NUREG-1026

Final Environmental Statement

related to the operation of Braidwood Station, Units 1 and 2

Docket Nos. STN 50-456 and STN 50-457

Commonwealth Edison Company

U.S. Nuclear Regulatory Commission

Office of Nuclear Reactor Regulation

June 1984

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ABSTRACT

This Final Environmental Statement contains the second assessment of the environmental impact associated with the operation of Braidwood Station, Units 1 and 2, pursuant to the National Environmental Policy Act of 1969 (NEPA) and Title 10 of the Code of Federal Regulations, Part 51, as amended, of the Nuclear Regulatory Commission regulations. This statement examines the environment, environmental consequences and mitigating actions, and environmental and economic benefits and costs. Land use and terrestrial and aquatic ecological impacts will be small. Operational impacts to historic and archeologic sites will be moderate. The effects of routine operations, energy transmission, and periodic maintenance of rights of way and transmission facilities should not jeopardize any populations of endangered or threatened species. No significant impacts are anticipated from normal operational releases of radioactivity. The risk of radiation exposure associated with accidental release of radioactivity is very low. The net socioeconomic effects of the project will be beneficial. On the basis of the analysis and evaluation set forth in this environmental statement, it is concluded that the action called for under NEPA and 10 CFR 51 is the issuance of operating licenses for Braidwood Station, Units 1 and 2.

SUMMARY AND CONCLUSIONS

This Final Environmental Statement, operating-license stage (FES-OL), 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 Commonwealth Edison Company (CECo) for the startup and operation of Units 1 and 2 of Braidwood Station (Docket Nos. STN 50-456, STN 50-457), located near the Kankakee River in Reed Township, Will County, Illinois, 2.3 km (1.4 mi)* south of Braidwood and 32 km (20 mi) south-southwest of Joliet, Illinois.

The plant will employ two pressurized water reactors to produce up to 6850 megawatts thermal (MWt). Two steam turbine-generators will use this heat to provide 2240 MW (net) of electrical power capacity. The maximum design thermal output of the units is 7130 MWt, with a corresponding maximum calculated electrical output of 2330 MWe. The exhaust steam will be condensed by cooling water circulated from a cooling pond. 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 Kankakee River.

(3) The information in this environmental statement represents the second assessment of the environmental impact associated with the Braidwood Station pursuant to the Commission's regulations as set forth in Title 10 of the Code of Federal Regulations Part 51 (10 CFR 51), which implements the requirements of the National Environmental Policy Act of 1969 (NEPA). After receiving an application in September 1973 to construct Units 1 and 2 of the Braidwood Station, the staff carried out a review of the environmental impact that would occur during construction and operation. This evaluation was issued in July 1974 as a Final Environmental Statement - construction-permit phase (FES-CP). After this environmental review, a safety review, an evaluation by the Advisory Committee on Reactor Safeguards, and public hearings in Rockford, Illinois, and Bethesda, Maryland, the U.S. Atomic Energy Commission (now U.S. Nuclear Regulatory Commission) issued permit Nos. CPPR-132 and CPPR-133 on December 31, 1975, for construction of Units 1 and 2 of the Braidwood Station. As of June 1, 1984, the construction of Unit 1 was about 73% complete and Unit 2 was about 54% complete. The applicant has applied for a license to operate Units 1

*Throughout the text of this document, values are presented in both metric and English units. For the most part, measurements and calculations were originally made in English units and subsequently converted to metric. The number of significant figures given in a metric conversion is not meant to imply greater or lesser accuracy than that implied in the original English value.

and 2 and has submitted, in November 1978, the required safety and environmental reports in support of the application. The applicant estimates fuel-loading dates of August 1985 for Unit 1 and August 1986 for Unit 2.

(4) The staff has reviewed the activities associated with the proposed operation of the station and the potential impacts, both beneficial and adverse. The staff's conclusions are summarized as follows:

(a) Alteration of about 1803 ha (4454 acres) of land for the plant has been necessary. This is not a significant detrimental environmental impact (Section 4.2.2).

(b) Surface water quality impacts for the Kankakee River caused by the blowdown discharge from the Braidwood cooling pond are predicted to be small based on the staff's assessment of pollutant loading of the cooling pond blowdown to the river and on the small blowdown flow rate compared to the river flow rate (Sections 5.3.2 and 5.5.2).

(c) The presence of the plant and plant operations will have a negligible effect on the 100-year flood plain (Section 5.3.3).

(d) Periodic operation of the diesel generators (the predominant contributors to air pollutant discharges) and auxiliary boilers should not have a significant impact on air quality (Section 5.4.2).

(e) The staff has found no evidence to date indicating that the operation of the Braidwood transmission system will have an adverse effect on the health of humans or that its operation will adversely affect plant or animal life (Section 5.5.1.2).

(f) The staff has evaluated the biological conditions anticipated with operation of the pond and concludes that the aquatic resources of the cooling pond will be typical of a generally stressed system characterized by possibly large numbers of a few heat-tolerant species. However, since the state has not identified the pond as a fishery resource and the applicant indicates that it will only be used for cooling purposes (ER-OL Section 5.1), the conditions in the cooling pond are not in conflict with any planned use of the water body (Section 5.5.2.1).

(g) Adverse effects on the biota of the cooling pond are not expected at the projected level of residual chlorine discharged to the cooling pond (Section 5.5.2.1).

(h) New estimates of blowdown flow rate and temperature increase to the Kankakee River are lower than previously described in the FES-CP. Therefore, effects of the blowdown on river biota are less than previously predicted. Adverse impacts to the allowed mixing zone will be minimal and localized (Section 5.5.2.2).

(i) Impacts from entrainment of biota in makeup water drawn from the Kankakee River are expected to be minimal. During extreme low-flow conditions in the river, the State of Illinois requires that water withdrawal be stopped so that impacts at low flow will be minimized (Section 5.5.2.2).

(j) Some fish may be impinged at the makeup water intake screens. Based on experience gained during filling of the cooling pond, impingement losses should have minimal effects on the fish fauna of the Kankakee River (Section 5.5.2.2).

(k) Operation of the Braidwood Station will not impact any terrestrial or aquatic species identified as threatened or endangered on the Federal or state lists. The pallid shiner, Notropis amnis, which has been proposed for the state's list of threatened species, has been collected downstream of the blowdown discharge location on the Kankakee River. Impacts to the pallid shiner from the blowdown discharge should be minimal (Section 5.6).

(l) The operation and maintenance of the Braidwood Station will have no significant impact on the archeological resources or historic sites with one provision. The NRC is in the process of having a determination of eligibility completed for archeological site 11Ka179 for possible inclusion in the National Register of Historic Places. The NRC will take the action required on this outstanding item dependent on the finding of the Keeper of the Register (Section 5.7).

(m) The staff concludes that the primary socioeconomic impacts of plant operation are tax benefits and employment. Other socioeconomic impacts are expected to be small (Section 5.8).

(n) The risk to public health and safety from exposure to radioactive effluents and the transportation of fuel and wastes from normal operations will be very small (Section 5.9.3).

(o) Activities off site that might adversely affect safe operation of the plant (nearby industrial, military, and transportation facilities that might create explosive, missile, toxic gas, or similar hazards) have been evaluated. The risk to Braidwood Station from such hazards is negligibly small (Section 5.9.4.4(2)).

(p) There are no special or unique circumstances about the Braidwood site and environs that would warrant consideration of alternatives for accident mitigation purposes (Section 5.9.4.6).

(q) The environmental impact of the Braidwood Station as a result of the uranium fuel cycle is very small when compared with the impact of natural background radiation (Section 5.10).

(r) Noise levels off site during station and river pumphouse operation are predicted by the staff to be somewhat above ambient levels. Examination of the predicted broadband noise and the potential for annoyance and activity interference as a result of audibility of tones indicates that adverse community reaction would not be expected from the noise of operation of the station (Section 5.12).

(s) The Braidwood Station will provide approximately 11 billion kWh of electrical energy annually (assuming that both units will operate at an annual average capacity factor of 55%). The addition of the station will add 2240 MW of operating capacity to the Commonwealth Edison Company system, resulting in increased system and regional reliability (Section 6).

(5) This statement assesses various impacts associated with the operation of the facility in terms of annual impacts and balances these impacts against the anticipated annual energy production benefits. Thus, the overall assessment and conclusion would not be dependent on specific operating life. Where appropriate, however, a specific operating life of 40 years was assumed.

(6) The Draft Environmental Statement was made available for comment to the public, to the Environmental Protection Agency, and to other agencies, as specified in Section 8. Comments received are addressed in Section 9 and the comment letters are reprinted in Appendix A.

(7) The personnel who participated in the preparation of this statement and their areas of responsibility are identified in Section 7.

(8) On the basis of the analyses and evaluations set forth in this statement, after weighing the environmental, economic, technical, and other benefits against environmental and economic costs at the operating-license stage, the staff concludes that the action called for under NEPA and 10 CFR 51 is the issuance of operating licenses for Braidwood Units 1 and 2, subject to the following conditions for the protection of the environment (Section 6.1):

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

(b) The applicant will carry out the environmental monitoring programs outlined in Section 5 of this statement, as modified and approved by the staff, and implemented in the Environmental Protection Plan and Technical Specifications that will be incorporated in the operating licenses for Braidwood Units 1 and 2. Monitoring of the aquatic environment shall be as specified in the National Pollutant Discharge Elimination System (NPDES) permit.

(c) If an adverse environmental effect or evidence of irreversible environmental damage is detected during the operating life of the plant, the applicant will provide the staff with an analysis of the problem and a proposed course of action to alleviate it.

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FOREWORD

This Final 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 regulations set forth in Title 10 of the Code of Federal Regulations, Part 51 (10 CFR 51), which implements the requirements of the National Environmental Policy Act of 1969 (NEPA).

This environmental review deals with the impacts of operation of Braidwood Station, Units 1 and 2. Assessments relating to operation that are presented in this statement augment and update those described in the Final Environmental Statement - construction phase (FES-CP) that was issued in July 1974 in support of issuance of construction permits for Braidwood Units 1 and 2.

The information to be found in various sections of this statement updates the FES-CP in four ways by

(1) evaluating changes in facility design and operation that will result in environmental effects of operation (including those that would enhance as well as degrade the environment) different from those projected during the preconstruction review

(2) reporting the results of relevant new information that has become available since the issuance of the FES-CP

(3) factoring into the statement new environmental policies and statutes that have a bearing on the licensing action

(4) identifying unresolved environmental issues or surveillance needs that are to be resolved by license conditions.

Introductions (résumés) in appropriate sections of this statement summarize both the extent of updating and the degree to which the staff considers the subject to be adequately reviewed.

Copies of this statement, the DES-OL (1983), and the FES-CP (1974) are available for inspection at the Commission's Public Document Room, 1717 H Street N.W., Washington, D.C., and at the Wilmington Township Public Library, Wilmington, Illinois. The documents may be reproduced for a fee at either location. Copies of this statement may be obtained by writing to sources indicated on the inside front cover.

Ms. Janice A. Stevens is the NRC Project Manager for the environmental review of this project. Should there be any questions regarding the content of this statement, Ms. Stevens may be contacted by telephone at (301)492-7144 or by writing to the following address:

Ms. Janice A. Stevens
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, DC 20555

1 INTRODUCTION

The proposed action is the issuance of an operating license to Commonwealth Edison Company (CECo) of Chicago, Illinois, for startup and operation of the Braidwood Station, Units 1 and 2, on an 1803-ha (4454-acre) site in Will County 32 km (20 mi) south-southwest of Joliet, Illinois, and 5 km (3 mi) southwest of the Kankakee River. Each of the two generating units consists of a pressurized-water reactor, four steam generators, one steam turbine-generator, a heat-dissipation system, and associated auxiliary and engineered safeguards. Waste heat will be dissipated to the atmosphere from a cooling pond. Makeup water will come from the Kankakee River; blowdown (i.e., water released to control the buildup of dissolved solids) will go into the Kankakee River downstream from the intake. The two units are designed to operate at a nominal/design-maximum thermal level of 6850/7130 MWt and to produce a nominal/design-maximum net electrical output of 2240/2330 MWe (ER-OL Section 3.2, FES-CP Section 1.1*). The plant is being constructed for CECo (the applicant) who prepared the ER-OL and will operate the plant.

1.1 Administrative History

On September 20, 1973 CECo filed an application with the Atomic Energy Commission, now Nuclear Regulatory Commission (NRC), for permits to construct the Braidwood Station, Units 1 and 2. Construction permits Nos. CPPR-132 and CPPR-133 were issued on December 31, 1975, following reviews by the Nuclear Regulatory Commission's staff (the staff) and its Advisory Committee on Reactor Safeguards, as well as public hearings before an Atomic Safety and Licensing Board in Rockford, Illinois, and Bethesda, Maryland, between September 4, 1974, and November 18, 1975. The conclusions resulting from the staff's environmental review were issued as a final environmental statement for construction permits in July 1974.

As of June 1, 1984, construction of Braidwood Unit 1 was about 73% complete and Unit 2 was about 54% complete. CECo estimates that Unit 1 will be ready for fuel loading in August 1985 and commercial operation in April 1986; Unit 2 is estimated to be ready for fuel loading in August 1986 and commercial operation in April 1987.

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*"Braidwood Station Environmental Report, Operating-License Stage," Vols 1 and 2, Commonwealth Edison Company, November 30, 1978. 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, Amendment 1 (February 1983), Amendment 2 (July 1983), Amendment 3 (September 1983), Amendment 4 (October 1983), Amendment 5 (December 1983), and Amendment 6 (June 1984). Likewise, "Braidwood Station Environmental Report, Construction-Permit Phase," Vols 1 and 2, Commonwealth Edison Company, September 13, 1973, is cited as ER-CP. The "Final Environmental Statement Related to the Proposed Braidwood Station, Units 1 and 2," July 1974, was prepared in connection with the construction-permit application and is referred to as FES-CP.

On June 27, 1978, CECo submitted an application including a Final Safety Analysis Report (FSAR) and Environmental Report (ER-OL) requesting issuance of operating licenses for Braidwood Station, Units 1 and 2. The FSAR and ER-OL were docketed on November 30, 1978, and operational safety and environmental reviews were then initiated.

1.2 Permits and Licenses

The applicant has provided in Section 12 of the ER-OL a status listing of environmentally related permits, approvals, and licenses required from Federal and state agencies in connection with the proposed project. The staff has reviewed the listing and other information and is not aware of any potential non-NRC licensing difficulties that would significantly delay or preclude the proposed operation of the plant. Pursuant to Section 401 of the Clean Water Act of 1977, the issuance of a water quality certification, or waiver therefrom, by the Illinois Environmental Protection Agency, Division of Water Pollution Control, is a necessary prerequisite to the issuance of an operating license by the NRC. This certification, covering the operational discharge into the Kankakee River, was granted on August 18, 1975 (ER-OL Table 12.0-1). The National Pollutant Discharge Elimination System (NPDES) permit, issued pursuant to Section 402 of the Clean Water Act, was granted by the U.S. Environmental Protection Agency on May 19, 1976. A modified NPDES permit was issued to the applicant by the Illionis Environmental Protection Agency on September 30, 1980. This permit expired on April 1, 1981, but has been administratively extended by the state. The applicant submitted a request for renewal of the NPDES permit on March 26, 1981, for the remainder of the construction phase and for the operational phase of Braidwood Station. The NPDES permit, as modified on September 30, 1980, is reproduced in Appendix G of this environmental statement.

2 PURPOSE AND NEED FOR THE ACTION

The Commission has amended 10 CFR 51, "Licensing and Regulatory Policy and Procedures for Environmental Protection," effective April 26, 1982, to provide that need for power issues will not be considered in ongoing and future operating license proceedings for nuclear power plants unless a showing of special circumstances is made under 10 CFR 2.758 or the Commission otherwise so requires (47 FR 12940, March 26, 1982). Need for power issues need not be addressed by operating license applicants in environmental reports to the NRC, nor by the NRC staff in environmental impact statements prepared in connection with operating license applications (10 CFR 51.53, 51.95, and 51.106(c)).

This policy has been determined by the Commission to be justified even in situations where, because of reduced capacity requirements on the applicant's system, the additional capacity to be provided by the nuclear facility is not needed to meet the applicant's load responsibility. The Commission has taken this action because the issue of need for power is correctly considered at the construction-permit stage of the regulatory review where a finding of insufficient need could factor into denial of issuance of a license. At the operating-license review stage, the proposed plant is substantially constructed and a finding of insufficient need would not, in itself, result in denial of the operating license.

Substantial information exists that supports an argument that nuclear plants are lower in operating costs than conventional fossil plants. If conservation or other factors lower anticipated demand, utilities remove generating facilities from service according to their costs of operation, with the most expensive facilities removed first. Thus, a completed nuclear plant would serve to substitute for less economical generating capacity (46 FR 39440, August 3, 1981, and 47 FR 12940, March 26, 1982).

Accordingly, this statement does not consider need for power issues. Section 6 does, however, consider the savings associated with the operation of the nuclear plant.

2.1 References

U.S. Nuclear Regulatory Commission, "Need for Power and Alternative Energy Issues in Operating License Proceedings," proposed rule, Federal Register, 46 FR 39440, August 3, 1981.

---, "Need for Power and Alternative Energy Issues in Operating License Proceedings," final rule, Federal Register, 47 FR 12940, March 26, 1982.

3 ALTERNATIVES TO THE PROPOSED ACTION

The Commission has amended its regulations in 10 CFR 51 effective April 26, 1982, to provide that issues related to alternative energy sources will not be considered in operating license proceedings for nuclear power plants unless a showing of special circumstances is made under 10 CFR 2.758 or the Commission otherwise so requires (47 FR 12940, March 26, 1982). In addition, these issues need not be addressed by operating license applicants in environmental reports to the NRC, nor by the NRC staff in environmental impact statements prepared in connection with operating license applications (see 10 CFR 51.53, 51.95, 51.106(c), and 51.106(d)).

The Commission has concluded that alternative energy source issues are resolved at the construction-permit (CP) stage, and the CP is granted only after a finding that, on balance, no superior alternative to the proposed nuclear facility exists. In addition, this conclusion is unlikely to change even if an alternative is shown to be marginally environmentally superior in comparison with operation of the nuclear facility because of the economic advantage that operation of the nuclear plant would have over available alternative sources (46 FR 39440, August 3, 1981, and 47 FR 12940, March 26, 1982). By earlier amendment (46 FR 28630, May 28, 1981), the Commission also stated that alternative sites will not be considered at the operating-license stage, except under special circumstances, in accordance with 10 CFR 2.758. Accordingly, this statement does not consider alternative energy sources or alternative sites.

3.1 References

U.S. Nuclear Regulatory Commission, "Alternative Site Issues in Operating License Proceedings," final rule, Federal Register, 46 FR 28630, May 28, 1981.

---, "Need for Power and Alternative Energy Issues in Operating License Proceedings," proposed rule, Federal Register, 46 FR 39440, August 3, 1981.

---, "Need for Power and Alternative Energy Issues in Operating License Proceedings," final rule, Federal Register, 46 FR 12940, March 26, 1982.

4 PROJECT DESCRIPTION AND AFFECTED ENVIRONMENT

4.1 Résumé

This résumé highlights changes in the plant operating characteristics and design as well as new information in the local environment obtained since the FES-CP was issued in July 1974.

The changes to the general description of the plant layout are (1) the turbine building was enlarged to accommodate the technical support center; (2) the permanent gatehouse and permanent parking area are being expanded; (3) the river screen house was modified to be lower in profile; and (4) the screen house was extensively landscaped (see Section 4.2.1). The only changes to the description of regional land use are that approximately 65 ha (160 acres) of strip-mined land were added to the site and two smaller tracts were removed. The final survey indicated that the site boundary encompassed 1803 ha (4454 acres), which is 54 ha (134 acres) larger than stated in the FES-CP (see Section 4.2.2). Water use and treatment are discussed in Section 4.2.3. In general, the amount of water projected to be used by the plant cooling water system has increased; however, the overall amount of water projected to be withdrawn from the Kankakee River has been decreased. The changes made in the cooling system are discussed in Section 4.2.4. The radioactive waste management system and effluent control measures are addressed in Section 4.2.5. The changes in the volume and character of nonradioactive effluents since the FES-CP was issued are addressed in Section 4.2.6. There also have been changes in the power transmission system. The originally planned connection to the Joliet Generating Station has been eliminated and the only new right-of-way from the plant is to the Crete substation (see Section 4.2.7).

New and updated information on surface water hydrology is provided in Section 4.3.1; updated water quality data are given in Section 4.3.2. New information on site atmospheric dispersion characteristics is provided in Section 4.3.3, and revised descriptions of terrestrial and aquatic resources are in Section 4.3.4. Section 4.3.5 addresses the state and federally recognized threatened and endangered species in the site area. Updated information on community characteristics and on historic and archaeologic sites is given in Sections 4.3.6 and 4.3.7, respectively.

4.2 Facility Description

4.2.1 External Appearance and Plant Layout

A description of the external appearance and plant layout is contained in FES-CP Section 3.1. The significant differences from that description follow. The turbine building was enlarged to accommodate the technical support center. The permanent gatehouse and the permanent parking area are both being expanded. The river screen house was modified to be lower in profile because the overhead crane penthouse was eliminated and the screen house area was extensively landscaped (ER-OL, response to staff question 310.1). A site layout map (Figure 4.1) shows the location of the significant structures.

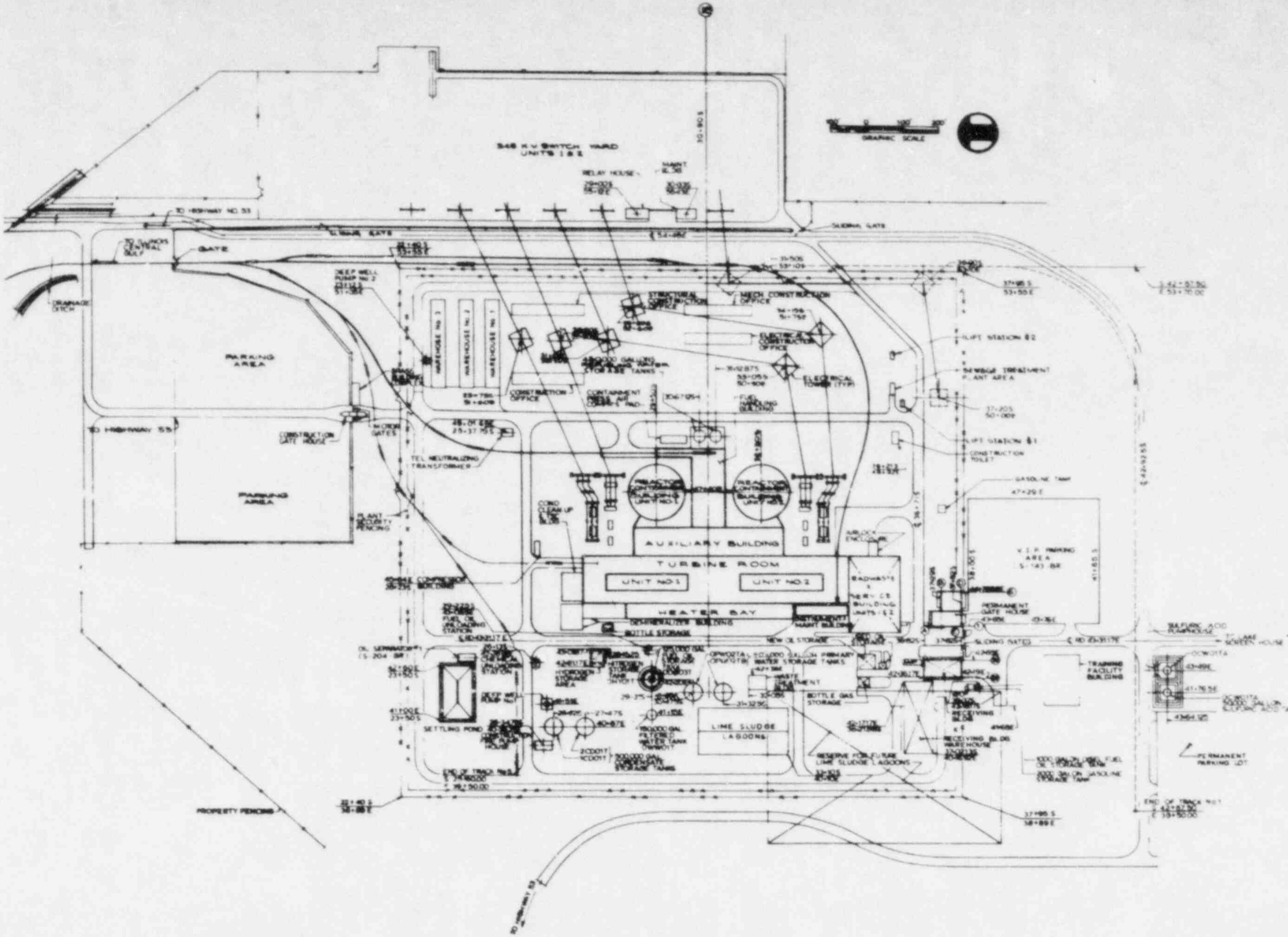

Figure 4.1 Location and orientation of principal plant structures
Source: ER-OL Figure 2.1-4

4.2.2 Land Use

A description of regional land use is given in FES-CP Section 2.2 and ER-OL Section 2.1.3. Since the FES-CP was issued, approximately 65 ha (160 acres) of strip-mined land were added to the southeast corner of the site and two smaller tracts were removed on the eastern edge. The final survey indicates that the station property line encompasses 1803 ha (4454 acres) and is identical with the site boundary. This is 54 ha (134 acres) larger than stated in the FES-CP (ER-OL, Amendment 3, response to staff question E290.7). The pipeline corridor and river screen house use 56 ha (139 acres) rather than the 40 ha (100 acres) given in the FES-CP.

For convenience of description the site can be divided into (1) the plant area, consisting of 225 ha (556 acres), and (2) the pond area consisting of 1578 ha (3898 acres) for a total site area of 1803 ha (4454 acres) (Figure 4.2). At the time of the most recent staff visit (September 1983), the plant area consisted of 87 ha (215 acres) of undisturbed agricultural land, 34 ha (85 acres) of undisturbed woodland, 51 ha (125 acres) of permanent plant facilities such as the main buildings, switchyard, roads, and parking areas, and 53 ha (131 acres) of disturbed land temporarily being used as laydown areas (ER-OL, Amendment 3, response to staff question E290.5). Once construction is completed and these laydown areas are no longer needed, they will be revegetated.

Of the 1578 ha (3898 acres) pond area, 1027 ha (2537 acres) are covered with water when the pond is filled to capacity, at an elevation of 181 m (595 ft) above mean sea level (MSL). The remaining 551 ha (1361 acres) consist of islands of strip-mine spoil and 26 km (16 mi) of internal and external dikes. Use of land at the site before construction was as stated in FES-CP Section 4.1.

The distances from the gaseous vent stack to the exclusion area boundary for 16 sectors are given in ER-OL Figure 2.1-5 and range from 495 m (1625 ft) to 747 m (2450 ft).

Before construction the site contained approximately 322 ha (796 acres) classified as prime agricultural land by the U.S. Soil Conservation Service (SCS). Of this total, 242 ha (598 acres) were located in the pond area and 80 ha (198 acres) in the plant area. Forty-four ha (108 acres) of prime agricultural land in the plant area remain undisturbed, another 15 ha (36 acres) are temporarily disturbed and 21 ha (54 acres) are permanently disturbed. All 242 ha (598 acres) of prime agricultural land in the pond area are permanently disturbed. The soil mapping units involved were primarily Maumee fine sandy loam, with one or two small areas (e.g., 1-2 ha (2.5-5 acres)) of Pittwood fine sandy loam and Canisteo loam. Sizeable areas of Watseka loamy fine sand, located principally in the western third of the cooling pond area, had been considered additional farmland of statewide importance (SCS, 1980).

4.2.3 Water Use and Treatment

4.2.3.1 General

Water for operation of the Braidwood plant is obtained from the Kankakee River. The primary water use associated with the plant will be for condenser cooling. The Braidwood plant will use a closed-cycle cooling water system that will reject heat to a cooling pond for evaporation and transfer of heat. With both

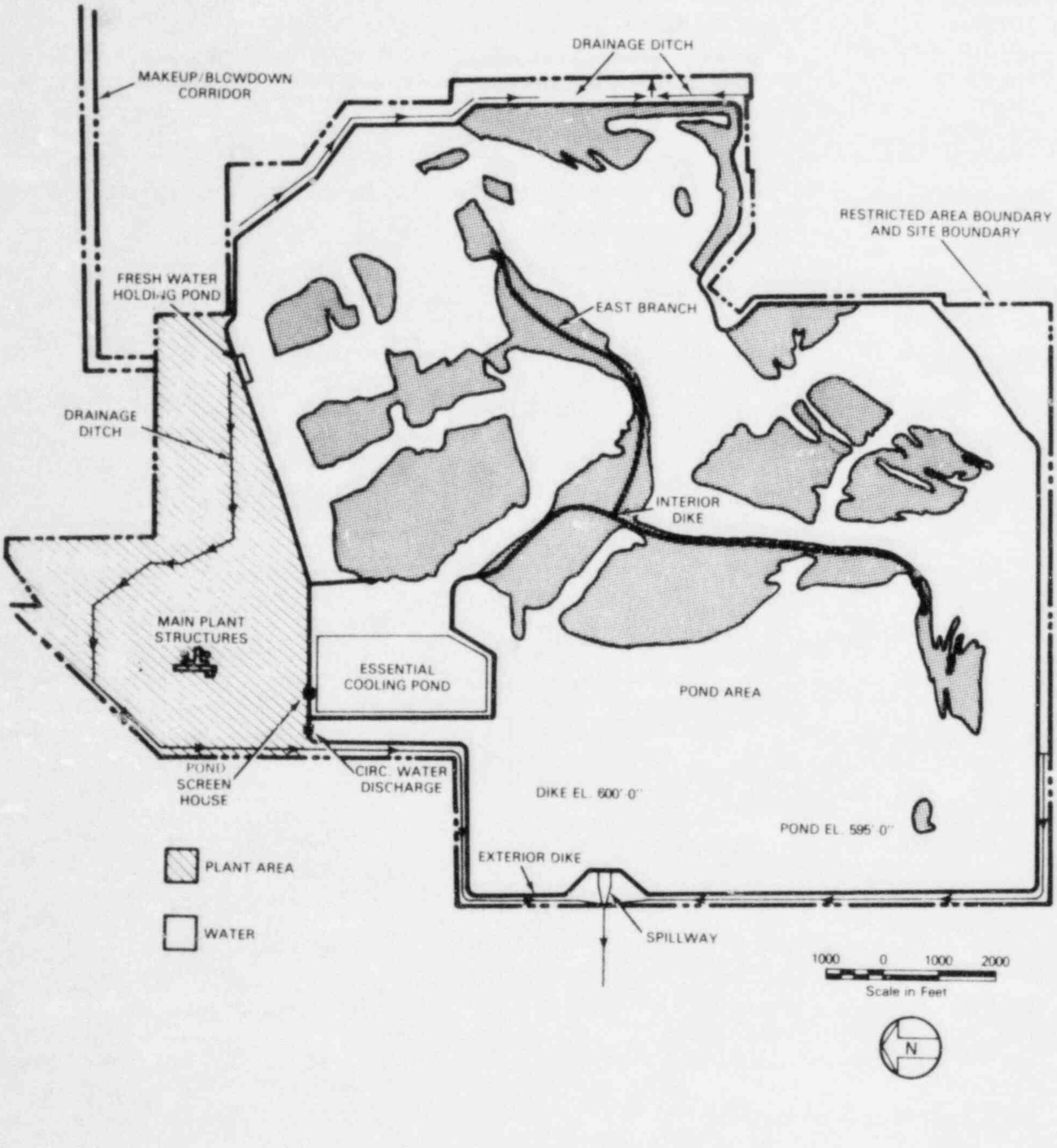

Figure 4.2 Braidwood site layout

units operating, the cooling water system will circulate 92 m^3/sec (3250 cfs) through the system and discharge it to the cooling pond (FES-CP and ER-OL Section 3.3). At full load the temperature increase will be 12C° (22F°) (ER-OL). This is an increase of 0.6C° (1.1F°) in the projected temperature rise over that predicted in the FES-CP.

Figure 4.3 details the location and predicted quantitative water use by the plant. In general, the amount of water projected to be used by the plant cooling water system has been increased since preparation of the FES-CP; however, the overall amount of water projected to be withdrawn from the Kankakee River has been decreased by 0.07 m^3/sec (2.5 cfs) (ER-OL Section 3.3). The applicant stated at the time the FES-CP was issued that the net water withdrawal from the Kankakee River would not exceed a maximum of 10% of the river flow. Since the FES-CP was issued, the applicant has entered into an agreement with the Illinois Department of Conservation to limit withdrawal of water from the Kankakee River for makeup to the station cooling pond (ER-OL Section 3.3.1; response to staff question E240.4). The maximum withdrawal rate from the river will be further limited to rates that would not cause the flow of the river to drop below 12.52 m^3/sec (442 cfs). The applicant has determined that this cutoff river flow rate would be 14.03 m^3/sec (495.5 cfs) (i.e., the limiting river flow rate plus the capacity of one makeup pump). Continued station operation when river flow drops below this value would require a drawdown of the cooling pond. The station can operate while drawing the cooling pond down from the normal operating level of 180.7 m (592.8 ft) MSL to 180.6 m (592.5 ft) MSL. Using the historic river flow records, assuming maximum station evaporation and no rainfall, the applicant estimates that the Braidwood Station would have to operate at a reduced load for only a single continuous 42-day period or be shut down for a single 8-day period because of excessive drawdown of the cooling pond (response to staff question E240.4). The mean monthly flow of the Kankakee River has been above the cutoff river flow rate 98% of the time over the period of record (1915-1982). The 7-day, 10-year recurrence low flow of the river at the intake point is 12.5 m^3/sec (442 cfs) as cited in the FES-CP.

4.2.3.2 Surface Water Use

A summary of water use by the cooling water system, which is discussed in Section 3.3 of the ER-OL, follows.

Cooling System

The makeup water for cooling water use by the station is expected to vary seasonally. Makeup water use for the station at full load will range from 2.1 m^3/sec (76.6 cfs) to 2.9 m^3/sec (105.2 cfs) with an average makeup intake of 2.6 m^3/sec (90.8 cfs) from the Kankakee River (compared with an annual mean flow of 111.9 m^3/sec (3952 cfs) for the Kankakee River). The expected seasonal variations in the parameters of the hydrologic balance for the cooling pond system are shown in ER-OL Table 3.3-1.

The evaporation rate from the cooling pond, which is expected to vary with weather conditions and the plant load factor, ranges seasonally between 0.9 and 2.0 m^3/sec (31.8 and 71.1 cfs) with the average being 1.5 m^3/sec (51.8 cfs) at full load. Water loss as the result of seepage from the cooling pond is projected to be 0.1 m^3/sec (5 cfs). Water loss from evaporation and seepage

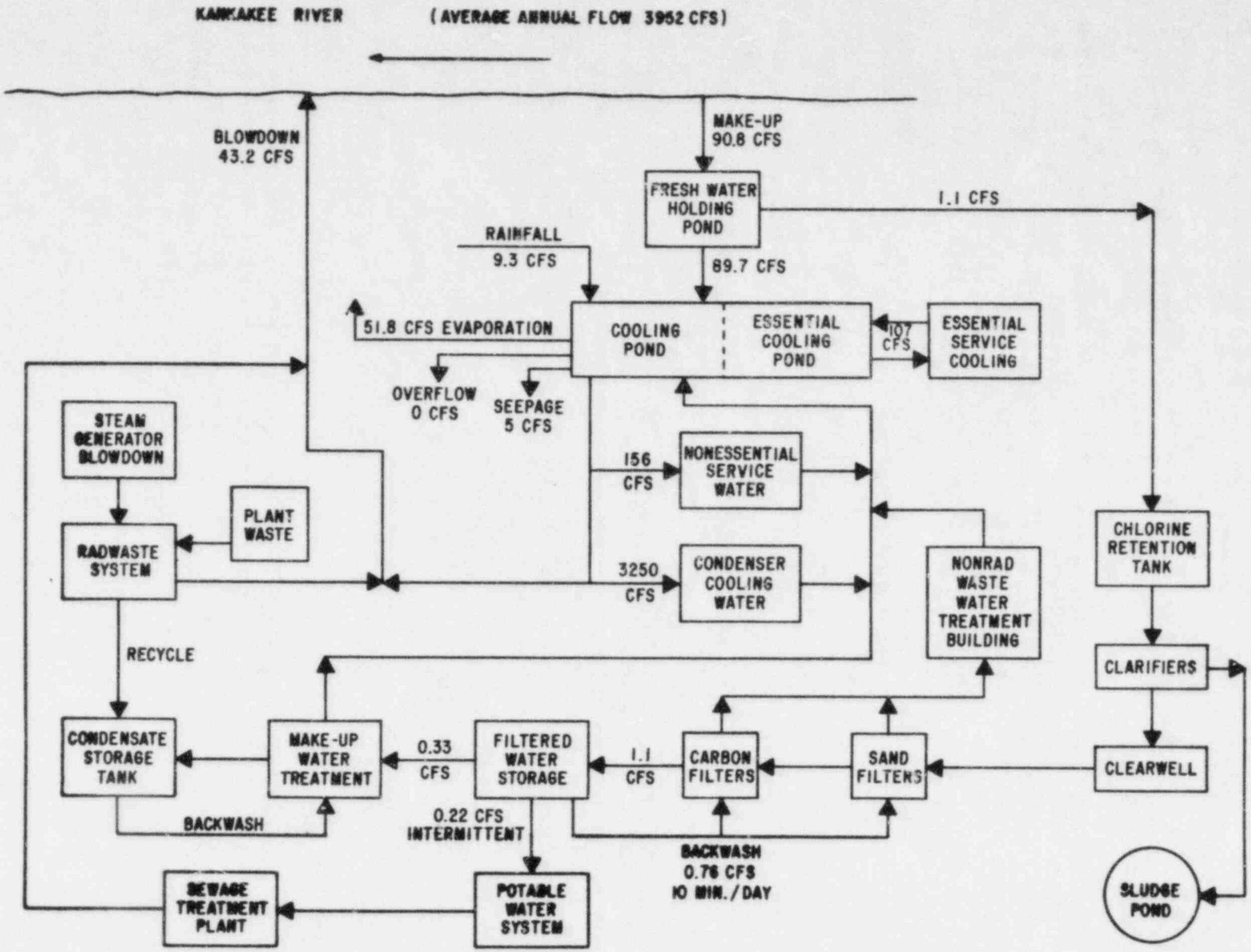

Figure 4.3 Water usage flow diagram (To convert from cfs to m^3/sec, multiply by 0.028.)
Source: ER-OL Figure 3.3-1

will be compensated, in part, by rainfall input. On the basis of an average annual rainfall of 91 cm (36 in.) and a cooling pond area of 1026 ha (253/ acres), the staff determined that the applicant's calculation of an average rainfall input rate of 0.3 m^3/sec (9.3 cfs) was reasonable. A blowdown averaging 1.2 m^3/sec (43.2 cfs) would maintain an average total dissolved-solids level of 900 mg/l in the cooling pond, about 2.1 times that in the makeup water. The net makeup withdrawal from the river by the station is expected to be 1.35 m^3/sec (47.6 cfs).

Service Water Systems

The nonessential service water system provides cooling water for equipment that is not safety related or essential for safe shutdown of the reactor. Water from the circulating water system is used by this system at a rate of 4.4 m^3/sec (156 cfs), then released to the cooling pond along with the condenser cooling water (see Figure 4.3).

The essential service water cools safety-related equipment, which includes the reactor containment fan coolers, diesel generator fan coolers, the component cooling heat exchangers, and other equipment necessary for safe shutdown of the reactor. The total required circulation rate for this system is approximately 1.5 m^3/sec (54 cfs) per unit. Water from the pond screen house is supplied to this system. After passage through the system, the heated water is discharged through a separate structure located in the essential cooling pond.

Potable Water

The FES-CP (Section 3.3) reported that potable water and makeup water for the steam system would be obtained from two deep wells at the plant site. Poor ground water quality caused the applicant to change the source for this water. According to Section 3.3.3 of the ER-OL (Amendment 2), potable water from the Kankakee River will be supplied for the plant via the freshwater holding pond portion of the cooling pond. Approximately 57 m^3/day (15,000 gpd) will be required for normal operation.

4.2.3.3 Ground Water Use

Ground water will not be used for sanitary and demineralizer systems, as proposed at the time the FES-CP was issued, because of the poor quality of ground water for this purpose (ER-OL Section 3.3).

4.2.3.4 Water Treatment

Biological growth and slime, and scale buildup in the station main condensers will be controlled by mechanical cleaning. Sponge-rubber balls, sized to the inside diameter of the condenser tubes will be continuously injected into the system at the inlet to the condenser. The balls will clean the tubes as they pass through the system and will be collected by a series of baffles and screens at the outlet of the condenser and returned to the condenser inlet. The balls will be periodically removed, sorted, replaced, and reinjected at the condenser inlet.

Algal growth in the remainder of the circulating water system and in the station main condensers in excess of that controlled by the mechanical cleaning system will be controlled by intermittent injection of sodium hypochlorite solution sequentially into the four water boxes of both the Unit 1 and Unit 2 condensers. Chlorination is anticipated to be used all year round with two injections per day for 5- to 30-min duration each (response to staff question E291.12). The target free available chlorine (FAC) concentration at the condenser outlet water box being treated is 0.5 mg/l. The concentration will be reduced when the treated water is mixed with the remaining flow from the other untreated condenser sections downstream of the condenser outlet water boxes. The reduction will be by a factor of 4 when one unit is operating and by a factor of 8 when both units are operating. The diluted concentration downstream of the condenser would therefore be about 0.1 mg/l FAC for single unit operation. The FAC concentration will be further reduced by the chlorine demand of the untreated circulating water. The applicant anticipates that there will be no detectable chlorine residual in the station discharge to the cooling pond, based on the dilution provided by the flow from the untreated condenser sections.

Scale buildup in the remainder of the circulating water system and in the condensers in excess of that controlled by the mechanical cleaning will be controlled by the addition of carbon dioxide to the circulating water at an average rate of 1600 kg (3500 lb) per hour. Use of carbon dioxide or polymers is proposed in the ER-OL rather than use of sulfuric acid as discussed in the FES-CP (Section 3.6). Carbon dioxide injected into the plant intake water will form carbonic acid (H_2CO_3) before it is drawn through the circulating and service water pumps (ER-OL Section 3.6.1.1).

The service water systems will be treated two times daily for half-hour periods with a 15% solution of hypochlorite to prevent biological growth. An average of 830 kg (1840 lb) will be added to the nonessential service water and 575 kg (1275 lb) will be added to the essential service systems daily (ER-OL Section 3.6.1). The water from the service water system that will contain residual chlorine after chlorination will be released to the cooling pond along with the circulating water. The resultant chlorine concentration of the service water discharges to the cooling pond is expected to be negligible (response to staff question E291.12).

Water from the freshwater holding pond at the inlet of the cooling pond will be used to supply the makeup water required for the steam cycle. The water passes through two parallel lime softeners and a chlorine retention tank, clarifiers, and a clear well before passing through three parallel sand filters. Each of the filters operates at 2.0 $l/sec/m^2$ (3.0 gpm/ft^2) during normal operation and at a maximum of 3.1 $l/sec/m^2$ (4.5 gpm/ft^2) when one filter is out of operation. After each use, each filter is backwashed for 5 to 10 min, using 63 l/sec (1000 gpm) of filtered water per filter. The filtered water produced is stored in a 5.7×10^5 l (150,000-gal) tank. This water is supplied to the demineralizer train for treatment before use in the steam cycle. There are two identical demineralizer trains that are each capable of producing the total daily requirement of demineralized water (9.5 l/sec (150 gpm)). The demineralizer train passes the water through a strong-acid cation exchange unit, a strong-base anion unit, and a mixed-bed unit. The treated water is then stored in the condensate storage tank or primary storage tank. Waste management associated with this system is discussed in Section 4.2.6.

4.2.4 Cooling System

4.2.4.1 Intake

Makeup water for the cooling pond is withdrawn from the Kankakee River at the average rate of 2.6 m^3/sec (90.8 cfs) to replace water losses from the pond resulting from evaporation, seepage, and blowdown (see Section 4.2.3). The intake structure is located approximately 600 m (2000 ft) downstream of the confluence of Horse Creek with the Kankakee River. Water will enter the intake structure at a velocity of 0.1 to 0.15 m/sec (0.32 to 0.48 fps) with both units operating. The intake structure along the margin of the Kankakee River is equipped with bar grills and vertical traveling screens to remove debris from the water. As is the case with material collected from the pond intake screens, all debris removed from the screens is disposed of off site by an independent contractor.

4.2.4.2 Cooling Pond

Cooling water for the Braidwood Station will be taken from the cooling pond, circulated through the various cooling systems, and returned to the cooling pond (Figure 4.4). When operating at full power, the plant will produce 1.6×10^{10} Btu/hr of waste heat, which will be transferred to the cooling water circulating at a rate of 90 m^3/sec (3250 cfs) through the condensers. The temperature of the water will be raised about 12C° (22F°) as it passes through the condenser. The closed-cycle cooling pond will serve as a heat sink to dissipate most of this heat to the atmosphere by evaporation.

The cooling pond, which consists of abandoned strip mining pits and excavated areas, has a total surface area of 1030 ha (2537 acres), an average depth of 2.7 m (9.0 ft), and a maximum depth of 14 m (45 ft). A detailed description of the pond can be found in Section 3.4 of the ER-OL. A brief summary for understanding cooling water discharge, circulation, and blowdown discharge follows. Interior dikes were built in the pond to prevent excessive channeling or short-circuiting of the heated water through the pond, thereby ensuring maximum utilization of the pond cooling area. The applicant has determined that some channeling of the heated water does occur in deep or side areas of the pond. Stratification of temperatures and velocities is expected to occur only in those areas that are deeper than the 3-m (10-ft) depth of the discharge. These areas were eliminated in determining the effective area and volume of the pond to be used in evaluating its thermal performance. On the basis of the availability of approximately 80% of the pond's volume for heat exchange, the applicant estimates that the residence time for heated water in the pond, flowing from the point of discharge to the cooling pond to the point of intake from the pond, is 2.9 days.

A smaller cooling pond (36.7 ha (99 acres) at elevation 590 ft MSL) within the main cooling pond was formed by excavating to a depth of 1.8 m (6 ft) below the existing grade or approximately 3.0 m (11 ft) total depth at a normal pond surface elevation of 595 ft MSL. This pond is designed to maintain a 30-day supply of water for the essential cooling system in the event that the larger pond fails. It is estimated that the water loss caused by seepage and evaporation in the pond would amount to 220,180 m^3 (178.5 acre-ft) for such a 30-day period. The pond storage volume is about 703,095 m^3 (520 acre-ft).

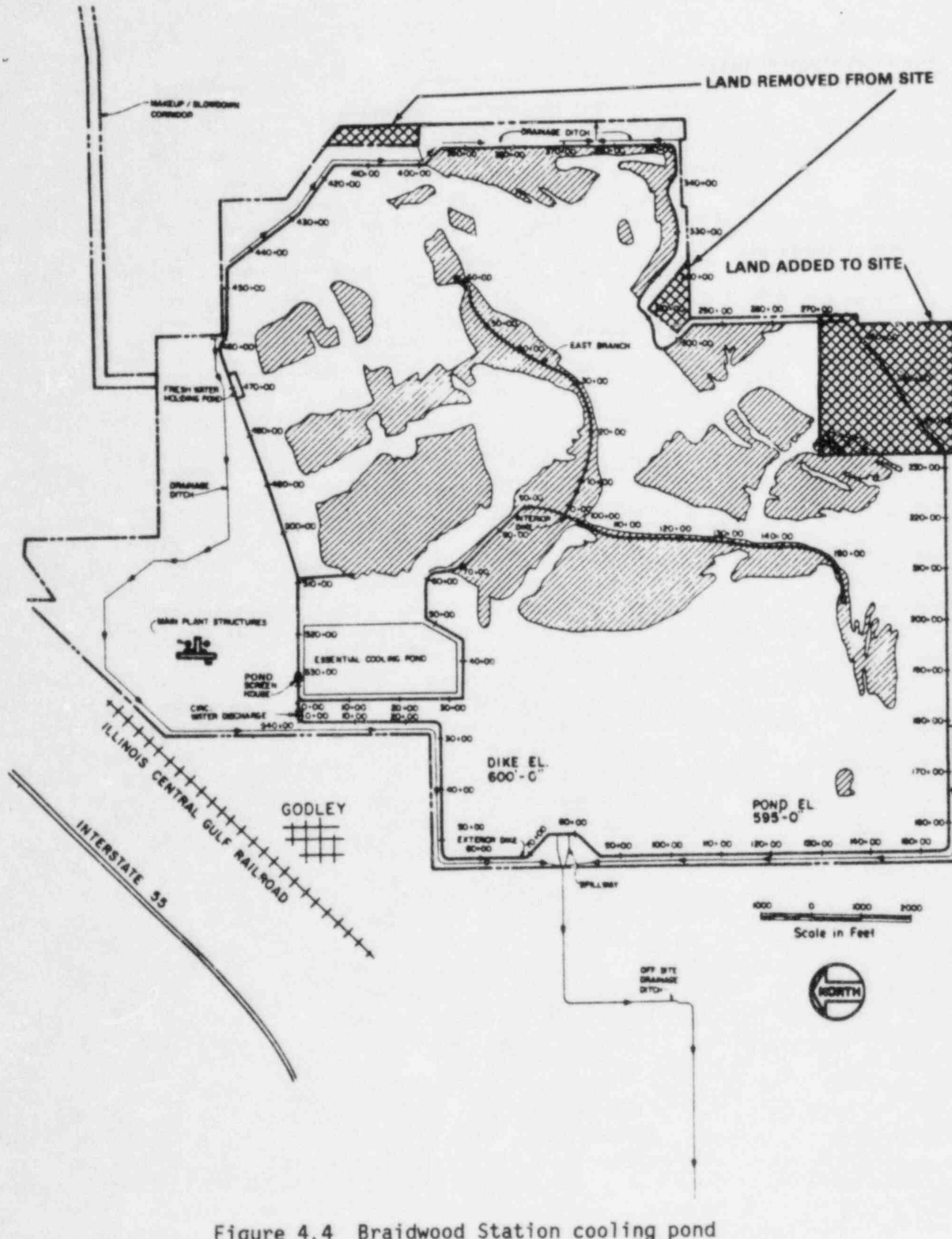

Figure 4.4 Braidwood Station cooling pond
Source: ER-OL Figure QE 290.7-1

Water is drawn from the cooling pond into the condenser cooling water system through the pond screen house by three vertical dry-pit circulating water pumps per unit. Water is drawn into the screen house through bar grills and vertical traveling screens. Debris removed from the screens is disposed of off site by an independent contractor. Water is drawn through two 4.9-m (16-ft)-diameter pipelines to the condensers, then through two other 4.9-m (16-ft)-diameter pipelines to the discharge outfall structure and back into the pond at a continuous flow of 92 m^3/sec (3250 cfs) for the two units.

4.2.4.3 Blowdown

The blowdown from the cooling pond is discharged to the Kankakee River about 150 m (500 ft) downstream of the intake structure. Blowdown is discharged from the blowdown outfall structure via a 80-m (275-ft) riprapped channel to the river. The blowdown outfall structure consists of a box that is wider at the discharge end and is equipped with concrete block energy dissipators to reduce the discharge velocity and minimize erosion. Flow control is provided on the blowdown line so that flow may be terminated when both units are shut down or being refueled (ER-OL Section 3.4). Discharge orientation is perpendicular to the river, and the maximum velocity of the discharge is 1.3 m/sec (4.3 fps). The predicted temperatures of the blowdown range from 9.4°C (49°F) in January to 31°C (88°F) in July. Table 4.1 provides a monthly summary of characteristics of the cooling pond blowdown, outlet discharge, and ambient river temperatures. The average temperature excess of the blowdown above the ambient river temperature is 7C° (12.6F°); the extremes are 3.6°C (6.5°F) in August and 10.1°C (18.1°F) in February. Depending on the temperature of the blowdown and the velocity of the river, the area covered by the 2.8°C (5°F) excess thermal plume produced by the discharge is predicted by the applicant to encompass an area from 400 to 1800 m^2 (0.10 to 0.45 acre) with a maximum area that could be encompassed in May of 3400 m^2 (0.85 acre) (FES-CP Section 3.4.2) (ER-OL Section 5.1).

4.2.5 Radioactive Waste Management System

Under requirements set by 10 CFR 50.34a, an application for a permit to construct a nuclear power reactor must include a preliminary design for 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 in relation to benefits to the public health and safety and other societal and socioeconomic considerations and in relation to the utilization of atomic energy in the public interest. Appendix I to 10 CFR 50 provides numerical guidance on radiation dose design objectives for light-water-cooled nuclear power reactors (LWRs) to meet the requirement that radioactive materials in effluents released to unrestricted areas be kept ALARA.

To comply with the requirements of 10 CFR 50.34a, the applicant provided 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 50. In addition, the applicant 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 reactor operations, including anticipated operational occurrences.

Table 4.1 Updated summary of temperature characteristics of the Braidwood cooling pond and the Kankakee River blowdown

(two nuclear units, 100% load factor)

	Braidwood pond				Kankakee River		
	Current estimates		Previous estimates				
Month	Outlet temperature (°F)	Plant inlet and pond blowdown temperature (°F)	Outlet temperature (°F)	Plant inlet and pond blowdown temperature (°F)	Average temperature (°F)	Average flow rate (cfs)	Fully mixed temperature excess (F°)
January	69	49	74	55	36.5	3840	0.005
February	72	52	75	56	33.9	5368	0.004
March	77	57	80	60	42.1	5869	0.003
April	86	66	88	68	54.1	7375	0.002
May	97	77	97	78	62.1	6288	0.003
June	105	85	106	86	70.9	3196	0.005
July	108	88	111	91	77.2	2444	0.006
August	107	86	111	91	79.5	1409	0.008
September	100	80	104	85	69.1	1531	0.010
October	91	71	96	75	60.1	1823	0.008
November	79	59	85	65	50.5	2121	0.007
December	71	51	77	57	33.5	3889	0.006

Source: ER-OL Table 5.1-4

The staff's detailed evaluation of the radwaste systems and the capability of these systems to meet the requirements of Appendix I was presented in Section 11 of the staff's Safety Evaluation Report (NUREG-1002), which was issued in November 1983. The quantities of radioactive material that the staff calculates will be released from the plant during normal operations, including anticipated operational occurrences, are presented in Appendix D of this statement, along with examples of the calculated doses to individual members of the public and to the general population resulting from these effluent quantities.

The staff's detailed evaluation of the solid radwaste system and its capability to accommodate the solid wastes expected during normal operations, including anticipated operational occurrences, is presented in Chapter 11 of the SER.

As part of the operating license for this facility, 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 facility operates in conformance with the radiation-dose-design objectives of Appendix I.

4.2.6 Nonradioactive Waste Management Systems

4.2.6.1 Demineralizer System Wastes

Regeneration of the ion exchange resin used in the makeup water demineralizer system will produce approximately 2.6×10^5 l (70,095 gal) of waste during each regeneration. Depending on the amount of makeup water used, the regeneration of the spent resins could occur once daily. Each regeneration lasts about 4 hours and requires 1000 kg (2240 lb) of 93% sulfuric acid (H_2SO_4) and 360 kg (792 lb) of 100% sodium hydroxide (NaOH) for regeneration and neutralization. The waste produced during regeneration will be discharged to the cooling pond with the main circulating water system discharge.

4.2.6.2 Filter Backwash Effluent

Sand and carbon filters for the makeup water treatment system are backwashed once daily with filtered water from the storage tank. The backwash water contains dissolved and suspended solids that are collected during the filtering process. The sand filters are backwashed for 10 min at a rate of 0.05 m^3/sec (1.9 cfs), and the carbon filters are backwashed at a rate of 0.02 m^3/sec (0.76 cfs) for 10 min. Discharge from the backwashing operation, which produces approximately 120 m^3/day (30,000 gpd) is routed to the waste treatment facility.

4.2.6.3 Liquid Waste Treatment

The waste treatment system consists of an oil separator, an agitated equalization basin, chemical addition, a separator, and filtration. The clean water effluent is routed to the circulating water system.

Oil removed by the oil separator skimmers flows to a waste oil-holding tank. The oil is disposed of, as necessary, by a licensed contractor. Sludge removed from the system is pumped to sludge drying beds. Underflow from the beds is pumped to the equalization tank. The dried sludge is scraped off and removed by a licensed contractor for disposal in an approved landfill site.

4.2.6.4 Sanitary Wastes

Sanitary wastes collected by means of a sewer system during plant operation will be discharged to an extended aeration system that is designed to handle 57,000 l/day (15,000 gpd). The effluent from the unit will receive tertiary treatment (filtration and recirculation in a packaged unit) and will be chlorinated before discharge. The treated effluent will be combined with the cooling pond blowdown and discharged to the Kankakee River. The effluent contains a maximum of 1 mg/l free chlorine. Approximately 5 x 10^4 l (14,000 gal) of treated effluent will be discharged daily based on approximately 550 operating personnel using approximately 95 l (25 gal) each per day.

4.2.7 Power Transmission System

The transmission lines from the Braidwood station are shown in Figure 4.5. The originally planned 48-km (30-mi) connection to the Joliet Generating Station (FES-CP Figure 3.12) has been eliminated because connecting Braidwood with the two existing 345-kV lines between LaSalle County Generating Station and the East Frankfort substation made it unnecessary (ER-OL response to staff question E290.6). The only new right-of-way for the plant, therefore, is for a new 345-kV line from the plant to the Crete substation, where the line will interconnect with existing lines to the Bloom and Burnham substations. The route traverses approximately 88 km (55 mi), most of which is nearly flat, previously cleared agricultural land. Width of the right-of-way varies from 139 m (455 ft) to 116 m (380 ft). About 12.5 km (7.8 mi) of the new right-of-way could accommodate a future 138/345-kV line (ER-OL Section 3.9.1, Amendment 1). Other segments, totalling 49 km (30 mi) in length, could accommodate a possible future 765-kV line. Structures on the line will be single shaft for tangent and slight angles and lattice steel towers for angles over 13°. No more than 4 towers per km (6 structures per mile) will be used on any segment of the line.

4.3 Project-Related Environmental Descriptions

4.3.1 Hydrology

4.3.1.1 Surface Water

The site for Braidwood Station, Units 1 and 2, is about 32 km (20 mi) south-southwest of the town of Joliet. It is a strip-mined region characterized by many water-filled trenches and ponds. Cooling water for the station is supplied by a cooling pond that covers one of the strip-mined areas. The pond has a normal pool elevation of 595 ft above mean sea level (MSL) with a surface area of 10.27 km^2 (2537 acres or 3.96 mi^2). The water surface area constitutes 75% of the pond's total drainage area of 13.7 km^2 (5.3 mi^2). The pond is contained by dikes with a top elevation of 600 ft MSL except for a small segment of the dike just south of the station, which has a top elevation of 602.5 ft MSL. The main plant area is drained by a storm drain system or weir flow over peripheral roads and railroads to a system of drainage ditches.

4.3.1.1.1 Granary Creek and Crane Creek

Granary Creek joins the Mazon River 1.6 km (1 mi) southwest of the site, and about 6.4 km (4 mi) south of the station facilities at the north end of the pond. Crane Creek is a tributary of Granary Creek. Both creeks have an intermittent water flow and a combined drainage area of about 135 km^2 (52 mi^2). The

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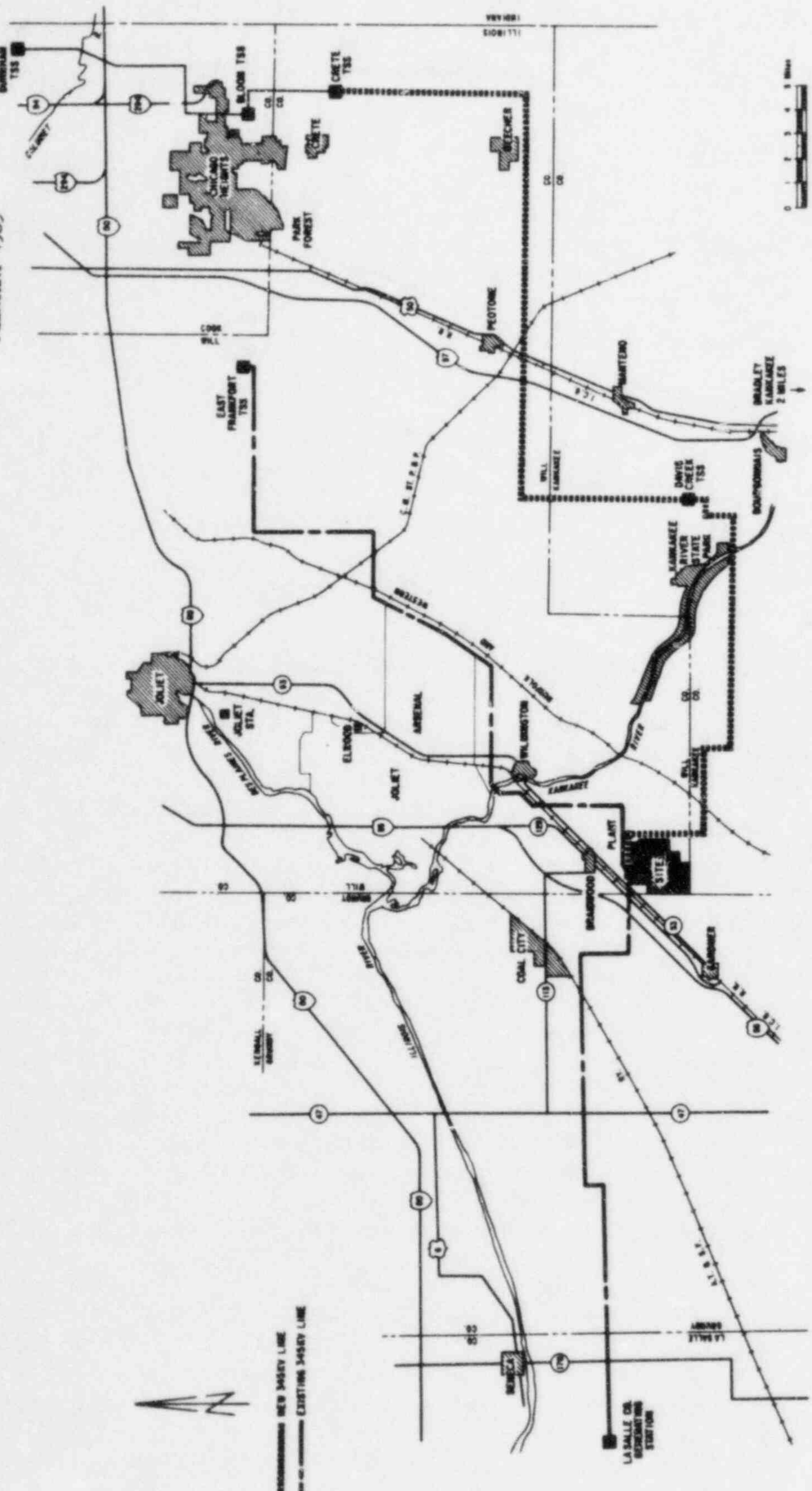

Figure 4.5 Transmission connections
Source: ER-OL Figure 3.9-1

average annual flow is estimated to be about 1.1 m^3/sec (38 cfs) for both creeks at the Kankakee-Grundy County line. The estimated 100-year peak discharge is 90.6 m^3/sec (3200 cfs) at the same location. Figure 4.6 shows the site in relation to the surface hydrologic features.

4.3.1.1.2 Horse Creek

Horse Creek lies 4 km (2.5 mi) east of the site at its closest point. It has a drainage area of 383 km^2 (148 mi^2) at its point of discharge to the Kankakee River at Custer Park. The creek's average annual flow is about 3.1 m^3/sec (110 cfs) and its 100-year flood peak is approximately 260 m^3/sec (9200 cfs) at its mouth.

4.3.1.1.3 Mazon River

The Mazon River lies 8 km (5 mi) west of the north end of the site. A tributary of the Illinois River, the Mazon River has a drainage area of about 570 km^2 (220 mi^2) at Mazon, 3.2 km (2 mi) west of the site. The average annual flow is about 3.8 m^3/sec (134 cfs). The estimated 100-year flood peak is 385 m^3/sec (13,600 cfs).

4.3.1.1.4 Kankakee River

The Kankakee River joins the Des Plaines River about 16 km (10 mi) directly north of the site to form the Illinois River at river mile 273. The Kankakee River Basin is 209 km (130 mi) long and 113 km (70 mi) wide at its widest point. The Kankakee River drains 13,675 km^2 (5280 mi^2). Low ridges of glacial origin define most of the drainage divide. Within Illinois, the Kankakee River is 95 km (59 mi) long and has widths ranging from 61 to 244 m (200 to 800 ft) and depths ranging from 0.3 to 4.6 m (1 to 15 ft). The total fall from the state line to the river mouth is 39 m (127 ft). Channel slopes vary from less than 0.095 m/km (0.5 ft/mi) to over 0.76 m/km (4 ft/mi). The channel slope in the site area is approximately 0.38 m/km (2 ft/mi). Most of the riverbed in Illinois is on or near bedrock. Relatively thin layers of sand and gravel overlie the bedrock with some small areas of silt.

There are two dams on the Kankakee River. One dam is at Wilmington, about 6.4 km (4 mi) downstream from the intake point; the other dam is at Kankakee, about 24.1 km (15 mi) upstream of the intake point. The Wilmington Dam is 3.4 m (11 ft) high and forms a pool 3.2 km (2 mi) long. The Kankakee Dam is 3.7 m (12 ft) high and forms a pool 9.7 km (6 mi) long. Both dams are constructed of solid concrete on bedrock. Neither dam is currently used for power production, although both dams were used for power generation at one time. There are no other control structures on the streams in the Braidwood Station vicinity.

