steam-line break	3.6	0.1
Large-break LOCA[c]	91.0	2.2

a Duration of release less than two hours.

b The site boundary distance that yields the highest radiological dose following an accident.

c Loss-of-coolant accident.

The results of these calculations show that, for these events, the limiting whole-body exposures are not expected to exceed 2.2 rems to any individual at the site boundary. They also show that radioiodine releases have the potential for offsite exposures ranging up to about 91 rems to the thyroid. For such an exposure to occur, an individual would have to be located at a point on the site boundary where the radioiodine concentration in the plume has its highest value and inhale at a breathing rate characteristic of a person jogging, for a period of two hours. The health risk to an individual receiving such a thyroid exposure is the potential appearance of benign or malignant thyroid nodules in about 3 out of 100 cases, and the development of a fatal cancer in about 1 out of 1000 cases.

None of the calculations of the impacts of design-basis accidents described in this section takes into consideration possible reduction in individual or population exposures as a result of taking any protective action.

*However, the containment system is assumed to prevent leakage in excess of that demonstrable by testing, as provided in 10 CFR Part 100.11(a).

Probabilistic Assessment of Severe Accidents

In this and the following three sections, there is a discussion of the probabilities and consequences of accidents of greater saverity than the design-basis accidents discussed in the previous section. They are considered less likely to occur, but their consequences could be severe, both for the plant itself and for the environment. These severe accidents can be distinguished from design-basis accidents in two primary respects: they involve substantial physical deterioration of the fuel in the reactor core, including overheating to the point of melting, and they involve deterioration of the capability of the containment structure to perform its intended function of limiting the release of radioactive materials to the environment. Heretofore, these accidents have frequently been called Class 9 accidents. As a class, they include all accidents involving sequences of failures more severe than those postulated for the design basis of the protective systems and engineered safety features. The consequences of such accidents could be severe.

The assessment methodology employed is that described in the Reactor Safety Study (RSS), which was published in 1975 (Ref. 40).* However, the sets of accident sequences that were found in the RSS to be the dominant contributors to the risk in the prototype PWR (Surry Unit 1) have recently been updated or "rebaselined" (Ref. 41). The rebaselining has been done largely to incorporate peer-group comments (Ref. 42) and better data and analytical techniques resulting from research and development after the publication of the RSS.

Entailed in the rebaselining effort was the evaluation of the individual dominant accident sequences as they are understood to evolve. The earlier technique of grouping a number of accident sequences into the encompassing release categories, as was done in the RSS, has been largely (but not completely) eliminated.

The Callaway Units 1 and 2 are Westinghouse-designed PWRs having design and operating characteristics similar to those of Surry Unit 1, which was used in the RSS as a prototype for PWRs. Therefore, the present assessment for Callaway has used as its starting point the rebaselined accident sequences and release categories referred to above, and more fully described in Appendix E. Characteristics of the sequences (and release categories) used (all of which involve partial to complete melting of the reactor core) are shown in Table 5.7. Sequences initiated by natural phenomena such as tornados, flood, or seismic events, and those that could be initiated by deliberate acts of sabotage, are not included in these event sequences. The radiological consequences of such events would not be different in kind from those that have been treated. Moreover, it is the staff's judgment, based on design requirements of 10 CFR Part 50, Appendix A, relating to effects of natural phenomena, and safeguards requirements of 10 CFR Part 73, that these events do not contribute significantly to risk.

Calculated probability per reactor year associated with each accident sequence (or sequence group) used is shown in the second column in Table 5.7. As in

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*Because this report has been the subject of considerable controversy, a discussion of the uncertainties surrounding it is provided in Section 5.9.4.4 Uncertainties.

Table 5.7. Summary of Atmospheric Releases in Hypothetical Accident Sequences in a PWR (Rebaselined)[a]

Accident Sequence or Release Category[c]	Probability per Reactor Year	Fraction of Core Inventory Released[b]						
		Xe-Kr	I	Cs-Rb	Te-Sb	Ba-Sr	Ru[d]	La[e]
Event V	2.0(-6)[f]	1.0	0.64	0.82	0.41	0.1	0.04	0.006
TMLB'	3.0(-6)	1.0	0.31	0.39	0.15	0.044	0.018	0.002
PWR 3	3.0(-6)	0.8	0.2	0.2	0.3	0.02	0.03	0.003
PWR 7	4.0(-5)	6(-3)	2(-5)	1(-5)	2(-5)	1(-6)	1(-6)	2(-7)

a See Section 5.9.4.4 Uncertainties for a discussion of uncertainties in risk estimates.

b Background on the isotope groups and release mechanisms is presented in Appendix VII of "Reactor Safety Study," WASH-1400, NUREG-75/014, October 1975.

c See Appendix E for a description of accident sequences and release categories.

d Includes Ru, Rh, Co, Mo, Tc.

e Includes Y, La, Zr, Nb, Ce, Pr, Nd, Np, Pu, Am, Cm.

f Exponential notation: $2.0(-6) = 2.0 \times 10^{-6}$.

the RSS there are substantial uncertainties in these probabilities. This is due, in part, to difficulties associated with the quantification of human error and to inadequacies in the data base on failure rates of individual plant components that were used to calculate the probabilities (Ref. 42) (see Sec. 5.9.4.4 Uncertainties). The probability of accident sequences from the Surry plant were used to give a perspective of the societal risk at Callaway Units 1 and 2 because, although the probabilities of particular accident sequences may be substantially different for Callaway, the overall effect of all sequences taken together is likely to be within the uncertainties (see Sec. 5.9.4.4 Uncertainties).

The magnitudes (curies) of radioactivity releases for each accident sequence or release category are obtained by multiplying the release fractions shown in Table 5.7 by the amounts that would be present in the core at the time of the hypothetical accident. These are shown in Table 5.5 for a Callaway reactor core at the thermal power level of 3636 megawatts.

The potential radiological consequences of these releases have been calculated by the consequence model used in the RSS (Ref. 43) and adapted to apply to a specific site. The essential elements are shown in schematic form in Figure 5.3. Environmental parameters specific to the Callaway site have been used and include the following:

1. One full year of consecutive hourly averages of 1974/1975 meteorological data from the site meteorological-monitoring systems, and precipitation data obtained from Columbia, which is about 24 km (15 mi) from the site;

2. Projected population for the year 2000 extending throughout regions of 80- and 560-km (50- and 350-mi) radii from the site;

3. The habitable land fraction within the 560-km (350-mi) radius; and

4. Land-use statistics, on a state-wide basis, including farm land values, farm product values including dairy production, and growing-season information, for the State of Missouri and each surrounding state within the 560-km (350-mi) region.

To obtain a probability distribution of consequences, the calculations are performed assuming the occurrence of each accident release sequence at each of 91 different "start" times throughout a one-year period. Each calculation uses the site-specific hourly meteorological data and seasonal information for the time period following each "start" time. The consequence model also contains provisions for incorporating the consequence-reduction benefits of evacuation and other protective actions. Early evacuation of people would considerably reduce the exposure from the radioactive cloud and the contaminated ground in the wake of the cloud passage. The evacuation model used, as discussed in Appendix F, has been revised from that used in the RSS for better site-specific application. The quantitative characteristics of the evacuation model used for the Callaway site are best-estimate values made by the staff and based on evacuation-time estimates prepared by the applicant. Actual evacuation effectiveness could be greater or less than that characterized, but would not be expected to be very much different.

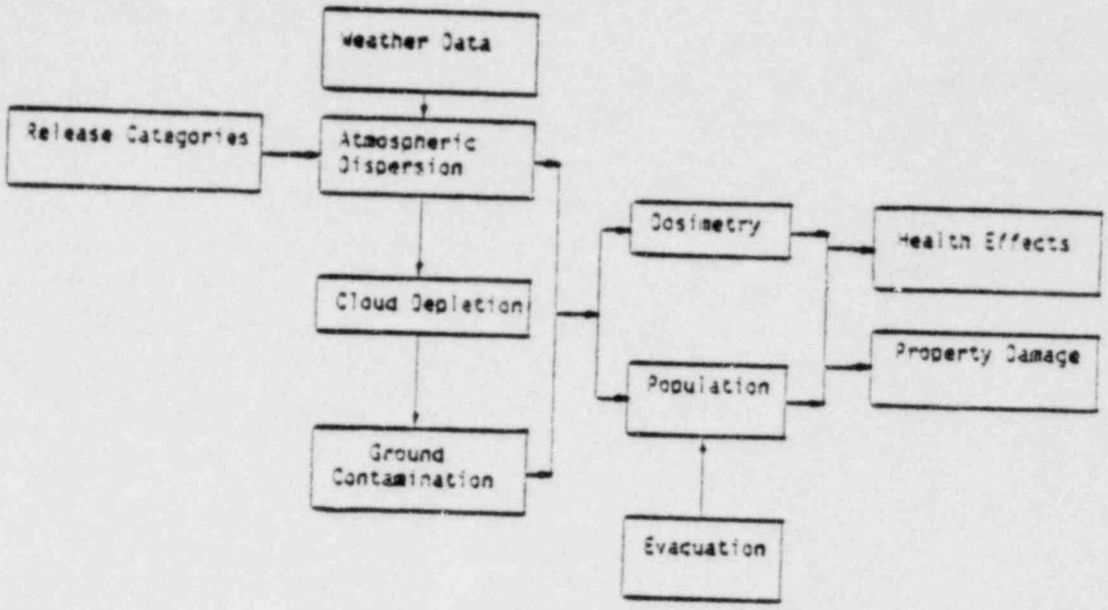

Figure 5.3. Schematic Outline of Consequence Model.

The other protective actions include: (1) either complete denial of use (interdiction) or permitting use only at a sufficiently later time after appropriate decontamination of foodstuffs such as crops and milk, (2) decontamination of severely contaminated environment (land and property) when it is considered to be economically feasible to lower the levels of contamination to protective-action-guide (PAG) levels, and (3) denial of use (interdiction) of severely contaminated land and property for varying periods of time until the contamination levels reduce to such values by radioactive decay and weathering so that land and property can be economically decontaminated as in (2) above. These actions would reduce the radiological exposure to the people from the immediate and/or subsequent use of, or living in, the contaminated environment.

Early evacuation within the plume-exposure-pathway EPZ and other protective actions as mentioned above are considered as essential sequels to serious nuclear reactor accidents involving significant release of radioactivity to the atmosphere. Therefore, the results shown for Callaway include the benefits of these protective actions.

There are also uncertainties in the estimates of consequences, and the error bounds may be as large as they are for the probabilities. However, in the judgment of the staff, it is more likely that the calculated results are overestimates of consequences rather than underestimates.

The results of the calculations using this consequence model are radiological doses to individuals and to populations, health effects that might result from these exposures, costs of implementing protective actions, and costs associated with property damage by radioactive contamination.

Dose and Health Impacts of Atmospheric Releases

The results of the calculations of dose effects and health impacts performed for the Callaway Plant and site are presented in the form of probability distributions in Figures 5.4 through 5.7 and are included in the impact-summary Table 5.8. All of the four accident sequences and release categories shown in Table 5.7 contribute to the results, the consequences from each being weighted by its associated probability.

Figure 5.4 shows the probability distribution for the number of persons who might receive whole-body doses equal to or greater than 200 rems and 25 rems, and thyroid doses equal to or greater than 300 rems from early exposure,* all on a per-reactor-year basis. The 200-rem whole-body dose figure corresponds approximately to a threshold value for which hospitalization would be indicated for the treatment of radiation injury. The 25-rem whole-body (which has been identified earlier as the lower limit for a clinically observable physiological effect) and 300-rem thyroid figures correspond to the Commission's guideline values for reactor siting in 10 CFR Part 100.

The figure shows in the left-hand portion that there are less than eight chances in a million per reactor year (i.e. 8×10^{-6}) that one or more persons may receive doses equal to or greater than any of the doses specified. The fact that the three curves run almost parallel and horizontal shows that if one person were to receive such doses, the chances are about the same that several tens to hundreds would be so exposed. The chances of larger numbers of persons being exposed at those levels are seen to be considerably smaller. For example, the chances are about one in a hundred million per reactor year (i.e. 10^{-8}) that 6000 or more people might receive doses of 200 rems or greater. A majority of the exposures reflected in this figure would be expected to occur to persons within an 80-km (50-mi) radius of the plant. Virtually all would occur within a 160-km (100-mi) radius.

Figure 5.5 shows the probability distribution for the total population exposure in person-rems, i.e. the probability per reactor year that the total population exposure will equal or exceed the values given. For the more severe accidents (first three accidents in Table 5.7) the population exposure up to 1 million person-rems would occur within 80 km (50 mi), and exposure greater than 10 million person-rems would result to persons beyond the 80-km (50-mi) range as shown.

For perspective, population doses shown in Figure 5.5 may be compared with the annual average dose to the population within 80 km (50 mi) of the Callaway site due to natural-background radiation of 50,000 person-rems, and to the anticipated annual population dose to the general public from normal plant operation of about 1 person-rem (excluding plant workers) (App. C, Tables C.7 and C.9).

Figure 5.6 shows the probability distributions for acute fatalities, representing radiation injuries that would produce fatalities within about one year

*Early exposure to an individual includes external doses from the radioactive cloud and the contaminated ground, and the dose from internally deposited radionuclides from inhalation of contaminated air during the cloud passage. Other pathways of exposure are excluded.

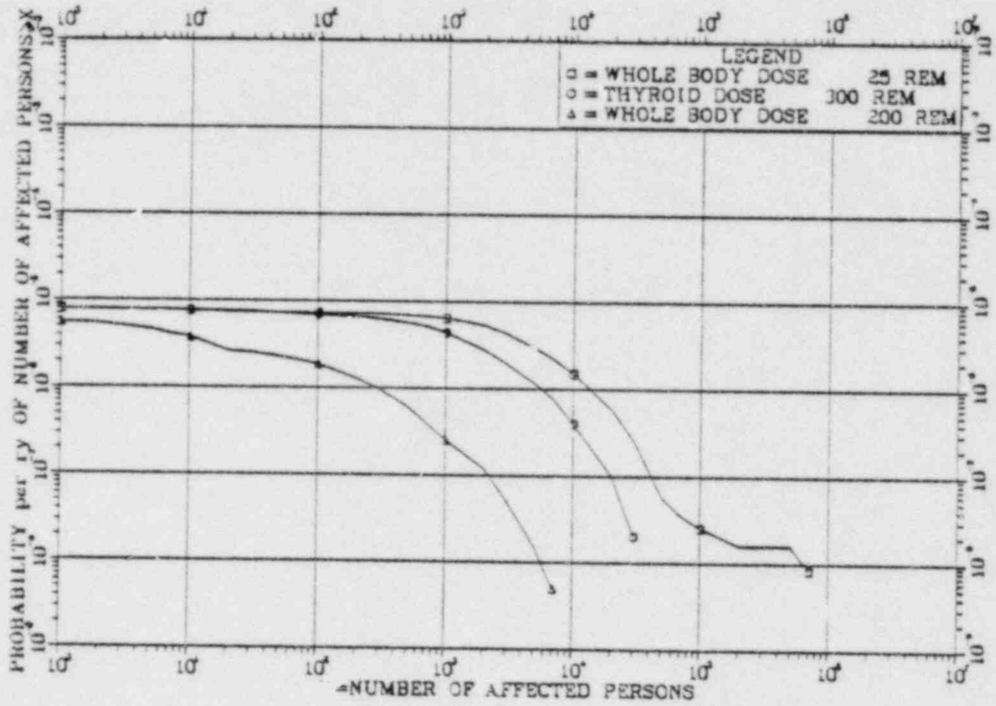

Figure 5.4. Probability Distribution of Individual Dose Impacts.

(See Sec. 5.9.4.4 Uncertainties for a discussion of uncertainties in risk estimates.) (50 mi = 80 km)

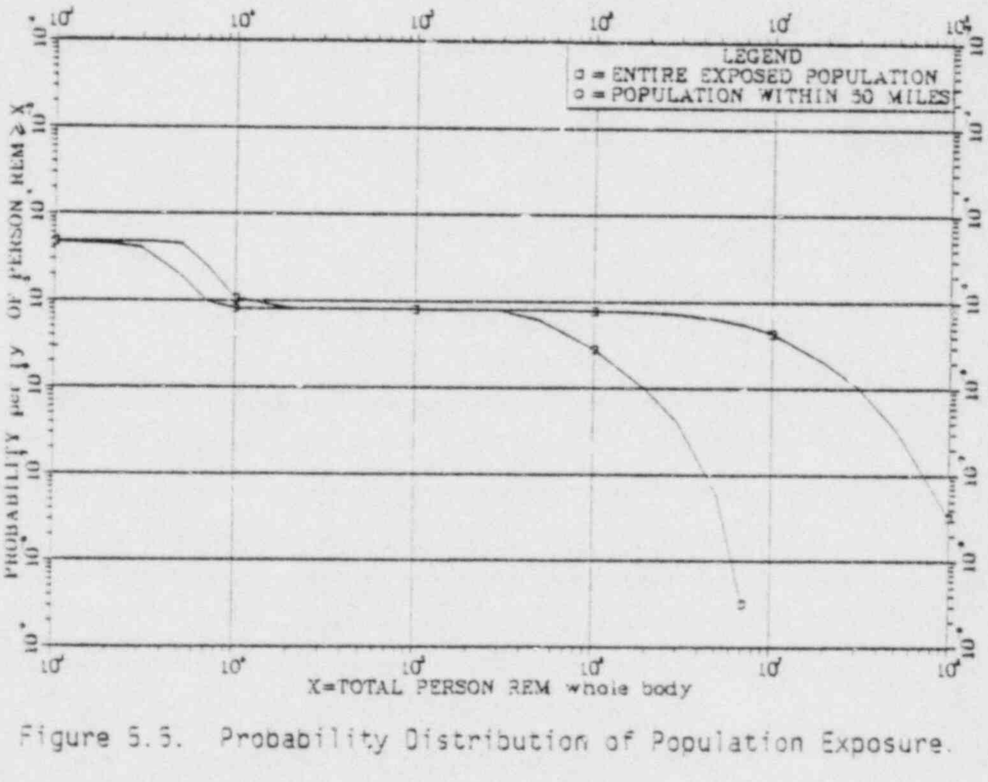

Figure 5.5. Probability Distribution of Population Exposure.

