5.7 Meteorological and Air Quality Impacts

The primary impacts of operation of the proposed Fermi 3 on local meteorology and air quality would be from releases to the environment of heat and moisture from the primary cooling system, operation of auxiliary equipment (e.g., generators and a boiler), and mobile emissions (e.g., worker vehicles) (Detroit Edison 2011a). The potential impacts of releases from operation of the cooling system are discussed in Section 5.7.1. Section 5.7.2 discusses potential air quality impacts from nonradioactive effluent releases from Fermi 3, and Section 5.7.3 discusses the potential air quality impacts associated with transmission lines during plant operation.

5.7.1 Cooling System Impacts

The proposed cooling system for Fermi 3 is a NDCT. The proposed NDCT removes excess heat by evaporating water. Upon exiting the tower, water vapor would mix with the surrounding air, and this process would generally lead to condensation and formation of a visible plume, which would have aesthetic impacts. Other meteorological and atmospheric impacts include fogging, icing, drift deposition from dissolved salts and chemicals found in the cooling water, cloud formation, plume shadowing, additional precipitation, and increased humidity. In addition, plumes from the NDCT could interact cumulatively with emissions from other sources and the Fermi 2 cooling towers. Two four-cell mechanical draft cooling towers (MDCTs) will be used to dissipate heat from the Plant Service Water System usually during plant shutdown (Detroit Edison 2011a). The heat dissipated by the MDCTs is orders of magnitude less than that dissipated by the NDCT, and its impacts are bounded by the impacts of the NDCT and are not discussed further.

The Electric Power Research Institute's SACTI (Seasonal/Annual Cooling Tower Impact) prediction computer code was used by Detroit Edison to estimate impacts associated with operating the NDCT. Site-specific, tower-specific, and circulating water-specific engineering data were used as input to the SACTI model. Five years (2003–2007) of onsite meteorological data combined with meteorological data from the Detroit Metropolitan Airport and mixing height data from White Lake, Michigan, were used (Detroit Edison 2011a). The NDCT was simulated by using a height of 600 ft and a top exit diameter of 292 ft.

5.7.1.1 Visible Plumes

Results from the SACTI analysis, as reported in the ER (Detroit Edison 2011a), indicated that, on average, the longest plumes would occur in the winter and the shortest in the summer. The model predicts an average plume length of about 1.5 mi in the winter and 0.24 mi in the summer. On an annual basis, SACTI predicts the plume lengths from the NDCT will be less than 3281 ft about half the time. For comparison, the nearest plant boundary is 2766 ft from the NDCT. The highest probability of a visible plume at the distance of the nearest plant boundary is 7.33 percent in any particular direction. The frequency of occurrence of long cooling tower plumes from the NDCT in a given direction is expected to be low and does not warrant mitigation.

Ground-level fogging occurs when a visible plume from a cooling tower contacts the ground. As noted in the ER (Detroit Edison 2011a), the SACTI model, based on studies of actual NDCTs, assumes that the occurrence of fogging is an insignificant event due to the height of the NDCTs and does not estimate their occurrence. However, meteorological conditions favoring natural fogs also favor cooling tower fogging. Natural fogging in the Fermi region occurs about 18 days per year on average (NCDC 2010). Any plume-induced event would thus be infrequent and likely to occur concurrently with a natural fog. Thus, the impacts of plume-induced fogging from the NDCT are expected to be negligible and would not warrant mitigation.

5.7.1.2 Icing

Icing may occur when the cooling tower plume comes in contact with the ground (i.e., fogging occurs) at below-freezing temperatures. There are about 130 days per year with a minimum temperature at or below freezing in the area (NCDC 2010). Icing would thus be less frequent than fogging because about one-third of fogging occurs in nonfreezing months. Thus, the impacts of plume-induced icing from the NDCT are expected to be negligible and would not warrant mitigation.

5.7.1.3 Drift Deposition

The NDCT would use drift eliminators to minimize the loss of cooling water from the tower via drift, but some droplets would still escape from the tower along with the moving airstream and would be deposited on the ground. Cooling water is also treated prior to discharge to reduce salt concentration. The SACTI model predicted maximum deposition rates of 0.0001 kg/ha/mo annually between 13,779 and 30,840 ft and 0.0002 kg/ha/mo during the winter between 14,436 and 30,840 ft east-northeast of the NDCT (Detroit Edison 2011a). These maximum impacts are well below the levels considered acceptable in NUREG-1555 (NRC 2000a) (i.e., deposition of salt drift at rates of 1 to 2 kg/ha/mo), which are generally not damaging to plants. Thus, the impacts of salt deposition on vegetation are expected to be negligible, and no further mitigation is warranted.

5.7.1.4 Cloud Formation and Plume Shadowing

Cloud formation due to NDCTs has been observed at several power plants (Detroit Edison 2011a). Plume shadowing from cloud development or from the cooling tower plume itself is predicted by the SACTI model by calculating the average number of hours the visible plume would shadow the ground. Maximum shadowing would occur 656 ft north of the NDCT for an average of 348 hr per year. Beyond the nearest property boundary, the average hours of plume shadowing would be about 92 hr per year, 2.1 percent of the annual daylight hours, which would be insignificant in terms of effects on agricultural production. Thus, the impacts of plume shadowing are expected to be minimal and would not require mitigation.

5.7.1.5 Additional Precipitation

Occasional light drizzle and snow have been observed within a few hundred meters of cooling towers. These events are localized and should have no effect beyond the plant boundaries (Detroit Edison 2011a). The SACTI model assesses additional precipitation as water deposition. The SACTI model predicted maximum water deposition of 5.9 kg/km^2/mo between 15,000 ft and 31,000 ft east-northeast of the Fermi 3 NDCT with an average deposition of 2.2 kg/km^2/mo within the 31,000-ft distance (considering all wind directions of plume travel). This maximum deposition is about 0.0001 percent of the average driest monthly rainfall and at most 0.000003 hundredths of an inch of additional ice accumulation in the Fermi area.