The Kankakee River flow is gauged near Wilmington, 14.1 km (8.8 mi) downstream from Braidwood Station's withdrawal point and 8.8 km (5.5 mi) upstream of the river mouth. The drainage area at the gauge is 13,333 km^2 (5150 mi^2). The average annual flow rate for the Kankakee River at the intake is 112 m^3/sec (3952 cfs). The corresponding river stage is 538 ft MSL and the average velocity is 0.6 m/sec (2.1 ft/sec).

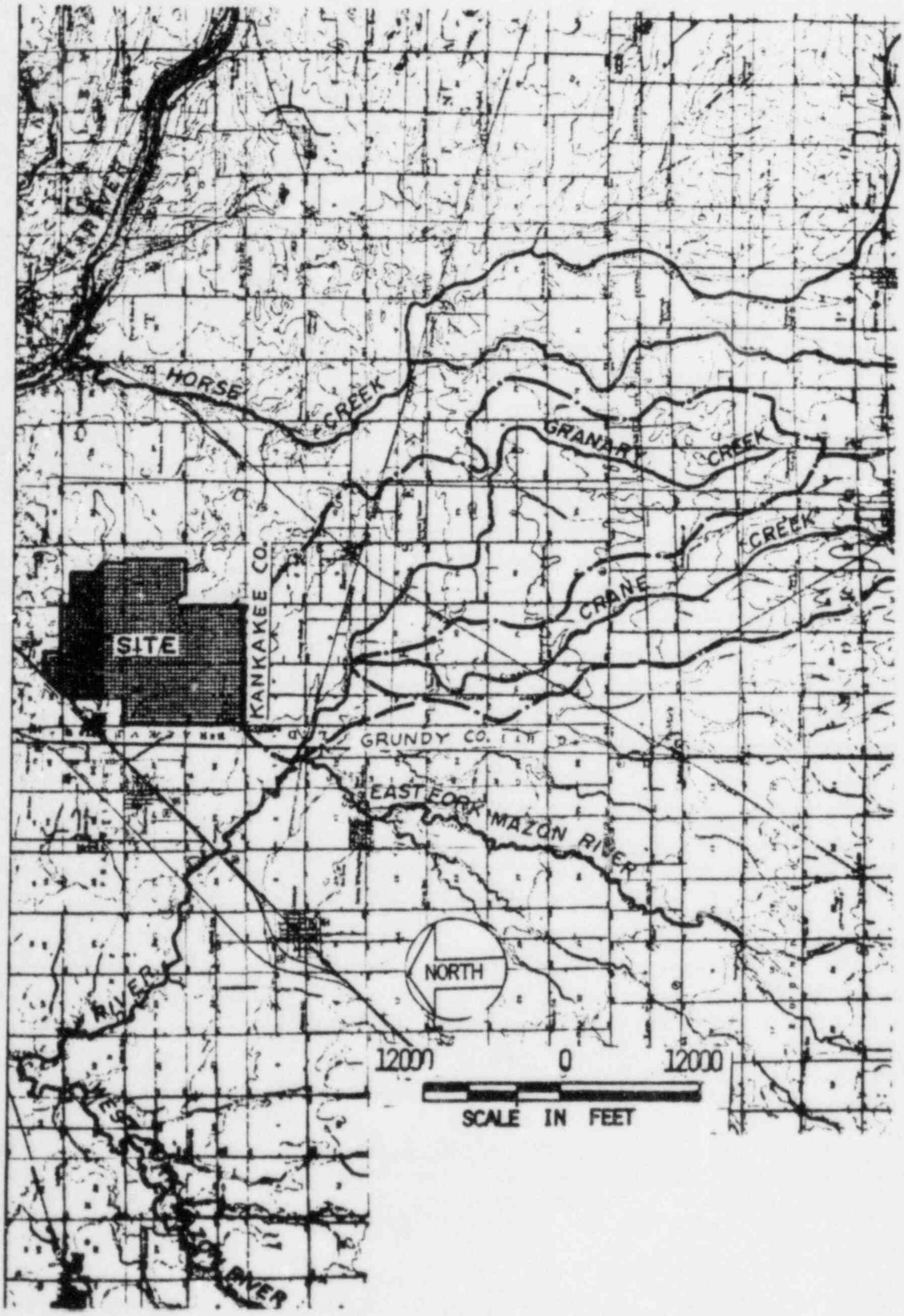

Figure 4.6 Site characteristics
Source: ER-OL Figure 2.4-2

4.3.1.1.5 Effects of Cooling Pond Dike Failure

The cooling pond dikes are designed to be extremely stable structures, with more conservative design criteria than those recommended in the National Dam Safety Program. Most of the exterior dike, except a portion on the west side, is either very low or the general ground level is at or above the top of the dike elevation. The cooling pond has a spillway designed to safely pass all floods up to and including the probable maximum flood (PMF). Sufficient freeboard is provided to contain wind waves on top of the PMF pool level. The upstream face of the dikes is protected with riprap. The dikes are also provided with a slurry trench cutoff. Therefore, it is highly unlikely that the dikes will fail due to heavy precipitation or due to any other natural causes.

The town of Godley is located about 1800 feet north of an east-west cooling pond dike and the town of Braceville is located about 4000 ft west of a north-south cooling pond dike as shown on Figure 4.6A. In order to quantify potential impacts as a result of a dike failure, the staff postulated 20-, 100-, and 200-ft dike breaches at each of the locations shown in Figure 4.6A. Table 4.1A shows the resulting discharge, depth and velocity at the approximate center of the potential flood area at Godley and Braceville.

The characteristics of the dikes make it virtually impossible for an instantaneous breach to occur. The staff therefore assumed that the postulated breach would start as a crack and gradually erode to the postulated breach width. Moreover, if a dike breach should occur, it is likely that it would erode to the 200-ft width postulated or wider because of the large volume of water available. However, wider breach widths (wider than 200 ft) would not result in higher discharges, depths, and velocities because the time required to erode the wider sections would allow the pond level to lower so that there would be insufficient head to generate higher discharges.

The areas downstream of the dike failure sections are mostly farmland and slope in a westerly direction toward the Mazon River. Flows from the postulated breach sections would collect along the embankments for Routes 53 and 129 and the Illinois Central Gulf Railroad and then proceed in a southwesterly direction to the Mazon River.

A discussion of the cross-sections, flow capacity, and discharge rating curves for the Mazon River between its junction with Granary Creek and the old Route 66 bridge, is given in Section 2.4 of the Braidwood FSAR. It can be seen from the rating curve (FSAR Figure 2.4-23) for the Mazon River that it can carry the maximum outflow of 24,500 cfs at an elevation of 575.0 ft MSL which is lower than the ground elevation in the towns of Godley and Braceville.

The community of Godley lies north of the east-west dike that was postulated to fail. The community has about 114 homes and a population of about 373. Most of these homes would be flooded by the dike breach. This community would probably not be affected by the postulated failure of the north-south cooling pond dike.

The community of Braceville lies west of the cooling pond; however, most of the town is northwest of the highway and railroad embankments which will protect it from direct flow from a breached cooling pond-dike. There is a small portion of Braceville, consisting of approximately 31 homes and 11 farmsteads with homes

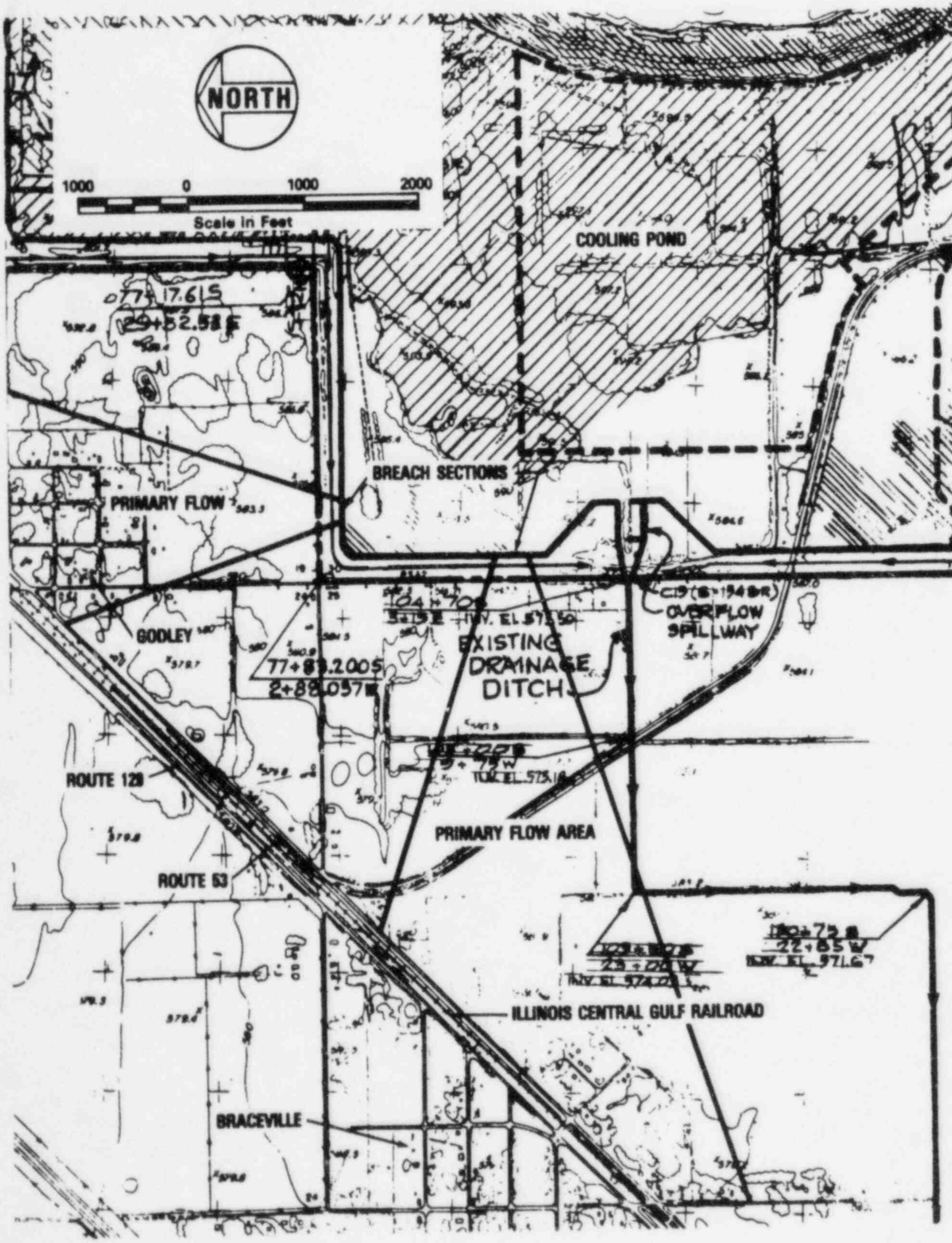

Figure 4.6A Cooling pond dike breach sections and flow areas

Table 4.1A Postulated discharge, depth, and velocity of dike breaches at approximate center of potential flood area at Godley and Braceville

Assumed failure section	Discharge (cfs)	Depth (ft)	Velocity (ft/sec)	Velocity (mph)
Dike south of Godley				
20' breach	2,050	0.2	4.9	3.3
100' breach	8,400	0.8	7.1	4.8
200' breach	16,800	1.2	9.5	6.5
Dike east of Braceville (south of dike spillway)				
20' breach	2,870	0.3	3.0	2.0
100' breach	12,300	0.8	4.9	3.3
200' breach	24,500	1.3	6.3	4.3

and a total population of about 119, located southeast of the railroad tracks, that would be in the flood area from the postulated dike breach in the north-south cooling pond dike. These properties would also probably be affected by the postulated breach in the east-west cooling pond dike, since the flow would follow the railroad embankment to the Mazon River.

Because of the large volume of water that would be released from the cooling pond, in the event of a dike failure, there is a good possibility that the water would pile up against the road and railroad embankments creating a backwater effect that would slightly increase the depths and decrease the velocities shown in Table 4.1A.

4.3.1.2 Floods

4.3.1.2.1 Flood History

The peak discharge, corresponding gauge height, and maximum gauge height (if higher) for each water year (October through September) of record on the Kankakee River near Wilmington are entered in Table 4.2. The gauge is located about 14.1 km (8.8 mi) downstream of the river intake for Braidwood Station. The intercepted drainage area is 13,333 km^2 (5150 mi^2). The gauge datum, or zero point, of the waterstage recorder at Wilmington is at an elevation of 510.86 ft MSL. Peak discharges shown for the water years 1915 through 1933 were derived from gauging records at Custer Park, 0.4 km (0.25 mi) upstream of Horse Creek. This gauge intercepted a drainage area of approximately 12,613 km^2 (4870 mi^2). The flow rates listed in the table were adjusted for the Wilmington site by multiplying the Custer Park discharge by the ratio of the square roots of the drainage areas.

Table 4.2 Floods on the Kankakee River near Wilmington

Water year	Peak flood: Discharge (m³/sec)	(cfs)	Stage[1] (meters)	(ft)	Maximum gauge[1] height (meters)	(ft)
1981	1161	41,000	1.97	6.45		Same[2]
1980	679	24,800	1.79	5.88		Same
1979	1358	48,000			3.68	12.07
1978	863	30,500	2.04	6.68	2.86	9.40
1977	458	16,200	1.38	4.54		Same
1976	923	32,600	2.12	6.95		Same
1975	767	27,100	1.90	6.24		Same
1974	1390	49,100	2.59	8.49	3.90	12.78
1973	940	33,200	2.14	7.03		Same
1972	447	15,800	1.36	4.47		Same
1971	357	12,600	1.24	4.07		Same
1970	1542	54,500	2.87	9.40		Same
1969	841	29,700	2.01	6.59		Same
1968	993	35,100	2.21	7.26	4.23	13.88
1967	549	19,400	1.58	5.18	3.07	10.08
1966	662	23,400	1.75	5.75	2.13	6.99
1965	552	19,500	1.58	5.20		Same
1964	306	10,800	1.13	3.70		Same
1963	623	22,000			2.96	9.72
1962	674	23,800	1.74	5.70	2.04	6.68
1961	481	17,000	1.48	4.86		Same
1960	552	19,500	1.60	5.25	2.78	9.13
1959	849	30,000			2.90	9.52
1958	865	30,600	2.05	6.72	3.02	9.92
1957	2148	75,900	3.47	11.40		Same
1956	458	16,200	1.43	4.70		Same
1955	408	14,400	1.34	4.38	2.17	7.13
1954	425	15,000	1.38	4.53		Same
1953	552	19,500	1.58	5.17		Same
1952	821	29,000	1.97	6.46	2.87	9.43
1951	849	30,000			3.30	10.83
1950	1070	37,800	2.32	7.61	3.47	11.39
1949	473	16,700	1.46	4.80	3.53	11.57
1948	651	23,000	1.73	5.67	1.83	6.00
1947	611	21,600	1.65	5.40		Same
1946	552	19,500	1.58	5.20		
1945	611	21,600	1.65	5.40		
1944	957	33,800	2.16	7.10		
1943	1358	48,000	2.70	8.87	3.07	10.06
1942	1319	46,600	2.65	8.70		
1941	234	8,290	1.00	3.30		
1940	314	11,100	1.20	3.95		

See footnotes at end of table

Table 4.2 (Continued)

Water year	Peak flood Discharge (m³/sec)	(cfs)	Stage[1] (meters)	(ft)	Maximum gauge[1] height (meters)	(ft)
1939	696	24,600	1.83	6.00		
1938	554	19,600	1.62	5.30		
1937	427	15,100	1.42	4.65		
1936	495	17,500	1.52	5.00		
1935	495	17,500	1.52	5.00		
1934	198	7,000				
1933	999	35,300				
1932	300	10,600				
1931	184	6,510				
1930	487	17,200				
1929	702	24,800				
1928	679	24,000				
1927	924	29,100				
1926	591	20,900				
1925	399	14,100				
1924	535	18,900				
1923	464	16,400				
1922	971	34,300				
1921	206	7,270				
1920	741	26,200				
1919	645	22,800				
1918	758	26,600				
1917	441	15,600				
1916	410	14,500				
1915	634	22,400				
1887					5.10	16.73
1883					5.10	16.73

[1]Water surface elevation is obtained by adding stage (ft) to the gauge zero of 510.86 ft MSL.
[2]Same = maximum gauge height is same as peak flood stage gauge height.
Note: Blank spaces indicate that data are not available.

The maximum known discharge near Wilmington was 2149 m³/sec (75,900 cfs) on July 13, 1957. The corresponding gauge height was 3.5 m (11.4 ft) above datum. The maximum stage of 4.23 m (13.88 ft) during the period of record was caused by ice jams. Ice jam floods in 1883 and 1887 reached a stage of 5.1 m (16.73 ft), but the corresponding discharge rates are unknown. All of the maximum stages that were greater than those caused by floods were caused by ice jams.

4.3.1.2.2 Ice Flooding

Ice flooding is common on the Kankakee River, but only the river screen house could be affected by ice flooding. In 17 of the last 34 years of record at the Wilmington gauging station, the highest annual water levels were caused by ice jams. The 1866 ice jam generated a stage of about el 553 ft MSL near Horse Creek. The 1883 ice jam destroyed the railroad bridge at Custer Park. It also completely destroyed the upper dam at Wilmington. Just before the Wilmington Dam failure, the jam was reportedly 20 ft higher than the crest elevation of 545.0 ft MSL (the present crest is at 530.5 ft MSL). The maximum elevation upstream of Custer Park, 554.5 ft MSL on February 15, 1959, was caused by an ice jam. Electrical equipment in the river screen house is above the historic ice flooding level; therefore, ice flooding is not expected to interfere with normal plant operation.

4.3.1.3 Low Flows

4.3.1.3.1 Historical Low Flow

Monthly average flow rates for the Kankakee River at the intake for the period 1941 to 1976 are given in Table 4.3. The lowest annual flow occurred during the 1964 water year and was 39.8 m^3/sec (1407 cfs). This table also lists the monthly mean flows for 1964. The historical daily low flow at the intake was estimated at 5.6 m^3/sec (198 cfs).

Table 4.3 Kankakee River flow characteristics at the intake

	Average flow (1941-1976)		Monthly mean flow (1964)	
Month	m^3/sec)	(cfs)	(m^3/sec)	(cfs)
October	52.0	1836	14.2	500
November	72.1	2547	18.1	638
December	95.7	3379	17.5	618
January	129.9	4586	22.3	787
February	158.0	5579	25.1	885
March	187.6	6625	45.6	1610
April	211.4	7463	123.4	4357
May	187.1	6608	67.1	2371
June	137.3	4847	56.6	1997
July	87.6	3094	45.6	1609
August	45.7	1613	16.2	572
September	38.3	1353	13.7	483

Low flow elevations in the Kankakee River at the Braidwood Station site are controlled by a rock ledge that lies across the river between the Resthaven and Lakewood shores, 2347 m (7700 ft) upstream of the Wilmington Dam. The ledge acts as a dam, creating a pool of water that reaches upstream to Custer Park, approximately 1.6 km (1 mi) upstream of the intake. Under low flow conditions, the rock ledge, which is at el 534 ft MSL, maintains a minimum water elevation of 534 ft MSL.

Low flow rates and their corresponding frequencies for the Kankakee River at the intake (see Table 4.4) were derived from the Wilmington gauge statistical summary based on the record from 1916 to 1976. The estimated 7-day, 10-year low flow at the intake is 12.5 m^3/sec (442 cfs).

Table 4.4 Low flow rates and frequencies for the Kankakee River at the intake

	Mean discharge in m^3/sec for flow frequency of*			
Duration	10-year	20-year	50-year	100-year
1-day	10.7 (378)	9.4 (332)	8.2 (288)	7.4 (262)
3-day	11.8 (415)	10.4 (369)	9.1 (323)	8.4 (296)
7-day	12.5 (440)	11.1 (393)	9.9 (348)	9.1 (321)
14-day	13.0 (460)	11.7 (412)	10.4 (366)	9.6 (339)
30-day	14.0 (494)	12.7 (449)	11.6 (408)	10.9 (385)
60-day	15.6 (552)	14.2 (503)	13.0 (460)	12.3 (436)
90-day	17.2 (609)	15.3 (541)	13.5 (478)	12.5 (443)
120-day	18.9 (667)	16.5 (582)	14.3 (504)	13.0 (460)

*Values in parentheses are cfs.

4.3.1.4 Ground Water

Ground water will not be used at the Braidwood Station during station operation. All station water requirements will be met by the Kankakee River. The use of ground water previously had been planned to fulfill potable water requirements, but the Kankakee River was chosen when poor quality water was withdrawn from a deep well drilled to supply construction water. Ground water from this well was used for construction purposes only.

The site area is underlain by six hydrogeologic units consisting of aquifers and aquitards (confining beds). Characteristics of the units are listed in Figure 4.7.

In the vicinity of the site, Quaternary-age Eolian sand, Lacustrine sand, and till overlie the bedrock. The Eolian and Lacustrine sands are predominantly fine to medium grained and form a water-table sand aquifer. Many domestic water supplies in the area are obtained from the sand aquifer with well points (shallow-driven wells). The underlying glacial drift ranges from clay to sand

SYSTEM	SERIES	GROUP OR FORMATION	HYDROGEOLOGIC UNIT		DESCRIPTION	HYDROGEOLOGIC CHARACTERISTICS
QUATERNARY	Pleistocene	Parkland Sand	Eolian sand	Sand Aquifer	Silty fine sand	Ground water occurs in the sand formations under water table conditions, perched on the underlying till. Ground water also occurs in the outwash layers within the till. The small thickness of the upper sand and the discontinuous nature of the outwash preclude extensive development of the sand aquifer or the aquifer within the till.
		Equality Formation	Lacustrine sand		Fine to medium sand with trace to little silt	
		Wedron Formation	Till	Aquitard	Silty clay, clayey silt, and sandy silt with interspersed sand and gravel, some discontinuous layers of gravelly sand or sandy gravel.	
PENNSYLVANIAN	Desmoinesian	Carbondale Formation	Pennsylvanian siltstone	Aquitard	Principally siltstone, with some interbedded shale, underclay, sandstone, limestone, and coal	Ground water occurs primarily in thin sandstone beds and occasionally in joints in thin limestone beds. Ground water occurs under leaky artesian conditions. The high proportion of siltstone makes the Pennsylvanian strata generally unfavorable as an aquifer. Yields are low and are suitable only for domestic and farm purposes.
		Spoon Formation				
SILURIAN	Alexandrian	Undifferentiated	Silurian dolomites	Shallow Dolomite Aquifer	Dolomite with thin shale partings, and dolomitic siltstone	Ground water occurs primarily in joints in the dolomites and limestones under leaky artesian conditions. The shales are generally not water yielding and act as confining beds between the shallow and deep aquifers.
ORDOVICIAN	Cincinnatian	Maquoketa Shale Group	Maquoketa shale	Aquitard	Silty dolomitic shale at top, silty to pure limestone, siltstone and shale at base	
	Champlainian	Galena Group	Galena-Platteville dolomites	Cambrian-Ordovician Aquifer	Dolomite and limestone, locally cherty, sandy at base, shale partings	Ground water occurs under leaky artesian conditions in the sandstones and in joints in the dolomites. Yields are variable and depend upon which units are open to the well.
		Platteville Group				
		Ancell Group	Glenwood-St. Peter sandstone		Sandstone, shale at top, little dolomite, locally cherty at base	
	Canadian	Prairie du Chien Group	Prairie du Chien, Eminence, Potosi and Franconia dolomites		Sandy dolomite, dolomitic sandstone, cherty at top, interbedded shale in lower part	
CAMBRIAN	Croixan	Eminence Formation				In terms of the total yield of a well penetrating the entire thickness of the Cambrian-Ordovician Aquifer, the Glenwood-St. Peter sandstone supplies about 15 percent, the Prairie du Chien, Eminence, Potosi and Franconia dolomites collectively supply about 35 percent, and the Ironton-Galesville sandstone supplies about 50 percent.
		Potosi Dolomite				
		Franconia Formation				
		Ironton Sandstone	Ironton-Galesville sandstone		Sandstone, upper part dolomite	
		Galesville Sandstone				
		Eau Claire Formation	Eau Claire shale (upper and middle beds)	Aquitard	Shales, dolomites and shaly dolomitic sandstone	Insignificant amounts of ground water may occur in joints. These beds act as a confining layer between the Cambrian-Ordovician Aquifer and the Mt. Simon Aquifer.
		Mt. Simon Sandstone	Eau Claire and Mt. Simon sandstones	Mt. Simon Aquifer	Sandstone	Ground water occurs under leaky artesian conditions. Ground water in this aquifer is too highly mineralized for most purposes. Adequate supplies for municipal and industrial use are more easily obtained from shallower aquifers.

Figure 4.7 Stratigraphic units and their hydrogeologic characteristics
Source: ER-OL Figure 2.4-11

and gravel, but is predominantly clayey till. In certain places, particularly in the northern part of the area, a discontinuous outwash deposit consisting mainly of silty sand and gravel serves as an aquifer within the glacial drift.

The sand aquifer and the aquifer in the glacial drift are thin or absent in the southern part of the area and have a combined average thickness of less than 6.1 m (20 ft) in the northern part. Analysis of boreholes on the site indicates that the thickness of the Quaternary deposits ranges from 7.92 to 18.9 m (26 to 62 ft), averaging approximately 12.8 m (42 ft). The saturated thickness of the sand aquifer at the site ranges from 0 to about 9.14 m (0 to 30 ft) and averages about 4.27 m (14 ft). The saturated thickness of the aquifer within the glacial drift ranges from 0 to 10.67 m (0 to 35 ft) and averages only about 1.52 m (5 ft) where it is present.

Ground water in the sand aquifer and the aquifer within the glacial drift occurs under water table conditions. These aquifers are recharged by precipitation. Ground water is discharged from these aquifers to surface streams and strip-mine pits, to the underlying bedrock, and to pumping wells. Reported well yields are suitable only for domestic or farm purposes, ranging from 7.57 to 18.93 l/min (2 to 5 gpm).

The Quaternary deposits are underlain by Pennsylvanian bedrock composed of siltstone, shale, sandstone, clay, limestone, and coal. Strip mining has removed the overlying units to the bottom of a coal horizon in the mined-out areas. The Pennsylvanian strata may locally yield up to 76 l/min (20 gpm) from interbedded sandstones, but they are essentially aquitards, as are the underlying Maquoketa shales. Silurian dolomite, which lies below the Pennsylvanian strata and forms a shallow dolomite aquifer northeast and east of the site, was encountered in only two site borings.

The most important aquifer in the region is the Cambrian-Ordovician Aquifer, made up of all bedrock between the shales of the Maquoketa Shale Group and the Eau Claire Formation. The Cambrian-Ordovician Aquifer is composed of the following strata, in descending order: the Ordovician-aged Galena, Platteville, Ancell (Glenwood - St. Peter Sandstone), and Prairie du Chien Groups, and the Cambrian-aged Eminence Formation, Potosi Dolomite, Franconia Formation, Ironton Sandstone, and Galesville Sandstone.

The shales of the Maquoketa Shale Group act as a confining bed between the overlying shallow dolomite aquifer, where present, and the underlying Cambrian-Ordovician Aquifer. Ground water in the Cambrian-Ordovician Aquifer occurs under artesian pressure. Available data indicate that, on a regional basis, the entire sequence of strata, from the top of the Galena-Platteville dolomites to the top of the Eau Claire shale beds, behaves hydraulically as one aquifer. In places, however, pressure heads between the water-bearing units differ, and the hydraulic connection is imperfect. The Cambrian-Ordovician Aquifer is recharged in northern Illinois.

The Eau Claire shales separate the Cambrian-Ordovician Aquifer from the Mt. Simon Aquifer. The Mt. Simon Aquifer includes sandstones in the lower portion of the Eau Claire Formation and the Mt. Simon Sandstone. Based on available well logs, the Mt. Simon Sandstone is anticipated at a depth of about 731.5 m (2400 ft) below the surface at the plant site. Few wells in the regional area extend to the Mt. Simon Aquifer, because adequate ground water supplies are more easily obtained from shallower aquifers, and the ground water may be too highly mineralized for most purposes.

Permeability values for the various hydrogeologic units at the site were determined from laboratory tests on soil samples, water pressure tests in the bedrock, and field permeability tests conducted in the essential service cooling pond area.

Laboratory permeability test results show that the permeability of the sand deposits range from 3.66×10^{-4} cm/sec to 7.32×10^{-2} cm/sec. The average permeability of the till was found to be 2.6×10^{-6} cm/sec. For discontinuous, well-graded gravel and silts within the glacial drift at a depth of 10.8 to 12.4 m (35.5 to 40.5 ft), the permeability was found to average 8.4×10^{-4} cm/sec.

Water pressure tests were performed in the Pennsylvanian-age Carbondale and Spoon Formations and in the underlying Brainard Shale and Fort Atkinson Limestone of the Ordovician-age Maquoketa Shale Group. No water losses (indicating no or low permeability) were recorded in 20% and 50% of the tested intervals in the Carbondale and Spoon Formations, respectively, or in 40% of the tested intervals in the Maquoketa Shale Group. In those intervals in which water losses were recorded, permeabilities ranged from 1.93×10^{-6} to 4.92×10^{-4} cm/sec in the Carbondale Formation, 1.76×10^{-6} to 6.20×10^{-4} cm/sec in the Spoon Formation, and 2.33×10^{-6} to 4.58×10^{-5} cm/sec in the Maquoketa Shale Group. These permeability values probably reflect secondary permeability along infrequent joints and fractures within these formations rather than intergranular, primary permeability of the rock mass. In addition, the upper tested intervals of the boreholes generally had higher permeabilities than those at greater depths, probably reflecting the effects of weathering on the strata. Ground water levels at the time the borings were drilled in the plant area (January 1973 to April 1973) were at approximately el 595 ft MSL.

Seepage from the sand aquifer into the power block excavation was limited by a slurry trench installed from approximately el 595 ft MSL to 0.6 m (2 ft) into the till underlying the sand aquifer. The combined quantities of seepage and precipitation were controlled using a sump pump. Eight observation wells were installed in the glacial drift around the power block excavation and outside the slurry trench in late 1975 to monitor ground water levels during construction. These observation wells were installed in pairs at varying distances away from the slurry trench. During the 3-year period 1976 through 1978, ground water levels in individual wells fluctuated from 3.1 to 6.4 m (10 to 21 ft) with upper and lower maximums of 595.5 and 572 ft MSL, respectively. For approximately 77% of the measurements, ground water levels were higher in the outer observation well of each pair, indicating some decline of ground water levels immediately adjacent to the slurry trench as a result of seepage into the excavation. The average difference in ground water levels between pairs of observation wells was 21.3 cm (0.7 ft). The slight decline in ground water levels and the small volume of seepage into the excavation indicate that ground water levels in the sand aquifer were affected only in the immediate proximity of the power block excavation.

4.3.1.5 Water Use

4.3.1.5.1 Surface Water

The average net loss of water from the Kankakee River resulting from operation of the Braidwood Station is estimated by the applicant to be 1.35 m^3/sec (47.6 cfs). This water loss is about 1% of the average flow and about 11% of the 7-day, 10-year recurrence low flow of the river at the station's intake.

Future uses of Kankakee River water are not expected to significantly lower minimum flows. It is predicted that the urban Kankakee area will gradually increase its withdrawal rate for public and industrial water supply, but that most of the supply will return to the river as wastewater. The City of Joliet may use the Kankakee River to supplement its water supply in the future. However, the withdrawal point would probably be downstream from the plant intake. Historical data indicate that low flow levels have increased irregularly since the lowest recorded flow at the Wilmington gauge occurred 47 years ago. The low flow frequency and duration information for the Kankakee River at the river screen house is shown in Table 4.4. For low-flow conditions in the Kankakee River, plant withdrawals will result in only negligible changes in water surface levels at the intake. For a river flow of 15.9 m^3/sec (532.8 cfs) (the minimum withdrawal flow plus average makeup), the change in water level at the intake would be less than 3 cm (0.1 ft). Table 4.5 shows the percentage of Kankakee River low flows required to arrive at an average net use of 1.35 m^3/sec (47.6 cfs) under several low flow conditions.

Table 4.5 Percent of Kankakee River flow required for an average net use of 1.35 m^3/sec (47.6 cfs)

Flow duration frequency	Percent
1-day 10-year low	12.5
3-day 10-year low	11.4
7-day 10-year low	10.8
30-day 10-year low	9.6
Average annual flow	1.2

4.3.1.5.2 Ground Water

Ground water will not be used at the Braidwood Station during station operation. All station water requirements will be met by the Kankakee River.

Seepage from the cooling pond should have little effect on ground water levels around the site. Seepage to the Cambrian-Ordovician Aquifer is limited by the relatively impermeable Pennsylvanian-age shales of the Carbondale and Spoon Formations and the Ordovician-age shales of the Maquoketa Shale Group. Seepage to the sand aquifer is limited by a slurry trench cutoff that extends all the way through the cooling pond dike to 0.6 m (2 ft) into the glacial till or to the Pennsylvanian-age bedrock where till is missing. The slurry trench serves as a continuous seepage cutoff around the entire pond perimeter.

During design evaluation for the slurry trench cutoff, a prototype slurry-trench test section was constructed in the cooling pond area. The test consisted of several pumping tests to determine the average permeability of the inplace soil-bentonite and cement-bentonite backfill materials. Test results were used in designing the slurry trench cutoff and the cooling pond. The maximum permeability values determined for the inplace slurry-trench test section were as follows:

Soil-bentonite (using natural, onsite soil)	6×10^{-7} cm/sec
Cement-bentonite	4.4×10^{-6} cm/sec

On the basis of these permeability values, the amount of seepage through the entire length of the cooling pond's exterior dike was estimated to be less than 0.14 m^3/sec (5 cfs). Considering the approximately 16-km (10-mi) perimeter of the cooling pond, the effect on local ground water levels will be negligible and will be restricted to the immediate perimeter of the cooling pond.

4.3.2 Water Quality

The water quality of the Kankakee River has been rated "excellent" by the Illinois Natural History Survey Board (FES-CP). Larimore and Skelly (1981) found the water quality of the river to be good; however, cadmium and manganese were found to exceed U.S. Environmental Protection Agency (EPA) (1976) standards as did dieldrin and PCBs. Analysis of FES-CP Table 2.2 and ER-OL Tables 2.2-5 through 2.2-17 shows that overall chemical and trace element levels in the river are within water criteria levels for protection of aquatic life (EPA) and state water quality standards (see ER-OL Table 2.2-14).

Comparison of ER-OL Tables 2.4-9 and 2.4-10, which present both water quality data for the Kankakee River for the period of record and corresponding state standards, shows that ammonia exceeded state standards during the period reported in 1971 and iron exceeded standards during the period of record in ER-OL Table 2.4-10 (1957 through 1961) and in 1976 (U.S. Geological Survey, 1976). The high levels of ammonia are probably from upstream agricultural runoff (ER-OL) and should have no adverse effects on water quality or aquatic biota. The high levels of iron (probably resulting, in part, from coal mining in the area) in the presence of dissolved oxygen can form hydroxide deposits, which can interfere with bottom-dwelling organisms (EPA, 1976). High levels of iron (above 0.3 mg/l) affect water taste and cause staining of plumbing fixtures and clothes during washing (EPA, 1976). The average total dissolved solids concentration is 362 mg/l and the maximum of record is 530 mg/l; the stream water quality standard is 1000 mg/l. The concentration of total dissolved solids in the blowdown discharge will average 967 mg/l (ER-OL Section 3.3.1). See Section 5.3 for further discussion of river water quality.

Suspended solids carried in makeup water from the Kankakee River will result in loss of some storage capacity of both the cooling pond and essential cooling pond. The limited area for runoff into the pond will result in negligible amounts of sediment from this source. The estimated rate of sediment deposition from the makeup water intake is estimated to be 470 m^3 (0.38 acre-ft) per year.

Over a 40-year station lifespan, this would amount to 18,800 m^3 (15.3 acre-ft) or 2.7% of the capacity of the essential cooling pond (0.08% of the estimated effective volume of the entire cooling pond) (ER-OL Section 2.4.1.4.2). Only part of the sediment deposition is expected to occur in the essential cooling pond. The applicant will conduct periodic surveys to determine sediment deposition and any changes in the pond bottom elevation (ER-OL Section 2.4.1.4.2).

Studies were conducted by the applicant to determine the potential chemical loading of the cooling pond from leaching of surface and subsurface soils. Comparison of ER-OL Tables 2.4-6 and 2.4-7 with ER-OL Table 3.6-1 shows that levels of the leached soil constituents are less than those occurring in the Kankakee River water and should have an insignificant effect on the water quality of the cooling pond.

The predicted concentrations of phosphorous (1.03 mg/l) and nitrogen (8.08 mg/l) in the cooling pond indicate a potential for development of nuisance algal conditions (see Section 5.5.2.1).

4.3.3 Meteorology

The discussion of the general climatology of the site and vicinity in the FES-CP remains unchanged, except for the following:

After the FES-CP was issued, the applicant installed an onsite meteorological measurement system. This system has been in continuous operation since it was installed in November 1973. For the 4-year period, 1979 through 1982, data from the 34-ft measurement indicated prevailing winds from the south and south-southwest, which occurred approximately 12 and 8% of the time, respectively, with winds from the west, west-northwest, and northwest occurring approximately 7% of the time in each of these sectors.

4.3.4 Terrestrial and Aquatic Resources

4.3.4.1 Terrestrial Ecology

FES-CP Sections 2.7.1.1 and 2.7.1.2 contain the results of terrestrial ecology studies conducted in the fall of 1972 and winter and spring of 1973 only. The ER-OL provides the results of the terrestrial ecology studies conducted in the summer of 1973 and from March 1974 through January 1975. The general description of the terrestrial ecology of the Braidwood site presented in the FES-CP remain valid. The additional terrestrial ecology studies mentioned above increased the number of species in all major groups (e.g., plants, birds, and mammals) found to inhabit the Braidwood site. Lists of these species and detailed descriptions of the additional surveys are given in ER-OL Section 2.2.2.

At the time of the most recent staff site visit (September 1983), terrestrial habitat on the site consisted of the partially revegetated dikes, mine spoil banks and islands in various stages of revegetation, fallow and formerly cultivated agricultural fields, and woodlands. About 87% (77 km, 48 mi) of the habitats along the 88-km (55-mi) transmission line right-of-way consist of cleared farmland. About 52 ha (129 acres) of the remaining area are open woodland and hedgerows, and 42 ha (105 acres) are riparian woodlands. About 3 ha (7.5 acres) of riparian habitat are located at the Kankakee River crossing located about 11 km (7 mi) north of Kankakee, Illinois (ER-OL Section 3.9); another 16 ha (40 acres) consist of small, discontinuous marshlands that are spanned by the transmission lines (ER-OL Section 3.9.8).

4.3.4.2 Aquatic Resources

The aquatic biota of the Kankakee River and Horse Creek in the site vicinity were sampled during 1974-1975, 1977-1979, and 1981-1982 as part of the baseline and/or construction phase aquatic monitoring program to supplement observations made during the 1972 through 1973 monitoring program. The sampling transects in the Kankakee River and Horse Creek were located in areas potentially influenced by the intake and discharge of the Braidwood Station (see Figure 4.8). The results of the 1974-1975 and 1977-1981 monitoring programs are discussed in detail in Sections 2.2.1 and 4.1, respectively, of the ER-OL. A brief discussion of the baseline monitoring program and the results of the 1981 and 1982 monitoring programs, as an update to the FES-CP, are presented in this section.

A total of five phytoplankton phyla were collected during the 1974-1975 program and representatives of three phyla were collected during construction monitoring. Over 200 species were identified, with most of the species belonging to two phyla: Chlorophyta (green algae) and Bacillariophyta (diatoms). Diatoms were the most numerous of the algal groups for both the Kankakee River and Horse Creek. The periphyton community was dominated by over 400 species of diatoms. Forty-five zooplankton species belonging to nine phyla were identified. Especially common were species of the family Cyclopidae and the order Cladocera. Station 5L showed the highest productivity and Station 4R showed the least on the basis of accumulated biomass (Larimore and Skelly, 1981). The most productive years for phytoplankton during the monitoring study were 1977 and 1978 (Larimore and Skelly, 1981).

Benthic macroinvertebrates collected from the Kankakee River and Horse Creek were dominated by oligochaete worms and by dipterans belonging to the family Chironomidae. Benthic macroinvertebrates collected from both streams by dredging and artificial substrates indicated the presence of a diverse benthic community, which exhibited seasonal and local fluctuations in composition and abundance. Changes in community structure and species abundance during the monitoring study were the result of natural causes particularly erosion (Larimore and Skelly, 1981).

Fifteen species of freshwater mussels and the Asiatic clam, Corbicula fluminea, were collected from the Kankakee River in the vicinity of the Braidwood Station in 1981. The predominant species of mussel in the study area was the musket, Actinonaias carimata. Greatest densities of mussels occurred in the riffle section of the study area, which was shallow (0.6-1.2 m (2-4 ft) in depth) and had a fast current velocity (Ecological Analysts, Inc., 1982). One live Asiatic clam was collected in 1981, and numerous fresh dead shells were observed (Ecological Analysts, Inc., 1982). In 1975, the upstream range of this species in the Illinois River was reported near Morris, Illinois (Thompson and Sparks, 1977).

Sparse to moderate macrophyte development was observed in the near-shore areas; 12 macrophyte species were collected from the Kankakee River. Water dock (Rumex verticillatus) was the dominant component of the community in May, and water willow (Justicia americana) was the dominant plant in the river in August.

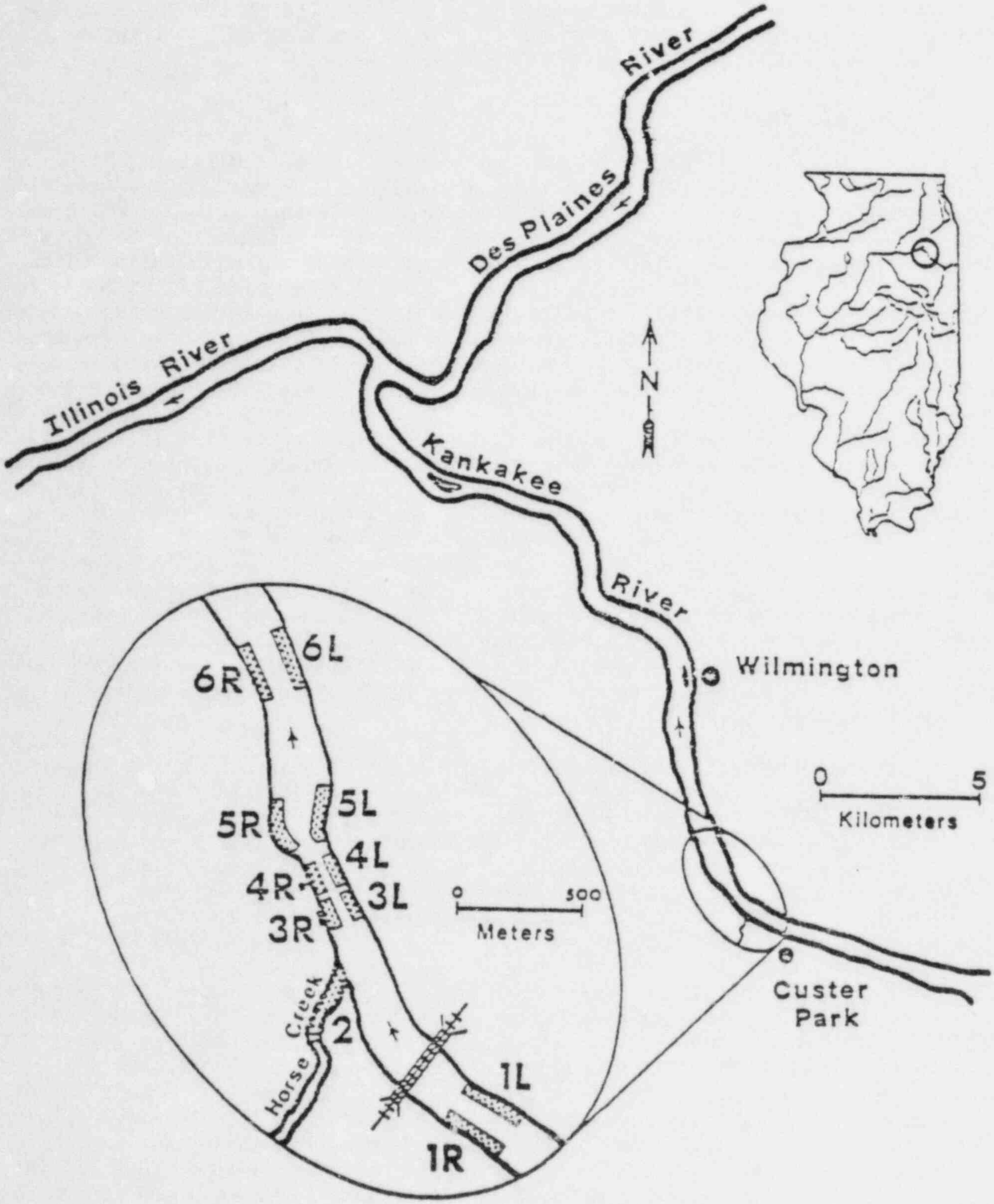

Figure 4.8 Locations of sampling stations within the Braidwood aquatic monitoring area of the Kankakee River
Source: Larimore and Skelly, 1982b, Figure 1

Seven major macrophyte beds were identified in the Kankakee River: four were water willow, one was water dock, and two were combinations of water dock, love grass, and arrowhead.

A total of 2221 fish representing 46 species was collected from the Kankakee River and Horse Creek during the 1974-1975 program. Thirty-eight species were collected from the Kankakee River. The majority of the fish belonged to the families Cyprinidae (minnows, shiners, and carp), Centrarchidae (sunfish), and Catostomidae (suckers). These families, respectively, represented 33%, 24%, and 14% of the total number of species collected. Other families represented were Aphredoderidae (pirate perch), Atherinidae (silversides), Clupeidae (herring), Esocidae (pike), Ictaluridae (catfish), Lepisosteidae (gar), Percidae (perch), and Salmonidae (trout). The numerically more abundant species (accounting for 5% or more of the total collection) in the Kankakee River were bluegill, rock bass, mimic shiner, spotfin shiner, shorthead redhorse, white crappie, and spottail shiner. Table 4.6 presents a summary of numbers, percent composition, biomass, and percent biomass of the fish species collected in the Kankakee River and Horse Creek in the vicinity of the plant during 1982. Collection of the central mudminnow (Umbra limi) in 1982 represented a new addition to the list of species collected from the monitoring area (Larimore and Skelly, 1982b). Results of the 1982 survey showed a reduction in both numbers and biomass compared with those in previous years, probably as the result of low-flow conditions during 1982.

Table 4.6 Total catch for each species collected from the Kankakee River and Horse Creek during August 1982

Species	Total			
	No.	%No.	Wt(g)	%Wt
Longnose gar	2	0.2	6.82	0.0
Bowfin	2	0.2	1,510.00	0.7
Gizzard shad	66	6.2	5,605.28	2.5
Central mudminnow	1	0.1	4.44	0.0
Grass pickerel	1	0.1	2.00	0.0
Northern pike	10	0.9	6,987.00	3.2
Stoneroller	1	0.1	0.96	0.0
Carp	49	4.6	59,589.00	26.9
Silverjaw minnow	1	0.1	1.44	0.0
Golden shiner	6	0.6	20.20	0.0
Pallid shiner	2	0.2	0.62	0.0
Striped shiner	83	7.7	65.93	0.0
Rosyface shiner	70	6.5	30.70	0.0
Spotfin shiner	41	3.8	147.35	0.1
Sand shiner	21	2.0	13.31	0.0
Redfin shiner	8	0.7	8.22	0.0
Mimic shiner	4	0.4	4.35	0.0
Suckermouth minnow	12	1.1	7.61	0.0
Unidentified minnows	2	0.2	0.10	0.0
Bluntnose minnow	47	4.4	55.80	0.0

Table 4.6 (Continued)

Species	Total			
	No.	%No.	Wt(g)	%Wt
Bullhead minnow	14	1.3	16.87	0.0
Creek chub	1	0.1	0.54	0.0
Quillback	43	4.0	20,665.00	9.3
White sucker	8	0.7	3,119.59	1.4
Northern hogsucker	18	1.7	6,793.94	3.1
Bigmouth buffalo	2	0.2	1,070.00	0.5
Silver redhorse	46	4.3	39,062.63	17.6
River redhorse	10	0.9	9,143.00	4.1
Black redhorse	3	0.3	755.00	0.3
Golden redhorse	83	7.7	26,005.00	11.7
Shorthead redhorse	22	2.1	10,325.00	4.7
Unidentified redhorse	2	0.2	1.90	0.0
Yellow bullhead	1	0.1	60.00	0.0
Channel catfish	1	0.1	450.00	0.2
Stonecat	1	0.1	20.00	0.0
Blackstripe topminnow	1	0.1	1.36	0.0
Rock bass	43	4.0	3,446.00	1.6
Green sunfish	75	7.0	1,377.50	0.6
Orangespotted sunfish	19	1.8	114.12	0.1
Bluegill	10	0.9	199.00	0.1
Longear sunfish	50	4.7	1,029.54	0.5
Green sunfish and bluegill	3	0.3	79.00	0.0
Unidentified hybrid sunfish	1	0.1	5.31	0.0
Unidentified sunfish	13	1.2	2.58	0.0
Smallmouth bass	100	9.3	22,228.32	10.0
Largemouth bass	26	2.4	280.66	0.1
White crappie	11	1.0	994.95	0.4
Black crappie	10	0.9	32.96	0.0
Johnny darter	20	1.9	7.79	0.0
Blackside darter	5	0.5	3.63	0.0
Walleye	1	0.1	5.47	0.0
All species	1,072		221,357.79	

Source: Modified from Table 1, Larimore and Skelly, 1982b

Sampling for fish eggs and larvae was performed as part of the 1974-1975 monitoring program. Horse Creek and some areas of the Kankakee River provide nursery grounds for fish. No eggs were obtained from transects 2 and 5 (Figure 4.8) during the entire sampling period (ER-OL Section 2.2.1).

Results of the 1982 study to determine changes in the aquatic communities of the Braidwood cooling pond 1 year after the pond was filled showed that the planktonic and benthic communities inhabiting the portions of the pond that were previously included in the strip-mining pit had not changed. The communities in the recently inundated areas had changed during the previous year. The phytoplankton, Cryptophyta, was consistently most abundant where nutrient levels were highest.

Following a decline in total biomass of zooplankton after the pond was filled, the standing stock of zooplankton in the second year was as great as or greater than in the first year after the pond was filled (Waite, 1982). The zooplankton community of the cooling pond is an immature fauna; however, changes in the faunal composition corresponds with the growing maturity of the pond system (Larimore and Skelly, 1982a).

The benthic community of the cooling pond is of two types: one associated with the deeper areas of the former stripmining pits and the other a littoral community in the more shallow, recently inundated area. Significant increases in mean total macroinvertebrate numbers and mean number of taxa per sampling site occurred in both areas from 1981 to 1982. The benthic community of the former stripmining pits will probably remain fairly constant with time (see Section 5.5.2.1). In contrast, the community characteristic of the newly inundated area will probably fluctuate with time as the pond matures and depositional layers are developed on the bottom (Warren et al., 1982).

Twenty-three species and two hybrids, representing ten families of fish were collected in 1982. The cooling pond was stocked with threadfin shad, channel catfish, tiger muskellunge, and walleye by the State of Illinois. Based on the percent of total biomass of fish collected by electrofishing, seine, and gill net, the catch from the cooling pond was dominated by gizzard shad, largemouth bass, and carp. Numerically, bluegill, gizzard shad, brook silverside, sand shiner, largemouth bass, and carp were the important fish. Total fish biomass in the pond increased from 1981 to 1982. The carp biomass decreased and the gizzard shad biomass increased from 1981 to 1982.

The total dissolved solids of the cooling pond averaged 832 mg/l in May 1982; the greatest component of this was sulfate (508 mg/l) (Commonwealth Edison Company, 1982). In sulfate-dominated waters the total standing crops of fish have been shown to be substantially reduced compared with those of waters characterized by carbonate-bicarbonate ionic dominance (Jenkins, 1968). In the cooling pond the greatest standing crop loss was clupeids and to a lesser extent sport fishes. At present the clupeid fauna of the cooling pond is much less abundant than is characteristic of midwestern lakes. This may be the result, in part, of the young age of the pond as well as the higher sulfate concentration. The introduction of water with low total dissolved solids and sulfate from the Kankakee River may help moderate levels of total dissolved solids and sulfate in the pond, but discharge of sulfates from resin regeneration will increase sulfate levels. The inflow, however, may have little effect on the amount of sulfates released from within the pond. It is probable that sulfate levels in the cooling pond will remain at levels that are not beneficial for production of an optimum fish fauna.

There were substantial increases in the biomass of gizzard shad, largemouth bass, and walleye in the cooling pond during the second year (Skelly and Epifanio, 1982). The largemouth bass is developing rapidly in the pond. Numerically, bluegill (29.7%), gizzard shad (21%), brook silversides (13.8%), sand shiners (11.5%) largemouth bass (7.0%), and carp (5.7%) were the important fish (Skelly and Epifanio, 1982).

4.3.5 Endangered and Threatened Species

4.3.5.1 Terrestrial

No federally listed endangered or threatened species have been observed on the site (ER-OL Section 2.2.2.5.1). The site is within the range of and includes habitat for the bald eagle (Haliaeetus leucocephalus) and the Indiana bat (Myotis sodalis), both federally listed as endangered (U.S. Department of the Interior, 1983). Bald eagles migrate through the area and may be transitory visitors to the site, feeding on fish and other animals in the cooling pond. The Indiana bat roosts and raises young in hollow trees in the summer, primarily in riparian woods (Humphrey et al., 1977), and hence may feed or roost near the river or, possibly, on site. In the winter, the bat hibernates in caves; there are none on the site or in the area. No Federal or State of Illinois endangered or threatened plants are known to occur on the site or along the transmission line right-of-way (ER-OL Section 2.2.2.5.1).

In addition to the above, several terrestrial animal species classified by the state as endangered or threatened in Illinois are known from Will County or adjacent counties and could occur on site (personal communication from V. R. Tolbert, Oak Ridge National Laboratory, to M. Sweet, Illinois Department of Conservation, September 29, 1983). State endangered species are the American bittern (Botaurus lentiginosus), marsh hawk (Circus cyaneus), upland sandpiper (Bartramia longicauda), short-eared owl (Asio flammeus), red-shouldered hawk (Buteo lineatus), black rail (Laterallus jamaicensis), yellow rail (Coturnicops noveboracensis), and Wilson's phalarope (Steganopus tricolor). State threatened species are the bobcat (Lynx rufus) and Henslow's sparrow (Ammodramus henslowii).

Of the above, the marsh hawk, red-shouldered hawk, and American bittern have been observed on the site at least once since 1972 (ER-OL Section 2.2.2). The upland sandpiper, short-eared owl, and Henslow's sparrow are prairie or grassland species less likely to be present on the site. The black rail has been seen in the state only once in the last 10 years (personal communication from V. R. Tolbert, Oak Ridge National Laboratory, to M. Sweet, Illinois Department of Conservation, September 29, 1983), but the remaining species might possibly occur on site. Additionally, the bobcat might occur along the Kankakee River in the vicinity of the intake and discharge structures or where the transmission line crosses the Kankakee River (personal communication from V. R. Tolbert, Oak Ridge National Laboratory, to M. Sweet, Illinois Department of Conservation, September 29, 1983).

4.3.5.2 Aquatic

There are no federally listed threatened or endangered aquatic species in the vicinity of the Braidwood plant (U.S. Department of the Interior, 1983).

The State of Illinois lists two threatened species (Notropis heterolepis, black-nose shiner, and Notropis anogenus, pug-nose shiner) and two endangered species (Hybopsis amblops, big-eyed chub, and Etheostoma camurum, bluebreast darter) as potentially occurring in the Kankakee River in the vicinity of Braidwood Station (M. Sweet, Illinois Department of Conservation, phone conversation, September 29, 1983). The research team from the Illinois Natural History Survey that has sampled in the Braidwood vicinity for the past 6 years has not found individuals of these four species (T. Skelly, phone conversation, October 4, 1983). However, the Illinois Natural History Survey team has found the pallid shiner (Notropis amnis), which was thought to have been extirpated from Illinois. The species has been proposed for the state's list of threatened species (T. Skelly, phone conversation, October 6, 1983). Eighteen individuals have been collected in the state, one from the Mississippi River and the remaining seventeen from the Kankakee River. All but one of these individuals were taken at transect 5 of the aquatic monitoring stations for Braidwood Station (see Figure 4.8). This area is characterized by a silt sand substrate and zero flow during most of the year. The other individual was collected at transect 3 before construction of the plant intake facility (T. Skelly, phone conversation, October 6, 1983).

4.3.6 Community Characteristics

The socioeconomic description of the area, including demography, land use, and community characteristics in general, are in FES-CP Sections 2, 4, 5, and 10. The Braidwood site is located in the southwest corner of Will County bordering on both Kankakee and Grundy Counties. It is about 80 km (50 mi) southwest of Chicago and 32 km (20 mi) south-southwest of Joliet (1980 population 3,005,072 and 77,956, respectively). The surrounding area is predominantly agricultural and shows evidence of the coal strip-mining that had occurred in the area. The applicant estimates a 1980 population of 27,482 within 16 km (10 mi) of the plant and projects it to be 35,411 in the year 2020. The FES-CP lists the 1970 population to have been 22,116. The 1980 census lists five towns within 16 km containing a population greater than 1000: Braidwood (3429), Wilmington (4424), Gardner (1322), Coal City (3028), and Diamond (1170). The applicant estimates the 0- to 80-km (0- to 50-mi) population to have been 4,580,641 in 1980 with the major portion of the figure including some residents of Chicago and its suburbs. The staff has reviewed the applicant's demography data by comparing the estimates with independent data sources, maps, and aerial photographs and found the applicant's estimates to be reasonable.

There are 10 firms located within 16 km of the plant that employ a total of less than 900 persons. Over one-third of the total are employed by the Personal Products Co. Division of Johnson & Johnson in Wilmington, about 10 km (6 mi) northeast of the station. The majority of the transient population within 16 km of the plant are visitors to the several state and privately owned recreational facilities in the area. These visitors are predominantly from outside the 16-km area and account for a peak daily attendance of about 50,500 persons.

4.3.7 Historic and Archeologic Sites

FES-CP Section 2.3 describes historic and archeologic sites and natural landmarks. Since the FES-CP was issued, the archeological surveys of most of the transmission line corridors have been completed. The survey reports indicated that one site, 11Ka179, was evaluated as being potentially eligible for nomination to the National Register of Historic Places. Under 36 CFR 800, the NRC is required to initiate a determination of eligibility for such sites; that effort has begun. Two parcels, however, on the Davis Creek-to-Crete right-of-way, remained unsurveyed because the landowner refused access. Access has since been granted for one parcel which was subsequently surveyed in May 1984. No sites were identified as being eligible for listing in the Register along that parcel. The landowner still refuses full access to conduct the survey for the other parcel. The staff determined on further review that this survey will not be required because neither construction nor maintenance activities will be conducted on the property.

The plant site and areas near it remain prime fossil hunting territory. The applicant has an agreement with the Field Museum of Natural History so that limited access to the site can be granted through the museum to serious collectors. The applicant intends to review its policy at the time of fuel delivery and fuel loading (ER-OL, response to staff question E310.6).

4.4 References

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5 ENVIRONMENTAL CONSEQUENCES AND MITIGATING ACTIONS

5.1 Résumé

This section evaluates changes in predicted environmental impacts since the FES-CP was issued in July 1974. Updated information concerning the use of water from the Kankakee River is provided in Section 5.3.1. Section 5.3.2 describes the changes in predicted impacts resulting from the volumes and concentrations of waste in the station effluents as a result of updated environmental data. Flood plain aspects are discussed in Section 5.3.3. Section 5.5 addresses terrestrial and aquatic impacts of operation, including impacts associated with operation of the transmission system. Section 5.8 provides the changes in the socioeconomic impacts.

Information in Section 5.9 on radiological impacts has been revised to reflect knowledge gained since the FES-CP was issued. The staff's analysis of the environmental impacts of postulated plant accidents is provided in Section 5.9.4. Information on the environmental effects of the uranium fuel cycle, decommissioning, noise, and operational monitoring programs is provided in Sections 5.10, 5.11, 5.12, and 5.14, respectively.

5.2 Land Use

5.2.1 Plant Site and Vicinity

The staff impact analysis of station operation on land use in FES-CP Section 5.1.1 remains valid. Briefly, the primary impact on land use will be to convert to industrial use (1) 404 ha (998 acres) of agricultural land, (2) 62 ha (152 acres) of woodland, and (3) 1,216 ha (3004 acres) of strip-mined land. Of the 404 ha (998 acres) of agricultural land, 90 ha (221 acres) are located in the plant area and 315 ha (777 acres) are in the pond area. Of the 62 ha (152 acres) of woodland, 14 ha (35 acres) are in the plant area and 47 ha (117 acres) are in the pond area. All 1216 ha (3004 acres) of strip-mined land are in the pond area. The U.S. Soil Conservation Service (SCS, 1980) classified 264 ha (652 acres) of this converted area to be prime agricultural land (22 ha (54 acres) in the plant area and 242 ha (598 acres) in the pond area). The total loss of agricultural land represents less than 1% of the agricultural productivity in Will County (FES-CP Section 4.1, ER-OL response to staff question E290.8). Nevertheless, the staff considers the essentially irreversible loss of prime farmland to be an adverse effect of the construction and operation of the plant. Reference to the proposed rules for evaluating prime farmland losses (SCS, 1983) suggests that the severity of the impact is increased because current land use in the area and adjacent to the site is agricultural. This impact is diminished somewhat because the plant will not prevent agriculture on adjacent land and because it would have been difficult to site the plant on land with a lower proportion of prime farmland.

5.2.2 Transmission Lines

Land use along transmission lines is not expected to change as a result of operation. Agricultural uses can continue under and along the lines; only the small areas under the tower bases are unavailable for farming. The potential impacts of transmission line operation on terrestrial biota and man are discussed in Section 5.5 of this report.

5.3 Water

5.3.1 Water Use

Section 5.2.1 of the FES-CP states that, based on the applicant's estimate, the average net loss of water from the Kankakee River would be 1.34 m^3/sec (47.3 cfs). Since the FES-CP was issued, the applicant has increased the water use estimate to 1.35 m^3/sec (47.6 cfs). At an average flow of 112 m^3/sec (3952 cfs), this average water use is 1% of the normal river flow and 11% of the 7-day, 10-year recurrence low flow (12.5 m^3/sec (442 cfs)) of the river at the plant intake. The applicant stated in the ER-OL (Section 3.3.1) that water withdrawal levels would be determined in consultation with the Illinois Department of Conservation. The applicant had committed to the net withdrawal from the Kankakee River being limited to a maximum of 10% of the river flow (FES-CP) as a design objective.

This would require some drawdown of the cooling pond if the river flow drops below 14 m^3/sec (495 cfs). The water withdrawal for the Braidwood Station is established by the Illinois Department of Conservation water withdrawal permit. According to R. Lutz of the Illinois Department of Conservation (in a telephone conversation on October 3, 1983), the applicant is limited by its water withdrawal permit to (1) withdrawing a maximum of 4.5 m^3/sec (160 cfs), (2) ceasing river water withdrawal when river flow is less than 12.5 m^3/sec (442 cfs) (7-day, 10-year low flow), and (3) withdrawing no more than is consistent with maintaining river water flow at 12.5 m^3/sec (442 cfs).

Depending on the rates of any future water withdrawals from the Kankakee River and the maximum withdrawal by the Braidwood Station, some impact on water availability downstream could occur. On an individual basis, however, withdrawal of 1% of the river flow at the Braidwood intake at normal flow should not have a significant effect on downstream water use. Because of changes in upstream water uses, water use and effects of water withdrawal by the Braidwood plant will probably change over the life of the plant. At present there are no downstream users of water from the Kankakee River. The Joliet Arsenal can withdraw 1.1 m^3/sec (38 cfs) but is presently in a standby status (CECo, March 12, 1984).

Metcalf and Eddy, Inc./Engineers recently completed the first phase of a three-phase Will County Public Water Supply Study. The Phase I report covers population and water usage projections. Will County currently uses groundwater supplies to fulfill municipal and industrial demands. The report states that continued use of the groundwater source is dependent on the ultimate effect of the current mining of this resource as reflected by declining water levels and quality. The report indicates that the 1980 maximum demand was 291 million liters/day (77 mgd or 119 cfs) and it projects a 2020 maximum demand of 428 million liters/day (113 mgd or 175 cfs). The difference between the 1980 and

2020 demands is 136 million liters/day (36 mgd or 56 cfs). This represents the water supply that would be required from the Kankakee River, assuming that Will County would retain its existing groundwater capability. Commonwealth Edison Company has an agreement with the State of Illinois that it will not withdraw water for the Braidwood Station to the extent that it would reduce Kankakee River flow below 12.5 m^3/sec (442 cfs), which is the 7-day, 10-year low flow. If a future Will County municipal intake were located downstream of the Braidwood Station intake, there should be sufficient water to meet the Will County incremental demand (56 cfs) during most low flow conditions.

If Will County were to withdraw water from the Kankakee River, it is likely that the intake would be located upstream of the Braidwood Station on land that Commonwealth Edison Company donated to Will County. Should this site prevail, then the Braidwood Station would probably not impact on the Will County intake, but, conversely, the Will County intake would probably impact on the Braidwood Station.

If the Will County intake is located upstream and the State of Illinois does not restrict withdrawal through its river permit system, then with the incremental withdrawal rate of 136 million liters/day (56 cfs), the applicant's commitment to the State that it would not reduce flows below 442 cfs in effect becomes a commitment at 498 cfs (442 + 56). The 498 cfs is about a 7-day, 5-year low flow. Under the above assumed conditions the required plant shutdown time or reduced power time would be altered upwards from the values discussed in FES Section 4.2.3.1.

During normal Kankakee River flows, there should be insignificant impacts, regardless of the location of the future Will County intake.