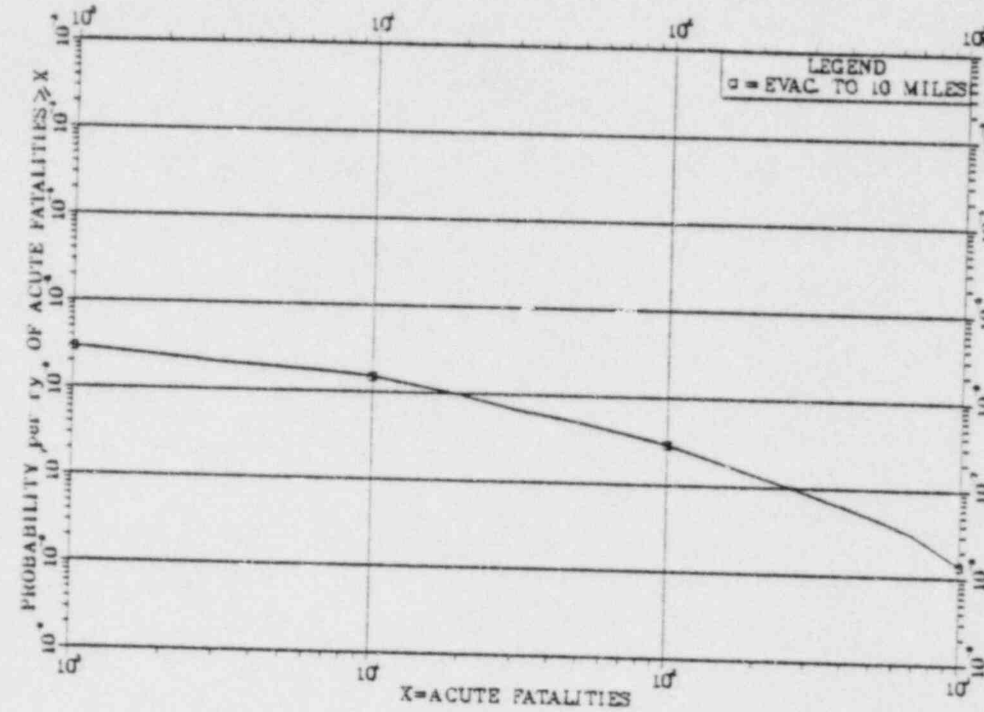

Figure 5.6. Probability Distribution of Acute Fatalities.

(See Sec. 5.9.4.4 Uncertainties for a discussion of uncertainties in risk estimates.) (10 mi = 16 km, 50 mi = 80 km)

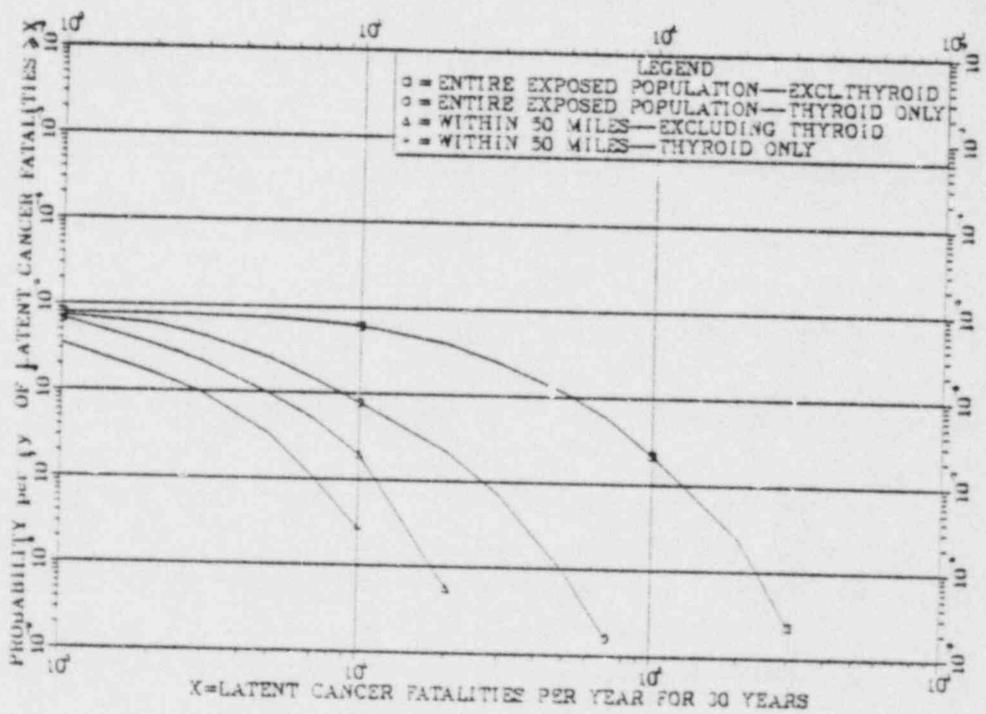

Figure 5.7. Probability Distribution of Cancer Fatalities.

Table 5.8. Summary of Environmental Impacts and Probabilities[a]

Probability per Year of Impact	Number of Persons Exposed > 200 rems	Number of Persons Exposed > 25 rems	Population Exposure (million person-rems) 80 km/total	Number of Fatalities: Acute	Number of Fatalities: Latent Cancer[b] 80 km/total	Cost of Offsite Mitigating Actions ($ million)
10^{-4}	0	0	0/0	0	0/0	0
10^{-5}	0	0	0.0065/0.01	0	0/0	2.5
5×10^{-6}	0	2,500	0.6/10.0	0	45/530	280
10^{-6}	300	13,000	2/30	19	210/1,860	1,000
10^{-7}	2,000	40,000	4.5/70	260	570/4,4[illegible]	2,800
10^{-8}	6,000	650,000	60/105	1,100	810/8,400	7,000
Related figure	5.4	5.4	5.5	5.6	5.7	5.8

a See Section 5.9.4.4 Uncertainties for a discussion of uncertainties in risk estimates.

b Thirty times the values in Figure 5.7 are shown in this column, reflecting the 30-year period over which they might occur. Genetic effects would be about twice the number of latent cancers.

after exposure. Virtually all the acute fatalities would be expected to occur within the 24-km (15-mi) radius. The results of the calculations shown in this figure and in Table 5.8 reflect the effect of evacuation within the 16-km (10-mi) plume-exposure-pathway EPZ only. For the very low probability accidents having the potential for causing radiation exposures above the threshold for acute fatality at distances beyond 16 km (10 mi), it would be realistic to expect that authorities would evacuate persons at all distances at which such exposures might occur. Therefore, acute-fatality consequences would be expected to be less than the numbers shown.

Figure 5.7 represents the statistical relationship between population exposure and the induction of fatal cancers that might appear over a period of many years following exposure. The impacts on the total population and the population within 80 km (50 mi) are shown separately. Further, the latent fatal cancers have been subdivided into those attributable to exposures of the thyroid and all other organs.

Economic and Societal Impacts

As noted in Section 5.9.4.1, the various measures for avoidance of adverse health effects, including those due to residual radioactive contamination in the environment, are possible consequential impacts of severe accidents. Calculations of the probabilities and magnitudes of such impacts for the Callaway Plant and environs have also been made. Unlike the radiation exposure and adverse health-effect impacts discussed above, impacts associated with adverse-health-effects avoidance are more readily transformed into economic impacts.

The results are shown as the probability distribution for costs of offsite mitigating actions in Figure 5.8 and are included in the impact-summary Table 5.8. The factors contributing to these estimated costs include the following:

1. Evacuation costs,

2. Value of crops c[illegible]ated and condemned,

3. Value of milk contaminated and condemned,

4. Costs of decontamination of property where practical, and

5. Indirect costs due to loss of use of property and incomes derived therefrom.

The last-named costs would derive from the necessity for interdiction to prevent the use of property until it is either free of contamination or can be economically decontaminated.

Figure 5.8 shows that at the extreme end of the accident spectrum these costs could approach ten billion dollars, but that the probability that this would occur is exceedingly small, less than one chance in one billion per reactor year.

Additional economic impacts that can be monetized include costs of decontamination of the facility itself and the costs of replacement power. Probability distributions for these impacts have not been calculated, but they are included in the discussion of risk considerations in Section 5.9.4.1 Risk Considerations.

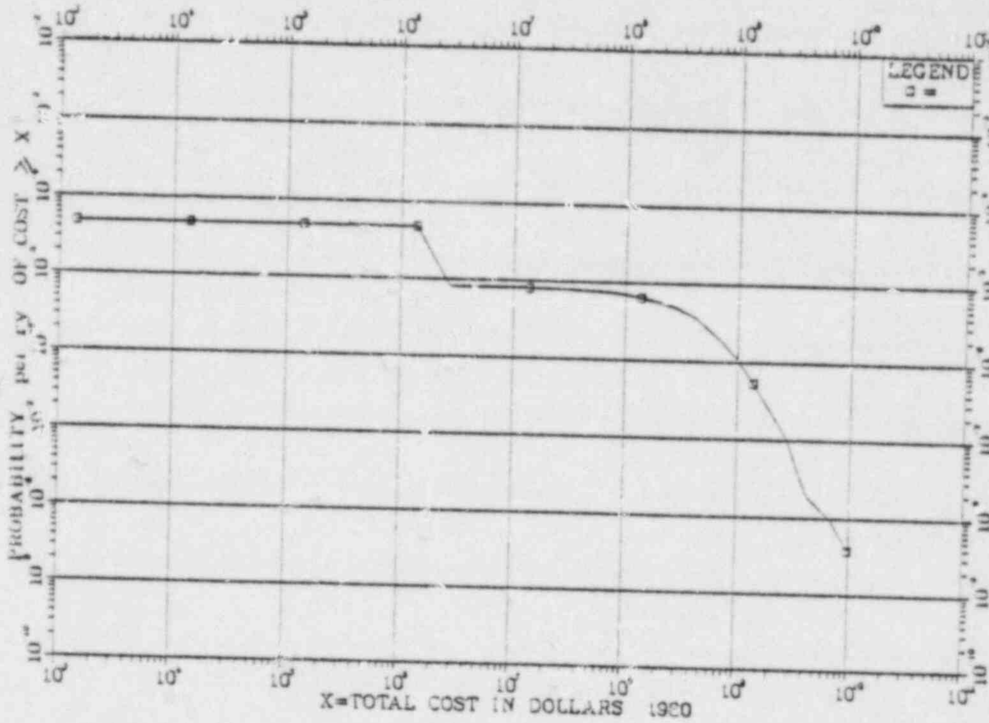

Figure 5.8. Probability Distribution of Mitigation-Measures Cost. (See Sec. 5.9.4.4 Uncertainties for a discussion of uncertainties in risk estimates.)

Release to Groundwater

A pathway for public radiation exposure and environmental contamination that could be associated with severe reactor accidents was identified in Section 5.9.4.1 Exposure Pathways. Consideration has been given to the potential environmental impact of this pathway for the Callaway Plant. The principal contributors to the risk are the core-melt accidents. The penetration of the basemat of the containment buildings can release molten core debris to the strata beneath the plant. Soluble radionuclides in this debris can be leached and transported with groundwater to downgradient domestic wells used for drinking or to surface-water bodies used for drinking water, aquatic food, and recreation. In pressurized water reactors, such as the Callaway units, there is an additional opportunity for groundwater contamination due to the release of contaminated sump water to the ground through a breach in the containment.

An analysis of the potential consequences of a liquid-pathway release of radioactivity for generic sites was presented in the "Liquid Pathway Generic Study" (LPGS) (Ref. 44). The LPGS compared the risk of accidents involving the liquid pathway (drinking water, irrigation, aquatic food, swimming and shoreline usage) for four conventional, generic land-based nuclear plants and a floating nuclear plant, for which the nuclear reactors would be mounted on a barge and moored in a water body. Parameters for the land-based sites were chosen to represent averages for a wide range of real sites and are thus "typical," but represented no real site in particular.

The discussion in this section is an analysis to determine whether or not the Callaway site liquid-pathway consequences would be unique when compared to land-based sites considered in the LPGS. The method consists of a direct scaling of LPGS population doses based on the relative values of key parameters characterizing the LPGS "small-river" site and the Callaway site. The parameters that are normally evaluated included amounts of radioactive materials entering the ground, groundwater travel time, sorption on geological media, surface-water transport, drinking-water use, aquatic-food consumption, and shoreline use.

Individual and population doses were calculated in the LPGS without consideration of interdiction methods such as isolating the contaminated groundwater or denying use of the water. In the event of surface-water contamination, alternative sources of water for drinking, irrigation, and industrial use would be expected to be found, if necessary. Commercial and sport fishing, as well as many other water-related activities, would be restricted. Therefore, the consequences would be largely economic or social, rather than radiological. In any event, the individual and population doses for the liquid pathway range from fractions to very small fractions of those that can arise from the airborne pathways.

The Callaway site is located above several aquifers. However, contamination from an assumed core-melt accident would affect only the upper water-table aquifer. This is because of the depths of the lower aquifers and the lack of hydraulic connection to the upper aquifer due to intervening aquicludes.

In its analysis of liquid tank spills in Section 2.4.13 of the Final Safety Analysis Report (Ref. 33), the applicant estimated groundwater transport time from the site to the nearest surface-water-drainage feature, a tributary of Mud Creek. Groundwater transport was assumed to occur in the Graydon Chert conglomerate, the Burlington Limestone, and Bushberg Sandstone. A conservative value of of 6.0×10^{-4} cm/s was used for horizontal permeability, the effective porosity was estimated to be 0.12, and the hydraulic gradient was chosen to be 0.0144. The staff considers these parameters to be conservative. Using these parameters, a minimum travel time of about 60 years was calculated for groundwater released at the site to reach the tributary of Mud Creek and subsequently the Missouri River. This compares to a travel time of about 0.6 year used for the LPGS river site.

For groundwater travel times of several years or longer, the LPGS showed that the only significant contributors to population dose from an assumed core-melt accident would be Sr-90 and Cs-137. To estimate the travel times of these nuclides the applicant estimated values of the retardation factors, which reflect the effects of sorption within the aquifer. Based on data obtained from similar geologic media, these values were 7.1 for Sr-90 and 14.5 for Cs-137. The staff considers these estimates to be consistent with ranges of retardation factors observed in a wide variety of geologic materials similar to those at the site (Ref. 45). Using these estimates, the transport time from the reactor building to Mud Creek is estimated to be 426 years for Sr-90 and 870 years for Cs-137.

When these times are compared to 5.7 years for Sr-90 and 5.1 years for Cs-137 in the LPGS land-based river case, the relatively larger travel times for the Callaway site would allow a much smaller portion of the radioactivity to enter the surface water. For an equal source of radioactive material, the quantity of materials entering the river would be reduced by a factor of at least 17,000 for Sr-90 and 1.8×10^{8} for Cs-137, compared to the LPGS case.

The nearest water well that could be affected by liquid releases to groundwater is about 2650 m (8700 ft) downgradient. The minimum groundwater travel time to this well has been conservatively calculated to be greater than 200 years. Therefore, direct contamination of groundwater drinking supplies has not been considered to contribute in any significant way to population dose.

Without further analysis it can be concluded that, because of the relatively long travel times, little or no radioactive materials could enter and contaminate surface water near the Callaway site. Therefore, the Callaway liquid-pathway contribution to population dose has been shown to be much smaller than that predicted for the LPGS river site, which represents a "typical" river site. Thus, the Callaway site is not unique in its liquid-pathway contribution to risk.

Furthermore, there are measures that could be taken to minimize the impact of the liquid pathway. The staff estimates that the minimum groundwater travel time from the site to Mud Creek would be about 60 years, and that the holdup radioactivity would be much greater, which would allow ample time for engineering measures such as slurry walls and well-point dewatering to isolate the radioactive contaminants at the source.

Risk Considerations

The foregoing discussions have dealt with both the frequency (or likelihood of occurrence) of accidents and their impacts (or consequences). Because the ranges of both factors are quite broad, it is useful to combine them to obtain average measures of environmental risk. Such averages can be particularly instructive as an aid to the comparison of radiological risks associated with accident releases and with normal operational releases.

A common way in which this combination of factors is used to estimate risk is to multiply the probabilities by the consequences. The resultant risk is then expressed as a number of consequences expected per unit of time. Such a quantification of risk does not at all mean that there is universal agreement that people's attitudes about risk, or what constitutes an acceptable risk, can or should be governed solely by such a measure. At best, it can be a contributing factor to a risk judgment, but not necessarily a decisive factor.

In Table 5.9 are shown average expected values of risk associated with population dose, acute fatalities, latent fatalities, and costs for evacuation and other protective actions. These average values are obtained by summing the probabilities multiplied by the consequences over the entire range of distributions. Because the probabilities are on a per-reactor-year basis, the averages shown are also on a per-reactor-year basis.

Table 5.9. Annual Average Expected Values of Environmental Risks Due to Accidents at the Callaway Plant[a]

Population exposure (person-rems)	
Within 80 km (50 mi)	9
Total	126
Number of acute fatalities	0.0001
Number of latent-cancer fatalities	
All organs excluding thyroid	0.0065
Thyroid only	0.0012
Cost of protective actions and decontamination ($)	4300

a See Section 5.9.4.4 Uncertainties for discussions of uncertainties in risk estimates.

The population-exposure and latent-cancer-fatality risks may be compared with those for normal-operation releases, shown in Appendix C, Tables C.7 and C.9. The radiological dose to the population due to normal operation of each unit may be about 44 person-rems per year. This dose may result in 0.0067 latent-cancer death to the exposed population. The latent-cancer death predicted to result from accidents is expected to be 0.0077 (Table 5.9). The comparison shows that accident risks are comparable to normal-operation risks.

There are no acute-fatality or economic risks associated with protective actions and decontamination for normal releases; therefore, these risks are unique for accidents. However, for perspective and understanding of the meaning of the acute-fatality risk of 0.0001 per year the staff notes that, to a good approximation, the population at risk is that within about 16 km (10 mi) of the plant, about 12,000 persons in the year 2000. Accidental fatalities per year for a population of this size, based on overall averages for the United States, are about two from motor-vehicle accidents, one from falls, one from drowning, and one from burns (Ref. 34).

Figure 5.9 shows the calculated risk expressed as whole-body dose to an individual from early exposure as a function of the distance from the plant within the plume-exposure-pathway EPZ. The values are on a per-reactor-year basis, and all accident sequences and release categories in Table 5.7, weighted by their associated probabilities, contributed to the dose.