Meteorological conditions conducive to induced snowfall can occur at the Fermi site. Observed snowfall accumulations associated with operating cooling towers have been less than 1 in. of very light, fluffy snow and have been only a small fraction of the snowfalls (about 44 in.) typical for the area (NCDC 2010). Thus, impacts of additional precipitation from the Fermi 3 NDCT are expected to be minimal and would not require mitigation.

5.7.1.6 Humidity Increases

Both the absolute and relative humidity aloft would increase in the vicinity of the NDCT vapor plume, as shown by the presence of a visible plume predicted by the SACTI model (Detroit Edison 2011a). However, ground-level increases in absolute humidity would be smaller. Increases in relative humidity could be larger in colder weather due to relatively low moisture-bearing capacities of cold air. Any increases in humidity should be localized and short-lived as the plume disperses and mixes with the far larger volume of surrounding air. Thus, increases in ground-level humidity are expected to be minimal and would not warrant mitigation.

5.7.1.7 Interaction with Other Pollutant Sources

The existing Fermi 2 NDCTs are located about 0.58 and 0.73 mi northeast of the planned location of the Fermi 3 NDCT (Detroit Edison 2011a). The plumes would usually travel in parallel, rather than in intersecting directions. Potential cumulative interaction of existing and new cooling tower plumes is expected to be insignificant, given the large separation distance and the fact that the plumes would travel along nonintersecting paths most of the time.

Existing combustion sources such as diesel generators and boilers currently operate infrequently at the Fermi site (not typically during normal plant operations); combustion sources that would be associated with Fermi 3 would similarly operate for limited periods. With the exception of particulates, these combustion sources emit pollutants (such as nitrogen oxides

[NO_x], sulfur dioxide [SO_2], and carbon monoxide [CO]) that are different from those produced by cooling towers (i.e., small amounts of particulate matter as drift). Interaction among pollutants emitted from these sources and the cooling tower plumes would be intermittent and would not have a significant impact on air quality. Based on the above considerations and the assumption that cooling towers associated with Fermi 3 would be similar to existing cooling towers used at other nuclear sites, the review team concludes that the cooling tower impacts on air quality would be minimal and additional mitigation of air quality impacts would not be warranted.

5.7.1.8 Summary of Cooling System Impacts

On the basis of the analysis presented by Detroit Edison in the ER and the review team's independent evaluation of that analysis, the review team concludes that atmospheric impacts of cooling tower operation would be minor and that no further mitigation is warranted.

5.7.2 Air Quality Impacts

Section 2.9 describes the meteorological characteristics and air quality of the Fermi site. Sources of air emissions (Detroit Edison 2011a) include stationary combustion sources (two SDGs, two ADGs, two diesel-driven FPs, and an auxiliary boiler), cooling towers (an NDCT and two MDCTs), and mobile sources (worker vehicles, onsite heavy equipment and support vehicles, and delivery of materials and disposal of wastes). Stationary combustion sources would operate only for limited periods, often for periodic maintenance testing. The NDCT would operate for the entire year, while the two four-cell MDCTs would operate during limited operating scenarios and during shutdown.

5.7.2.1 Criteria Pollutants

Air pollutants emitted from stationary combustion sources (e.g., particulates, sulfur oxides, carbon monoxide, volatile organic compounds [VOCs], and nitrogen oxides) and from cooling towers (particulates as drift) associated with Fermi 3 operations would be permitted in accordance with MDEQ and Federal regulatory requirements. Shown in Table 5-22 are Detroit Edison's estimated annual emissions for stationary combustion sources during operation of Fermi 3, which are based on the anticipated number of units, power rating, and hours of operation: 48 hr per year for two SDGs and two diesel-driven FPs; 8 hr per year for two ADGs; and 720 hr per year for an auxiliary boiler. In addition, $PM_{2.5}$ (particulate matter with an aerodynamic diameter of less than or equal to 2.5 μm) emissions for cooling towers were estimated based on continuous operation for the entire year at the maximum water flow rate.

Monroe County has been designated nonattainment for $PM_{2.5}$ and maintenance for 8-hr ozone (EPA 2010a). In July 2011, the MDEQ submitted a request asking the EPA to redesignate southeast Michigan as being in attainment with the $PM_{2.5}$ NAAQS (MDEQ 2011). In July 2012,

Table 5-22. Estimated Annual Emissions of $PM_{2.5}$, NO_x, VOCs, SO_2, and CO_2 Associated with Operation of Fermi 3

	Annual Emissions (tons/yr)				
Source Category	**$PM_{2.5}$**	**NO_x**	**VOCs**	**SO_2**	**CO_2**
Stationary combustion sources[(a)]	0.85	9.91	0.94	0.11	7734
NDCT[(b)]	6.63	NA[(c)]	NA	NA	NA
MDCT[(b)]	1.84	NA	NA	NA	NA
Worker vehicles[(d)]	0.18	5.63	6.47	0.13	14,419
Onsite heavy equipment and support vehicles	0.01	0.19	0.17	0.00[(e)]	228
Delivery of materials and disposal of wastes[(f)]	0.00	0.18	0.03	0.00	32
Total	**9.51**	**15.9**	**7.61**	**0.24**	**22,413**

Source: Detroit Edison 2011a, 2012d

(a) Includes emissions from two SDGs, two ADGs, two diesel-driven FPs, and an auxiliary boiler.

(b) It is conservatively assumed that the NDCT and one of the two MDCTs would continuously operate for the entire year at the maximum water flow rate. Typically, the two MDCTs would operate during plant shutdown conditions only, which normally last one month.

(c) NA = Not applicable.

(d) It is assumed that operation workers would travel through the nonattainment/maintenance area to and from the Fermi site with a roundtrip distance of 39.3 mi.

(e) 0.00 denotes less than 0.005.