5.3.2 Water Quality

The water quality standards for the Kankakee River as determined by the State of Illinois (Illinois Water Pollution Control Board, 1979) require that the standards be met at every point outside the mixing zone and that no mixing zone exceed the area of a circle with a radius of 180 m (600 ft). Part 203 of the general standards also requires that temperature-related standards, designed to protect surface waters in Illinois for aquatic life, agricultural use, primary and secondary contact use, most industrial uses, and aesthetic quality, be met (Illinois Water Pollution Control Board, 1979). The water quality standards also require that the discharge structure must be designed to ensure that the mixing zone allows a reasonable zone of passage for aquatic life and must not encompass more than 25% of the cross-sectional area or volume of flow, except in those instances where the dilution ratio is less than 3:1 (ER-OL Section 5.1). See Section 5.5.2 for further discussion.

The major source of chemical and biocide discharges into the Kankakee River from the Braidwood Station is blowdown from the cooling pond. With the exception of biocides, the blowdown will contain the same chemical constituents as the river but at higher concentrations because of the evaporative water losses. The expected chemical composition of the cooling pond blowdown and the applicable state standards are shown in Table 5.1. The addition of carbon dioxide to prevent scale formation in the heat exchange equipment will increase the total dissolved solids concentrations in the blowdown above that which would be expected as the result of evaporation alone. The average total dissolved solids

Table 5.1 Chemical discharges of the Braidwood Station, including leaching effects (All values except pH in mg/liter.)
Source: ER-OL Table 5.3-1

Chemical discharge	Ambient river[a]	Average pond blowdown	Average discharge to river	Applicable Illinois standards: Effluent	Applicable Illinois standards: Water quality
Alkalinity (as $CaCO_3$)	170	120	120	None	None
Calcium	77.6	100	100	None	None
Chlorides	22.0	44	44	None	500
Magnesium	23.5	50	50	None	None
Nitrates	2.3	5	5	None	None
pH	7.0-9.0	Within limits	Within standards	5-10	6.5-9.0
Silica	3.2	6	6	None	None
Sodium	13.0	26	26	None	None
Sulfates	65.6	273	273	None	None
Total dissolved solids	388	900	900	3500[b]	1000

[a]From Table 3.6-1 (ER-OL).

[b]Applicable limit for recycling or other pollution abatement practices.

concentration in the cooling pond and blowdown discharge to the river is calculated to be 900 mg/l (Table 5.1), and the maximum anticipated is 980 mg/l (Table 5.2). Both discharge levels are within limits established by the State of Illinois for the effluent and water quality standards (Table 5.1). The pH of the blowdown discharge to the river will be monitored and treated as necessary to meet applicable standards. Of all the chemicals in the discharge, sulfate concentrations will be increased by the greatest percentage above ambient (Table 5.1). The sulfate levels are, however, within limits for effluent and water quality standards. Using the same formula to calculate chemical dilution as thermal dilution, sulfate concentrations will approach that of the maximum river water concentration at the 2°F isotherm. Concentrations at this isopleth are well below state standards and, in addition, should have no adverse effect on water quality. At the 2°F isotherm boundary, chloride levels are approximately the same as the maximum ambient level and should have no adverse effect on water quality. The 2°F isotherm covers a maximum area of 2.2×10^4 m^2 (5.4 acres) and is well within the maximum area of the mixing zone required by the State of Illinois (1.05×10^5 m^2 (26 acres)). On the basis of information presented in Section 4.3.2 and in ER-OL Section 2.4.1.4.2, there should be only minor changes in the water quality of the cooling pond and of water discharged to the river as the result of leaching of surface and subsurface soils. If the estimates of normal and maximum effluent and blowdown constituents determined by the applicant are proved accurate by operational monitoring, there should be no significant adverse impacts of plant operation on water quality of the Kankakee River.

Sanitary wastes will receive tertiary treatment to remove nutrients, followed by chlorination to control fecal coliform bacteria numbers. The effluent chlorine level is 1 mg/l. The average discharge rate is less than 0.003 m^3/sec (0.1 cfs) into the pond blowdown. The dilution afforded by the pond blowdown flow should minimize the residual chlorine concentration discharged to the river and is expected to reduce nutrient levels to less than that of the river.

5.3.3 Flood Plain Aspects

The flood hazard areas, resulting from the 1%-chance flood in the Kankakee and Mazon Rivers and their tributaries, in the vicinity of the Braidwood site are shown in Figure 5.1. These flood hazard areas were delineated by the Federal Emergency Management Agency (1978, 1982).

The plant area, cooling pond, river screen house, and blowdown structure, which are located in or near the flood plains of the Kankakee and Mazon Rivers, are also shown in Figure 5.1. It can be seen from Figure 5.1 that the plant and cooling pond areas do not alter the flood plain of the adjacent rivers or their tributaries so as to affect the flood-prone areas.

The river screen house and blowdown structure are located on the Kankakee River approximately 4 mi upstream of the dam at Wilmington, Illinois. The river screen house and blowdown structure encroach onto the Kankakee River flood plain. The encroachment of the river screen house is shown in Figure 5.2. The 100-year discharge in the Kankakee River near the river screen house is about 1416 m^3/sec (50,000 cfs) and the corresponding flood level in the Kankakee River at the screen house for prestation construction is at el 547.5 ft MSL (U.S. Department of Housing and Urban Development, 1979).

Table 5.2 Estimated maximum concentrations of chemicals discharged to the Kankakee River (All values in mg/liters.)
Source: ER-OL, Table 5.3.2

	MAXIMUM DISCHARGE	AT 5° ISOTHERM[a]	AT 2° ISOTHERM[b]	MAXIMUM AMBIENT RIVER
Alkalinity (as $CaCO_3$)	160	203	222	235
Calcium	120	119	118	118
Chlorides	46	34	29	25
Magnesium	70	48	38	31
Nitrates	9	7	7	6.2
Silica	8	6	6	5.3
Sodium	33	29	27	25.6
Sulfates	360	248	198	164
Total Dissolved Solids	980	699	573	489

[a]Estimated August isotherm area = 0.16 acres.

[b]Estimated August isotherm area = 1.42 acres.

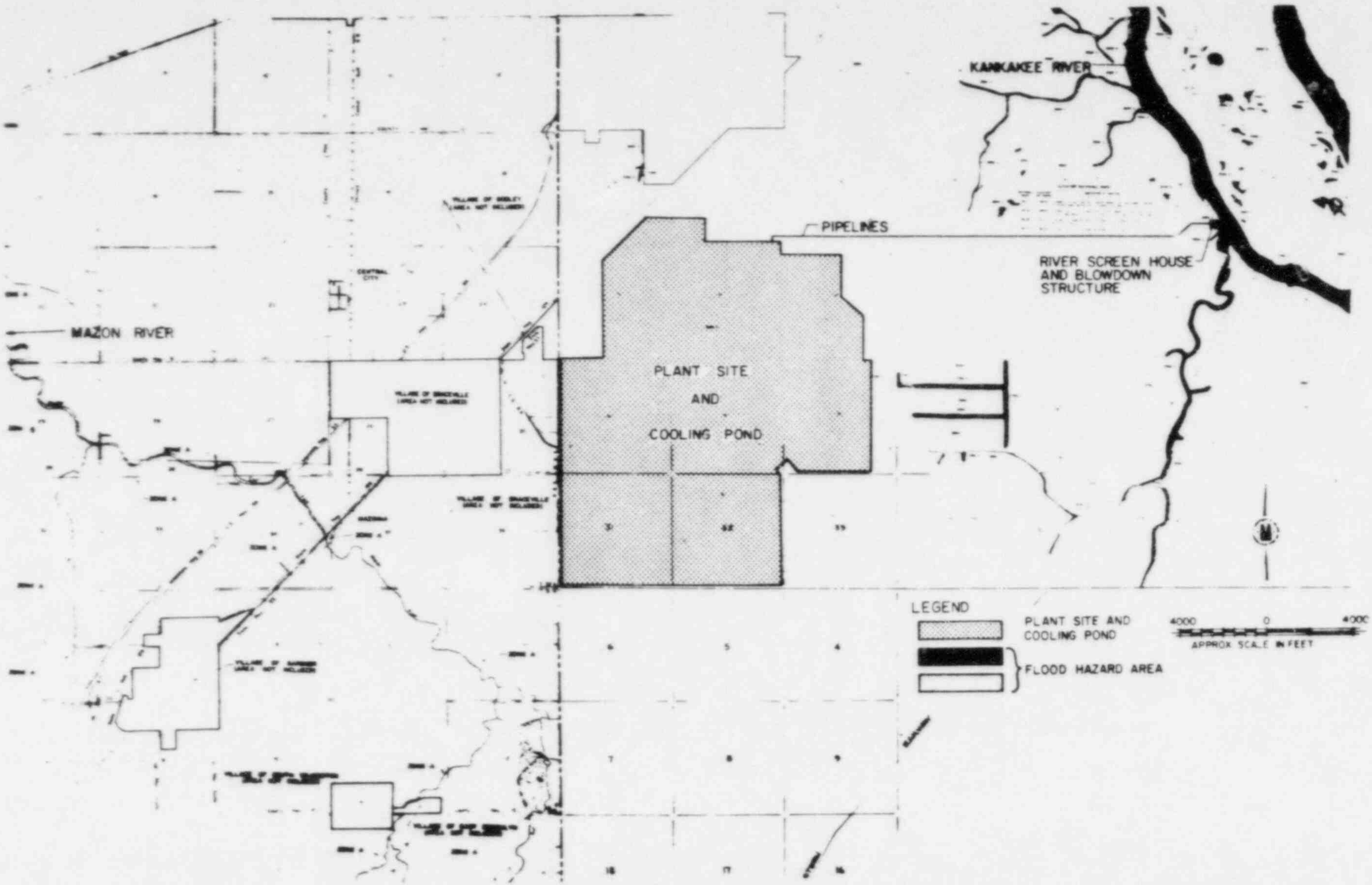

Figure 5.1 Flood hazard areas of Kankakee and Mazon Rivers
Source: ER-OL Figure QE 240.1-1

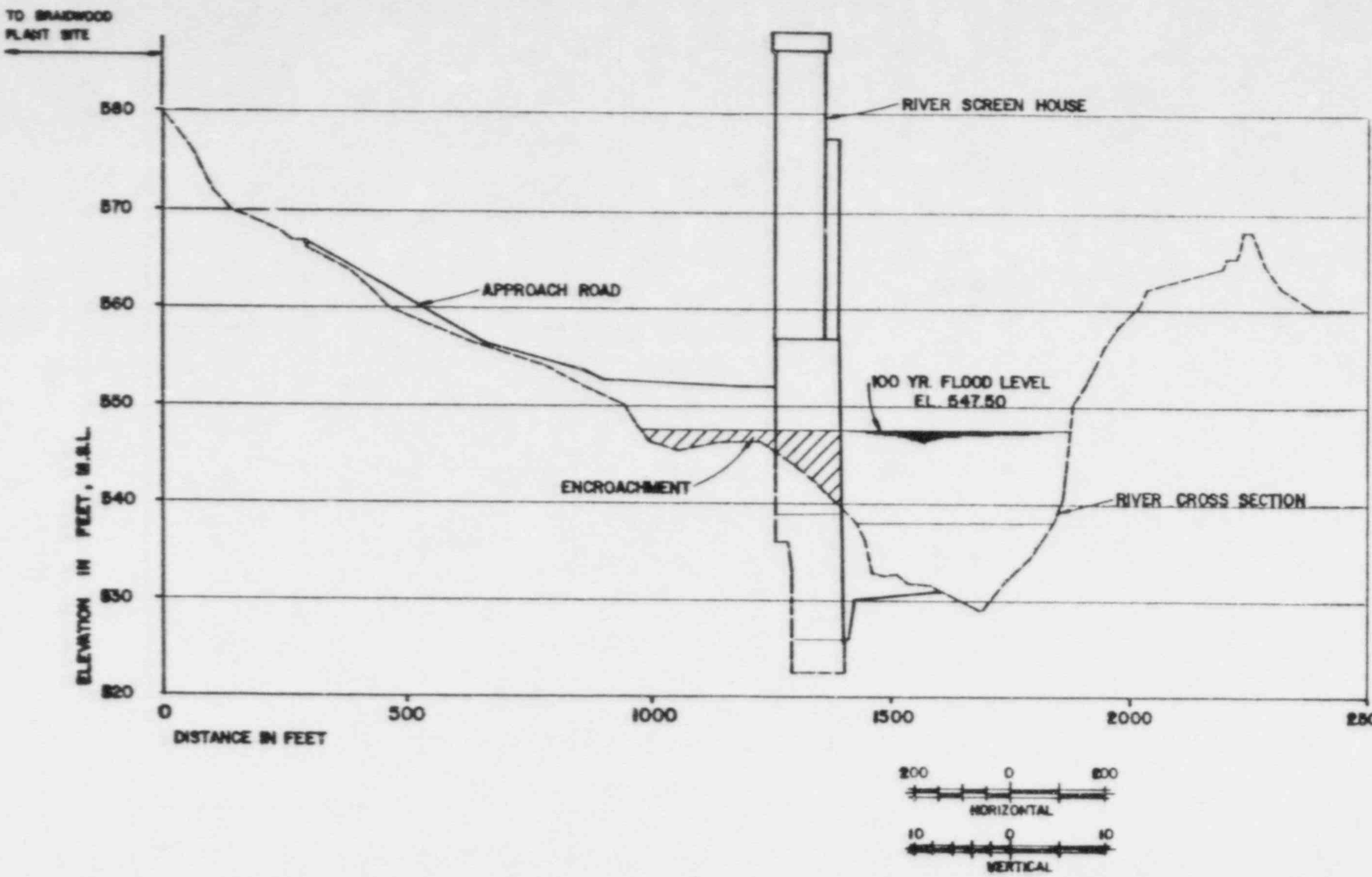

Figure 5.2 Kankakee River cross section
Source: ER-OL QE 240.1-2

Figure 5.2 shows the river cross section at the screen house with and without the screen house. At el 547.5 ft, the cross-sectional area under natural conditions is 7900 ft^2, and the area of cross section with the screen house in place is 7000 ft^2. Thus, the river screen house encroachment during a 1%-chance flood in the Kankakee River is 11.4% of the river cross section. This reduction in area will only increase the 100-year flood stage upstream of the screen house about 6 cm (0.2 ft).

It is clear from the above discussion that Braidwood Station, particularly the river screen house, does not appreciably alter either flood flows or flood levels upstream and downstream of the screen house.

5.4 Air Quality

Air quality in the area is reasonably good, as indicated by the statistics that showed less than 10 forecast days of high air pollution potential in a 5-year period (Holzworth, 1972). The nearby Chicago SMSA (Standard Metropolitan Statistical Area) shows general improvement of levels of various air pollutants (Council on Environmental Quality (CEQ), 1983). The plant emissions resulting from infrequent operation of the auxiliary diesel generators will be described in Section 5.4.2.

5.4.1 Fog and Ice

The material presented in FES-CP Section 5.4.1.2 is still appropriate.

5.4.2 Other Emissions

Gaseous effluents other than normal, routine operational radioactive releases will result from the combustion products emitted by four diesel auxiliary generators and four other diesel generators used infrequently during equipment testing.

Similarly, two oil-fired steam boilers are infrequently used during plant startup or when the plant is shut down. The boiler emissions of SO_2 and particulates are within the State of Illinois guidelines for SO_2 and particulates. Normally, one boiler is expected to operate about 2 weeks per year.

The staff concludes, on the basis of the information provided by the applicant and the staff's experience with evaluations of other facilities, that the operation of the auxiliary boilers and the diesel generators should not have a significant impact on the air quality in the vicinity of the plant.

5.5 Ecology

5.5.1 Terrestrial Ecology

5.5.1.1 Plant Site and Vicinity

The immediate effects of constructing and filling the cooling pond on terrestrial ecology were described in FES-CP Section 4.3.1. The effects on terrestrial biota that will occur as vegetation (e.g., trees, grasses, and semi-aquatic plants) developed on the dikes and islands were described in FES-CP

Section 5.4.1.1. The staff has reviewed these analyses and considers them still valid. Briefly, about 1027 ha (2537 acres) of former terrestrial habitats (cultivated and fallow fields, woodlands, and strip-mined soil) have been converted to aquatic habitat. About 551 ha (1361 acres) occupied by the dikes and islands will become increasingly suitable terrestrial habitat as revegetation progresses. Terrestrial organisms adapted to open water or shoreline habitats, such as waterfowl, muskrats, and frogs, will be favored. None of the terrestrial habitats destroyed is unique or uncommon in Illinois.

About 174 ha (431 acres) of the plant area will not be needed for operation of the nuclear plant. Of this area, 121 ha (300 acres) are undisturbed and 53 ha (131 acres) will be revegetated when construction is completed. The applicant is working with the county soil conservationist to revegetate about 15 ha (36 acres) in the northeast portion of the site, part as native prairie and part as wildlife habitat (ER-OL, response to NRC staff question E290.4). The conservationist's recommendations for fertilizer, seeding mixtures, and maintenance of ground covers also have been followed for land on the site, on the makeup-blowdown corridor, and at the river screen house (ER-OL, response to staff question E290.4). Of the 1803-ha (4454-acre) site, about 725 ha (1792 acres) are available for terrestrial wildlife habitat (ER-OL, response to staff question E290.8).

5.5.1.2 Transmission System

Impacts that could be associated with operation of the transmission system include corona effects, induced electric and magnetic fields, bird collisions, and effects resulting from maintenance of the corridors.

Corona is noticeable primarily on 500-kV and higher voltage lines, especially during wet weather, but also occurs at lower voltages. Corona may result in audible noise, radio and television reception interference, light, and production of ozone and oxides of nitrogen (NO_x). The concentration of corona-produced ozone is usually less than the daily natural variation in ozone concentration (Lee et al., 1982) and adverse impacts are consequently unlikely. Production of oxides of nitrogen is similarly insignificant. The applicant designed the station-related portion of the transmission system to meet or exceed all requirements of the Illinois Commerce Commission General Order 160, which is identical to the National Electric Safety Code for the construction of transmission lines, to ensure the safeguarding of persons from hazards resulting from operation of overhead lines (ER-OL Section 3.9.2). The applicant has used modern tower designs for the plant transmission system, which minimize audible noise and interferences (Lee et al., 1982). The applicant investigates all complaints about such corona effects and corrects problems to the extent practical (ER-OL Section 3.9.6, Amendment 1).

Equipment, such as tractors, operated or parked under the lines can develop a static charge that may cause a slight sensation or shock at a person's touch. Ungrounded fences and gates can develop charges that will deliver a painful shock to a grounded individual touching them (Lee et al., 1982). Hence, ungrounded fences and gates on or adjacent to the right-of-way are routinely grounded and electric fences are equipped with drain coils at appropriate intervals (ER-OL Section 3.9.6, Amendment 1). These measures will reduce potential shock hazards to levels well below 4.5 mA, which is considered the maximum safe level for children (Lee et al., 1982).

Electric fields measured on 500-kV lines at a height of 1 m averaged 2.4 kV/m (maximum 6.9 kV/m) on the centerline and 1.3 kV/m (maximum 6.0 kV/m) at the edge of a 30-m right-of-way (Sendaula et al., 1983). Fields on a 345-kV line would be no higher; the applicant has calculated that fields associated with parallel 345-kV and 765-kV lines would be, at worst, only slightly higher than for a 345-kV line alone (ER-OL Section 3.9.6). Experience has shown that calculated values are almost always higher than actual field measurements (Sendaula et al., 1983).

Research on effects of electric fields on humans and other organisms has produced variable results (Lee et al., 1982). For the most part, adverse effects have been demonstrated only for higher fields (e.g., greater than 15 kV/m) or longer exposure times than would occur for people residing near or working under transmission lines. Also, some of the studies purporting to demonstrate adverse effects used poor experimental design or inadequate statistical treatment of results (Lee et al., 1982). Results of research studies on electric field effects on growth and development of plants and animals indicate that neither serious injuries nor abnormalities were apparent from exposure to a 50-kV/m field (Bankoski et al., 1976). Minor physical damage to corn, bluegrass, and alfalfa leaf tips occurred from exposures to field strengths of 25 kV/m and above. The same series of studies, investigating electric field effects on small animals, indicated no apparent adverse abnormalities in behavior or external appearance from exposures to electric fields of 50 kV/m.

Bird collisions with power lines are most evident where lines pass through areas with large concentrations of birds, such as reservoirs and certain agricultural fields. Studies on mortality of waterfowl under such conditions suggest that less than 0.07% of total nonhunting waterfowl mortality is caused by power lines (Stout and Cornwell, 1976). Because concentrations of waterfowl may occur on the Braidwood cooling pond, some potential exists for bird collisions with the power lines associated with the plant. Because lines enter the switchyard well north of the cooling pond, this possibility is small. Waterfowl use of the Kankakee River in the area crossed by the Braidwood transmission line is limited because of the swift current and gravelly bottom (telephone conversation, C. L. McDonough (Commonwealth Edison Company) and G. LaRoche (NRC), November 11, 1983). Therefore, the impact on waterfowl populations is expected to be negligible.

Because the transmission line traverses mostly active, cleared agricultural land, there will be limited need for right-of-way maintenance. No construction of new permanent access roads will be necessary (ER-OL Section 5.5.1). In wooded areas, periodic pruning and cutting of trees and brush, and possibly very limited selective herbicide application, will be necessary. Typically, herbicides are applied to stumps to prevent sprouting and as a basal spray on standing brush and trees. All herbicides used in the control programs will be transported, handled, and applied in accordance with the restrictions stated on the registered container labels (ER-OL, response to staff question E290.2). Fallow fields in the right-of-way may have to be cleared every few years. These maintenance activities will produce very little change in existing terrestrial habitat on the right-of-way and consequently no significant adverse impacts.

5.5.2 Aquatic Resources Impacts

5.5.2.1 Cooling Pond

On the basis of the existence of stripmining lakes before construction of the cooling pond and intake of makeup water from the Kankakee River, the cooling pond should initially have a relatively diverse aquatic community. In addition the State of Illinois has stocked the pond with threadfin shad, channel catfish, tiger muskellunge, and walleye. Information presented in Larimore and Skelly (1982) and in Section 4.3.4.2 showed that the aquatic resources of the cooling pond appear to be developing in a manner that is consistent with the maturation of new ponds.

Information provided by Commonwealth Edison Company (1982) showed that existing levels of sulfate in the cooling pond were high (508 mg/l of the 832 mg/l total dissolved solids). Levels of sulfate in excess of 390 mg/l have been shown to have adverse effects on the standing stocks of fish in reservoirs (Jenkins and Morais, 1971). The standing stock of clupeids, particularly gizzard shad, was found to be reduced in the cooling pond from 1981 to 1982 although the species did exhibit a wide range of size classes.

The applicant reported in the ER-OL that mixing within the cooling pond should be relatively uniform except in the deeper areas [>3 m (10 ft)], which are associated with the previous stripmining pits and are deeper than the discharge level. These areas may be used by fish during the summer months, when the overall temperature of the pond is at its highest, as a means of escaping elevated temperatures. If dissolved oxygen levels in these deeper areas are low, as is probable, fish species may be precluded from using these areas. Consequently, the only areas that may be available to fish during periods of high temperatures will be the area adjacent to the makeup water inflow from the Kankakee River and possibly isolated coves in the cooling pond that are poorly mixed. Overall, the effects of operation of the cooling pond will have an adverse effect on aquatic organisms during periods when the temperature in the cooling pond exceeds 30°C (86°F) (Langford, 1983). It is possible that fish can avoid these high temperatures by taking refuge in deeper, cooler areas of the cooling pond. The cooling pond has the potential to support a diverse fish fauna during all but the hottest parts of the year (June through August) since it will receive plankton and benthic organisms, as well as small fish, larvae, and eggs in the makeup water from the Kankakee River. Because of the high temperatures and high nutrient availability in the cooling pond, algal blooms will probably occur during periods of warm weather and adequate solar radiation. In addition there will be periods when potentially extensive algal masses may die off, reducing dissolved oxygen levels and adversely affecting water quality. Algal blooms and die-offs will probably occur only in the more shallow areas; fish and other mobile species should be able to avoid these areas.

The applicant expects that the overall low target level of chlorination to be used and the intermittent and sequential treatment of cooling systems and components, thereby affording dilution of chlorine-containing flows with unchlorinated flows, will result in no detectable residual chlorine in the station discharges. The practicable field detection limit for total residual chlorine (TRC) in power plant cooling waters has been variously reported to be in the range of 0.03 mg/l (U.S. EPA, 1980) to 0.085 mg/l (NUS, 1980). The residual chlorine in power plant discharges normally consists of combined available chlorine, with free available chlorine concentration being below detectable limits. Dickson et al. (1974) and Brooks and Seegert (1978) examined the effects of intermittent exposures of warm water fish to residual chlorine. Their studies concluded that exposures to not greater than 0.2 mg/l TRC intermittently for a total time of up to 2 hours per day would "probably be adequate to protect more resistant warm water fish such as the bluegill" (Dickson et al., 1974) and that intermittent exposures to combined available chlorine totaling 160 min would not produce mortality to the most sensitive of 10 warm water fish tested at concentrations at or below 0.21 mg/l, respectively. The most sensitive species in the latter study was the emerald shiner. The other species tested were the common shiner, spotfin shiner, bluegill, carp, white sucker, channel catfish, white bass, sauger, and freshwater drum. On the basis of the applicant's projected discharge of residual chlorine from the Braidwood Station, adverse effects on the biota of the cooling pond would not be expected.

The staff has evaluated the biological conditions anticipated with operation of the pond and concludes that the aquatic resources of the cooling pond will be typical of a generally stressed system characterized by possibly large numbers of a few heat-tolerant species. However, since the state has not identified the pond as a fishery resource and the applicant indicates that it will only be used for cooling purposes (ER-OL Section 5.1), the conditions in the cooling pond are not in conflict with any planned use of the water body.

5.5.2.2 Kankakee River

This section discusses the predicted thermal impact of the blowdown discharge to the Kankakee River, the impact of removing riverine organisms in the makeup water, and the impact of the water intake structure on fish species.

The size of the thermal plume is regulated by the requirements of the State of Illinois Water Pollution Control Board (IWPCB, 1979). The mixing zone is restricted to an area that covers no more than a circle whose radius is 183 m (600 ft). The calculated area is (10.5 ha (26 acres). According to requirements of the IWPCB (1979), the maximum temperature rise above natural temperatures shall not exceed 2.7°C (5°F). This maximum temperature rise would correspond to a (5°F) isotherm area of 0.2 ha (0.45 acres) (ER-OL Section 5.1.1). At no time shall the temperature exceed the maximum temperature of 16°C (60°F) from December through March or 32°C (90°F) from April through November outside the 10.5-ha (26-acre) mixing zone more than 1% of any continuous 12-month period (IWPCB, 1979).

According to ER-OL Table 5.1-1 the highest river-water temperature occurs in August [26°C (79.5°F)]; the temperature of the discharge to the river is 33°C (91°F). At a temperature increase of 7C° (11.5F°) the temperature excess outside the mixing zone would be 0.004C° (0.008F°). The area occupied by the 5.6°C (10°F) isotherm is 0.004 ha (0.01 acre); consequently, the area in which the 7C° (11.5F°) temperature rise occurs is sufficiently small so that only a small area of the river should be affected by a temperature in excess of 32°C (90°F).

New estimates of blowdown flow rate and temperature increase are lower than those described in the FES-CP. Therefore effects of the discharge should be less than previously predicted. Table 5.3 provides a numerical summary of the thermal plume areas having temperatures above ambient temperatures of the river.

Table 5.3 Estimated isotherm areas resulting from a discharge into the Kankakee River (All values in acres.)
Source: ER-OL, Table 5.1-2

MONTH	EXCESS ISOTHERMS (°F)						
	20°	15°	10°	5°	4°	3°	2°
January		0.01	0.05	0.30	0.47	0.95	2.60
February		0.02	0.07	0.29	0.43	0.78	1.94
March		0.01	0.04	0.18	0.28	0.48	1.05
April			0.01	0.10	0.15	0.26	0.52
May			0.02	0.13	0.20	0.35	0.74
June			0.03	0.21	0.35	0.65	0.92
July			0.02	0.20	0.34	0.75	2.4
August			0.01	0.16	0.29	0.59	1.42
September			0.05	0.38	0.64	1.38	3.95
October			0.05	0.37	0.71	1.64	5.4
November			0.03	0.26	0.48	1.03	3.12
December	0.01	0.03	0.10	0.45	0.72	1.52	4.58

The maximum area that is associated with the 2.7°C (5°F) isotherm (0.45 acre) occurs in December. The maximum area of the mixing zone permitted by the State is 10.5 ha (26 acre) (IWPCB, 1979). The thermal plume is projected to cover a surface area of 18% of the river width in August, 21% in September, and 13% in December (ER-OL Section 5.1.2). Therefore, the thermal plume should not act as a barrier to up or downstream movement by mobile aquatic biota.

Under conditions of low flow and high blowdown temperature, plankton carried by the river current past the discharge point would be exposed to a 2.7C° (5F°) temperature increase for approximately 10 min and higher temperatures for shorter periods. Impacts to the phytoplankton community should be minor and of minimal duration because: the 2.7°C (5°F) thermal plume only covers an area of 0.2 ha (0.45 acre); the residence time within the plume is short; and the regeneration time of phytoplankton is rapid.

Benthic organisms should not be significantly affected by blowdown discharge from the Braidwood Station, except perhaps in the immediate vicinity of the discharge outfall. Mobility of juvenile and adult fish will enable them to avoid the heated water during periods of maximum temperature discharge (i.e., August). Individuals of some species may actively move into the heated plume during the winter months in an attempt to maintain their preferred temperature levels. Cold water shock should not cause a significant problem because blowdown to the river is from a large cooling pond that would cool slowly upon station shutdown. The temperature in the vicinity of the discharge would be cooled at a rate of approximately 1C° (2F°) per hour. This rate of cooling would allow acclimation by fish in the discharge vicinity and minimize adverse impacts.

Because most spawning in the vicinity of the plant occurs upstream, impacts of the discharge on spawning should be minimal. Those larval fish found in the river could be stressed on passage through the thermal plume. Depending upon the river and streambed configuration and the flow of the river, flow in the river in the vicinity of the intake and discharge can be toward the far bank (Ill. Nat. History Survey, 1981). Flow of the river and creek discharge toward the far bank would minimize discharge effects on larval and juvenile fish. Because of variable flow direction in the river, the residence time in the plume being short, and natural mortality of larval fish that do not remain in spawning areas until they can withstand river flow reaching more than 99%, the overall impacts on adult fish populations in the river from larval mortality associated with the thermal plume should not be significant.

The greatest mussel-bed densities occur upstream in the riffle areas adjacent to Horse Creek (Ecological Analysts, Inc., 1982). Because mussel beds are sporadic in distribution and low in density in the vicinity of the intake and discharge, there should be minimal impacts to the mussel fauna from operation of the plant.

In FES-CP Section 5.4.2.2.1, the staff discussed the effects of entrainment associated with intake of water from the Kankakee River. The staff concluded that, with an average intake withdrawal of 2.6 m^3/sec (93 cfs), approximately 2.4% of the river phytoplankton would be entrained. Because of the small removal rate and the rapid regeneration time of both phytoplankton and zooplankton, the staff concluded that impacts from this entrainment would be minor.

The projected amount of makeup water needed by the plant is slightly less than previously projected (FES-CP Section 3.3) so that the number of plankton entrained will be slightly less.

During the spring spawning period, eggs, fry, and small juvenile fish may be entrained. These organisms will be entrained in proportion to the number found in the water column. Because during some years the flow from Horse Creek does not mix with that in the Kankakee River but rather hugs the right bank of the river (intake side), there will be a larger proportion of larvae from Horse Creek entrained when this occurs than from the Kankakee River (Ill. Nat. History Survey, 1978, 1979, 1980). These studies concluded, however, that the densities of larvae in the river and creek were very similar; therefore, there should be no significant effect of entrainment on the larvae in the plant vicinity. When the flow in the river is toward the far side (Ill. Nat. History Survey, 1981), the impact from entrainment will be further reduced. The predominant larvae in Horse Creek were species of Percidae, Catostomidae, Ambloplites rupertris (rock bass), and Cyprinidae (Ill. Nat. History Survey, 1979). Most sport fish species found in the Kankakee River produce demersal or attached embryos which generally develop in shallow backwater, near-shore areas and are not present in the mainstream of the river until they achieve the ability to swim in prevailing river currents; therefore, most species should be able to avoid entrainment in the intake (Commonwealth Edison Co., 1977). Unless physically damaged during passage through the intake system, these organisms will be released (discharged) into the freshwater holding pond associated with the cooling pond and will serve as an incidental source of fish for the cooling pond. Most eggs, fry, or juvenile fish entrained in the cooling water that is drawn from the cooling pond will probably be killed during passage through the plant. Most spawning in the Kankakee River in the vicinity of the Braidwood Station occurs in the shallow water areas and the riffle at the mouth of Horse Creek (according to T. Skelly in a telephone conversation on October 6, 1983), rather than the vicinity of the makeup water intake.

At normal water intake rates during a 7-day, 10-year low flow of the Kankakee River at the station site, approximately 21% of the plankton could be removed from the river. In addition to low flow and low nutrient input, this removal rate could stress the aquatic community in the station vicinity. The State of Illinois requires that water withdrawal by the Braidwood Station be stopped under these low-flow conditions (see Section 5.3.1) so that impacts at low flow will be minimized. Assuming a low flow of 14 m^3/sec (500 cfs), approximately 17% of the plankton could be removed from the river flow passing the station makeup intake. Under low-flow conditions, impacts from entrainment of fish eggs, fry, and small juveniles are expected to be minimal. Lower flows would occur in late summer, after spring spawning and the period of highest ichthyoplankton densities had passed.

On the basis of calculations of 1 to 3% of the river flow being withdrawn by the Braidwood plant during the spawning peak, April-July, the staff expects the number of fry and small juveniles entrained to be small in relation to the populations in the river. Consequently, the impact of fish entrainment during the period of spawning should be small.

The applicant anticipates the average annual intake flow from the Kankakee River to be 2.6 m^3/sec (90.8 cfs). The approach velocities for the station intake will range from 0.10 to 0.15 m/sec (0.3 to 0.5 ft/sec) depending on the water level of the river. The velocity of the water passing through the traveling screens will range from 0.3 to 0.5 m/sec (1.0 to 1.5 ft/sec) depending on the water level of the river. At the above approach velocities most adult riverine fish should be able to swim away from and avoid the intake. Because of slower swimming speeds of smaller fish, some may be impinged. An impingement study was conducted by the applicant during filling of the cooling pond from December 1980 through February 1981 (Commonwealth Edison Co., 1981). Results of the 2½-month study showed that eight species of fish constituted 75% of the total number of fish impinged. In decreasing order of abundance, these species were rock bass, rosyface shiner, channel catfish, bluegill, smallmouth bass, bullhead minnow, white crappie, and orangespotted sunfish. The majority of the impinged fish were young-of-the-year; the average weights of all but 4 of the 32 taxa in the catch were less than 28 gm (1 oz). The total estimated impingement for the time period December through February (Table 5.4) was 1201 individuals weighing approximately 16 kg (36 lb) and representing 32 species (Commonwealth Edison Company Co., 1981). The numbers in Table 5.4 can be compared with the total number of the various fish species collected in the plant vicinity during the aquatic monitoring program from 1974 through 1975 (ER-OL Table 2.2-45). The number of rock bass impinged was in proportion to the number found in the population, a situation that was generally true for all impinged species.

The highest number of fish impinged typically occurs during the winter months when water temperatures are low and fish swimming speeds are reduced. Impinged fish are washed from the screens and removed from the site to an approved disposal area by a licensed contractor. Consequently, any fish impinged by the intake structure are removed from the population. On the basis of the low numbers of individuals of the various species impinged during the December through February study (Table 5.4) and the generally high natural mortality rates of young-of-the-year fish, the staff concludes that operation of the Braidwood intake structure on the Kankakee River should have minimal effects on the fish fauna of the river.

The cooling pond blowdown will contain the same chemical constituents as the river although at higher concentrations because of evaporative water losses (see Table 5.1). The total dissolved solids concentrations will be higher because of the carbon dioxide added (Section 5.3.2) to prevent scale formation in the heat exchange equipment. The expected chemical concentrations of the blowdown from the cooling pond to the Kankakee River and the State effluent and water quality standards are shown in Table 5.1.

The total amount of dissolved solids discharged to the river is less than the maximum allowed limits. The maximum expected concentrations of both chlorides and total dissolved solids are within water quality standards without dilution. After dilution within the mixing zone (a maximum area of 10.5 ha (26 acres)), the effluent sulfate concentration will be well below the 500 mg/l standard. Sulfate discharged at 588 mg/l would meet the water quality standard during low river flow in August within an area corresponding to the 1°C (2°F) isotherm.

The station sewage plant effluent chlorine level is about 1 ppm. This concentration is discharged at an average rate of less than 0.1 cfs into the cooling pond blowdown, which is maintained at an average flow of about 43.2 cfs. Dilution by this means should be more than adequate to reduce the nutrient and residual chlorine levels to values below that of the river. Blowdown to the river

Table 5.4 Estimated total number, percent occurrence of fish impinged, Braidwood Station, December 1, 1980 - February 21, 1981
Source: Commonwealth Edison Co., 1981, Table 2

Species	December		January		February		Total	
	Number	%	Number	%	Number	%	Number	%
Rock bass	98.1	15.5	62.6	19.5	54.0	21.7	214.7	17.8
Rosyface shiner	86.4	13.6	41.1	12.9	11.7	4.7	139.2	11.6
Channel catfish	39.7	6.3	42.7	13.4	51.4	20.7	133.8	11.1
Bluegill	84.0	13.2	14.7	4.6	2.3	0.9	101.0	8.4
Smallmouth bass	72.4	11.4	14.7	4.6	11.7	4.4	98.8	8.2
Bullhead minnow	44.4	7.0	17.8	5.6	14.0	5.6	76.2	6.3
White crappie	49.1	7.7	14.7	4.6	10.0	4.0	73.8	6.1
Orangespotted sunfish	28.0	4.4	7.6	2.4	35.3	14.2	70.9	5.9
Green sunfish	16.3	2.6	27.7	8.7	7.0	2.8	51.0	4.2
Black crappie	14.0	2.2	31.5	9.9	4.7	1.9	50.2	4.2
Spotfin shiner	30.3	4.8	2.3	0.7	7.0	2.8	39.6	3.3
Sand shiner	11.7	1.8	5.3	1.7	18.6	7.5	35.6	3.0
Stonecat	6.9	1.1	6.9	2.2	7.0	2.8	20.8	1.7
Pumpkinseed	4.7	0.7	7.0	2.2	4.7	1.9	16.4	2.4
<u>Notropis</u>, spp	6.9	1.1	6.1	1.9	2.3	0.9	15.3	1.3
Redear sunfish	2.3	0.4	5.3	1.7	--	--	7.6	0.6
Golden shiner	4.7	0.7	--	--	2.3	0.9	7.0	0.6
Bluntnose minnow	4.7	0.7	--	--	2.3	0.9	7.0	0.6
Gizzard shad	--	--	2.3	0.7	2.3	0.9	4.6	0.4
Suckermouth minnow	4.6	0.7	--	--	--	--	4.6	0.4
Spotted sunfish	4.6	0.7	--	--	--	--	4.6	0.4
Yellow bullhead	2.3	0.4	2.3	0.7	--	--	4.6	0.4
Banded darter	--	--	3.0	0.9	--	--	3.0	0.2
Longnose gar	2.3	0.4	--	--	--	--	2.3	0.2
Grass pickeral	2.3	0.4	--	--	--	--	2.3	0.2
Fathead minnow	2.3	0.4	--	--	--	--	2.3	0.2
Quillback	--	--	2.3	0.7	--	--	2.3	0.2
Black bullhead	2.3	0.4	--	--	--	--	2.3	0.2
Pirate perch	2.3	0.4	--	--	--	--	2.3	0.2
Brook silverside	2.3	0.4	--	--	--	--	2.3	0.2
Largemouth bass	2.3	0.4	--	--	--	--	2.3	0.2
Yellow perch	2.3	0.4	--	--	--	--	2.3	0.2
Total	634.5	100.2	317.9	99.6	248.6	99.5	1201	100.9

is not expected to contain residual chlorine from station cooling water biofouling treatment because of the long path (16 km (10 mi)) and long time (approximately 3 days) before the plant effluent reaches the discharge.

5.6 Threatened and Endangered Species

5.6.1 Terrestrial

Two federally listed endangered terrestrial species, the bald eagle and the Indiana bat, may visit the site (Section 4.3.5.1). No serious impacts are expected to either species resulting from operation of the station. The greatest threat to survival of the Indiana bat is that a large proportion of the known population hibernates in only a few caves, where the bats are subject to destruction or disturbance (Harvey, 1975). Because there are no caves in the area, the operation of a nuclear power plant is unlikely to adversely affect the species.

Bald eagles may infrequently feed on the cooling pond, resulting in a slight potential for collisions with power lines. Eagles are known to collide with power lines occasionally; for example, Kroodsma (1978) estimated from the literature that as much as 10% of bald eagle mortality might be the result of such collisions. However, because no lines cross the pond or its borders and eagles are not common in the area (Ackerman, 1975), the staff considers the potential for eagle mortality extremely remote.

Several state-listed endangered or threatened species have been observed or may occur onsite as described in Section 4.3.5.1. Creation of terrestrial habitats on dikes and islands of the cooling pond, revegetation of remaining mine spoils, and seeding of an area to prairie plant species will have minimal adverse impacts on, and may actually benefit, any state-listed species occurring on the site.

5.6.2 Aquatic

No federally or state-listed threatened or endangered species were identified during preoperational monitoring in the vicinity of the site. The pallid shiner, *Notropis amnis*, was collected during monitoring. This is a rare species in Illinois and has been proposed for the state threatened-species list (according to T. Skelly in a telephone conversation on October 6, 1983). This species occurs over the sand/silt substrate, along both banks of the river at transect 5. Transect 5 is downstream of the blowdown discharge point and potentially could be affected by the discharge from the plant. However, this transect is located downstream of the projected thermal plume limits and is considered by the applicant to represent a potential recovery area from any impacts that may be associated with the discharge (ER-OL Section 6.1.1). Transect 5 is located in an area where widening of the river occurs after a narrow segment past the discharge point so that flow along the banks at transect 5 is reduced (see Figure 4.7). Because of the habitat preference of this species, impacts to this species from the station blowdown discharge to the river should be minimal.

5.7 Historic and Archeologic Impacts

The staff concludes, with one provision, that the operation and maintenance of the Braidwood Station will have no significant impacts on sites listed or eligible for listing in the *National Register of Historic Places*. The NRC is in the process of having a determination of eligibility completed for archeological site 11Ka179 for possible inclusion in the National Register. The NRC will take the action required on this issue dependent on the finding of the Keeper of the Register. The NRC has been in consultation with the State Historic Preservation Officer (SHPO) on its findings and has requested the SHPO's comments on these findings.

5.8 Socioeconomic Impacts

The socioeconomic impacts of station operation are analyzed in Sections 5.5 and 10.4 of the FES-CP. Several changes have occurred since that report was issued. The estimated operating work force has been increased to 553 permanent jobs with a payroll of $14.6 million (1982 dollars). The staff does not expect either the operating workers or their families to have any significant impact on public or private facilities in the area. The annual tax payments received by local taxing units for Braidwood Station are estimated to be about $9.2 million (1982 dollars) when the plant is scheduled to begin operation. The largest recipients are estimated to be local school district U-225 and Will County. Tax payments, however, are considered as indirect benefits of the station's operation because they are transfer payments. The staff anticipates no other significant socioeconomic impacts from the operation of Braidwood Station.

5.9 Radiological Impacts

5.9.1 Regulatory Requirements

Nuclear power reactors in the United States must comply with certain regulatory requirements in order to operate. The permissible levels of radiation in unrestricted areas and of radioactivity in effluents to unrestricted areas are recorded in 10 CFR 20, "Standards for Protection Against Radiation." These regulations specify limits on levels of radiation and limits on concentrations of radionuclides in the facility's effluent releases to the 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, as a result of facility operation, of more than 0.5 rem in 1 calendar year, or if an individual were continuously present in an area, 2 mrems in any 1 hour or 100 mrems in any 7 consecutive 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 20, there are recorded in 10 CFR 50.36a license requirements 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 operations, including expected operational occurrences, ALARA. Appendix I of 10 CFR 50 provides numerical guidance on dose-design objectives for LWRs to meet this ALARA requirement. Applicants for permits to construct and for licenses to operate an LWR shall provide reasonable assurance that the following calculated dose-design objectives will be met for all unrestricted areas: 3 mrems/year to the total body or 10 mrems/year to any organ from all pathways of exposure from liquid effluents; 10 mrads/year gamma radiation or 20 mrads/year beta radiation air dose from gaseous effluents near ground level--and/or 5 mrems/year to the total body or 15 mrems/year to the skin from gaseous effluents; and 15 mrems/yr to any organ from all pathways of exposure from airborne effluents that include the radioiodines, carbon-14, tritium, and the particulates.

Experience with the design, construction, and operation of nuclear power reactors indicates that compliance with these design objectives will keep average annual releases of radioactive material in effluents at small percentages of the limits specified in 10 CFR 20 and, in fact, will result in doses generally below the dose-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 ensure that the public is provided a dependable source of power, even under unusual operating conditions that may temporarily result in releases higher than such small percentages but still well within the limits specified in 10 CFR 20.

In addition to the impact created by facility radioactive effluents as discussed above, within the NRC policy and procedures for environmental protection described in 10 CFR 51 there are generic treatments of environmental effects of all aspects of the uranium fuel cycle. These environmental data have been summarized in Table S-3 of 10 CFR 51.51 and are discussed in this report in Section 5.10. In the same manner the environmental impact of transportation of fuel and waste to and from an LWR is summarized in Table S-4 of 10 CFR 51.52 and presented in Section 5.9.3 of this report.

An additional operational requirement for uranium-fuel-cycle facilities, including nuclear power plants, was established by the Environmental Protection Agency in 40 CFR 190. This regulation limits annual doses (excluding radon and daughters) for members of the public to 25 mrems total body, 75 mrems thyroid, and 25 mrems other organs from <u>all</u> fuel-cycle facility contributions that may impact a specific individual in the public.

5.9.2 Operational Overview

During normal operations of the Braidwood Station, Units 1 and 2, small quantities of radioactivity (fission, corrosion, and activation products) will be released to the environment. As required by the National Environmental Policy Act (NEPA), the staff has determined the estimated dose to members of the public outside of the plant boundaries as a result of the radiation from these radioisotope releases and relative to natural-background-radiation dose levels.

These facility-generated environmental dose levels are estimated to be very small because of both the plant design and the development of a program that will be implemented at the facility to contain and control all radioactive emissions and effluents. Radioactive-waste management systems are incorporated into the plant and are designed to remove most of the fission-product radioactivity that is assumed to leak from the fuel, as well as most of the activation and corrosion-product radioactivity produced by neutrons in the reactor-core vicinity. The effectiveness of these systems will be measured by process and effluent radiological monitoring systems that permanently record the amounts of radioactive constituents remaining in the various airborne and waterborne process and effluent streams. The amounts of radioactivity released through vents and discharge points to areas outside the plant boundaries are to be recorded and published semiannually in the Radioactive-Effluent-Release Reports for the facility.

Airborne effluents will diffuse in the atmosphere in a fashion determined by the meteorological conditions existing at the time of release and are generally dispersed and diluted by the time they reach unrestricted areas that are open to the public. Similarly, waterborne effluents will be diluted with plant waste water and then further diluted as they mix with the Kankakee River beyond the station boundaries.

Radioisotopes in the facility's effluents that enter unrestricted areas will produce doses through their radiations to members of the general public in a manner similar to the way doses are produced from background radiations (that is, cosmic, terrestrial, and internal radiations), which also include radiation from nuclear-weapons fallout. These radiation doses can be calculated for the many potential radiological-exposure pathways specific to the environment around the facility, such as direct-radiation doses from the gaseous plume or liquid effluent stream outside of the plant boundaries, or internal-radiation-dose commitments from radioactive contaminants that might have been deposited on vegetation, or in meat and fish products eaten by people, or that might be present in drinking water outside the plant or incorporated into milk from cows at nearby farms.

These doses, calculated for the "maximally exposed" individual (that is, the hypothetical individual potentially subject to maximum exposure), form the basis of the staff's evaluation of impacts. Actually, these estimates are for a fictitious person because assumptions are made that tend to overestimate the dose that would accrue to members of the public outside the plant boundaries. For example, if this "maximally exposed" individual were to receive the total body dose calculated at the plant boundary as a result of external exposure to the gaseous plume, he/she is assumed to be physically exposed to gamma radiation at that boundary for 70% of the year, an unlikely occurrence.

Site-specific values for 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 (for example, wind speed and direction) specific to the site topography and effluent release points, and hydrological information pertaining to dilution of the liquid effluents as they are discharged.

An annual land census will identify changes in the use of unrestricted areas to permit modifications in the programs for evaluating doses to individuals from principal pathways of exposure. This census specification will be incorporated into the radiological Technical Specifications and satisfies the requirements of Section IV.B.3 of Appendix I to 10 CFR 50. 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 that might possibly occur for any individual member of the public for each applicable foodchain pathway. The estimate considers, for example, where people live, where vegetable gardens are located, and where cows are pastured.

An extensive radiological environmental monitoring program, designed specifically for the environs of the Braidwood Station, provides measurements of radiation and radioactive contamination levels that exist outside of the facility boundaries both before and after operations begin. In this program, offsite radiation levels are continuously monitored with thermoluminescent detectors (TLDs). In addition, measurements are made on a number of types of samples from the surrounding area to determine the possible presence of radioactive contaminants that, for example, might be deposited on vegetation, be present in drinking water outside the plant, or be incorporated into cow's milk from nearby farms. The results for all radiological environmental samples measured during a calendar year of operation are recorded and published in the Annual Radiological Environmental Operating Report for the facility. The specifics of the final operational-monitoring program and the requirement for annual publication of the monitoring results will be incorporated into the operating license radiological Technical Specifications for the Braidwood facility.

5.9.3 Radiological Impacts From Routine Operations

5.9.3.1 Radiation Exposure Pathways: Dose Commitments

The potential environmental pathways through which persons may be exposed to radiation originating in a nuclear power reactor are shown schematically in Figure 5.3. When an individual is exposed through one of these pathways, the dose is determined in part by the amount of time he/she is in the vicinity of the source, or the amount of time the radioactivity inhaled or ingested is retained in his/her body. The actual effect of the radiation or radioactivity is determined by calculating the dose commitment. The annual dose commitment is calculated to be the total dose that would be received over a 50-year period, following the intake of radioactivity for 1 year under the conditions existing 20 years after the station begins operation. (Calculation for the 20th year, or midpoint of station operation, represents an average exposure over the life of the plant.) However, with few exceptions, most of the internal dose commitment for each nuclide is given during the first few years after exposure because of the turnover of the nuclide by physiological processes and radioactive decay.

There are a number of possible exposure pathways to humans that are appropriate to be studied to determine the impact of routine releases from the Braidwood facility on members of the general public living and working outside of the site boundaries, and whether the releases projected at this point in the licensing process will in fact meet regulatory requirements. A detailed listing of these exposure pathways would include external radiation exposure from the gaseous effluents, inhalation of iodines and particulate contaminants in the air, drinking milk from a cow or 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 may be contaminated by similar deposits, and drinking water or eating fish caught near the point of discharge of liquid effluents.

Other less important 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, boating and swimming activities near lakes or streams that may be contaminated by effluents, drinking potentially contaminated water, and direct radiation from within the plant itself. Note that for the Braidwood site there is no drinking water pathway of concern since the first drinking water intake is 194 km (121 mi) downstream of the plant and dilution of the plant effluent makes any effect of liquid released radioactivity 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, as demonstrated

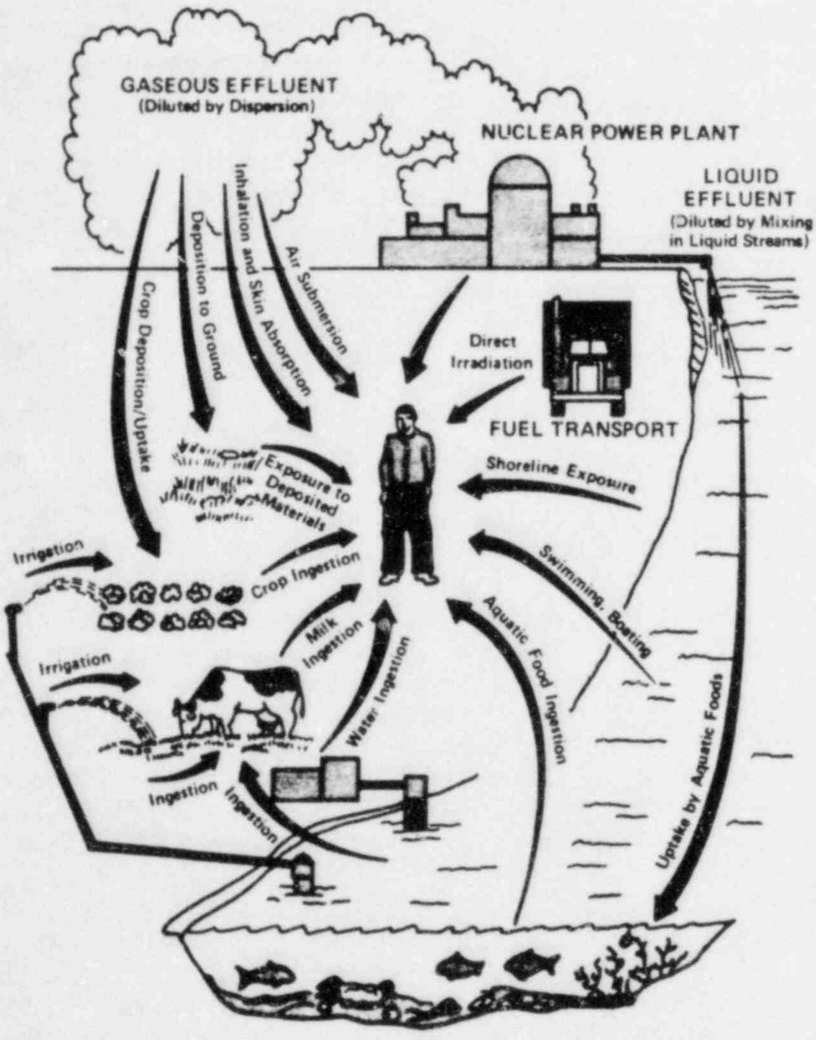

Figure 5.3 Potentially meaningful exposure pathways to individuals

by calculations, has shown that all individual dose commitments (>0.1 mrem/year) for radioactive effluents are accounted for within a radius of 80 km from the plant. Beyond 80 km the doses to individuals are smaller than 0.1 mrem/year, which is far below natural-background doses, and the doses are subject to substantial uncertainty because of limitations of predictive mathematical models.

The staff has made a detailed study of all of the above important 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 the facility. A discussion of these evaluations follows.

5.9.3.1.1 Occupational Radiation Exposure for Pressurized Water Reactors

Most of the dose to nuclear plant workers results from external exposure to radiation coming from radioactive materials outside of the body rather than from internal exposure from inhaled or ingested radioactive materials. Experience shows that the dose to nuclear plant workers varies from reactor to reactor and from year to year. For environmental impact purposes, it can be projected by using the experience to date with modern pressurized water reactors (PWRs). Recently licensed 1000-MWe PWRs are operated in accordance with the post-1975 regulatory requirements and guidance that place increased emphasis on maintaining occupational exposure at nuclear power plants ALARA. These requirements and guidance are outlined primarily in 10 CFR 20, SRP Section 12 (NUREG-0800), and RG 8.8, "Information Relevant to Ensuring That Occupational Radiation Exposures at Nuclear Power Stations Will Be as Low as Is Reasonably Achievable."

The applicant's proposed implementation of these requirements and guidelines is reviewed by the staff during the licensing process, and the results of that review are reported in the staff's Safety Evaluation Report. The license is granted only after the review indicates that an ALARA program can be implemented. In addition, regular reviews of operating plants are performed to determine whether the ALARA requirements are being met.

Average collective occupational dose information for 270 PWR years of operation is available for those plants operating between 1974 and 1981. (The year 1974 was chosen as a starting date because the dose data for years before 1974 are primarily from reactors with average rated capacities below 500 MWe.) These data indicate that the average reactor annual collective dose at PWRs has been about 500 person-rems, although some plants have experienced annual collective doses averaging as high as about 1400 person-rems/year over their operating lifetime (NUREG-0713, Vol 3). These dose averages are based on widely varying yearly doses at PWRs. For example, for the period mentioned above, annual collective doses for PWRs have ranged from 18 to 3223 person-rems per reactor. However, the average annual dose per nuclear plant worker of about 0.8 rem (NUREG-0713, Vol 3) has not varied significantly during this period. The worker dose limit, established by 10 CFR 20, is 3 rems/quarter, if the average dose over the worker lifetime is being controlled to 5 rems/year, or 1.25 rems/quarter if it is not.

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

In recognition of the factors mentioned above, staff occupational dose estimates for environmental impact purposes for Braidwood Station, Units 1 and 2, are based on the assumption that the facility will experience the annual average occupational dose for PWRs to date. Thus the staff has projected that the collective occupational doses for each unit at the Braidwood site will be 500 person-rems, but annual collective doses could average as much as three times this value over the life of the plant.

In addition to the occupational radiation exposures discussed above, during the period between the initial power operation of Unit 1 and the similar startup of Unit 2, construction personnel working on Unit 2 will potentially be exposed to sources of radiation from the operation of Unit 1. The applicant has estimated that the integrated dose to construction personnel, over a period of 2 years, will be about 80 person-rems. This radiation exposure will result predominantly from Unit 1 radioactive components and gaseous effluents from Unit 1. Based on experience with other PWRs, the staff finds that the applicant's estimate is reasonable. A detailed breakdown of the integrated dose to the construction workers by the location of their work and its duration is given in ER-OL Table 4.4-1.

The average annual dose of about 0.8 rem per nuclear plant worker at operating BWRs and PWRs has been well within the limits of 10 CFR 20. However, for impact evaluation, the staff has estimated the risk to nuclear power plant workers and compared it in Table 5.5 to published risks for other occupations. Based on these comparisons, the staff concludes that the risk to nuclear plant workers from plant operation is comparable to the risks associated with other occupations.

In estimating the health effects resulting from both offsite (see Section 5.9.3.2) and occupational radiation exposures as a result of normal operation of this facility, the staff used somatic (cancer) and genetic risk estimators that are based on widely accepted scientific information. Specifically, the staff's estimates are based on information compiled by the National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR I). The estimates of the risks to workers and the general public are based on conservative assumptions (that is, the estimates are probably higher than the actual number). The following risk estimators were used to estimate health effects: 135 potential deaths from cancer per million person-rems and 258 potential cases of all forms of genetic disorders per million person-rems. The cancer-mortality risk estimates are based on the "absolute risk" model described in BEIR I. Higher estimates can be developed by use of the "relative risk" model along with the assumption that risk prevails for the duration of life. Use of the "relative risk" model would produce risk values up to about four times greater than those used in this report. The staff regards the use of the "relative risk" model values as a reasonable upper limit of the range of uncertainty. The lower limit of the range would be zero because there may be biological mechanisms that can repair damage caused by radiation at low doses and/or dose rates. The number of potential nonfatal cancers would be approximately one and a half to two times the number of potential fatal cancers, according to the 1980 report of the National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR III).

Values for genetic risk estimators range from 60 to 1500 potential cases of all forms of genetic disorders per million person-rems (BEIR I). The value of 258 potential cases of all forms of genetic disorders is equal to the sum of the geometric means of the risk of specific genetic defects and the risk of defects with complex etiology.

The preceding values for risk estimators are consistent with the recommendations of a number of recognized radiation-protection organizations, such as the

Table 5.5 Incidence of job-related mortalities

Occupational group	Mortality rates (premature deaths per 10^5 person-years)
Underground metal miners*	~1300
Uranium miners*	420
Smelter workers*	190
Mining**	61
Agriculture, forestry, and fisheries**	35
Contract construction**	33
Transportation and public utilities**	24
Nuclear-plant worker***	23
Manufacturing**	7
Wholesale and retail trade**	6
Finance, insurance, and real estate**	3
Services**	3
Total private sector**	10

*The President's Report on Occupational Safety and Health, "Report on Occupational Safety and Health by the U.S. Department of Health, Education, and Welfare," E. L. Richardson, Secretary, May 1972.

**U.S. Bureau of Labor Statistics, "Occupational Injuries and Illness in the United States by Industry, 1975," Bulletin 1981, 1978.

***The nuclear-plant workers' risk is equal to the sum of the radiation-related risk and the nonradiation-related risk. The estimated occupational risk associated with the industry-wide average radiation dose of 0.8 rem is about 11 potential premature deaths per 10^5 person-years due to cancer, based on the risk estimators described in the following text. The average nonradiation-related risk for seven U.S. electrical utilities over the period 1970-1979 is about 12 actual premature deaths per 10^5 person-years as shown in Figure 5 of the paper by R. Wilson and E. S. Koehl, "Occupational Risks of Ontario Hydro's Atomic Radiation Workers in Perspective," presented at Nuclear Radiation Risks, A Utility-Medical Dialog, sponsored by the International Institute of Safety and Health in Washington, D.C., September 22-23, 1980. (Note that the estimate of 11 radiation-related premature cancer deaths describes a potential risk rather than an observed statistic.)

International Commission on Radiological Protection (ICRP, 1977), the National Council on Radiation Protection (NCRP, 1975), the National Academy of Sciences (BEIR III), and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR, 1982).

The risk of potential fatal cancers in the exposed work-force population at the Braidwood facility is estimated as follows: multiplying the annual plant-worker-population dose (about 1000 person-rems) by the somatic risk estimator, the staff estimates that about 0.14 cancer death may occur in the total exposed population. The value of 0.14 cancer death means that the probability of one cancer death over the lifetime of the entire work force as a result of 1 year of facility operation is about 14 chances in 100. The risk of potential genetic disorders attributable to exposure of the work force is a risk borne by the progeny of the entire population and is thus properly considered as part of the risk to the general public.

5.9.3.1.2 Public Radiation Exposure.

Transportation of Radioactive Materials

The transportation of "cold" (unirradiated) nuclear fuel to the reactor, of spent 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 51.52. 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 51.52, reproduced herein as Table 5.6. The cumulative dose to the exposed population as summarized in Table 5.6 is very small when compared to the annual collective dose of about 60,000 person-rems to this same population or 26,000,000 person-rems to the U.S. population from background radiation.

Table 5.6 Environmental impact of transportation of fuel and waste to and from one light-water-cooled nuclear power reactor[1] (Summary Table S-4)

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	1,100	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 for PWRs

Radiation fields are produced around nuclear plants as a result of radioactivity within the reactor and its associated components, as well as a result 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 mrems/year).

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

Radioactive-Effluent Releases: Air and Water

Limited quantities of radioactive effluents will be released to the atmosphere and to the hydrosphere during normal operations. Plant-specific radioisotope-release rates were developed on the basis of estimates regarding fuel performance and descriptions of the operation of radwaste systems in the applicant's FSAR, and by using the calculative models and parameters described in NUREG-0017.

These radioactive effluents are then diluted by the air and water into which they are released before they reach areas accessible to the general public.

Radioactive effluents can be divided into several groups. Among the airborne effluents, the radioisotopes of the fission product noble gases, krypton and xenon, as well as the radioactivated gas argon, do not deposit on the ground nor are they absorbed and accumulated within living organisms; therefore, the noble gas effluents act primarily as a source of direct external radiation emanating from the effluent plume. Dose calculations are performed for the site boundary where the highest external-radiation doses to a member of the general public as a result of gaseous effluents have been estimated to occur; these include the total body and skin doses as well as the annual beta and gamma air doses from the plume at that boundary location.

Another group of airborne radioactive effluents--the fission product radioiodines, as well as carbon-14 and tritium--are also gaseous but these tend to be deposited on the ground and/or inhaled into the body during breathing. 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 interest.

A third group of airborne effluents, consisting of particulates that remain after filtration of airborne effluents in the plant before release, includes fission products such as cesium and strontium and activated corrosion products such as cobalt and chromium. The calculational model determines the direct external radiation dose and the internal radiation doses for these contaminants 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 50.

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

The release rates 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 RG 1.109 (October 1977).

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

5.9.3.2 Radiological Impact on Humans

Although the doses calculated in Appendix D are based primarily on radioactive-waste treatment system capability and are below the 10 CFR 50, Appendix I, design objective values, the actual radiological impact associated with the operation of the facility 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 50.

Operation of the Braidwood facility will be governed by operating license Technical Specifications that will be based on the dose-design objectives of Appendix I to 10 CFR 50. 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 (~100 mrems/year) or the dose limits (500 mrems/year - total body) specified in 10 CFR 20 as consistent with considerations of the health and safety of the public. As a result, the staff concludes that there will be no measurable radiological impact on any member of the public from routine operation of the Braidwood facility.

Operating standards of 40 CFR 190, "The Environmental Protection Agency's Environmental Radiation Protection Standards for Nuclear Power Operations," specify that the annual dose equivalent must not exceed 25 mrems to the whole body, 75 mrems to the thyroid, and 25 mrems 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 concludes that under normal operations the Braidwood facility is capable of operating within these standards.

The radiological doses and dose commitments resulting from 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 observable 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 that have occasionally been 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 that result from nuclear power plant effluents, upper bound 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 of the site boundaries or to the total population outside of the boundaries can be readily calculated and recorded. These risk estimates for the Braidwood facility are presented below.

The risk to the maximally exposed individual is estimated by multiplying the risk estimators presented in Section 5.9.3.1.1 by the annual dose-design objectives for total-body radiation in 10 CFR 50, Appendix I. This calculation results in a risk of potential premature death from cancer to that individual from exposure to radioactive effluents (gaseous or liquid) from 1 year of reactor operations of less than one chance in one million.* The risk of potential premature death from cancer to the average individual within 80 km (50 miles) of the reactors from exposure to radioactive effluents from the reactors is much less than the risk to the maximally exposed individual. These risks are very small in comparison to natural cancer incidence from causes unrelated to the operation of the Braidwood facility.

Multiplying the annual U.S. general public population dose from exposure to radioactive effluents and transportation of fuel and waste from the operation of this facility (that is, 74 person-rems) by the preceding somatic risk estimator, the staff estimates that about 0.01 cancer death may occur in the exposed population. The significance of this risk can be determined by comparing it to the natural incidence of cancer death in the U.S. population. Multiplying the estimated U.S. population for the year 2000 (~260 million persons) by the current incidence of actual cancer fatalities (~20%), about 52 million cancer deaths are expected (American Cancer Society, 1981).