Within the 16-km (10-mi) radius plume-exposure-pathway EPZ, the calculations show that the best-estimate evacuation can reduce the risk of acute fatality to an individual to near zero. Evacuation and other protective actions also reduce the risk to an individual of latent-cancer fatality. Figures 5.10 and 5.11 show curves of constant risk per reactor year to an individual living

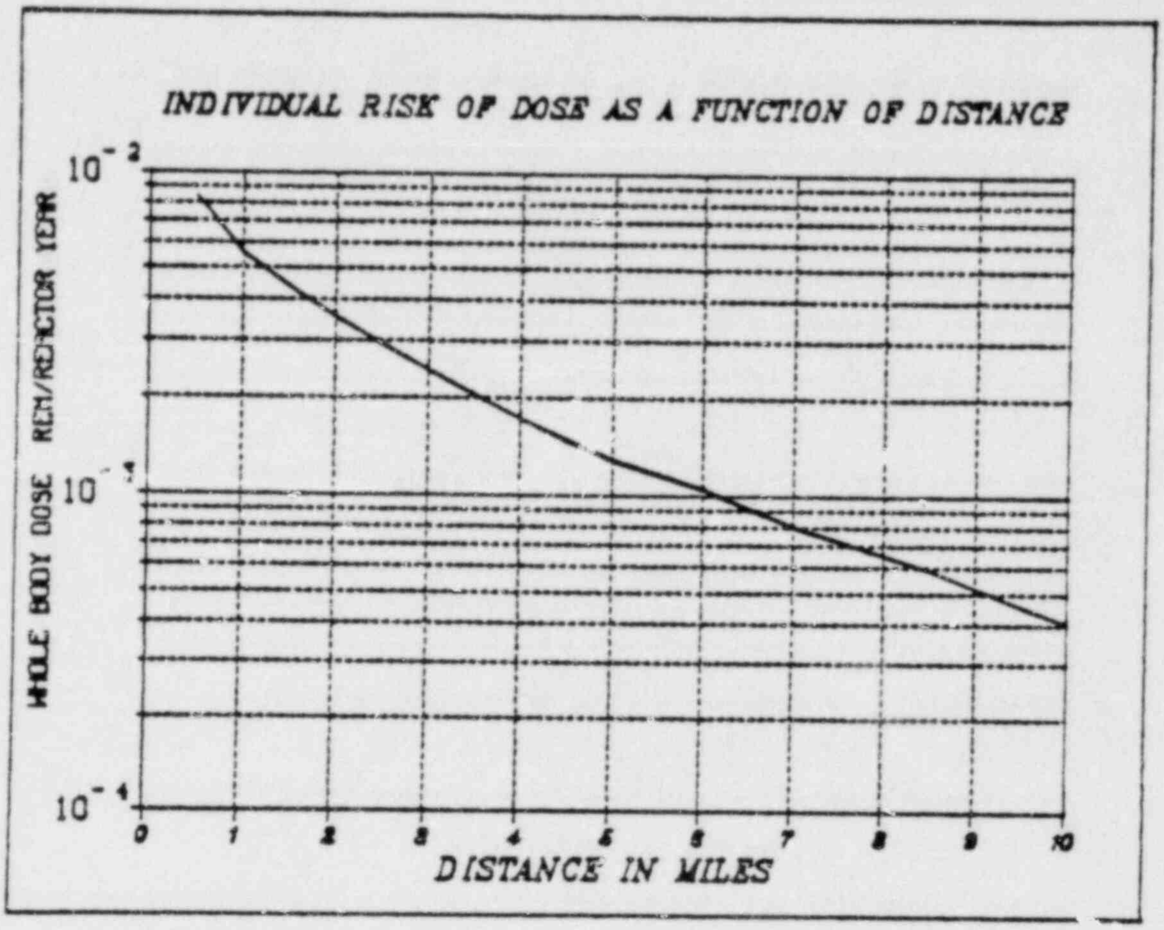

Figure 5.9. Individual Risk of Dose as a Function of Distance. (See Sec. 5.9.4.4 Uncertainties for a discussion of uncertainties in risk estimates.) (To convert mi to km, multiply by 1.6093.)

within the plume exposure-pathway EPZ of the Callaway Plant of acute death and of death from latent cancer, respectively, as a function of distance due to potential accidents in a reactor. Directional variation of these curves reflects the variation in the average fraction of the year the wind would be blowing into each direction from the plant. For comparison, the following risks of fatality per year to an individual living in the United States may be noted: automobile accident 2.2×10^{-4}, falls 7.7×10^{-5}, drowning 3.1×10^{-5}, burning 2.9×10^{-5}, and firearms 1.2×10^{-5} (Ref. 34).

The economic risk associated with evacuation and other protective actions could be compared with property-damage costs associated with alternative energy-generation technologies. The use of fossil fuels, coal or oil for example, would emit substantial quantities of sulfur dioxide and nitrogen oxides into the atmosphere and, among other things, lead to environmental and ecological damage through the phenomenon of acid rain (Ref. 34, pp. 559-560). However, this effect has not been sufficiently quantified to draw a useful comparison at this time.

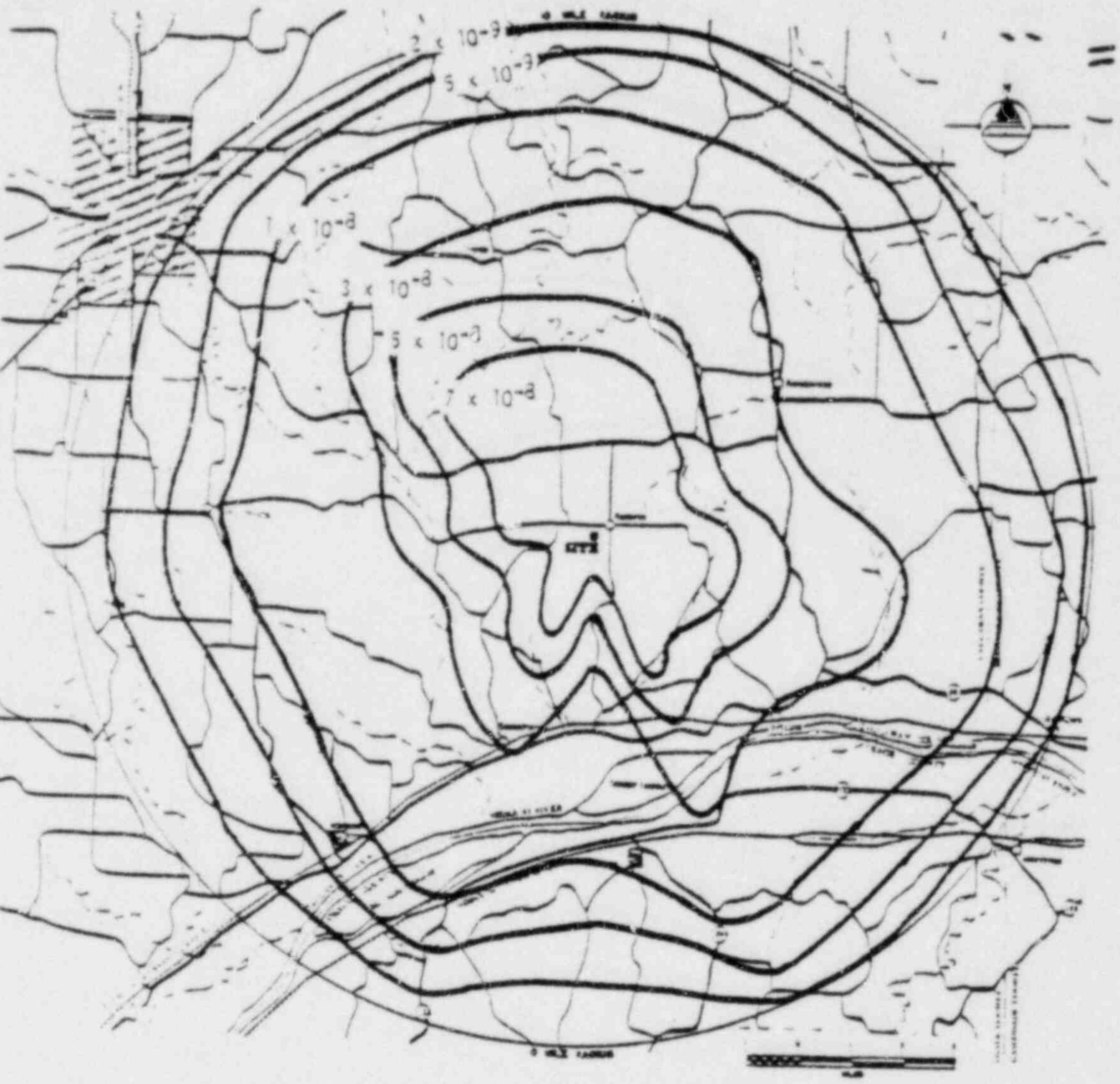

Figure 5.10. Isopleths of Risk of Acute Fatality per Reactor Year to an Individual. (To convert mi to km, multiply by 1.6093.)

There are other economic impacts and risks that can be monetized that are not included in the cost calculations discussed in Section 5.9.4.4 Economic and Societal Impacts. These impacts relate to the added cost to the public due to the loss of the nuclear unit itself. The costs associated with this loss include those for decontamination, repair or replacement of the plant, and replacement power.

No detailed methodology has been developed for estimating the contribution of an accident to the economic risk to the licensee for decontamination and restoration of the plant. Experience with such costs is currently being accumulated as a result of the Three Mile Island accident. If an accident occurs during the first year of the Callaway Unit 1 operation, the economic penalty

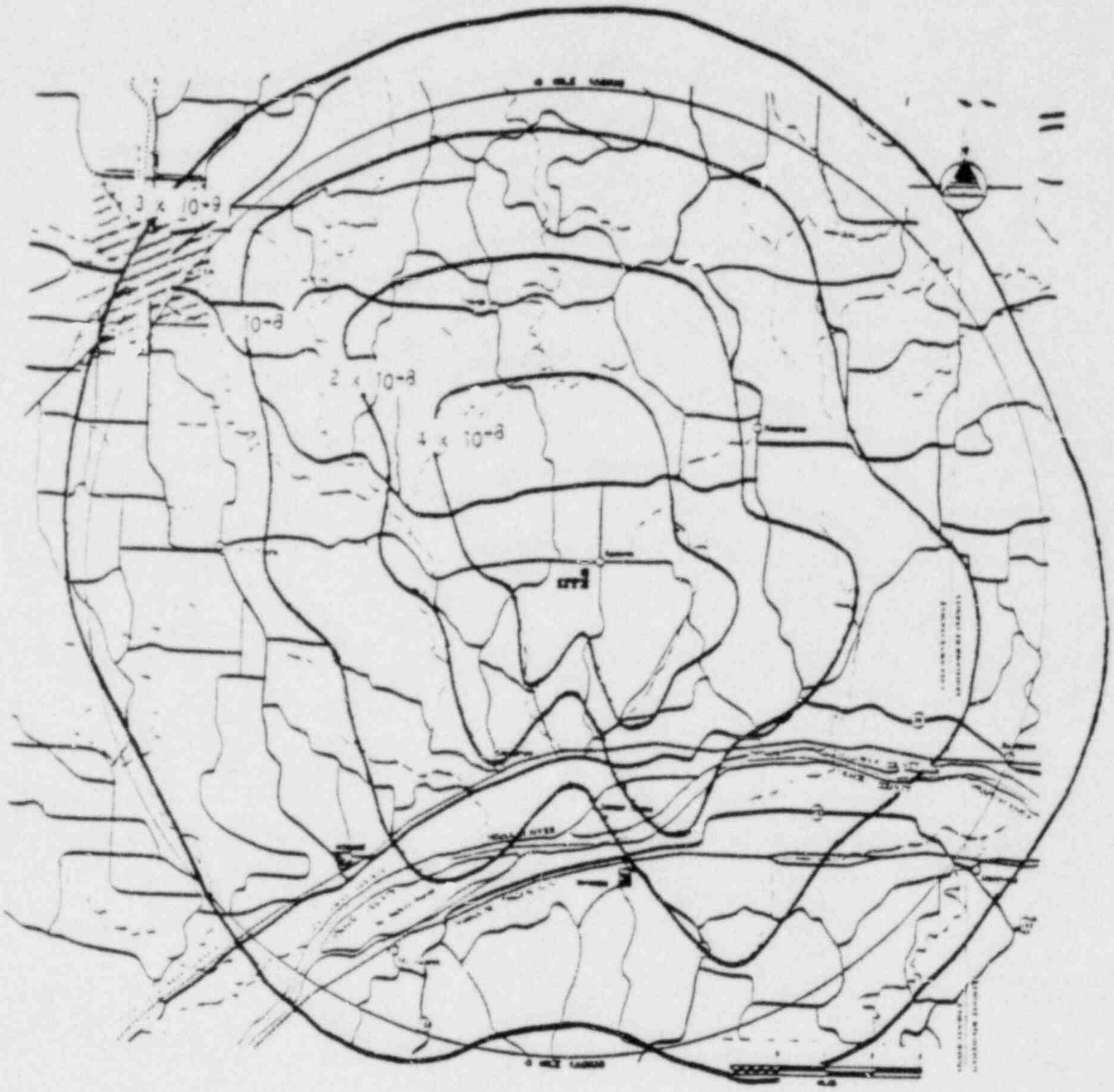

Figure 5.11. Isopleths of Risk of Latent-Cancer Fatality per Reactor Year to an Individual. (To convert mi to km, multiply by 1.6093.)

in present-worth dollars, reflected to the initial year of Unit 1 operation, is estimated at $1.3 billion for decontamination and restoration of the plant and $600 million for replacement power during the period the plant is being restored. This estimate assumes that the plant would be out of commission for eight years and that the energy that would have been forthcoming from the Callaway unit (assuming 60% capacity factor) would be replaced largely by coal-fired generation within the general area.

If the probability of sustaining a total loss of the original plant is taken as the sum of the probabilities of the occurrence of core-melt accidents, there would be about 4.8 chances in 100,000 (i.e. probability of 4.8×10^{-5}) that a disabling accident would happen during each year of service life of the units. Multiplying the previously estimated cost of $1900 million for an accident to Callaway Unit 1 during the initial year of its operation by the 4.8×10^{-5} probability results in an economic risk of $91,000 applicable to Callaway Unit 1 during that year. This is also the approximate economic risk during the second and each subsequent year of its operation. Although the nuclear units depreciate in value and probably operate at reduced capacity factors such that the economic consequences due to an accident become less as the units become older, this is offset by higher cost (due to inflation) of decontamination and restoration of the units in the later years.

Uncertainties

The foregoing probabilistic and risk-assessment discussion has been based on the methodology presented in the Reactor Safety Study (RSS), which was published in 1975.

In July 1977, the NRC organized an Independent Risk Assessment Review Group to (1) clarify the achievements and limitations of the RSS Group, (2) assess the peer comments thereon and the responses to the comments, (3) study the current state of such risk-assessment methodology, and (4) recommend to the Commission how and whether such methodology can be used in the regulatory and licensing process. The results of this study were issued in September 1978 (Ref. 42). This report, called the Lewis Report, contains several findings and recommendations concerning the RSS. Some of the more significant findings are summarized below:

1. A number of sources of both conservatism and nonconservatism in the probability calculations in RSS were found, which were very difficult to balance. The Review Group was unable to determine whether the overall probability of a core melt given in the RSS was high or low, but they did conclude that the error bands were understated.

2. The methodology, which was an important advance over earlier methodologies that had been applied to reactor risk, was sound.

3. It is very difficult to follow the detailed thread of calculations through the RSS. In particular, the Executive Summary is a poor description of the contents of the report, should not be used as such, and has lent itself to misuse in the discussion of reactor risk.

On 19 January 1979, the Commission issued a statement of policy concerning the RSS and the Review Group Report. The Commission accepted the findings of the Review Group.

The accident at Three Mile Island occurred in March 1979 at a time when the accumulated experience record was about 400 reactor years. It is of interest to note that this was within the range of frequencies estimated by the RSS for an accident of this severity (Ref. 37, p. 553). It should also be noted that the Three Mile Island accident has resulted in a very comprehensive evaluation of reactor accidents like that one, by a significant number of investigative groups both within NRC and outside it. Actions to improve the safety of nuclear power plants have come out of these investigations, including those from the President's Commission on the Accident at Three Mile Island, and NRC staff investigations and task forces. A comprehensive "NRC Action Plan Developed as a Result of the TMI-2 Accident," NUREG-0660, Vol. I, May 1980, collects the various recommendations of these groups and describes them under the subject areas of: Operational Safety; Siting and Design; Emergency Preparedness and Radiation Effects; Practices and Procedures; and NRC Policy, Organization, and Management. The action plan presents a sequence of actions, some already taken, that will result in a gradually increasing improvement in safety as individual actions are completed. The Callaway Plant is receiving and will receive the benefit of these actions on the schedule indicated in NUREG-0660. However, the improvement in safety from these actions has not been quantified, and the radiological risk of accidents discussed in this section does not reflect these improvements.

5.9.4.5 Conclusions

The foregoing sections consider the potential environmental impacts from accidents at the Callaway Plant. These have covered a broad spectrum of possible accidental releases of radioactive materials into the environment by atmospheric and groundwater pathways. Included in the considerations are postulated design-basis accidents and more severe accident sequences that lead to a severely damaged reactor core or core melt.

The environmental impacts that have been considered include potential radiation exposures to individuals and to the population as a whole, the risk of near- and long-term adverse health effects that such exposures could entail, and the potential economic and societal consequences of accidental contamination of the environment. These impacts could be severe, but the likelihood of their occurrence is judged to be small. This conclusion is based on (1) the fact that considerable experience has been gained with the operation of similar facilities without significant degradation of the environment; (2) that, in order to obtain a license to operate the Callaway Plant, it must comply with the applicable Commission regulations and requirements; and (3) a probabilistic assessment of the risk based on the methodology developed in the RSS. The overall assessment of environmental risk of accidents, assuming protective action, shows that it is less than the risk for normal operational releases, although accidents have a potential for acute fatalities and economic costs that cannot arise from normal operations. The risks of acute fatality from potential accidents at the site are small in comparison with the risks of acute fatality from other human activities in a comparably sized population.

The staff concludes that there are no special or unique features about the Callaway site and environs that would warrant special mitigation features for the Callaway Plant.

5.10 THE URANIUM FUEL CYCLE

The uranium-fuel-cycle rule, 10 CFR Part 51.20 (44 FR 45362), reflects the latest information relative to reprocessing of spent fuel and to radioactive-waste management as discussed in NUREG-0116, "Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle" (Ref. 46), and NUREG-0216 (Ref. 47), which presents staff responses to comments on NUREG-0116. The rule also considers other environmental factors of the uranium fuel cycle, including aspects of mining and milling, isotopic enrichment, fuel fabrication, and management of low- and high-level wastes. These are described in the AEC report WASH-1248, "Environmental Survey of the Uranium Fuel Cycle" (Ref. 48). The Commission also directed that an explanatory narrative be developed that would convey in understandable terms the significance of releases tabulated in the final rule. The narrative was also to address such important fuel-cycle impacts as environmental dose commitments and health effects, socioeconomic impacts, and cumulative impacts, where these are appropriate for generic treatment. This explanatory narrative was published in the Federal Register on 4 March 1981 (46 FR 15154-15175). Appendix G addresses those impacts of the fuel cycle that reasonably appear to have significance for individual reactor licensing sufficient to warrant attention for NEPA purposes.

Table S-3 of the final uranium-fuel-cycle rule is reproduced in its entirety herein as Table 5.10. Specific categories of natural-resource use included in the table relate to land use, water consumption and thermal effluents, radioactive releases, burial of transuranic and high- and low-level wastes, and radiation doses from transportation and occupational exposures. The contributions in the table for reprocessing, waste management, and transportation of wastes are maximized for either of the two fuel cycles (uranium only and no recycle); that is, the cycle that results in the greater impact is used.