(f) It is assumed that delivery trucks would travel from the Fermi site to the farthest point within the nonattainment/maintenance area with a roundtrip distance of 184 mi.

the EPA issued a proposed rule designating southeastern Michigan as having attained both the 1997 annual $PM_{2.5}$ NAAQS and the 2006 24-hour $PM_{2.5}$ NAAQS, based on 2009–2011 ambient air monitoring data (77 FR 39659, dated July 5, 2012), but the final determination has yet to be made. If this designation is eventually approved, Monroe County would then become a maintenance area for $PM_{2.5}$. In either case, facility operations for Fermi 3 are subject to conformity analysis under 40 CFR Part 93, Subpart B. Thus, Detroit Edison provided estimates for project-related direct and precursor emissions of $PM_{2.5}$ and ozone ($PM_{2.5}$, NO_x, VOCs, and SO_2). PM_{10} (particulate matter with an aerodynamic diameter of less than or equal to 10 μm) emissions from operation were not estimated to determine the applicability of conformity requirements for operations because the area is designated as an attainment area for PM_{10}.

Table 5-22 presents Detroit Edison's estimated annual emissions associated with operations of Fermi 3. Annual emissions from operation of Fermi 3 would be up to about 0.15 percent (for $PM_{2.5}$) of total emissions in Monroe County and up to 0.03 percent (for $PM_{2.5}$) of total emissions in all neighboring counties that are currently designated as $PM_{2.5}$ nonattainment or as an ozone maintenance area (EPA 2010b).

All the estimated annual emissions shown in Table 5-22 are well below the 100 tons/yr conformity determination thresholds for direct and precursor emissions for $PM_{2.5}$ and ozone.

Therefore, a general conformity determination is unlikely to be needed for facility operations of the Fermi 3 based on Detroit Edison's emissions estimate.

New or modified sources of air pollution are considered to be a major source and need to undergo a new source review (NSR) before construction if they emit or have the potential to emit (PTE)[a] 100 tons/yr or more of any criteria air pollutant. The review team has estimated the Fermi 3 PTE for NO_x to be about 116 tons/yr (EPA 1995; MDEQ 2005), which exceeds the major source threshold. To avoid being a major source, Fermi 2 and Fermi 3 would need to limit their combined PTE to be eligible as a "synthetic minor" (or "opt-out") source.[b] Fermi 2 has a synthetic minor permit with a NO_x limit of 89.4 tons/yr based on a 12-month rolling time period, a limit that is met by monitoring monthly fuel usage and calculating the associated NO_x emissions. Detroit Edison has not initiated an application to the Air Quality Division of MDEQ for a Permit to Install for the proposed Fermi 3.

The SDGs, ADGs, and FPs would be required to comply with the requirements of the "National Emission Standards for Hazardous Air Pollutants" given in 40 CFR 63.6603 and 63.6604. These regulations specify emission limits and, for nonemergency diesels, performance tests, limitations on fuel sulfur content, and operating limitations. In addition, depending on when the engines are built and installed, there may be additional requirements under the "Standards of Performance for Stationary Compression Ignition Internal Combustion Engines" (40 CFR Part 60, Subpart IIII). These Federal requirements would be administered by the State and included in the Permit to Install. No open burning would occur during operations.

Given the small size and infrequent operation of combustion equipment, their impact on offsite air quality is expected to be minimal. The NDCT, which emits particulate matter only as drift, would be equipped with drift eliminators to limit drift to 0.001 percent or less of total water flow. The tabulated $PM_{2.5}$ emissions from the NDCT and MDCTs would account for about 89 percent of total emissions from Fermi 3 operations, but potential particulate matter (PM) impacts at the ground level outside the Fermi property would be minimal due to the tall height of the tower, which allows for good dispersion of the drift.

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[a] PTE is defined as the maximum capacity of a stationary source to emit a pollutant under its physical and operation design. Typically, PTE is the maximum amount of air pollutants that the facility could emit if it continuously operates 24 hr/day and 365 days/yr at its full design capacity with air pollution control equipment being turned off (but only if the operation of the device is required by a legally enforceable permit condition, rule, or compliance/enforcement document) (MDEQ 2005). To estimate PTE in this analysis, it is assumed that SDGs, ADGs, and diesel-driven FPs would operate 500 hr/yr each and an auxiliary boiler would operate 8760 hr/yr (EPA 1995; MDEQ 2005).

[b] A synthetic minor source is a facility that can operate as a major source, but for which the applicant is voluntarily requesting a Federally enforceable limit on one or more parameters (e.g., throughput or operating time) such that the PTE of the facility remains below major source thresholds. The legally enforceable permit conditions should contain a monitoring/recordkeeping requirement that can be used to demonstrate compliance with the permit.

There are no mandatory Class I Federal areas where visibility is an important value within a 275-mi radius of the Fermi 3 site. Considering the distance to the Class I areas and the minor nature of air emissions from the Fermi 3 site, there is little likelihood that activities at the Fermi 3 site could adversely affect air quality and air quality-related values (e.g., visibility or acid deposition) in any of the Class I areas.

Given the significant distance between the operations area and offsite sensitive receptors, no offsite impacts from fugitive dust are expected during operation (Detroit Edison 2011a). However, Detroit Edison notes that watering, reseeding, or paving of areas used for construction could be used if fugitive dust problems develop. Commitments to using these measures are expected to be included in the application for the Permit to Install submitted to MDEQ.

Based on the information provided by Detroit Edison and the review team's independent evaluation, the review team concludes that the air quality impacts of criteria pollutants would not be noticeable and additional mitigation would not be warranted, given Detroit Edison's commitment to manage and mitigate emissions in accordance with applicable regulations.

5.7.2.2 Greenhouse Gases

The operation of a nuclear power plant involves emissions of some greenhouse gases (GHGs), primarily CO_2. Table 5-22 shows Detroit Edison's site-specific estimates of 22,413 tons/yr of CO_2 during operations of Fermi 3, about 7734 tons/yr from combustion sources and 14,679 tons/yr from mobile sources (Detroit Edison 2011a, 2012d). This amounts to about 0.008 percent of the total projected GHG emissions in Michigan during 2010 at 253,800,000 metric tons of gross[a] CO_2 equivalent (CO_2e)[b] in 2010 (CCS 2008). This also equates to about 0.0004 percent of total CO_2 emissions in the United States during 2009, at 5.5 billion metric tons (EPA 2011b). Workforce transportation accounts for about 64 percent of the total CO_2 emissions shown in Table 5-22. Measures to mitigate transportation impacts, such as encouraging car pooling, would reduce CO_2 emissions.