For purposes of evaluating the potential genetic risks, the progeny of workers are considered members of the general public. Multiplying the sum of the U.S.

*The risk of potential premature death from cancer to the maximally exposed individual from exposure to radioiodines and particulates would be in the same range as the risk from exposure to the other types of effluents.

population dose from exposure to radioactivity attributable to the normal annual operation of the plant (that is, 74 person-rems), and the estimated dose from occupational exposure (that is, 1000 person-rems) by the preceding genetic risk estimators, the staff estimates that about 0.28 potential genetic disorder may occur in all future generations of the exposed population. Because BEIR III indicates that the mean persistence of the two major types of genetic disorders is about 5 generations and 10 generations, in the following analysis the risk of potential genetic disorders from the normal annual operation of the plant is conservatively compared with the risk of actual genetic ill health in the first 5 generations, rather than the first 10 generations. Multiplying the estimated population within 80 km of the plant (~4,830,000 persons in the year 2000) by the current incidence of actual genetic ill health in each generation (~11%), about 2,660,000 genetic abnormalities are expected in the first 5 generations of the 80-km population (BEIR III).

The risks to the general public from exposure to radioactive effluents and transportation of fuel and wastes from the annual operation of the facility are very small fractions of the estimated normal incidence of cancer fatalities and genetic abnormalities. On the basis of the preceding comparison, the staff concludes that the risk to the public health and safety from exposure to radioactivity associated with the normal operation of the facility will be very small.

5.9.3.3 Radiological Impacts on Biota Other Than Humans

Depending on the pathway and the radiation source, terrestrial and aquatic biota will receive doses that are approximately the same or somewhat higher than humans receive. Although guidelines have not been established for acceptable limits for radiation exposure to species other than humans, it is generally agreed that the limits established for humans are sufficiently protective for other species.

Although the existence of extremely radiosensitive biota is possible and increased radiosensitivity in organisms may result from environmental interactions with other stresses (for example, heat or 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 the facility. Furthermore, at all nuclear plants for which radiation exposure to biota other than humans has been analyzed (Blaylock and Witherspoon, 1976), there have been no cases of exposure that can be considered significant in terms of harm to the species, or that approach the limits for exposure to members of the public that are permitted by 10 CFR 20. Inasmuch as the 1972 BEIR Report (BEIR I) concluded that evidence to date indicated that no other living organisms are very much more radiosensitive than humans, no measurable radiological impact on populations of biota is expected as a result of the routine operation of this facility.

5.9.3.4 Radiological Monitoring

Radiological environmental monitoring programs are established to provide data where there are measurable levels of radiation and radioactive materials in the site environs and to show that in many cases no detectable levels exist. Such monitoring programs are conducted to verify the effectiveness of inplant 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 environmental monitoring programs could identify the highly unlikely existence of releases of radioactivity from unanticipated release points that are not monitored. An annual surveillance (land census) program will be established to identify changes in the use of unrestricted areas to provide a basis for modifications of the monitoring programs or of the Technical Specifications conditions that relate to the control of doses to individuals.

These programs are discussed generically in greater detail in RG 4.1, Revision 1, and in the Radiological Assessment Branch Technical Position, Revision 1, November 1979, "An Acceptable Radiological Environmental Monitoring Program."*

5.9.3.4.1 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 facility, the training of personnel, and the evaluation of procedures, equipment, and techniques. The applicant proposed a radiological environmental-monitoring program to meet these objectives in the ER-CP, and it was discussed in the FES-CP. This early program has been updated and expanded; it is presented in Section 6.1.5 of the applicant's ER-OL and is summarized here in Table 5.7.

The applicant states that the preoperational program will have been implemented at least 2 years before initial criticality of Unit 1 to document background levels of direct radiation and concentrations of radionuclides that exist in the environment. The preoperational program will continue up to initial criticality of Unit 1 at which time the operational radiological monitoring program will commence.

The staff has reviewed the preoperational environmental monitoring plan of the applicant and finds that it is generally acceptable as presented.

5.9.3.4.2 Operational

The operational, offsite radiological monitoring program is conducted to provide data on measurable levels of radiation and radioactive materials in the site environs in accordance with 10 CFR 20 and 50. It assists and provides backup support to the effluent-monitoring program recommended in RG 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."

The applicant states that the operational program will in essence be a continuation of the preoperational program described above, with some periodic adjustment of sampling frequencies in expected critical exposure pathways. The final operational monitoring program proposed by the applicant will be reviewed in detail by the staff before plant operation, and the specifics of the required monitoring program will be incorporated into the operating license radiological Technical Specifications.

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*Available from the Radiological Assessment Branch, Office of Nuclear Reactor Regulation, U.S. Nuclear Regulatory Commission, Washington, D.C. 20555.

Table 5.7 Preoperational radiological environmental monitoring program summary
Source: ER-OL Table 6.1-10

SAMPLE MEDIA	COLLECTION SITES	TYPE AND FREQUENCY OF ANALYSIS[a,b]	FREQUENCY OF COLLECTION
Airborne Particulate Filter	Braidwood, Custer Park, County Line Road, Essex, Gardner, and Godley	Gross Beta - W Sr-89, Sr-90 - Q Comp. Gamma Spec. - Q Comp.	Weekly
Charcoal Cartridge	Same as for Airborne Particulate Filter Sites	I-131	Every 2 weeks beginning 3 months before fuel loading
Direct Radiation	a. Same as for Airborne Particulate Filter Sites b. Inner ring: 16 sectors, site boundary[d] c. Outer ring, 16 sectors, 6-8 km range[d]	TLD	Quarterly
Surface Water[c]	Downstream at sampling Station 5	Sr-89, Sr-90 - Q Comp. Gamma Spec. - M Comp. Gross Beta - W Tritium - Q Comp.	Weekly
Intake/Discharge Pipes[c]	I/D Pipes if pumping; if not pumping, at Sampling Stations 3 and 4	Gross Beta - W Sr-89, Sr-90 - M Comp. Tritium - M Comp. Gamma Spec. - M Comp.	Weekly
Precipitation	Two nearby Dairies	Gamma Spec. - Q Comp. Sr-89, Sr-90 - Q Comp. Gross Beta - M Tritium - Q Comp.	Monthly
Well Water (offsite)	Nearest Well	Gamma Spec. Sr-89, Sr-90 Gross Beta Tritium	Quarterly
Vegetables	Farms within 10 miles	Gross Beta Sr-89, Sr-90 Gamma Spec. I-131 (leafy vegetable)	As available at harvest time
Cattle Feed and Grass	Two nearby Dairies	Gross Beta Sr-89, Sr-90 Gamma Spec.	Quarterly Grass: May-October Feed: November, December
Milk	Two nearby Dairies	Gamma Spec. Sr-89, Sr-90 - M I-131 (pasture season)	Monthly
Sediment Aquatic Plants[c]	Downstream at Sampling Station 5, Upstream at Sampling Station 1	Gross Beta Gamma Spec.	3 times a year if available
Fish[c]	Sampling Station 5	Gross Beta Gamma Spec. Sr-89, Sr-90	3 times a year

[a]If frequency of analysis is not given, it is the same as frequency of collection.

[b]Frequency of analysis key: W = Weekly; M = Monthly; Q = Quarterly; Comp. = Composite.

[c]See Figure 6.1-2 for sampling locations.

[d]This monitoring will start in 1984.

5.9.4 Environmental Impacts of Postulated Accidents

5.9.4.1 Plant Accidents

The staff has considered the potential radiological impacts on the environment of possible accidents at the Braidwood plant site, in accordance with the June 13, 1980, Statement of Interim Policy issued by the NRC. The discussion below reflects the staff's considerations and conclusions.

Section 5.9.4.2 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 the consequences should accidents 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 societal impacts associated with actions to avoid such health effects as a result of air, water, and ground contamination from accidents also are identified.

Next, actual experience with nuclear power plant accidents and their observed health effects and other societal impacts are described. This is followed by a summary review of safety features of the Braidwood facilities 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 within the design basis are then given. Also described are the results of calculations for the Braidwood site using probabilistic methods to estimate the possible impacts and the risks associated with severe accident sequences of exceedingly low probability of occurrence.

5.9.4.2 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. The predominant focus, therefore, is on events that can lead to releases substantially in excess of permissible limits for normal operation. Normal release limits are specified in the Commission's regulations in 10 CFR 20 and 10 CFR 50, Appendix I.

There are several features that combine to reduce the risk associated with accidents at nuclear power plants. Safety features in 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 the Braidwood plant are in the applicant's FSAR. The most important mitigative features are described in Section 5.9.4.4(1).

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.

(1) Fission Product Characteristics

By far the largest inventory of radioactive material in a nuclear power plant is produced as a byproduct of the fission process and is located in the uranium oxide fuel pellets in 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. Table 5.8 lists the inventories of radionuclides that could be expected in a Braidwood reactor core.

Table 5.8 Activity of radionuclides in a Braidwood Station reactor core at 3565 MWt

Group/radionuclide	Radioactive inventory in millions of curies	Half-life (days)
A. NOBLE GASES		
Krypton-85	0.62	3950
Krypton-85m	27	0.183
Krypton-87	52	0.0528
Krypton-88	76	0.117
Xenon-133	190	5.28
Xenon-135	38	0.384
B. IODINES		
Iodine-131	95	8.05
Iodine-132	130	0.0958
Iodine-133	190	0.875
Iodine-134	210	0.0366
Iodine-135	170	0.280
C. ALKALI METALS		
Rubidium-86	0.029	18.7
Cesium-134	8.4	750
Cesium-136	3.3	13.0
Cesium-137	5.2	11,000
D. TELLURIUM-ANTIMONY		
Tellurium-127	6.6	0.391
Tellurium-127m	1.2	109
Tellurium-129	35	0.048
Tellurium-129m	5.9	34.0
Tellurium-131m	14	1.25
Tellurium-132	130	3.25
Antimony-127	6.8	3.88
Antimony-129	37	0.179

Table 5.8 (Continued)

Group/radionuclide	Radioactive inventory in millions of curies	Half-life (days)
E. ALKALINE EARTHS		
Strontium-89	100	52.1
Strontium-90	4.1	11,030
Strontium-91	120	0.403
Barium-140	180	12.8
F. COBALT AND NOBLE METALS		
Cobalt-58	0.87	71.0
Cobalt-60	0.32	1,920
Molybdenum-99	180	2.8
Technetium-99m	160	0.25
Ruthenium-103	120	39.5
Ruthenium-105	80	0.185
Ruthenium-106	28	366
Rhodium-105	55	1.50
G. RARE EARTHS, REFRACTORY OXIDES AND TRANSURANICS		
Yttrium-90	4.3	2.67
Yttrium-91	130	59.0
Zirconium-95	170	65.2
Zirconium-97	170	0.71
Niobium-95	170	35.0
Lanthanum-140	180	1.67
Cerium-141	170	32.3
Cerium-143	140	1.38
Cerium-144	95	284
Praseodymium-143	140	13.7
Neodymium-147	67	11.1
Neptunium-239	1800	2.35
Plutonium-238	0.063	32,500
Plutonium-239	0.023	8.9×10^6
Plutonium-240	0.023	2.4×10^6
Plutonium-241	3.8	5,350
Americium-241	0.0019	1.5×10^5
Curium-242	0.56	163
Curium-244	0.026	6,630

Note: The above grouping of radionuclides corresponds to that in Table 5.10.

These radioactive materials exist in a variety of physical and chemical forms. Their potential for dispersion into the environment depends 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. Some, however, 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 low-frequency but credible events (see Section 5.9.4.3). It is for this reason that the safety analysis of each nuclear power plant incorporates a hypothetical design-basis accident that postulates the release of the entire contained inventory of radioactive noble gases from the fuel into the containment structure. If these gases were 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 structure 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 they may be quite volatile. For these reasons, they have traditionally been regarded as having a relatively high potential for release from the fuel. If the radionuclides are 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. Because of this, the potential for release of radioiodines to the atmosphere is reduced by the use of special systems designed to retain the iodine.

The chemical forms in which the fission product radioiodines are found are generally solid materials at room temperatures, so they have a strong tendency to condense (or "plate out") on cooler surfaces. In addition, most of the iodine compounds are quite soluble in, or chemically reactive with, water. Although these properties do not inhibit the release of radioiodines from degraded fuel, they do act to mitigate the release from containment structures 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.

Other radioactive materials formed during the operation of a nuclear power plant have lower volatilities and, therefore, by comparison with the noble gases and iodines, have a much smaller tendency to escape from degraded fuel unless the temperature of the fuel becomes very 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 they are transported to a lower temperature region and/or dissolve in water when it is present. The former mechanism can result in production of 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 (fallout) or by precipitation (washout or rainout), 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. Many of them decay through a sequence or chain of decay processes and all eventually become stable (nonradioactive) materials. The radiation emitted during these decay processes renders the radioactive materials hazardous.

(2) Exposure Pathways

The radiation exposure (hazard) to individuals is determined by their proximity to the radioactive materials, the duration of exposure, and factors that act to shield the individual from the radiation. Pathways for radiation and the transport of 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 5.3. There are two additional possible pathways that could be significant for accident releases that are not shown in Figure 5.3. 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 via ground water. These pathways may lead to external exposure to radiation and to internal exposure if radioactive material is contacted, 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 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 upon the weather conditions existing at the time.

(3) Health Effects

The cause-and-effect relationships between radiation exposure and adverse health effects are quite complex (CONAES, 1979; Land, 1980), but these relationships have been more exhaustively studied than for 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 shortly thereafter. 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 close proximity of such accidents if measures are not or cannot be taken to provide protection, such as 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 randomly occurring cancer in the exposed population and genetic changes in future generations after exposure of a prospective parent. Occurrences of 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), occurrences of cancer may begin to develop at birth (no latent period) and end at age 10 (i.e., the plateau period is 10 years). The occurrence of cancer itself is not necessarily indicative of fatality. The health consequences model currently being used is based on the 1972 BEIR Report of the National Academy of Sciences (NAS) (BEIR I). Most authorities agree that a reasonable--and probably conservative--estimate of the randomly occurring number of health effects of 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 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, approximately 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 staff.

(4) Health-Effects Avoidance

Radiation hazards in the environment tend to disappear by the natural process of radioactive decay. Where the decay process is a slow one, however, and where the material becomes relatively fixed in its location as an environmental contaminant (such as in soil), the hazard can continue to exist for a relatively long period of time--months, years, or even decades. Thus, a possible 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.

5.9.4.3 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 early 1983, there were 76 commercial nuclear power reactor units licensed for operation in the United States at 52 sites with power-generating capacities ranging from 50 to 1180 MWe. The Braidwood units are designed for an electric power output of 1175 MWe (stretch power). The combined experience with these operating units represents approximately 650 reactor-years of operation over an elapsed time of about 22 years. Accidents have occurred at several of these facilities (Bertini, 1980; NUREG-0651; Thompson and Beckerley, 1964). Some of these accidents 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, nor any significant individual or collective public radiation exposure, nor any significant contamination of the environment. This experience does not provide a large enough base for a reliable statistical inference. It does, however, suggest that significant environmental impacts caused by 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 March 28, 1979.

In addition to the release of a few million curies of xenon (mostly xenon-133), it has been estimated that approximately 15 curies of radioiodine were also released to the environment at TMI-2 (Rogovin, 1980). This amount represents a 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 (Rogovin, 1980; President's Commission, 1979). The total population exposure has been estimated to be in the range from about 1000 to 5000 person-rems (this range is discussed on page 2 of NUREG-0558). 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 approximately a half-million cancers are expected to develop in this group over its lifetime (Rogovin, 1980; President's Commission, 1979), primarily from causes other than radiation. 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 affected.

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 reactor accidents (although there have been higher exposures to individual workers as a result of other unusual occurrences). However, the collective worker exposure levels (person-rems) are a small fraction of the exposures experienced during normal routine operations; these exposures average about 440 to 1300 person-rems in a PWR and 740 to 1650 person-rems in a BWR per reactor-year.

Accidents have also occurred at other nuclear reactor facilities in the United States and in other countries (Bertini, 1980; Thompson and Beckerley, 1964). Because of inherent differences in design, construction, operation, and purpose of most of these other facilities, their accident record has 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 Enrico Fermi Atomic Power Plant Unit 1. Fermi Unit 1 was a sodium-cooled fast breeder demonstration reactor designed to generate 61 MWe. The damages were repaired and the reactor reached full power 4 years after the accident. It operated successfully and completed its mission in 1973. The Fermi accident did not release any radioactivity to the environment.

A reactor accident in 1957 at Windscale, England, released a significant quantity of radioiodine, approximately 20,000 Ci, to the environment (United Kingdom Atomic Energy Office, "Accident at Windscale," 1957). 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 (characteristic of a graphite-moderated 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 518-km^2 (200-mi^2) area around the facility was impounded for up to 44 days. The United Kingdom National Radiological Protection Board (Crick and Linsley, 1982) estimated that the releases may have caused as many as 260 cases of thyroid cancer, about 13 of them fatal, and as many as 7 deaths from other cancers or hereditary diseases. This kind of accident cannot occur in a water-moderated-and-cooled reactor like Braidwood, however.

5.9.4.4 Mitigation of Accident Consequences

Pursuant to the Atomic Energy Act of 1954, as amended, the NRC has conducted a safety evaluation (NUREG-1002, 1983) of the application to operate the Braidwood Station, Units 1 and 2. Although this safety evaluation contains more detailed information on plant design, the principal design features are presented in the following section.

(1) Design Features

The Braidwood Station 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 (ESFs). The possibilities or probabilities of failure of these systems are incorporated in the assessments discussed in Section 5.9.4.5.

The steel-lined concrete containment building is a passive mitigating system, which 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. Cooling fans provide heat removal capability inside the containment following steam release in accidents and help to prevent containment failure resulting from overpressure. Similarly, the containment spray system is designed to spray cool water into the containment atmosphere. The spray water also contains an additive (sodium hydroxide) which will chemically react with any airborne radioiodine to remove it from the containment atmosphere and prevent its release to the environment.

All 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 building also has accident-mitigating systems. The safety-grade 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 that outleakage will not occur through building openings. If radioactivity were to be released into the building, it would be drawn through the ventilation system and any radioactive iodine and particulate fission products would be removed from the flow stream before exhausting to the outdoor atmosphere.

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 atmospheric dump valves can significantly reduce the amount of water-soluble radionuclides released to the environment.

Much more extensive discussions of the safety features and characteristics of the Braidwood Station may be found in the FSAR. The staff evaluation of these features is in the Braidwood SER (NUREG-1002, 1983). In addition, the implementation of the lessons learned from the TMI-2 accident--in the form of improvements in design, procedures, and operator training--will significantly reduce the likelihood of a degraded core accident which could result in large releases of fission products to the containment. Specifically, the applicant will be required to meet those TMI-2 related requirements specified in NUREG-0737.

(2) Site Features

The NRC's reactor site criteria, 10 CFR 100, require that the site for every power reactor have certain characteristics that tend to reduce the risk and potential impact of accidents. The discussion that follows briefly describes the Braidwood site characteristics and how they meet these requirements.

First, the site has an exclusion area, as required by 10 CFR 100. The total site area is about 1803 ha (4454 acres). The exclusion area, located within the site boundary, is a rectangular area with a minimum distance of 485 m (1591 ft) from the outer edge of the containment wall to the exclusion area boundary. There are no residents within the exclusion area. The applicant owns all surface and mineral rights in the exclusion area, and has the authority, required by 10 CFR 100, to determine all activities in this area. No public highways, railroads, or waterways traverse the exclusion area. There are no other activities unrelated to plant operation within the exclusion area.

Second, beyond and surrounding the exclusion area is a low population zone (LPZ), also required by 10 CFR 100. The LPZ for Braidwood is a circular area with a 1810-m (1-1/8-mi) radius. Within this zone, the applicant must ensure that there is a reasonable probability that appropriate protective measures could be taken on behalf of the residents in the event of a serious accident. The applicant has indicated that 705 persons lived within a 1810-m radius in 1980 and projects that the population will increase to 911 in the year 2000. The cumulative population for 0-1810 m, including transients at local recreational areas in 1980, was stated to be 1205 persons. In case of a radiological emergency, the applicant has made arrangements to carry out protective actions, including evacuation of personnel in the vicinity of the nuclear plant. (See also the following section on emergency preparedness.)

Third, 10 CFR 100 also requires that the distance from the reactor to the nearest boundary of a densely populated area containing more than about 25,000 residents be at least one and one-third times the distance from the reactor to the outer boundary of the LPZ. Because accidents of greater potential hazards than those commonly postulated as representing an upper limit are conceivable, although highly improbable, it was considered desirable to add the population center distance requirement in 10 CFR 100 to provide for protection against excessive doses to people in large centers. The city of Joliet, Illinois, with a 1980 population of 77,950 located 32 km (20 mi) north-northeast of the site, is the nearest population center. The population center distance is at least one and one-third times the LPZ distance. The population density within a 16-km (10-mi) radius of the site was 87 people/mi^2 in 1980 and is projected to increase to 113 people/mi^2 by the year 2020.

The safety evaluation of the Braidwood site has also included a review of potential external hazards, that is, activities off site that might adversely affect the operation of the nuclear plant and cause an accident. The review encompassed nearby industrial and transportation facilities that might create explosive, fire, missile or toxic gas hazards.

The risk to the Braidwood facility from such hazards has been found to be negligible. A more detailed discussion of the compliance with the Commission's siting criteria and the consideration of external hazards was reported in the staff's SER (NUREG-1002).

(3) Emergency Preparedness

Emergency preparedness plans including protective action measures for the Braidwood Station and environs are in an advanced, but not yet fully completed stage. In accordance with the provisions of 10 CFR 50.47, effective November 3, 1980, no operating licenses will 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 (EPZs). 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 zones; 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 a radiological emergency.

NRC findings will be based on a review of the Federal Emergency Management Agency (FEMA) 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. NRC staff findings are included in the SER. The staff's overall conclusions on the state of emergency preparedness for Braidwood Station and its associated emergency planning zones will be reported in an SER supplement. Although the presence of adequate and tested emergency plans cannot prevent the occurrence of an accident, it is the judgment of the staff that such plans can and will substantially mitigate the consequences to the public if one should occur.

5.9.4.5 Accident Risk and Impact Assessment

(1) Design-Basis Accidents

As a means of ensuring that certain features of the Braidwood Station 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 off site. 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.

Three categories of accidents have been considered based on their probability of occurrence: (1) incidents of moderate frequency (events that can reasonably be expected to occur during any year of operation), (2) infrequent accidents (events that might occur once during the lifetime of the plant), and (3) limiting faults (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 similar to the consequences from normal operation that are discussed in Section 5.9.3. Some of the initiating events postulated in the second and third categories for the Braidwood plant are shown in Table 5.9. These events are designated design-basis accidents in that specific design and operating features such as described in Section 5.9.4.4(1) are provided to limit their potential radiological consequences. Approximate radiation doses that might be received by a person at the nearest boundary of the plant exclusion area, which is about 485 m (0.30 mi) distant from the reactor, during the first 2 hours of the accident are also shown in the table. The results shown in the table reflect the expectation that engineered safety and operating features designed to mitigate the consequences of the postulated accidents would function as intended. An important implication of this expectation is that the releases considered are limited to noble gases and radioiodines and that any other radioactive materials (e.g., in particulate form) are not expected to be released. The results are also quasiprobabilistic in nature in the sense that the meteorological dispersion conditions are taken to be neither the best nor the worst for the site, but rather a median value determined by actual site measurements. To contrast the results of these calculations with those using more pessimistic, or conservative, assumptions described below, the doses shown in Table 5.9 are sometimes referred to as "realistic" doses.

Table 5.9 Approximate 2-hour radiation doses from design-basis accidents at exclusion area boundary

Accident	Dose (rems) at 533 m[1] Whole body
Infrequent accident:	
Steam generator tube rupture[2]	0.075
Fuel-handling accident	0.0075
Limiting faults:	
Main steam line break	0.001
Control rod ejection	0.125
Large-break loss-of-coolant accident	1.25

[1]Plant exclusion area boundary distance.
[2]See NUREG-0651 for descriptions of three steam generator tube rupture accidents that have occurred in the United States.

The staff has also carried out calculations to estimate the potential upper bounds for individual exposures from the same initiating accidents in Table 5.9 for the purpose of implementing the provisions of 10 CFR 100. For these calculations, much more 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 amounts of radioactive material released by the initiating events, additional single failures in equipment, operation of ESFs in a degraded mode,* and poor meteorological dispersion conditions. The results of these calculations taken from the Braidwood SER (NUREG-1002) show that for these events the limiting whole-body exposures are not expected to exceed 4 rems and most would not exceed 1 rem to any individual at the exclusion area boundary. They also show that radioiodine releases have the potential for offsite exposures ranging up to about 143 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 2 hours. The health risk to an individual receiving such an exposure to the thyroid is the potential appearance of benign or malignant thyroid nodules in about 5 out of 100 cases, and the development of a fatal thyroid cancer in about 2 out of 1000 cases.

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

(2) Probabilistic Assessment of Severe Accidents

In this and the following three sections, a discussion of the probabilities and consequences of accidents of greater severity than the design-basis accidents discussed in the previous section is provided. As a class, they are considered less likely to occur, but their consequences could be more severe, both for the plant itself and for the environment. These severe accidents, heretofore frequently called Class 9 accidents, can be distinguished from design-basis accidents in two primary respects: (1) they involve substantial physical deterioration of the fuel in the reactor core, including overheating to the point of melting, (2) 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.

The assessment methodology employed is that described in the Reactor Safety Study (RSS), which was published in 1975 (WASH-1400, now designated NUREG-75/014). A less comprehensive but more up-to-date treatment is given in NUREG/CR-2300, "PRA Procedures Handbook." Because WASH-1400 has been subject to considerable controversy, a discussion of the uncertainties surrounding it is provided in Section 5.9.4.5(7). However, the staff has selected a set of updated accident sequences, their associated probabilities, and the resultant releases that are appropriate to Braidwood. The earlier technique of grouping a number of accident sequences into release categories has been refined. Also, the "smoothing technique" used in the RSS for adjusting probabilities, which was criticized in the Lewis Report (NUREG/CR-0400), was not used in this study.

The Braidwood units are Westinghouse-designed PWRs. The present assessment for Braidwood used plant- and site-specific information along with more general information generated from in-depth analyses of other PWRs. In particular, the Zion and the Indian Point 2 and 3 probabilistic risk assessments (PRAs) and the

*The containment structure, however, is assumed to prevent leakage in excess of that which can be demonstrated by testing, as provided in 10 CFR 100.11(a).

staff reviews thereof provided the framework for selecting the accident sequences, containment failure modes, and release categories used for Braidwood. The release categories and their associated probabilities are used directly to calculate the consequences and risks of potential accidents. Each release category is specific to a certain type and timing of core damage and containment failure, but different accident sequences can lead to the same release category. The release categories are described in Appendix E. Characteristics of the release categories used (all of which involve partial to complete melting of the reactor core) are shown in Table 5.10. Sequences initiated by external phenomena such as tornadoes, floods, or seismic events, and those that could be initiated by man, including deliberate acts of sabotage, are not included in the event sequences corresponding to the listed release categories. The only plants for which external events have been assessed in detail in a probabilistic sense are Zion (NUREG/CR-3300, draft), Indian Point (NUREG/CR-2934), and Limerick (NUREG-0974). In these cases, no estimates of risk from sabotage were made, and these estimates are considered beyond the state of the art. The staff notes, however, that the consequences of large releases caused by sabotage should not be different in kind from the releases estimated for severe internally initiated accidents. For both Zion and Limerick, the licensees submitted probabilistic risk assessments that indicate external events can be significant contributors to risk. For Indian Point, staff evaluations also indicate significant risks as a result of external events other than sabotage. By "significant," the staff means that the best estimates of the additional risk from external events other than sabotage were calculated to be as much as a factor of 30 higher compared with the best-estimate risks from internal events at Indian Point, but about 2 to 10 times the best-estimate risk from internal events at Zion.

Although the staff made no numerical assessment of externally initiated accident risks for Braidwood, it did draw on information from the Zion, Limerick, and Indian Point studies. That is, the staff concludes the actual risks from internal and external causes (exclusive of sabotage) could be higher than those presented here, but are unlikely to exceed those determined from risk multipliers computed for Zion, Limerick, and Indian Point. These multipliers would not result in risks at Braidwood outside an uncertainty range of a factor of 100 times the risks from internal events, as discussed in Section 5.9.4.5(7).

The calculated probability per reactor-year associated with each release category used is shown in the first row in Table 5.10. As in 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 (see Section 5.9.4.5(7)).

The magnitudes (curies) of radioactivity release for each release category are obtained by multiplying the release fractions shown in Table 5.10 by the amounts that would be present in the core at the time of the hypothetical accident. These are shown in Table 5.8 for a Braidwood unit at a core thermal power level of 3565 MWt, the power level used in the safety evaluation. Of the hundreds of radionuclides present in the core, the 54 listed in the table were selected as significant contributors to the health and the economic risks of severe accidents. The core radionuclides were selected on the basis of (1) half-life, (2) approximate relative offsite dose contribution, and (3) health effects of the radionuclides and their daughter products.

Table 5.10 Summary of atmospheric releases, defined by release categories, for Braidwood

	Release category*				
Parameter	B	C	F	H	I
Probability per reactor-year	1.1×10^{-6}	4.7×10^{-6}	2.8×10^{-6}	9.1×10^{-6}	8.3×10^{-5}
Release time (hr)	1	13	3.0	72.0	2
Release duration (hr)	0.5	0.5	0.5	8.0	8.0
Release energy (10^6 Btu/hr)**	0.5	98	180	0	0
Warning time (hr)	1	8	1	67	1
Radionuclide group (fractions of total core inventory)†					
Xe-Kr	1.0	9.6×10^{-1}	8.5×10^{-1}	7.0×10^{-1}	5.0×10^{-4}
I-Br	7.0×10^{-1}	9.8×10^{-2}	7.8×10^{-2}	4.0×10^{-4}	5.0×10^{-6}
Cs-Rb	5.0×10^{-1}	3.4×10^{-1}	6.2×10^{-2}	1.0×10^{-3}	1.0×10^{-5}
Te	1.0×10^{-1}	3.8×10^{-1}	4.9×10^{-2}	1.0×10^{-3}	1.0×10^{-5}
Ba-Sr	6.0×10^{-2}	3.7×10^{-2}	7.1×10^{-3}	1.0×10^{-4}	1.0×10^{-6}
Ru††	2.0×10^{-2}	2.9×10^{-2}	4.3×10^{-3}	7.0×10^{-5}	1.0×10^{-6}
La#	2.0×10^{-3}	4.9×10^{-3}	6.6×10^{-4}	1.0×10^{-5}	2.0×10^{-7}

*Release categories are a description of the type of releases expected from various types of core damage and containment failure. See Appendix E for further discussion.

**cal/sec = 14.29 Btu/hr.

†Background on the isotope groups and release mechanisms is presented in WASH-1400, Appendix VII, and in NUREG/CR-2300.

††Includes Ru, Rh, Co, Mo, and Te.

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

The potential radiological consequences of these releases have been calculated by the consequence model used in the RSS (NUREG/CR-2300), adapted and modified as described below to apply to a specific site. The essential elements are shown in schematic form in Figure 5.4. Environmental parameters specific to the Braidwood site have been used and include the following:

(a) meteorological data for the site representing a full year of consecutive hourly measurements and seasonal variations

(b) projected population for the year 2000 extending throughout regions of 80-km (50-mi) and 563-km (350-mi) radii from the site

(c) the habitable land fraction within a 563-km (350-mi) radius

(d) land-use statistics, on a statewide basis, including farm land values, farm product values including dairy production, and growing season information, for the State of Illinois and each surrounding state within the 563-km (350-mi) region (land-use statistics for Canada were assumed to be the same as for adjacent states).

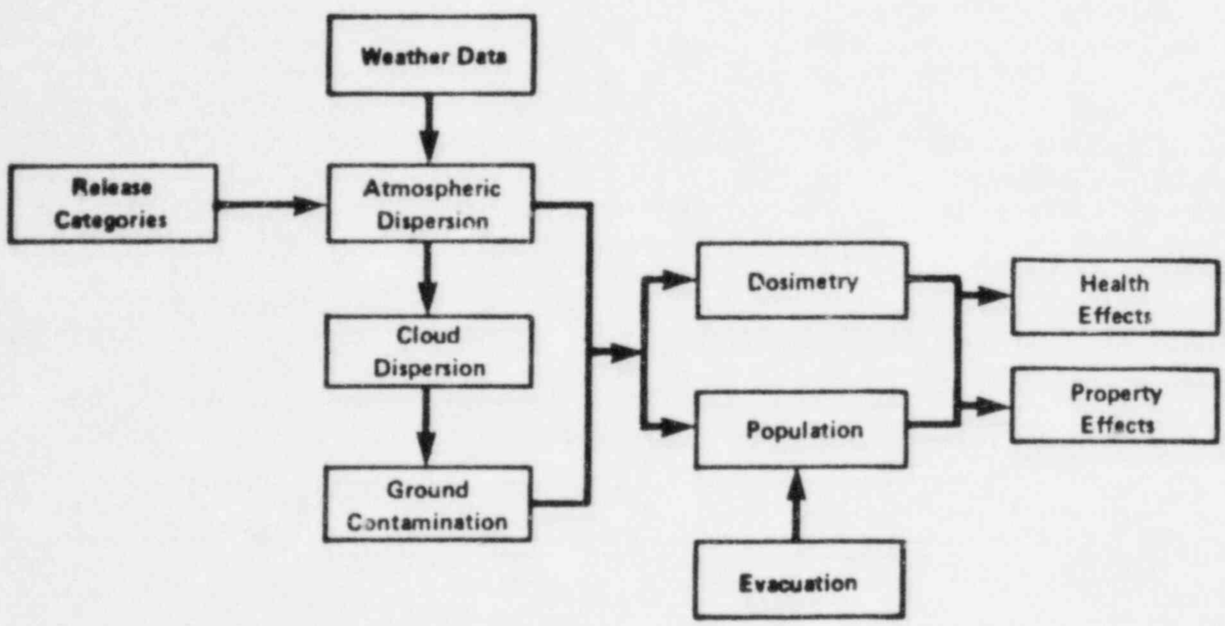

Figure 5.4 Schematic of atmospheric pathway consequence model

To obtain a probability distribution of consequences, the calculations are performed assuming the releases, as defined by the release categories, at each of 91 different "start" times throughout a 1-year period. Each calculation used (1) the site-specific hourly meteorological data, (2) the population projections for the year 2000 out to a distance of 563 km (350 mi) around the Braidwood site, and (3) seasonal information for the time period following each "start" time. The consequence model also contains provisions for incorporating the consequence-reduction benefits of evacuation, relocation, and other protective actions. Early evacuation and relocation of people would considerably reduce the exposure from the radioactive cloud and the contaminated ground in the wake of the cloud passage from severe releases. The evacuation model used (see 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 Braidwood site are estimates made by the staff. There normally would be some facilities near a plant, such as schools or hospitals, where special equipment or personnel may be required to effect evacuation, and some people near a site who may choose not to evacuate. Such facilities (including Braidwood Elementary and Middle School, Reed Custer High School, and Braceville Elementary School) have been identified near the Braidwood site. Therefore, actual evacuation effectiveness could be greater or less than that characterized, but it would not be expected to be very much less, because special consideration will be given in emergency planning for the Braidwood plant to any unique aspects of dealing with special facilities.

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 are reduced to such values by radioactive decay and weathering that land and property can be economically decontaminated as in (2) above. These actions would reduce the radiological exposure to the people from immediate and/or subsequent use of, or living in, the contaminated environment.

Early evacuation within and early relocation of people from outside the plume exposure pathway zone (see Appendix F) 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 Braidwood include the benefits of these protective actions.

There are also uncertainties in each facet of the estimates of consequences and the error bounds may be as large as they are for the probabilities (see Figure 5.4).

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.

(3) Dose and Health Impacts of Atmospheric Releases

The results of the atmospheric pathway calculations of dose and health impacts performed for the Braidwood facility and site are presented in the form of probability distributions in Figures 5.5 through 5.8* and are included in the impact summary table, Table 5.11. All of the release categories shown in Table 5.10 contribute to the results, the consequences of each being weighted by its associated probability.

Figure 5.5 shows the probability distribution for the number of persons who might receive bone marrow doses equal to or greater than 200 rems, whole-body doses equal to or greater than 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 bone marrow 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 dose (which has been identified earlier as the lower limit for a clinically observable physiological effect in nearly all people) and 300-rem thyroid dose figures correspond to the Commission's guideline values for reactor siting in 10 CFR 100.

Figure 5.5 shows in the left-hand portion that there are approximately 8 chances in 1,000,000 (8×10^{-6}) per reactor-year that one or more persons may receive doses equal to or greater than any of the doses specified. The fact that the three curves initially run almost parallel in horizontal lines shows that if one person were to receive such doses, the chances are about the same that ten 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 1 in 100,000,000 (1×10^{-8}) that 10,000 or more people might receive doses of 200 rems or greater. Virtually all of the exposures reflected in this figure would occur within a 97-km (60-mi) radius.

Figure 5.6 shows the probability distribution for the total population exposure in person-rems; that is, the probability per reactor-year that the total population exposure will equal or exceed the values given. Most of the population exposure up to 1,000,000 person-rems would be expected to occur within 80 km (50 mi), but the more severe releases (as in the first two release categories in Table 5.10) could result in exposure to persons beyond the 80-km range as shown.

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*Figures 5.5 through 5.9 and Figure F.1 (Appendix F) are called complementary cumulative distribution functions. They are intended to show the relationship between the probability of a particular type of consequence being equalled or exceeded and the magnitude of the consequence. Probability per reactor-year (r-y) is the chance that a given event will occur in 1 year for one reactor. Because the different accident releases, atmospheric dispersion conditions, and chances of a health effect (e.g., early fatalities) result in a wide range of calculated consequences, they are presented on a logarithmic plot in which numbers varying over a very large range can be conveniently illustrated by a grid indicated by powers of 10. For instance, 10^6 means one million or 1,000,000 (1 followed by 6 zeroes). The cumulative probabilities of equalling or exceeding a given consequence are also calculated to vary over a large range (because of the varying probabilities of accidents and atmospheric dispersion conditions), so the probabilities are also plotted logarithmically. For instance, 10^{-6} means one millionth or 0.000001.

**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.

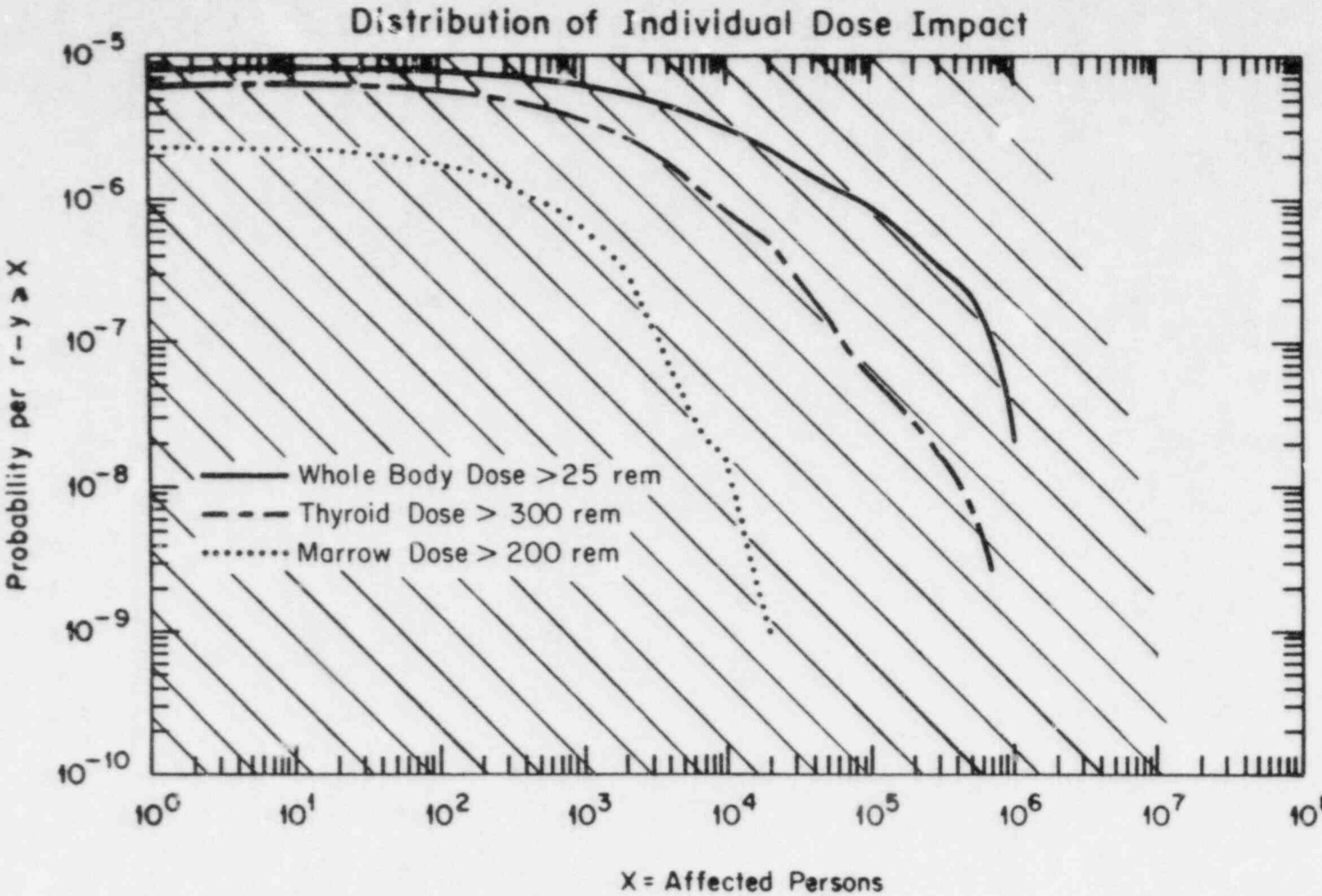

Figure 5.5 Probability distributions of individual dose impacts (See Section 5.9.4.5(7) for a discussion of uncertainties in risk estimates. Also see footnote in section entitled "Dose and Health Impacts of Atmospheric Releases" for help in interpreting this figure. The hatched area encloses confidence level loci of all points on the uppermost curve.)

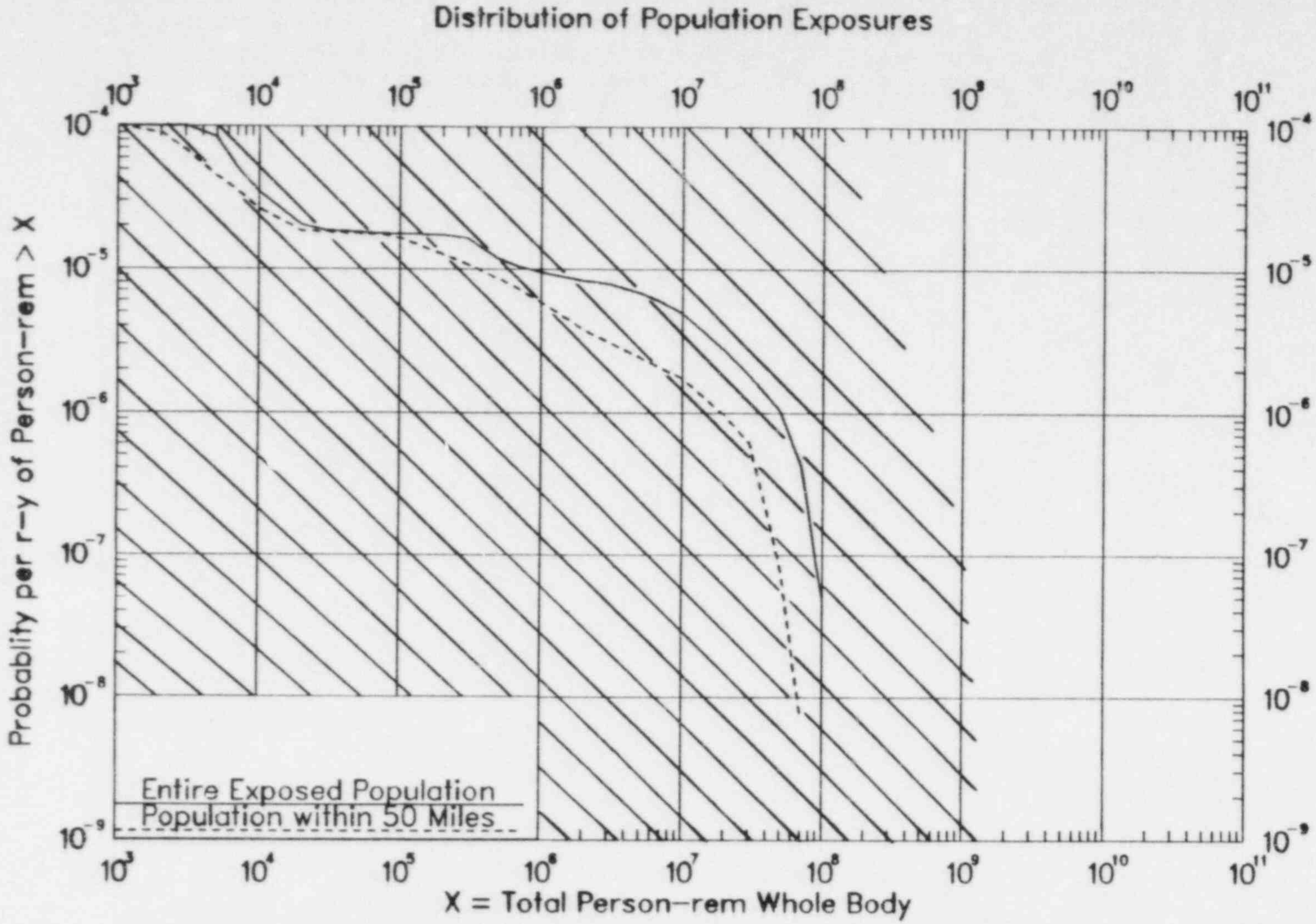

Figure 5.6 Probability distributions of population exposures (See Section 5.9.4.5(7) for a discussion of uncertainties in risk estimates) (50 mi = 80 km). Also see footnote in section entitled "Dose and Health Impacts of Atmospheric Releases" for help in interpreting this figure. The hatched area encloses confidence level loci of all points on the uppermost curve.)

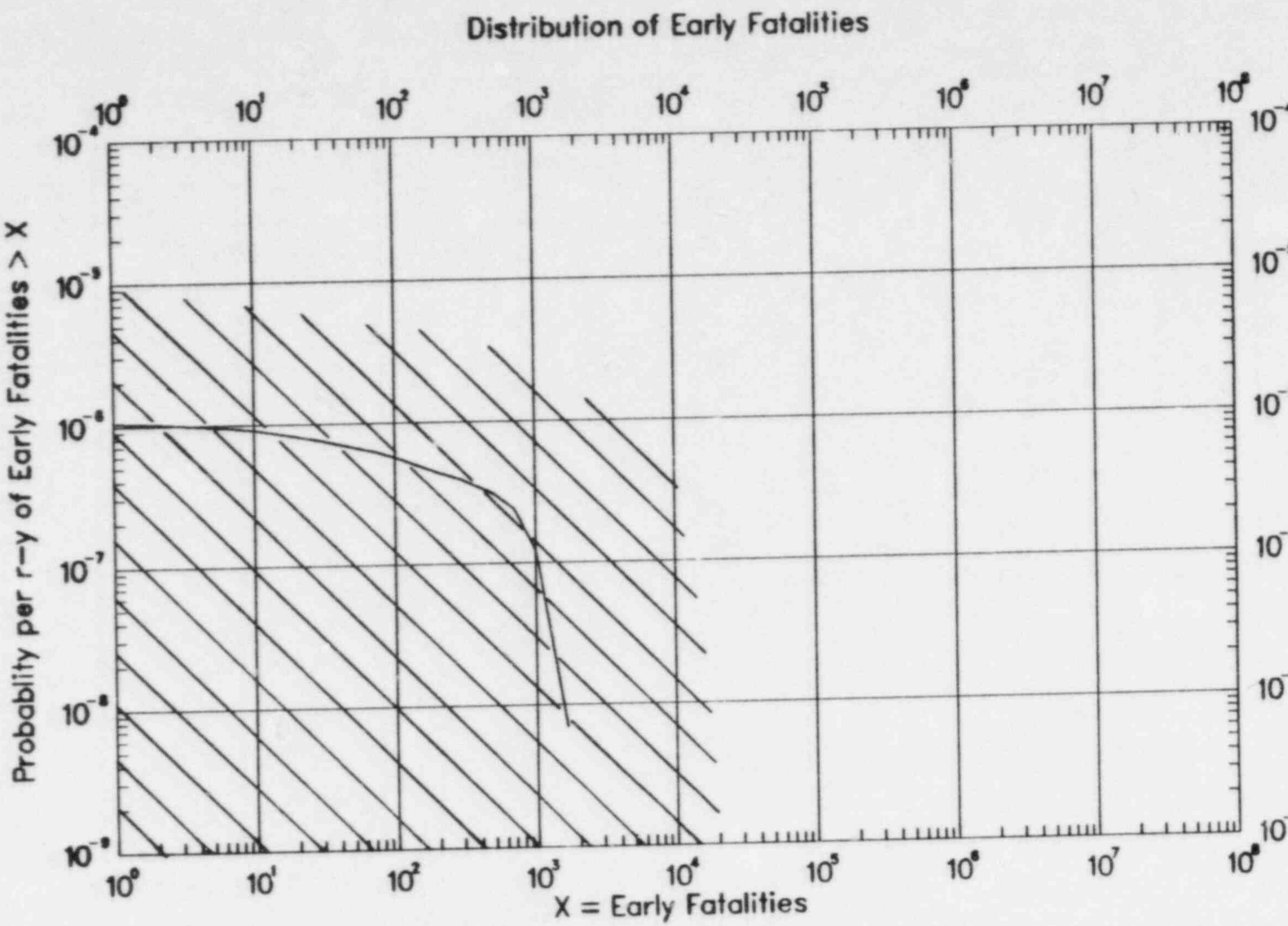

Figure 5.7 Probability distribution of early fatalities (See Section 5.9.4.5(7) for a discussion of uncertainties in risk estimate (50 mi = 80 km). Also see footnote in section entitled "Dose and Health Impacts of Atmospheric Releases" for help in interpreting this figure. The hatched area encloses confidence level loci of all points on the uppermost curve.)

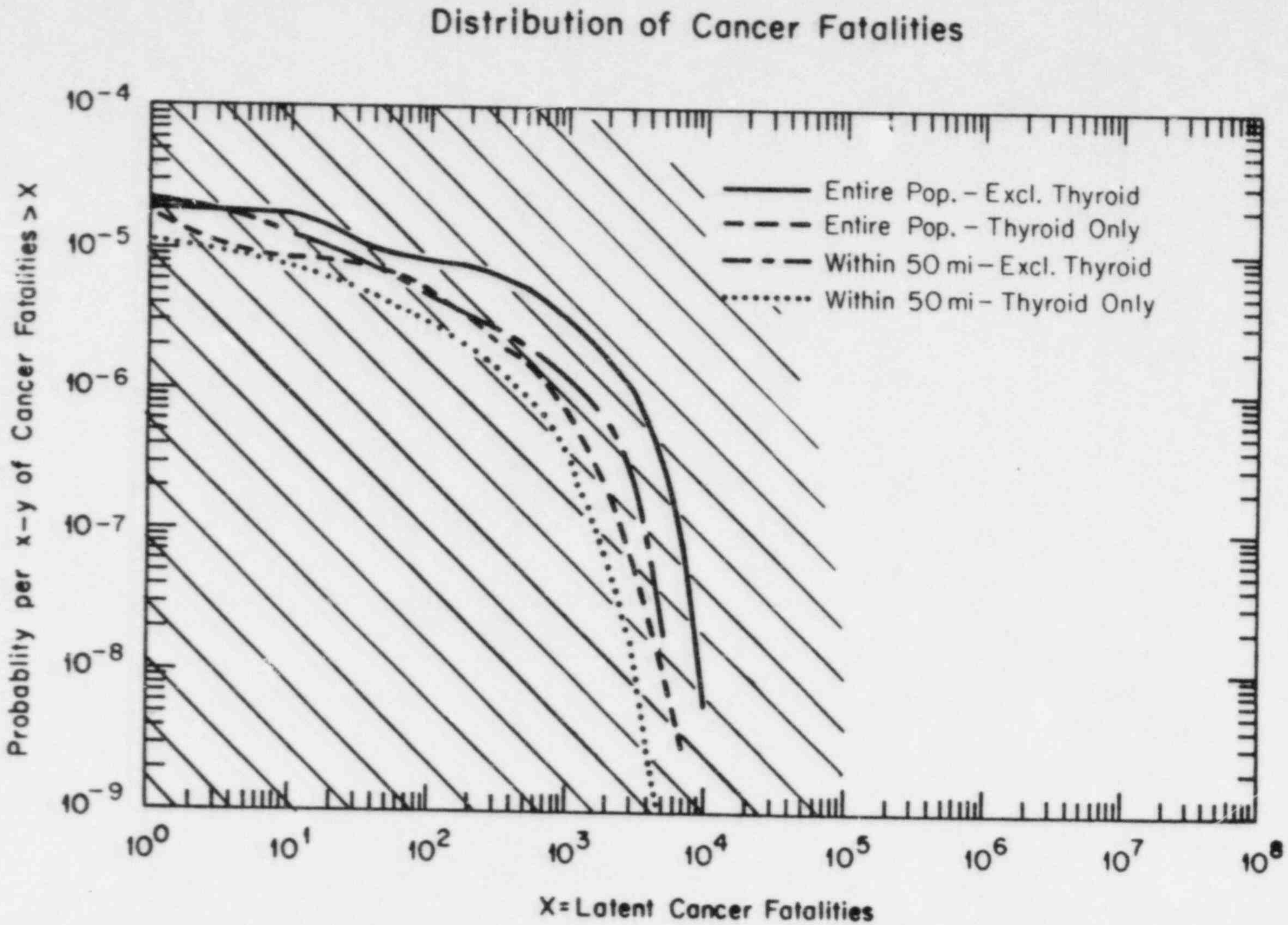

Figure 5.8 Probability distributions of cancer fatalities (See Section 5.9.4.5(7) for a discussion of uncertainties in risk estimate (50 mi = 80 km). Also see footnote in section entitled "Dose and Health Impacts of Atmospheric Releases" for help in interpreting this figure. The hatched area encloses confidence level loci of all points on the uppermost curve.)

For perspective, population doses shown in Figure 5.6 may be compared with the annual average dose to the population within 80 km of the Braidwood site resulting from background radiation of 520,000 person-rems and to the anticipated annual population dose to the general public (total U.S.) from normal plant operation (both units) of 72 person-rems (excluding plant workers) (Appendix D, Tables D-7 and D-9).

Figure 5.7 shows the probability distributions for early fatalities, representing radiation injuries that would produce fatalities within about 1 year after exposure. All of the early fatalities would be expected to occur within a 28-km (18-mi) radius and the majority within a 5-km (3-mi) radius. The results of the calculations shown in this figure and in Table 5.11 reflect the effect of evacuation within the 16-km (10-mile) plume exposure pathway zone. Figure F.1 in Appendix F shows the sensitivity of the early fatalities to the emergency response variations including (1) no evacuation and relocation after 1 day and (2) no evacuation and relocation after 12 hours.

Figure 5.8 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 are shown separately. Further, the fatal latent cancers have been subdivided into those attributable to exposures of the thyroid and all other organs. These estimates may be compared to the cancer fatality risk per individual per year from all causes of 1.9×10^{-3} (American Cancer Society, 1981).

(4) Economic and Societal Impacts

As noted in Section 5.9.4.2, the various measures for avoidance of adverse health effects, including those resulting from residual radioactive contamination in the environment, are possible consequential impacts of severe accidents. Calculations of the probabilities and magnitudes of such impacts for the Braidwood facility and environs have also been made. Unlike the radiation exposure and 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 5.9 and are included in Table 5.11. The factors contributing to these estimated costs include the following:

(a) evacuation costs
(b) value of crops contaminated and condemned
(c) value of milk contaminated and condemned
(d) costs of decontamination of property where practical
(e) indirect costs attributable 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 5.9 shows that at the extreme end of the accident spectrum, these costs could exceed several billion dollars, but that the probability that this would occur is exceedingly small (about 1 chance in 1 million per reactor-year).

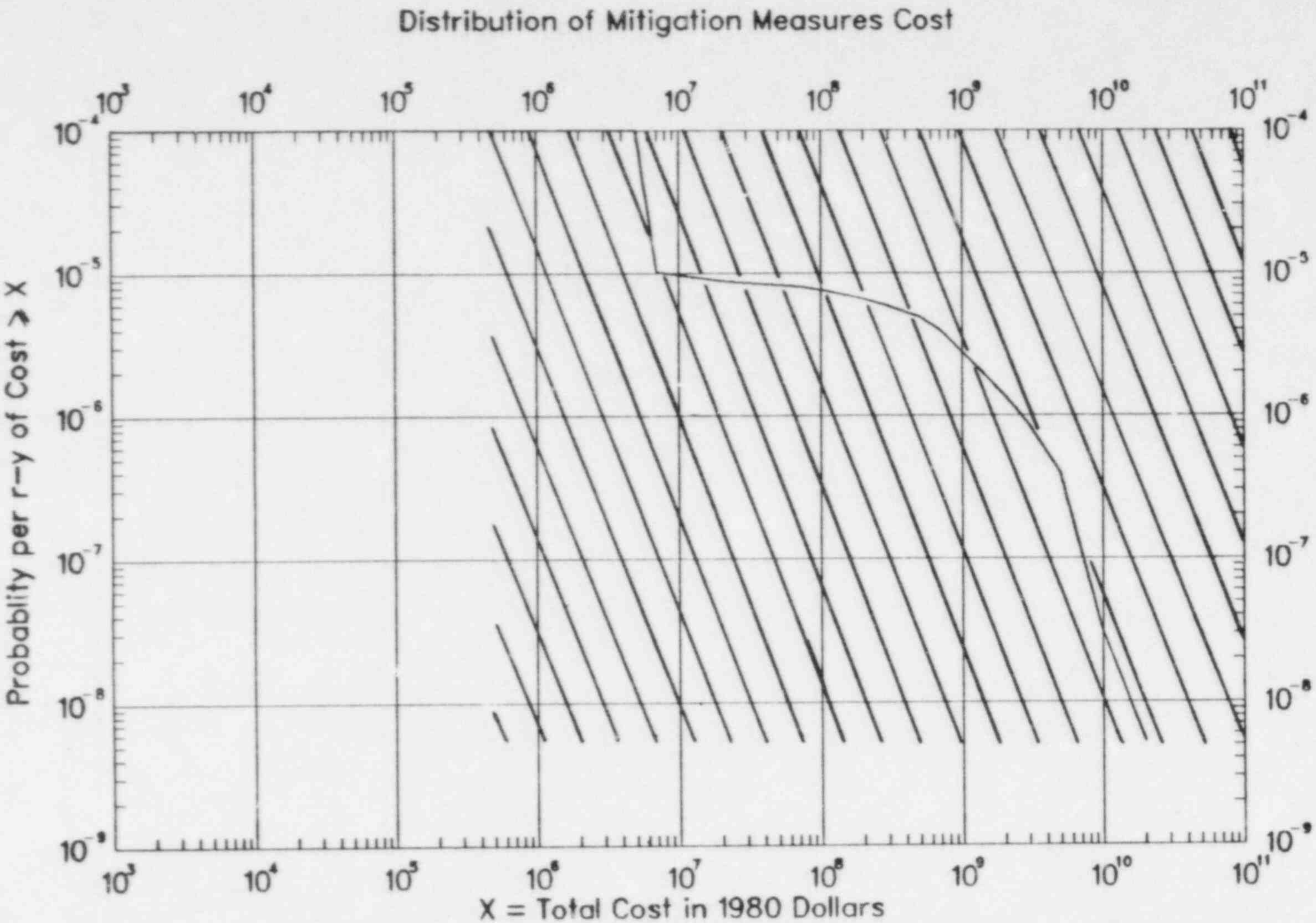

Figure 5.9 Probability distribution of mitigation measures cost (See Section 5.9.4.5(7) for a discussion of uncertainties in risk estimates. Also see footnote in section entitled "Dose and Health Impacts of Atmospheric Releases" for help in interpreting this figure. The hatched area encloses confidence level loci of all points on the uppermost curve.)

Table 5.11 Summary of environmental impacts and probabilities

Probability of impact per reactor-yr	Persons exposed over 200 rems	Persons exposed over 25 rems	Early fatalities	Population exposure, millions of person-rems, 80-km (50-mi)/ total	Latent* cancers, 80-km (50-mi)/ total	Cost of offsite mitigating actions, $ millions
10^{-4}	0	0	0	0/<0.003	0/0	< 5
10^{-5}	0	0	0	0.35/0.81	71/220	7
5×10^{-6}	0	3,400	0	1.3/12	220/730	470
10^{-6}	480	87,000	3	19/51	1,400/3,100	2,600
10^{-7}	3,200	730,000	1,000	47/88	3,600/6,400	7,100
10^{-8}	10,100	730,000	1,500	67/88	8,100/9,000	16,000
Related figure	5.9	5.9	5.11	5.10	5.12	5.13

*Includes cancers of all organs. Genetic effects would be approximately twice the number of latent cancers.

NOTE: Please refer to Section 5.9.4.5(7) for a discussion of uncertainties in risk estimates.

Additional economic impacts that can be monetized by the RSS consequence model include costs of decontamination of the facility itself. Another cost of impact is the replacement power. Probability distributions for these impacts have not been calculated, but they are included in the discussion of risk considerations in Section 5.9.4.5(6).

(5) Possible Releases to Ground Water

A ground water pathway for public radiation exposure and environmental contamination that would be associated with severe reactor accidents was identified in Section 5.9.3.1. Consideration has been given to the potential environmental impact of this pathway for the Braidwood plant. The principal contributors to the risk are the core melt accidents associated with the evaluated accident sequences and release categories. The penetration of the basemat of the containment buildings can release molten core debris to the strata beneath the station. Radionuclides in this debris can be leached and transported with ground water to downgradient domestic wells used for drinking or to surface water bodies used for drinking, aquatic food, and recreation. In pressurized water reactors, such as the Braidwood units, there is an additional opportunity for ground water contamination resulting from 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) (NUREG-0440). The LPGS compared the risk of accidents involving the liquid pathway (drinking water, irrigation, aquatic food, swimming and shoreline usage) for five conventional, generic types of land-based nuclear plant sites, and for 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.

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

Beneath the Braidwood site the hydrogeologic units (ER-OL; FSAR) in descending order are Eolian sand; Lacustrine sand; till; Pennsylvanian siltstone; Silurian dolomites; Maquoketa shale; Galena-Platteville dolomites; Glenwood-St. Peter sandstone; Prairie du Chien, Eminence, Potosi and Franconia dolomites; Ironton-Galesville sandstone; and Eau Claire shale. The Quaternary-age Eolian sand, lacustrine sand, and till overlie the bedrock. The Eolian and lacustrine sand form a water-table sand aquifer. The underlying glacial drift ranges from clay to sand and gravel but is predominantly clayey till. In places, particularly in the northern part of the area, a discontinuous outwash deposit consisting mainly of silty sand and gravel serves as a water-table aquifer within the glacial drift. These aquifers are recharged by precipitation. Ground water is discharged from these aquifers to surface streams and strip mine pits, to the underlying bedrock, and to pumping wells. Reported well yields are suitable only for domestic or farm purposes, ranging from 2 to 5 gpm.

The Quaternary deposits are underlain by Pennsylvanian bedrock composed of siltstone, shale, sandstone, clay, limestone, and coal. The Pennsylvanian strata can yield up to 20 gpm from interbedded sandstones locally; however, the Pennsylvanian and underlying Maquoketa shales generally function as aquitards.

The most important aquifer in the region, the Cambrian-Ordovician Aquifer, is composed of bedrock and lies between the shales of the Maquoketa Shale Group and the Eau Claire Formation. Ground water in the Cambrian-Ordovician Aquifer occurs under artesian pressure.

At the site the top of bedrock is about el 560 ft mean sea level (MSL) and ground elevation is about 600 ft MSL. The containment basemat, at about el 539.0 ft, is in the Pennsylvanian strata. The Cambrian-Ordovician Aquifer is about 1500 ft thick and lies between el 328 ft MSL and -1192 ft MSL.

In the event of a core-melt accident, there could be a release of radioactivity to the bedrock (Pennsylvanian siltstone, shale, sandstone, coal) beneath the reactor. However, in order for the confined Cambrian-Ordovician Aquifer to become contaminated, radioactive water would have to travel through 64 m (211 ft) of bedrock, which in this area is an aquitard. It is extremely unlikely that a core-soil mass would penetrate to this depth. Using boundary heat transfer calculations, the Reactor Safety Study (WASH-1400) estimated that the core-soil mass would form a cylinder about 15 m (50 ft) high with a diameter of about 21 m (70 ft). The core-soil mass would thus be expected to remain at least 49 m (161 ft) above the confined aquifer. In addition, the confined aquifer is under artesian pressure so any penetration of the overlying confining layer would induce outward flow from the aquifer.

The surface water body that is closest to the containment building is the on-site cooling pond. The lowest elevation in the cooling pond is about 520 ft MSL. There is a slurry trench between the plant and the pond that would limit possible radionuclide migrations from the plant. However, the pond is not a sink for local ground water, but rather a recharge area. The normal pond water level is el 595 ft MSL, which is greater than any ground water levels in the surrounding area. Thus, ground water gradients are away from the pond, and the pond is not a potential surface water receiving body for radioactive releases from a core-melt accident.

The next closest surface water body to the containment area is the Mazon River which is located about 5950 m (19,500 ft) to the southwest. The thalweg (lowest point in channel) of the Mazon River at this location is el 556 ft MSL, which is 5 m (17 ft) above the containment basemat elevation. It is not likely that a core-melt release would disperse vertically to intersect the Mazon River. However, the staff has conservatively assumed that this is the nearest surface water release point. The ground water travel time for the 5950-m (19,500-ft) distance to the Mazon River is estimated to be 1990 years. This travel time is based on an average permeability of 0.283 ft per day, a gradient of 0.0019, and an effective porosity of 2% (Lawrence Livermore Laboratory, 1976).