Appendix G contains a description of the environmental impact assessment of the uranium fuel cycle as related to the operation of CAL-1. The environmental impacts are based on the values given in Table S-3 and on an analysis of the radiological impact from radon releases. The staff finds that the environmental impact of CAL-1 on the U.S. population from radioactive gaseous and liquid releases (including radon) due to the uranium fuel cycle is inconsequential when compared to the impact of natural-background radiation. In addition, the nonradiological impacts of the uranium fuel cycle are found to be acceptable.

5.11 DECOMMISSIONING

Decommissioning of a nuclear power reactor does not usually involve environmental impacts that are unique to a specific project. The technology for decommissioning nuclear facilities is well in hand and, although technical improvements in decommissioning techniques are to be expected, at the present time decommissioning can be performed safely and at reasonable cost. Radiation doses to the public as a result of decommissioning activities should be very small and would come primarily from the transportation of decommissioning waste to waste-burial grounds. Radiation doses to decommissioning workers should be a small fraction of the worker exposure over the operating lifetime of the facility; these doses usually will be well within the occupational-exposure limits imposed by regulatory requirements. Decommissioning costs for reactors are a small fraction of the present-worth commissioning costs. A full analysis of decommissioning is available in NUREG-0586, "Draft Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities" (Ref. 49).

5.12 EMERGENCY PLANNING IMPACTS

Construction of the facilities is discussed in Section 4.2.1. The staff believes the only noteworthy potential source of impacts to the public from emergency planning would be associated with the testing of the early notification system. The test requirements and noise levels will be consistent with those used for existing alert systems; therefore, the staff concludes that the noise impacts from the system will be infrequent and insignificant.

Table 5.10. (Table S-3) Uranium-Fuel-Cycle Environmental Data[1]

[Normalized to model LWR annual fuel requirement [WASH-1248] or reference reactor year [NUREG-0116]]

Environmental considerations	Total	Maximum effect per annual fuel requirement or reference reactor year of model 1,000 MWe LWR
NATURAL RESOURCES USE		
Land (acres):		
Temporarily committed[1]	100	
Undisturbed area	79	
Disturbed area	22	Equivalent to a 110 MWe coal-fired power plant.
Permanently committed	13	
Overburden moved (millions of MT)	2.8	Equivalent to 95 MWe coal-fired power plant.
Water (millions of gallons):		
Discharged to air	160	=2 percent of model 1,000 MWe LWR with cooling tower.
Discharged to water bodies	11,090	
Discharged to ground	127	
Total	11,377	< 4 percent of model 1,000 MWe LWR with once-through cooling.
Fossil fuel:		
Electrical energy (thousands of MW-hour)	323	<5 percent of model 1,000 MWe LWR output.
Equivalent coal (thousands of MT)	118	Equivalent to the consumption of a 45 MWe coal-fired power plant.
Natural gas (millions of scf)	135	<0.4 percent of model 1,000 MWe energy output.
EFFLUENTS—CHEMICAL (MT)		
Gases (including entrainment):[1]		
SO_x	4,400	
NO_x[1]	1,190	Equivalent to emissions from 45 MWe coal-fired plant for a year.
Hydrocarbons	14	
CO	29.6	
Particulates	1,154	
Other gases:		
F	67	Principally from UF_6 production, enrichment, and reprocessing. Concentration with[illegible] range of state standards—below level th[illegible] has effects on human health.
HCl	014	
Liquids:		
SO_4^-	9.9	From enrichment, fuel fabrication, and reprocessing steps. Components that constitute a potential for adverse environmental effect are present in dilute concentrations and receive additional dilution by receiving bodies of water to levels below permissible standards. The constituents that require dilution and the flow of dilution water are:
NO_3^-	25.8	NH_3—600 cfs.
Fluoride	12.9	NO_3—20 cfs.
Ca^{++}	5.4	Fluoride—70 cfs.
Cl^-	8.5	
Na^+	12.1	
NH_3	10.0	
Fe	4	
Tailings solutions (thousands of MT)	240	From mills only—no significant effluents to environment.
Solids	91,000	Principally from mills—no significant effluents to environment.

Table 5.10. (Table S-3) (Continued)

Environmental considerations	Total	Maximum effect per annual fuel requirement or reference reactor year of model 1,000 MWe LWR
EFFLUENTS—RADIOLOGICAL (CURIES)		
Gases (including entrainment)[5]:		
Rn-222		Presently under reconsideration by the Commission.
Ra-226	.02	
Th-230	.02	
Uranium	.034	
Tritium (thousands)	18.1	
C-14	24	
Kr-85 (thousands)	400	
Ru-106	.14	Principally from fuel reprocessing plants.
I-129	1.3	
I-131	.83	
Tc-99		Presently under consideration by the Commission.
Fission products and transuranics	.203	
Liquids:		
Uranium and daughters	2.1	Principally from milling—included tailings liquor and returned to ground—no effluents; therefore, no effect on environment.
Ra-226	.0034	From UF_6 production.
Th-230	.0015	
Th-234	.01	From fuel fabrication plants—concentration 10 percent of 10 CFR 20 for total processing 26 annual fuel requirements for model LWR.
Fission and activation products	5.9×10^{-6}	
Solids (buried on site):		
Other than high level (shallow)	11,300	9,100 Ci comes from low level reactor wastes and 1,500 Ci comes from reactor decontamination and decommissioning—buried at land burial facilities. 600 Ci comes from mills—included in tailings returned to ground. Approximately 60 Ci comes from conversion and spent fuel storage. No significant effluent to the environment.
TRU and HLW (deep)	1.1×10^{7}	Buried at Federal Repository.
Effluents—thermal (billions of British thermal units)	4,063	< 5 percent of model 1,000 MWe LWR.
Transportation (person-rem):		
Exposure of workers and general public	2.5	
Occupational exposure (person-rem)	22.6	From reprocessing and waste management.

[1] In some cases where no entry appears it is clear from the background documents that the matter was addressed and that, in effect, the Table should be read as if a specific zero entry had been made. However, there are other areas that are not addressed at all in the Table. Table S-3 does not include health effects from the effluents described in the Table, or estimates of releases of Radon-222 from the uranium fuel cycle or estimates of Technetium-99 released from waste management or reprocessing activities. These issues may be the subject of litigation in the individual licensing proceedings.

[2] Data supporting this table are given in the "Environmental Survey of the Uranium Fuel Cycle," WASH-1248, April 1974; the "Environmental Survey of the Reprocessing and Waste Management Portion of the LWR Fuel Cycle," NUREG-0116 (Supp. 1 to WASH-1248); the "Public Comments and Task Force Responses Regarding the Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle," NUREG-0216 (Supp. 2 to WASH-1248); and in the record of the final rulemaking pertaining to Uranium Fuel Cycle Impacts from Spent Fuel Reprocessing and Radioactive Waste Management, Docket RM-50-3. The contributions from reprocessing, waste management and transportation of wastes are maximized for either of the two fuel cycles (uranium only and no recycle). The contribution from transportation excludes transportation of cold fuel to a reactor and of irradiated fuel and radioactive wastes from a reactor which are considered in Table S-4 of § 51.20(g). The contributions from the other steps of the fuel cycle are given in columns A-E of Table S-3A of WASH-1248.

[3] The contributions to temporarily committed land from reprocessing are not prorated over 30 years, since the complete temporary impact accrues regardless of whether the plant services one reactor for one year or 57 reactors for 30 years.

[4] Estimated effluents based upon combustion of equivalent coal for power generation.

[5] 1.2 percent from natural gas use and process.

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6. EVALUATION OF THE PROPOSED ACTION

6.1 UNAVOIDABLE ADVERSE IMPACTS

The staff has reassessed the physical, social, biological, and economic impacts that can be attributed to the operation of CAL-1. Its construction was 77% complete as of 1 July 1981, and most of the predicted and expected impacts of the construction phase are evident, have already occurred, or have been mitigated by the applicant. Changes in plant design and operating procedures and the use of updated data have led to minor adjustments in the preconstruction estimates of unavoidable adverse operational impacts. No major additional adverse effects attributable to plant operation were found, and the adjustments in the preconstruction estimates do not invalidate the preconstruction presentation (FES-CP, Sec. 10.1). Most operational impacts are significantly less than as described in the FES-CP because the conclusions in this statement are for a single unit, whereas those in the FES-CP are for two units.

6.2 IRREVERSIBLE AND IRRETRIEVABLE COMMITMENTS OF RESOURCES

There have been no significant changes in the staff's assessment of resource commitments made prior to construction (FES-CP, Sec. 10.3) except that the continuing escalation of costs has increased the dollar values of materials used for construction and fueling of the plant. CAL-1 will consume about 30 t of uranium by fission over 30 years of operation at an average capacity factor of 60% (FES-CP, Table 10.2; ER-OL, Sec. 5.7.2). About 6000 t of U_3O_8 in the form of yellowcake will be needed to provide this fuel (Ref. 1).

6.3 RELATIONSHIP BETWEEN SHORT-TERM USES AND LONG-TERM PRODUCTIVITY

There have been no significant changes in the staff's preconstruction evaluation of the relation between the environmental effects of short-term uses (construction and operation of the plant) and long-term productivity (FES-CP, Sec. 10.2). The conclusion that the dedication of resources for a nuclear power plant at the Callaway site is consistent with the balancing of short- and long-term objectives for use of the environment is still valid.

6.4 BENEFIT-COST SUMMARY

The benefits and costs of operating CAL-1 are summarized in Table 6.1, which provides the staff's assessments of degrees of benefit or cost, as well as magnitudes of impact where they are quantifiable. References that contain further information are indicated.

6.4.1 Benefits

The primary benefits to be derived from operation of CAL-1 include an annual production of about 6 billion kWh of baseload electrical energy over the life

Table 6.1. Benefit-Cost Summary for CAL-1

Benefit or Cost (Reference)	Magnitude or Reference†[1]	Staff Assessment of Benefit or Cost†[2]
	BENEFITS	
	Direct	
Electrical energy (Sec. 2.2)	6 billion kWh/yr	Moderate
Additional UE capacity (Sec. 2.4)	1150 MWe	Moderate
Reduced generating costs (Sec. 2.2)	$90 million/yr†[3]	Large
Diversity of fuel supply	(Sec. 2.3)	Large
System reliability	(Sec. 2.4)	Large
	Indirect	
Local property taxes (Sec. 5.8.2)	$6.1 million/yr†[4]	Large
Employment (Sec. 5.8.1)	281 employees†[5]	Moderate
Payroll (Sec. 5.8.1)	$8.1 million/yr†[5]	Moderate
Local purchases (Sec. 5.8.1):		
By employees	$2.7 million/yr†[5]	Moderate
By utility	$700,000/yr†[5]	Small
	COSTS	
	Economic	
Fuel (Sec. 2.2)	7.5 mill/kWh†[4]	Small
Operation and maintenance (Sec. 2.2)	3.2 mill/kWh†[4]	Small
Decommissioning (Sec. 2.2)	$59 to $73 million†[6]	Small
	Environmental and Socioeconomic	
Resources committed:		
Land (Sec. 5.2)	2926 ha	Small
Water (Sec. 5.3.1)	0.7 billion m^3	Small
Uranium - U_3O_8 (Sec. 6.2)	About 6000 t	Small
Other materials and supplies	(FES-CP, Sec. 10.3.4)	Small
Damages suffered by other water users due to:		
Surface-water consumption (Sec. 5.3.1)	1 m^3/s (maximum)	Small
Surface-water contamination	(Sec. 5.3.2.1)	Small
Groundwater consumption (Sec. 5.3.1)	Zero	None
Groundwater contamination	(Sec. 5.3.2.2)	None
Damage to aquatic biota due to:		
Impingement and entrainment	(Sec. 5.5.2.1)	Small
Thermal effects	(Sec. 5.5.2.2)	Small
Chemical discharges	(Sec. 5.5.2.3)	Small
Damage to terrestrial resources due to:		
Sludge lagoons	(Sec. 5.5.1.1)	Small
Fog and ice	(Sec. 5.5.1.2)	None
Cooling-tower drift	(Sec. 5.5.1.2)	Small
Bird impaction	(Secs. 5.5.1.3 and 5.5.1.5)	Small

Table 6.1. (Continued)

Benefit or Cost (Reference)	Magnitude or Reference†1	Staff Assessment of Benefit or Cost†2
	COSTS (Continued)	
	Environmental and Socioeconomic (Continued)	
Adverse socioeconomic effects due to:		
Loss of historic or archeological resources	(Sec. 5.7)	Small
Visual intrusion	(Sec. 5.8.4)	Small
Noise	(Sec. 5.8.6)	None
Increased traffic	(Sec. 5.8.4)	Small
Increased demands on public facilities and services	(Sec. 5.8.5)	Small
Increased demands on private facilities and services	(Sec. 5.8.3)	Small
Adverse nonradiological health effects due to:		
Air-quality changes	(Sec. 5.4)	Small
Water-quality changes	(Sec. 5.3.2)	Small
Adverse radiological health effects due to:		
Reactor operation on:		
General population	(Sec. 5.9.3)	Small
Workers onsite	(Sec. 5.9.3)	Small
Balance of fuel cycle	(Sec. 5.10)	Small
Accident risks	(Sec. 5.9.4)	Small

†1 If an estimate of the magnitude of the benefit or cost under consideration has not been made, the section of this environmental statement (or other reference) containing further information is indicated.

†2 The basis for the assignments of descriptors used by the staff to make judgmental comparative assessments of quantitatively incommensurable benefits and costs is as follows:

None: Absolutely none, or too small to have detectable consequences and be estimated by a credible procedure.

Small: Benefits or costs for which impacts are of such a minor nature that, based on currently available information, detailed consideration of the relevant adverse impacts or mitigative actions is not warranted.

Moderate: Benefits or costs for which the relevant impacts are likely to be clearly evident. Mitigation alternatives are usually considered for moderate adverse impacts.

Large: Major benefits or costs for which the relevant adverse impacts require careful consideration of all reasonable mitigation alternatives and, if mitigation not feasible, must be offset by overriding project considerations.

†3 For 1984, the first full year of operation (see Table 2.1).

†4 Estimated value for 1983.

†5 Estimated value for 1982.

†6 In 1985 dollars.

of the plant, improved reliability of the UE system brought about by the addition of 1150 MWe of generating capacity to the system, a saving from 1984 onward of about $90 million or more per year in production costs (Table 2.1), and an increase in the diversity of the fuel supply of the system as a result of providing baseload generating capacity using a fuel other than coal (Sec. 2).

Secondary benefits arising from operation of CAL-1 include wages paid to operating personnel (projected to be $8.1 million per year in 1982) and taxes paid to local political subdivisions (Sec. 5.8.1). The applicant paid $3.25 million in property taxes on the Callaway Plant in 1980, and projects a tax payment of $6.1 million in 1983 (Sec. 5.8.2). About 70% of the 1980 tax revenues were paid to Callaway Count, school districts (ER-OL, Table 8.1-14). The applicant estimates that retail purchases by plant operating personnel will be about $2.7 million in 1982 (Sec. 5.8.1).

6.4.2 Costs

6.4.2.1 Economic

The economic costs associated with plant operation include fuel costs and operation and maintenance costs, which--for 1983, the first year CAL-1 is expected to operate commercially--are 7.5 mill/kWh and 3.2 mill/kWh in 1983 dollars, respectively (Table 2.1). The cost of decommissioning is a small additional cost of plant operation. The applicant's estimate for decommissioning CAL-1 is $59 to $73 million in 1983 dollars (Sec. 2.2).

6.4.2.2 Environmental and Socioeconomic

Changes in plant design, operating procedures, and environmental data that were taken into consideration in this operating-license review have not led to significant increases in the environmental or socioeconomic costs over the corresponding costs that were estimated during the construction-permit review. Most of the costs are significantly less than those estimated in the FES-CP because the latter were for two operating units, and those summarized here are for one unit. The costs considered include those attributable to the uranium fuel cycle and to plant accidents. All costs are small or negligible.

6.4.3 Conclusions

As a result of the analysis and review of potential environmental, technical, economic, and social impacts, the staff has prepared an updated forecast of the effects of operation of CAL-1. No new information has been obtained that alters the overall balancing of the benefits versus the environmental costs of plant operation. Consequently, the staff has determined that the plant will most likely operate with only minimal environmental impact. The staff finds that the primary benefits of minimizing system production costs and increasing baseload generating capacity by 1150 MWe greatly outweigh the environmental, social, and economic costs.

Reference

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7. LIST OF CONTRIBUTORS

The following personnel of the Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, Washington, DC, participated in the preparation of this draft environmental statement:

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R.L. Devine	Aquatic Ecology, Fisheries; M.S. (Life Sciences) 1959; Biology, 30 years.
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B.N. Jaroslow	Terrestrial Ecology, Land Use; Ph.D. (Biology) 1953; Biology, 29 years.
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A.A. Siczek	Nonradioactive Waste Discharges, Water Quality; Ph.D. (Physical Chemistry) 1974; Chemistry Physics, and Chemical Engineering, 15 years.

8. LIST OF AGENCIES AND ORGANIZATIONS REQUESTED TO COMMENT ON THE DRAFT ENVIRONMENTAL STATEMENT

The following Federal, state, and local agencies are asked to comment on this draft environmental statement:

Advisory Council on Historic Preservation
Attorney General, State of Missouri
County Commissioners, Callaway County, Missouri
Department of Agriculture, Forest Service
Department of Agriculture, Soil Conservation Service
Department of the Army, Corps of Engineers
Department of Commerce
Department of Energy
Department of Health and Human Services
Department of Housing and Urban Development
Department of the Interior, Geological Survey
Department of the Interior, Office of Environmental Projects Review
Department of Transportation
Environmental Protection Agency
Federal Emergency Management Agency
Federal Energy Regulatory Commission
Food and Drug Administration
Mid-Missouri Council of Governments
Missouri Department of Natural Resources
Missouri Office of Administration, Division of Budget and Planning
Missouri River Basin Commission
Office of the Governor, State of Missouri

APPENDIX A. RESERVED FOR: RESPONSE TO COMMENTS

ON THE DRAFT ENVIRONMENTAL STATEMENT -

OPERATING LICENSE STAGE

CALLAWAY PLANT UNITS 1 AND 2

APPENDIX B. PERMITS

[National Pollutant Discharge Elimination System (NPDES) Permit]

(From the ER-OL, Rev. 1, App. 5A)

MISSOURI DEPARTMENT OF NATURAL RESOURCES
P.O. Box 1368 2010 Missouri Blvd. Jefferson City, Missouri 65102 (314) 751-3241

File No. 3.500 Callaway County
Callaway Power Plant

NPDES Permit No. MO-0098001

August 8, 1980

Union Electric Company
1901 Gratiot Street
P.O. Box 149
St. Louis, MO 63166

Dear Permittee:

Pursuant to the Federal Water Pollution Control Act, under the authority granted to the State of Missouri and in compliance with the Missouri Clean Water Law, we have issued and are enclosing your National Pollutant Discharge Elimination System (NPDES) Permit to Discharge from your above-referenced facility.