Another estimate of the relative size of the Fermi 3 operation emissions can be made based on the information in Appendix L, which provides the review team's estimate of emissions for a generic 1000-MW(e) nuclear power plant. Plant operations and operation workforce emissions for the generic 1000-MW(e) nuclear power plant totaled about 353,000 tons (320,000 metric tons) over 40 years, or about 8800 tons/yr. The NRC staff used a scaling factor of 1.535 to

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(a) Excluding GHG emissions removed due to forestry and other land uses and excluding GHG emissions associated with exported electricity.

(b) A measure to compare the emissions from various GHGs on the basis of their global warming potential (GWP), defined as the ratio of heat trapped by one unit mass of the GHG to that of one unit mass of CO_2 over a specific time period.

adjust the differences in power generation capacity [1000 MW(e) versus 1535 MW(e)] between the reference plant and Fermi 3. Scaled plant operations and operations workforce emission estimates equate to about 13,500 tons/yr for Fermi 3. This also amounts to a small percentage of projected GHG emissions for Michigan and the United States.

Based on the small amount of Fermi 3 CO_2 emissions compared to the total Michigan and United States GHG emissions, the review team concludes that the atmospheric impacts of GHG emissions from plant operations would not be noticeable and additional mitigation would not be warranted.

EPA promulgated the Prevention of Significant Deterioration (PSD) requirements and Title V GHG Tailoring Rule on June 3, 2010 (75 FR 31514). This rule states that, among other items, new and existing sources not already subject to a Title V permit, or that have the potential to emit at least 100,000 tons/yr (or 75,000 tons/yr for modifications at existing facilities) CO_2e, will become subject to the PSD and Title V requirements effective July 1, 2011. The rule also states that sources with emissions (PTE) below 50,000 tons/yr CO_2e will not be subject to PSD or Title V permitting before April 30, 2016. Note that using the emission factors presented in ER Section 3.6.3.1 and assuming the SDGs, ADGs, and FPs operate 500 hr/yr each and the auxiliary boiler operates 8760 hr/yr, a combined CO_2 PTE of about 92,900 tons/yr was estimated. However, as discussed in Section 5.7.2.1, Fermi 3 could be exempted from GHG-related PSD or a Title V permit if it is eligible and chooses to be considered a “synthetic minor” source, which could significantly reduce the PTE emissions.

5.7.2.3 Summary of Air Quality Impacts

The review team has considered the timing and magnitude of atmospheric releases related to operation of Fermi 3, the existing air quality around the Fermi site, the distance to the closest Class I area, and the Detroit Edison commitment to manage and mitigate emissions in accordance with applicable regulations. On these bases, the review team concludes that the air quality impacts of operation of Fermi 3 would not be noticeable. Based on its assessment of the carbon footprint of plant operations, the review team concludes that the atmospheric impacts of GHGs from plant operations would not be noticeable.

5.7.3 Transmission Line Impacts

Impacts of existing transmission lines on air quality are addressed in the GEIS (NRC 1996). Small amounts of ozone and even smaller amounts of oxides of nitrogen are produced by transmission lines. The production of these gases was found to be insignificant for 745-kV transmission lines (the largest lines in operation) and for a prototype 1200-kV transmission line. In addition, it was determined that potential mitigation measures, such as burying transmission lines, would be very costly and would not be warranted.

Three new 345-kV transmission lines would be constructed between the Fermi 3 switchyard and the Milan Substation to accommodate the new power generating capacity (Detroit Edison 2011a). This size is well within the range of transmission lines evaluated in NUREG-1437 (NRC 1996). The review team therefore concludes that air quality impacts from the transmission lines would not be noticeable and mitigation would not be warranted.

5.7.4 Summary of Meteorological and Air Quality Impacts

The review team evaluated potential impacts on air quality associated with criteria pollutants and GHG emissions from operating Fermi 3. The review team also evaluated potential impacts of cooling system emissions and transmission lines. In each case, the review team determined that the impacts would be minimal. On this basis, the review team concludes that the impacts of operation of Fermi 3 on air quality from emissions of criteria pollutants, CO_2 emissions, and cooling system emissions would be SMALL and that no additional mitigation is warranted.

5.8 Nonradiological Health Impacts

This section addresses the nonradiological health impacts of operating the proposed new Fermi 3 at the Fermi site. Health impacts on the public from operation of the cooling system, noise generated by operations, EMFs, transport operations, and transport of outage workers are discussed. Health impacts from these same sources on workers at Fermi 3 are also evaluated. Health impacts from radiological sources during operations are discussed in Section 5.9.

5.8.1 Etiological Agents

Operation of the proposed Fermi 3 would result in a thermal discharge to Lake Erie (Detroit Edison 2011a). Such discharges have the potential to increase the growth of etiological agents, both in the circulating water system and the lake. Etiological agents include enteric pathogens (such as *Salmonella* spp.), *Pseudomonas aeruginosa*, thermophilic fungi, bacteria (such as *Legionella* spp.), and free-living amoeba (such as *Naegleria fowleri* and *Acanthamoeba* spp.). These microorganisms could result in potentially serious human health concerns, particularly at high exposure levels.

The proposed discharge pipe from Fermi 3 would be located southeast of Fermi 2, extend approximately 1300 ft into Lake Erie, and include a high-rate effluent diffuser for enhanced mixing of the thermal effluent with the receiving waters (Detroit Edison 2011a). On the basis of a thermal plume analysis for the worst-case scenario, it is estimated that the total plume surface area would be only approximately 55,300 ft^2 (Detroit Edison 2011a). The heated effluent discharge from Fermi 3 would be in a restricted industrial area that would not be used for recreation activities, such as boating, swimming, diving, and other water sports. The thermal plume would be approximately 1291 ft from the shoreline (Detroit Edison 2011a) and thus offer only a very limited chance that people on the shoreline would contact the warm water that could support etiological agents. The NRC staff conducted an independent analysis of the thermal discharge (see Section 5.2.3.1), and that analysis demonstrated that all State of Michigan requirements for thermal discharge would be met.