It was demonstrated in the LPGS that, for travel times on the order of years, virtually all of the population dose from the liquid pathway in an assumed core-melt accident would result from Sr-90 and Cs-137. Based on their half-lives, the staff has calculated the fraction of Sr-90 and Cs-137 that could reach the Mazon River after the 1990-year travel time to be 2.4×10^{-22} and 1.1×10^{-20}, respectively. This calculation, using a 1990-year travel time, assumes that the Sr-90 and Cs-137 are moving with the ground water. These chemically active nuclides would, however, travel through the ground water pathway at a much slower rate because of the process of sorption onto the soil and rock media. This would further reduce the fraction of these nuclides that could eventually reach the Mazon River to virtually zero.

In contrast, the fractions of Sr-90 and Cs-137 estimated to reach the nearest surface water body in the LPGS small river case were 0.87 and 0.31, respectively. Without further analysis of actual drinking water populations, aquatic food consumption and shoreline usage, the staff can conclude that the liquid pathway consequences of an assumed core-melt accident at the Braidwood Station would be considerably less than that calculated in the LPGS. The staff, therefore, concludes that the Braidwood Station is not unusual in its liquid pathway contribution to risk when compared to other land-based sites in the LPGS.

Finally, there are measures that could be taken to further minimize the impact of the liquid pathway. The staff has conservatively estimated that the minimum ground water travel time from the containment building to the nearest site boundary would be about 38 years. This would allow ample time for engineered measures to be taken, such as slurry walls and well point dewatering, to isolate the radioactive contamination near the source and to establish a ground water monitoring program that would ensure early detection if any contaminants should escape the immediate plant area.

(6) Risk Considerations

<u>Environmental Risks</u>

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 also useful to combine them to obtain average measures of environmental risk. Such averages provide a useful perspective and 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 risks, 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.

Table 5.12 shows average values of risk associated with population dose, early 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 the distributions. Because the probabilities are on a per-reactor-year basis, the averages shown are also on a per-reactor-year basis.

Table 5.12 Average values of environmental risks due to accidents per reactor-year

Environmental risk	Average value
Population exposure	
Person-rems within 80 km	60
Total person-rems	180
Early fatalities	
Evacuation to 16 km and relocation outside 16 km based on projected dose	0.00038
Latent cancer, fatalities	
All organs excluding thyroid	0.011
Thyroid only	0.0028
Cost of protective actions and decontamination, 1980 dollars	$14,000

Note: See Section 5.9.4.5(7) for discussions of uncertainties in risk estimates.

The population exposures and latent cancer fatality risks may be compared with those for normal operation shown in Appendix D. The comparison (excluding exposure to the plant personnel) shows that the accident dose risks (expressed in person-rems) to the total population are similar to the dose from normal operation, but the accident dose risks within 80 km (50 mi) are about 10 times higher than the normal operation dose within 80 km.

The latent cancer fatality risks from potential accidents can also be compared to the cancer risk from all other sources. For accidents, this risk, averaged over those within 80 km (50 mi) of the Braidwood plant, is 1.2×10^{-9} per year per person, compared with the cancer fatality risk from all other sources of 1.9×10^{-3} per year.

There are no early fatality or economic risks associated with protective actions and decontamination for normal releases; therefore, these risks are unique for accidents. For perspective and understanding of the meaning of the early fatality risk of 3.8×10^{-4} per reactor-year, however, the staff notes that to a good approximation the population at risk is that within about 16 km (10 mi) of the plant, about 33,500 persons in the year 2000. Accidental fatalities per year for a population of this size, based on overall averages for the United States, are approximately 7.4 from motor vehicle accidents, 2.6 from falls, 1.0 from drowning, 0.97 from burns, and 0.40 from firearms. The average early fatality risk from reactor accidents is thus an extremely small fraction of the total risk embodied in the above combined accident modes.

Figure 5.10 shows the calculated risk expressed as whole-body dose to an individual from early exposure as a function of the downwind distance from the plant within the plume exposure pathway zone. The values are on a per-reactor-year

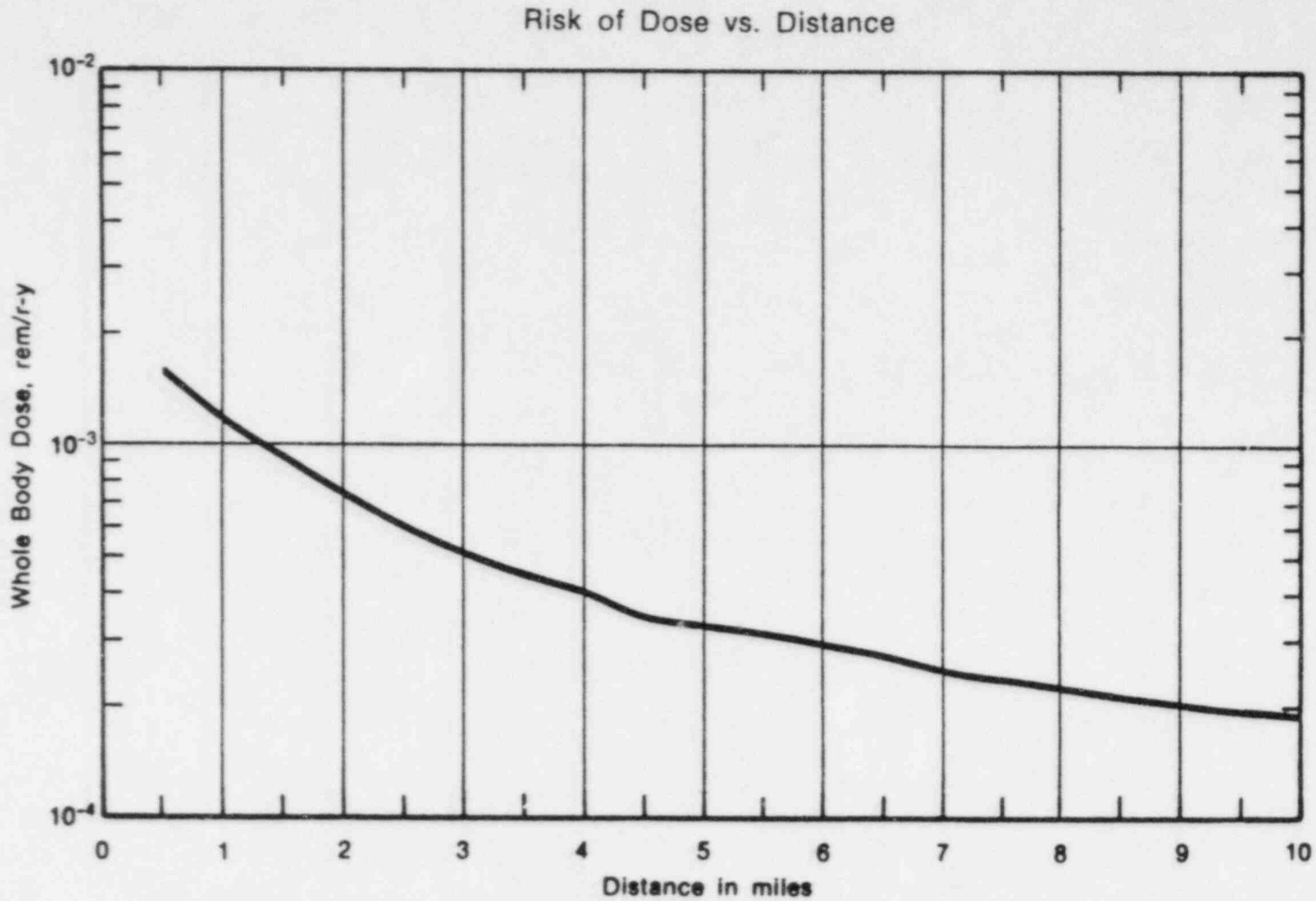

Figure 5.10 Individual risk of dose as function of distance (See Section 5.9.4.5(7) for a discussion of uncertainties in risk estimates. To convert mi to km, multiply by 1.6093. Also see footnote in section entitled "Dose and Health Impacts of Atmospheric Releases" for help in interpreting this figure.)

basis and all accident sequences and release categories in Table 5.10 contributed to the dose, weighted by their associated probabilities.

Evacuation and other protective actions can reduce the risk to an individual of early fatality or of latent cancer fatality. Figure 5.11 shows lines of constant risk per reactor-year to an individual living within the emergency planning zone of the Braidwood site, of early fatality as functions of distance resulting from potential accidents in the reactor. Figure 5.12 shows curves of constant risk of latent cancer fatality. Directional variation of these plots reflects the variation in the average fraction of the year the wind would be blowing in different directions from the plant. For comparison the following risks of fatality per year to an individual living in the United States may be noted (CONAES, p 577): 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}.

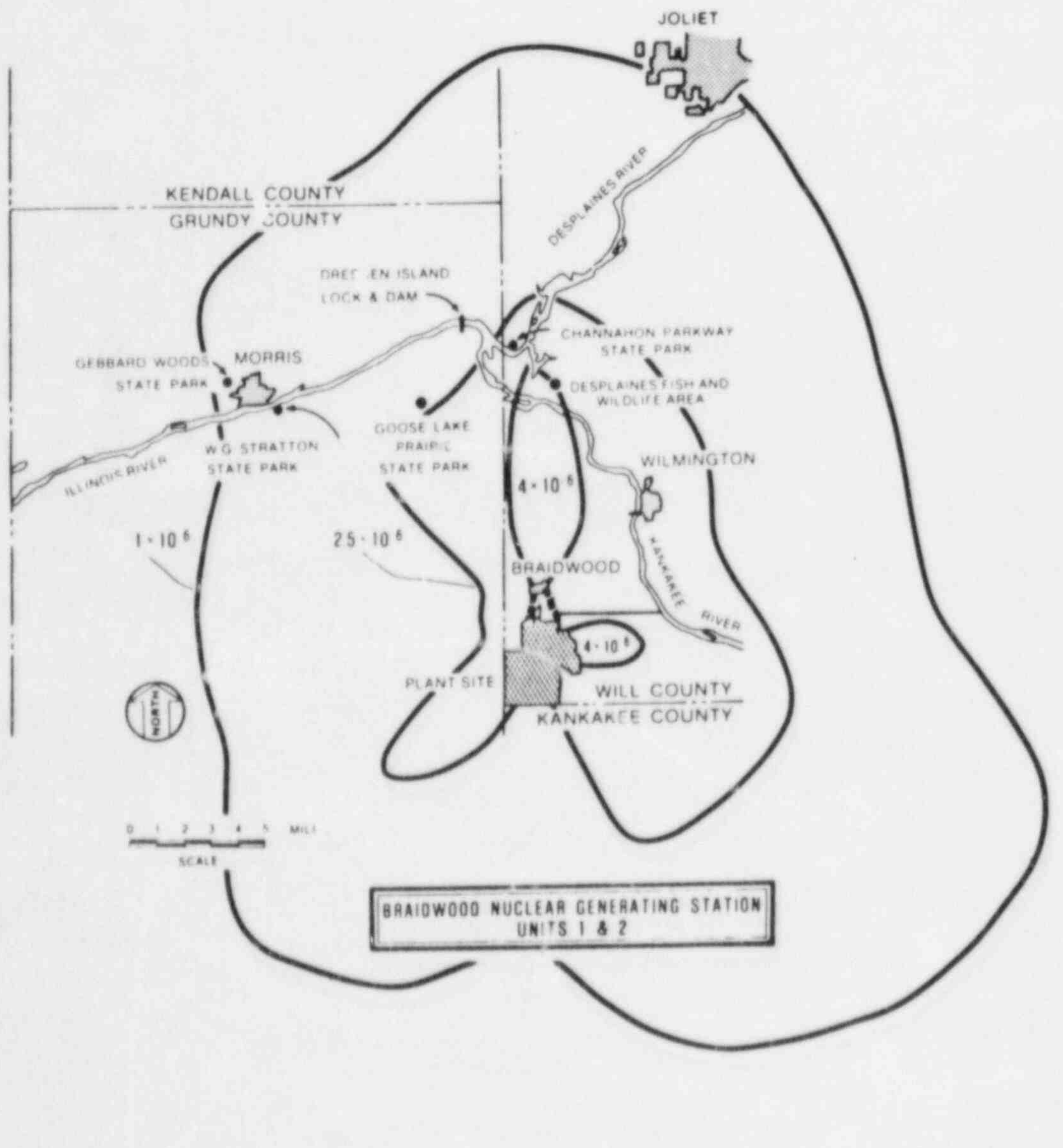

Figure 5.11 Isopleths of risk of early fatality per reactor-year to an individual (To convert mi to km, multiply by 1.6093.)

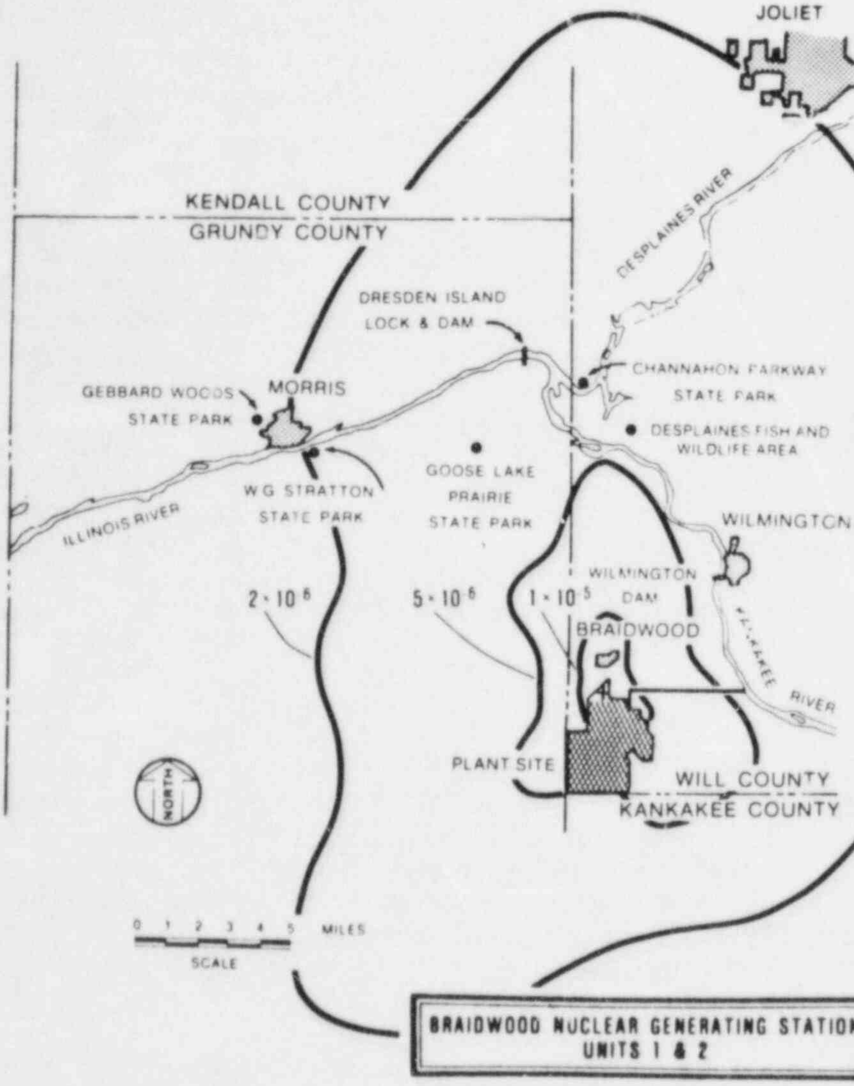

Figure 5.12 Isopleths of risk of latent cancer fatality per reactor-year to an individual (To convert mi to km, multiply by 1.6093.)

The relative consequences and risks from contamination of Lake Michigan as a result of atmospheric fallout from severe accidents in a Braidwood Station reactor would be similar to those determined for contamination of Lake Erie and the other Great Lakes via the severe accident atmospheric fallout route for the Perry Nuclear Power Plant (NUREG-0884) reactor which was, in turn, based on calculations performed for the Fermi 2 plant (NUREG-0769). Braidwood Station is, however, more than 75 km from Lake Michigan, whereas Perry is on the Lake Erie shore. Thus, the atmospheric concentrations of airborne radionuclides over Lake Michigan as the result of a severe accident at Braidwood would be substantially less than similar concentrations over Lake Erie as a result of a severe accident at Perry.

The consequences and risks to society and an individual of delayed cancer fatalities from unrestricted (without any decontamination or interdiction of exposure pathways) use of Lake Michigan and the other Great Lakes contaminated by fallout from atmospheric releases from each Braidwood reactor would be of similar orders of magnitude as those resulting from the exposure pathways from air and ground contamination following these releases, as shown in Tables 5.11 and 5.12. These consequences and risks were calculated only after exposure pathways interdiction or decontamination was assumed. If similar interdiction or decontamination in exposure pathways arising from Lake Michigan and the other Great Lakes were assumed, then the consequences and risks from fallout on the Great Lakes would be small compared to those from air and ground contamination, and would not alter conclusions with respect to accident risks compared to risks of normal operation, or with respect to Braidwood accident risks compared to other accident risks to which the general population is exposed.

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 cause substantial quantities of sulfur dioxide and nitrogen oxides to be emitted into the atmosphere and, among other things, lead to environmental and ecological damage through the phenomenon of acid rain (CONAES, 1979, pp. 559-560). This effect has not, however, been sufficiently quantified for a useful comparison to be drawn at this time.

Other Economic Risks

There are other impacts and risks that can be expressed in monetary terms, but are not included in the cost calculations discussed in the section on economic and societal impacts. These impacts, which would result from an accident at the facility, produce added costs to the public (i.e., ratepayers, taxpayers, and/or shareholders). These costs would accrue from decontamination and repair or replacement of the facility and from replacement power provided during restoration of the facility. Experience with such costs is being accumulated as a result of the accident at the Three Mile Island facility.

If an accident occurs during the first year of operation of Braidwood Unit 1 (1986), the economic penalty to which the public would be exposed would be approximately $1680 million (1986 dollars) for decontamination and restoration including replacement of the damaged nuclear fuel. This estimate is based on a conservative (high) 10% annual escalation of the 1980 economic penalty determined for the Three Mile Island facility (Comptroller General, 1981). Although insurance would cover $300 million or more of the $1680 million accident cost, the insurance is not credited against this cost because the arithmetic product of the insurance payment and the risk probability would theoretically balance the insurance premium.

In addition, the staff estimates that system fuel costs would increase by approximately $74 million (1986 dollars) for replacement power during each year Braidwood Unit 1 is out of service. This estimate assumes that the unit will operate at an average 60% capacity factor and that replacement energy will be provided primarily from coal-fired generation. Assuming the unit does not operate for 8 years, the replacement power cost would amount to $592 million (1986 dollars).

The probability of a core melt or severe reactor damage is assumed to be as high as 10^{-4} per reactor-year (this accident probability is intended to account for all severe core-damage accidents leading to large economic consequences for the owner and not just those leading to significant offsite consequences.) Multiplying the previously estimated cost of $2272 million for an accident to Braidwood Unit 1 during the initial year of its operation by the above 10^{-4} probability results in an economic risk of approximately $227,200 (1986 dollars) applicable in Braidwood Unit 1 during its first year of operation. This is also the approximate economic risk (1986 dollars) to Braidwood Unit 1 during the second year and each subsequent year of operation. Although nuclear units depreciate in value and may operate at reduced capacity factors so that the economic consequences resulting from an accident become less as the unit becomes older, this is conservatively (high cost) considered to be offset by an escalation rate that is slightly higher than the discount rate.

The economic risk to Braidwood Unit 2 is also approximately $227,200 (1986 dollars) during its first year and each subsequent year of operation resulting from the balancing effect of escalation and the present worth discount factor. The $227,200 annual risk for each unit (1986 dollars) is equivalent to an annual risk of approximately $171,000 (1983 dollars) assuming a 10% discount rate.

Regional Industrial Impacts

A severe accident that requires the interdiction and/or decontamination of land areas could force numerous businesses to temporarily or permanently close. These closures would have additional economic effects beyond the contaminated areas through the disruption of regional markets and sources of supplies. This section provides estimates of these impacts, which were made using (1) the RSS consequence model discussed elsewhere in this section and (2) the Regional Input-Output Modeling System (RIMS II) developed by the Bureau of Economic Analysis (BEA) (NUREG/CR-2591).

The industrial impact model developed by BEA takes into account contamination levels of a physically affected area defined by the RSS consequence model. Contamination levels define an interdicted area immediately surrounding the plant, followed by an area of decontamination, an area of crop interdiction, and finally an area of milk interdiction. (The industry-specific impacts are estimated for the five levels of accident severity listed in Table 5.10.)

Assumptions used in the analysis include:

(1) In the interdicted area all industries would lose total production for more than a year.

(2) In the decontamination zone there would be a 3-month loss in nonagricultural output; a 1-year loss in all crop output, except no loss in greenhouse, nursery, and forestry output; a 3-month loss in dairy output; and a 6-month loss in livestock and poultry output.

(3) In the crop interdicted area there would be no loss in nonagricultural output; a 1-year loss in agricultural output, except no loss in greenhouse, nursery, and forestry output; no loss in livestock and poultry output; and a 2-month loss of dairy output.

(4) In the milk interdiction zone there would be only a 2-month loss in dairy output.

The estimates of industrial impacts are made for an economic study area that consists of a physically affected area and a physically unaffected area. An accident that causes an adverse impact in the physically affected area (e.g., the loss of agricultural output) could also adversely affect output in the physically unaffected area (e.g., food processing). In addition to the direct impacts in the physically affected area, the following additional impacts could occur in the physically unaffected area:

(a) decreased demand (in the physically affected area) for output produced in the physically unaffected area

(b) decreased availability of production inputs purchased from the physically affected area

Only the impacts occurring during the first year following an accident are considered. The longer term consequences are not considered because they will vary widely depending on the level and nature of efforts to mitigate the accident consequences and to decontaminate the physically affected areas.

The estimates assume no compensating effects, such as the use of unused capacity in the physically unaffected area to offset the initial lost production in the physically affected area, or income payments to individuals displaced from their jobs that would enable them to maintain their spending habits. These compensating effects would reduce the industrial impacts. Realistically, these compensating effects would occur over a lengthy period. The estimates using no compensating effects are the best measures of first-year economic impacts.

Table 5.13 presents the regional economic output and employment impacts and corresponding expected risks associated with the five different release categories. The estimated overall risk value using output losses as the measure of accident consequences, expressed in a per-reactor-year basis, is $61,237. This number is composed of direct impacts of $44,597 in the nonagricultural sector and $9,933 in the agricultural sector, and indirect impacts of $6,707 from decreased exports and supply constraints. The corresponding expected employment loss per reactor-year is about three and a quarter jobs.

It should be noted that over 70% of the expected losses, or $43,152, result from releases occurring toward the north-northeast. The H release category contributes $21,861 of that amount. On an absolute basis, an H category release to the north-northeast would result in a loss of over $17 billion and 944,000 jobs. Releases to the northeast contribute only $215 to the total expected annual loss. For each release category, for all directions, the minimal expected losses are from $0 to $100. No offsite regional economic impacts are included for release category I, which has no containment failure.

The staff has also considered the health care costs resulting from hypothetical accidents in a generic model developed by the Pacific Northwest Laboratory (Nieves, 1983). On the basis of this generic model, the staff concludes that such costs may be a fraction of the offsite costs evaluated herein, but that the model is not sufficiently constituted for application to a specific reactor site.

Table 5.13 Regional economic impacts of output and employment

Release category	Wind direction	Economic impact, millions of 1980$				Loss in employment, annualized jobs	Expected loss in output/reactor-yr, 1980$
		Direct					
		Non agricultural	Direct agricultural	Indirect	Total		
Maximum losses							
B	NNE	15091	69	1865	17025	944000	2643
C	NNE	15091	69	1865	17025	944000	11880
F	NNE	14348	59	1772	16179	898000	6769
H	NNE	14348	59	1772	16179	898000	21861
I	---	0	0	0	0	0	0
Minimum losses							
B	NE	54	101	19	174	8000	22
C	NE	54	101	19	174	8000	100
F	NE	54	7	8	69	4000	22
H	NE	54	7	8	69	4000	70
I	---	0	0	0	0	0	0
Expected losses per reactor-year							
B	All directions	2997	778	464	4239	< 1	*
C	"	13473	3495	2087	19055	1	
F	"	6650	1338	983	8971	< 1	
H	"	21477	4322	3173	28972	< 2	
I	---	0	0	0	0	0	
All release categories	All directions	44597	9933	6707	61237	3.3	

*Not applicable, as the expected loss is already expressed in the "Total" column for this portion of the table.

Source: Bureau of Economic Analysis, U.S. Department of Commerce with assumptions supplied by the NRC staff.

(7) Uncertainties

The probabilistic risk assessment discussed above has been based mostly on the methodology presented in the Reactor Safety Study (RSS), which was published in 1975 (NUREG-75/014). Although substantial improvements have been made in various facets of the RSS methodology after its publication, there are still large uncertainties in the results of the analysis presented in the preceding sections, including uncertainties associated with the likelihoods of the accident sequences and containment failure modes leading to the release categories, the source terms for the release categories, and the estimates of environmental consequences. The relatively more important contributors to uncertainties in the results presented in this environmental statement are as follows:

(a) Probability of occurrence of accident: If the probability of a release category would change by a certain factor, the probabilities of various types of consequences from that release category would also change exactly by the same factor. Thus, an order of magnitude uncertainty in the probability of a release category would result in an order of magnitude uncertainty in both societal and individual risks stemming from the release category. As in the RSS, there are substantial uncertainties in the probabilities of the release categories. 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, and in the data base on external events and their effects on plant systems and components that are used to calculate the probabilities.

Another related area of uncertainty is risks from externally caused accidents (such as earthquakes, floods, and man-caused events--including sabotage). No evaluations of such risks have been made for Braidwood. Some of these types of risks have been evaluated for the Indian Point reactors in New York State, the Limerick reactors in Pennsylvania, and for the Zion reactors in Illinois; such risks were found within a factor of less than 100 times greater than risks from internally initiated accidents at the corresponding plants. Such experiences in plant-specific probabilistic risk assessments cannot be extended directly to Braidwood because of site and plant design characteristics. However, the staff judges such risks to be within the uncertainty bounds discussed below.

(b) Quantity and chemical form of radioactivity released: This relates to the quantity of each radionuclide species that would be released, and its chemical form, from a reactor unit during a particular accident sequence. Such releases would originate in the fuel, and would be attenuated by physical and chemical processes in route to being released to the environment. Depending on the accident sequence, attenuation in the reactor vessel, the primary cooling system, the containment, and adjacent buildings would influence both the magnitude and chemical form of radioactive releases. The source terms used in the staff analysis were determined using the RSS methodology applied to a PWR with a large dry containment. Information available in NUREG-0772 and from the latest research activities sponsored by the Commission and the industry indicate that the best-estimate source terms cannot be much worse than the larger source terms used in this analysis (release categories B and C of Table 5.10), but they could be substantially lower then the release categories used here for the same types of initiating accident sequences. The impact of smaller source terms would be substantially lower estimates of health effects, particularly early fatalities and injuries.

(c) Atmospheric dispersion modeling for the radioactive plume transport, including the physical and chemical behavior of radionuclides in particulate form in the atmosphere: This uncertainty relates to the differences in modeling the atmospheric transport of radioactivity in gaseous and particulate states and the actual transport, diffusion and deposition or fallout that would occur during an accident (including the effects of condensation and precipitation). The phenomenon of plume rise resulting from heat associated with the atmospheric release, effects of precipitation on the plume, and fallout of particulate matter from the plume all have considerable impact on the magnitudes of early health consequences, and the distance from the reactor out to which these consequences would occur. The staff judgment is that these factors can result in substantial overestimates or underestimates of both early and later effects (health and economic).

Other areas that have substantial but relatively less effect on uncertainty than the preceding items are

(a) <u>Duration and energy of release, warning time, and in-plant radionuclide decay time</u>: This relates to the differences between assumed release duration, energy of release, and the warning and the in-plant radioactivity decay times compared with those that would actually occur during a real accident.

For a relatively long duration (more than 1/2 hour) of an atmospheric release, the actual cross-wind spread (i.e., the width) of the radioactive plume that would develop would likely be larger than the width calculated by the dispersion model in the staff code (CRAC). However, the effective width of the plume is calculated in the code using a plume expansion factor that is determined by the release duration. For a given quantity of radionuclides in a release, the plume and, therefore, the area that would come under its cover would become wider if the release duration were made longer. In effect, this would result in lower air and ground concentrations of radioactivity, but a greater area of contamination.

The thermal energy associated with the release affects the plume rise phenomenon which results in relatively lower air and ground concentrations in the closer regions, and relatively higher concentrations as a result of fallout in the regions that are more distant. Therefore, if a large thermal energy were associated with a release containing large fractions of core inventory of radionuclides, it could increase the distance from the reactor over which early health effects may occur. If, on the other hand, the release behavior were dominated by the presence of large amounts of condensing steam, very much the reverse could occur because of the close deposition of radionuclides induced by the falling water condensed from the steam.

Warning time before evacuation has considerable impact on the effectiveness of offsite emergency response. Longer warning times would improve the effectiveness of the response.

The time from reactor shutdown until the beginning of the release to the environment (atmosphere), known as the time of release, is used to calculate the depletion of radionuclides by radioactive decay within the plant before release. The depletion factor for each radionuclide (determined by the radioactive decay constant and the time of release) multiplied by the release fraction of the radionuclide and its core inventory determines the actual quantity of the radionuclide released to the environment. Later releases would result in the release of fewer curies to the environment for given values of release fractions.

The first three of the above parameters can have significant impacts on accident consequences, particularly early consequences. The staff judgment is that the early consequences and risks calculated for this review could be substantial underestimates or substantial overestimates, because of uncertainties in the first three parameters.

(b) Meteorological sampling scheme used: This relates to the possibility that the meteorological sequences used with the selected 91 start times (sampling) in the CRAC code may not adequately represent all meteorological variations during the year, or that the year of meteorological data may not represent all possible conditions. This factor is judged to produce greater uncertainties for early effects and less for latent effects.

(c) Emergency response effectiveness: This relates to the differences between modeling assumptions regarding the emergency response of the people residing near the Braidwood site compared to what would happen during an actual severe reactor accident. Included in these considerations are such subjects as evacuation effectiveness under different circumstances, possible sheltering and its effectiveness, and the effectiveness of population relocation. The staff judgment is that the uncertainties associated with emergency response effectiveness could cause large uncertainties in early health consequences. The uncertainties in latent health consequences and costs are considered smaller than those for early health consequences. A limited sensitivity analysis in this area is presented in Appendix F.

(d) Dose conversion factors and dose response relationships for early health consequences, including benefits of medical treatment: This relates to the uncertainties associated with estimates of dose and early health effects on individuals exposed to high levels of radiation. Included are the uncertainties associated with the conversion of contamination levels to doses, relationships of doses to health effects, and considerations of the availability of what was described in the RSS as supportive medical treatment (a specialized medical treatment program of limited availability that would minimize the early health effect consequences of high levels of radiation exposure following a severe reactor accident). Previous staff analysis indicates that uncertainty from this last source is less than a factor of three.

(e) Dose-conversion factors and dose-response relationships for latent health consequences: This relates to the uncertainties associated with dose estimates and latent (delayed and long-term) health effects on individuals exposed to lower levels of radiation and on their succeeding generations. Included are the uncertainties associated with conversion of contamination levels to doses and doses to health effects. The staff judgment is that this category has a large uncertainty. The uncertainty could result in relatively small underestimates of consequences, but also in substantial overestimates of consequences. (Note: radiobiological evidence on this subject does not rule out the possibility that low level radiation could produce zero consequences.)

(f) Chronic exposure pathways, including environmental decontamination and the fate of deposited radionuclides: This relates to uncertainties associated with chronic exposure pathways to man from long-term use of the contaminated environment. Uncertainty arises from the possibility of different protective action guide levels that may actually be used for interdiction or decontamination of the exposure pathways from those assumed in the staff analysis. Further, uncertainty arises because of lack of precise knowledge about the fate of the radionuclides in the environment as influenced by natural processes such as runoff and weathering. The staff's qualitative judgment is that the uncertainty from these considerations is substantial.

(g) Economic data and modeling: This relates to uncertainties in the economic parameters and economic modeling, such as costs of evacuation, relocation, medical treatment, cost of decontamination of properties, and other costs of property damage. Uncertainty in this area could be substantial.

The state of the art for quantitative evaluation of the uncertainties in the probabilistic risk analysis such as the type presented here is not well developed. Therefore, although the staff has made a reasonable analysis of the risks presented herein consistent with current data and methodology, there are large uncertainties associated with the results shown. It is the qualitative judgment of the staff that the uncertainty bounds could be well over a factor of 10, but not as large as a factor of 100. Within these uncertainty bounds, however, the uncertainties associated with the probability-integrated values of consequences (i.e., the risks) are likely to be less (although still large) than uncertainties in the curves in the figures showing probability distribution of consequences, as a result of partial cancellation of uncertainties by integration.

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 (CONAES, 1979, p 553). It should also be noted that the Three Mile Island accident has resulted in a very comprehensive evaluation of reactor accidents by a significant number of investigative groups. 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 1) collected 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 results in a gradually increasing improvement in safety as individual actions are completed. The Braidwood units are receiving and will receive the benefit of these actions.

(8) Comparison of Braidwood Risks With Other Plants

Figures 5.13 to 5.17 illustrate selected risks as computed for other nuclear power plants that are either operating or are receiving staff consideration for issuance of a license to operate. These figures are included to supply some context in which to view the computed Braidwood societal risks, although direct comparison among plants is subject to some of the uncertainties discussed above.

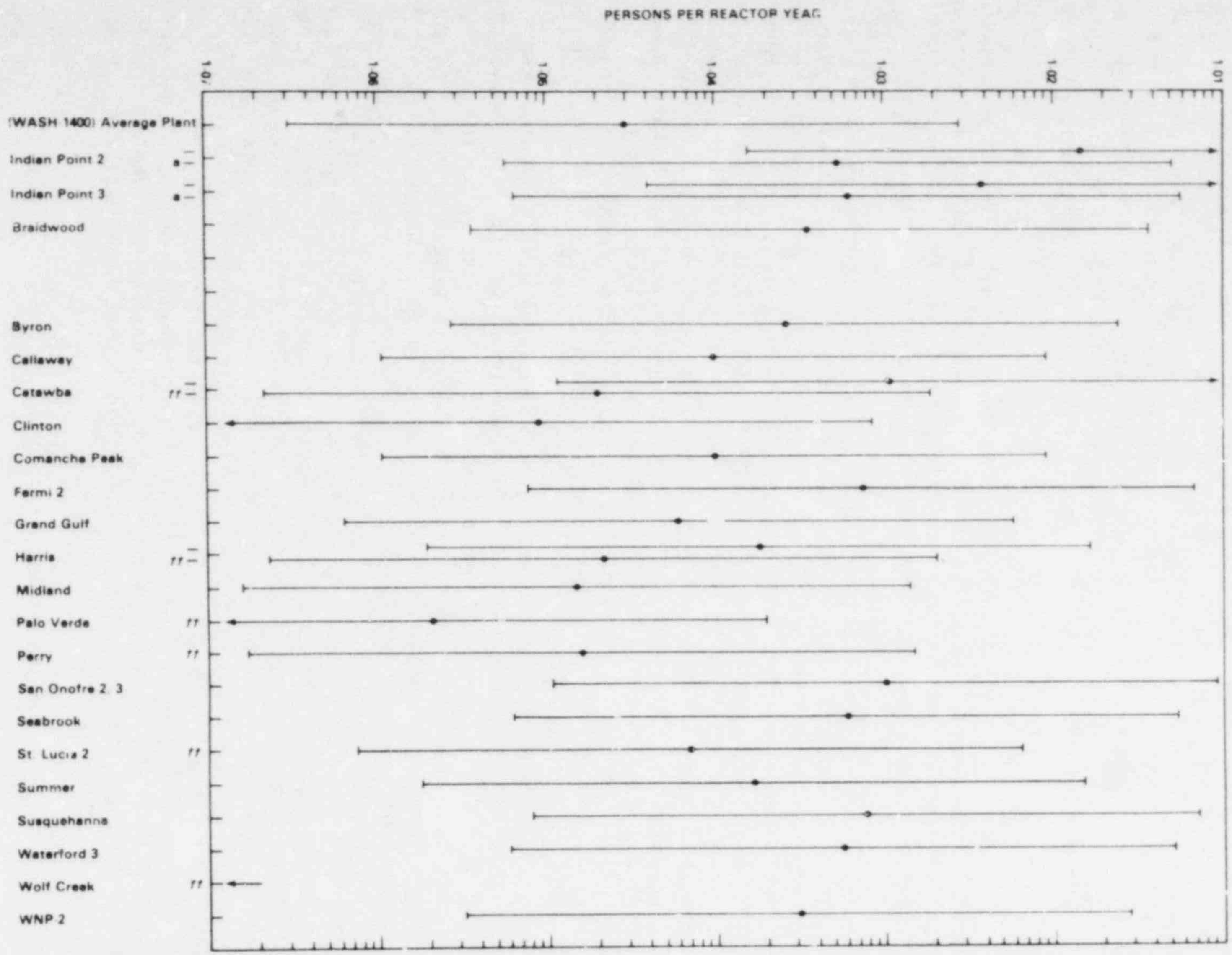

Figure 5.13 Estimated early fatality risk with supportive medical treatment (persons) from severe reactor accidents for several nuclear power plants either operating or receiving consideration for issuance of license to operate (See footnotes following Figure 5.17.)

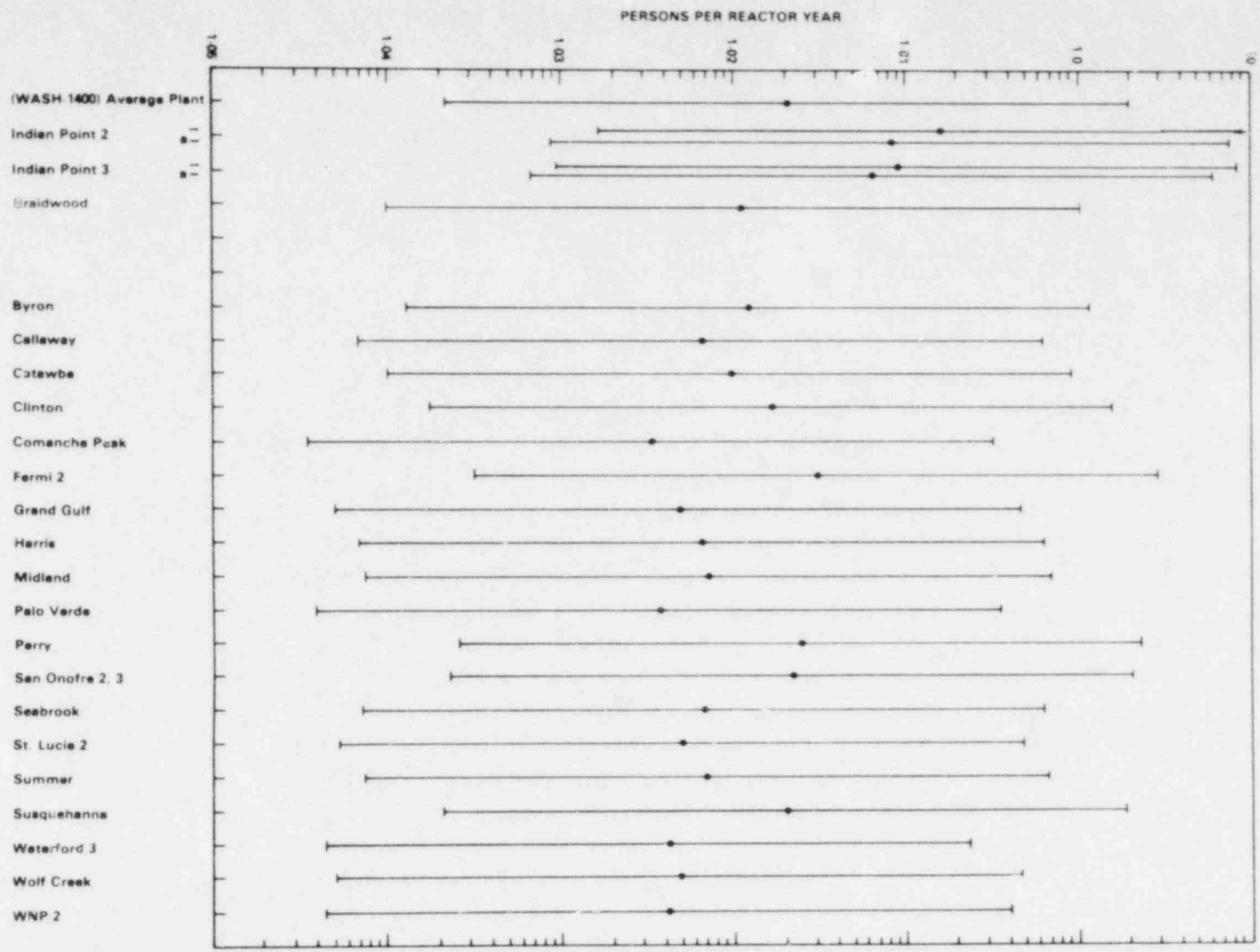

Figure 5.14 Estimated latent cancer fatality risk, excluding thyroid (persons), from severe reactor accidents for several nuclear power plants either operating or receiving consideration for issuance of license to operate (See footnotes at the end of Figure 5.17.)

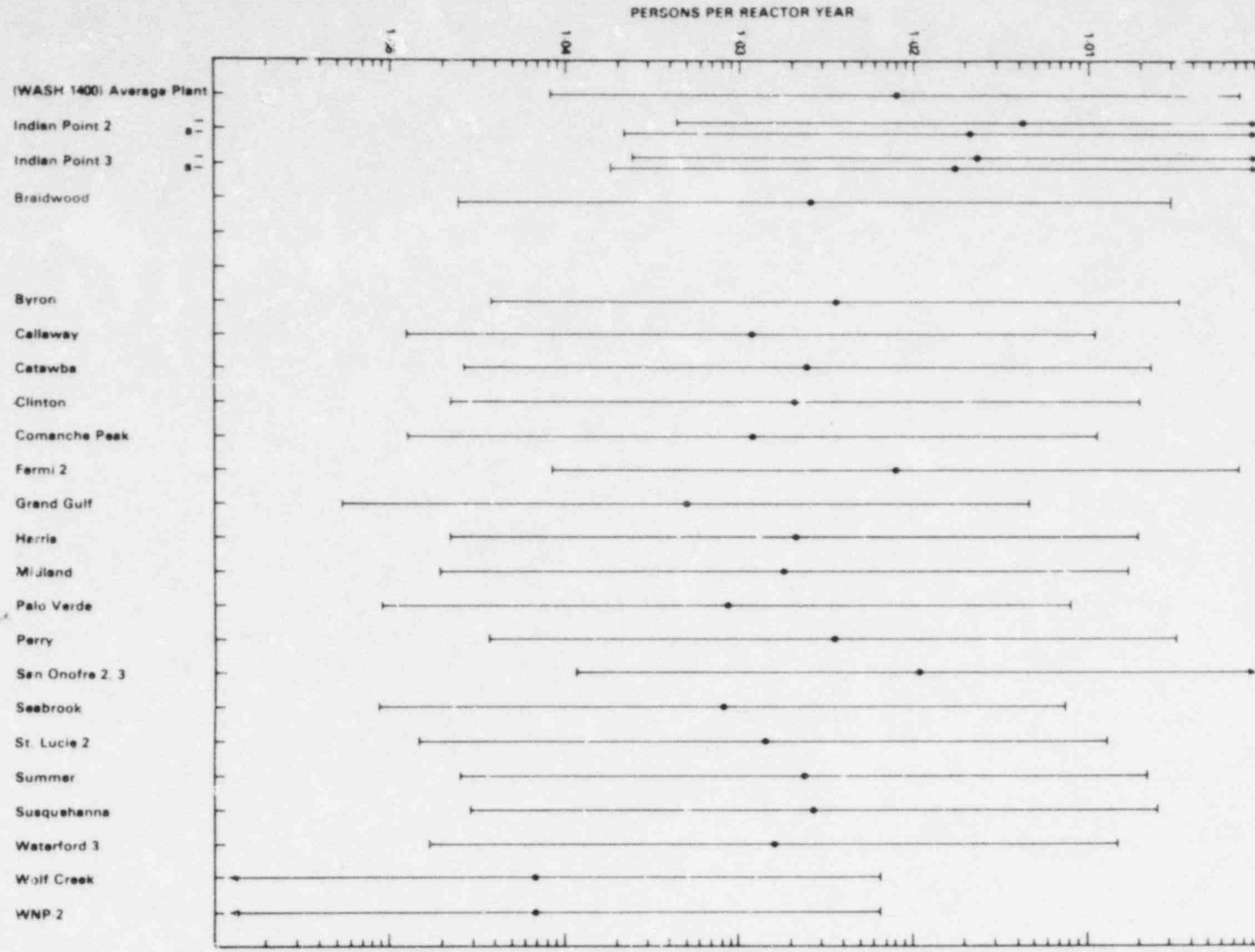

Figure 5.15 Estimated latent thyroid cancer fatality risk (persons) from severe reactor accidents for several nuclear power plants either operating or receiving consideration for issuance of license to operate (See footnotes at the end of Figure 5.17.)

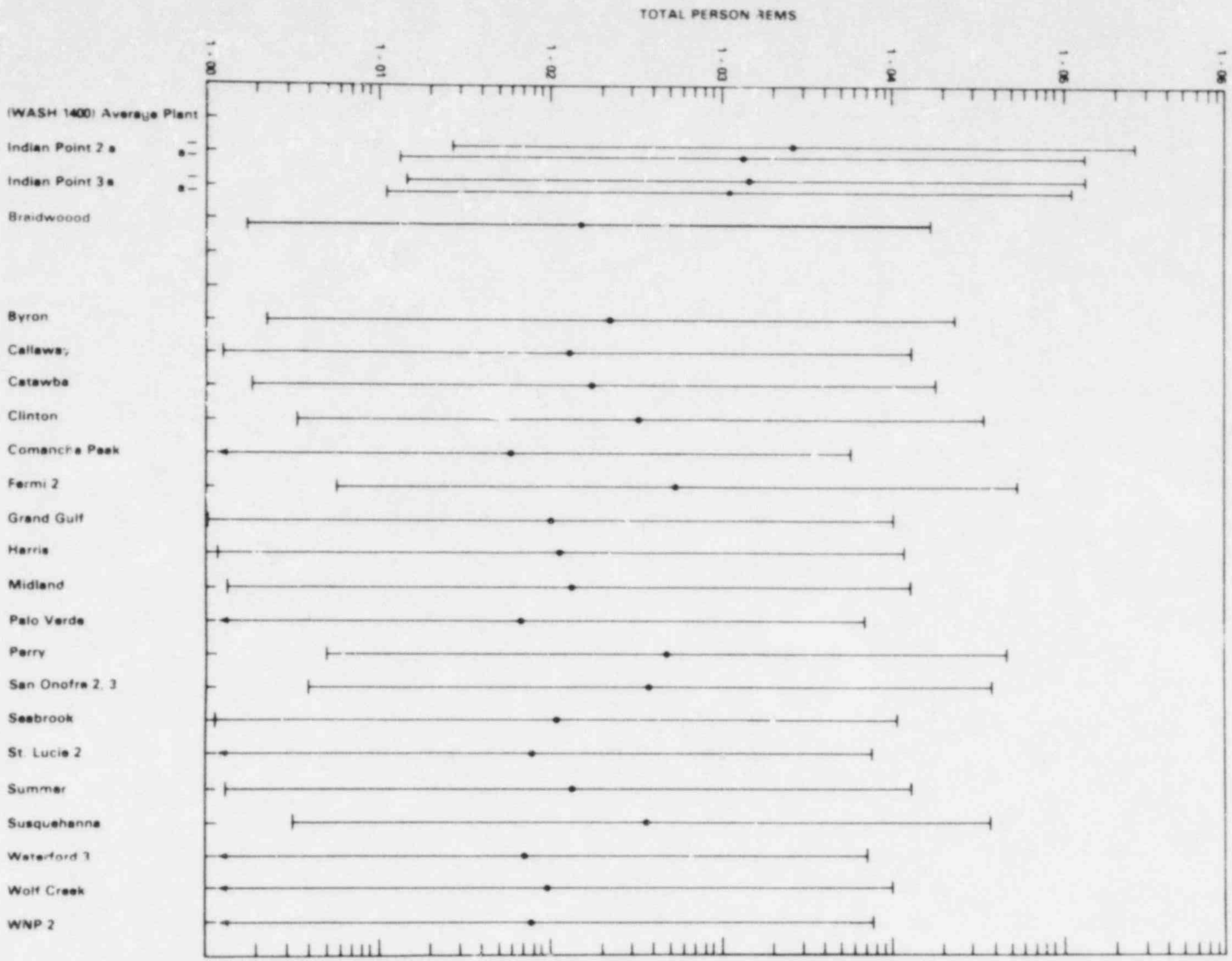

Figure 5.16 Estimated total person-rem risk from severe reactor accidents for several nuclear power plants either operating or receiving consideration for issuance of license to operate (See footnotes at the end of Figure 5.17.)

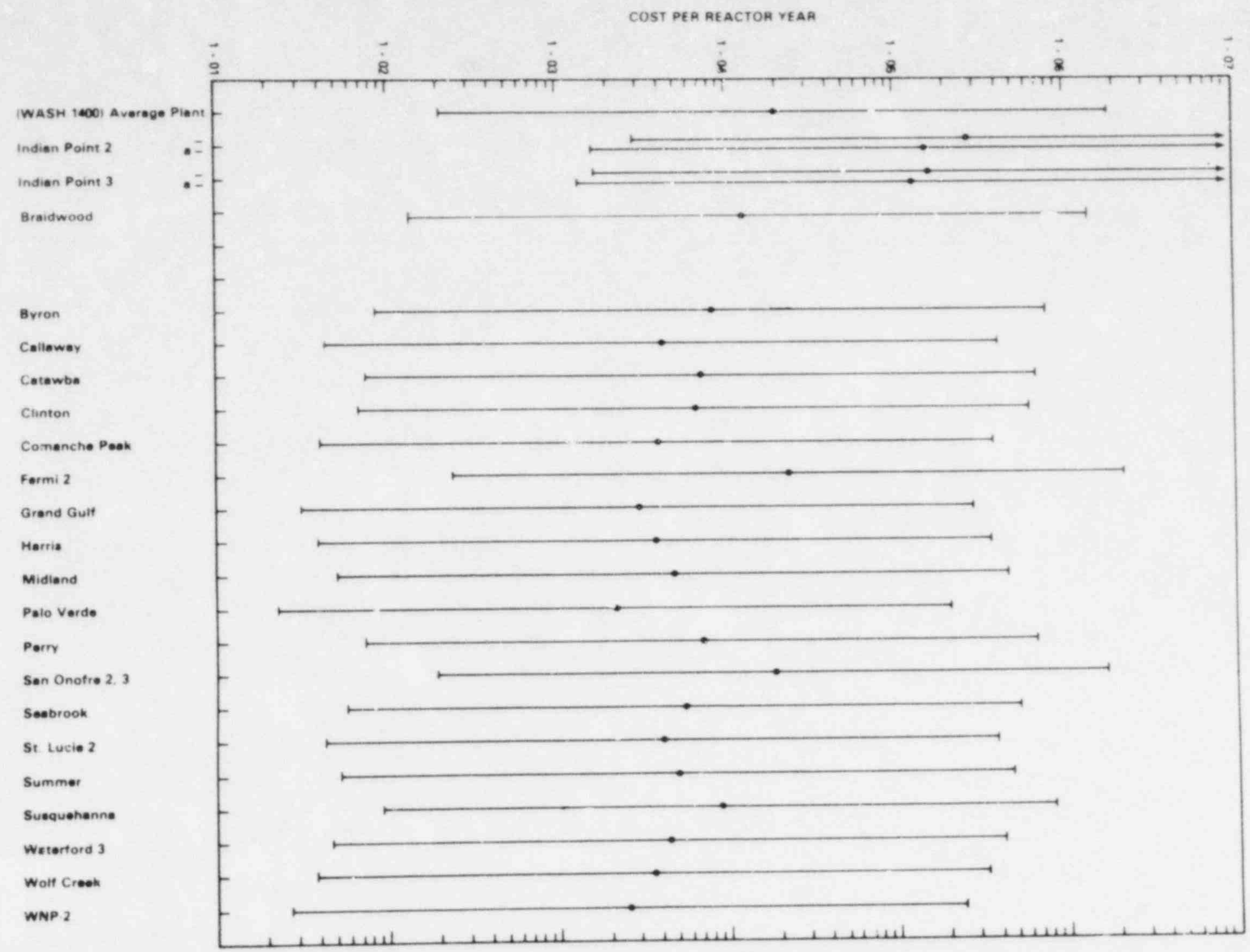

Figure 5.17 Estimated risk of offsite mitigation measures (1980 dollars) from severe reactor accidents for several nuclear power plants either operating or receiving consideration for issuance of license to operate (See footnotes on the following page.)

Notes for Figures 5.13 through 5.17

- Except for Indian Point and Limerick, risk analyses for other plants in these figures are based on WASH-1400 generic source terms and probabilities for severe accidents and do not include external event analyses.

- 1-01 = 1×10^{-1} and so forth.

- Please see Section 5.9.4.5(7) for discussion of uncertainties.

††With evacuation within 10 miles and relocation from 10-25 miles.

[a]Excluding severe earthquakes and hurricanes.

In light of these uncertainties, these figures can only serve to indicate that the Braidwood plant and site pose computed measures of societal risk that are neither the highest nor the lowest of those computed for other plants and sites.

5.9.4.6 Conclusions

The foregoing sections consider the potential environmental impacts from accidents at the Braidwood facility. 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 core melt.

The environmental impacts that have been considered include potential releases of radioactivity to the environment with resulting 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 Braidwood facility, the applicant must comply with the applicable Commission regulations and requirements, and (3) a probabilistic assessment of the risk based on the methodology developed in the Reactor Safety Study. The overall assessment of environmental risk of accidents, assuming protective actions, shows that it is on the same order as the risks from normal operation, although accidents have a potential for early fatalities and economic costs that cannot arise from normal operations. The risks of early fatality from potential accidents at the site are small in comparison with risks of accidental deaths from other human activities in a comparably sized population.

On the basis of the above considerations, the staff concluded that there are no special or unique circumstances about the Braidwood site and environs that would warrant consideration of alternatives for the Braidwood units.

5.10 Impacts from the Uranium Fuel Cycle

The uranium fuel cycle rule, 10 CFR 51.20 (44 FR 45362), reflects the latest information relative to the 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," and NUREG-0216, 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 U.S. Atomic Energy Commission (AEC) report WASH-1248, "Environmental Survey of the Uranium Fuel Cycle." The NRC staff was also directed to develop an explanatory narrative that would convey in understandable terms the significance of releases in the table. 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. A proposed explanatory narrative was published in the Federal Register on March 4, 1981 (46 FR 15154-15175). Appendix C to this report contains a number of sections that address those impacts of the LWR-supporting fuel cycle that reasonably appear to have significance for individual reactor licensing sufficient to warrant attention for NEPA purposes. 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.

Table S-3 of the final rule is reproduced in its entirety as Table 5.14 herein.*

Appendix C to this report contains a description of the environmental impact assessment of the uranium fuel cycle as related to the operation of the Braidwood facility. The environmental impacts are based on the values given in Table 5-14, and on an analysis of the radiological impact from radon-222 and technetium-99 releases. The staff has determined that the environmental impact of this facility on the U.S. population from radioactive gaseous and liquid releases (including radon and technetium) resulting from the uranium fuel cycle is very small when compared with the impact of natural background radiation. In addition, the nonradiological impacts of the uranium fuel cycle have been found to be acceptable.

5.11 Decommissioning

The purposes of decommissioning are (1) to safely remove nuclear facilities from service and (2) to remove or isolate the associated radioactivity from the environment so that part of the facility site that is not permanently committed can be released for other uses. Alternative methods of accomplishing these purposes and the environmental impacts of each method are discussed in NUREG-0586.

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*The U.S. Supreme Court has upheld the validity of the S-3 rule in Baltimore Gas & Electric Co., et al. v. Natural Resources Defense Council, Inc., No. 82-524, issued June 6, 1983, 51 U.S. Law Week, 4678.

Table 5.14 Table of 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[2]	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)		
SO_x	4,400	
NO_x[3]	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 within range of state standards—below level that 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	
Fluoride	12.9	
Ca^{++}	5.4	
Cl^-	8.5	
Na	12.1	
NH_3	10.0	
Fe	4	NH_3—600 cfs. NO_3—20 cfs. Fluoride—70 cfs.
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
EFFLUENTS—RADIOLOGICAL (CURIES)		
Gases (including entrainment)		
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.

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.

[2] 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.

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

[4] 1.2 percent from natural gas use and process.

Since 1960, 68 nuclear reactors--including 5 licensed reactors that had been used for the generation of electricity--have been or are in the process of being decommissioned. Although, to date, no large commercial reactor has undergone decommissioning, the broad base of experience gained from smaller facilities is generally relevant to the decommissioning of any type of nuclear facility.

Radiation doses to the public as a result of end-of-life decommissioning activities should be small; they will come primarily from the transportation of waste to appropriate repositories. Radiation doses to decommissioning workers should be well within the occupational exposure limits imposed by regulatory requirements.

The NRC is currently conducting generic rulemaking that will develop a more explicit overall policy for decommissioning commercial nuclear facilities.

Specific licensing requirements are being considered that include the development of decommissioning plans and financial arrangements for decommissioning nuclear facilities.

Estimates of the economic cost of decommissioning are provided in Section 6.

5.12 Noise

The staff examined three sources of potential noise impact to the community in the vicinity of the Braidwood site. These sources are (1) the transformers at the station site itself, (2) the compressors and pump motors inside the pump house adjacent to the Kankakee River, and (3) the transformer at the west side of the river pumphouse building. The staff examined both the increase in broadband noise and/or the creation of tonal noise (i.e., noise energy concentrated at a particular frequency or in a relatively narrow band of frequencies) in the community at residences close to the station site or the river pumphouse. The locations of these nearest residences to the station site and river pumphouse are shown on Figures 5.18 and 5.19, respectively.

Calculations of operational noise level predictions were based on the applicant's responses to staff questions E290.9 through E290.16, manufacturer's noise data, and the University of Illinois/Argonne National Laboratory noise model (Dunn, et al., 1982). The model accounts for hemispherical spreading, atmospheric attenuation, and barrier effects in computing broadband and tonal impacts from stationary noise sources. For the calculations used in the Braidwood analysis, the noise level for the transformers and associated fans were obtained from the applicant (response to staff questions E290.11 and E290.20) and the sound power levels of the transformer tones were obtained from measurements on similar transformers (Gordon et al. 1980).

The broadband noise from the operation of the transformers and associated fans (main transformers only) was evaluated in terms of a computed increase in ambient at each of the 13 receptor locations shown in Figure 5.18. The ambient measured by the applicant at the town of Godley was taken as the most appropriate background level because of its close proximity to the site. Selected results of the computer calculations are presented in Table 5.15. A small increment to ambient results from the presence of the operating fans at the transformers. The effects of the auxiliary transformers were not included in these calculations because of their expected negligible influence (those transformers are surrounded by elevated walls and a significantly lower noise level compared to the main transformers).

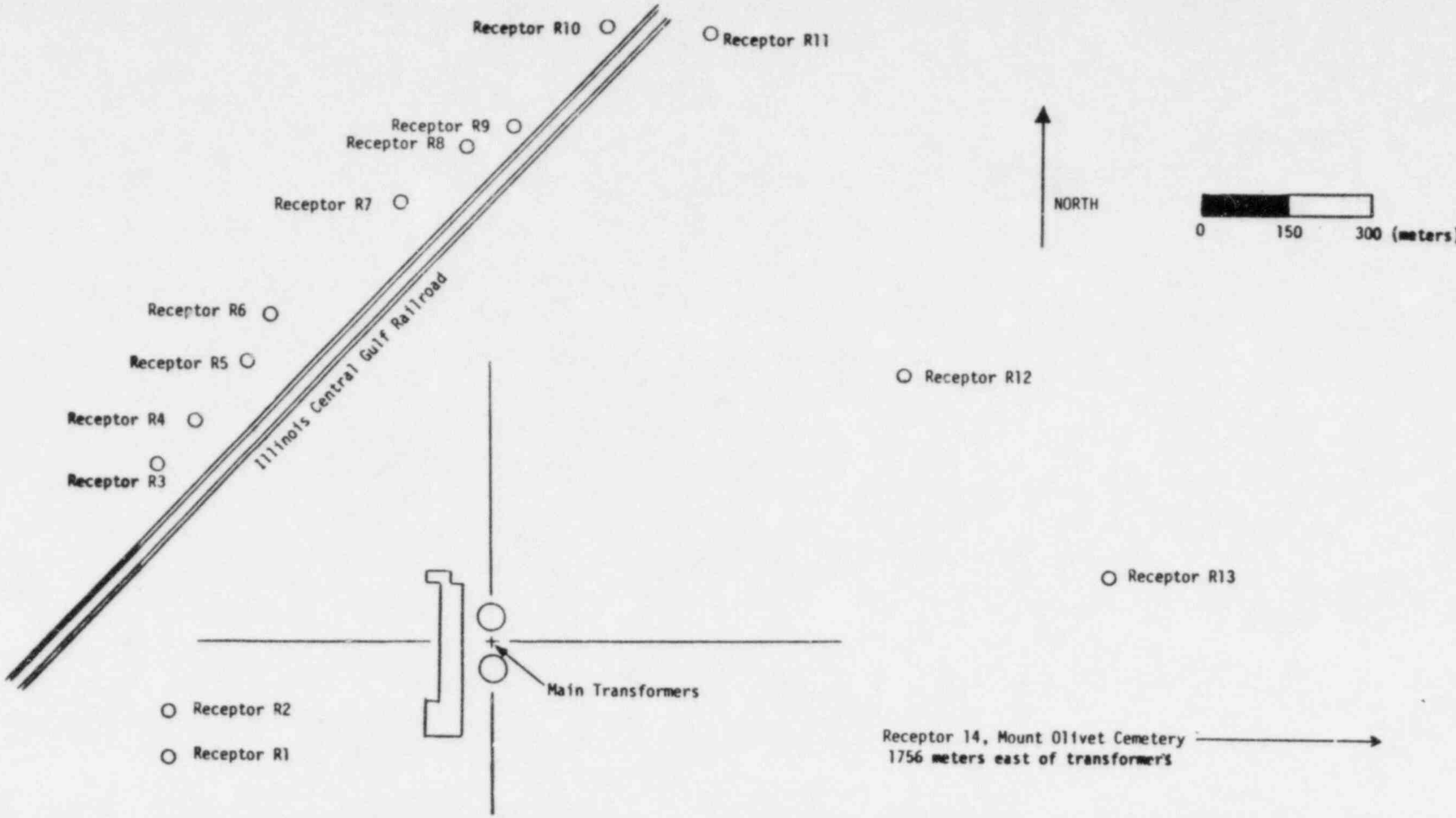

Figure 5.18 Location of transformers and nearest noise-sensitive areas with respect to Braidwood main site
Source: Commonwealth Edison Co. Response to staff question E290.10

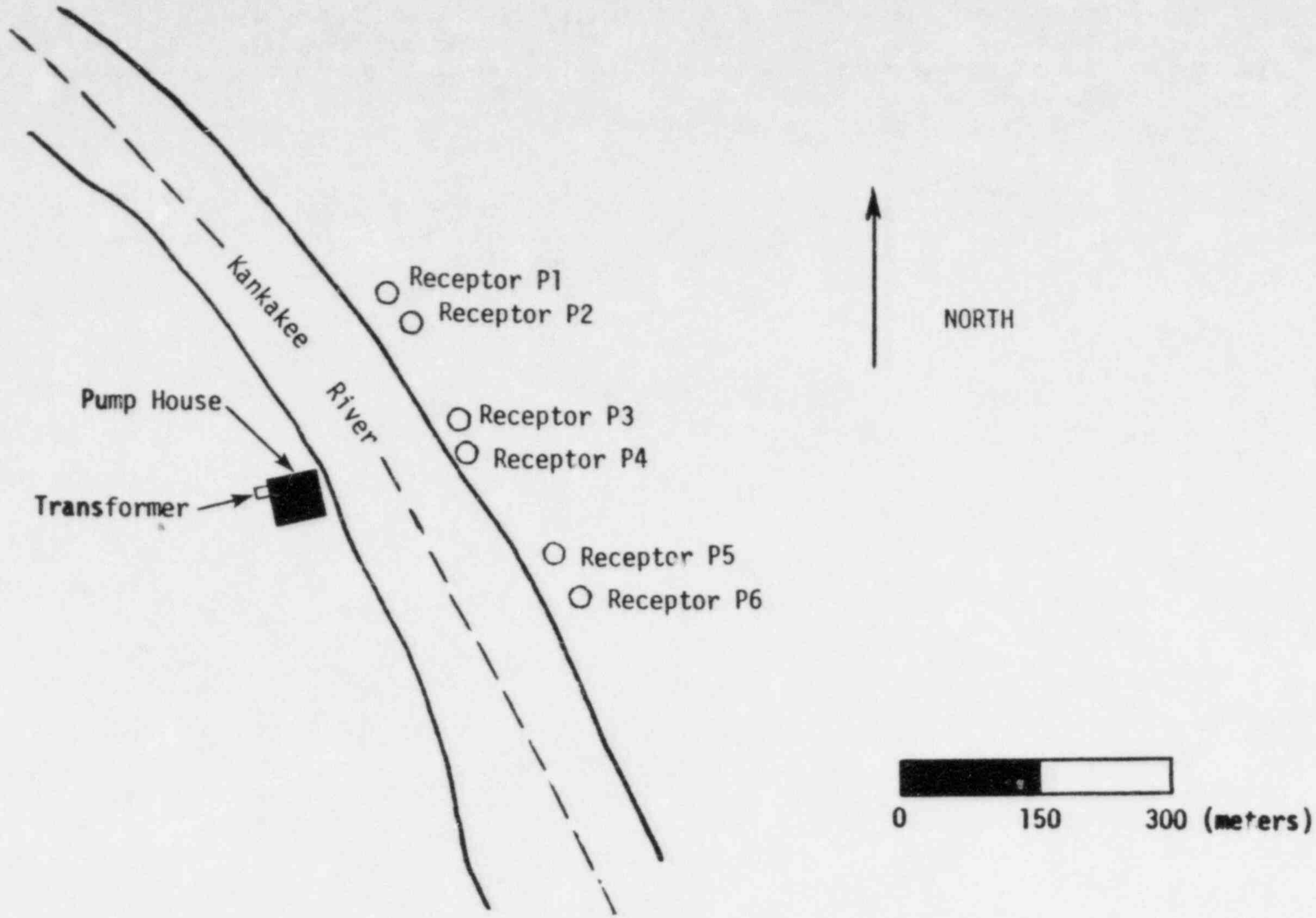

Figure 5.19 Location of Braidwood pumphouse and associated transformer with respect to the nearest residences and the Kankakee River
Source: Commonwealth Edison Co. Response to staff question E290.16

Table 5.15 Noise levels near the Braidwood site: Measured ambient and predicted operational levels due to station main transformers

Levels	Frequency (Hz) 31	63	125	250	500	1000	2000	4000	8000	Overall (dBA)
Ambient sound pressure level from Godley, dB	51	50	46	43	41	36	21	14	15	41.5
Sound power levels for main transformers fans, dB	106	112	114	109	109	103	98	93	86	
Predicted sound pressure levels at selected receptors during operation of main transformers and fans, dB										
Receptors										
R 7	52	52	51	46	45	38	25	15	15	44.9
R 8	51	52	50	46	44	37	24	14	15	44.1
R12	51	52	50	46	44	37	24	14	15	44.1
R13	51	51	49	45	43	37	22	14	15	43.3

The effect of the tones emitted by the main transformers also was computed. It was found that none of the tones (120, 240, 360, 480 Hz) would be audible at any of the 13 receptors. The presence of buildings just behind and to the sides of the main transformers blocked the noise for receptors R1 through R6, preventing audibility there. An audible tone would have been present at receptor R7 except that the transformer fans increased the broadband noise level, providing additional masking for the 120 Hz tone.