Please READ your Permit carefully: Your NPDES Permit to Discharge includes standard and special conditions which must be followed to remain in compliance with the requirements of the Federal Water Pollution Control Act and the Missouri Clean Water Law.

Monitoring reports required by the special conditons must be submitted on a periodic basis. Copies of the necessary report forms are enclosed. If you have any questions concerning these reports, please do not hesitate to call this office or our regional office in your area.

This NPDES Permit is both your Federal discharge permit and your new State operating permit and replaces all previous State operating permits for this facility. In all future correspondence regarding this facility, please refer to your NPDES Permit number, the facility name, and the file number listed at the top of this page.

I am sure that you appreciate the importance of eliminating pollution from our Nation's waters and will abide by the terms and conditions of the NPDES Permit. If you have any questions concerning this permit, please do not hesitate to call this office or our Regional Office at P.O. Box 1368, Jefferson City, MO 65101, phone: (314) 751-2729.

Yours truly,

Robert H. Hentges
Chief of Permit Section
Water Quality Program

RHH/gt

Enclosure

CC: EPA - Permit Branch
Billing Dept. - Permit Branch
Jefferson City Regional Office

Joseph P. Teasdale Governor
Fred A. Lafser Director

Division of Environmental Quality
James P. Odendahl Director

MISSOURI DEPARTMENT OF
NATURAL RESOURCES

Permit No. MO-0098001
Applicant No. MO-0098001

MISSOURI CLEAN WATER COMMISSION
AUTHORIZATION TO DISCHARGE UNDER THE
NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

In compliance with the Federal Water Pollution Control Act, Public Law 92-500, 92nd Congress, (Hereinafter, the Act) as amended, and the Missouri Clean Water Law, (Chapter 204 R.S. Mo. Cum. Supp. 1973, hereinafter, the Law),

Owner: Union Electric Company

Owner's Address: 1901 Gratiot Street, P.O. Box 149, St. Louis, Missouri 63166

Facility Name: Callaway Power Plant

Facility Address: Reform, Missouri 65077

Legal Description: River Mile 115.4, Callaway County

Receiving Stream & Basin: Missouri River - Missouri River Basin

is authorized to discharge from the facility described herein, in accordance with effluent limitations and monitoring requirements as set forth herein.

FACILITY DESCRIPTION

Units one and two of the Callaway Power Plant located in the NE¼, Sec. 14, T46N, R8W, Callaway County, Missouri. The wastewater effluents will enter the Missouri River at River Mile 115.4. The maximum daily combined flow from the following outfalls will be 15,802,273 gal per day.

#001 - Radwaste treatment system (.028473 mgd) - leakage from coolant system, steam generator leakage, wastes from the laundry of clothing worn in contaminated areas, hot shower drains, floor drains in the containment, auxiliary and Radwaste buildings, and generator blowdown are processed in the liquid radwaste treatment system prior to re-use or discharge. The treatment system has strainers, filters, heat exchangers, carbon filtration, demineralization, waste evaporation to separate water from impurities, reverse osmosis, and waste monitor tanks. All processing in the Liquid Radwaste Processing System is done on a batch basis. After monitoring for radioactive content, release rates are controlled administratively to insure the "as low as practicable" radioactive discharge criteria are met. (continued on page 2)

This permit shall become effective on August 8, 1980, unless appealed in accordance with Section 204.051.6 of the Law.

This permit and authorization to discharge shall expire at midnight, August 7, 1985.

Dated this 8th day of August, 1980.

Fred A. Lafser, Director
Department of Natural Resources
Permit Administrator for Missouri Clean Water Commission

FACILITY DESCRIPTION (continued)

#002 - Cooling tower blowdown (13.4[illegible]1 mgd)

#003 - Water treatment plant sludge (.4608 mgd)

#004 - Demineralizer system wastes (.26[illegible] mgd)

#005 - Oil separator discharge (.144 mgd)

#006 - Circulating and Service Water Pumphouses oil separator and neutralization sump (0.144 mgd)

#007 - Two 20,000 gpd Clow Aer-O-Flow Model [illegible]-20[illegible]-55-5 extended aeration treatment units preceded by a [illegible]5,000 gallon aerated surge tank. (.034[illegible] mgd)

#008 - Chemical Water Treatment Unit (.004 mgd)

#009 - Intake structure sump (.2[illegible] mgd)

A. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

The permittee is authorized to discharge from outfall(s) with serial number(s) as specified in the application for this permit. The effluent limitations shall become effective on the dates specified herein. Such discharges shall be controlled, limited, and monitored by the permittee as specified below:

	EFFLUENT LIMITATIONS			MONITORING REQUIREMENTS	
	Interim Limitations	Interim Limitations	Final Limitations		
Effective Date			Issuance		
Outfall Number and Effluent Parameter(s)			mg/l (lbs/day)	Measurement Frequency	Sample Type
Outfall #001 - Radwaste System					
Flow-m^3/Day (MGD)			***	when discharge occurs	24 hr. total
Total Suspended Solids					
*Monthly Average			30 (7.1)	when discharge occurs	grab
**Daily Maximum			45(10.7)	when discharge occurs	grab
Oil and Grease					
*Monthly Average			15 (3.6)	when discharge occurs	grab
**Daily Maximum			20 (4.7)	when discharge occurs	grab
pH - Units (Not to be averaged)			6.0 - 9.0	when discharge occurs	grab
Outfall #002 - Cooling Tower Blowdown					
Flow-m^3/Day (MGD)			***	continuous	24 hr. recorder
Total Suspended Solids			***	once/week	grab
Total Dissolved Solids			***	once/week	grab
Oil and Grease					
*Monthly Average			15 (168.)	once/week	grab
**Daily Maximum			20 (2247)	once/week	grab
Dissolved Copper					
*Monthly Average			1.0 (112)	once/month	grab
**Daily Maximum			1.5 (169)	once/month	grab
Dissolved Nickel					
*Monthly Average			1.0 (112)	once/month	grab
**Daily Maximum			1.5 (169)	once/month	grab
Free Available Chlorine					
*Monthly Average			0.2 (22)	once/week	grab
*Daily Maximum			0.5 (56)	once/week	grab
Temperature - $^{\circ}F(^{\circ}C)$			$95^{\circ}F(35^{\circ}C)$	continuous	24 hr. recorder

A. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

The permittee is authorized to discharge from outfall(s) with serial number(s) as specified in the application for this permit. The effluent limitations shall become effective on the dates specified herein. Such discharges shall be controlled, limited, and monitored by the permittee as specified below:

	EFFLUENT LIMITATIONS			MONITORING REQUIREMENTS	
	Interim Limitations	Interim Limitations	Final Limitations		
Effective Date			Issuance		
Outfall Number and Effluent Parameter(s)			mg/l (lbs/day)	Measurement Frequency	Sample Type
Outfall #002 - continued					
pH - Units (Not to be averaged)			6.0 - 9.0	continuous	24 hour recorder
Outfall #003 - Water Treatment Plant					
Flow-m^3/Day (MGD)			***	once/week	instantaneous
Total Suspended Solids					
*Monthly Average			30 (115)	once/month	grab
*Daily Maximum			100 (384)	once/month	grab
Oil & Grease					
*Monthly Average			15 (58)	once/month	grab
**Daily Maximum			20 (77)	once/month	grab
pH - Units (Not to be averaged)			6.0 - 9.0	once/month	grab
Outfall #004 - Demineralizer System					
Flow-m^3/Day (MGD)			***	once/week	instantaneous
Total Suspended Solids					
*Monthly Average			30 (67)	once/month	grab
**Daily Maximum			100 (223)	once/month	grab
Oil & Grease					
*Monthly Average			15 (33)	once/month	grab
**Daily Maximum			20 (45)	once/month	grab

A. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

The permittee is authorized to discharge from outfall(s) with serial number(s) as specified in the application for this permit. The effluent limitations shall become effective on the dates specified herein. Such discharges shall be controlled, limited, and monitored by the permittee as specified below:

	EFFLUENT LIMITATIONS			MONITORING REQUIREMENTS	
	Interim Limitations	Interim Limitations	Final Limitations		
Effective Date			Issuance		
Outfall Number and Effluent Parameter(s)			mg/l (lbs/day)	Measurement Frequency	Sample Type
Outfall #004 - continued)					
pH - Units (Not to be averaged)			6.0 - 9.0	once/month	grab
Outfall #005 - Oil Separator					
Flow-m^3/Day (MGD)			***	once/week	instantaneou
Total Suspended Solids					
*Monthly Average			30 (36)	once/month	grab
**Daily Maximum			100 (120)	once/month	grab
Oil and Grease					
*Monthly Average			15 (18)	once/month	grab
**Daily Maximum			20 (24)	once/month	grab
pH - Units (Not to be averaged)			6.0 - 9.0	once/month	grab
Outfall #006 - Circulating and Service Water					
Flow-m^3/Day (MGD)			***	once/week	instantaneou
Total Suspended Solids					
*Monthly Average			30 (36)	once/month	grab
**Daily Maximum			100 (120)	once/month	grab
Oil and Grease					
*Monthly Average			15 (18)	once/month	grab
**Daily Maximum			20 (24)	once/month	grab
pH - Units (Not to be averaged)			6.0 - 9.0	once/month	grab
Outfall #007 - Sanitary Waste					
Flow-m^3/Day (MGD)			***	once/week	24 hr. total
Biochemical Oxygen Demand$_5$					
*Monthly Average			30 (8.6)	once/month	comp.****
**Daily Maximum			45 (13)	once/month	comp.****
Total Suspended Solids					
*Monthly Average			30 (8.6)	once/month	comp.****
**Daily Maximum			45 (13)	once/month	comp.****
pH - Units (Not to be averaged)			6.0 - 9.0	once/month	grab
Outfall #008 - Chemical Water Treatment Unit					
Flow-m^3/Day (MGD)			***	once/month	instantaneou
Total Suspended Solids					
*Monthly Average			30 (1.0)	once/month	grab
**Daily Maximum			100 (3.3)	once/month	grab

A. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

The permittee is authorized to discharge from outfall(s) with serial number(s) as specified in the application for this permit. The effluent limitations shall become effective on the dates specified herein. Such discharges shall be controlled, limited, and monitored by the permittee as specified below:

	EFFLUENT LIMITATIONS			MONITORING REQUIREMENTS	
	Interim Limitations	Interim Limitations	Final Limitations		
Effective Date			Issuance		
Outfall Number and Effluent Parameter(s)			mg/l (lbs/day)	Measurement Frequency	Sample Type
Outfall #008 - continued					
Oil and Grease					
*Monthly Average			15 (0.5)	once/month	grab
**Daily Maximum			20 (0.67)	once/month	grab
pH - Units (Not to be averaged)			6.0 - 9.0	once/month	grab
Outfall #009 - Intake Structure Sump					
Flow-m^3/Day (MGD)			***	once/week	24 hr. total
Total Suspended Solids					
*Monthly Average			30 (54)	once/week	grab
Daily Maximum			100 (180)	once/week	grab
Oil and Grease					
*Monthly Average			15 (27)	once/week	grab
**Daily Maximum			20 (36)	once/week	grab
pH - Units (Not to be averaged)			6.0 - 9.0	once/week	grab

* Monthly Average: the total mass or concentration of all daily discharges sampled during a calendar month divided by the number of daily discharges sampled or measured during that month.

** Daily Maximum: an effluent limitation that specifies the total mass or average concentration of pollutants that may be discharged in a calendar day.

*** Monitoring requirement only.

**** Composite shall consist of a minimum of 4 grab samples in a 24 hour period with a minimum of 2 hours between each grab sample.

Monitoring reports shall be submitted quarterly ; the first report is due 1/28/81.

There shall be no discharge of floating solids or visible foam in other than trace amounts.

B. STANDARD CONDITIONS

In addition to specified conditions stated herein, this permit is subject to the attached Part I standard conditions dated October 1, 1975, and hereby incorporated as though fully set forth herein.

C. SCHEDULE OF COMPLIANCE Not applicable

D. SPECIAL CONDITIONS

In issuing this permit, the Missouri Clean Water Commission has not determined whether or not the radioactive discharges from this plant will affect waters of the state. Radioactive discharges are the responsibility of the Nuclear Regulatory Commission, and any discharges of these constituents will be under the NRC's regulation.

E. OTHER REQUIREMENTS

1. Discharge Limitations - There shall be no discharge of polychlorinated biphenyl compounds.

2. Intake Structure(s)

Within 90 days of the receipt of the permit the permittee shall submit to the Department for review, modification and approval the design for an intake monitoring program to document the effects of the plant intake structures on the various species and life stages of fish. Sampling shall be performed weekly (unless the permittee justifies an alternative schedule to the satisfaction of the Department) on random days and shall include the number, size, weight and species of fish trapped by the present intake structure. An assessment shall also be made of other nekton which may be entrained in the water used for cooling. The sampling program must be conducted in a manner to evaluate diel and seasonal fluctuations. The program shall also include stream flow, cooling water flow, source and discharge water temperature and screen operation schedule.

The monitoring program shall be implemented within 90 days after approval of the monitoring program. Monthly monitoring reports shall be submitted.

Within 18 months after plan approval the permittee shall submit a final report to the Department. Development of the report shall be guided by the "Development Document for Best Technology Available for minimizing Adverse Environmental Impact of Cooling Water Intake Structures" as proposed by EPA.

This report shall be evaluated with regard to Section 316(b) of the Act. As a result of this evaluation, the Department may modify the permit to establish an implementation schedule to ensure compliance with Section 316(b) of the Act.

3. Pesticides

Any pesticide discharge from any point source shall comply with the requirements of the Federal Insecticide, Fungicide, and Rodenticide Act, as amended (7 U.S.C. 136 et. seq.) and the use of such pesticides shall be in a manner consistent with its label.

4. This permit shall be modified, or alternatively, revoked and reissued, to comply with any applicable effluent standard or limitation issued or approved under sections 301(b)(2) (C), and (D), 304(b)(2), and 307(a)(2) of the Clean Water Act, if the effluent standard or limitation so issued or approved:

   1. Contains different conditions or is otherwise more stringent than any effluent limitation in the permit; or

   2. Controls any pollutant not limited in the permit.

   The permit as modified or reissued under this paragraph shall also contain any other requirements of the Act then applicable.

5. The permittee shall conduct the following radiological monitoring:

   a. Liquid Radwaste discharge, surface water and drinking water supply:

Location		Frequency	Sample Type
I	Radwaste building discharge	daily	continuous
II	Drinking water supply, Portland, Mo.	once/month	grab
III	Upstream of discharge line	once/month	grab
IV	Downstream of discharge line	once/month	grab
V	Western border of St. Louis County	once/month	grab

   Samples are to be analyzed for gross alpha, gross beta and tritium and gamma - scanned for significant radionuclitides.

   b. Groundwater - monthly sampling of the groundwater from all test wells established for NRC permit requirements, or any other test wells established by Union Electric for monitoring groundwater in the area. At a minimum these shall include the three test wells identified in Figure 6.1-14 of the Environmental Report Volume 1 Callaway Plant Units 1 and 2 dated 30 May, 1974.

   Grab samples are to be analyzed for gross alpha, gross beta, and tritium and gamma - scanned for significant radionuclitides.

   c. Aquatic biota - monthly sampling of the edible flesh of the five most important/abundant species of fish. Samples shall be taken from at least the locations specified in III, IV, and V of 5.a. (listed above), Other Requirements. Samples are to be analyzed for gross alpha and gross beta and gamma - scanned for significant radionuclitides.

   d. Bottom Sediment - monthly samples of bottom sediment from at least the locations specified in III, IV, and V of 5.a., Other Requirements. Samples are to be analyzed for gross alpha, gross beta, Strontium 90 and Cesium 137. Also, gamma spectroscopy is to be performed on these samples.

   e. All radionuclitide monitoring data performed as required above shall be reported in the Discharge Monitoring Report (DMRs) submitted quarterly. The data collected shall be available for inspection during normal working hours. The submission shall include the exact time and location of sample collections, as well as, any other reporting requirements listed in the Standard Conditions attached to this permit.

APPENDIX C. EXAMPLES OF SITE-SPECIFIC DOSE-ASSESSMENT CALCULATIONS

C.1 CALCULATIONAL APPROACH

As mentioned in the text, the quantities of radioactive material that may be released annually from CAL-1 are estimated on the basis of the description of the radwaste systems in the applicant's ER and FSAR and by using the calculational model and parameters described in NUREG-0017 (Ref. 1). These estimated effluent-release values, along with the applicant's site and environmental data in the ER and in subsequent answers to staff questions, are used in the calculation of radiation doses and dose commitments.

The models and considerations for environmental pathways that lead to estimates of radiation doses and dose commitments to individual members of the public near the plant, and of cumulative doses and dose commitments to the entire population within an 80-km (50-mi) radius of the plant as a result of plant operation, are discussed in detail in Regulatory Guide 1.109 (Ref. 2). Use of these models with additional assumptions for environmental pathways that lead to exposure to the general population outside the 80-km radius are described in Appendix D of this environmental statement.

The calculations performed by the staff for the potentially contaminated atmosphere and hydrosphere provide total integrated-dose commitments to the entire population within 80 km (50 mi) of the plant based on the projected population distribution in the year 2000. The dose commitments represent the total dose that would be received over a 50-year period following the intake of radioactivity for one year under the conditions existing 15 years after the plant begins operation (i.e. the midpoint of plant operation). For younger persons, changes in organ mass and metabolic parameters with age after the initial intake of radioactivity are accounted for.

C.2 DOSE COMMITMENTS FROM RADIOACTIVE-EFFLUENT RELEASES

Radioactive effluents released to the atmosphere and to the hydrosphere from CAL-1 will result in very small radiation-dose commitments to individual members of the public and to the general population. Staff estimates of expected gaseous and particulate releases (Table C.1) and expected liquid releases (Table C.2), along with site meteorological and hydrological considerations (Tables C.3 and C.4, respectively), were used to estimate radiation doses and dose commitments.

Annual average relative-concentration (χ/Q) and relative-deposition (D/Q) values were calculated using the straight-line Gaussian model described in Regulatory Guide 1.111 (Ref. 3). A composite three-year period of record (from 4 May 1973 to 3 May 1975 and from 16 March 1978 to 15 March 1979) of meteorological data collected at the site was used. Wind-speed and -direction data were based on measurements at the 10-m level and atmospheric stability was defined by the vertical temperature gradient measured between the 10-m and

60-m levels. All releases through the unit vent were considered to be mixed mode (i.e. partially elevated and partially ground level). All other releases were considered to be ground level with mixing within the turbulent wake of the plant structures. The results of the straight-line model were not adjusted to consider spatial and temporal variations in airflow, because a comparison of the results of a variable-trajectory model with the results of the straight-line model, performed by the applicant, indicated good agreement between the models.