Available data assembled by the U.S. Centers for Disease Control and Prevention (CDC) for the years 2000 to 2008 (CDC 2002, 2003, 2004, 2005, 2006, 2007, 2008a, 2009, 2010) were reviewed for outbreaks of Legionellosis, Salmonellosis, or Shigellosis. Outbreaks that occurred in Michigan were within the range of national trends in terms of cases per populations of 100,000 and in terms of total cases per year, and the outbreaks were associated with pools, spas, or lakes. According to the Detroit Edison correspondence with Michigan Department of Community Health (MDCH) in April 2008, the department did not record any major waterborne disease outbreaks within Michigan in the last 10 years (Detroit Edison 2010d). The CDC Council of State and Territorial Epidemiologists Naegleria Work Group, after reviewing the data from different sources, identified 121 fatal cases of primary amebic meningoencephalitis (PAM, caused by *Naegleria fowleri*) in the United States from 1937 to 2007. Most cases occurred in southern States during the months of July and September (CDC 2008b).

The standard practices for operating cooling towers include adding biocides to the water to limit growth of microorganisms inside the towers and providing appropriate protective equipment for workers who enter the cooling towers for maintenance operations. Detroit Edison would use biocides to reduce the levels of microbial populations in the cooling tower and condenser and would comply with OSHA standards for Fermi 3 operational workers, as is currently done for Fermi 2 (Detroit Edison 2011a). The biocides in the water entering the cooling towers would limit microbial growth and minimize the potential for any aerosol releases. The use of biocides in various water systems for the proposed Fermi 3 is discussed in Section 3.4.2.4 of the EIS. No outbreaks of Legionnaires' disease, PAM, or any other waterborne disease associated with Fermi 2 operations have been reported in the past. The use of biocides would likely minimize the exposure of personnel to Legionella in the cooling water system.

Because of the historical low incidence of diseases from etiological agents in Michigan (Detroit Edison 2010d), the small and limited increase in temperature in Lake Erie expected as a result of operating Fermi 3, the currents around the proposed discharge structure, the distance of the discharge structure from the shore, and the relative absence of swimming or other activities that result in water immersion in the vicinity of the proposed discharge structures, the review team concludes that the impacts on human health would be SMALL and that further mitigation would not be warranted.

5.8.2 Noise

In NUREG-1437 (NRC 1996), the NRC staff discusses the environmental impacts of noise at existing nuclear power plants. Common sources of noise from plant operation include cooling towers and transformers, with intermittent contributions from loud speakers and auxiliary equipment such as diesel generators and vehicle traffic.

The existing Fermi 2 at the Fermi site uses primarily two NDCTs. Fermi 3 would use one NDCT to reject the waste heat from the system. Addition of the proposed cooling system could increase the noise level over the existing cooling system, which is considered in the noise study (Detroit Edison 2011a) as part of the ambient noise level. The ER (Detroit Edison 2011a) presented noise modeling results that included the noise sources from normal station operation, including cooling systems, transformers, and onsite and nearby offsite transmission lines. The switchyard was not modeled because it is not a significant noise source, and equipment in enclosures, such as diesel generators were not modeled, either. Predicted noise levels were compared with existing L_{90} values (i.e., noise levels that are exceeded 90 percent of the time and commonly used as the background level) with Fermi 2 in operation at the seven noise-sensitive receptor locations (residences) within 1.5 mi of the site. Noise levels resulting only from Fermi 3 operation are predicted to be relatively low, with a maximum of 37 dBA at the nearest residence, which is about 1900 ft north-northeast of the proposed Fermi 3 switchyard and 3200 ft north-northwest of the proposed Fermi 3 cooling tower. Sound-level increases over existing L_{90} values due to Fermi 3 operation would range between 0 and 2 dBA at six residences, a range that is lower than a barely discernible increase of about 3 dB (NWCC 2002). One exception is an expected 6-dB increase over the existing L_{90} value at the same nearest residence. This increase would occur during a small portion of nighttime hours and would be a noticeable change over existing L_{90} levels. However, combined (including background) day-night average sound levels (L_{dn}) modeled at three residences ranged between 54 and 63 dBA, indicating there was no increase over existing L_{dn} levels.

According to NUREG-1437 (NRC 1996), noise levels below 60 to 65 dBA as the day-night average noise level (DNL or L_{dn}) are considered to be of small significance. More recently, the impacts of noise were considered in NUREG-0586, Supplement 1 (NRC 2002). The criterion for assessing the level of significance was not expressed in terms of sound levels but based on the effect of noise on human activities and on threatened and endangered species. The criterion in NUREG-0586, Supplement 1, is stated as follows:

> The noise impacts [...] are considered detectable if sound levels are sufficiently high to disrupt normal human activities on a regular basis. The noise impacts [...] are considered destabilizing if sound levels are sufficiently high that the affected area is essentially unsuitable for normal human activities, or if the behavior or breeding of a threatened and endangered species is affected.

For Fermi 3 operations, the maximum predicted noise increase of 6 dBA over the existing L_{90} would occur at the nearest residence during a small portion of nighttime hours. However, during other times of day and night and at other nearby residences, predicted noise levels would not represent a significant increase over existing L_{90} levels. In addition, no increases of the L_{dn}

would be expected at any of the noise-sensitive residences. Given the postulated noise levels for Fermi 3, the review team concludes that the noise increases would be SMALL and that mitigation would not be warranted.