Located within the river pumphouse are three 24,000-gpm circulating water makeup pumps driven by three 2250-hp induction motors. In addition, there are two booster pumps with a design pressure of 275 psig, driven by 25-hp motors. The pumphouse also contains a reciprocating air compressor. The octave band power levels for these sources were determined by using Edison Electric Institute Noise Guide. An additional noise source considered in the analysis is the HVAC air intake system. Located within the pumphouse are two 150,000-cfm vaneaxial intake fans. The sound power levels used in the analysis were provided by Joy Manufacturing Co. with a 5-dB tone correction added to the blade passage frequency (125 Hz). Equipment sound power levels used and the conversion to pumphouse interior sound pressure levels are shown in Table 5.16.

Location P4 was selected in the vicinity of the pumphouse to determine the presence of any operational noise impacts because that location represents the nearest residence to the pumphouse. It is located 195 m (640 ft) east-northeast of the pumphouse across the river. This residence received noise contributions from both the north- and south-wall HVAC louvers. Any contribution from the

Table 5.16 Calculation of pumphouse noise at receptor P4

Steps	63	125	250	500	1000	2000	4000	8000	Overall SPL (dBA)
				Octave bands (Hz)					
Total sound power of interior sources, dB	110	112	105	104	104	103	98	91	
Interior sound pressure level, dB	90	93	86	84	83	82	75	68	
Exterior sound pressure level, dB	79	84	77	76	73	71	62	55	
Total sound pressure level after considering louvers, dB	95	99	92	92	89	87	78	71	
Subtract distance attenuation and air absorption to P4, dB	-52	-53	54	54	55	58	58	61	
Sound pressure level at P4, dB	42	46	39	38	38	32	21	10	
A-weighted sound pressure level at P4, dBA									40
Estimated nighttime residual sound level at P4, dBA									30

large door located on the east wall is shielded by the corrugated-metal wall installed in front of the pumphouse trash racks.

The sound power emitted outside the pumphouse by the doors and louvers was estimated by consideration of the area of the doors and louvers and their sound transmission loss. Calculation of door sound power emissions showed that they would be insignificant.

These outside-source sound power levels were used in the calculation of reception sound pressure levels and the attenuation of each source/receptor path. The A-weighted values of these results were compared with the A-weighted value of the estimated baseline ambient sound pressure level (pumphouse not operating) to evaluate the potential for environmental impact.

The results show that the greatest potential for annoyance (identified as receptor P4) is the residence located approximately 195 m (640 ft) east-northeast of the pumphouse across the river. At this location, relative to an estimated nighttime residual sound level of 30 dBA, the impacts were estimated to be on the order of 10 dBA resulting primarily from the compressors, HVAC fans, and circulating water pump motors. At location P1, the residence located approximately 223 m (730 ft) northeast of the pumphouse across the river, the impact is estimated to be about 6 dBA, relative to the same estimated residual of 30 dBA, as a result of the compressors, HVAC fans, and circulating water pump motors. Arithmetically, impacts could be larger or smaller, depending on the actual ambient noise levels at locations P4 and P1. It is concluded that at these locations, the pumphouse noise is effectively masked by the intake water noise, reported as the main source of noise by the residents along the river.

Sound power levels at each of the 120, 240, 360, 480 Hz tones are computed using the measurements from the Ritzveille 1 transformer (Stevens et al., 1955). This transformer is most similar to the one at the site and has sound power levels measured for it. Accounting for atmospheric attenuation and attenuation as a result of distance, noise level 4 dB above masking level is estimated for receptor locations P1 through P4. Receptors P5 and P6 are blocked by the pumphouse structure from direct line of sight and thereby will not be affected by the transformer tonal noise. A value of 4 dB above masking level is judged to cause little likelihood of complaints by area residents. Attenuation as a result of the presence of trees will further lower noise levels during most of seasons of the year. The value of ambient for the residences, for the purpose computing tonal noise impacts was taken to be the onsite measurements made by Commonwealth Edison during operation of the pumphouse. Broadband noise from the pumphouse will tend to add additional masking, reducing the effect of the tones emitted by the transformers.

All operational phase noise levels predicted for the community locations considered in this analysis are within Illinois Rule 203 limiting octave band sound pressure levels from stationary noise sources.

5.13 Emergency Planning Impacts

In connection with the promulgation of the Commission's upgraded emergency planning requirements, the NRC staff issued NUREG-0658, "Environmental Assessment for Effective Changes to 10 CFR Part 50 and Appendix E to 10 CFR Part 50; Emergency Planning Requirements for Nuclear Power Plants." 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 NRC staff concludes that the noise impacts from the system will be infrequent and insignificant.

The emergency operations facility for the Dresden, La Salle County, and Braidwood Stations is located in Mazon, Illinois. Because this is an existing facility, no additional environmental impacts are expected.

5.14 Environmental Monitoring

5.14.1 Terrestrial Monitoring

No operational terrestrial monitoring programs were required as a condition of the construction permit (FES-CP Summary and Conclusions). The applicant conducted extensive terrestrial baseline and construction surveys through 1975 and has taken false-color infrared aerial photographs of the site and vicinity since

1979 (ER-OL Section 6.1.4.3). The applicant has not detected any offsite effects resulting from filling the cooling pond, and no offsite effects have been observed that could be attributed either to the filling of the pond or to the presence of the pond. Therefore, the applicant has terminated this survey.

5.14.2 Aquatic Monitoring

The certifications and permits required under the Clean Water Act provide the mechanisms for protecting water quality and aquatic biota. Operational monitoring of effluents will be required by the NPDES permit. A copy of the NPDES permit is included as Appendix G.

Operational monitoring programs are to be conducted in accordance with the Environmental Protection Plan (EPP) and the Environmental Technical Specifications for radiological monitoring 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) keep the NRC informed of the status of the NPDES permit or State certification pursuant to Section 401 of the Clean Water Act; and (4) report unusual or important environmental events.

The EPP will be included as Appendix B to the Braidwood Station operating license. This plan will include requirements for prompt reporting by the applicant of important events that potentially could result in significant environmental impact causally related to plant operation. Examples of reportable important events include fish kills, occurrence and/or mortality of species protected by the Endangered Species Act, occurrence of nuisance organisms or conditions, and unanticipated or emergency discharge of waste water or chemical substances.

5.14.3 Atmospheric Monitoring

Meteorological data have been collected on a 98-m (320-ft) tower situated about 573 m (0.4 mi) northeast of the Unit 1 reactor building since November 1973. The measurements, following the guidance of RG 1.23 for equipment accuracies and sensitivities, include the parameters as follows:

Meteorological Parameter	Level of Measurement
Wind speed and wind direction at	34 ft (~10 m) and 203 ft (~62 m)
Temperature difference between	30 ft (~10 m) and 199 ft (~61 m)
Dewpoint temperature at	30 ft (~10 m) and 199 ft (~61 m)
Ambient air temperature at	30 ft (~9.1 m)

Precipitation is measured at ground level near the tower.

All measurement signals except for precipitation are transmitted to the control room.

Data collected from January 1979 through December 1982 yielded over 97% joint frequency data recovery, exceeding the 90% recovery rate suggested in RG 1.23.

The operational phase of the onsite meteorological measurement program will be identical to that described above for the preoperational phase.

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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 Braidwood Station. These impacts are summarized in Table 6.1.

The applicant is required to adhere to the following conditions for the protection of the environment:

(1) Before engaging in any additional construction or operational activities that may result in any significant adverse environmental impact that was not evaluated or that is significantly greater than that evaluated in this statement, the applicant will provide written notification of such activities to the Director of the Office of Nuclear Reactor Regulation and will receive written approval from that office before proceeding with such activities.

(2) The applicant will carry out the environmental monitoring programs outlined in Section 5 of this statement, as modified and approved by the staff and implemented in the Environmental Protection Plan and Technical Specifications that will be incorporated in the operating licenses.

(3) If an adverse environmental effect or evidence of irreversible environmental damage is detected during the operating life of the plant, the applicant will provide the staff with an analysis of the problem and a proposed course of action to alleviate it.

6.2 Irreversible and Irretrievable Commitments of Resources

There has been no change in the staff's assessment of this impact since the earlier review except that the continuing escalation of costs has increased the dollar values of the materials used for constructing and fueling the plant.

6.3 Relationship Between Short-Term Use and Long-Term Productivity

There have been no significant changes in the staff's evaluation for Braidwood Station since the construction permit stage environmental review.

6.4 Benefit-Cost Summary

6.4.1 Summary

Sections below describe the economic, environmental, and socioeconomic benefits and costs that are associated with the operation of Braidwood Station, Units 1 and 2.

Table 6.1 Benefit-cost summary for Braidwood Station

Primary impact and effect on population or resources	Quantity (Section)	Impacts*
BENEFITS		
Capacity		
Additional generating capacity	2240 MWe	Large
Economic		
Reduction in existing system production costs	11 billion kWh/yr @ 26.7 mills/kWh or $294 million/yr**	Moderate
COSTS		
Economic		
Fuel	10.8 mills/kWh**	Small
Operation and maintenance	7.0 mills/kWh**	Moderate
Total	$196 million/yr**	Moderate
Decommissioning	$48-77 million***	Small-moderate
Environmental		
Damages suffered by other water users		
Surface water consumption	(Sec. 5.3.1)	Small
Surface water contamination	(Sec. 5.3.2)	Small
Ground water consumption	(Sec. 4.3.1)	None
Ground water contamination	(Sec. 4.3.1)	None
Damage to aquatic resources		
Impingement and entrainment	(Sec. 5.5.2)	Small
Thermal effects	(Sec. 5.3.2)	Small
Chemical discharges	(Sec. 5.3.2)	Small
Cooling pond drawdown	(Sec. 5.5.2)	Small
Damage to terrestrial resources		
Station operations	(Sec. 5.5.1.1)	Small
Transmission line maintenance	(Sec. 5.5.1.2)	Small

See footnotes at end of table.

Table 6.1 (Continued)

Primary impact and effect on population or resources	Quantity (Section)	Impacts*
Adverse socioeconomic effects		
Loss of historic or archeological resources	(Sec. 5.7)	Moderate
Increased demands on public facilities and services	(Sec. 5.8)	Small
Increased demands on private facilities and services	(Sec. 5.8)	Small
Noise	(Sec. 5.12)	Moderate-small
Adverse nonradiological health effects		
Water quality changes	(Sec. 5.3.2)	None
Air quality changes	(Sec. 5.4)	None
Adverse radiological health effects		
Routine operation	(Sec. 5.9.3)	Small
Postulated accidents	(Sec. 5.9.4)	Small
Uranium fuel cycle	(Sec. 5.10)	Small

*Subjective measure of costs and benefits is assigned by reviewers, where quantification is not possible: "Small" = impacts that in the reviewers' judgments, are of such minor nature, based on currently available information, that they do not warrant detailed investigations or considerations of mitigative actions; "Moderate" = impacts that in the reviewers' judgments are likely to be clearly evident (mitigation alternatives are usually considered for moderate impacts); "Large" = impacts that in the reviewers' judgments, represent either a severe penalty or a major benefit. Acceptance requires that large negative impacts should be more than offset by other overriding project considerations.

**1986 dollars. The reduced generating cost is the difference between $294 million/yr and $196 million/yr, which is $98 million/yr for both units. This is equivalent to $49 million/yr per unit as reflected in the DES.

***1983 dollars

6.4.2 Benefits

A major benefit to be derived from the operation of the Braidwood Station is the lower production cost for approximately 11 billion kWh of baseload electrical energy that will be produced annually (this projection assumes that both units will operate at an annual average capacity factor of 55%). The addition of the plant will also improve the applicant's ability to supply system load requirements by contributing 2240 MW of generating capacity to the Commonwealth Edison Company system (1120 MW from Unit 1 in 1986 and 1120 MW from Unit 2 in 1987).

The staff estimates that production costs incurred by the existing fossil units will be reduced by approximately 26.7 mills per kWh, resulting in a total reduction per year on the existing generation of $294 million (1986).

6.4.3 Economic Costs

The economic costs associated with station operation include fuel costs and operating and maintenance costs, which are expected to average approximately 10.8 mills per kWh and 7.0 mills per kWh, respectively (ER-OL Table 8.1.1, 1986 dollars, adjusted for a 55% average capacity factor, rather than applicant's estimate of a 60% average capacity factor). Total production costs for the $11 billion kWh per year produced by the nuclear units would be $196 million per year (1986 dollars).

The applicant's estimate of decommissioning costs for each Braidwood unit ranges from $48 million to $77 million in 1983 dollars (ER-OL Table 5.8.1-1).

6.4.4 Socioeconomic Costs

No significant socioeconomic costs are expected from either the operation of Braidwood Station or from the number of station personnel and their families living in the area. The socioeconomic impacts of a severe accident could be large; however, the probability of such an accident is small.

6.5 Conclusion

As a result of its analysis and review of potential environmental, technical, and social impacts, the NRC staff has prepared an updated forecast of the effects of operation of Braidwood Station. The NRC staff has determined that Braidwood Station can be operated with minimal environmental impact. To date, no new information has been obtained that alters the overall favorable balancing of the benefits of station operation versus the environmental costs that resulted from evaluations made at the construction permit stage.

6.6 Reference

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

7 LIST OF CONTRIBUTORS

The following personnel participated in the preparation of this Final Environmental Statement:

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

The following Federal, state, and local agencies were asked to comment on the Draft Environmental Statement:

Advisory Council on Historic Preservation
    Department of Conservation
Brookhaven National Laboratory
Federal Emergency Management Administration
Federal Energy Regulatory Commission
Illinois Department of Nuclear Safety
Illinois Institute of Natural Resources
Illinois State Attorney General
Illinois State Clearinghouse
U.S. Army Corps of Engineers
U.S. Coast Guard
U.S. Department of Agriculture
    Forestry Service
    Natural Resources and Economics Division
    Rural Electrification Administration
    Soil Conservation Service
U.S. Department of Commerce
    Office of Ecology and Conservation
U.S. Department of Energy
U.S. Department of Health and Human Services
    Food and Drug Administration
U.S. Department of Housing and Urban Development
U.S. Department of the Interior
U.S. Department of Transportation
U.S. Environmental Protection Agency
    Eastern Environmental Radiation Facility, Montgomery, Alabama
    EIS Review Coordinator, Region V, Chicago, Illinois
    Office of Radiation Programs, Las Vegas, Nevada
    Office of Radiation Programs, Washington, D.C.
U.S. House of Representatives
    The Honorable Tom Corcoran
Will County Board of Supervisors

9 STAFF RESPONSES TO COMMENTS ON THE DRAFT ENVIRONMENTAL STATEMENT

Pursuant to 10 CFR 50, the "Draft Environmental Statement Related to the Operation of Braidwood Station, Units 1 and 2" (DES) was transmitted, with a request for comments, to the agencies and organizations listed in Section 8. In addition, the NRC requested comments on the DES from interested persons by a notice published in the Federal Register on January 20, 1984.

The agencies, organizations, and individuals who responded to the requests for comments are listed below in alphabetical order by abbreviated form. The comment letters are reproduced in the same order in Appendix A. The page in Appendix A on which the comment letter begins is given.

CECo	Commonwealth Edison Company................................	A-1
DA/ERS	U.S. Department of Agriculture, Economic Research Service.	A-14
DA/SCS	U.S. Department of Agriculture, Soil Conservation Service.	A-15
EPA	U.S. Environmental Protection Agency, Region V............	A-16
IDC	Illinois Department of Conservation.......................	A-19
IDNS	Illinois Department of Nuclear Safety.....................	A-23
JFD	John F. Doherty...	A-26
NIPC	Northeastern Illinois Planning Commission.................	A-28
WCDD	Will County Development Department........................	A-32

The letters from DA/ERS and DA/SCS did not require a staff response since they had no comments at this time. The remaining comment letters did require staff responses.

The staff's consideration of these comments and the disposition of the issues involved are reflected, in part, by text revisions in the pertinent sections of this FES and, in part, by the discussion in the subsections below.

The section numbers assigned here generally correspond to the section numbers in the FES and DES except that each is preceded by the digit "9." Comments on the appendices are addressed in Section 9.10. References appear in Section 9.11. Individual comments are designated by the commentor's initials (given above) and designated numbers indicated in the letter margins in Appendix A.

9.1 Introduction

CECo 1: CECo stated that the construction schedule for Braidwood Station has been revised.

Staff Response: The text has been revised as suggested by the applicant.

9.4 Project Description and Affected Environment

9.4.1 Résumé

CECo 2: CECo stated that the only new right-of-way from the plant is to the Crete substation.

Staff Response: The text, in Section 4.1, has been revised as suggested by the applicant.

9.4.2 Facility Description

9.4.2.1 External Appearance and Plant Layout

CECo 3: CECo stated that Figure 4.1 has been revised.

Staff Response: The revised figure has been included in the FES (Figure 4.1).

9.4.2.3 Water Use and Treatment

CECo 4: CECo stated that the period of record for the historic river flows on the Kankakee River was from 1915 through 1982 rather than from 1946 through 1976.

Staff Response: The text, in Section 4.2.3.1, has been revised as suggested by the applicant.

CECo 5: CECo stated that either carbon dioxide or polymers would be used to control scale buildup in the condenser cooling system beyond that controlled by the mechanical cleaning system.

Staff Response: The text, in Section 4.2.3.4, has been revised to indicate the proposed use of carbon dioxide or polymers for control of scale in the circulating water system or in the condensers for buildup beyond that controlled by the mechanical cleaning system.

CECo 6: CECo stated that sponge-rubber balls would be continuously injected into the condensers for mechanical cleaning purposes.

Staff Reponse: The text, in Section 4.2.3.4, has been revised to indicate that the applicant plans to operate the mechanical cleaning system continuously.

CECo 7: CECo stated that the target free available chlorine concentration at the condenser outlet water box being treated is 0.5 mg/l rather than 0.1 mg/l.

Staff Response: The text, in Section 4.2.3.4, has been revised to more clearly indicate the treatment of the condenser cooling water with chlorine and the expected concentration in the condenser outlet water boxes and downstream circulating water system.

CECo 8: CECo stated that the number of times per day that the service water system will be treated is 2 rather than 3.

Staff Response: The text has been revised as suggested by the applicant to describe the treatment frequency.

CECo 9: CECo provided additional information concerning the treatment of water from the freshwater holding pond.

Staff Response: The text has been revised as suggested by the applicant to correct descriptive material and typographical errors.

CECo 10: CECo provided additional information concerning the treatment of water in the demineralizer train.

Staff Response: The text has been revised as suggested by the applicant to reflect changes which will be documented in Amendment 6 to the applicant's environmental report.

9.4.2.4 Cooling System

NIPC 1: NIPC stated that the DES did not address the environmental impacts of the pipeline to the Kankakee River.

Staff Response: There are no operational impacts from the make-up and blow-down pipelines to the Kankakee River. Hence no change is needed in the text.

CECo 11: CECo suggested a revision to the maximum cooling pond depth value.

Staff Response: The basis for the staff's reference to a 30-m maximum depth is a discussion between the staff and applicant personnel during the environmental site visit in May 1983. Applicant's response to staff question E291.8 did not substantiate this value, however. This response included a map entitled "Braidwood Lake Topographic Map-Index Braidwood Station Units 1 and 2, Commonwealth Edison Co., Chicago, Illinois" (Sargent and Lundy Engineers drawing No. S-450-BR Rev A). This map showed standing water in several areas of the cooling pond. Depth measurements were taken at five transects in the vicinity of dike stations 450+00 - 480+00, as shown on FES Figure 4.4. These transects indicate depths as great as about 14 m (45 ft). The maximum depth value in Section 4.2.4.2 has been changed to indicate this deepest verified value.

The areas of greater depth indicated to the staff during the site visit are located in the region of the cooling pond traversed by a line drawn between perimeter dike station 130+00 and interior dike station 150+00, as shown on FES Figure 4.4.

CECo 12: CECo stated that the surface area of the ultimate heat sink was 99 acres at elevation 590 ft MSL rather than 93.5 acres.

Staff Response: The text has been revised to clarify the size of the ultimate heat sink by including an elevation reference for the area cited.

CECo 13: CECo stated that cooling pond water is drawn through two pipelines to the condensers, then through two other pipelines to the discharge outfall structure, and back into the pond for the two units.

Staff Response: The text has been revised as suggested by the applicant to clarify the system description.

CECo 14: CECo provided clarifying information concerning the average temperature excess of the blowdown above the ambient river temperature.

Staff Response: Section 4.2.4.3 has been clarified to reflect the reference to the difference between the blowdown and the ambient river temperature. The reference to the size of the 5°F isotherm has also been clarified.

CECo 15: CECo corrected the value in Table 4.1 for the Kankakee River average flow rate.

Staff Response: The value in Table 4.1 has been corrected as suggested by the applicant.

9.4.2.5 Radioactive Waste Management System

IDNS 6: IDNS questioned whether Braidwood Station has the capability to handle radioactive chemical decontamination waste.

Staff Response: The Braidwood Station does not have the capability to handle a major radioactive chemical decontamination. It does have the capability to handle the small quantities of chemical decontaminants typically used during normal operations at a nuclear power plant. No text revision is required.

EPA 1: EPA stated that the Braidwood SER Section 11, Radioactive Waste Management, has not been completed.

Staff Response: The Environmental Impact Statement references the Braidwood SER Section 11, Radioactive Waste Management. As noted in the SER, this section is the same as in the Byron SER. Since Braidwood Station is a duplicate of Byron Station, considerable reference to the Byron SER was made in the Braidwood SER. No text revision is required.

EPA 2: EPA stated that the DES failed to address the manner in which the applicant would ensure that radiation levels from all sources at the plant, including storage of high level waste, will be maintained within the EPA Radiation Standards (40 CFR 190).

Staff Response: Paragraph 3 of Section 5.9.3.2 of the DES discussed the impact of the operation of the Braidwood plant on the general environment with regard to its position in the uranium fuel cycle. Within this context all sources of radiation at the plant, including the contribution from high level waste, were considered. The staff has concluded that, insofar as normal operations are concerned, the Braidwood facility is capable of operating within the EPA standards. No text revision is required.

9.4.2.7 Power Transmission System

CECo 16: CECo stated that there are no plans for a 765-kV line in the foreseeable future and the necessary right-of-way for such a line is not continuous.

Staff Response: The spelling of "Burnham" and the width of the right-of-way have been revised in Section 4.2.7. The last part of the comment provides additional information about the 765-kV line but does not require revision of the text.

CECo 17: CECo noted that the legend symbol for the new 345-kV lines was incorrect in Figure 4.5.

Staff Response: Figure 4.5 has been revised as suggested by the applicant.

9.4.3 Project-Related Environmental Descriptions

9.4.3.2 Water Quality

CECo 18: CECo corrected a typographical error.

Staff Response: The text has been revised as suggested by the applicant.

9.4.3.3 Meteorology

CECo 19: CECo corrected a typographical error.

Staff Response: The text has been revised as suggested by the applicant.

9.4.3.4 Terrestrial and Aquatic Resources

CECo 20: CECo stated that the acreage of small discontinuous marshlands is 40.

Staff Response: The text, in Section 4.3.4.1, has been revised as suggested by the applicant.

CECo 21: CECo corrected the time period during which aquatic biota of the Kankakee River and Horse Creek in the site vicinity were sampled.

Staff Response: The text has been revised to correct the description of the aquatic monitoring program.

CECo 22: CECo corrected the time period during which the monitoring programs were conducted.

Staff Response: The text has been revised as suggested by the applicant. Reference to Section 4.7 of the ER-OL, as suggested by the applicant, is erroneous. The correct reference is to Section 4.1 of the ER-OL.

CECo 23: CECo corrected the time period during which phytoplankton phyla were collected.

Staff Response: The text has been revised as suggested by the applicant.

CECo 24: CECo corrected the time period during which fish were collected from the Kankakee River and Horse Creek.

Staff Response: The text has been revised as suggested by the applicant.

CECo 25: CECo corrected the time period during which fish eggs and larvae were sampled.

Staff Response: The text has been revised as suggested by the applicant.

9.4.3.7 Historic and Archeologic Sites

NIPC 4: NIPC stated that site development activities, including future activities, should be done with the consultation of the State Historic Preservation Officer, the Illinois Archeological Survey, and the Illinois Natural History Survey.

Staff Response: NRC is fulfilling its legal responsibilities with regard to these areas as described in Sections 4.3.7, 5.7, and Appendix H of the Environmental Impact Statement. No text revision is required.

9.5 Environmental Consequences and Mitigating Actions

9.5.3 Water

9.5.3.1 Water Use

WCDD 3: WCDD stated that the Will County Public Water Supply System was not included as a potential downstream water user.

Staff Response: Section 5.3.1 of the FES includes a discussion of potential impacts resulting from a possible future Will County municipal intake on the Kankakee River. During the May 1984 environmental site visit, the staff visited the Will County Development Department. At that time, no mention was made of a possible future municipal intake on the Kankakee River. Subsequent to the Will County DES comments, the staff requested and received a copy of the Will County Public Water Supply Study, Phase I Report, dated January 1984. This is a reconnaissance-type report on population and water use projections which postdates the December 1983 issuance date of the Braidwood DES.

To the best of our knowledge the site of a future Will County municipal intake has not been selected. However, it is our understanding that the most likely site for the future intake will be upstream of the Braidwood Station intake and discharge facilities, on land that was donated to Will County by Commonwealth Edison Company. Should this site prevail, the Braidwood Station would not impact the Will County intake unless the State of Illinois applies limitations (through its permit system) on the Kankakee River. Conversely, the Will County intake would more likely impact the Braidwood Station. The FES discusses potential impacts assuming both upstream and downstream locations for the possible future Will County intake.

WCDD 5: WCDD stated that the DES did not address the increased costs to the proposed Will County Public Water Supply System because of mitigating measures that may be required as a result of the effects of the Braidwood Station upstream.

Staff Response: There is insufficient information available about the possible future Will County municipal water supply system to determine if mitigating measures would be necessary or to estimate costs thereof. No text revision is required.

CECo 26: CECo clarified the water withdrawal agreement with the Illinois Department of Conservation.

Staff Response: The text, in Section 5.3.1, paragraph 1, has been revised to provide more background on establishment of the requirements of the water withdrawal permit.

CECo 27: CECo corrected a typographical error.

Staff Response: The text has been revised as suggested by the applicant.

CECo 28: CECo clarified the water withdrawal agreement with the Illinois Department of Conservation.

Staff Response: The text has been revised as suggested by the applicant to clarify the requirements of the water withdrawal permit.

CECo 29: CECo stated that at present there are no downstream uses of water from the Kankakee River.

Staff Response: The text has been revised as suggested by the applicant to reflect the current status of downstream water use.

9.5.3.2 Water Quality

WCDD 1: WCDD stated its concern with the impact on the proposed Will County Public Water Supply System as as result of degradation of water quality from discharge of cooling water to the river.

Staff Response: In Section 5.3.2 the staff indicated that the blowdown discharge will contain the same chemical constituents as the river but they will at higher concentrations because of evaporation. It is further stated in Section 5.3.2 that discharge levels are within limits established by the State of Illinois for the effluent and water quality standards. At the normal and maximum discharge levels calculated, plant operation should cause no significant adverse impacts on the water quality of the Kankakee River. No text revisions are required.

CECo 30: CECo corrected the acreage of the 2°F isotherm.

Staff Response: The text has been corrected as suggested by the applicant.

CECo 31: CECo corrected the value for "Ambient river - Chlorides."

Staff Response: Table 5.1 has been corrected to reflect the change reported by the applicant.

9.5.5 Ecology

9.5.5.1 Terrestrial Ecology

NIPC 2: NIPC urged that final landscaping and ongoing operations be conducted in a manner that minimizes adverse offsite esthetic impacts.

Staff Response: Landscaping impacts are considered at the CP stage. Hence no change is needed in the text.

CECo 32: CECo stated that about 15 ha would be revegetated. part as native prairie and part as wildlife habitat.

Staff Response: The text in Section 5.5.1.1 has been revised as suggested by the applicant.

EPA 3: EPA stated that CECo needs to better maintain the soil erosion program.

Staff Response: The erosion control program is an ongoing process; steps are taken to correct and repair rills and gulleys when they occur in areas that would constitute an operational or safety problem. With regard to the spoil islands in the cooling pond, no action has been taken at this point to revegetate the slopes because of the commitment to continue the fossil-hunting program. Plans are being made to seed areas of the slopes which are less desirable from a fossil-hunting standpoint, if water quality dictates. The effect of this would be stabilization of the slopes and reduced leachate. At this time no cooling system deficiencies due to water quality are anticipated. No change in the text is required.

9.5.5.2 Aquatic Resources Impacts

IDC 1: IDC noted that general statements relative to impacts were given in the DES without a thorough presentation of data or references to support these statements.

Staff Response: The staff has reviewed the applicant's monitoring reports and considered the data presented in those documents in the staff's independent analysis of potential impacts attributable to operation of the Braidwood Station. The text in Section 5.5.2 has been revised to more fully document, by reference citings, the bases for the staff's conclusions.

IDC 2: IDC stated that the DES contained two conflicting statements concerning the thermal plume in the Kankakee River.

Staff Response: The statement in Section 5.3.2 (page 5-2 of the DES) refers to the cross-sectional area of the river. The statement in Section 5.5.2.2 (page 5-13 of the DES) refers to the surface area covered by the plume at its maximum width. The plume does not extend from the surface to the bottom of the river across the entire width of the plume. The applicant indicates that the ER-OL will be amended to show the following values for the 5° thermal plume cross-sectional areas when the depth of the plume and river cross-sections are considered: 18% in August, 21% in September, and 13% in December. These predicted cross-sectional areas meet the Illinois water quality standards. The text on page 5-13 (DES) has been revised to clarify the meaning of the thermal plume projection.

IDC 3: IDC suggested that the FES assessment of impacts on eggs and larval fish include a discussion of studies CECo has conducted to determine distribution of larval drift through river cross-sections.

Staff Response: As described in the staff response to IDC 2 (above), the thermal plume should not be a barrier to movement of mobile aquatic organisms. On the basis of studies done for the applicant by the Illinois Natural History Survey, it appears that the distribution of larval drift varies with the flow of the river and the size of a sandbar upstream of the intake structure. The distribution of some species may depend on habitat preferences, e.g., preferences for near-shore versus mid-channel areas. To seek out preferred habitat, the organism would have to be capable of directed movement rather than passive (planktonic) transport. This suggests that the same organism to some degree should be capable of moving away from unpreferred habitat under some flows. A greater potential effect would be expected for those larval organisms preferring the near-shore area and for planktonic larvae versus demersal larvae because the thermal plume will primarily be on the surface and near shore at the blowdown discharge to the Kankakee River. Larvae discharged from Horse Creek would be subjected to intake and discharge effects when flow from the creek "hugs" the river bank. This effect will vary from year to year because of the differences in creek and river flows during spawning time and, also, in the direction of flow of the creek into the river because of sandbar deposition at the mouth of the creek. The applicant's studies have shown the density and species composition to be very similar between Horse Creek and Kankakee River samples. A demonstration of no significant impact from operation of the intake and discharge should show that the densities and species composition at upstream and downstream sample locations remain similar to preoperational values.

The monitoring study conducted in 1980 by the Illinois Natural History Survey indicated that the productivity of the monitoring stations along the left bank (far side) of the Kankakee River was greater than at the intake monitoring sites. This resulted from the sandbar at the mouth of Horse Creek that channeled flow toward the far bank. Studies of egg and larval distribution conducted by the Illinois Natural History Survey (1978, 1979, 1980) monitored both bottom-attached and planktonic eggs and larvae along cross-sectional transects. Results of the 1980 study showed that drift densities were greatest in Horse Creek and that the drift rate was highest at the upstream sampling station on the Kankakee River. The 1981 study found that of 131 fish eggs collected in Horse Creek and the Kankakee River, 91 eggs (or 69%) were viable. Larval collections showed that catostomids had higher densities at shoreline areas; *Ictalurus punctatus* larvae were most dense at the mid-channel sites, and unidentified cyprinid and percid larvae were most dense along the plant-side shoreline. Studies in 1978 and 1979 showed that most of the larval drift occurred at dusk and dawn.

When Unit 1 begins normal commercial operation, the applicant is committed to conduct an entrainment study during the spawning season. In addition to fish and egg and larval samples at the intake structure, samples will also be taken in the river. Samples will be taken over a 24-hour period once a week. These studies will provide further data to evaluate the effects of plant operation on the fish populations in the river. Requirements for this type of operational program are included as part of the NPDES permit issued by the Illinois Environmental Protection Agency (a copy is provided in Appendix G).

The text has been revised in Section 5.5.2.2 to more fully reflect the results of the applicant's study and the use of those results in the staff's analyses.

IDC 4: IDC suggested that the FES fully address CECo's commitment to conduct 12-month impingement entrainment studies after plant startup.

Staff Response: The estimated total number of fish impinged (Table 5.4, p. 5-16, DES) was based on impingement analyses conducted during filling of the Braidwood cooling pond; these numbers are based on a limited, mid-winter sample. The applicant is committed to conducting a 12-month impingement study at the intake structure on the Kankakee River. The study will begin when Braidwood Unit 1 begins normal commercial operation. It is expected that the study will be conducted in the same manner as was the study performed during the filling of the cooling pond. Therefore, impingement samples will be collected on three consecutive 24-hour periods each week.

Requirements for this type of operational program are included as part of the NPDES permit issued by the Illinois Environmental Protection Agency (a copy is provided in Appendix G). Therefore, no text revision is required.

CECo 33: CECo corrected a typographical error.

Staff Response: The text has been revised as suggested by the applicant.

CECo 34: CECo corrected the reference to the normal intake flow from the Kankakee River.

Staff Response: The text has been revised to reflect that the value used represents the average annual intake flow.

NIPC 3: NIPC encouraged the safe use of the cooling pond for wildlife management and related recreational activities.

Staff Response: No commitments have been made with regard to use of the cooling pond for wildlife management and related recreational activities. Commonwealth Edison Company has committed to cooperating with the Illinois Department of Conservation on such matters. No text revision is required.

9.5.6 Threatened and Endangered Species

9.5.6.2 Aquatic

IDC 5: IDC indicated that the FES should address CECo's specific plans for river monitoring and study of the pallid shiner before and after plant startup.

Staff Response: The Illinois Natural History Survey studies (1981, 1982) found the pallid shiner to occur at station 5, a slack-water area downstream of the discharge. This station is downstream of the projected thermal plume and should be, therefore, beyond the influence of the plant. The applicant has indicated the intent to pay particular attention to this species and will continue to monitor station 5 for the pallid shiner and for thermal effects of the discharge as part of the operational monitoring survey. No text revision is required.

9.5.9 Radiological Impacts

9.5.9.3 Radiological Impacts From Routine Operations

IDNS 2: IDNS questioned what has been done at Braidwood Station to preclude unmonitored and/or unplanned radioactive releases, both gaseous and liquid.

Staff Response: The Technical Specifications for Braidwood Station will include a limiting condition for operation which will require that liquid and gaseous effluent monitoring instrumentation be operable. If this instrumentation is inoperable, the technical specifications call for various plant actions to ensure that releases are within the limits of 10 CFR Part 20. Some of these actions involve taking periodic grab samples, performing additional sampling and analysis, and verifying release calculations. However, experience has shown that even with these specifications, unmonitored releases do occur from time to time, but on an infrequent basis. No text revision is required.

IDNS 3: IDNS asked if the range of annual man-rems anticipated for the occupational radiation exposure includes the radiation exposure received for special repair and maintenance considerations.

Staff Response: The 500 person-rem occupational dose projected for Braidwood Units 1 and 2 discussed in Section 5.9.3.1.1 of the DES assumes that the same average amount of special and routine maintenance experienced at currently operating PWRs will be required at Braidwood. No text revision is required.

IDNS 4: IDNS asked if the staff took into account the proposed revision of 10 CFR Part 20 in developing Section 5.9.3.1.1 of the DES.

Staff Response: The staff did not consider any changes to Part 20 because the current proposal is a draft internal staff document that is subject to change before being issued as an effective rule. No text revision is required.

JFD 2: JFD questioned the use of zero as the lower limit in the range of risk estimators used in Section 5.9.3.1.1 of the DES.

Staff Response: The BEIR III report in its summary and conclusions states that it could not conclude if dose rates of 100 mrad/yr are detrimental to man because any somatic effects at this level would be masked by environmental or other factors that produce health effects (BEIR III, 1980). In addition, there may be biological mechanisms that repair damage caused by radiation at low doses and/or dose rates. Since the dose rates considered in the DES are limited by Appendix I of 10 CFR Part 50 to about 1/6 of this value, a lower limit of zero cannot be excluded. No text revision is required.

WCDD 2: WCDD requested that the staff consider the long-term human effects and risks associated with effluents containing low levels of radioactive discharge entering the river.

Staff Response: Section 5.9.3.2 of the DES discussed the radiological impacts on humans from routine operations of the Braidwood plant. This discussion considered both the effects of low-level radioactive liquid effluent entering the river and low-level gaseous effluent entering the atmosphere. In addition, Appendix D tabulated projected quantities of radioactive materials for the routine releases of radioactive effluents and the resulting calculated doses to individuals living near the plant and the general population within 50 miles of the plant. This information is also presented in the FES; no text revision is required. On the basis of this information the staff has concluded that the risk to the public health and safety from exposure to radioactivity associated with normal operation of the Braidwood plant will be very small.

9.5.9.4 Environmental Impacts of Postulated Accidents

CECo 35: CECo corrected the minimum distance from the outer edge of the containment wall to the exclusion area boundary.

Staff Response: The staff concurs with this change; however, the applicant's conversion from meters to feet is incorrect (485 meters x 3.28 = 1591 ft, not 1478 ft). The text has been revised accordingly.

CECo 36: CECo stated that based on S. Levine's uncertainty analysis testimony for the Byron ASLB hearing, the approach and the resulting numerical value for the probabilistic assessment of severe accidents is too conservative.

Staff Response: The staff reiterates the support of its approach and the resulting numerical values. We note that a known non-conservatism is the exclusion of externally initiated accidents, except those involving loss of offsite power, and sabotage-initiated events. No text revision is required.

CECo 37: CECo stated that under release category B, the value should be no greater than 2×10^{-7} for Braidwood, based on the risk studies done for Byron.

Staff Response: The staff has acknowledged that the Braidwood design reflects the concerns about event V, and that this design represents an improvement over older plants. However, in the absence of a full-scale probabilistic risk assessment, and as stated in Appendix E of the DES, the probability for release category B was conservatively taken to be the upper end of the range for plants with systems similar to Braidwood. No text revision is required.

CECo 38: CECo stated that under release category F, the value should be essentially zero based on the risk studies done for Byron.

Staff Response: As stated in the response to CECo 37, the staff's estimate of probability is based on assessments of plants with similar designs, not on a Braidwood-specific PRA (probabilistic risk assessment). Although some probabilities may appear conservative, this only reflects the staff's concern for the uncertainty in its estimation of these numbers and does not present an unduly pessimistic view of the risk from severe accidents. No text revision is required.

CECo 39: CECo stated that under release category B, the 1-hour value is overly conservative.

Staff Response: As described in Appendix E, release category B consists of event V binned with some other early failures. The assumed sequence for event V is check valve failure followed by rupture of the low-pressure ECCS piping. This results in a LOCA outside containment with no ECCS available and a rapid progression to core melt and fission product release. No text revision is required.

CECo 40: CECO stated that under release category F, using the NRC's conservative H_2 burn secenario, it would seem very unlikely that enough core-concrete attack could occur by 3 hours to boost H_2 inventory high enough to have a containment failure. Core melt and vessel failure would likely take 2 to 4 hours.

Staff Response: As stated in Appendix E, containment failure in release category F is caused by early hydrogen burn. This burn takes place about the time of vessel failure which, as CECo states, would likely take 2 to 4 hours. No text revision is required.

CECo 41: CECo stated that under release category B, there is no driving force for such a rapid release time of 0.5 hour. A duration time of 2 to 3 hours would be more realistic.

Staff Response: The release duration of 0.5 hour is consistent with the description of the accident as outlined in the response to CECo 39 and WASH-1400 (NUREG-75/014). No text revision is required.

CECo 42: CECo stated that a footnote should be added to Table 5.10 to show that the current work on source terms indicates that the values herein are likely to be conservative.

Staff Response: It is the staff's belief that, although the source terms presented in the DES are considered conservative, the source term work now under way by the Office of Nuclear Regulatory Research has not advanced to the point where it can be accepted for use in this document. No text revision is required.

CECo 43: CECo stated that Figures 5.7 and 5.8 indicate complementary cumulative distribution functions which are more severe than those contained in WASH-1400. CECo believes that these tables overstate the risks associated with Braidwood since it is not a high population site; removal of some of the WASH-1400 conservatisms should yield lower effects.

Staff Response: The significance of the comparison with WASH-1400 is not necessarily highly meaningful. New release categories were used, for instance, for Braidwood. The estimated latent cancer fatality risk (Figure 5.14) for Braidwood is less than for an average WASH-1400 plant. Calculational uncertainties also make comparison difficult. No text revision is required.

CECo 44: CECo stated that even if an accident affected out to 10 miles, there would not be numerous businesses affected since there are only 10 industries within the radius.

Staff Response: The staff analyzed low probability accidents which have impacts beyond 10 miles. However, the referenced sentence has been revised to read: "A severe accident that requires the interdiction and/or decontamination of land areas could force numerous businesses to temporarily or permanently close."

IDNS 1: IDNS questioned how Braidwood's radioactive waste gas decay tank system design differs from Zion's design, which experienced an unplanned accidental release of noble gases on May 26, 1980.

Staff Response: Staff records (IE Region III Report Nos. 50-295/80-12 and 50-304/80-12) indicate that on May 6, 1980, at Zion Station, the licensee started draining hold-up tank "0" to the hold-up tank (HUT) room floor, which drains to the auxiliary building sump "A." The drainage was performed to remove high silica water from the system. This high silica water was produced by the use of boric acid evaporators in another plant system. According to the "B" operator and the radwaste log book, about 2 hours later, the operator, suspecting a problem, went to the hold-up tank room and heard gas escaping from the HUT "0" drain line. Almost 3 hours later, the inspector noted that HUT "0" indicated 6% full. The released gas swept from the HUT room through the normal ventilation pathway in the auxiliary building and was discharged mainly from the Unit 1 stack. The apparent substantive cause of the event was erroneous HUT "0" level indication, which read 6% full when the tank was empty. This was caused by an out-of-calibration level at Zion and was a one-time occurrence.

The Braidwood Station design, in contrast, uses a thermal regeneration system, rather than the boric acid evaporators used at Zion. This Braidwood system uses a 4% solution of boric acid, rather than the 12% boric acid solution used in the Zion system. Since the source of silica is impurities in the boric acid, and the applicants do not expect to drain the hold-up tanks in order to reduce silica formation at Braidwood, no similar noble gas release is expected to occur at Braidwood Station. No text revision is required.

IDNS 5: IDNS indicated that sequences initiated by natural phenomena, such as seismic events, were not evaluated. The staff indicated in the DES that these sequences would not contribute significantly to risk. IDNS requested justification as to why design analysis for these sequences was not provided.

Staff Response: The site and plant design characteristics needed for an extensive probabilistic risk assessment including severe accidents triggered by seismic events and other externally generated accident-triggering events are not available for Braidwood. If this information (related to natural phenomena/sabotage) is provided by an applicant, it is normally provided as part of a plant-specific probabilistic risk assessment submitted to the staff. No such documentation was required, nor was it submitted, for Braidwood. No text revision is required.

IDNS 7: IDNS noted that the analyses in Section 5.9.4.5 relied heavily upon the Reactor Safety Study (WASH-1400) and the Zion and Indian Point probabilistic risk assessment studies. In light of the high degree of uncertainty associated with the probability values in WASH-1400, IDNS questioned whether a more realistic study should be performed for Braidwood Station.

Staff Response: A plant-specific probabilistic risk assessment (PRA) is not required for Braidwood; hence the applicant did not provide one. If a plant-specific (PRA) had been performed for Braidwood Station, a more plant-specific staff study would have been performed. Release categories for Braidwood were based on those generated for Indian Point 2 and 3 Hearing Testimony. The staff's best judgment of the present level of uncertainty in computed risks is a factor of between 10 and 100 for Braidwood. No text revision is required.

IDNS 9: The DES stated that it was the qualitative judgment of the staff that the uncertainty bounds could be well over a factor of 10, but not as large as a factor of 100. IDNS requested the basis for the staff's qualitative judgment.

Staff Response: The basis for the staff's qualitative judgment is the staff's collegial distillation of its cumulative experience in calculating a wide range of complementary cumulative distribution functions (CCDFs) and risks in performing probabilistic risk analyses for nuclear power plants.

JFD 3: JFD questioned whether any credit was given in the accident evaluation analysis for applicant compliance with any TMI-related requirements of NUREG-0737, "Clarification of TMI Action Plan Requirements."

Staff Response: The improvements in safety obtained from compliance with the NUREG-0737 requirements have not been quantified. Thus, accident risks computed in Chapter 5 of the Draft Environmental Statement do not reflect the reductions obtainable by means of implementation of these improvements.

WCDD 4: WCDD stated its concern with the impact on the proposed Will County Public Water Supply System due to possible contamination of the water supply in the case of power plant malfunction and emergency.

Staff Response: FES Section 5.9.4.5(5) contains a discussion of the liquid pathway from a postulated core-melt release into the Pennsylvanian strata beneath the plant. On the basis of the conservative parameters used in that analysis, it can be shown that strontium-90, the most critical radionuclide relative to potential groundwater contamination, would travel only 1000 feet through the groundwater in 970 years. The concentration after that time and that distance would be less than the 10 CFR Part 20, Appendix B requirements for radioactive effluents in an unrestricted area. Since the Kankakee River is more than 20,000 feet from the plant, concentrations in the river would be only a small fraction of 10 CFR Part 20 limits. This FES section also explains that the main regional aquifer (Cambrian-Ordovician) is protected from contamination by an overlying aquitard and the fact that it is under artesian pressure. Thus, there is no potential for widespread radioactive contamination from accidental releases into the Pennsylvanian strata.

The surficial Quaternary-age Eolian and Lacustrine sand, which are recharged by precipitation, could receive contamination from some form of pipe leak or surface spill. The power block area for the Braidwood Station is surrounded by a slurry trench, that extends to the Pennsylvanian strata. The trench was installed by the applicant during construction and would act to inhibit the migration of any radioactive material accidentally released within the power block area. In order to evaluate the potential for contamination of the sand aquifer, the staff conservatively assumed the entire contents of a radwaste storage tank was instantaneously released to the sand aquifer. Using conservative parameters for the aquifer material and ignoring the affects of the slurry trench, the staff determined that concentrations at the nearest downgradient well (1850 feet) would be lower than the 10 CFR Part 20 limits. At the Kankakee River or any other surface stream, the concentrations would be virtually zero.

In addition, there are engineering measures available to further mitigate the affects of an accidental release of radioactive material at the Braidwood Station. No text revision is required.

9.5.12 Noise

CECo 45: CECo noted that the noise levels of the power unit auxiliary, and system auxiliary transformers include the noise of both transformers and associated fans.

Staff Response: The text of Section 5.12 has been revised to clarify the components of the transformers' noise sources. A reference to the responses to staff questions E290.11 and E290.20 has also been added to the text.

CECo 46: CECo noted that the term "transformer fans" in reference to noise levels means the noise produced by the transformers and their associated fans at full load.

Staff Response: The text of Section 5.12 has been revised to clarify the noise source components as suggested by the applicant.

CECo 47: CECo stated that the title of Table 5.15 should be changed.

Staff Response: The title of Table 5.15 has been changed to make it more descriptive of its contents.

CECo 48: CECo stated that the sound power levels for main transformer fans at 2000 Hz should be 98 rather than 90.

Staff Response: This typographical error has been corrected.

CECo 49: CECo stated that sound levels at the receptors R7, R8, R12, and R13 are defined as "sound power levels."

Staff Response: The "sound power levels" citation for the receptor locations was incorrect. The values shown were sound pressure levels. The citation in Table 5.15 has been corrected.

CECo 50: CECo stated that the A-weighted and estimated nighttime residual sound levels presented at receptor P4 in Table 5.16 are integrated overall values, rather than values at 1000 Hz as could be interpreted from the column heading.

Staff Response: These overall sound levels have been moved to a new, appropriately designated column in Table 5.16.

CECo 51: CECo noted that the impacts of 10 dBA and 6 dBA, respectively, apply to an ambient noise level of 30 dBA. The impacts would be less for higher ambient noise levels and greater for lower ambient noise levels.

Staff Response: The text has been clarified with additional reference to the estimated residual noise levels at locations P1 and P4.

CECo 52: CECo corrected a typographical error in the statement concerning sound power level computations.

Staff Response: This typographical error has been corrected.

9.5.14 Environmental Monitoring

9.5.14.1 Terrestrial Monitoring

CECo 53: CECo stated that a proposal for termination of the aerial infrared photographic program was made in the ER-OL Amendment 5.

Staff Response: The staff has consulted with the applicant and concluded that termination of the aerial survey is appropriate. The text has been revised accordingly.

9.5.14.3 Atmospheric Monitoring

CECo 54: CECo corrected a typographical error concerning the location of the 98-m tower used for collecting meteorological data.

Staff Response: The text has been revised as suggested by the applicant.

CECo 55: CECo corrected the levels of measurement for the meteorological parameters.

Staff Response: The text has been revised as suggested by the applicant.

9.6 Evaluation of the Proposed Action

9.6.1 Unavoidable Adverse Impacts

CECo 56: CECo stated that a proposal for termination of the aerial infrared photographic program was made in the ER-OL Amendment 5.

Staff Response: The staff has consulted with the applicant and concluded that termination of the aerial survey is appropriate. No text revision is required.

9.6.4 Benefit-Cost Summary

9.6.4.1 Summary

CECo 57: CECo noted that under "Benefits" in Table 6.1, the quantity of electrical energy is shown as 11 billion kWh/yr, which is based on an average annual capacity factor of 55% with reduced generating costs of $49 million/unit/yr (1986 dollars). This estimate is low.

Staff Response: In performing the analysis at issue, it was the staff's intent to determine what potential impact the operation of the Braidwood facility would have on the applicant's annual production (operating) costs. The analysis indicates that substantial savings (costs avoided) will accrue as a result of the plant's operation. These savings were derived even though the staff employed considerable conservatism in its assumptions regarding capacity factor and sources of replacement energy.

Although the staff agrees that the estimate provided in the DES may be low, the staff feels that the applicant's calculation of savings is optimistically high. It appears that the applicant's analysis excludes the total operating and maintenance (O&M) cost as part of the operating cost for the Braidwood units.

Recent information indicated that the O&M cost for a nuclear facility is largely fixed, i.e., this cost will be incurred regardless of the amount of energy generated. However, these fixed costs will only be incurred after an operating license has been granted. If the unit is not licensed (the issue under consideration), no O&M cost will result. To exclude O&M cost in performing a comparative analysis of this type develops biased results. This is particularly true when considering that O&M costs are projected to account for a substantial portion of operating cost (ER-OL Table 8.1.1). No text revision is required.

CECo 58: CECo noted that under "Costs" in Table 6.1, the values shown for fuel costs and operation and maintenance costs were derived from ER-OL Table 8.1-1. These values represent estimated total generating costs for Braidwood Unit 1 during the first 12 months of commercial operation, rather than 10-year levelized cost as noted in Table 6.1.

Staff Response: Staff agrees that the reference to "levelized costs" is inappropriate. Section 6.4.3 has been revised to read: "The economic costs associated with station operation include fuel costs and operating and maintenance costs, which are expected to average 10.8 mills per kWh and 7.0 mills per kWh, respectively" (ER-OL Table 8.1.1, 1986 dollars, adjusted for a 55% average capacity factor, rather than applicant's estimate of a 60% average capacity factor).

CECo 59: CECo noted that under "Adverse socioeconomic effects" in Table 6.1, the loss of historic or archeological resources impacts is judged to be moderate. Since no impacted historic resources have been identified and since there have been only a small number of archeological sites identified, a rating of "none" or "small" would seem more appropriate.

Staff Response: The footnotes to Table 6.1 described the impacts as being "Subjective measure of costs and benefits...assigned by reviewers." The footnotes also note that moderate impacts are clearly evident (mitigation alternatives are usually considered for moderate impact). "Because of the mitigative efforts involved for site 11Ka179, which was deemed worthy of protection from impacts before further evaluations are made" (Appendix H), no inconsistency exists according to the table's definitions and the staff's measurement.

CECo 60: CECo noted that under "Adverse nonradiological health effects" in Table 6.1, no impact quantification is shown for "air quality changes." In view of the circumstances, a rating of "none" would be appropriate.

Staff Response: The text has been revised as suggested by the applicant.

9.6.4.2 Benefits

CECo 61: CECo noted that decreased costs are shown as $49 million (1986 dollars) per unit per year. This estimate is low.

Staff Response: See response to CECo 57.

9.6.4.3 Economic Costs

CECo 62: CECo noted that under "Costs" in Table 6.1, the values shown for fuel costs and operation and maintenance costs were derived from ER-OL Table 8.1-1. These values represent estimated total generating costs for Braidwood Unit 1 during the first 12 months of commercial operation, rather than 10-year levelized cost as noted in Table 6.1.

Staff Response: See response to CECo 58.

9.10 Appendices

9.10.C Impacts of the Uranium Fuel Cycle

JFD 1: JFD stated that the staff had not considered the range and number of non-fatal cancers and birth defects induced by radon-222 released during the fuel cycle.

Staff Response: This comment refers to the population dose commitments from the release of radon-222 from stabilized-tailings piles at uranium mills for each year of operation of the model 1000-MWe light water reactor (LWR). With regard to birth defects, the staff has revised Appendix C of the DES to incorporate this comment and to clarify this issue in the FES. With regard to the number of non-fatal cancers, the staff considered and discussed the number of potential non-fatal cancers in paragraphs 8, 9, and 10 of Section 5.9.3.1.1 of the DES. The last sentence of paragraph 8 gave the range of the total number of potential non-fatal cancers relative to the number of potential fatal cancers as follows:

The number of potential non-fatal cancers would be approximately 1.5 to 2 times the number of potentially fatal cancers, according to the 1980 report of the National Academy of Sciences Advisory Committee on the Biological Effects of Ionizing Radiation (BEIR III, 1980).

9.10.D Examples of Site-Specific Dose Assessment Calculations

CECo 63: CECo stated that the values for I-131 and I-133 in Table D-1 should be revised since no credit was given for the charcoal filter system present in the steam jet air-ejector exhaust stream.

Staff Response: The staff did not credit the Braidwood Station with the use of the charcoal filtration unit in the steam jet air ejector exhaust stream because the applicant did not commit to use this system either on a continuous basis or when radioactivity from this exhaust was detected. Therefore, there were no assurances that the system would be utilized. No text revision is required.

IDNS 8: IDNS requested an explanation as to why there are differences in the liquid and gaseous release type data given in the FES-CP and DES-OL.

Staff Response: There is a difference between the liquid and gaseous effluents calculated at the Braidwood DES-OL stage and the FES-CP stage because the equipment, which was assumed to be utilized to treat liquid and gaseous radwaste, was changed between the CP and OL stages of licensing. A discussion of these differences was presented in Section 11 of the Byron SER. This discussion is equally applicable to Braidwood. No text revision is required.

IDNS 10: IDNS requested an explanation as to why the gaseous release rates given in Table D-1 are lower than those given in Regulatory Guide 1.BB.

Staff Response: Draft Regulatory Guide 1.BB has not been utilized since March 1976 when Regulatory Guide 1.109, "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," was issued. The latter guide references NUREG-0017, "Calculation of Releases of Radioactive Materials in Gaseous and Liquid Effluents From Pressurized Water Reactors," as the method for estimating releases from PWRs. As noted in Section 11 of the Byron SER, which is applicable to Braidwood, the staff utilized NUREG-0017 to calculate effluent releases. The releases calculated for Braidwood are consistent with this report. As explained in NUREG-0017, releases are a function of the type of radwaste treatment and the air cleaning systems incorporated in the plant design. No text revision is required.

9.10.E Release Categories and Probabilities for Braidwood

CECo 64: CECo noted that because of design differences between Braidwood and Indian Point 2, early containment failure is much less likely for Braidwood.

Staff Response: The likelihood of early containment failure from external events (discounting station blackout) at Braidwood may have been less than that for Indian Point 2, had this possibility been included. No text revision is required.

CECo 65: CECo noted that the reference to the shutdown cooling system should be changed to residual heat removal system. Also, the reference to a closed motor-operated valve should be changed, since this valve is not normally closed.

Staff Response: The text has been revised as suggested by the applicant.

CECo 66: CECo stated that the sequence discussed in paragraph 2 is not valid since the assumed steam spike, if it were to happen, would not be of sufficient magnitude to cause containment failure due to overpressure.

Staff Response: Although a steam spike following vessel failure is unlikely, having been assumed to occur only about 0.5% of the time that core melt occurs following loss of ac power, it is not impossible. This leads to the concomitant assumption of loss of containment integrity, with small, but present likelihood. No text revision is required.

CECo 67: CECo stated that it is not possible to generate enough H_2, given that sprays are still available, to result in containment failure from burning H_2. Even a 100% Zr/H_2O reaction would not give enough H_2 to cause containment failure. The sprays and fan coolers would keep the debris cooled and minimize H_2 formation from core/concrete interaction.

Staff Response: In the response to CECo 40 the staff explained that the hydrogen burn represented by release category F is the early burning of hydrogen from the reaction of cladding and water. Although explosive detonation of this hydrogen is considered unlikely, it is assumed to occur in a small fraction of the cases. This release category also includes the possibility of a hydrogen burn failing containment penetrations. Regarding the effect of sprays and fan coolers, containment sprays may be capable of supplying water to a coolable debris bed if such a formation is possible. This is not a certainty. Fan coolers have no direct heat removal effect on the core debris. No text revision is required.

CECo 68: CECo stated that the assumption that 10% of all core-melt acccident sequences not accounted for by release categories B, C, and F are assumed to result in release category H is overestimated. Only TMLB or sequences without sprays and fan coolers could result in base mat penetration after a core-melt accident.

Staff Response: The availability of sprays or fan coolers, as the staff has previously noted, does not guarantee that base mat penetration will not occur. Even with a constant supply of water, there is a large uncertainty associated with the formation of a coolable debris bed. In all cases where a source of water and containment heat removal are not available, or where a coolable geometry for the core debris is not formed, core-concrete interaction and subsequent base mat penetration will take place. No text revision is required.

CECo 69: The DES stated that the range of probabilities for core-melt accidents resulting from internal events for reactors was 10^{-3} to 10^{-5} per reactor-year. CECo noted that for the newer plants, however, the range is 10^{-4} to 10^{-5} per reactor-year. Therefore the 10^{-4} value considered for Braidwood is conservative.

Staff Response: The accepted range of probabilites for core-melt accidents resulting from internal events for reactors is 10^{-3} to 10^{-5} per reactor-year, as stated in the DES. Additional information must be provided before the narrower range of 10^{-4} to 10^{-5}, as proposed by the applicant, could be qualified.

9.10.F Consequence Modeling Considerations

CECo 70: CECo noted that on the basis of the most recent evacuation time estimates study for the area around Braidwood Station, CECo has calculated an effective evacuation speed of 2.83 m per second (6.32 mph) which would be more appropriate than the value of 1.1 mph developed by the NRC staff.

Staff Response: The evacuation speed of 1.1 mph developed by the staff was based on the data available at the time of the review. The staff does not intend to reevaluate the evacuation speed based on the improved evacuation time estimates study.

9.11 References

Advisory Committee on the Biological Effects of Ionizing Radiations, BEIR III, "The Effects on Populations of Exposures to Low Levels of Ionizing Radiation," National Academy of Sciences/National Research Council, July 1980.

Illionis Natural History Survey, "Construction and Preoperational Aquatic Monitoring Program for the Kankakee River," Braidwood Station, First Annual Report, Vol I - Text, Urbana, Illinois, 1978.

---, "Construction and Preoperational Aquatic Monitoring Program for the Kankakee River," Braidwood Station, Second Annual Report, Vol I - Text, Urbana, Illinois, 1979.

---, "Construction and Preoperational Aquatic Monitoring Program for the Kankakee River," Braidwood Station, Third Annual Report, Vol I - Text, Urbana, Illinois, 1980.

---, "Kankakee River Aquatic Monitoring Program for the Braidwood Station," Vol I - Text, Urbana, Illinois, August 1981.

---, "Kankakee River Fishes of the Braidwood Aquatic Monitoring Area," Urbana, Illinois, August 1982.

U.S. Nuclear Regulatory Commission, NUREG-75/014, "Reactor Safety Study--An Assessment" (formerly WASH-1400), October 1975.

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

---, NUREG-0737, "Clarification of TMI Action Plan Requirements," November 1980.

APPENDIX A

COMMENTS ON THE DRAFT ENVIRONMENTAL STATEMENT

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DA/ERS	U.S. Department of Agriculture, Economic Research Service...	A-14
DA/SCS	U.S. Department of Agriculture, Soil Conservation Service...	A-15
EPA	U.S. Environmental Protection Agency, Region V..............	A-16
IDC	Illinois Department of Conservation.........................	A-19
IDNS	Illinois Department of Nuclear Safety.......................	A-23
JFD	John F. Doherty...	A-26
NIPC	Northeastern Illinois Planning Commission...................	A-28
WCDD	Will County Development Department..........................	A-32

CECo

Commonwealth Edison
72 West Adams Street, Chicago, Illinois
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Chicago, Illinois 60690

March 12, 1984

Director
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Subject: Braidwood Station Units 1 and 2
Docket Nos. STN 50-456 and STN 50-457

Dear Sir:

Enclosed are Commonwealth Edison Company's comments pertaining to the Braidwood Station Units 1 and 2 Draft Environmental Statement (NUREG-1026). These comments are being submitted for consideration by the Commission in accordance with 10 CFR Part 51.

Sincerely,

C. L. McDonough

C. L. McDonough
Director of Environmental
Assessment

4342E
BBB:CLM:ds
Enclosures

CECo

Commonwealth Edison Company's Comments Pertaining to the Braidwood Station Units 1 and 2 Draft Environmental Statement

Page/Section		Comments
vi/Summary Item (3)		Due to revision of the construction schedule for Braidwood Station the last sentence in Item 3 should be revised to read: "The applicant estimates fuel-loading dates of August, 1985 for Unit 1 and August, 1986 for Unit 2."
1-1/1.1 (Par. 2)	1	For the reason stated in the preceding comment the last sentence in Paragraph 2 should be revised to read: "CECo. estimates that Unit 1 will be ready for fuel loading in August, 1985 and commercial operation in April, 1986; Unit 2 is estimated to be ready for fuel loading in August, 1986 and commercial operation in April, 1987."
4-1/4.1	2	The last sentence of the second paragraph should be changed to read as follows: "The originally planned connection to the Joliet Generating Station has been eliminated and the only new right-of-way from the plant is to the Crete Substation."
4-2/Figure 4.1	3	Figure 2.1-4 will be revised in Amendment 6 to the Braidwood Station ER-OLS. An advance copy of the revised figure is attached to these comments for inclusion in the FES.
4-5/4.2.3.1	4	The fourth from the last sentence in the Section should read be revised to read: " . . . 180.7 m (592.8 ft.) MSL." The third from the last sentence in the Section refers to historic river flows on the Kankakee River and the possible restrictions on station operation. The period of record for the response to Question E240.4 was 66 years, 1915 through 1982 rather than from 1946 though 1976. Based on that historic flow record (1915 though 1982) there was only one occurrence, 1936, when the stations power production would have had to be curtailed because of low Kankakee River flow below 495.5 cfs.
4-7/4.2.3.4 (Par. 1)	5	Paragraph one should be revised to read: "Scale buildup in the condenser cooling system will be controlled by a combination of chlorination and mechanical cleaning (Amertap). If scale cannot be controlled with chlorination and mechanical cleaning then either carbon dioxide or polymers will be used. Carbon dioxide would be added at the rate of 1600 kg (3500 lb) per hour."