C.2.1 Radiation-Dose Commitments to Individual Members of the Public

As explained in the text, calculations are made for a hypothetical individual member of the public (i.e. the maximally exposed individual) who would be expected to receive the highest radiation dose from all appropriate pathways. This method tends to overestimate the doses because assumptions are made that would be difficult for a real individual to fulfill.

Individual receptor locations and pathway locations considered for the maximally exposed individual are listed in Table C.5. The estimated dose commitments to the individual who is subject to maximum exposure at selected offsite locations from airborne releases of radioiodine and particulates, and from waterborne releases, are listed in Tables C.6, C.7, and C.8, as are the maximum annual gamma and beta air doses and the maximum total-body and skin doses to an individual at the site boundary.

The maximally exposed individual is assumed to consume well-above-average quantities of the potentially affected foods and to spend more time at potentially affected locations than the average person, as indicated in Tables E-4 and E-5 of Regulatory Guide 1.109 (Ref. 2).

C.2.2 Cumulative Dose Commitments to the General Population

Annual radiation-dose commitments from airborne and waterborne radioactive releases from CAL-1 are estimated for two populations in the year 2000: (1) all members of the general public within 80 km (50 mi) of the plant (Table C.7) and (2) the entire U.S. population (Table C.9). Dose commitments beyond 80 km are based on the assumptions discussed in Appendix D. For perspective, annual background-radiation doses are given in the tables for both populations.

References

1. "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents from Pressurized Water Reactors (PWR-GALE Code)." NUREG-0017, U.S. Nuclear Regulatory Commission, April 1976.

2. "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I." Reg. Guide 1.109, Rev. 1, U.S. Nuclear Regulatory Commission, October 1977.

3. "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Reactors." Regulatory Guide 1.111, Rev. 1, U.S. Nuclear Regulatory Commission, July 1977.

Table C.1. Calculated Releases of Radioactive Materials in Gaseous Effluents from CAL-1 (Ci/yr)

Nuclide	Gas Stripping		Building Ventilation - Continuous			Air-Ejector Exhaust	
	Periodic	Continuous	Reactor	Auxiliary	Turbine	Continuous	Total
Kr-83m	a	a	3	a	a	a	3
Kr-85m	a	a	29	2	a	2	33
Kr-85	4	250	5	a	a	a	260
Kr-87	a	a	7	1	a	a	8
Kr-88	a	a	40	5	a	3	48
Kr-89	a	a	a	a	a	a	a
Xe-131m	a	3	13	a	a	a	16
Xe-133m	a	a	63	2	a	1	66
Xe-133	a	1	3300	110	a	70	3500
Xe-135m	a	a	a	a	a	a	a
Xe-135	a	a	120	7	a	4	130
Xe-137	a	a	a	a	a	a	a
Xe-138	a	a	1	1	a	a	2
Total, noble gases							4100
Mn-54	b	b	0.0002	0.018	b	b	0.018
Fe-59	b	b	0.00008	0.006	b	b	0.006
Co-58	b	b	0.0008	0.060	b	b	0.060
Co-60	b	b	0.0003	0.027	b	b	0.027
Sr-89	b	b	0.00002	0.0013	b	b	0.0013
Sr-90	b	b	b	0.00024	b	b	0.00024
Cs-134	b	b	0.00022	0.018	b	b	0.018
Cs-137	b	b	0.00038	0.030	b	b	0.030
Total, particulates							0.16
I-131	c	c	0.054	0.014	b	0.008	0.077
I-133	c	c	0.060	0.020	b	0.012	0.092
C-14	a	a	a	a	a	8	8
H-3	-	-	-	-	-	-	1000

a Less than 1 Ci/yr for noble gases and carbon-14.

b Less than 1% of total for nuclide.

c Less than 0.0001 Ci/yr.

Table C.2. Calculated Releases of Radioactive Materials in Liquid Effluents from CAL-1

Nuclide	Ci/yr
Corrosion and Activation Products	
Cr-51	0.00016
Mn-54	0.00014
Fe-55	0.00018
Fe-59	0.0001
Co-58	0.002
Co-60	0.0011
Zr-95	0.00014
Nb-95	0.0002
Np-239	0.00002
Fission Products	
Br-83	0.00001
Rb-86	0.00008
Sr-89	0.00004
Mo-99	0.0017
Tc-99m	0.0016
Ru-103	0.00002
Ru-106	0.00024
Ag-110m	0.00004
Te-127m	0.00003
Te-127	0.00003
Te-129m	0.00012
Te-129	0.00008
I-130	0.00005
Te-131m	0.00002
I-131	0.04
Te-132	0.0006
I-132	0.001
I-133	0.014
Cs-134	0.038
I-135	0.0024
Cs-136	0.011
Cs-137	0.029
Ba-137m	0.025
Ba-140	0.00001
La-140	0.00002
Ce-144	0.00052
All others[a]	0.00005
Total, except tritium	0.17
Tritium	390

a Nuclides with release rates less than 10 μCi/yr are not individually listed, but are included in this category.

Table C.3. Summary of Atmospheric Dispersion Factors (χ/Q) and Relative Deposition Values for Maximum Site Boundary and Receptor Locations near CAL-1

Location	Source[a]	χ/Q (s/m^3)	Relative Deposition (m^{-2})
Site boundary/nearest[b] residence (N, 1.4 km)	A	2.1×10^{-7}	2.6×10^{-9}
	B	1.4×10^{-6}	8.3×10^{-9}
Nearest milk goat/residence/garden/meat animal (NW, 2.6 km)	A	1.3×10^{-7}	8.0×10^{-10}
	B	6.8×10^{-7}	2.8×10^{-9}

a A: plant vent stack at top of containment.
B: turbine and radwaste buildings.

b "Nearest" refers to that type of location where the highest radiation dose is expected to occur from all appropriate pathways.

Table C.4. Summary of Hydrologic Transport and Dispersion for Liquid Releases from CAL-1

Location	Transit Time (hours)	Dilution Factor
ALARA Calculations		
Fish ingestion	0	100
Drinking water	~ 16	> 1000
Shoreline exposure	0	100
Population-Dose Calculations[a]		
Commercial fishing (Missouri River)	8	1800
Sport fishing	8	1800

a From the ER-OL.

Table C.5. Nearest Pathway Locations Used for Dose Commitments to a Maximally Exposed Individual near CAL-1

Location	Sector	Distance (km)
Site boundary/residence[a]	N	1.4
Milk goat/residence/garden/meat animal[b]	NW	2.6

a Beta and gamma air doses and total-body and skin doses from noble gases are determined at site boundaries.

b Dose pathways, including inhalation of atmospheric radioactivity, exposure to deposited radionuclides, and submersion in gaseous radioactivity, are evaluated at residences.

Table C.6. Annual Dose Commitments to a Maximally Exposed Individual near CAL-1

Location	Pathway	Dose (millirems per year per unit) Total Body	Skin	Organ	Air Dose (millirads per year per unit) Gamma	Beta
Noble Gases in Gaseous Effluents						
Nearest[a] site boundary/ residence (N, 1.4 km)	Direct radiation from plume	0.02	0.03		0.02	0.04
Iodine and Particulates in Gaseous Effluents[b]						
Nearest[c] milk goat/ residence/garden/ meat animal (NW, 2.6 km)	Ground deposit	0.03 (I)		0.03 (I) (thyroid & bone)		
	Inhalation	< 0.01 (T)		0.01 (C) (thyroid)		
	Vegetable consumption	0.05 (C)		0.06 (T) (bone)		
	Goat-milk consumption	0.06 (I)		1.1 (I) (thyroid)		
Liquid Effluents (adults)						
Nearest drinking water (> 80 km downstream)	Water ingestion	< 0.01		0.01 (thyroid)		
Nearest fishing (~ 0.1 km downstream)	Fish ingestion	0.29		0.40 (liver)		
Nearest shore access (~ 0.1 km downstream)	Shoreline exposure	< 0.01	< 0.01			

a "Nearest" refers to the site-boundary location where the highest radiation doses due to gaseous effluents have been estimated to occur.

b Doses are for the age group that results in the highest dose: (T) = teen, (C) = child, (I) = infant.

c "Nearest" refers to the location where the highest radiation dose to an individual from all applicable pathways has been estimated.

Table C.7. Calculated Appendix I Dose Commitments to a Maximally Exposed Individual and to the Population from Operation of CAL-1

Maximally Exposed Individual

		Appendix I Design Objectives[a]	Calculated Doses
		Annual Dose per Reactor Unit	
Liquid effluents			
Dose to total body from all pathways	(millirems)	3	0.3
Dose to any organ from all pathways	(millirems)	10	0.4 (liver)
Noble-gas effluents (at site boundary)			
Dose in air			
Gamma	(millirads)	10	0.02
Beta	(millirads)	20	0.04
Dose to an individual			
Total body	(millirems)	5	0.02
Skin	(millirems)	15	0.03
Radioiodines and particulates[b]			
Dose to any organ from all pathways	(millirems)	15	1.1 (thyroid, infant)

Population Within 80 km

	Total Body	Thyroid
	Annual Dose per Reactor Unit (person-rems)	
Natural-background radiation[c]	47,000	-
Liquid effluents	0.4	0.05
Noble-gas effluents	0.05	0.05
Radioiodine and particulates	0.58	1.3

a Design objectives from Sections II.A, II.B, II.C, and II.D of Appendix I, 10 CFR Part 50 consider doses to maximum individual and population per reactor unit.

b Carbon-14 and tritium have been added to this category.

c "Natural Radiation Exposure in the United States," U.S. Environmental Protection Agency, ORP-SID-72-1, June 1972; using the average background dose for Missouri of about 100 millirems per year, and year-2000 projected population of 466,000.

Table C.8. Calculated RM-50-2 Dose Commitments to a Maximally Exposed Individual from Operation of CAL-1[a]

Maximally Exposed Individual		Annual Dose per Site	
		RM-50-2 Design Objectives[b]	Calculated Doses
Liquid effluents			
Dose to total body or any organ from all pathways	(millirems)	5	0.4
Activity-release estimate, excluding tritium	(Ci/yr)	10	0.2
Noble-gas effluents (at site boundary)			
Dose in air			
Gamma	(millirads)	10	0.02
Beta	(millirads)	20	0.04
Dose to total body of an individual	(millirems)	5	0.02
Radioiodine and particulates[c]			
Dose to any organ from all pathways	(millirems)	15	1.1 (thyroid)
I-131 activity release	(Ci/yr)	1	0.08

a An optional method of demonstrating compliance with the benefit-cost section (Sec. II.D) of Appendix I to 10 CFR Part 50.

b Annex to Appendix I to 10 CFR Part 50.

c Carbon-14 and tritium have been added to this category.

Table C.9. Annual Total-Body Population-Dose Commitments in the Year 2000

Category	U.S. Population-Dose Commitment (person-rems per year)
Natural-background radiation[a]	25 000,000
CAL-1 operation	
Plant workers	440
General public	
Radioiodine and particulates	0.6
Liquid effluents[b]	0.4
Noble-gas effluents	38
Transportation of fuel and waste	7

a Using the average U.S. background dose (100 millirems per year) and year-2000 projected U.S. population from "Population Estimates and Projections," Series II, U.S. Department of Commerce, Bureau of the Census, Series P-25, No. 541, February 1975.

b 80-km (50-mi) population dose.

APPENDIX D. NEPA POPULATION-DOSE ASSESSMENT

Population-dose commitments are calculated for all individuals living within 80 km (50 mi) of CAL-1, employing the same models used for individual doses--as in Regulatory Guide 1.109, Rev. 1 (Ref. 1)--for the purpose of meeting the "as low as reasonably achievable" (ALARA) requirements of 10 CFR Part 50, Appendix I (Ref. 2). In addition, dose commitments to the population residing beyond 80 km, associated with the export of food crops produced within the 80-km region and with the atmospheric and hydrospheric transport of the more mobile effluent species, such as noble gases, tritium, and carbon-14, are taken into consideration for the purpose of meeting the requirements of the National Environmental Policy Act of 1969 (NEPA). This appendix describes the methods used to make these NEPA population-dose estimates.

D.1 IODINES AND PARTICULATES RELEASED TO THE ATMOSPHERE

Effluent nuclides in this category deposit onto the ground as the effluent moves downwind; thus, the concentration of these nuclides remaining in the plume is continuously being reduced. Within 80 km (50 mi) of the plant, the deposition model in Regulatory Guide 1.111, Rev. 1 (Ref. 3) is used in conjunction with the dose models in Regulatory Guide 1.109, Rev. 1 (Ref. 1). Site-specific data concerning production and consumption of foods within 80 km of the plant are used. For estimates of population doses beyond 80 km it is assumed that excess food not consumed within the 80-km distance would be consumed by the population beyond 80 km. It is further assumed that none, or very few, of the particulates released from the plant will be transported beyond the 80-km distance; thus, they will make no contribution to the population dose outside the 80-km region.

D.2 NOBLE GASES, CARBON-14, AND TRITIUM RELEASED TO THE ATMOSPHERE

For locations within 80 km (50 mi) of CAL-1, exposures to these effluents are calculated with a constant mean wind-direction model according to the guidance provided in Regulatory Guide 1.111, Rev. 1 (Ref. 3), and the dose models described in Regulatory Guide 1.109, Rev. 1 (Ref. 1). For estimating the dose commitment from these radionuclides to the U.S. population residing beyond 80 km, two dispersion regimes are considered, which are referred to as first-pass dispersion and world-wide dispersion. The model for the first-pass-dispersion regime estimates the dose commitment to the population from the radioactive plume as it leaves the plant and drifts to the northeastern corner of the United States. The model for the world-wide-dispersion regime estimates the dose commitment to the U.S. population after the released radionuclides mix uniformly in the world's atmosphere or oceans.

D.2.1 First-Pass Dispersion

For estimating the dose commitment to the U.S. population residing beyond 80 km (50 mi) due to the first pass of radioactive pollutants, it is assumed that the pollutants disperse laterally and vertically along the plume path. The direction of movement of the plume is assumed to be from the plant toward the northeastern corner of the United States. The extent of vertical dispersion is assumed to be limited by the ground plane and the stable atmospheric layer aloft, the height of which determines the mixing depth. The shape of such a plume geometry can be visualized as a right-cylindrical wedge whose height is equal to the mixing depth. Under the assumption of constant population density, the population dose associated with such a plume geometry is independent of the extent of lateral dispersion, and dependent only on the mixing depth and other related nongeometrical factors (Ref. 4). The mixing depth is estimated to be 1000 m (3300 ft); a uniform population density of 62 people/km^2 (24 people/mi^2) along the plume path and an average plume-transport velocity of 2 m/s (4.5 mph) are assumed.

The total-body population-dose commitment from the first pass of radioactive effluents is due principally to external exposure from gamma-emitting noble gases, and to internal exposure from inhalation of air containing tritium and ingestion of food containing carbon-14 and tritium.

D.2.2 World-Wide Dispersion

For estimating the dose commitment to the U.S. population after the first pass, world-wide dispersion is assumed. Nondepositing radionuclides with half-lives greater than one year are considered. Noble gases and carbon-14 are assumed to mix uniformly in the atmosphere (3.8×10^{18} m^3), and radioactive decay is taken into consideration. The world-wide-dispersion model estimates the activity of each nuclide at the end of a 15-year release period (midpoint of reactor life) and estimates the annual population-dose commitment at that time, taking into consideration radioactive decay. The total-body population-dose commitment from the noble gases is due mainly to external exposure from gamma-emitting nuclides, whereas from carbon-14 it is due mainly to internal exposure from ingestion of food containing carbon-14.

The population-dose commitment due to tritium releases is estimated in a manner similar to that for carbon-14 except that, after the first pass, all the tritium is assumed to be absorbed by the world's oceans (2.7×10^{16} m^3). The concentration of tritium in the oceans is estimated at the time after which releases have occurred for 15 years, taking into consideration radioactive decay; the population-dose-commitment estimates are based on the incremental concentration at that time. The total-body population-dose commitment from tritium is due mainly to internal exposure from the consumption of food grown with irrigation water.

D.3 LIQUID EFFLUENTS

Population-dose commitments due to effluents in the receiving water within 80 km (50 mi) of the plant are calculated as described in Regulatory Guide 1.109 (Ref. 1). It is assumed that no depletion by sedimentation of the nuclides present in the receiving water occurs within 80 km. It is also assumed that aquatic biota concentrate radioactivity in the same manner as was assumed in the ALARA evaluation for the maximally exposed individual. However, food-consumption values appropriate for the average, rather than the maximum, individual are used. It is further assumed that all the sport and commercial fish and shellfish caught within 80 km are eaten by the U.S. population.

For the region beyond 80 km, it is assumed that all the liquid-effluent nuclides except tritium have deposited on the sediments so that they make no further contribution to population exposures. The tritium is assumed to mix uniformly in the hydrosphere and to result in an exposure to the U.S. population in the same manner as discussed for tritium in gaseous effluents.

References

1. "Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I." Reg. Guide 1.109, Rev. 1, U.S. Nuclear Regulatory Commission, October 1977.

2. "Domestic Licensing of Production and Utilization Facilities." Title 10 Code of Federal Regulations, Part 50, January 1981.

3. "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Reactors." Regulatory Guide 1.111, Rev. 1, U.S. Nuclear Regulatory Commission, July 1977.

4. K.F. Eckerman et al. "Users Guide to GASPAR Code." NUREG-0597, U.S. Nuclear Regulatory Commission, June 1980.

APPENDIX E. REBASELINING OF THE RSS RESULTS FOR PWRs

The results of the Reactor Safety Study (RSS) have been updated. The update was done largely to incorporate results of research and development conducted after the October 1975 publication of the RSS and to provide a baseline against which the risk associated with various LWRs could be consistently compared.

Primarily, the rebaselined RSS results reflect use of advanced modeling of the processes involved in meltdown accidents, i.e., the MARCH computer code modeling for transient and LOCA initiated sequences and the CORRAL code used for calculating magnitudes of release accompanying various accident sequences. These codes* have led to a capability to predict the transient and small LOCA initiated sequences that is considerably advanced beyond what existed at the time the RSS was completed. The advanced accident process models (MARCH and CORRAL) produced some changes in our estimates of the release magnitudes from various accident sequences in WASH-1400. These changes primarily involved release magnitudes for the iodine, cesium, and tellurium families of isotopes. In general, a decrease in the iodines was predicted for many of the dominant accident sequences while some increases in the release magnitudes for the cesium and tellurium isotopes were predicted.

Entailed in this rebaselining effort was the evaluation of individual dominant accident sequences as we understand them to evolve rather than the technique of grouping large numbers of accident sequences into encompassing, but synthetic, release categories as was done in WASH-1400. The rebaselining of the RSS also eliminated the "smoothing technique" that was criticized in the report by the Risk Assessment Review Group (sometimes known as the Lewis Report, NUREG/CR-0400).