5.8.3 Acute Effects of Electromagnetic Fields

Electric shock resulting from either direct access to energized conductors or induced charges in metallic structures is an example of an acute effect from EMFs associated with transmission lines (NRC 1996). In the ER, Detroit Edison (2011a) stated that three new transmission lines and a separate switchyard would be required to connect Fermi 3 to the existing transmission system. Onsite transmission lines that would connect Fermi 3 to the proposed new Fermi 3 switchyard would be constructed and owned by Detroit Edison (Detroit Edison 2011a). Transmission lines that serve Fermi 3 offsite would be created and operated by ITC*Transmission* (Detroit Edison 2011a), which also operates and manages the existing Fermi 2 transmission system at the Fermi site (Detroit Edison 2011a). The existing ITC*Transmission* system meets National Electric Safety Code (NESC) criteria for induced currents (Detroit Edison 2011a). Detroit Edison stated that all transmission lines would comply with applicable regulatory standards and that the design and construction of the proposed Fermi 3 substation and transmission circuits would comply with NESC provisions (Detroit Edison 2011a). ITC*Transmission* would ensure that the electric field strength under the new transmission lines would conform to NESC guidelines (less than 7.5 kV/m maximum within the ROW and less than 2.6 kV/m maximum at the edge of the ROW) (Detroit Edison 2011a).

Knowing that Detroit Edison is committed to ensuring that the design of new transmission lines meet NESC criteria, the review team concludes that the impact on the public from the acute effects of EMFs would be SMALL and that additional mitigation is not be warranted.

5.8.4 Chronic Effects of Electromagnetic Fields

Power transmission lines in the United States operate at 60 Hz. The EMFs resulting from 60-Hz power transmission lines fall under the category of nonionizing radiation and are considered to be extremely low frequency (ELF) EMFs. Research on the potential for chronic effects from 60-Hz EMFs from energized transmission lines was reviewed by the NRC and is addressed in NUREG-1437 (NRC 1996). At the time of that review, research results were not conclusive. The National Institute of Environmental Health Sciences (NIEHS) directs related research through the DOE. An NIEHS report (NIEHS 1999) contains the following conclusion:

> The NIEHS concludes that ELF-EMF (extremely low frequency-electromagnetic field) exposure cannot be recognized as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard. In our opinion, this finding is insufficient to warrant aggressive regulatory concern. However, because virtually everyone in the United States uses electricity and therefore is routinely exposed to ELF-EMF, passive regulatory action is

> warranted such as a continued emphasis on educating both the public and the regulated community on means aimed at reducing exposures. The NIEHS does not believe that other cancers or non-cancer health outcomes provide sufficient evidence of a risk to currently warrant concern.

The staff reviewed available scientific literature on chronic effects to human health from ELF-EMFs published since the NIEHS report and found that several other organizations reached the same conclusions (AGNIR 2006; WHO 2007a). Additional work under the auspices of the World Health Organization (WHO) updated the assessments of a number of scientific groups that reflected the potential for transmission line EMFs to cause adverse health impacts in humans. The monograph summarized the potential for ELF-EMFs to cause diseases such as cancers in children and adults; depression; suicide; reproductive dysfunction; developmental disorders; immunological modifications; and neurological disease. The results of the review by WHO (2007b) found that the extent of scientific evidence linking these diseases to EMF exposure is not conclusive.

These conclusions by four national and international groups are in agreement. The current scientific evidence regarding the chronic effect of ELF-EMFs does not conclusively link ELF-EMFs to adverse health impacts. The staff will continue to follow developments in this area.

5.8.5 Occupational Health

In general, occupational health risks for new units are expected to be dominated by occupational injuries (e.g., falls, electric shock, asphyxiation) to workers engaged in activities such as maintenance, testing, and plant modifications. The 2008 annual incidence rates (the number of injuries and illnesses per 100 full-time workers) for electrical power generation, transmission, and distribution workers for the State of Michigan and the United States are 3.7 and 3.2, respectively (USBLS 2009a, b). Historically, actual injury and fatality rates at nuclear reactor facilities have been lower than the average U.S. industrial rates, with a 2008 average incidence rate of 0.7 per hundred workers (USBLS 2009a). Based on the assumption of a total operations workforce of 900 (Detroit Edison 2011a), these rates suggest that operation of Fermi 3 would be associated with approximately 6 occupational injuries and illnesses per year. However, these are gross estimates and do not take into account risks workers would face if they are employed somewhere other than the Fermi 3. Occupational injury and fatality risks are reduced by strict adherence to NRC and OSHA safety standards (29 CFR Part 1910), practices, and procedures. Appropriate State and local statutes must also be considered when the occupational hazards and health risks associated with new nuclear unit operation are being assessed. The staff assumes adherence to NRC, OSHA, and State safety standards, practices, and procedures during Fermi 3 operations.

Additional occupational health impacts may result from exposure to hazards such as noise, toxic or oxygen-replacing gases, etiological agents in the condenser bays, and caustic agents.

Detroit Edison (2011a) reports that it maintains a health and safety program to protect workers from industrial safety risks at the operating units and would implement the program for the proposed new units. Health impacts on workers from nonradiological emissions, noise, and EMFs would be monitored and controlled in accordance with the applicable OSHA regulations and would be SMALL.

5.8.6 Impacts of Transporting Operations Personnel to the Proposed Site

The general approach used to calculate nonradiological impacts from fuel and waste shipments was the same as that used to calculate the impacts from transport of operations and outage personnel to and from the Fermi site. However, the only data available for estimating these impacts were from preliminary estimates. The assumptions made to provide reasonable estimates of the parameters needed to calculate nonradiological impacts are discussed below.

- The average number of workers needed for operations was given as 900 in the ER (Detroit Edison 2011a), which also stated that a peak refueling staff of 1200 to 1500 temporary workers was required every 24 months. It was assumed that no sharing of personnel with Fermi 2 operations staff would occur. With approximately 10 percent of the workforce expected to carpool (Detroit Edison 2011a), there would be about 855 vehicle roundtrips per day for operations workers if two persons shared a ride for those who carpooled. For refueling outages, it was assumed that there would be an additional 1425 vehicle roundtrips per day during an outage because of the extra 1500 temporary workers estimated by using the same carpooling assumption.
- The average commute distance for operations and outage workers was assumed to be 23.5 mi one way (Detroit Edison 2011a).
- To develop representative commuter traffic impacts, a source was located that provided Michigan-specific accident, injury, and fatality rates for all traffic in the surrounding counties (Lenawee, Monroe, Washtenaw, and Wayne) for the years 2004 to 2008 (MDSP 2005, 2006, 2007, 2008, 2009).