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Page/Section		Comments
4-7/4.2.3.4 (Cont.) (Par. 2)	6	The second, third and fourth sentences should be revised to read: "Sponge rubber balls, sized to the inside diameter of the condenser tubes will be continuously injected into the system at the inlet to the condenser. The balls will clean the tubes as they pass though the system and will be collected by a series of baffles and screens at the outlet of the condenser and returned to the inlet. The balls will be removed and sorted periodically."
4-8/4.2.3.4 (Par. 3)	7	In the third sentence - the value for chlorine concentration should be changed from 0.1 mg/l to 0.5 mg/l.
(Par. 4)	8	In the first sentence - the number of times per day that the service water system will be treated should be changed from three times daily to twice daily.
(Par. 5)	9	The second sentence should be revised to read: "The water passes through a chlorine retention tank, clarifiers and a clear well before passing through two parallel lime softeners and three parallel sand filters. In the fifth sentence - the size of the filtered water storage tank is 150,000 gallons. In the sixth sentence - "cycler" should be changed to "cycle."
	10	The eighth sentence should be revised to read: "The demineralizer train passes the water through a strong-acid cation exchange unit, a strong-base anion unit, and a mixed bed unit." (Note: the above changes, relating to water treatment, will be included in revisions to ER-OLS sections: 3.6.1.1, 3.6.1.2 and 3.6.2 in Amendment 6 to the ER-OLS).
4-9/4.2.4.2 (Par. 2)	11	The first sentence should be revised to read: ". . . 3.0 m (9.0 ft), and a maximum depth of 5 m (15 ft.)."
(Par. 3)	12	The first sentence should be revised to read: "A smaller (3.8 x 10^5 m^2 (99 acre)) cooling pond . . . ".
(Par. 4)	13	The fourth sentence should be revised to read: "Water is drawn through two 4.9-m (16-ft.) - diameter pipelines to the condensers, then through two other 4.9-m (16 ft.) - diameter pipelines to the discharge outfall structure and back into the pond at a continuous flow of 92 m^3/sec (3250 cfs) for the two units."

Page/Section		Comments
4-11/4.2.4.3	14	In sentence seven reference is made to Table 4.1 and in sentence eight values for average temperature above the ambient are given from Table 4.1. The values shown are the differences between the outlet temperature from the station to the cooling pond rather than the plant inlet and pond blowdown temperature. If the intention is to illustrate the difference between blowdown and river ambient temperatures, then the sentence should read: "The average temperature excess above ambient is 7°C (12.6°F); the extremes are 3.6°C (6.5°F) in August and 10.1°C (18.1°F) in February". If the intention is as stated (outlet discharge minus ambient river temperature) than the maximum extreme should read: ". . . in August and 21.2°C (38.1°F) in February." In the ninth sentence the excess 5°F isotherm ranges between 0.10 and 0.45 acres not 0.45 to 0.85 acres.
4-12/Table 4.1	15	The average flow rate for May should be 6288 cfs.
4-14/4.2.7	16	In the third sentence - "Burham" - should be changed to "Burnham". In the fifth sentence - the maximum width of the right-of-way is "139 m (455 ft)." (See ER-OL Figure 3.9-2). In the seventh sentence - reference is made to a "possible future 765 kV line". It should be pointed out that there are no plans for the 765 kV line in the forseeable future and the necessary right-of-way for such a line is not continuous.
4-15/Figure 4.5	17	The Legend symbol for new 345 kV lines appears to be solid rather than dashed.
4-26/4.3.2 (Par. 3)	18	In the fourth and sixth sentences - the ER-OL section is 2.4.1.4.2.
4-27/4.3.3	19	The third sentence should be revised to read: "For the 4 year period, 1979 through 1982, . . . ".
4-27/4.3.4.1 (Par. 2)	20	In the third sentence - delete "marshlands and". In the fourth sentence - the acreage of small discontinous marshlands is 40.
4-27/4.3.4.2 (Par. 1)	21	The first sentence should be revised to read: "The aquatic biota of the Kankakee River and Horse Creek in the site vicinity were sampled during 1974-75, 1977-79 and 1981-82, as part of the baseline and/or construction phase aquatic monitoring . . . "

Page/Section		Comments
4-28/4.3.4.2 (Par. 1)	22	The third sentence should be revised to read: "The results of the 1974-75 and 1977-1981 monitoring programs are discussed in detail in Section 2.2.1 and Section 4.7 respectively of the ER-OL."
(Par. 2)	23	First sentence should be revised to read: "A total of five phytoplankton phyla were collected during the 1974-75 program." In the fifth sentence - change "fifty five" to "forty five".
(Par. 6)	24	The first sentence should be revised to read: "A total of 2221 fish representing 46 species was collected from the Kankakee River and Horse Creek during the 1974-75 program."
4-31/4.3.4.2 (Par.7)	25	The first sentence should be revised to read: "Sampling for fish eggs and larvae was performed as part of the 1974-75 monitoring program."
5-2/5.3.1 (Par. 1)	26	In the fifth sentence, the committment to limit the maximum withdrawal of water to 10% of the river flow (FES-CP) was a design objective. This objective was superceded by the water withdrawal agreement summated in the last sentence in the paragraph (also see response to Question E240.4, Amendment 3, Braidwood ER-OLS). This agreement was formulated in response to the Illinois Department of Conservations concerns of potential effects on the river during low flow conditions.
	27	In the sixth sentence-"518 cfs" should be changed to "495 cfs".
(Par. 2)	28	In the first sentence - the 10% maximum withdrawal criterion has been superceded by the agreement with the Illinois Department of Conservation described in the preceding paragraph.
	29	The last sentence in the paragraph should be revised to read: "At present there are no downstream uses of water from the Kankakee River. The Joliet Arsenal has the capacity to withdraw 38 cfs but is presently in a standby status."
5-3/5.3.2 (Par. 2)	30	In the thirteenth sentence - the acreage of the 2°F isotherm should be changed from 1.46 acres to 5.4 acres. In the fourteenth sentence - ER-OL section should be changed from 2.4.2.4.2 to 2.4.1.4.2.
5-4/Table 5.1	31	The value for "Ambient River-Chlorides" should be changed from 27 to 22. ER-OL Table 5.3-1 will be revised in ER-OL Amendment 6.

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Page/Section		Comments
5-9/5.5.1.1 (Par. 2)	32	The third sentence should be revised to read: "The applicant is working with the county soil conservationist to revegetate about 15 ha (36 acres) in the northeast portion of the site, part as native prairie and part as wildlife habitat (ER-OL, response to NRC staff question 290.4)."
5-12/5.5.2.2 (Par. 2)	33	The first sentence should be revised to read: " . . . August [26°C (79.5°F)] . . . "
5-15/5.5.2.2 (Par. 4)	34	In the first sentence - a value of 2.6 m^3/sec (90.8 cfs) is shown for "normal intake flow from the Kankakee River." That value is for the "average annual intake flow." The correct value for "normal intake flow" is 3.0 m^3/sec (107 cfs).
5-42/5.9.4.4 (Par. 2)	35	The third sentence should be revised to read: "The exclusion area, located within the site boundary, is a rectangular area with a minimum distance of 485 m (1478 ft.) from the outer edge of the containment wall to the exclusion area boundary."
5-46/5.9.4.5 (Par. 1)	36	Based on S. Levine's uncertainty analysis testimony submitted on Byron Station during the ASLB hearing and the similarities between Byron and Braidwood plants, this approach and the resulting numerical value is too conservative.
5-47/5.9.4.5 (Table 5.10)	37	<u>Parameter: Probability per reactor year</u> Under release category B, the value should be no greater than 2 x 10^{-7} for Braidwood based on the risk studies done for Byron, which has similar design features.
	38	Under release category F, the value should be essentially zero, again based on these studies done on Byron.
	39	<u>Parameter: Release time (hr)</u> Under release category B, the 1 hour value is overly conservative. Since the 4 high-head ECCS pumps will continue to supply water to the core for just about 1 hour, a release time of 2 to 3 hours would be more realistic.

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Page/Section		Comments
5-47/5.9.4.5 (Table 5.10) (Cont.)	40	Under release category F, using the NRC's conservative H_2 burn scenario, it would seem very unlikely that enough core-concrete attack could occur by 3 hours to boost H_2 inventory high enough to have a containment failure. Core melt and vessel failure would likely take 2 to 4 hours.
	41	Parameter: Release Duration (hr) Under release category B, there is no driving force for such a rapid release time of 0.5 hour. A duration time of 2 to 3 hours would be more realistic.
	42	Footnotes An additional footnote should be added to this table to indicate that the current work on source terms indicate that the values herein are likely to be conservative.
5-52/5.9.4.5 (Par. 3 & 4)	43	Figures 5.7 and 5.8, referred to in these paragraphs, indicate complementary cumulative distribution functions which are more severe than those contained in WASH-1400. We believe these tables overstate the risks associated with Braidwood. Braidwood is not a high population site. Removal of some of the WASH-1400 conservatisms should yield lower effects.
5-66/5.9.4.5 (Par 1)	44	Under Regional Industrial Impacts, the first sentence should be revised to read: "A severe accident that requires the interdiction and/or decontamination of land areas will force a few industries to temporarily or permanently close." As shown on the ER-OLS Table 2.1-7 there are only 10 industries within a radius of 10 miles, therefore, even if an accident affected out to 10 miles there would not be "numerous businesses" affected.
5-84/5.12 (Par. 1)	45	The last sentence should take into consideration that the noise levels of the power, unit auxiliary and system auxiliary transformers that were provided as responses to staff questions E 290.11 and E290.20, Amendment 4 to ER-OLS, include noise of both transformers and associated fans.
(Par. 2)	46	The first sentence should take into consideration that the term "transformer fans" with reference to noise levels means the noise produced by the transformers and its associated fans at full load. This comment is applicable to each instance in which the term "transformer fans" is used in this section.

Page/Section		Comments
5-84/Table 5.15	47	The title to this table should make reference to the purpose of the table which is the calculated sound levels at nearest residences utilizing ambient noise levels and noise from the "main transformer fans".
	48	The sound power levels for main transformer fans at 2000 Hz should be 98 rather than 90.
	49	The sound levels at the receptors R7, R8, R12 and R13 are defined as "sound power levels". Noise at receptors are generally cited as "sound pressure levels" as are utilized in Table 5.16 for receptor P4.
5-85/(Table 5/16)	50	The A-weighted and estimated nighttime residual sound levels presented at receptor P4, are integrated overall values, not only at 1000 Hz as could be interpreted from the column heading.
5-86/5.12 (Par. 4)	51	In sentences two and three - a note should be added to this paragraph to indicate that the impacts of 10 dBA and 6 dBA, respectively, apply only to an ambient noise level of 30 dBA. The impacts would be less for higher ambient noise levels and greater for lower ambient noise levels.
(Par. 5)	52	In sentence one - "140" should be "240".
5-87/5.14.1 (Par. 1)	53	With regard to the committment to continue the aerial infrared photographic program until 2 years after Unit 2 begins operation, a proposal for termination of this program was made in the ER-OLS Amendment 5 to Section 6.2.2. The reasons given there are that the program was designed to detect any off-site effects resulting from filling the cooling pond and, that no off-site effects have been observed that could be attributable either to the filling of the pond or to the presence of the pond.
5-88/5.14.3 (Par. 1)	54	The first sentence should be revised to read: " . . . 573 m (0.4 mi) northeast of the Unit 1 reactor building since November 1973."
	55	Under the column heading - "Level of Measurement," the following should be revised to read:

Meteorological Parameter	Level of Measurement
Wind speed and wind direction	34 ($\sim$10 m) and 203 ft. ($\sim$62 m)
Temperature difference between	30 ($\sim$9.1 m) and 199 ft. (60.6 m)
Dewpoint temperature	30 ($\sim$9.1 m) and 199 ft. (60.6 m)
Ambient air temperature	30 ft. ($\sim$9.1 m)

Page/Section		Comments
6-1/6.1 (Par. 2)	56	See comment regarding 5-87/5.14.1 (Par. 1) above.

6-2/Table 6.1

Under "Benefits": The quantity of electrical energy is shown as 11 billion KWh/yr, which is based on an average annual capacity factor of 55%, with reduced generating costs of $49 million/unit/yr (1986 dollars). This estimate is low. Recent studies based on an average annual capacity factor ranging from 55 to 58% for the years 1988 (first year with both units in service for the full year) through 1992 show increased production costs without Braidwood as shown below:

57

Year	Increased Production Cost without Braidwood Units - $million*
1986	83
1987	196
1988**	224
1989	262
1990	294
1991	307
1992	335

*Costs are in late 1983 dollars
**First year with both units in service full year

58 Under "Costs": The values shown for fuel costs and operation and maintenance costs were derived from ER-OLS Table 8.1-1 and are discussed in DES Section 6.4.3 where the Table is said to present "10 year levelized cost". The title of ER-OLS Table 8.1.1 is "Estimated Total Generating Costs for Braidwood Unit 1 for First 12 months of Commercial Operation." Estimates have been made for each Braidwood Unit for total generating costs for the first ten years levelized and are presented below:

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Estimated Total Generating Cost for Braidwood Station
Unit 1 for First Ten Years Levelized

Cost Component	Dollars[a] (thousands)	Mills per[a] kilowatt hour
Fuel	$ 78,838	14.61
Operating and Maintenance	48,619	9.01
Carrying Charges	394,297	73.07
Other	38.690	7.17
Total Generating Cost	$560,444	103.86

Note: Values are based on commercial operation starting October, 1985.

[a]Costs are in 1986 dollars and are based on 55% capacity factor (generating 5,396,160 MWH per year)

Estimated Total Generating Cost for Braidwood Station
Unit 2 for First Ten Years Levelized

Cost Component	Dollars[a] (thousands)	Mills per[a] kilowatt hour
Fuel	$ 83,964	15.56
Operating and Maintenance	51,803	9.60
Carrying Charges	279,251	51.75
Other	32,647	6.05
Total Generating Cost	$447,665	82.96

Note: Values are based on commercial operation starting October, 1986.

[a]Costs are in 1987 dollars and are based on 55% capacity factor (generating 5,396,160 MWH per year)

Page/Section		Comments
6-3/Table 6.1 (Continued)	59	Under "Adverse socioeconomic effects" the loss of historic or archaeological resources" impacts is judged to be "moderate". Since no impacted historic resources have been identified and since there have been only a small number of archeological sites identified (none of which were impacted by construction) a rating of "none" or at most "small" would seem more appropriate.
	60	Under "Adverse nonradiological health effects", no impact quantification is shown for "air quality changes". In view of the circumstances a rating of "none" would be appropriate.
6-4/6.4.2 (Par. 2)	61	Decreased costs are shown as $49 million (1986 dollars) per unit per year. See above comments on Table 6.1.
6-4/6.4.3 (Par. 1)	62	The discussion of generating costs on the basis of 10-year levelized costs was commented on, see above comments on Table 6.1.
D-2/Appendix D Table D-1	63	In the column headed "Air-Ejector Exhaust - Continuous" the value for I-131 should be revised to 0.0028 and I-133 should be revised to 0.0041. The "Total" column should reflect these changes, I-131 = 0.0868 and I-133 = 0.0721. The reason for these revisions is that apparently no credit was given for the charcoal filter system present in the steam jet air-ejector exhaust stream of the Byron/Braidwood design.
E-2/Appendix E (Par. 3)	64	It should be pointed out that Indian Point 2 has some unique design features that, given specific external events, led to a significant probability of early containment failure. These design features do not exist at Braidwood. Braidwood is much like Zion in this regard and early containment failure is unlikely for either station.
E-4/Appendix E (Par. 1)	65	Line 8 - "shutdown cooling system (SCS)": should be changed to "residual heat removal system" (RHR). Change "SCS to RHR". Line 10 - Change SCS to RHR. Line 11 - delete "and a closed motor-operated valve". This valve is not normally closed.
(Par. 2)	66	The sequence discussed in this paragraph is not valid in that the assumed steam spike, if it were to happen, could not be of sufficient magnitude to have containment failure due to over pressure.

Page/Section		Comments
E-4/Appendix E (Cont.) (Par. 5)	67	Given that sprays are still available, it is not possible to generate enough H_2 to result in containment failure from burning H_2. Even 100% Zr/H_2O reaction would not give enough H_2 to cause containment failure. The sprays and fan coolers would keep the debris cooled and minimize H_2 formation from core/concrete interaction.
E-5/Appendix E (Par. 3)	68	The assumption that 10% of all core-melt-accident sequences not accounted for by release catagories B, C, and F are assumed to result in release catagory H is over estimated. Only TMLB or sequences without sprays and fan coolers could result in base mat penetration after a core-melt-accident.
E-5/Appendix E (Par. 5)	69	It is stated that the range of probabilities for core melt accidents resulting from internal events for reactors for which probabilistic risk assessments were performed to be in the range of 10^{-3} to 10^{-5} per reactor-year. For the newer plants, however, the range is 10^{-4} to 10^{-5} per reactor-year. Therefore the 10^{-4} considered for Braidwood is at the high end of the newer plants and is therefore conservative.
F-3/Appendix F (Par. 2&3)	70	Based upon the most recent evacuation time estimates study (ETES) for the area around Braidwood Station, applicant has determined that an effective evacuation speed of 2.83 m per second [6.32 mph] would be more appropriate than the value of 1.1 mph developed by the NRC staff. The Braidwood ETES (currently scheduled to be submitted April, 1984) indicates that the average evacuation travel time to clear the Braidwood EPZ is 95 minues or less for most of the scenarios evaluated by the ETES.

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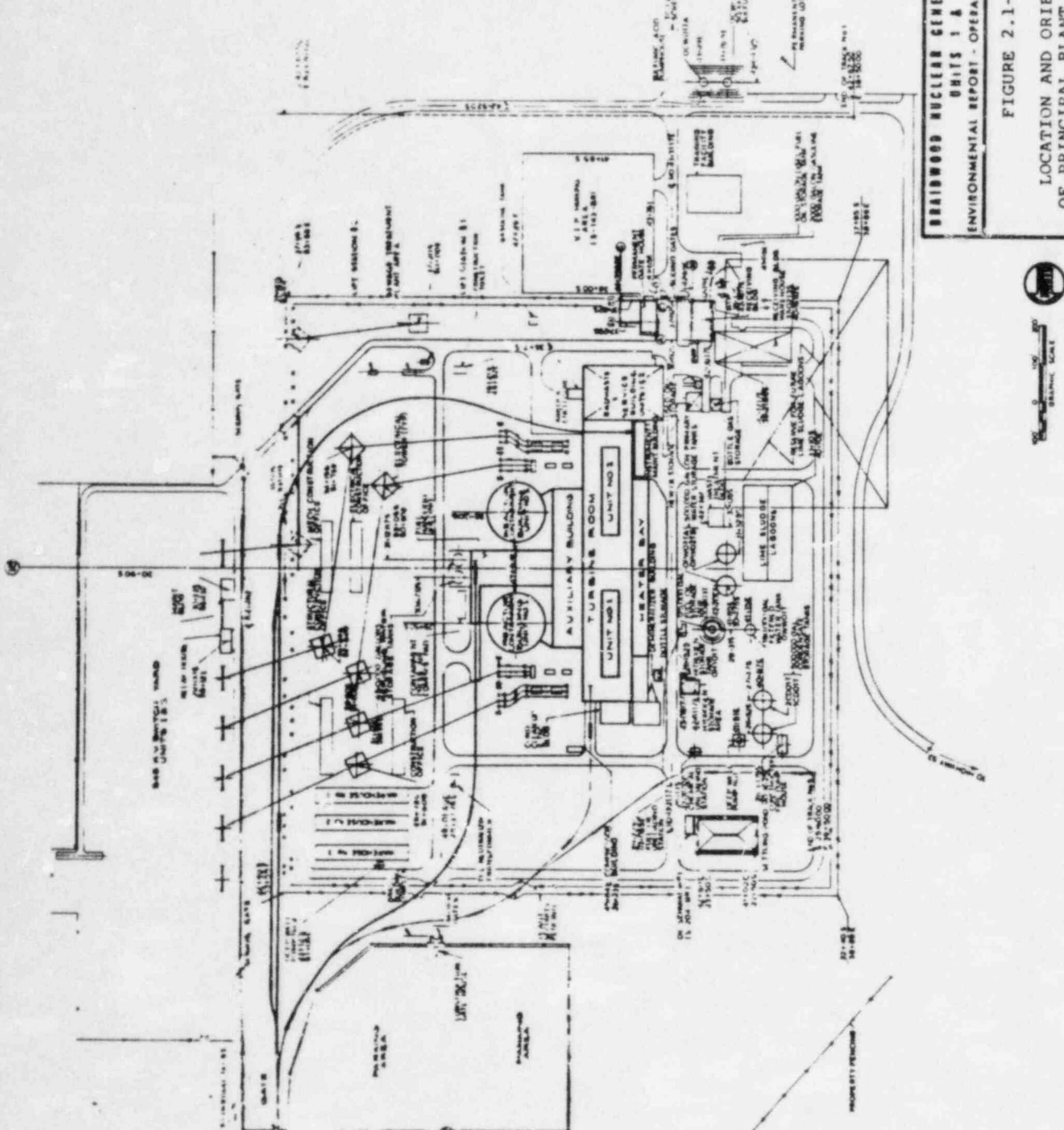

BRAIDWOOD NUCLEAR GENERATING STATION
UNITS 1 & 2
ENVIRONMENTAL REPORT - OPERATING LICENSE STAGE

FIGURE 2.1-4

LOCATION AND ORIENTATION
OF PRINCIPAL PLANT STRUCTURES

DA/ERS

United States Department of Agriculture
Economic Research Service
Washington, D.C. 20250

January 27, 1984

Mr. B. J. Youngblood
Chief, Licensing Branch No. 1
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

Dear Mr. Youngblood:

Thank you for forwarding the Draft Environmental Statement concerning the issuance of an operating license to the Commonwealth Edison Company for the startup and operations of Units 1 and 2 of Braidwood Station located south-southwest of Joliet, Illinois.

We have reviewed Docket Nos. STN 50-456 and STN 50-457 and have no comments.

Sincerely,

Velmar W. Davis

VELMAR W. DAVIS
Acting Director
Natural Resource Economics Division

DA/SCS

United States Department of Agriculture

Soil Conservation Service

Springer Federal Building
301 N. Randolph Street
Champaign, IL 61820

February 6, 1984

B. J. Youngblood, Chief
Licensing Branch No. 1
Division of Licensing
U.S. Nuclear Regulatory Comm.
Washington, D.C. 20555

Dear Mr. Youngblood:

Members of our staff have reviewed the data for the draft environmental impact statement related to the operation of Braidwood Station Units 1 and 2, Docket Nos. STN 50-456 and STN 50-457 in Will County, Illinois, and have no comments to add to those made in an earlier review.

Sincerely,

John J. Eckes
State Conservationist

cc: Peter C. Myers, Chief, SCS, USDA, Washington, D.C.
Roger Rowe, AISWCD, Marseilles, IL
Steve Chard, IDOA, Springfield, IL
Don Manecke, Orion, IL
B. Smith, AC, A-2
A. May, DC, A-2

EPA

UNITED STATES
ENVIRONMENTAL PROTECTION AGENCY
REGION V
230 SOUTH DEARBORN ST
CHICAGO, ILLINOIS 60604

REPLY TO ATTENTION OF:

NEPA-DE-NRC-F06018-IL
(84005)

MAR 1 2 1984

Mr. B. J. Youngblood, Chief
Licensing Branch No. 1
Division of Licensing
United States Nuclear
Regulatory Commission
Washington, D.C 20555

Dear Mr. Youngblood:

We have completed our review of the Draft Environmental Impact Statement related to the Operation of Braidwood Station Units 1 and 2 in Will County, Illinois. This nuclear power plant will employ two pressurized water reactors to produce up to 6850 megawatts of thermal energy. Two steam turbine-generators will use this heat to provide 2240 megawatts of electrical power. Exhaust steam will be condensed by cooling water circulated from a cooling pond. Makeup and blowdown will be taken from a discharged to the Kankakee River.

Based upon our review of the Draft EIS and reference documents, we do not have any major objections to the operation of the Braidwood Station however, additional information should be provided in the Final EIS regarding the radioactive waste treatment systems and maintenance of the soil erosion control programs implemented at the time of construction. We have rated our detailed comments on the Draft EIS, which are attached, as LO-2. Specifically this means that we have no objections to the proposed operation of the nuclear power station and that additional information is necessary regarding the topics cited above.

We appreciate your providing us the opportunity to review this Draft EIS. If you have any questions regarding our comments please contact Mr. Bill Franz at 886-7500 (FTS) or 312-886-7500 (Commercial).

Sincerely yours,

Larry G. Reed

Larry G. Reed, Deputy Director
Planning and Management Division

Enclosure

EPA

U.S. Environmental Protection Agency Region V's
Comments on the Draft Environmental Impact Statement
Related to the Operation of the Braidwood Station Units 1 and 2

The proposed action is the issuance of an operating license to the Commonwealth Edison Company (CECo) for the startup and operation of Units 1 and 2 of Braidwood Station, located near the Kankakee River in Reed Township, Will County, Illinois, 2.3 km (1.4 mi) south of Braidwood and 32 km south-southwest of Joliet, Illinois.

The plant will employ two pressurized water reactors to produce up to 6850 megawatts of thermal energy (MWt). Two steam turbine-generators will use this heat to provide 2240 MW (net) of electrical power capacity. The maximum design thermal output of the units is 7130 MWt, with a corresponding maximum calculated electrical output of 2330 MWe. The exhaust steam will be condensed by cooling water circulated from a cooling pond. 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 Kankakee River.

Radiological Impacts

1 The Draft Environmental Impact Statement (EIS) description of the radioactive waste treatment system and the Nuclear Regulatory Commission staff's evaluation was insufficient for a detailed analysis. The Draft EIS referenced the Safety Evaluation Report (SER) which has not been completed. We recommend that the Safety Evaluation Report be completed prior to the issuance of the Final EIS in order to permit thorough evaluation of the radioactive waste treatment system.

In view of the concern for development of nuclear waste disposal sites for solid waste, the section of the report on "Radioactive Waste Management" in the SER needs to be completed. The Draft EIS refers to Section 11 of the SER for the presentation of the staff's detailed evaluation of the solid radioactive waste system and its capability to accommodate the solid wastes expected during normal operations as well as emergency situations. However, Section 11 of the SER has not been completed.

Based upon our review of the available information it appears that the radioactive waste treatmnent systems are capable of controlling emissions to levels such that, when the direct radiation is considered, operations will still be within the EPA Environmental Radiation Standards, 40 CFR 190.

2 The Draft EIS does not address the problem of storing the high level waste. The impact of "away from reactor" and/or "at the reactor" storage needs to be controlling emissions to levels such that when the direct radiation is considered, operations will still be within the EPA Environmental Radiation Standards (40 CFR 190).

In view of the concern for development of nuclear waste disposal sites for solid waste, the section of the report on "Radioactive Waste Management" in the SER needs to be completed. The presentation of the staff's detailed evaluation expected during normal operations, including anticipated operational occurances needs to be made.

Water Quality Impacts

3 During construction of the Braidwood station erosion control programs were developed and implemented by the Commonwealth Edison Company. As part of the scoping process for this Draft EIS, we participated in a site visit to the Braidwood Station. While on this site visit, we noticed several areas where the measures to control soil erosion had failed and rill and gulleys were the result. Islands in the cooling pond were also void of vegetation and were eroding. Commonwealth Edison needs to better maintain the soil erosion program. Minimization of suspended solids in the cooling pond should also improve the efficiency of the power plant's cooling system.

IDC

Illinois Department of Conservation
life and land together

LINCOLN TOWER PLAZA • 524 SOUTH SECOND STREET • SPRINGFIELD 62706
CHICAGO OFFICE - ROOM 100, 160 NO. LASALLE 60601
David Kenney, Director • James C. Helfrich, Assistant Director

March 8, 1984

U. S. Nuclear Regulatory Commission
Washington, D.C. 20555

Attn: Director, Division of Licensing

Dear Director:

The Department has reviewed the Draft Environmental Statement (DES) related to the operation of Braidwood Station Units 1 and 2.

1 Generally, we are pleased to note that major environmental concerns we had identified during the early 1970s, and appropriate mitigating actions to alleviate these concerns, are adequately reflected in this DES. During our review of the DES, however, we did note the tendency to present general statements relative to impacts without a thorough presentation of data or references to support these statements. It is our opinion much more data relative to aquatic impacts has been collected than is presented or referenced in this DES.

Specific comments on the DES follow:

Section 5.5.2.2 Kankakee River

2 On page 5-2, last paragraph, it is stated, "The water quality standards also require that the discharge structure must be designed to ensure that the mixing zone allows a reasonable zone of passage for aquatic life and must not encompass more than 25% of the cross-sectional area or volume of flow, except in those instances where the dilution ratio is less than 3:1 (ER-OL Section 5.1))"

On page 5-13, first paragraph, it is stated, "The thermal plume is projected to extend to 28% of the river width in August, 33% in September, and 22% in December---."

These two statements appear to be in conflict; therefore, further clarification should be presented in the Final Environmental Statement (FES).

According to the DES (page 5-13, first paragraph), "the thermal plume should not act as a barrier to up or downstream movement by mobile aquatic biota." The DES further states (page 5-13, fourth paragraph) "Larval fish could be stressed on passage through the thermal plume; however, ---larval mortality associated with the thermal plume should not be significant." The DES rationalizes these conclusions on the basis of short residence time in the plume and the statement "natural mortality of larval fish can reach more than 99%." (page 5-13, paragraph 4).

It seems appropriate here to point out that because year class strength is determined by the success in survival of eggs and larval fish and natural factors alone can account for 99% mortality, additional stress on the remaining 1% from removal by entrainment or mortality from a thermal plume should not be so easily dismissed. Here, also, the size and shape of the thermal plume may come into play. If egg and/or larval drift is not evenly or randomly distributed throughout the cross section of the river, then there is a possibility that a disproportionate amount of drift is passing along the shore of the station and subject to entrainment or thermal stress. There may be particular species of fish more affected than others, i.e. species whose entire drift would be concentrated into the river area where it will be entrained or pass through the thermal plume.

3 For these reasons, we suggest the FES assessment of impacts on eggs and larval fish include a discussion of studies Commonwealth Edison has conducted to determine distribution of larval drift across the cross-section of the river. We are most interested in learning if an analysis by species and percent of drift already dead was conducted so a meaningful comparison can be made by species prior to entering the intake and/or heated water area and after passing through these hazards. If these studies have not been conducted at this site then the FES should include a definite statement relative to the need for such studies after plant start-up.

Based on the information presented in table 5.4 (page 5-16), and contrary to impingement losses at plants on other rivers where numbers of gizzard shad are commonly 50-80% of the loss, sport fish comprised the large share of impinged fish - 17.8% of the total number were rock bass, 11.1% channel catfish, 8.4% bluegill, 8.2% smallmouth bass, 6.1% white crappie, 4.2% black crappie, and 2.4% pumpkinseed for close to 60% of the total number impinged. Gizzard shad numbers were only .4% of the total.

We are aware that impingement mortality of large numbers of forage fish, such as gizzard shad, are dismissed each year without much concern because of their great reproductive potential; however, predator fish do not have that same potential. Gizzard shad females average 375,000 eggs per fish as compared to an average 5,000 per female rock bass. Thus a loss of tens of thousands of shad each year from impingement is of much less concern than the loss of thousands of predator/sport fish such as rock bass. The assumption of highesst mortality in winter (page 5-17, first paragraph), again ignores differences between species or families of fish. During closed cycle operation of the Quad-Cities Station in 1976, 63% of the shad impinged (shad were 86% of total impingement) were lost in December, January, and February. However, only 14% of the annual loss of crappie occurred in the December-February period. It seems logical to expect that impingement at Braidwood may actually be much higher outside the winter period since it includes such a small proportion of shad and large proportions of centrarchids such as crappies.

4 For the above reasons, we suggest the FES fully discuss Commonwealth Edison's commitment to conduct 12 month impingement entrainment studies after plant start-up. We look to this study to provide answers to the aforementioned concerns.

Section 5.6.2 Aquatic

5 The DES (page 5-18) discusses the pallid shiner. The document correctly points out that this fish is "a rare species in Illinois" (page 5-18). In fact, according to Smith in The Fishes of Illinois, it "is one of the rarest and least known American fishes." For this reason, the discovery of more than 17 individuals of this species at one of the Braidwood monitoring stations is noteworthy

> and deserves further attention and study. The FES should address Commonwealth Edison's specific plans for river monitoring and study of this species prior to and following plant start-up.

The Department appreciates the opportunity to comment on the DES.

Sincerely,

David Kenney

David Kenney

DK:RWL:alc

cc: Commonwealth Edison Co.

IDNS

Illinois Department of Nuclear Safety

1035 Outer Park Drive Springfield, Illinois 62704 (217) 546-8100

Don Etchison
Director

Terry Lash
Deputy Director

February 22, 1984

Director, Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

RE: Braidwood Station Units 1 & 2
Docket Nos. STN50-456, STN50-457
Draft Environmental Statement
(NUREG-1026) Operating License
Stage

Dear Director:

After a review of the Braidwood Environmental Statement, the following questions and comments are directed to your attention:

A. 5.9.4.4.(1) - Environmental Impacts of Postulated Accidents - Design Features

1 1. How does the Braidwood Station's radioactive waste gas decay tank system design differ from the Zion Station design which experienced an unplanned accidental release of noble gases on May 26, 1980?

Please provide information as to how Braidwood Station's waste gas decay tank design would prevent such an accidental radioactive gas release.

2. 5.9.3. - Radiological Impacts from Routine Operations

2 What has been done at Braidwood Station to preclude unmonitored and/or unplanned radioactive releases, both gaseous and liquid? An example of such is the past unmonitored liquid tritium release at Zion Station.

3. 5.9.3.1.1. - Occupational Radiation Exposure for Pressurized Water Reactors

3 Does the range of annual man-rems anticipated for the occupational radiation exposure include the radiation exposure received for

IDNS

3. special considerations such as steam generator tube repair and maintenance on the reactor coolant pump seals?

4. IBID (3)

4 Did the staff take into account the proposed revision of 10CFR20 in developing this section on occupational radiation exposure?

5. 5.9.4.5 - Accident Risk & Impact Assessement (7) Uncertainties (Page 5-69)

5 This section indicates that sequences initiated by natural phenomena, such as seismic events, are not included in the sequences being evaluated. The staff also indicates this, as well as other natural phenomena effects, would not contribute significantly to risk. Please provide justification as to why, at least for the seismic event, design analysis was not provided for the Braidwood Station.

B. General Comments

6 1. Does Braidwood Station have the capability to handle radioactive chemical decontamination waste?

7 2. The staff relied heavily upon the Reactor Safety Study (Wash. 1400), and the Zion and Indian Point probabilistic risk assessment studies in Section 5.9.4.5, "Accident Risk and Impact Assessment", in its analyses.

In light of the high degrees of uncertainty associated with the probability values in Wash. 1400, should not a more realistic study be performed for Braidwood Station in order to be able to place a higher degree of confidence in the risk assessment results?

8 3. Please provide an explanation as to why there are differences in the following tables:

Type of Document

Release Type	FES-CLS	DES-OLS
Liquid	Table 3.5	Table D-4
Gaseous	Table 3.6	Table D-1

9 4. "It is the qualitative judgement of the staff that the uncertainty bounds could be well over a factor of 10, but not as large as a factor of 100". (Page 5-72).

What is the basis for the staff's qualitative judgement?

IDNS

10 5. Some of the isotopic values given in Table D-1 are lower by a factor of 10-100 than the corresponding release rates per reactor as given in the Table on Page B23 of Regulatory Guide 1.BB, which are used in the NRC PWR/GALE computer code to determine the off-site gaseous doses for normal operations.

Please provide an explanation for the reduction of the gaseous release rates.

Thank you for the opportunity to review the Braidwood Station's Draft Environmental Statement - operating permit stage. Your consideration of the above comments is appreciated.

Very truly yours,

Don Etchison

Don Etchison
Director

DE:RRM:jt

JFD

March 7, 1984

COMMENTS OF JOHN F. DOHERTY TO BRAIDWOOD STATION DES (DECEMBER 1983)

Ms. Janice A. Stevens
Division of Licensing
U. S. Nuclear Regulatory Commission
Washington D. C. 20555

John F. Doherty, of 318 Summit Ave., Brighton, Mass. 02135, comments as below on the DES (NUREG-1026) for the Braidwood Station, Units 1 & 2, Docket Nos. STN 50-456,457

COMMENT DOHERTY 1

In Appendix C, at page C-6, the following statement is made:

"To illustrate: A single model 1000-MWe LWR operating at 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."

1 My concern is that the DES has not completely described the fuel cycle impact in Appendix C. The concern is not impact of the operation of the plant to the general public. Specifically, the DES should contain a statement of:

a) The range of number of non-fatal cancer injuries induced by fuel cycle radon-222 for providing fuel for the Braidwood Station, Units 1 & 2, for its projected capacity factor (80%) and licensing period (40 years).

b) The range of number of non-fatal birth defects induced by fuel cycle radon-222 for providing fuel for the Braidwood Station, Units 1 & 2, for its projected capacity factor (80%) and licensing period (40 years).

COMMENT DOHERTY 2

2 On Page 5-26 of the Statement, it says, "The lower limit of the range would be zero because there may be biological mechanisms that can repair damage caused by radiation at low dose and/or dose rates." (The discussion is of risk of deaths from cancer due to exposure to plant radioactive materials, etc.) This statement is

unsupported by reference, or documentation, and this Commentor knows but one item doing this. The Statement should be altered to include what backs this position.

COMMENT DOHERTY 3

3 The Statement needs to clarify if in the analysis of environmental impacts of postulated accidents any credit was given for Applicant compliance with any of the TMI-related requirements of NUREG-737 "Clarification of TMI Action Plan Requirements".

Thank you for the opportunity to comment.

John F. Doherty

John F. Doherty

NIPC

northeastern illinois planning commission

400 West Madison Street Chicago, Illinois 60606 (312)454-04C

February 22, 1984

Ms. Janice A. Stevens
Division of Licensing
U.S. Nuclear Regulatory Commission
Washington, D.C. 20555

SUBJECT: NIPC Project No. 84-022 U.S. Nuclear Regulatory Commission/Commonwealth Edison Company - Draft environmental statement for the operation of the Braidwood Station, Units 1 and 2.

Dear Ms. Stevens:

Your application referenced above has been reviewed under provisions of the federal Office of Management and Budget Circular No. A-95 (Revised) and the Commission's present areawide clearinghouse and bi-state procedures.

The application was considered by the Commission at a meeting held today of its Governmental Services Committee. The finding of the Commission is detailed under the heading "A-95 Summary Recommendations" in the enclosed statement.

Copies of any comments on this project we have received from local agencies, governments, or individuals are also enclosed. This letter, any comments, and our review statement are to be included with your final application to the funding agency, along with your statement that you have considered the comments and recommendations before submitting the application. You must also include comments you may receive separately from the Illinois State Clearinghouse.

Please direct any questions relating to Commission review activities to our Project Review Section.

Sincerely,

Deborah L. Washington

Deborah L. Washington
Project Review Officer

DLW:fg
cc: C. L. McDonough, Commonwealth Edison
Barbara Mabie, Illinois State Clearinghouse
Elizabeth Hollander, Chicago DP
Robert Clark, Illinois EPA

(S3)

NIPC

NIPC PROJECT NO. 84-022

A-95 SUMMARY RECOMMENDATIONS

NORTHEASTERN ILLINOIS PLANNING COMMISSION

APPLICANT: U.S. Nuclear Regulatory Commission/Commonwealth Edison Company

SUBJECT: Draft Environmental Statement for the operation of the Braidwood Station, Units 1 and 2.

STAFF RECOMMENDATION: Transmittal of following review statement:

REVIEW STATEMENT

The Commission reviewed the Braidwood Plant proposal in 1973 and
expressed concerns related to several aspects of construction and
operation. The draft statement which is the object of this
review is oriented toward plant operations. Perhaps as a result
1 of this orientation the draft statement does not address the
environmental impacts of the pipline to the Kankakee River, even
though the impacts of the plant, cooling pond and intake and
discharge facilities on the Kankakee River are discussed in
detail. There is no discussion of esthetic impacts except for
re-vegetation plans for the site and the expected impacts related
to noise and air quality. Given that the facility is already
2 constructed the Commission urges that final landscaping and
ongoing operations be conducted in a manner which minimize
adverse off-site esthetic impacts.

NIPC

The Regional Open Space and Recreation Policy Plan encourages
increased availability of open space in northeastern Illinois.
Since cooling ponds become major aquatic and waterfowl habitat
areas, the Commission encourages their safe use for wildlife
3 management and related recreational activities. The Commission
encourages Commonwealth Edison's cooperation with the Illinois
Department of Conservation on this matter. NIPC policies
encourage the preservation of historic resources and, therefore,
the protection of archeological resources on the site which may
be found to be eligible for inclusion in the National Register.
Site development activity, including future activities, should be
4 done with the consultation of the State Historic Preservation
officer, the Illinois Archeological Survey and the Illinois
Natural History Survey. The arrangement with the Field Museum
regarding fossil collecting seems appropriate. The accessibility
provided by this arrangement should be continued and fossil
resouces on the site protected during the operation of the
facility.

The Commission urges that all appropriate safeguards be used to ensure safe operation of this facility. Its failure to operate in such a manner could have serious adverse economic impacts, as well as life threatening impacts, on the metropolitan area. The Commission is concerned for the well-being of the region's small communities, several of which are near the facility, as well as its large population concentrations.

NIPC

The Commission notes that it develops the official population, household and employment forecasts for the region, in conjunction with the Illinois Bureau of the Budget. The Commission recommends that such forecasts be used in the planning and design of regional transportation, water supply, wastewater treatment and energy facilities. If decisions remain concerning operation of the facility as it relates to forecasted growth, the Commission encourages Commonwealth Edison to consult with NIPC and the Illinois Bureau of the Budget regarding the use of their official forecasts.

The future of the region is dependent upon the protection of the region's ground and surface water resources. Responsible agencies should evaluate with extreme care the plant's impact on these resources during normal, as well as emergency, conditions.

WILL COUNTY DEVELOPMENT DEPARTMENT

501 Ella Avenue
Joliet, Illinois 60433
(815) 727-8767

WCDD

March 2, 1984

U.S. Nuclear Regulatory Commission
Washington, D.C. 20555
Attn: Director, Division of Licensing

Dear Sir:

Will County is concerned with the impact the water withdrawal from, and discharge of cooling water into the Kankakee River from the Braidwood Station will have, on the proposed Will County Public Water Supply System planned to be located downstream of the Braidwood Station. The Will County Development Department is currently conducting the Will County Public Water Supply Study. The study considers the Kankakee River a prime source for possible water supply and the costs to construct and operate a system from the river will be identified in the study.

The impacts of most concern on the proposed water supply system discussed in the December 1983 draft Environmental Statement (NUREG-1026) are as follows:

1 1. Degradation of water quality from cooling water discharge to the river.

2 2. Long-term human health effects and risks associated with effluents entering the river containing low levels of radioactive discharge.

3 3. Inadequate volume of river flow downstream to support the water supply system. Specifically, page 5-2, item 5.3.1 of the statement does not include the Will County Public Water Supply System as a potential downstream water user.

4 4. Risk of possible contamination of the water supply in the case of power plant malfunction and emergency.

5 5. Increased costs to the proposed water system due to mitigating measures that may be required to address the effects of the Braidwood Station upstream.

Please consider and incorporate where appropriate these comments in preparation of the final Environmental Statement.

Sincerely,

John R. Gallagher, Jr.
Director of Development

JRG/AR/pc

APPENDIX B

NEPA POPULATION-DOSE ASSESSMENT

APPENDIX B

NEPA POPULATION-DOSE ASSESSMENT

Population-dose commitments are calculated for all individuals living within 80 km (50 miles) of the Braidwood facility, employing the same dose calculation models used for individual doses (see RG 1.109, Revision 1), for the purpose of meeting the "as low as reasonably achievable" (ALARA) requirements of 10 CFR 50, Appendix I. In addition, dose commitments to the population residing beyond the 80-km region, 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, 1969 (NEPA). This appendix describes the methods used to make these NEPA-population dose estimates.

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 of the facility, the deposition model in RG 1.111, Revision 1, is used in conjunction with the dose models in RG 1.109, Revision 1. Site-specific data concerning production and consumption of foods within 80 km of the reactor are used. For estimates of population doses beyond 80 km, it is assumed that excess food not consumed within the 80-km area would be consumed by the population beyond 80 km. It is further assumed that none, or very few, of the particulates released from the facility will be transported beyond the 80-km distance; thus, they will make no significant contribution to the population dose outside the 80-km region, except by export of food crops. This assumption was tested and found to be reasonable for the Braidwood Station.

2. Noble Gases, Carbon-14, and Tritium Released to the Atmosphere

For locations within 80 km of the reactor facility, exposures to these effluents are calculated with a constant mean wind-direction model according to the guidance provided in RG 1.111, Revision 1, and the dose models described in RG 1.109, Revision 1. For estimating the dose commitment from these radionuclides to the U.S. population residing beyond the 80-km region, two dispersion regimes are considered. These are referred to as the first-pass-dispersion regime and the world-wide-dispersion regime. The model for the first-pass-dispersion regime estimates the dose commitment to the population from the radioactive plume as it leaves the facility and drifts across the continental U.S. toward the northeastern corner of the U.S. 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.

(a) First-Pass Dispersion

For estimating the dose commitment to the U.S. population residing beyond the 80-km region as a result of the first pass of radioactive pollutants, it is assumed that the pollutants disperse in the lateral and vertical directions along the plume path. The direction of movement of the plume is assumed to be from the facility toward the northeast corner of the U.S. 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 is only dependent upon the mixing depth and other nongeometrical related factors (NUREG-0597). The mixing depth is estimated to be 1000 m, and a uniform population density of 62 persons/km^2 is assumed along the plume path, with an average plume-transport velocity of 2 m/s.

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 from ingestion of food containing carbon-14 and tritium.

(b) 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 1 year are considered. Noble gases and carbon-14 are assumed to mix uniformly in the world's 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 20-year release period (midpoint of reactor life) and estimates the annual population-dose commitment at that time, taking into consideration radioactive decay and physical removal mechanisms (for example, carbon-14 is gradually removed to the world's oceans). 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 as a result of 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 immediately distributed in the world's circulating water volume (2.7×10^{16} m^3) including the top 75 m of the seas and oceans, as well as the rivers and atmospheric moisture. The concentration of tritium in the world's circulating water is estimated at the time after 20 years of releases have occurred, 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.

3. Liquid Effluents

Population-dose commitments due to effluents in the receiving water within 80 km of the facility are calculated as described in RG 1.109, Revision 1. It is assumed that no depletion by sedimentation of the nuclides present in the receiving water occurs within 80 km. It also is assumed that aquatic biota concentrate radioactivity in the same manner as was assumed for 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 the 80-km area are eaten by the U.S. population.

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 world's circulating water volume and to result in an exposure to the U.S. population in the same manner as discussed for tritium in gaseous effluents.

4. References

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

---, RG 1.109, "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," Revision 1, October 1977.

---, RG 1.111, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Reactors," Revision 1, July 1977.

APPENDIX C

IMPACTS OF THE URANIUM FUEL CYCLE

APPENDIX C

IMPACTS OF THE URANIUM FUEL CYCLE

The following assessment of the environmental impacts of the LWR-supporting fuel cycle as related to the operation of the proposed project is based on the values given in Table S-3 of Title 10 of the Code of Federal Regulations, Part 51 (10 CFR 51) (see Table 5.14 in the main body of this report) and the NRC staff's estimates of radon-222 and technetium-99 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 the Braidwood Nuclear Station.

1. Land Use

The total annual land requirement for the fuel cycle supporting a model 1000-MWe LWR is about 460,000 m^2 (113 acres). Approximately 53,000 m^2 (13 acres) per year are permanently committed land, and 405,000 m^2 (100 acres) per year are temporarily committed. (A "temporary" land commitment is a commitment for the life of the specific fuel-cycle plant, such as a 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 405,000 m^2 per year of temporarily committed land, 320,000 m^2 are undisturbed and 90,000 m^2 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.

2. Water Use

The principal water-use requirement for the fuel cycle supporting a model 1000-MWe LWR is that required to remove 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 are required for this purpose, assuming that these plants use once-through cooling. Other water uses involve the discharge to air (for example, evaporation losses in process cooling) of about 0.6×10^6 m^3 (16×10^7 gal) per year and water discharged to the ground (for example, mine drainage) of about 0.5×10^6 m^3 per year.

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 per year is about 2% of that from the

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*A coal-fired plant of 1000-MWe capacity using strip-mined coal requires the disturbance of about 810,000 m^2 (200 acres) per year for fuel alone.

model 1000-MWe LWR using cooling towers. The maximum consumptive water use (assuming that all plants supplying electrical energy to the nuclear fuel cycle used cooling towers) would be about 6% of the model 1000-MWe LWR using 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.

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 primarily generated 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.

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. On the basis of data in a Council on Environmental Quality report (CEQ, 1976), the staff finds that these emissions constitute an extremely small additional atmospheric loading in comparison with the same emissions from the stationary fuel-combustion and transportation sectors in the U.S.; that is, 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 U.S. 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.

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 set forth in Table S-3. Using these data, the staff has calculated for 1 year of operation of the model 1000-MWe LWR, the 100-year environmental dose commitment* to the U.S. population from the LWR-supporting fuel cycle. Dose commitments are provided in this section for exposure to four categories of radioactive releases: (1) airborne effluents that are quantified in Table S-3 (that is, all radionuclides except radon-222 and technetium-99), (2) liquid effluents that are quantified in Table S-3 (that is, all radionuclides except technetium-99): (3) the staff's estimates of radon-222 releases; and (4) the staff's estimate of technetium-99 releases. Dose commitments from the first two categories are also described in a proposed explanatory narrative for Table S-3, which was published in the Federal Register on March 4, 1981 (46 FR 15154-15175).

Airborne Effluents

Population dose estimates for exposure to airborne effluents are based on the annual releases listed in Table S-3, using an environmental dose commitment (EDC) time of 100 years.* The computational code used for these estimates is the RABGAD code originally developed for use in the "Generic Environmental Impact Statement on the Use of Mixed Oxide Fuel in Light-Water-Cooled Nuclear Power Plants," GESMO (NUREG-0002, Chapter IV, Section J, Appendix A). Two generic sites are postulated for the points of release of the airborne effluents: (1) a site in the midwestern United States for releases from a fuel reprocessing plant and other facilities, and (2) a site in the western United States for releases from milling and a geological repository.

The following environmental pathways were considered in estimating doses: (1) inhalation and submersion in the plume during its initial passage; (2) ingestion of food; (3) external exposure from radionuclides deposited on soil; and (4) atmospheric resuspension of radionuclides deposited on soil. Radionuclides released to the atmosphere from the midwestern site are assumed to be transported with a mean wind speed of 2 m/sec over a 2413-km (1500-mile)** pathway from the midwestern United States to the northeast corner of the United States, and deposited on vegetation (deposition velocity of 1.0 cm/sec) with subsequent uptake by milk- and meat-producing animals. No removal mechanisms are assumed during the first 100 years, except normal weathering from crops to soil (weathering half-life of 13 days). Doses from exposure to carbon-14 were estimated using the GESMO model to estimate the dose to U.S. population from the initial passage of carbon-14 before it mixed in the world's carbon pool. The model developed by Killough (1977) was used to estimate doses from exposure to carbon-14 after it mixed in the world's carbon pool.

In a similar manner, radionuclides released from the western site were assumed to be transported over a 3218-km (2000-mile) pathway to the northeast corner of the United States. The agricultural characteristics that were used in computing doses from exposure to airborne effluents from the two generic sites are described in GESMO (NUREG-0002, page IV J(A)-19). To allow for an increase

*The 100-year environmental dose commitment is the integrated population dose for 100 years; that is, it represents the sum of the annual population doses for a total of 100 years.

**Here and elsewhere in this narrative, insignificant digits are retained for purposes of internal consistency in the model.

in population, the population densities used in this analysis were 50% greater than the values used in GESMO (NUREG-0002, page IV J(A)-19).

Liquid Effluents

Population dose estimates for exposure to liquid effluents are based on the annual releases listed in Table S-3 and the hydrological model described in GESMO (NUREG-0002, pages IV J(A)-20, -21, and -22). The following environmental pathways were considered in estimating doses: (1) ingestion of water and fish; (2) ingestion of food (vegetation, milk, and beef) that had been produced through irrigation; and (3) exposure from shoreline, swimming, and boating activities.

It is estimated from these calculations that the overall total-body dose commitment to the U.S. population from exposure to gaseous releases from the fuel cycle (excluding reactor releases and the dose commitment due to radon-222 and technetium-99) would be approximately 450 person-rems to the total body for each year of operation of the model 1000-MWe LWR (reference reactor year, or RRY). Based on Table S-3 values, the additional total-body dose commitments to the U.S. population from radioactive liquid effluents (excluding technetium-99) as a result of all fuel-cycle operations other than reactor operation would be about 100 person-rems per year of operation. Thus, the estimated 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 550 person-rems to the total body (whole body) per RRY.

Because there are higher dose commitments to certain organs (for example, lung, bone, and thyroid) than to the total body, the total risk of radiogenic cancer is not addressed by the total body dose commitment alone. Using risk estimators of 135, 6.9, 22, and 13.4 cancer deaths per million person-rems for total-body, bone, lung, and thyroid exposures, respectively, it is possible to estimate the total body risk equivalent dose for certain organs (NUREG-0002, Chapter IV, Section J, Appendix B). The sum of the total body risk equivalent dose from those organs was estimated to be about 100 person-rems. When added to the above value, the total 100-year environmental dose commitment would be about 650 person-rems (total body risk equivalent dose) per RRY (Section 5.9.3.1.1 describes the health effects models in more detail).

Radon-222

At this time the quantitites of radon-222 and technetium-99 releases are not listed in Table S-3. Principal radon releases occur during mining and milling operations and as emissions from mill tailings, whereas principal technetium-99 releases occur from gaseous diffusion enrichment facilities. The staff has determined that radon-222 releases per RRY from these operations are as given in Table C-1. The staff has calculated population-dose commitments for these sources of radon-222 using the RABGAD computer code described in Volume 3 of NUREG-0002 (Chapter IV, Section J, Appendix A). The results of these calculations for mining and milling activities prior to tailings stabilization are listed in Table C-2.

Table C-1 Radon releases from mining and milling operations and mill tailings for each year of operation of the model 1000-MWe LWR*

Radon source	Quantity released
Mining**	4060 Ci
Milling and tailings*** (during active mining)	780 Ci
Inactive tailings*** (before stabilization)	350 Ci
Stabilized tailings*** (several hundred years)	1 to 10 Ci/year
Stabilized tailings*** (after several hundred years)	110 Ci/year

*After 3 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. Because 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. Subsequent to ALAB-640, a second ASLAB decision (ALAB-654, issued September 11, 1981) permits intervenors a 60-day period to challenge the Perkins record on the potential health effects of radon-222 emissions

**R. Wilde, NRC transcript of direct testimony given "In the Matter of Duke Power Company (Perkins Nuclear Station)," Docket No. 50-488, April 17, 1978.

***P. Magno, NRC transcript of direct testimony given "In the Matter of Duke Power Company (Perkins Nuclear Station)," Docket No. 50-488, April 17, 1978.

The staff has considered the health effects associated with the releases of radon-222, including both the short-term effects of mining and milling and active tailings, and the potential long-term effects from unreclaimed open-pit mines and stabilized tailings. The staff has assumed that after completion of active mining, underground mines will be sealed, returning releases of radon-222 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 per RRY. However, because the distribution of uranium-ore reserves available by conventional mining methods is 66% underground and 34% open pit (U.S. Department of Energy, 1978), the staff has further assumed

Table C-2 Estimated 100-year environmental dose commitment per year of operation of the model 1000-MWe LWR

Radon source	Radon-222 releases (Ci)	Environmental dose commitments (person rems) Total body	Bone	Lung (bronchial epithelium)	Total body risk equivalent dose
Mining	4100	110	2800	2300	630
Milling and active tailings	1100	29	750	620	170
Total	5200	140	3600	2900	800

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 0.34 x 110 or 37 Ci per year per RRY.

Based on a value of 37 Ci per year per RRY for long-term releases from unreclaimed open-pit mines, 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 environmental dose commitments for a 100- to 1000-year period would be as shown in Table C-3.

These commitments represent a worst-case situation in that 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.

Table C-3 Estimated 100-year environmental dose commitments from unreclaimed open-pit mines for each year of operation of the model 1000-MWe LWR

Time span (years)	Radon-222 releases (Ci)	Environmental dose commitments (person rems) Total body	Bone	Lung (bronchial epithelium)	Total body risk equivalent dose
100	3,700	96	2,500	2,000	550
500	19,000	480	13,000	11,000	3,000
1,000	37,000	960	25,000	20,000	5,500

For long-term radon releases from stabilized tailings piles, the staff has assumed that these tailings would emit, per RRY, 1 Ci per year for 100 years, 10 Ci per year for the next 400 years, and 100 Ci per year for periods beyond 500 years. With these assumptions, the cumulative radon-222 release from stabilized-tailings piles per RRY would be 100 Ci in 100 years, 4090 Ci in 500 years, and 53,800 Ci in 1000 years (Gotchy, 1978). The total-body, bone, and bronchial epithelium dose commitments for these periods are as shown in Table C-4.

Table C-4 Estimated 100-year environmental dose commitments from stabilized-tailings piles for each year of operation of the model 1000-MWe LWR

Time span (year)	Radon-222 releases (Ci)	Environmental dose commitments (person rems)			Total body risk equivalent dose (person rems)
		Total body	Bone	Lung (bronchial epithelium	
100	100	2.6	68	56	15
500	4,090	110	2,800	2,300	630
1,000	53,800	1,400	37,000	30,000	8,200

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 resulting from mining, milling, and active-tailings emissions of radon-222 (that is, Table C-2) is about 0.11 cancer fatality per RRY. When the risks from radon-222 emissions from stabilized tailings and from reclaimed and unreclaimed open-pit mines are added to the value of 0.11 cancer fatality, the overall risks of radon-induced cancer fatalities per RRY are as follows:

0.19 fatality for a 100-year period
2.0 fatalities for a 1000-year period

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, 1975), the staff calculates the average radon-222 concentration in air in the contiguous United States to be 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-lung-rems used to predict cancer fatalities for the model 1000-MWe LWR, the staff estimates that 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 to 1000 years, respectively.

Current NRC regulations (10 CFR 40, Appendix A) require that an earth cover not less than 3 meters in depth be placed over tailings to reduce the Rn-222 emanation from the disposed tailings to less than 2 pCi/m^2-sec, on a calculated basis above background. In October 1983, the U.S. Environmental Protection Agency (EPA) published environmental standards for the disposal of uranium and thorium mill tailings at licensed commercial processing sites (EPA 1983). The EPA regulations (40 CFR 192) require that disposal be designed to limit Rn-222 emanation to less than 20 pCi/m^2-sec, averaged over the surface of the disposed tailings. The NRC Office of Nuclear Material Safety and Safeguards is reviewing its regulations for tailings disposal to ensure that they conform with the EPA regulations. Although a few of the dose estimates in this appendix would change if NRC adopts EPA's higher Rn-222 flux limit for disposal of tailings, the basic conclusion of this appendix should still be valid. That conclusion is: "The staff concludes that both the dose commitments and health effects of the LWR-supporting uranium fuel cycle are very small when compared with dose commitments and potential health effects to the U.S. population resulting from all natural-background sources."

Technetium-99

The staff has calculated the potential 100-year environmental dose commitment to the U.S. population from the release of technetium-99. These calculations are based on the gaseous and the hydrological pathway model systems described in Volume 3 of NUREG-0002 (Chapter IV, Section J, Appendix A) and are described in more detail in the staff's testimony at the operating license hearing for the Susquehanna Station (Branagan and Struckmeyer, 1981). The gastrointestinal tract and the kidney are the body organs that receive the highest doses from exposure to technetium-99. The total body dose is estimated at less than 1 person-rem per RRY and the total body risk equivalent dose is estimated at less than 10 person-rems per RRY.

Summary of Impacts

The potential radiological impacts of the supporting fuel cycle are summarized in Table C-5 for an environmental dose commitment time of 100 years For an environmental dose commitment time of 100 years, the total body dose to the U.S. population is about 790 person-rems per RRY, and the corresponding total body risk equivalent dose is about 2000 person-rems per RRY. In a similar manner, the total body dose to the U.S. population is about 3000 person-rems per RRY, and the corresponding total body risk equivalent dose is about 15,000 person-rem per RRY using a 1000-year environmental dose commitment time.

Multiplying the total body risk equivalent dose of 2000 person-rems per RRY by the preceding risk estimator of 135 potential cancer deaths per million person-rems, the staff estimates that about 0.27 cancer death per RRY may occur in the U.S. population as a result of exposure to effluents from the fuel cycle. Multiplying the total body dose of 790 person-rems per RRY by the genetic risk estimator of 258 potential cases of all forms of genetic disorders per million person-rems, the staff estimates that about 0.20 potential genetic disorder per RRY may occur in all future generations of the population exposed during the 100-year environmental dose commitment time. In a similar manner, the staff estimates that about 2 potential cancer deaths per RRY and about 0.8 potential genetic disorder per RRY may occur using a 1000-year environmental dose commitment time.

Table C-5 Summary of 100-year environmental dose commitments per year of operation of the model 1000-MWe light-water reactor

Source	Total body (person-rems)	Total body risk equivalent (person-rems)
All nuclides in Table S-3 except radon-222 and technetium-99	550	650
Radon-222		
Mining, milling, and active tailings, 5200 Ci	140	800
Unreclaimed open-pit mines, 3700 Ci	96	550
Stabilized tailings, 100 Ci	3	15
Technetium-99, 1.3 Ci*	<1	<10
Total	790	2000

*Dose commitments are based on the "prompt" release of 1.3 Ci/RRY. Additional releases of technetium-99 are estimated to occur at a rate of 0.0039 Ci/yr/RRY after 2000 years of placing wastes in a high-level-waste repository.

Some perspective can be gained by comparing the preceding estimates with those from naturally occurring terrestrial and cosmic-ray sources. These 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 3 billion person-rems and 30 billion person-rems for periods of 100 and 1000 years, respectively. These natural-background dose commitments could produce about 400,000 and 4,000,000 cancer deaths and about 770,000 and 7,700,000 genetic disorders, during the same time periods. From the above analysis, the staff concludes that both the dose commitments and health effects of the LWR-supporting uranium fuel cycle are very small when compared with dose commitments and potential health effects to the U.S. population resulting from all natural-background sources.

6. Radioactive Wastes

The quantities of buried radioactive waste material (low-level, high-level, and transuranic wastes) associated with the uranium fuel cycle 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. The Commission notes that high-level and transuranic wastes are to be buried at a Federal repository and that no release to the environment is associated with such disposal. NUREG-0116, which provides background and context for the high-level and transuranic waste values in Table S-3 established by the Commission, indicates that these high-level and transuranic wastes will be buried and will not be released to the biosphere. No radiological environmental impact is anticipated from such disposal.

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 have a small environmental impact.

8. Transportation

The transportation dose to workers and the public is specified in Table S-3. This dose is small in comparison with the natural-background dose.

9. Fuel Cycle

The staff's analysis of the uranium fuel cycle did 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.

10. References

Atomic Safety and Licensing Appeal Board, "Decision in the Matters of Philadelphia Electric Co. et al., Metropolitan Edison et al., and Public Service Electric and Gas Co.," ALAB-640, May 13, 1981.

---, "Memorandum and Order," ALAB-654, September 11, 1981.

Branagan, E., and R. Struckmeyer, testimony from "In the Matter of Pennsylvania Power & Light Company, Allegheny Electric Cooperatives, Inc. (Susquehanna Steam Electric Station, Units 1 and 2)," U.S. Nuclear Regulatory Commission, Docket Nos. 50-387 and 50-388, presented on October 14, 1981, in the transcript following page 1894.

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

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

Killough, G. G., "A Diffusion-Type Model of the Global Carbon Cycle for the Estimation of Dose to the World Population from Releases of Carbon-14 to the Atmosphere," ORNL-5269, May 1977.

Magno, P., testimony from "In the Matter of Duke Power Company (Perkins Nuclear Station)," Docket No. 50-488, filed April 17, 1978.

National Council on Radiation Protection, NCRP, "Natural Background Radiation in the United States," NCRP Report No. 45, November 1975.

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

U.S. Environmental Protection Agency, "Environmental Standards for Uranium and Thorium Mill Tailings at Licensed Commercial Processing Sites (40 CFR 192), "Federal Register, Vol 48, No. 196, pp. 45926-45947, October 7, 1983.

U.S. Nuclear Regulatory Commission, "Summary and Conclusions of Final Generic Environmental Statement on the Use of Mixed Oxide Fuel in Light Water Cooled Reactors--Health, Safety and Environment," NUREG-0002, August 1976.

---, "Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle" (Supp. 1 to WASH-1248), NUREG-0116, October 1976.

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

APPENDIX D

EXAMPLES OF SITE-SPECIFIC DOSE ASSESSMENT CALCULATIONS

APPENDIX D

EXAMPLES OF SITE-SPECIFIC DOSE ASSESSMENT CALCULATIONS

1. Calculational Approach

As mentioned in the main body of this report, the quantities of radioactive material that may be released annually from the Braidwood facility are estimated on the basis of the description of the design and operation of the radwaste systems as contained in the applicant's FSAR and by using the calculative models and parameters described in NUREG-0017. These estimated effluent release values for normal operation, including anticipated operational occurrences, 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 operations are discussed in detail in RG 1.109, Revision 1. Use of these models with additional assumptions for environmental pathways that lead to exposure to the general population outside the 80-km radius is described in Appendix B of this statement.

The calculations performed by the staff for the releases to the atmosphere and hydrosphere provide total integrated dose commitments to the entire population within 80 km of this facility 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 1 year under the conditions existing 20 years after the station begins operation (that is, the mid-point of station operation). For younger persons, changes in organ mass and metabolic parameters with age after the initial intake of radioactivity are accounted for.