In both of the RSS designs (PWR and BWR), the likelihood of an accident sequence leading to the occurrence of a steam explosion (α) in the reactor vessel was decreased. (A key to accident-sequence symbols is given in Table E.1.) This was done to reflect both experimental and calculational indications that such explosions are unlikely to occur in those sequences involving small size LOCAs and transients because of the high pressures and temperatures expected to exist within the reactor coolant system during these scenarios. Furthermore, if such an explosion were to occur, there are indications that it would be unlikely to produce as much energy and the massive missile-caused breach of containment as was postulated in WASH-1400.

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*It should be noted that the MARCH code was used on a number of scenarios in connection with the TMI-2 recovery efforts and for post-TMI-2 investigations to explore possible alternative scenarios that TMI-2 could have experienced.

Table E.1. Key to PWR Accident-Sequence Symbols

Symbol	Definition
A	Intermediate to large LOCA.
B	Failure of electric power to ESFs.
B'	Failure to recover either onsite or offsite electric power within about one to three hours following an initiating transient that is a loss of offsite AC power.
C	Failure of the containment spray injection system.
D	Failure of the emergency core cooling injection system.
F	Failure of the containment spray recirculation system.
G	Failure of the containment heat removal system.
H	Failure of the emergency core cooling recirculation system.
K	Failure of the reactor protection system.
L	Failure of the secondary system steam relief valves and the auxiliary feedwater system.
M	Failure of the secondary system steam relief valves and the power conversion system.
Q	Failure of the primary system safety relief valves to reclose after opening.
R	Massive rupture of the reactor vessel.
S_1	A small LOCA with an equivalent diameter of about 5 to 15 cm (2 to 6 in).
S_2	A small LOCA with an equivalent diameter of about 1.3 to 5 cm (0.5 to 2 in).
T	Transient event.
V	LPIS check valve failure.
α	Containment rupture due to a reactor vessel steam explosion.
β	Containment failure resulting from inadequate isolation of containment openings and penetrations.
γ	Containment failure due to hydrogen burning.
δ	Containment failure due to overpressure.
ε	Containment vessel melt-through.

For rebaselining of the RSS-PWR design, the release magnitudes for the risk dominating sequences, e.g., Event V, TMLB' δ, γ, and S_2C-δ (described later) were explicitly calculated and used in the consequence modeling rather than being lumped into release categories as was done in WASH-1400. The rebaselining led to a small decrease in the predicted risk to an individual of early fatality or latent cancer fatality relative to the original RSS-PWR predictions. This result is believed to be largely attributable to the decreased likelihood of occurrence for sequences involving severe steam explosions (α) that breached containment. In WASH-1400, the sequences involving severe steam explosions (α) were artificially elevated in their risk significance (i.e., made more likely) by use of the "smoothing technique."

In summary, the rebaselining of the RSS results led to small overall differences from the predictions in WASH-1400. It should be recognized that these small differences due to the rebaselining efforts are likely to be far outweighed by the uncertainties associated with such analyses.

The accident sequences which are expected to dominate risk from the RSS-PWR design are described below. These sequences are assumed to represent the approximate accident risks from the Callaway PWR design. Accident sequences are designated by strings of identification characters in the same manner as in the RSS. Each of the characters represents a failure in one or more of the important plant systems or features that ultimately would result in melting of the reactor core and a significant release of radioactive materials from containment.*

Event V (Interfacing System LOCA)

During the RSS a potentially large risk contributor was identified due to the configuration of the multiple check valve barriers used to separate the high pressure reactor coolant system from the low design pressure portions of the ECCS (i.e., the low pressure injection subsystem - LPIS). If these valve barriers were to fail in various modes, such as leak-rupture or rupture-rupture, and suddenly exposed the LPIS to high overpressures and dynamic loadings, the RSS judged that a high probability of LPIS rupture would exist. Since the LPIS is largely located outside of containment, the Event V scenario would be a LOCA that bypassed containment and those mitigating features (e.g., sprays) within containment. The RSS assumed that if the rupture of LPIS did not entirely fail the LPIS makeup function (which would ultimately be needed to prevent core damage), the LOCA environment (flooding, steam) would. Predictions of the release magnitude and consequences associated with Event V have indicated that this scenario represents one of the largest risk contributors from the RSS-PWR design. The NRC has recognized this RSS finding, and has taken steps to reduce the probability of occurrence of Event V scenarios in both existing and future LWR designs by requiring periodic surveillance testing of the interfacing valves to assure that these valves are properly functioning as pressure boundary isolation barriers during plant operations. Accordingly, Event V predictions for the RSS-PWR are likely to be conservative relative to the design and operation of the Callaway PWR.

*For additional information detail see Appendix V of "Reactor Safety Study," WASH-1400, NUREG-75/014, October 1975.

TMLB'-δ, γ

This sequence essentially considers the loss and nonrestoration of all AC power sources available to the plant along with an independent failure of the steam turbine driven auxiliary feedwater train which would be required to operate to remove shutdown heat from the reactor core. The transient event is initiated by loss of offsite AC power sources which would result in plant trip (scram) and the loss of the normal way that the plant removes heat from the reactor core (i.e., via the power conversion system consisting of the turbine, condenser, the condenser cooling system, and the main feedwater and condensate delivery system that supplies water to the steam generators). This initiating event would then demand operation of the standby onsite emergency AC power supplies (2 diesel generators) and the standby auxiliary feedwater system, two trains of which are electrically driven by either onsite or offsite AC power. With failure and nonrestoration of AC and the failure of the steam turbine driven auxiliary feedwater train to remove shutdown heat, the core would ultimately uncover and melt. If restoration of AC was not successful during (or following) melt, the containment heat removal and fission product mitigating systems would not be operational to prevent the ultimate overpressure (δ, γ) failure of containment and a rather large, energetic release of activity from the containment. Next to the Event V sequence, TMLB'δ, γ is predicted to dominate the overall accident risks in the RSS-PWR design.

S_2C-δ (PWR 3)

In the RSS the S_2C-δ sequence was placed into PWR release Category 3 and it actually dominated all other sequences in Category 3 in terms of probability and release magnitudes. The rebaselining entailed explicit calculations of the consequences from S_2C-δ and the results indicated that it was next in overall risk importance following Event V and TMLB'δ, γ.

The S_2C-δ sequence included a rather complex series of dependencies and interactions that are believed to be somewhat unique to the containment systems (subatmospheric) employed in the RSS-PWR design.

In essence, the S_2C-δ sequence included a small LOCA occurring in a specific region of the plant (reactor vessel cavity); failure of the recirculating containment heat removal systems (CSRS-F) because of a dependence on water draining to the recirculation sump from the LOCA and a resulting dependence imposed on the quench spray injection system (CSIS-C) to provide water to the sump. The failure of the CSIS(C) resulted in eventual overpressure failure of containment (δ) due to the loss of CSRS(F). Given the overpressure failure of containment the RSS assumed that the ECCS functions would be lost due either to the cavitation of ECCS pumps or from the rather severe mechanical loads that could result from the overpressure failure of containment. The core was then assumed to melt in a breached containment leading to a significant release of radioactive materials.

Approximately 20% of the iodines and 20% of the alkali metals present in the core at the time of release would be released to the atmosphere. Most of the release would occur over a period of about 1.5 hours. The release of radioactive material from containment would be caused by the sweeping action of gases generated by the reaction of the molten fuel with concrete. Since these gases would be initially heated by contact with the melt, the rate of sensible energy release to the atmosphere would be moderately high.

PWR 7

This is the same as the PWR release Category 7 of the original RSS which was made up of several sequences such as S_2D-ε (the dominant contributor to the risk in this category), S_1D-ε, S_2H-ε, S_1H-ε, AD-ε, AH-ε, TML-ε, and TKQ-ε. All of these sequences involved a containment basemat melt-through as the containment failure mode. With exception of TML-ε and TKQ-ε, all involve the potential failure of the emergency core cooling system following occurrence of a LOCA with the containment ESFs continuing to operate as designed until the base mat was penetrated. Containment sprays would operate to reduce the containment temperature and pressure as well as the amount of airborne radioactivity. The containment barrier would retain its integrity until the molten core proceeded to melt through the concrete containment basemat. The radioactive materials would be released into the ground, with some leakage to the atmosphere occurring upward through the ground. Most of the release would occur continuously over a period of about 10 hours. The release would include approximately 0.002% of the iodines and 0.001% of alkali metals present in the core at the time of release. Because leakage from containment to the atmosphere would be low and gases escaping through the ground would be cooled by contact with the soil, the energy release rate would be very low.

·ENDIX F. EVACUATION MODEL

"Evacuation", us· ·n the context of offsite emergency response in the event of a substant· amount of radioactivity released to the atmosphere in a reactor acci· ·, denotes an early and expeditious movement of people to avoid exposure t· ·e passing radioactive cloud and/or to acute ground contamination in the w· ·of the cloud passage. It should be distinguished from "relocation", which denotes a postaccident response to reduce exposure to long-term ground contamination. The "Reactor Safety Study" (RSS) (Ref. 1) consequence model contains provision for incorporating radiological-consequence-reduction benefits of public evacuation. Benefits of a properly planned and expeditiously carried out public evacuation would be well manifested in reduction of acute health effects associated with early exposure; namely, in the number of cases of acute fatality and acute radiation sickness that would require hospitalization. The evacuation model originally used in the RSS consequence model is described in WASH-1400 (Ref. 1) as well as in NUREG-0340 (Ref. 2). However, the evacuation model used herein is a modified version (Ref. 3) of the RSS model and is, to a certain extent, oriented to site emergency planning. The modified version is briefly outlined below:

The model uses a circular area with a specified radius, such as a 16-km (10-mi) plume-exposure-pathway emergency-planning zone (EPZ), with the reactor at the center. It is assumed that people living within portions of this area would evacuate if an accident should occur involving imminent or actual release of significant quantities of radioactivity to the atmosphere.

Significant atmospheric releases of radioactivity would, in general, be preceded by one or more hours of warning time (postulated as the time interval between the awareness of impending core melt and the beginning of the release of radioactivity from the containment building). For the purpose of calculation of radiological exposure, the model assumes that all people who live in a fan-shaped area (fanning out downwind from the reactor) within the circular zone--who would potentially be under the radioactive cloud that would develop following the release--would leave their residences after lapse of a specified delay time* and then evacuate. The delay time is reckoned from the beginning of the warning time and is the sum of the times required by the reactor operators to notify responsible authorities; by the authorities to interpret the data, decide to evacuate, and direct the people to evacuate; and by the people to mobilize and get underway.

The model assumes that each evacuee would move radially downwind with an average effective speed* (obtained by dividing the zone radius by the average time taken to clear the zone after the delay time) over a fixed distance* from the evacuee's starting point. This distance is selected to be 24 km (15 mi),

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*Assumed to be a constant value, which would be the same for all evacuees.

8 km (5 mi) more than the 16-km (10-mi) plume-exposure-pathway EPZ radius. After reaching the end of the travel distance the evacuee is assumed to receive no further radiation exposure. (An important assumption incorporated in the RSS consequence model is that if the calculated ground dose to the total marrow over a 7-day period were to exceed 200 rems in the regions beyond the evacuation zone, then this high dose rate would be detected by actual field measurements following the accident, and people from those regions would be relocated immediately. Therefore, the model limits the period for ground-dose calculation to only 24 hours for those regions. When no evacuation at all is assumed, this manner of ground-dose calculation applies to all regions, beginning at the reactor location. CRAC code implements this feature irrespective of the evacuation model used.)

The model incorporates a finite length of the radioactive cloud in the downwind direction that would be determined by the product of the time over which the atmospheric release would take place and the average wind speed during the release. It is assumed that the front and the back of the cloud formed would move with equal speeds that would be the same as the prevailing wind speed; therefore, its length would remain constant at its initial value. At any time after the release, the concentration of radioactivity is assumed to be uniform over the length of the cloud. If the delay time were less than the warning time, then all evacuees would have a head start; i.e. the cloud would be initially trailing behind the evacuees. On the other hand, if the delay time were more than the warning time, depending on initial locations of the evacuees the possibilities are that (1) an evacuee would still have a head start, (2) the cloud would be already overhead when an evacuee starts to leave, or (3) an evacuee would be initially trailing behind the cloud. However, this initial picture of relative position would change as the evacuees travel, depending on the relative speeds of the cloud and people. It may become possible that the cloud and an evacuee would overtake each other one or more times before the evacuee would reach his or her destination. In the model, the radial position of an evacuee, while stationary or in transit, is compared to the front and the back of the cloud as a function of time to determine a realistic period of exposure to airborne radionuclides. The model calculates the periods during which people are exposed to radionuclides on the ground while they are stationary and while they are in transit. Because radionuclides would be deposited continually from the cloud as it passed a given location, a person under the cloud would be exposed to ground contamination less concentrated than if the cloud had completely passed. To account for this, at least in part, the revised model assumes that persons are exposed to the total calculated ground-contamination concentration (that existing after complete passage of the cloud) when completely passed by the cloud, to one-half the calculated concentration when anywhere under the cloud, and to no concentration when in front of the cloud. The model provides for use of different values of the shielding-protection factors for exposure from airborne radioactivity and contaminated ground, and the breathing rates for stationary and moving evacuees during delay and transit periods.

It is realistic to expect that authorities would evacuate persons at distances from the site where exposures above the threshold for causing acute fatalities could occur regardless of the plume-exposure-pathway EPZ distance. Figure F.1 illustrates a slight reduction in acute fatalities that can occur by extending evacuation to a larger distance, such as 24 km (15 mi), from the Callaway site. Calculation shows that if the evacuation distance is increased to 32 km (20 mi),

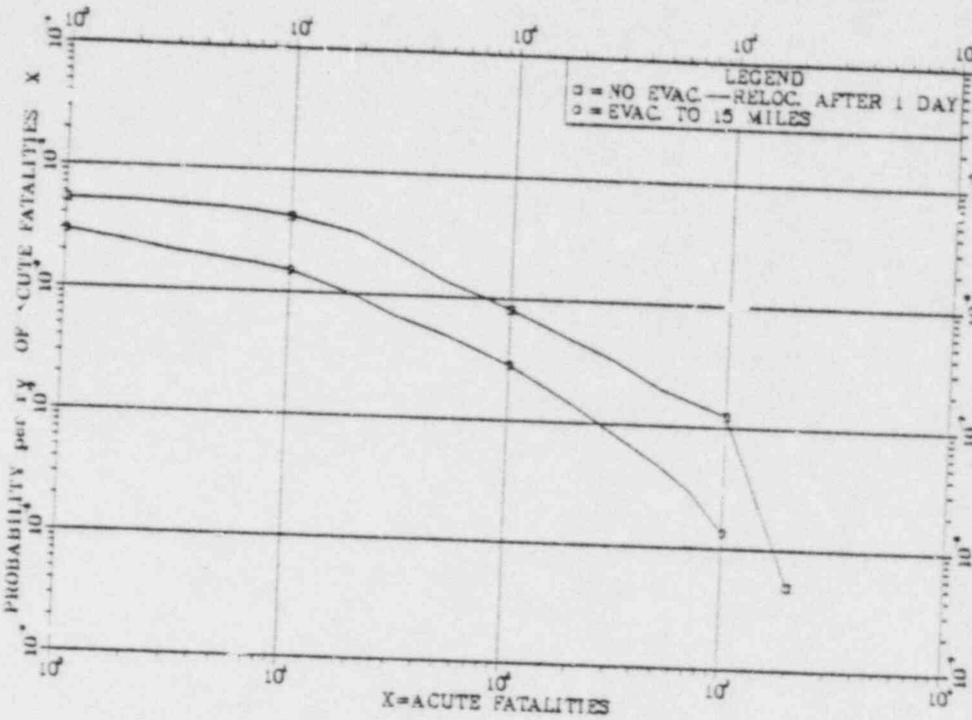

Figure F.1. Sensitivity of Acute Fatalities to Evacuation Characteristics. (15 mi = 24 km) (For evacuation to 32 km or more, the acute fatalities do not change. See Sec. 5.9.4.4 Uncertainties for a discussion of uncertainties in risk estimates.)

there would be no reduction in acute fatalities at all probability levels for this site. Also illustrated in the figure is a pessimistic case for which no early evacuation is assumed: all persons are assumed to be exposed for the first 24 hours following an accident and are then relocated.

The model has the same provision for calculation of the economic cost associated with implementation of evacuation as in the original RSS model. For atmospheric releases with durations of three hours or less, the model assumes that all people living within a circular area of 8-km (5-mi) radius centered at the reactor, plus all people within a 45° sector centered on the downwind direction within the plume-exposure-pathway EPZ, would evacuate and temporarily relocate. However, if the duration of release were to exceed three hours, the cost of evacuation is based on the assumption that all people within the entire plume-exposure-pathway EPZ would evacuate and temporarily relocate. For either of these situations, the cost of evacuation and relocation is assumed to be $125 per person (1980 dollars), which includes the cost of food and temporary shelter for one week.

References

1. "Reactor Safety Study." WASH-1400, NUREG-75/014, U.S. Nuclear Regulatory Commission, October 1975.

2. "Overview of the Reactor Safety Study Consequences Model." NUREG-0340, U.S. Nuclear Regulatory Commission, October 1977.

3. "A Model of Public Evacuation for Atmospheric Radiological Releases." SAND 78-0092, June 1978.

APPENDIX G. IMPACTS OF THE URANIUM FUEL CYCLE

The following assessment of the environmental impacts of the fuel cycle as related to the operation of CAL-1 is based on the values given in Table S-3 (Table 5.10 in Sec. 5.10) and the staff's analysis of the radiological impact from radon releases. For the sake of consistency, the analysis of fuel-cycle impacts has been cast in terms of a model 1000-MWe light-water-cooled reactor (LWR) operating at an annual capacity factor of 80%. In the following review and evaluation of the environmental impacts of the fuel cycle, the staff's analysis and conclusions would not be altered if the analysis were to be based on the net electrical power output of CAL-1.

G.1 LAND USE

The total annual land requirement for the fuel cycle supporting a model 1000-MWe LWR is about 46 ha (113 acres); about 5 ha (13 acres) are permanently committed and 41 ha (100 acres) are temporarily committed. (A "temporary" land commitment is a commitment for the life of the specific fuel-cycle plant; e.g. mill, enrichment plant, or succeeding plants. On abandonment or decommissioning, such land can be used for any purpose. "Permanent" commitments represent land that may not be released for use after plant shutdown and/or decommissioning.) Of the 41 ha temporarily committed annually, 32 ha (79 acres) are undisturbed and 9 ha (22 acres) are disturbed. Considering common classes of land use in the United States,* fuel-cycle land-use requirements to support the model 1000-MWe LWR do not represent a significant impact.