The estimated impacts of transporting permanent operations personnel and temporary outage workers to and from the Fermi 3 site are shown in Table 5-23. The total annual traffic fatalities during operations, including both operations and outage personnel, represents about a 0.7 percent increase above the average 23 traffic fatalities/yr that occurred in Monroe County, Michigan, from 2004 to 2008 (MDSP 2005, 2006, 2007, 2008, 2009). This represents a small increase relative to the current traffic fatality risk in the area surrounding the proposed Fermi 3 site.

On the basis of the information provided by Detroit Edison, the review team's independent evaluation, and the fact that this increase would be small relative to the number of current traffic

Table 5-23. Nonradiological Impacts of Transporting Workers to and from the Fermi 3 Site

Type of Workers	Accidents per Year	Injuries per Year	Fatalities per Year
Permanent	4.3	12	0.14
Outage	3.0	0.85	0.0094

fatalities in the surrounding area, the review team concludes that the nonradiological impacts of transporting personnel to the Fermi 3 site would be minimal and that mitigation is not warranted.

5.8.7 Summary of Nonradiological Health Impacts

The staff evaluated health impacts on the public and workers from operation of the Fermi 3 cooling system, noise generated by Fermi 3 operations, acute and chronic impacts of EMFs from transmission lines, transport operations, and the transport of outage workers to and from Fermi 3. Health risks to workers are expected to be dominated by occupational injuries at rates below the average U.S. industrial rates. Health impacts on the public and workers from etiological agents, noise generated by Fermi 3 operations, and acute impacts of EMF are expected to be minimal. On the basis of the information provided by Detroit Edison and the review team's independent review, the review team concludes that the potential nonradiological health impacts resulting from the operation of Fermi 3 would be SMALL and that mitigation would not be warranted. Scientific evidence regarding the chronic impacts of EMFs on public health is inconclusive.

5.9 Radiological Impacts of Normal Operations

This section addresses the radiological impacts from normal operations of the proposed Fermi 3, including a discussion of the estimated radiation dose to a member of the public and to the biota inhabiting the area around the Fermi site. Estimated doses to workers from Fermi 3 operations are also discussed. The determination of radiological impacts was based on the General Electric-Hitachi Nuclear Energy Americas, LLC (GEH) Economic Simplified Boiling Water Reactor (ESBWR) design and the liquid and gaseous radiological effluent rates discussed in Section 3.4.2.3.

Revision 2 of Detroit Edison's ER incorporates Revision 7 of the Design Control Document (DCD); therefore, the COL application and evaluation of radiological impacts of normal operations presented here are based on Revision 7 of the DCD (GEH 2010a). Subsequently, GEH has submitted Revision 9 of the ESBWR DCD. However, in the new DCD, liquid and gaseous effluent rates have not changed (GEH 2010f).

5.9.1 Exposure Pathways

The public and biota would be exposed to increased ambient background radiation from Fermi 3 via the liquid effluent, gaseous effluent, and direct radiation pathways. Detroit Edison estimated the potential exposures to the public and biota by evaluating exposure pathways typical of those surrounding a nuclear unit at the Fermi site. Detroit Edison considered pathways that could cause the highest calculated radiological dose on the basis of the use of the environment by the residents located around the site (Detroit Edison 2011a). For example, factors such as the location of homes in the area, consumption of meat, fish, and shellfish from the area, and consumption of vegetables grown in area gardens were considered.

For the liquid effluent release pathway, Detroit Edison (2011a) considered the following exposure pathways in evaluating the dose to the maximally exposed individual (MEI): ingestion of aquatic food (i.e., fish and invertebrates); ingestion of drinking water; ingestion of meats, vegetables, and milk (using irrigation water contaminated by liquid effluent); and direct radiation exposure from shoreline activities, swimming, and boating (Figure 5-2). The analysis for population dose considered the same exposure pathways as those used for the individual dose assessment.

As discussed in the Final Safety Analysis Report (FSAR), the design of Fermi 3 includes a number of features to prevent and mitigate leakage from system components such as pipes and tanks that may contain radioactive material (Detroit Edison 2011b). In addition, Detroit Edison (2011b) committed to use the guidance in the *Generic FSAR Template Guidance for Life-Cycle Minimization of Contamination*, developed by the Nuclear Energy Institute (NEI 2009), to the extent practicable in the development of operating programs and procedures. However, the potential still exists for leaks of radioactive material such as tritium into the ground. Based on the discussion above, the NRC staff expects that the impacts from such potential leakage from Fermi 3 would be minimal.

For the gaseous effluent release pathway, Detroit Edison (2011a) considered the following exposure pathways in evaluating the dose to the individual: immersion in the radioactive plume, direct radiation exposure from deposited radioactivity, inhalation of airborne activity, ingestion of garden fruit and vegetables, and ingestion of meat and milk. For population doses from gaseous effluents, Detroit Edison (2011a) used the same exposure pathways as those used for the individual dose assessment. For calculations of the population dose, it was assumed that all agricultural products grown within 50 mi of Fermi 3 would be consumed by the population within 50 mi of Fermi 3.