2. Dose Commitments from Radioactive Effluent Releases

The staff's estimates of the expected gaseous and particulate releases, continuous and periodic (listed in Table D-1), along with the site meteorological considerations (summarized in Table D-2) were used to estimate radiation doses and dose commitments for airborne effluents. Individual receptor locations and pathway locations considered for the maximally exposed individual in these calculations are listed in Table D-3.

Three years of meteorological data were used in the calculation of concentrations of effluents. The calculation followed guidance given in RG 1.111, Revision 1. Onsite meteorological data collected from January 1979 through December 1982, with wind speed and direction measured at an elevation of 62 m and vertical temperature gradient measured between 9.1 and 61 m, were used as

Table D-1 Calculated releases of radioactive materials in gaseous effluents from the Braidwood Station Units 1 and 2 (Ci/yr/reactor)

Nuclide	Gas stripping		Building ventilation			Air-ejector exhaust (continuous)	Total
	Periodic	Continuous	Reactor (periodic)	Auxiliary (continuous)	Turbine (continuous)		
Ar-41	a	a	25	a	a	a	25
Kr-83m	a	a	a	a	a	a	a
Kr-85m	a	a	a	3	a	2	5
Kr-85	45	280	65	2	a	a	390
Kr-87	a	a	a	2	a	a	2
Kr-88	a	a	a	5	a	3	8
Kr-89	a	a	a	a	a	a	a
Xe-131m	6	15	23	2	a	2	48
Xe-133m	a	a	11	5	a	3	19
Xe-133	71	94	1900	420	a	260	2700
Xe-135m	a	a	a	a	a	a	a
Xe-135	a	a	3	9	a	6	18
Xe-137	a	a	a	a	a	a	a
Xe-138	a	a	a	1	a	a	1
Total noble gases							3200
Mn-54	b	0.0045	b	0.00018	b	b	0.0047
Fe-59	b	0.0015	b	0.00006	b	b	0.0016
Co-58	b	0.015	b	0.00060	b	b	0.016
Co-60	b	0.007	b	0.00027	b	b	0.0073
Sr-89	b	0.00033	b	0.000013	b	b	0.00034
Sr-90	b	0.00006	b	0.0000024	b	b	0.00006
Cs-134	b	0.0045	b	0.00018	b	b	0.0047
Cs-137	b	0.0075	b	0.00030	b	b	0.0078
Total particulates						0.043	
I-131	c	c	0.002	0.081	0.001	0.028	0.112
I-133	c	c	0.001	0.066	0.001	0.041	0.110
C-14	a	7	1	a	a	a	8
H-3	-	-	140	790	-	-	930

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

[b]Less than 1% of total for nuclide.

[c]Less than 0.001 Ci/yr.

a measure of atmospheric stability. A straight line Gaussian dispersion model, corrected for effluent recirculation, was utilized for the routine gaseous release dispersion calculation.

The NRC staff estimates of the expected liquid releases (listed in Table D-4), along with the site hydrological considerations (summarized in Table D-5), were used to estimate radiation doses and dose commitments from liquid releases.

(a) 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 (that is, the maximally exposed individual) who would be expected to receive the highest radiation dose from all pathways that contribute.

Table D-2 Summary of atmospheric dispersion factors (χ/Q) and relative deposition values for maximum site boundary and receptor locations near the Braidwood nuclear facility*

Location**	Source***	χ/Q (sec/m^3)	Relative deposition (m^{-2})
Nearest effluent-control boundary (0.61 km N of Unit 1)	A B	1.2×10^{-6} 7.1×10^{-7}	3.3×10^{-8} 1.9×10^{-8}
Nearest residence and garden (0.81 km N of Units 1 and 2)	A B	9.6×10^{-7} 5.2×10^{-7}	2.6×10^{-8} 1.4×10^{-8}
Nearest milk cow (3.7 km ESE of Units 1 and 2)	A B	2.0×10^{-7} 6.9×10^{-8}	2.2×10^{-9} 7.7×10^{-10}
Nearest meat animal (3.9 km N of Units 1 and 2)	A B	2.4×10^{-7} 9.8×10^{-8}	2.1×10^{-9} 8.7×10^{-10}

*The values presented in this table are corrected for radioactive decay and cloud depletion from deposition, where appropriate, in accordance with Regulatory Guide 1.111, Rev. 1, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light Water Reactors," July 1977.

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

***Sources:
A - Reactor-building stack, Unit 1 or 2, and gas stripping exhaust, Unit 1 or 2, intermittent release, 20 releases per year, eight hours each release.
B - Auxiliary-building exhaust stack, Unit 1 or 2, turbine-building-ventilation exhaust, Unit 1 or 2, gas stripping exhaust, Unit 1 or 2, and main-condenser air-ejector exhaust, Unit 1 or 2, continuous release.

This method tends to overestimate the doses because assumptions are made that would be difficult for a real individual to fulfill.

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 waterborne releases are listed in Tables D-6, D-7, and D-8. The maximum annual total body and skin dose to a hypothetical individual and the maximum beta and gamma air dose at the site boundary are presented in Tables D-6, D-7, and D-8.

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 Revision 1 of RG 1.109.

Table D-3 Nearest pathway locations used for maximally exposed individual dose commitments for the Braidwood nuclear facility

Location	Sector	Distance (km)
Nearest effluent-control boundary*	N	0.61
Residence and garden**	N	0.81
Milk cow	ESE	3.7
Meat animal	N	3.9

*Beta and gamma air doses, total body doses, and skin doses from noble gases are determined at the effluent-control boundaries in the sector where the maximum potential value is likely to occur.

**Dose pathways including inhalation of atmospheric radioactivity, exposure to deposited radionuclides, and submersion in gaseous radioactivity are evaluated at residences. This particular location includes doses from vegetable consumption as well.

(b) Cumulative Dose Commitments to the General Population

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

3. References

U.S. Department of Commerce, Bureau of the Census, "Population Estimates and Projections," Series II (Series P-25, No. 704), July 1977.

U.S. Environmental Protection Agency, "Natural Radiation Exposure in the United States," ORP-SID-72-1, June 1972.

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

---, RG 1.109, "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," Revision 1, October 1977.

---, RG 1.111, "Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water Reactors," Revision 1, July 1977.

Table D-4 Calculated release of radioactive materials in liquid effluents from Braidwood nuclear facility, Units 1 and 2

Nuclide	Ci/yr/reactor	Nuclide	Ci/yr/reactor
Fission Products		Corrosion and Activation Products	
Br-93	0.00054	Cr-51	0.00047
Rb-86	0.00021	Mn-54	0.00110
Rb-88	0.034	Fe-55	0.00040
Sr-89	0.00011	Fe-59	0.00028
Sr-91	0.00011	Co-58	0.008
Y-91m	0.00012		
Mo-99	0.023	Co-60	0.0092
Tc-99m	0.065	Zr-95	0.0014
Ru-103	0.00015	Nb-95	0.002
Ru-106	0.0024	Np-239	0.00025
Ag-110m	0.00044		
Te-127	0.00035	All Others*	0.00059
Te-129m	0.00035		
Te-129	0.0022	Total (except tritium)	0.73
I-130	0.00069		
Te-131m	0.00053	Tritium	710
Te-131	0.0021		
I-131	0.1522		
Te-132	0.0061		
I-132	0.039		
I-133	0.15		
I-134	0.0022		
Cs-134	0.073		
I-135	0.045		
Cs-136	0.027		
Cs-137	0.064		
Ba-137m	0.038		
Ce-144	0.0052		

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

---, RG 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I," April 1977.

Table D-5 Summary of hydrologic transport and dispersion for liquid releases from the Braidwood facility*

Location	Transit time (hours)	Dilution factor
Nearest drinking-water intake (Peoria, Illinois)	80	250
Nearest sport-fishing location (discharge area)**	0	90
Nearest shoreline (bank of Kankakee River near discharge area)	0	5

*See Regulatory Guide 1.113, "Estimating Aquatic Dispersion of Effluents from Accidental and Routine Reactor Releases for the Purpose of Implementing Appendix I," April 1977.

**Assumed for purposes of an upper-limit estimate; detailed information not available.

Table D-6 Annual dose commitments to a maximally exposed individual near the Braidwood nuclear station

Location	Pathway	Doses (mrems/yr per unit, except as noted)				
		Noble gases in gaseous effluents				
		Total body	Skin	Gamma air dose (mrads/yr/unit)	Beta air dose (mrads/yr/unit)	
Nearest* site boundary (0.61 km N)	Direct radiation from plume	a	a	<0.10	0.12	
		Iodine and particulates in gaseous effluents**				
		Total body		Organ		
Nearest*** site boundary (0.61 km N)	Ground deposition	0.17	(T)	0.17	(C)	(thyroid)
	Inhalation	a	(T)	a	(C)	(thyroid)
Nearest residence and garden (0.81 km N)	Ground deposition	0.13	(C)	0.13	(C)	(thyroid)
	Inhalation	a	(C)	a	(C)	(thyroid)
	Vegetable consumption	0.20	(C)	0.72	(C)	(thyroid)
Nearest milk cow (3.7 km ESE)	Ground deposition	a	(I)	a	(I)	(thyroid)
	Inhalation	a	(I)	a	(I)	(thyroid)
	Vegetable consumption	a	(I)	a	(I)	(thyroid)
	Cow milk consumption	a	(I)	0.84	(I)	(thyroid)
Nearest meat animal (3.9 km N)	Meat consumption	a	(C)	a	(C)	(bone)
		Liquid effluents**				
		Total body		Organ		
Nearest fish at plant-discharge area	Fish consumption	0.2	(A)	0.2	(A)	(liver)
Nearest shore access near plant-discharge area	Shoreline recreation	a	(A)	a	(A)	(liver)

*"Nearest" refers to that site boundary location where the highest radiation doses as a result of gaseous effluents have been estimated to occur.

**Doses are for the age group and organ that results in the highest cumulative dose for the location: A=adult, T=teen, C=child, I=infant. Calculations were made for these age groups and for the following organs: gastrointestinal tract, bone, liver, kidney, thyroid, lung, and skin.

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

[a]Less than 0.1 mrem/year.

Table D-7 Calculated Appendix I dose commitments to a maximally exposed individual and to the population from operation of the Braidwood nuclear facility

Category	Annual dose per reactor unit	
	Individual	
	Appendix I design objectives*	Calculated doses**
Liquid effluents		
Dose to total body from all pathways	3 mrems	0.2 mrem
Dose to any organ from all pathways	10 mrems	0.2 mrem (liver)
Noble-gas effluents (at site boundary)		
Gamma dose in air	10 mrads	a
Beta dose in air	20 mrads	0.1 mrad
Dose to total body of an individual	5 mrems	b
Dose to skin of an individual	15 mrems	b
Radioiodines and particulates***		
Dose to any organ from all pathways	15 mrems	0.9 mrem (thyroid)
	Population dose within 80 km (person-rems)	
	Total body	Thyroid
Natural-background radiation†	520,000	
Liquid effluents	5.2	2.4
Noble-gas effluents	0.58	0.58
Radioiodine and particulates	28	31

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

**Numerical values in this column were obtained by summing appropriate values in Table D-6. Locations resulting in maximum doses are represented here.

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

†"Natural Radiation Exposure in the United States," U.S. Environmental Protection Agency, ORP-SID-72-1, June 1972; using the average background dose for Illinois of 107 mrems/yr, and year 2000 projected population of 4,830,000.

[a]Less than 0.1 mrad/year.

[b]Less than 0.1 mrem/year.

Table D-8 Calculated RM-50-2 dose commitments to a maximally exposed individual from operation of the Braidwood nuclear facility*

Category	Annual dose per site	
	RM-50-2 design objectives**	Calculated doses
Liquid effluents		
Dose to total body or any organ from all pathways	5 mrems	0.5 mrem
Activity-release estimate, excluding tritium	10 Ci	1.5 Ci
Noble-gas effluents (at site boundary)		
Gamma dose in air	10 mrads	0.1 mrad
Beta dose in air	20 mrads	0.2 mrad
Dose to total body of an individual	5 mrems	a
Dose to skin of an individual	15 mrems	0.2 mrem
Radioiodines and particulates***		
Dose to any organ from all pathways	15 mrems	1.7 mrems (thyroid)
I-131 activity release	2 Ci	<0.10 Ci

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

**Annex to Appendix I to 10 CFR Part 50.

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

[a]Less than 0.1 mrem/year.

Table D-9 Annual total-body population dose commitments, year 2000 (both units)

Category	U.S. population dose commitment (person-rems/yr)
Natural background radiation*	26,000,000*
Braidwood Nuclear Station Units 1 and 2 (combined) operation	
Plant workers	1000
General public:	
Liquid effluents**	10
Gaseous effluents	56
Transportation of fuel and waste	6

*Using the average U.S. background dose (100 mrems/yr) 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. 704, July 1977.

**80-km (50-mi) population dose

APPENDIX E

RELEASE CATEGORIES AND PROBABILITIES FOR BRAIDWOOD

APPENDIX E

RELEASE CATEGORIES AND PROBABILITIES FOR BRAIDWOOD

The NRC staff, licensees, applicants, and contractors have used the methodology of the Reactor Safety Study (RSS) (NUREG-75/014, formerly WASH-1400) to study potential severe accidents for several different reactors. For the current study, the staff examined the features of Braidwood most salient in severe accidents, together with results developed during the Zion and Indian Point studies (NUREG-0850), to derive release sequence descriptions and probabilities specific to the Braidwood units and site.

The new information and results available for this study reflect the use of advanced modeling of the processes involved in meltdown accidents, i.e., the MARCH computer code modeling for transient- and loss-of-coolant-accident (LOCA)-initiated sequences and the CORRAL code used for calculating magnitudes of releases accompanying various accident sequences. These codes* have led to a capability to predict the transient- and small-LOCA-initiated sequences that was greater than that in WASH-1400 (NUREG-75/014). The improved accident process models (MARCH and CORRAL) produced some changes in staff estimates of the release magnitudes (expressed as a fraction of the total core inventory for various groups of elements) from various accident sequences in NUREG-75/014. In general, a decrease in iodine and bromine radioisotopes was predicted for many of the dominant accident sequences; there were some predicted increases in the release magnitudes for cesium and tellurium isotopes.

The staff recently identified nine release categories that would encompass the range of expected releases from accidents in large, dry containments (U.S. pressurized water reactors (PWRs) without ice containments, of which Braidwood is one). For Braidwood, dominant accident sequences and containment failure modes were identified that would lead to five of these release categories. The staff believes that these categories are more valid than the synthetic release categories defined in WASH-1400 because of the more mechanistic treatment of the fission product behavior and release. The present study also eliminates the "smoothing technique" that the Risk Assessment Review Group criticized in the Lewis Report (NUREG/CR-0400).

Since WASH-1400, the staff has reduced its estimate of the likelihood of an accident sequence leading to the occurrence of a steam explosion α in the reactor vessel to reflect both experimental and calculative indications that such explosions are unlikely in those sequences involving small LOCAs and transients. Furthermore, if such an explosion occurred, there are indications that it would be unlikely to produce as much energy and the massive missile-caused breach of

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*The MARCH code was used in a number of scenarios involving the recovery efforts and the investigations for the Three Mile Island 2 (TMI-2) accident, as well as more recent studies of Zion, Indian Point, and other reactors.

containment as was postulated in WASH-1400. Also, the staff has considerably reduced its estimate of the likelihood of an accident sequence leading to containment failure by steam-spike overpressurization--which happens (if it happens at all) shortly after vessel failure.

For this study, site- and plant-specific accident sequence probabilities were determined by a review of the Braidwood plant features that affect the probability of a core melt, and by incorporating the loss-of-offsite-power frequency observed for the Braidwood region (Thadani, 1983). The conditional probability of various containment failure modes, given a certain accident sequence, was estimated by comparing the Braidwood containment design to designs for which the staff and contractors performed extensive analyses (Sherun, 1983). The containment failure mode and the amount of radionuclides available for release during and after containment failure determine the release category, which is simply a definition of the release time, release duration, amount of energy released with the material, the warning time, and the release fractions for each of seven groups of elements (each element of interest will have one or more radioactive isotopes). The grouping of the elements is shown in Table 5.8. Each group consists of elements whose physical and chemical properties as they relate to release from the core and containment are similar. The staff determined that the release categories could be represented by five of the release categories described in the testimony supporting the Indian Point 2 and 3 study (Section III.B of Indian Point 2 and 3 Hearing Testimony, by J. Meyer and W. T. Pratt). The staff did not identify new release categories explicitly for Braidwood because an in-depth probabilistic risk assessment (PRA) would be necessary and a PRA is not required for licensing of the plant. Further, the staff concluded that the basic containment and reactor design is sufficiently similar to that of Indian Point 2 and 3 that the use of the same release categories is valid. The phenomena controlling fission product release and transport in the two designs are predicted to be similar, so the methodology for the treatment of one should be valid for the other.

Four of the release categories defined in the Indian Point Study were not used because either they represented a very small fraction of the total risk or the accident sequence leading to them was not analyzed. For instance, the probability for Braidwood that a hydrogen burn would occur without the sprays being available was determined to be so small (because pumps in two different systems would have to fail) that the two release categories resulting from that sequence would contribute very little to the risk and could be dropped from further analysis. On the other hand, no accident-initiating external events were considered for Braidwood, except a loss of offsite power that could lead to a core melt. Had external events like earthquakes been considered, another release category involving early containment collapse might have been added.

The five release categories presented in Table 5.10 and used in the calculations for this study are designated B, C, F, H, and I. They are each described below. The release category nomenclature is that of the Indian Point Study (Testimony Section III.B); the PWR accident sequence symbols (see Table E.1) are the same as those in WASH-1400. The numerical description of the release categories is presented in Table 5.10.

Table E.1 Key to PWR accident sequence symbols

Symbol	Accident sequence
A	Intermediate to large loss-of-coolant accident (LOCA)
D	Failure of the emergency core cooling injection system
H	Failure of the emergency core cooling recirculation system (not the same as release category H described in text)
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
S_1	A small LOCA with an equivalent diameter of about 2 to 6 in.
S_2	A small LOCA with an equivalent diameter of about ½ to 2 in.
T	Transient event
V	Low-pressure injection system check valve failure
α	Containment rupture resulting from a reactor vessel steam explosion
β	Containment failure resulting from inadequate isolation of containment openings and penetrations
γ	Containment failure resulting from hydrogen burning
δ	Containment failure resulting from overpressure
ε	Containment vessel melt-through

Release Category B

During the Reactor Safety Study (WASH-1400), a potentially large risk contributor was identified by examining the configuration of the multiple check valves used to separate the high-pressure reactor coolant system from the low-pressure portions of the emergency core cooling system (ECCS) (i.e., the low-pressure injection system (LPIS)). If these valves were to fail in various modes (such as a leak in one and rupture of the other, or rupture of both) and suddenly expose the LPIS to high pressure and dynamic loads, the authors of WASH-1400 concluded that an LPIS rupture would be highly probable. Because most of the LPIS is located outside the containment, an LPIS rupture likely would provide a pathway for the leaking reactor coolant to bypass containment and the mitigating features inside containment, like containment spray. This scenario is called Event V in WASH-1400, and all accident sequences starting with Event V are predicted to lead to release category B. The authors of WASH-1400 assumed that if the LPIS rupture did not entirely fail the LPIS makeup function (which would ultimately be needed to prevent core damage), the flooding and steam caused by the LOCA would. Past release magnitude and consequence calculations for Event V have indicated that this sequence represents one of the largest risk contributors for PWRs. The NRC has recognized this finding and has taken steps to reduce the probability of Event V scenarios in both existing and future LWR designs by requiring periodic surveillance testing of the interfacing check valves to ensure that they are properly functioning as pressure boundary isolation barriers during plant operations. The Braidwood design reflects the concerns about Event V. At Braidwood, the low-pressure system is called the residual heat removal system (RHR). The RHR suction valves are two motor-operated valves per line, designed for full reactor coolant pressure and equipped with independent interlocks preventing their opening at high pressure. The RHR discharge lines each have two check valves. The check valve design permits leak testing, which is judged to reduce the probability of Event V below that originally predicted. The probability of Event V, as it contributes to release category B for this study, was conservatively taken to be the upper end of the range of probabilities calculated for plants with systems similar to those at Braidwood.

Another sequence assigned to release category B is a core melt caused by loss of ac power, followed by a steam spike shortly after vessel failure, which fails containment. The staff assumes a steam spike could occur about 0.5% of the time that the core melts after loss of ac power.

Release Category C

For Braidwood, the only containment failure mode in category C is overpressure of containment from steam and noncondensible gas buildup. The accident sequence leading to this is the loss of offsite power (which scrams the reactor and initiates the accident), failure of onsite diesel generators, failure of the ac-power-independent auxiliary feedwater pump, and failure to restore offsite power in time to provide core and containment cooling and prevent containment overpressure.

Associated with this could be a reactor coolant pump seal LOCA, since pump seal cooling would be lost as a result of the loss of component cooling water (which requires ac power). Assuming that a seal failure occurs within 30 min of loss of seal flow, this small LOCA would cause a core melt beginning about 2 hours after loss of ac power. Regional data were used to estimate the probability of loss and nonrestoration of offsite power for Braidwood; the unavailability of onsite electric power was taken to be 2×10^{-3} per demand (specific to a plant with two diesel generators, from NUREG/CR-2497). For this release category, the probability consistent with nonrestoration of ac power for 8 hours was used.

Release Category F

Category F includes those containment failures resulting from an early hydrogen burn with containment sprays still available. About 3% of a variety of core-melt scenarios for which sprays are still available and for which containment is not already breached or bypassed are estimated to result in an early hydrogen burn of enough energy to fail containment. The probability of the Braidwood sprays being available is high because they are in a separate system from the core cooling system postulated to fail and lead to the core melt. (The primary possibility for common-cause failure of the two systems, loss of ac power, is accounted for in release category C.) The containment sprays will reduce the amount of airborne fission products available for release when the burn occurs, so the radionuclide release fractions are less than for release categories B and C.

Release Category H

Category H includes those accident sequences that lead to basemat melt-through. A variety of core-melt accidents may lead to containment penetration through basemat failure: for example, S_2D-ε, S_1D-ε, S_2H-ε, S_1H-ε, AD-ε, AH-ε, TML-ε, and TKQ-ε. Except for the last two, all the listed sequences involve the potential failure of the ECCS following a LOCA with the containment engineered safety features continuing to operate as designed until the basemat is penetrated. Containment sprays would reduce the containment temperature and pressure as well as the amount of airborne radioactivity. The only containment penetration would be the basemat melt-through, which would release radionuclides into the ground with some leakage to the atmosphere occurring upward through the ground. Release is postulated to occur after about 3 days. The combination of removal by containment spray and retention in the soil greatly reduces the released fraction of all types of radionuclides except noble gases. Decay before release would further lessen the effects of short-lived radionuclides.

About 10% of all core-melt-accident sequences not accounted for by release categories B, C, and F are assumed to result in release category H.

Release Category I

All core-melt sequences that result in no containment failure are assigned to category I. The containment is assumed to leak at 1% per day. Containment sprays are assumed available to reduce the airborne concentration of all nuclides except noble gases. The probability was taken to be the probability of all core melts less those accounted for in release categories B, C, F, and H.

For Braidwood, no specific calculation of the probability of all core melts was made. The design and construction of Braidwood benefitted from considerations of severe accidents and from the information generated from the TMI-2 accident investigations. The probability of all core melts for Braidwood was assumed to be in the lower end of the range of probabilities determined for internal events in reactors for which probabilistic risk assessments were performed. This range is 10^{-3} to 10^{-5} per reactor-year; a value of 10^{-4} per reactor-year was used for the Braidwood consequence calculations.

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APPENDIX F

CONSEQUENCE MODELING CONSIDERATIONS

APPENDIX F

CONSEQUENCE MODELING CONSIDERATIONS

F.1 Evacuation Model

"Evacuation," used in the context of offsite emergency response in the event of substantial amount of radioactivity release to the atmosphere in a reactor accident, denotes an early and expeditious movement of people to avoid exposure to the passing radioactive cloud and/or to acute ground contamination in the wake of the cloud passage. It should be distinguished from "relocation," which denotes a postaccident response to reduce exposure from long-term ground contamination after plume passage. The Reactor Safety Study (RSS) (NUREG-75/014, formerly WASH-1400) consequence model contains provisions for incorporating radiological consequence reduction benefits of public evacuation. The benefits of a properly planned and expeditiously executed public evacuation would be manifested in a reduction of early health effects associated with early exposure; namely, in the number of cases of early fatality (see Section F.2) and acute radiation sickness that would require hospitalization. The evacuation model originally used in the RSS consequence model is described in WASH-1400 as well as in NUREG-0340 and NUREG/CR-2300. The evacuation model that has been used herein is a modified version of the RSS model (Sandia, 1978) and is, to a certain extent, site emergency planning oriented. The modified version is briefly outlined below.

The model uses a circular area with a specified radius (the 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 from the reactor) within the circular zone with the downwind direction as its median--that is, those people who would potentially be under the radioactive cloud that would develop following the release--would leave their residences after lapse of a specified amount of delay time* and then evacuate. The delay time is calculated from the beginning of the warning time and is recognized as the sum of the time required by the reactor operators to notify the responsible authorities; the time required by the authorities to interpret the data, decide to evacuate, and direct the people to evacuate; and the time required for the people to mobilize and get under way.

*Assumed to be a constant value, 1 hour, that would be the same for all evacuees.

The model assumes that each evacuee would move radially outward* away from the reactor 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) (which is 8 km or 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.

The model incorporates a finite length of the radioactive cloud in the downwind direction that would be determined by the product of the duration 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 would move with an equal speed which 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; that is, the cloud would be trailing behind the evacuees initially. On the other hand, if the delay time were more than the warning time, then, depending on initial locations of the evacuees, it is possible that (1) an evacuee would still have a head start, or (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 cloud/people disposition would change as the evacuees travel, depending on the relative speed and positions between the cloud and people. The cloud and an evacuee might overtake one another one or more times before the evacuee would reach his/her destination. In the model, the radial position of an evacuating person, either 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 time periods during which people are exposed to radionuclides on the ground while they are stationary and while they are evacuating. 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 (1) exposed to the total ground contamination concentration that is calculated to exist after complete passage of the cloud, after they are completely passed by the cloud; (2) exposed to one-half the calculated concentration when anywhere under the cloud; and (3) not exposed when they are in front of the cloud. Different values of the shielding protection factors for exposures from airborne radioactivity and ground contamination have been used.

Results shown in Section 5.9.4.5 of the main body of this report for accidents involving significant release of radioactivity to the atmosphere were based on the assumption that all people within the 16-km (10-mi) plume exposure pathway EPZ would evacuate according to the evacuation scenario described above.

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*In the RSS consequence model, the radioactive cloud is assumed to travel radially outward only, spreading out as it moves away.

**Assumed to be a constant value, 1.1 mi (1.8 km) per hour, that would be the same for all evacuees.

Because sheltering can be a mitigative feature, it is not expected that detailed inclusion of any facility (see Section 5.9.4.5(2)) near a specific plant site, where not all persons would be quickly evacuated, would significantly alter the conclusions. For the delay time before evacuation, a value of 1 hour was used. The staff believes that such a value appropriately reflects the Commission's emergency planning requirements. The applicant has provided estimates of the time required to clear the 16-km (10-mi) zone.

From these estimates, the staff has conservatively estimated the effective evacuation speed to be 0.5 m per second (1.1 mph). It is realistic to expect that the authorities would aid and encourage evacuation at distances from the site where exposures above the threshold for causing early fatalities could be reached regardless of the EPZ distance. As an additional emergency measure for the Braidwood site, it was also assumed that all people beyond the evacuation distance who would be exposed to the contaminated ground would be relocated 12 hours after passage of the plume.

A modification of the RSS consequence model was used, which incorporates the assumption that if the calculated ground dose to the total marrow over a 7-day period were to exceed 200 rems, then this high dose rate would be detected by actual field measurements following plume passage, and people from these regions would be relocated immediately. For this situation the model limits the period of ground dose calculation to 24 hours; otherwise, the period of ground exposure is limited to 7 days for calculation of early dose.

Figure F.1 shows the early fatalities for (1) a pessimistic case for which no early evacuation is assumed and all persons are assumed to be exposed for the first 24 hours following plume passage and are then conditionally relocated on the basis of projected dose as described above and (2) a less pessimistic case, the same as (1) except relocation occurs 12 hours after plume passage.

The model has the same provision for calculation of the economic cost associated with implementation of evacuation as the original RSS model. For this purpose, the model assumes that for atmospheric releases of durations 3 hours or less, all people living within a circular area of 8-km (5-mi) radius centered at the reactor plus all people within a 45° angular sector within the plume exposure pathway EPZ and centered on the downwind direction will be evacuated and temporarily relocated. However, if the duration of release would exceed 3 hours, the cost of evacuation is based on the assumption that all people within the entire plume exposure pathway EPZ would be evacuated and temporarily relocated. For either of these situations, the cost of evacuation and relocation is assumed to be $225 (1980 dollars) per person, which includes cost of food and temporary sheltering for a period of 1 week.

F.2 Early Health Effects Model

The medical advisors to the Reactor Safety Study (WASH-1400, Appendix IV, Section 9.2.2, and Appendix F) proposed three alternative dose-mortality relationships that can be used to estimate the number of early fatalities in an exposed population. These alternatives characterize different degrees of postexposure medical treatment, from "minimal" to "supportive" to "heroic"; they are more fully described in NUREG-0340. There is uncertainty associated with the mortality relationships (NUREG/CR-3185) and the availability and effectiveness of different classes of medical treatment (Andrulis, 1982).

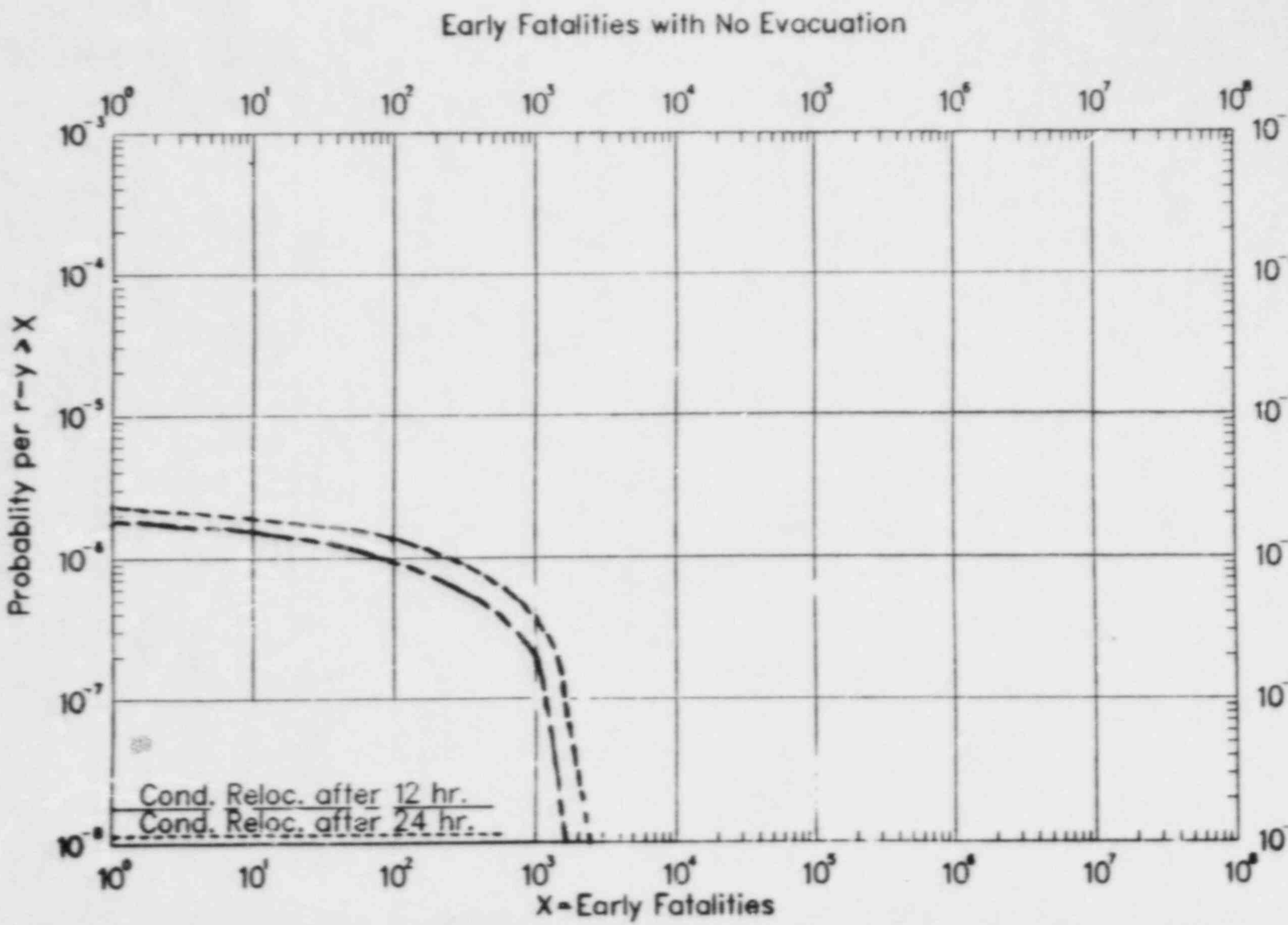

Figure F.1 Sensitivity of early fatalities to evacuation characteristics (See Section 5.9.4.5(7) for a discussion of uncertainties in risk estimates. See also footnote in section entitled "Dose and Health Impacts of Atmospheric Releases" for help in interpreting this figure.)

The calculated estimates of the early fatality risks presented in Section 5.9.4.5(3) of the main body of this report and in Section F.1 of this appendix used the dose-mortality relationship that is based on the supportive treatment alternative. This implies the availability of medical care facilities and services that are designed for radiation victims exposed in excess of 170 rems, the approximate level above which the medical advisors to the Reactor Safety Study recommended more than minimum medical care to reduce early fatality risks. At the extreme low-probability end of the spectrum (i.e., at the 3 chances in 100 million per reactor-year level), the number of persons involved might exceed the capacity of facilities that provide the best such services, in which case the number of early fatalities might have been underestimated. However, this number may not have been greatly underestimated, because the hospitals now in the United States are likely to be able to supply considerably better care to radiation victims than the medical care that the sometimes assumed minimal medical treatment relationship is based on. Further, a major reactor accident at Braidwood would certainly cause a mobilization of the best available medical services with a high national priority to save the lives of radiation victims. Therefore, the staff expects that the mortality risks would be less than those indicated by the RSS description of minimal treatment (and much less, of course, for those who will be given the type of treatment defined as "supportive"). For these reasons, the staff has concluded that the early fatality risk estimates are bounded by the range of uncertainties discussed in Section 5.9.4.5(7).

F.3 References

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NPDES Permit No. IL0048321

Illinois Environmental Protection Agency

Division of Water Pollution Control

2200 Churchill Road

Springfield, Illinois 62706

NATIONAL POLLUTANT DISCHARGE ELIMINATION SYSTEM

Modified (NPDES) Permit

Expiration Date: April 1, 1981
Modification Issue Date: September 30, 1980
Modification Effective Date: Oct. 30, 1980

Issue Date: December 30, 1976
Effective Date: December 30, 197(

Permittee: Commonwealth Edison Company

Facility Name and Address: Commonwealth Edison Company, Braidwood Nuclear Generating Station, Godley, Illinois, Will County

Receiving Waters: Unnamed ditch tributary to the Mazon River and the Kankakee River

In compliance with the provisions of the Illinois Environmental Protection Act, the Chapter 3 Rules and Regulations of the Illinois Pollution Control Board, and the FWPCA, the above-named permittee is hereby authorized to discharge at the above location to the above-named receiving stream in accordance with the standard conditions and attachments herein.

Permittee is not authorized to discharge after the above expiration date. In order to receive authorization to discharge beyond the expiration date, the permittee shall submit the proper application as required by the Illinois Environmental Protection Agency (IEPA) not later than 180 days prior to the expiration date.

Thomas G. McSwiggin, P.E.
Manager, Permit Section
Division of Water Pollution Control

TGM:DLR:bld/1052b/sp

Permit No. IL0048321
AS MODIFIED SEP 30 1980

PART I
bld/sp1052b

A. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

1. During the period beginning on the effective date of this permit and lasting until April 1, 1981, the permittee is authorized to discharge from outfall(s) serial number(s) 001(a) - South Construction Area Runoff.

Such discharges shall be limited and monitored by the permittee as specified below:

EFFLUENT CHARACTERISTIC	DISCHARGE LIMITATIONS kg/day (lbs/day)		Other Units (Specify)		MONITORING REQUIREMENTS*	
	Daily Avg	Daily Max	Daily Avg	Daily Max	Measurement Frequency	Sample Type
Flow-M^3/Day (MGD)	-	-	-	-	Weekly	Total Flow Estimate
Suspended Solids	-	-	-	50 mg/l	Weekly	Grab
Oil & Grease	-	-	-	15 mg/l	Monthly	Grab

*During Period of Discharge

The pH shall not be less than 6.0 nor greater than 9.0 and shall be monitored weekly on a grab.

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

Samples taken in compliance with the monitoring requirements specified above shall be taken at the following location(s): At a point representative of the discharge from the treatment system.

Permit No. IL0048321
AS MODIFIED SEP 30 1980

PART I
bld/sp1052b

A. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

1. During the period beginning on the effective date of this permit and lasting until April 1, 1981, the permittee is authorized to discharge from outfall(s) serial number(s) 001(b) - Sanitary Waste Discharge.

Such discharges shall be limited and monitored by the permittee as specified below:

EFFLUENT CHARACTERISTIC	DISCHARGE LIMITATIONS kg/day (lbs/day)		Other Units (Specify)		MONITORING REQUIREMENTS	
	Daily Avg	Daily Max	Daily Avg	Daily Max	Measurement Frequency	Sample Type
Flow-M^3/Day (MGD)	-	-	-	-	Weekly	Daily Aver. Flow Esti.
BOD5	-	-	10 mg/l	25 mg/l	Monthly	Grab
Suspended Solids	-	-	12 mg/l	30 mg/l	Monthly	Grab
Fecal Coliform	-		200 counts/100 ml	400 counts/100 ml	Monthly	Grab

The pH shall not be less than 6.0 nor greater than 9.0 and shall be monitored weekly on a grab.

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

Samples taken in compliance with the monitoring requirements specified above shall be taken at the following location(s): At a point representative of the discharge from the treatment plant.

Beginning on the effective date of this permit and continuing for a period of two (2) years, a residual chlorine test may be used in lieu of the fecal coliform laboratory analysis. A chlorine residual of a minimum of 0.2 mg/l and maximum of 0.75 mg/l is to be maintained at all times.

Permit No. IL0048321
AS MODIFIED SEP 30 1980

PART I
bld/sp1052b

A. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

1. During the period beginning on the effective date of this permit and lasting until April 1, 1981, the permittee is authorized to discharge from outfall(s) serial number(s) 002 - North Construction Area Runoff.

   Such discharges shall be limited and monitored by the permittee as specified below:

EFFLUENT CHARACTERISTIC	DISCHARGE LIMITATIONS kg/day (lbs/day)		Other Units (Specify)		MONITORING REQUIREMENTS*	
	Daily Avg	Daily Max	Daily Avg	Daily Max	Measurement Frequency	Sample Type
Flow-M^3/Day (MGD)	-	-	-	-	Weekly	Total Flow Estimate
Suspended Solids	-	-	-	50 mg/l	Weekly	Grab
Oil & Grease	-	-	-	15 mg/l	Monthly	Grab

*During Period of Discharge

The pH shall not be less than 6.0 nor greater than 9.0 and shall be monitored weekly on a grab.

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

Samples taken in compliance with the monitoring requirements specified above shall be taken at the following location(s): At a point representative of the discharge from the treatment system.

PART I

MODIFIED DATE: SEP 30 1980

MONITORING AND REPORTING

1. Representative Sampling - Samples and measurements taken as required herein shall be representative of the volume and nature of the monitored discharge.

2. Reporting - The permittee shall record monitoring results on Discharge Monitoring Report forms, using one such form for each discharge each month. The completed monthly forms shall be retained by permittee for a period of three months beginning with each calendar quarter, and the forms from those three months shall be mailed to USEPA no later than the 28th day of the following month; i.e. (a) January, February, March (submit April 28); (b) April, May, June (submit July 28); (c) July, August, September (submit October 28); October, November, December (submit January 28).

The permittee shall retain a copy of all reports submitted. All reports shall be submitted to:

U. S. Environmental Protection Agency
Attention: Chief, Compliance Unit
230 South Dearborn Street
Chicago, Illinois 60604

The permittee shall submit these monitoring reports each month to the appropriate District Office of the Illinois Environmental Protection Agency by the 15th day of the following month unless otherwise directed by the Illinois Environmental Protection Agency.

3. Noncompliance Notification - If, for any reason, the permittee does not comply with or will be unable to comply with any daily maximum effluent limitation specified in this permit, the permittee shall provide the Regional Administrator and the State with the following information, in writing, within five (5) days of becoming aware of such condition: (a) a description of the discharge; (b) cause of noncompliance, (c) the period of noncompliance, including exact dates and times; (d) if not corrected, the anticipated time the noncompliance is expected to continue, and (e) steps being taken to reduce, eliminate and prevent recurrence of the noncomplying discharge.

4. Definitions

a. "Daily Average" Discharge

1. Weight Basis - The "daily average" discharge means the total discharge by weight during a calendar month divided by the number of days in the month that the production or commercial facility was operating. Where less than daily sampling is required by this permit, the daily average discharge shall be determined by the summation of the measured daily discharges by weight divided by the number of days during the calendar month when the measurements were made.

2. Concentration Basis - The "daily average" concentration means the arithmetic average (weighted by flow value) of all the daily determinations of concentration made during a calendar month. Daily determination of concentration made using a composite sample shall be the concentration of the composite sample. When grab samples are used, the daily determination of concentration shall be the arithmetic average (weighted by flow value) of all the samples collected during the calendar day.

b. "Daily Maximum" Discharge

1. Weight Basis - The "daily maximum" discharge means the maximum total discharge by weight permitted during any calendar day.

2. Concentration Basis - The "daily maximum" concentration means the maximum value in terms of concentration permitted in the discharge during any calendar day.

5. Test Procedures - Test procedures for the analysis of pollutants shall conform to regulations published pursuant to section 304(g) of the Act, under which such procedures may be required.

6. Recording of Results - For each measurement or sample taken pursuant to the requirements of this permit the permittee shall record the following information: (a) the exact place, date, and time of sampling; (b) the dates the analyses were performed; (c) the person(s) who performed the analyses; (d) the analytical techniques or methods used; and (e) the results of all required analyses.

7. Additional Monitoring by Permittee - If the permittee monitors any pollutant at the location(s) designated herein more frequently than required by this permit, using approved analytical methods as specified above, the results of such monitoring shall be included in the calculation and reporting of the values required in the Discharge Monitoring Report Form (EPA No. 3320-1). Such increased frequency shall also be indicated.

8. Records Retention - All records and information resulting from the monitoring activities required by this permit including all records of analyses performed and calibration and maintenance of instrumentation and recordings from continuous monitoring instrumentation shall be retained for a minimum of three (3) years, or longer if requested by the Regional Administrator or the State Water Pollution Control Agency.

PART II - A. MANAGEMENT REQUIREMENTS

1. Change in Discharge - All discharges authorized herein shall be consistent with the terms and conditions of this permit. The discharge of any pollutant identified in this permit more frequently than or at a level in excess of that authorized shall constitute a violation of the permit. Any anticipated facility expansions, production increases, or process modifications which will result in new, different, or increased discharges of pollutants must be reported by submission of a new NPDES application or, if such changes will not violate the effluent limitations specified in this permit, by notice to the permit issuing authority of such changes. Following such notice, the permit may be modified to specify and limit any pollutants not previously limited.

SEP 30 1980

MODIFIED DATE:

2. Facilities Operation - The permittee shall at all times maintain in good working order and operate as efficiently as possible all treatment or control facilities or systems installed or used by the permittee to achieve compliance with the terms and conditions of this permit.

3. Adverse Impact - The permittee shall take all reasonable steps to minimize any adverse impact to navigable waters resulting from noncompliance with any effluent limitations specified in this permit, including such accelerated or additional monitoring as necessary to determine the nature and impact of the noncomplying discharge.

4. Bypassing - Any diversion from or bypass of facilities necessary to maintain compliance with the terms and conditions of this permit is prohibited, except (i) where unavoidable to prevent loss of life or severe property damage, or (ii) where excessive storm drainage or runoff would damage any facilities necessary for compliance with the effluent limitations and prohibitions of this permit. The permittee shall promptly notify the Regional Administrator and the State in writing of each such diversion or bypass.

5. Removed Substances - Solids, sludges, filter backwash, or other pollutants removed from or resulting from treatment or control of wastewaters shall be disposed of in a manner such as to prevent any pollutant from such materials from entering navigable waters.

6. Power Failures - In order to maintain compliance with the effluent limitations and prohibitions of this permit, the permittee shall either: (a) in accordance with the Schedule of Compliance contained in Part I, provide an alternative power source sufficient to operate the wastewater control facilities; or, if no date implementation appears in Part I, (b) halt, reduce or otherwise control production and/or all discharges upon the reduction, loss, or failure of one or more of the primary sources of power to the wastewater control facilities.

B. RESPONSIBILITIES

1. Right of Entry - The permittee shall allow the head of the State Water Pollution Control Agency, the Regional Administrator, and/or their authorized representatives, upon the presentation of credentials: (a) to enter upon the permittee's premises where an effluent source is located or in which any records are required to be kept under the terms and conditions of this permit; and (b) at reasonable times to have access to and copy any records required to be kept under the terms and conditions of this permit; to inspect any monitoring equipment or monitoring method required in this permit; and to sample any discharge of pollutants.

2. Transfer of Ownership or Control - In the event of any changes in control or ownership of facilities from which the authorized discharges emanate, the permittee shall notify the succeeding owner or controller of the existence of this permit by letter, a copy of which shall be forwarded to the Regional Administrator and the State Water Pollution Control Agency.

3. Availability of Reports - Except for data determined to be confidential under Section 308 of the Act, all reports prepared in accordance with the terms of this permit shall be available for public inspection at the offices of the State Water Pollution Control Agency and the Regional Administrator. As required by the Act, effluent data shall not be considered confidential. Knowingly making any false statement on any such report may result in the imposition of criminal penalties as provided for in Section 309 of the Act.

4. Permit Modification - After notice and opportunity for a hearing, this permit may be modified, suspended, or revoked in whole or in part during its term for cause including, but not limited to, the following: (a) violation of any terms or conditions of this permit; (b) obtaining this permit by misrepresentation or failure to disclose fully all relevant facts; or (c) a change in any condition that requires either a temporary or permanent reduction or elimination of the authorized discharge.

5. Toxic Pollutants - Notwithstanding Part II, B-4 above, if a toxic effluent standard or prohibition (including any schedule of compliance specified in such effluent standard or prohibition) is established under Section 307(a) of the Act for a toxic pollutant which is present in the discharge and such standard or prohibition is more stringent than any limitation for such pollutant in this permit, this permit shall be revised or modified in accordance with the toxic effluent standard or prohibition and the permittee so notified.

6. Civil and Criminal Liability - Except as provided in permit conditions on "Bypassing" (Part II, A-4) and "Power Failures" (Part II, A-6), nothing in this permit shall be construed to relieve the permittee from civil or criminal penalties for noncompliance.

7. Oil and Hazardous Substance Liability - Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties to which the permittee is or may be subject under Section 311 of the Act.

8. State Law - Nothing in this permit shall be construed to preclude the institution of any legal action or relieve the permittee from any responsibilities, liabilities, or penalties established pursuant to any applicable State law or regulation under authority preserved by Section 510 of the Act.

9. Property Rights - The issuance of this permit does not convey any property rights in either real or personal property, or any exclusive privileges, nor does it authorize any injury to private property or any invasion of personal rights, nor any infringement of Federal, State or local laws or regulations.

10. Severability - The provisions of this permit are severable, and if any provision of this permit, or the application of any provision of this permit to any circumstance, is held invalid, the application of such provision to other circumstances, and the remainder of this permit, shall not be affected thereby.

PART III

A. OTHER REQUIREMENTS

1. Additional Reporting of Monitoring to Illinois Environmental Protection Agency

   Monitoring results obtained during the previous one month shall be summarized and reported on a Discharge Monitoring Report Form (EPA No. 3320-1) and mailed no later than the 15th day of the month following the completed reporting period. The first monthly report is due on June 15, 1976. The signed reports required herein, shall be submitted monthly to the State at the following address:

   Environmental Protection Agency
   State of Illinois
   Division of Water Pollution Control
   2200 Churchill Road
   Springfield, Illinois 62706

   Attention: Compliance Assurance Unit

2. This Permit incorporates all applicable provisions of the Illinois Environmental Protection Act and of the Rules and Regulations of the Illinois Pollution Control Board, as if they were set forth herein. All such provisions shall become conditions of this Federal NPDES permit granted to you as provided by Section 401(d) of the Federal Water Pollution Control Act Amendments of 1972.

3. This permit is specifically for the listed pollutants to be discharged from the designated outfalls only. Discharge of pollutants added in other than trace amounts or discharged from an undesignated outfall is not permitted.

B. Rainfall Runoff

1. Rainfall runoff from construction activity at the generating facility site and from material storage areas shall be controlled to meet all effluent restrictions specified in Part I A(3) of this permit.

2. Any untreated overflow from facilities designed, constructed and operated to treat the volume of material storage runoff and construction runoff which is associated with a 10 year, 24 hour rainfall event shall not be subject to the limitations for Suspended Solids and pH specified in Part I A(3) of this permit.

C. Erosion Control

The permittee shall utilize EPA Publication No. 430/9-73-007 "Process, Procedures, and Methods to Control Pollution Resulting from Construction Activity," October 1973, in developing and implementing procedures and methods for controlling erosion and sediment deposition.

As a minimum, the following practices shall be instituted:

1. Minimization of the duration of excavation and grading activities.

2. Control of the speed and volume of stormwater runoff, as necessary, by:

   a. Proper sizing of drainage ditches;
   b. Use of energy dissipative devices such as check dams and pooling area.

3. Construction of sediment traps and settling areas as necessary to prevent sediment from leaving the site.

4. Soil stabilization by minimizing slopes, revegetating spoil banks and cleared surfaces by seeding or sodding and through the proper and timely surfacing of parking lots, roads and laydown areas with crushed rock or gravel.

5. Taking all necessary precautions to minimize erosion through proper timing and installation of necessary erosion control devices, by avoiding land clearing in fall (insofar as feasible) and prior to installation of sediment traps, runoff drainage system or any necessary impoundments for sediment control.

D. Control of Other Construction - Related Activity

1. The company will dike and berm such areas as necessary to prevent accidental spills and leakage of fuel and oil.

2. Proper receptables will be provided for collection of oil-soaked rags and papers to prevent contact with area runoff.

3. In the event that drainage from equipment maintenance area results in discharges of oil to the receiving waters, such discharges will meet the following effluent quality and will be monitored during periods of discharge at a representative point prior to discharge into receiving waters:

Parameter	Limits Monthly Average	Limits Daily Maximum	Frequency	Sample Type
Flow			Monthly	Daily Maximum Flow Estimate
Oil and Grease	15 mg/l	20 mg/l	Monthly	Grab

E. Intake Structure Requirements

Within 180 days of the issuance of this permit, the permittee shall submit to the Regional Administrator and the Illinois Environmental Protection Agency a demonstration detailing the ability of the intake system to meet the requirements of Section 316(b) of the Act. The report shall be based on presently available information regarding receiving water hydrology, intake siting and design, proposed intake operation and the biological population. Development of the report shall be guided by the "Development Document for Minimizing Adverse Environmental Impact for Cooling Water Intake Structures," as proposed by the U.S. EPA, and any other publications relating to intake impacts.

This report will be evaluated with regard to Section 316(b) of the Act. As a result of this evaluation, the Regional Administrator may modify the permit in accordance with Part II B.4 to establish an implementation schedule to insure compliance with Section 316(b).

F. "This permit may be modified or revised, or, alternatively revoked and reissued, to comply with an applicable effluent limitation issued purusant to the order of the United States District Court for the District of Columbia issued on June 8, 1976, in Natural Resources Defense Council, Inc. et. al. v. Russell E. Train, 8 ERC 2120 (D.D.C. 1976), in the effluent limitation so issued:

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

2. controls any pollutant not limited in the permit."

This permit may be revised, following notice by the Agency that applicable effluent limitations covered by the Natural Resources Defense Council, Inc. et. al. v. Train, 8 E.R.C. 2120 (D.D.C. 1976) will not be promulgated, to incorporate any applicable effluent limitations determined unuer Section 402(a)(1) of the Federal Water Pollution Control Act. (FWPCA) Amendments of 1972 as necessary to carry out the provisions of Section 301(b)(2)(a) of the FWPCA, if the effluent limitations so determined;

a. Is more stringent than any effluent limitation in the permit; or

b. Controls any pollutant not limited in the permit.

PART IV

Proposed Conditions for Future Discharges

The following are proposed conditions for a permit to be issued to the Company upon the expiration of this permit on April 1, 1981. These proposed conditions reflect the present assessment of U.S. EPA and the Illinois EPA and are for informational purposes only. The limitations apply to discharges or waste sources not in existence during the construction phase of the Braidwood Generating Station.

Permit No. IL008321
AS MODIFIED SEP 30 1986

PART IV
bld/sp1052b

A. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

1. During the period beginning April 2, 1981 and lasting until April 2, 1986, the permittee is authorized to discharge from outfall(s) serial number(s) Boiler Blowdown, Demineralizer Wastes, Radiation Waste Treatment System, Filter Backwash.

Such discharges shall be limited and monitored by the permittee as specified below:

EFFLUENT CHARACTERISTIC	DISCHARGE LIMITATIONS kg/day (lbs/day)		Other Units (Specify)		MONITORING REQUIREMENTS	
	Daily Avg	Daily Max	Daily Avg	Daily Max	Measurement Frequency	Sample Type
Flow-M^3/Day (MGD)	-	-	-	-	Weekly	Daily Average Flow Estimate
Suspended Solids	-	-	-	15 mg/l	Weekly	8-hr composite
Total Copper	-	-	-	1.0 mg/l	Weekly	8-hr composite
Total Iron	-	-	-	1.0 mg/l	Weekly	8-hr composite

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

Samples taken in compliance with the monitoring requirements specified above shall be taken at the following location(s): At a point representative of the treatment system discharge prior to dilution with condenser cooling water.

Permit No. IL004821
AS MODIFIED SEP 30 1980

PART IV
bld/sp1052b

A. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

1. During the period beginning on April 2, 1981 and lasting until April 2, 1986, the permittee is authorized to discharge from outfall(s) serial number(s) Intake Screen Backwash.

Such discharges shall be limited and monitored by the permittee as specified below:

EFFLUENT CHARACTERISTIC	DISCHARGE LIMITATIONS kg/day (lbs/day)		Other Units (Specify)		MONITORING REQUIREMENTS	
	Daily Avg	Daily Max	Daily Avg	Daily Max	Measurement Frequency	Sample Type
Flow-M^3/Day (MGD)	-	-	-	-	Monthly	Daily Average Flow Estimate

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

Samples taken in compliance with the monitoring requirements specified above shall be taken at the following location(s): N/A

PART IV
bld/sp1052b

A. EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

1. During the period beginning on April 2, 1981 and lasting until April 2, 1986, the permittee is authorized to discharge from outfall(s) serial number(s) Cooling System Blowdown.

Such discharges shall be limited and monitored by the permittee as specified below:

EFFLUENT CHARACTERISTIC	DISCHARGE LIMITATIONS kg/day (lbs/day)		Other Units (Specify)		MONITORING REQUIREMENTS	
	Daily Avg	Daily Max	Daily Avg	Daily Max	Measurement Frequency	Sample Type
Flow-M^3/Day (MGD)	-	-	-	-	Continuous	Continuous
Total Chlorine Residual (1)*	-	-	-	0.2 mg/l*	Continuous During Chlorination	
Discharge Temperature (1)	-	-	-	-	Continuous	Continuous
Intake Temperature	-	-	-	-	Continuous	Continuous
Plant Load Factor	-	-	-	-	Monthly Average	

The pH shall not be less than 6.0 nor greater than 9.0 and shall be monitored on a continuous basis at the discharge to the discharge canal.

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

Samples taken in compliance with the monitoring requirements specified above shall be taken at the following location(s): (1) measured at a point representative of the discharge to the Kankakee River.

A.4. THERMAL EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS

Discharge of wastewater from this facility must not alone or in combination with other sources cause the receiving stream to violate the following thermal limitations:

a. Maximum temperature rise above natural temperature must not exceed 5oF.

b. Water temperature at representative locations in the main river shall not exceed the maximum limits in the following table during more than one (1) percent of the hours in the 12-month period ending with any month. Moreover, at no time shall the water temperature at such locations exceed the maximum limits in the following table by more than 3oF. (Main river temperatures are temperatures of those portions of the river essentially similar to and following the same thermal as the temperatures of the main flow of the river.)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.
oF	60	60	60	90	90	90	90	90	90	90	90	60
oC	15.6	15.6	15.6	32.2	32.2	32.2	32.2	32.2	32.2	32.2	32.2	15.6

c. The mixing zone shall not extend over more than 25% of the cross-sectional area of the river.

d. In addition, the permittee shall perform the following thermal monitoring:

The permittee shall determine the 2.8oC(5oF) contour, the contour of the applicable monthly maximum and the areas within these contours at three (3) month intervals for a period of one year after the effective date of this permit. After the initial year of measurements, the permittee shall continue to determine these areas and contours every three months but may use estimating procedures based on the first years data. The results of these determinations shall be reported to the Regional Administrator and the Illinois EPA on a quarterly basis.

APPENDIX H

HISTORIC AND ARCHEOLOGIC SITES

STATE OF ILLINOIS
DEPARTMENT OF CONSERVATION
SPRINGFIELD 62706

[redacted]

RECEIVED FEB 15 1974

Docket Nos.: STN 50-454, STN 50-455
STN 50-456, STN 50-457
STN 50-461, STN 50-462

DOCKETED USAEC FEB 15 1974 REGULATORY MAIL SECTION DOCKET CLERK

Mr. Daniel R. Muller
Assistant Director for Environmental Projects
Directorate of Licensing
U. S. Atomic Energy Commission
Washington, D. C. 20545

Dear Mr. Muller:

The environmental reports prepared by Commonwealth Edison on Braidwood Station (Units 1 and 2, Will County) and Byron Station (Units 1 and 2, Ogle County) and Illinois Power Company's environmental report on the Clinton Power Station (Units 1 and 2, De Witt County) have been reviewed. This review was made to determine what effect, if any, undertaking the Byron, Braidwood, or Clinton projects would have on cultural and historical sites of significance within or adjacent to project work boundaries.

Archaeological studies conducted on the project sites by members of the Illinois Archaeological Survey for Illinois Power and Commonwealth Edison indicate the existence of archaeological sites within the boundaries of each of the three projects. Results of the archaeological surveys for each site should be included in the final environmental statements. The final statements should also indicate Commonwealth Edison's and Illinois Power's plans for archaeological salvage of the located sites and their plans for recording and salvage of archaeological sites which may be discovered during project construction.

It has been determined that, with the exception of the aforementioned archaeological sites, no cultural or historical sites of significance are located within the projects' boundaries. No National Register of

RECYCLED PAPER

2.6A-1

1258

Historic Places sites are found within the project boundaries of the Braidwood, Byron, or Clinton Power Stations.

Sincerely,

Anthony T. Dean

Anthony T. Dean
Director
State Historic Preservation Officer

ATD:gjf

cc. Mr. George Montet, Building 11A, Environmental Statement Projects, Argonne National Laboratory, 9700 South Cass Avenue, Argonne, Illinois 60439

Mr. Charles Bareis, Illinois Archaeological Survey, 109 Davenport Hall, University of Illinois, Urbana, Illinois 61801

Mrs. Ann Webster Smith, Director, Office of Compliance, Advisory Council on Historic Preservation, Washington, D. C. 20240

ILLINOIS ARCHAEOLOGICAL SURVEY

109 DAVENPORT HALL   UNIVERSITY OF ILLINOIS   URBANA, ILLINOIS 61801

Cooperating Institutions:
University of Illinois
Southern Illinois University
Illinois State Museum

April 15, 1974

Mr. Daniel R. Muller
Assistant Director for Environmental Projects
United States Atomic Energy Commission
Washington, D.C. 20545

Dear Mr. Muller:

Thank you for a Draft Environmental Statement of the Braidwood Station, Will County, Illinois, of the Commonwealth Edison Company. An archaeological assessment for this station was prepared by the Illinois State Museum, one of our affiliates, and your summary on Page 2-1 of their findings is adequate.

We appreciate your concern with preserving our archaeological environment.

Cordially yours,

Charles J. Bareis

Charles J. Bareis
Secretary-Treasurer

CJB:dg

Commonwealth Edison
72 West Adams Street, Chicago, Illinois
Address Reply to: Post Office Box 767
Chicago, Illinois 60690

June 24, 1983

Ms. Margaret K. Brown
Illinois Department of Conservation
405 East Washington Street
Springfield, Illinois 62706

Dear Ms. Brown:

The Illinois State Museum conducted archaeological investigations along Commonwealth Edison's transmission line right-of-way between the Braidwood Generating Station and the Crete Transmission Substation. The investigations were begun in 1978 and continued into 1980. An interim report covering this work was issued in 1981. The investigations were completed in 1983 and a final summarizing report has been prepared. Copies of both reports are enclosed for your review and comments.

The initial phase of the investigations was a survey of the right-of-way between Braidwood Station and the proposed Davis Creek Transmission Substation (there were four parcels that were contested and access was not available for survey). Three sites were located on this right-of-way and, since none of these sites needed to be impacted by construction, in 1980 Museum personnel resurveyed and flagged the sites so that they could be avoided by construction crews. However, only one of these sites, 11 Ka 179, was evaluated as being potentially eligible for nomination to the National Register of Historic Places and deemed worthy of protection from impact before further evaluations are made. Five sites were located on the substation site and since all of them could be impacted, resurvey testing was done prior to the beginning of substation construction activities in 1979. Each site was subjected to intensive surficial examination and collection. Three of the sites, plus an additional site that was identified during the resurvey, were also subjected to subsurface testing by shovel probes and soil cores. No additional cultural features were found by surficial examination or subsequent subsurface testing on any of these sites.

Investigations of the Davis Creek to Crete portion of the right-of-way began in 1979 and continued in 1980 at which time all but four contested land parcels had been surveyed. Five prehistoric and one historic site were located on this segment of the right-of-way. One of the prehistoric sites which was located under an existing line on the right-of-way and the historic site were not recommended for further investigation. Resurvey testing on the other four prehistoric sites in 1983 revealed no subsurface cultural features at any of the sites. Survey work was also done in 1983 on the four parcels which were previously unavailable because of owner objections. At two locations landowners still refused full access to conduct the survey. In one case the small area of land will not be affected by construction and on the other, survey work will be conducted in 1984 when construction of the transmission line is scheduled to begin and if any cultural resources are found, the site(s) will be avoided or retested.

The archaeological investigations were also conducted on the four previously contested parcels on the Braidwood to Davis Creek portion of the right-of-way in 1983. Only one new site was located but was not recommended for protection from future impact. This site was not impacted by the construction of the transmission line in 1980.

All of the recommended resurvey work has been completed. The final recommendations of the investigators are for unrestricted clearance on the corridor and substation except for two unsurveyed parcels on the Davis Creek to Crete R/W, and one site, 11Ka179. This site will be recorded on our engineering drawings so that proper notification can be made if any future construction is planned that would impact on it.

We hereby request your concurrence that we have adequately addressed the archaeological resources on the Braidwood-Davis Creek-Crete right-of-way associated with the Braidwood Station.

If there are any questions regarding this matter or the original report, please contact me at 312/294-4431 or Ben Barickman 312/294-4437.

Sincerely,

C. L. McDonough

C. L. McDonough
Director of Environmental Assessment

2555E
BBB:CLM:pp
Enclosure

CONCUR
By: William G. Farrar
Deputy State Historic Preservation Officer
Date: 7/7/83

NRC FORM 335
(8-83)

U.S. NUCLEAR REGULATORY COMMISSION

BIBLIOGRAPHIC DATA SHEET

1. REPORT NUMBER (Assigned by TIDC, add Vol. No., if any)

NUREG-1026

2. Leave blank

3. TITLE AND SUBTITLE

Final Environmental Statement related to the Operation of Braidwood Station, Units 1 and 2

4. RECIPIENT'S ACCESSION NUMBER

5. DATE REPORT COMPLETED

MONTH	YEAR
June	1984

6. AUTHOR(S)

7. DATE REPORT ISSUED

MONTH	YEAR
June	1984

8. PERFORMING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)

Division of Licensing
Office of Nuclear Reactor Regulation
U. S. Nuclear Regulatory Commission
Washington, D. C. 20555

9. PROJECT/TASK/WORK UNIT NUMBER

10. FIN NUMBER

11. SPONSORING ORGANIZATION NAME AND MAILING ADDRESS (Include Zip Code)

Same as 8 above.

12a. TYPE OF REPORT

Technical

12b. PERIOD COVERED (Inclusive dates)

November 30, 1978 - June 30, 1984

13. SUPPLEMENTARY NOTES

Docket Nos. STN 50-456 and STN 50-457

14. ABSTRACT (200 words or less)

The information in this statement is the second assessment of the environmental impact associated with the construction and operation of the Braidwood Station, Units 1 and 2, located in northeastern Illinois within Reed Township, Will County, Illinois. The first assessment was the Final Environmental Statement related to construction issued in July 1974 prior to issuance of the Braidwood Construction Permits. The present assessment is the result of the NRC staff review of the activities associated with the proposed operation of the plant.

15a. KEY WORDS AND DOCUMENT ANALYSIS

Braidwood Station, Units 1 ans 2
Final Environmental Statement

15b. DESCRIPTORS

16. AVAILABILITY STATEMENT

Unlimited

17. SECURITY CLASSIFICATION (This report)

Unclassified

18. NUMBER OF PAGES

19. SECURITY CLASSIFICATION (This page)

Unclassified

20. PRICE

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120555078877 1 1AN
US NRC
ADM-DIV OF TIDC
POLICY & PUB MGT BR-PDR NUREG
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NUCLEAR REGULATORY COMMISSION
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