G.2 WATER USE

The principal water-use requirement for the fuel cycle supporting a model 1000-MWe LWR is that required for removal of waste heat from the power stations supplying electrical energy to the enrichment step of this cycle. Of the total annual requirement of 43×10^6 m^3 (11.4×10^9 gal), about 42×10^6 m^3 (11.1×10^9 gal) are required for this purpose, assuming that these plants use once-through cooling. Other annual water uses involve the discharge to air (e.g. evaporation losses in process cooling) of about 0.6×10^6 m^3 (160×10^6 gal) and water discharged to ground (e.g. mine drainage) of about 0.5×10^6 m^3 (130×10^6 gal).

On a thermal-effluent basis, annual discharges from the nuclear fuel cycle are about 4% of those from the model 1000-MWe LWR using once-through cooling. The consumptive water use of 0.6×10^6 m^3/yr is about 2% of that from the model 1000-MWe LWR using cooling towers. The maximum consumptive water use (assuming that all plants supplying electrical energy to the nuclear fuel cycle use cooling towers) would be about 6% of that of the model 1000-MWe LWR using

*A coal-fired power plant of 1000-MWe capacity using strip-mined coal requires the disturbance annually of about 81 ha (200 acres) for fuel alone.

cooling towers. Under this condition, thermal effluents would be negligible. The staff finds that these combinations of thermal loadings and water consumption are acceptable relative to the water use and thermal discharges of the proposed project.

G.3 FOSSIL-FUEL CONSUMPTION

Electrical energy and process heat are required during various phases of the fuel-cycle process. The electrical energy is usually produced by the combustion of fossil fuel at conventional power plants. Electrical energy associated with the fuel cycle represents about 5% of the annual electrical power production of the model 1000-MWe LWR. Process heat is generated primarily by the combustion of natural gas. This gas consumption, if used to generate electricity, would be less than 0.3% of the electrical output from the model plant. The staff finds that the direct and indirect consumptions of electrical energy for fuel-cycle operations are small and acceptable relative to the net power production of the proposed project.

G.4 CHEMICAL EFFLUENTS

The quantities of chemical, gaseous, and particulate effluents associated with fuel-cycle-processes are given in Table S-3. The principal species are sulfur oxides, nitrogen oxides, and particulates. Judging from data in a Council on Environmental Quality report (Ref. 1), the staff finds that these emissions constitute an extremely small additional atmospheric loading in comparison with these same emissions from the stationary fuel-combustion and transportation sectors in the United States; i.e. about 0.02% of the annual national releases for each of these species. The staff believes that such small increases in releases of these pollutants are acceptable.

Liquid chemical effluents produced in fuel-cycle processes are related to fuel-enrichment, -fabrication, and -reprocessing operations and may be released to receiving waters. These effluents are usually present in dilute concentrations such that only small amounts of dilution water are required to reach levels of concentration that are within established standards. The flow of dilution water required for specific constituents is specified in Table S-3. Additionally, all liquid discharges into the navigable waters of the United States from plants associated with the fuel-cycle operations will be subject to requirements and limitations set forth in the NPDES permit.

Tailings solutions and solids are generated during the milling process. These solutions and solids are not released in quantities sufficient to have a significant impact on the environment.

G.5 RADIOACTIVE EFFLUENTS

Radioactive effluents estimated to be released to the environment from reprocessing and waste-management activities and certain other phases of the fuel-cycle process are listed in Table S-3. Using these data, the staff has calculated the 100-year involuntary environmental dose commitment* to the U.S.

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*The environmental dose commitment (EDC) is the integrated population dose for 100 years; i.e. it represents the sum of the annual population doses for a total of 100 years. The population dose varies with time, and it is not practical to calculate this dose for every year.

population. It is estimated from these calculations that the overall involuntary total-body gaseous dose commitment to the U.S. population from the fuel cycle (excluding reactor releases and the dose commitment due to radon-222) would be about 400 person-rems for each year of operation of the model 1000-MWe LWR (reference reactor year, or, RRY). Based on Table S-3 values, the additional involuntary total-body dose commitment to the U.S. population from radioactive liquid effluents due to all fuel-cycle operations other than reactor operation would be about 100 person-rems for each year of operation. Thus, the estimated involuntary 100-year environmental dose commitment to the U.S. population from radioactive gaseous and liquid releases due to these portions of the fuel cycle is about 500 person-rems (whole body) per RRY.

At this time, the radiological impacts associated with radon-222 releases are not addressed in Table S-3. Principal radon releases occur during mining and milling operations and as emissions from mill tailings. The staff has determined that releases per RRY from these operations are as given in Table G.1. The staff has calculated population-dose commitments for these sources of radon-222 using the RABGAD computer code described in NUREG-0002, Appendix A, Section IV.J (Ref. 2). The results of these calculations for mining and milling activities prior to reclamation of open-pit uranium mines and tailings stabilization are given in Table G.2.

Table G.1. Radon Releases from Mining and Milling Operations and Mill Tailings for Each Year of Operation of the Model 1000-MWe LWR*

Source	Radon-222 Release
Mining[a]	4060 Ci
Milling and tailings[b] (during active milling)	780 Ci
Inactive tailings[b] (prior to stabilization)	350 Ci
Stabilized tailings[b] (for several hundred years)	1 to 10 Ci/yr
Stabilized tailings[b] (after several hundred years)	110 Ci/yr

a Testimony of R. Wilde from: "In the Matter of Duke Power Company (Perkins Nuclear Station)," U.S. Nuclear Regulatory Commission, Docket No. 50-488, filed 17 April 1978.

b Testimony of P. Magno from: "In the Matter of Duke Power Company (Perkins Nuclear Station)," U.S. Nuclear Regulatory Commission, Docket No. 50-488, filed 17 April 1978.

*After three days of hearings before the Atomic Safety and Licensing Appeal Board (ASLAB) using the Perkins record in a "lead case" approach, the ASLAB issued a decision on May 13, 1981 (ALAB-640) on the radon-222 release source term for the Uranium Fuel Cycle. The decision, among other matters, produced new source term numbers based on the record developed at the hearings. These new numbers did not differ significantly from those in the Perkins record which are the values set forth in this Table. Any health effects relative to radon-222 are still under consideration before the ASLAB. Since the source term numbers in ALAB-640 do not differ significantly from those in the Perkins record, the staff continues to conclude that "both the dose commitments and health effects of the uranium fuel cycle are insignificant when compared to dose commitments and potential health effects to the U.S. population resulting from all natural background sources." (see page C-6)

Table G.2. Estimated 100-Year Environmental Dose Commitment for Each Year of Operation of the Model 1000-MWe LWR

Source	Radon-222 Release (Ci)	Population-Dose Commitment (person-rems)		
		Total Body	Bone	Lung (bronchial epithelium)
Mining	4100	110	2800	2300
Milling and active tailings	110u	29	750	620
Total		140	3600	2900

When added to the 500 person-rem total-body dose commitment for the balance of the fuel cycle, the overall estimated total-body involuntary 100-year environmental dose commitment to the U.S. population from the fuel cycle for the model 1000-MWe LWR is about 640 person-rems. Over this period of time, this dose is equivalent to 0.00002% of the natural-background total-body dose of about three billion person-rems to the U.S. population.*

The staff has considered health effects associated with the releases of radon-222, including both the short-term effects of mining, milling, and active tailings, and the potential long-term effects from unreclaimed open-pit mines and stabilized tailings. The staff has assumed that underground mines will be sealed after completion of active mining, with the result that releases of radon-222 from them will return to background levels. For purposes of providing an upper-bound impact assessment, the staff has assumed that open-pit mines will be unreclaimed and has calculated that if all ore were produced from open-pit mines, releases from them would be 110 Ci/yr per RRY. However, because the distribution of uranium-ore reserves available using conventional mining methods is 66% underground and 34% open-pit (Ref. 3), the staff has further assumed that uranium to fuel LWRs will be produced by conventional mining methods in these proportions. This means that long-term releases from unreclaimed open-pit mines will be 37 Ci/yr (0.34 × 110) per RRY.

Based on these assumptions, the radon released from unreclaimed open-pit mines over 100- and 1000-year periods would be about 3700 Ci and 37,000 Ci per RRY, respectively. The total dose commitments for periods of 100, 500, and 1000 years would be as shown in Table G.3. These commitments represent a worst-case situation because no mitigating circumstances are assumed. However, state and Federal laws currently require reclamation of strip and open-pit coal mines, and it is very probable that similar reclamation will be required for open-pit uranium mines. If so, long-term releases from such mines should approach background levels.

*Based on an annual average natural-background individual dose commitment of 100 millirems and a stabilized U.S. population of 300 million.

Table G.3. Population-Dose Commitments from Unreclaimed Open-Pit Mines for Each Year of Operation of the Model 1000-MWe LWR

Time Period (yr)	Radon-222 Release (Ci)	Population-Dose Commitment (person-rems)		
		Total Body	Bone	Lung (bronchial epithelium)
100	3,700	96	2,500	2,000
500	19,000	480	13,000	11,000
1,000	37,000	960	25,000	20,000

For long-term radon releases from stabilized-tailings piles, the staff has assumed that the tailings would emit, per RRY, 1 Ci/yr for 100 years, 10 Ci/yr for the next 400 years, and 100 Ci/yr for periods beyond 500 years. With these assumptions, the cumulative radon-222 release per RRY from stabilized-tailings piles would be 100 Ci in 100 years, 4090 Ci in 500 years, and 53,800 Ci in 1000 years (Ref. 4). The total-body, bone, and bronchial-epithelium dose commitments for these periods are as shown in Table G.4.

Using risk estimators of 135, 6.9, and 22 cancer deaths per million person-rems for total-body, bone, and lung exposures, respectively, the estimated risk of cancer mortality due to mining, milling, and active-tailings emissions of radon-222 is about 0.11 cancer fatality per RRY. When the risk due to radon-222 emissions from stabilized tailings over a 100-year release period is added, the estimated risk of cancer mortality over a 100-year period is unchanged. Similarly, a risk of about 1.2 cancer fatalities per RRY over a 1000-year release period is estimated. When potential radon releases from

Table G.4. Population-Dose Commitments from Stabilized-Tailings Piles for Each Year of Operation of the Model 1000-MWe LWR

Time Period (yr)	Radon-222 Release (Ci)	Population-Dose Commitment (person-rems)		
		Total Body	Bone	Lung (bronchial epithelium)
100	100	2.6	68	56
500	4,090	110	2,800	2,300
1,000	53,300	1,400	37,000	30,000

reclaimed and unreclaimed open-pit mines are included, the overall risks of radon-induced cancer fatalities per RRY range as follows:

0.11-0.19 fatality for a 100-year period,
0.19-0.57 fatality for a 500-year period, and
1.2 -2.0 fatalities for a 1000-year period.

To illustrate: A single model 1000-MWe LWR operating at an 80% capacity factor for 30 years would be predicted to induce between 3.3 and 5.7 cancer fatalities in 100 years, 5.7 and 17 in 500 years, and 36 and 60 in 1000 years as a result of releases of radon-222.

These doses and predicted health effects have been compared with those that can be expected from natural-background emissions of radon-222. Using data from the National Council on Radiation Protection (NCRP) (Ref. 5), the average radon-222 concentration in air in the contiguous United States is about 150 pCi/m^3, which the NCRP estimates will result in an annual dose to the bronchial epithelium of 450 millirems. For a stabilized future U.S. population of 300 million, this represents a total lung-dose commitment of 135 million person-rems per year. Using the same risk estimator of 22 lung-cancer fatalities per million person-rems (lung) used to predict cancer fatalities for the model 1000-MWe LWR, estimated lung-cancer fatalities alone from background radon-222 in the air can be calculated to be about 3000 per year, or 300,000 to 3,000,000 lung cancer deaths over periods of 100 and 1000 years, respectively.

In addition to the radon-related potential health effects from the fuel cycle, other nuclides produced in the cycle, such as carbon-14, will contribute to population exposures. It is estimated that an additional 0.08 to 0.12 cancer death per RRY may occur (assuming that no cure for or prevention of cancer is ever developed) over the next 100 to 1000 years, respectively, from exposures to these other nuclides.

These exposures also can be compared with those from naturally-occurring terrestrial and cosmic-ray sources, which average about 100 millirems. Therefore, for a stable future population of 300 million persons, the whole-body dose commitment would be about 30 million person-rems per year, or three billion person-rems and 30 billion person-rems for periods of 100 and 1000 years, respectively. These dose commitments could produce about 400,000 and 4,000,000 cancer deaths during the same time periods. From the above analysis the staff concludes that both the dose commitments and health effects of the uranium fuel cycle are insignificant when compared with dose commitments and potential health effects to the U.S. population resulting from all natural-background sources.

G.6 RADIOACTIVE WASTES

The quantities of buried radioactive waste material (low-level, high-level, and transuranic wastes) are specified in Table S-3. For low-level waste disposal at land-burial facilities, the Commission notes in Table S-3 that there will be no significant radioactive releases to the environment. For high-level and transuranic wastes, the Commission notes that these are to be buried at a Federal repository, and that no release to the environment is associated with such disposal. It is indicated in NUREG-0116 (Ref. 6), in which are provided background and context for the high-level and transuranic Table S-3 values established by the Commission, that these high-level and transuranic wastes will be buried and will not be released to the biosphere. No radiological environmental impact is expected from such disposal.

G.7 OCCUPATIONAL DOSE

The annual occupational dose attributable to all phases of the fuel cycle for the model 1000-MWe LWR is about 200 person-rems. The staff concludes that this occupational dose will not have a significant environmental impact.

G.8 TRANSPORTATION

The transportation dose to workers and the public is specified in Table S-3. This dose is small and is not considered significant in comparison with the natural-background dose.

G.9 FUEL CYCLE

The staff's analysis of the uranium fuel cycle does not depend on the selected fuel cycle (no recycle or uranium-only recycle), because the data provided in Table S-3 include maximum recycle-option impact for each element of the fuel cycle. Thus, the staff's conclusions as to acceptability of the environmental impacts of the fuel cycle are not affected by the specific fuel cycle selected.

References

1. "The Seventh Annual Report of the Council on Environmental Quality." Figures 11-27 and 11-28, pp. 238-239, Council on Environmental Quality, September 1976.

2. "Final Generic Environmental Statement on the Use of Recycle Plutonium in Mixed Oxide Fuel in Light-Water-Cooled Reactors." NUREG-0002, U.S. Nuclear Regulatory Commission, August 1976.

3. "Statistical Data of the Uranium Industry." GJO-100(8-78), U.S. Department of Energy, 1 January 1978.

4. Testimony of R. Gotchy from: "In the Matter of Duke Power Company (Perkins Nuclear Station)." U.S. Nuclear Regulatory Commission, Docket No. 50-488, filed 17 April 1978.

5. "Natural Background Radiation in the United States." Publication No. 45, National Council on Radiation Protection and Measurements, November 1975.

6. "Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle." NUREG-0116 (Supplement 1 to WASH-1248), U.S. Nuclear Regulatory Commission, October 1976.

APPENDIX H. HISTORIC AND PREHISTORIC SITES

UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

JUL 21 1981

Docket Nos.: 50-483
and 50-486

Mr. John K. Bryan
Vice President
Union Electric Company
Post Office Box 149
St. Louis, Missouri 63166

Dear Mr. Bryan:

Subject: Cultural Resources - Callaway Plant

Since receiving your May 4, 1981 request to review your proposal of the cultural resources survey and assessment for Callaway Nuclear Power Plant, the NRC has received the Missouri Department of Natural Resources comments on that Research Design and your subsequent response to those comments.

As part of its review of the Research Design, the NRC requested the Interagency Archeological Service (IAS), National Park Service, United States Department of Interior in Denver, Colorado to review and comment on the Research Design. The IAS comments are provided in the attached letter. NRC concurs with these comments and request that you consider them in your final design.

A map clearly defining the survey area should be sent to the NRC as soon as it has been prepared. The survey area should include the area of potential environmental impact related to the operation and maintenance of the nuclear power plant and associated facilities. Suitable buffer zones and identifiable secondary or indirect impact areas should be included in the survey area (see paragraph two of the attached IAS letter). The map should be accompanied by a discussion and justification of the boundary line determination.

Your May 4, 1981 proposal with your June 23, 1981 response to the Missouri Department of Natural Resources satisfies our request that you provide NRC your program prior to proceeding with the survey. We believe your consultation with the state as you finalize the Research Design, conclude the survey, evaluate resources found and prepare a cultural resources management plan is necessary to achieving a quality cultural resources survey and assessment.

A copy of the final Research Design should be sent to the NRC upon its completion and we should be kept apprised of the survey effort as it continues.

Sincerely,

B. J. Youngblood

B. J. Youngblood, Chief
Licensing Branch No. 1
Division of Licensing

Enclosure:
As stated

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IN REPLY REFER TO:
H2415

July 1, 1981

Mr. Louis Bykoski
USNRC
Washington, D. C. 20555
Mail Stop AR3-5109

Dear Mr. Bykoski:

We reviewed with interest the research proposal for "Cultural Resources Survey and Assessment of the Union Electric Nuclear Plant Site, Callaway County, Missouri" by American Resources Group, Ltd. The major points are summarized below.

We are uncertain how it was decided that 5,300 of the 7,600 acres should be intensively inventoried and where these 5,300 acres are located vis-a-vis the entire holding. While it is laudable that Union Electric is willing to inventory this large area, it is possible that this exceeds the company's obligation. Union Electric Company is obligated to inventory that area of direct impact, a suitable bufferzone, and identifiable secondary or indirect impact areas. In this particular case it is hard to perceive that there will be any indirect impact area. The buffer should be determined on an individual case basis, depending upon the activity in that part. However, 50 meters should generally be ample. It is not necessary for Union Electric to inventory areas that it will not be impacting, for example, agricultural fields that will remain in cultivation.

The research proposal was prepared by a firm from Illinois and certain deficiencies in their proposal can be tied directly to their lack of familiarity with the literature and archaeology of central Missouri State Historic Preservation and the Missouri Association of Professional Archaeologists (MAPA). Generally, the proposal is under-referenced and demonstrates a lack of familiarity a) with pertinent research questions and b) with the literature dealing with Missouri archaeology. Reference to Illinois archaeology is not acceptable here due to the significant differences.

An adequate literature search will be necessary before the contractor attempts to write the final report as it is doubtful that the final report would be of an acceptable quality without it. This work should concentrate on the ar_heology of central Missouri and generally it is done prior to fieldwork. This familiarity necesary in order to propertly evaluate the cultural resources that will be found and to evaluate them as per the National Register of Historic Places. Also with a greater familiarity with the literature, the contractor will be able to pose realistic research questions.

Each state has developed a state Historic Preservation Plan that contains suggested research questions for each time period and/or culture. The consultant might find this document contains material that is of interest to him.

The Missouri Archaeological Survey could also be consulted for sites and projects in the vacinity of the United Electric Nuclear Plant project.

I hope this brief review will be of use to you. If I may be of further assistance to you, please do not hesitate to call upon me.

Sincerely,

Jack R Rudy

Jack R Rudy
Chief, Interagency Archaeological Services Branch