Detroit Edison (2011a) states that the reactor buildings would be the primary sources of direct radiation exposure to the public from Fermi 3. However, Detroit Edison asserts that contained sources of radiation at Fermi 3 would be shielded and would not contribute significantly to the

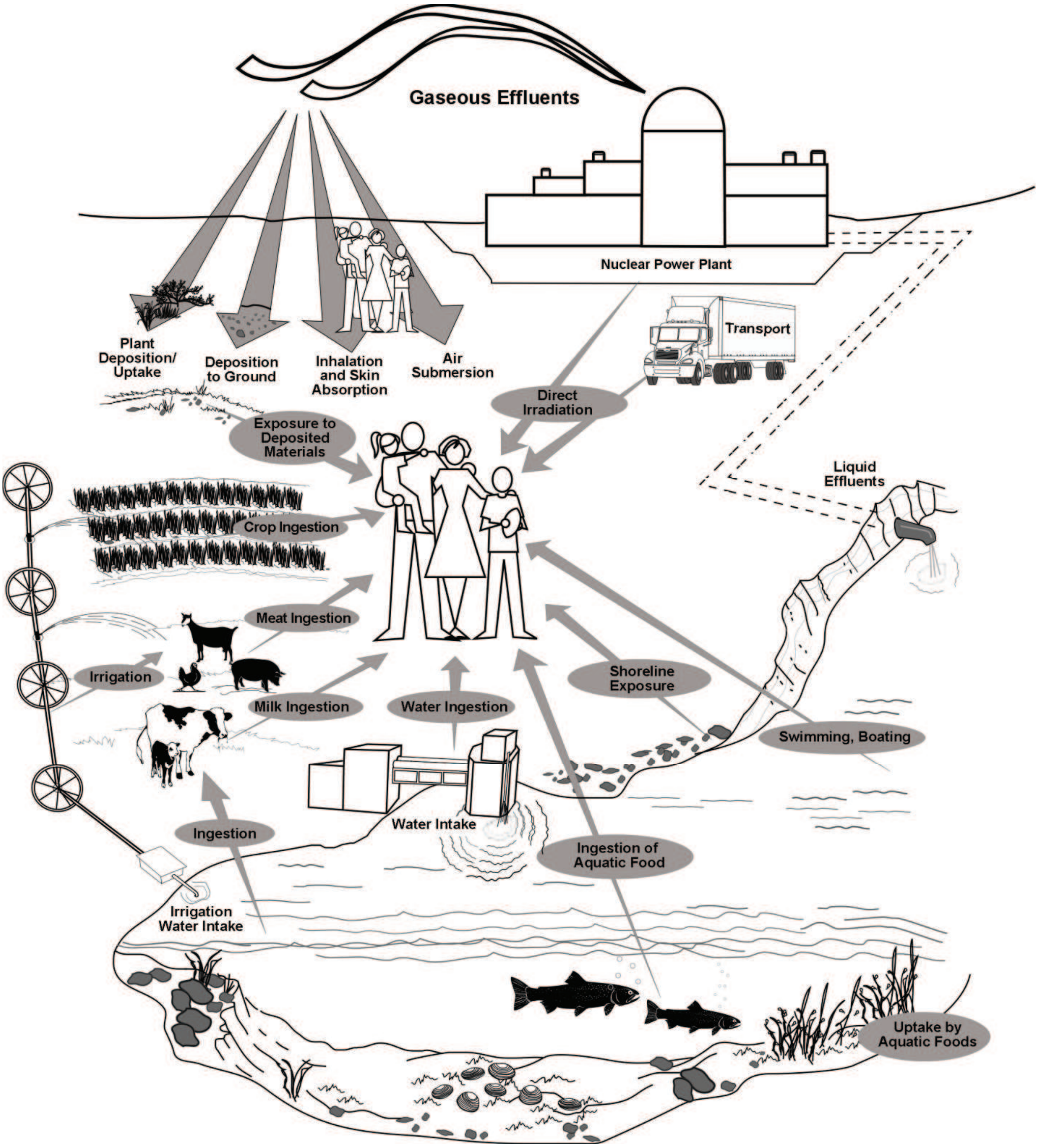

Figure 5-2. Exposure Pathways to Man (adapted from Soldat et al. 1974)

external dose to the MEI or the population. This assumption of a negligible contribution from direct radiation beyond the site boundary is supported by the DCD (GEH 2010a).

Exposure pathways considered by Detroit Edison in the ER (Detroit Edison 2011a) in evaluating the dose to the biota are shown in Figure 5-3 and include:

- Ingestion of aquatic foods
- External exposure from water immersion and shoreline sediments
- Inhalation of airborne radionuclides
- External exposure to immersion in gaseous effluent plumes
- Surface exposure from deposition of iodine and particulates from gaseous effluents (NRC 1977).

The NRC staff reviewed the exposure pathways for the public and nonhuman biota identified by Detroit Edison (2011a) and, on the basis of a documentation review, a tour of the site and surrounding areas, and interviews with Detroit Edison staff and contractors during a site visit in February 2009, found them to be appropriate.

5.9.2 Radiation Doses to Members of the Public

Detroit Edison calculated the dose to the MEI and the population living within a 50-mi radius of the site from both the liquid and gaseous effluent release pathways (Detroit Edison 2010a). As discussed in the Section 5.9.1, direct radiation exposure to the MEI from sources of radiation at Fermi 3 would be negligible.

5.9.2.1 Liquid Effluent Pathway

Liquid pathway doses to the MEI were calculated by using the LADTAP II computer program (Strenge et al. 1986). The following activities were considered in the dose calculations: (1) consumption of drinking water contaminated by liquid effluents; (2) consumption of fish, shellfish, or other aquatic organisms from water sources contaminated by liquid effluents; and (3) direct radiation from swimming in, boating on, and shoreline use of water bodies contaminated by liquid effluents. Detroit Edison stated that water from Lake Erie is not used for irrigation in the vicinity of Fermi 3 (Detroit Edison 2011a).

The liquid effluent releases used in the estimates of dose are found in Table 12.2-19b of the DCD (GEH 2010a). Other parameters used as inputs to the LADTAP II program – including the effluent discharge rate, dilution factor for discharge, transit time to receptor, and liquid pathway consumption and usage factors (i.e., shoreline usage, fish consumption, and drinking water consumption) – are found in Tables 5.4-1 and 5.4-2 of the ER (Detroit Edison 2011a).

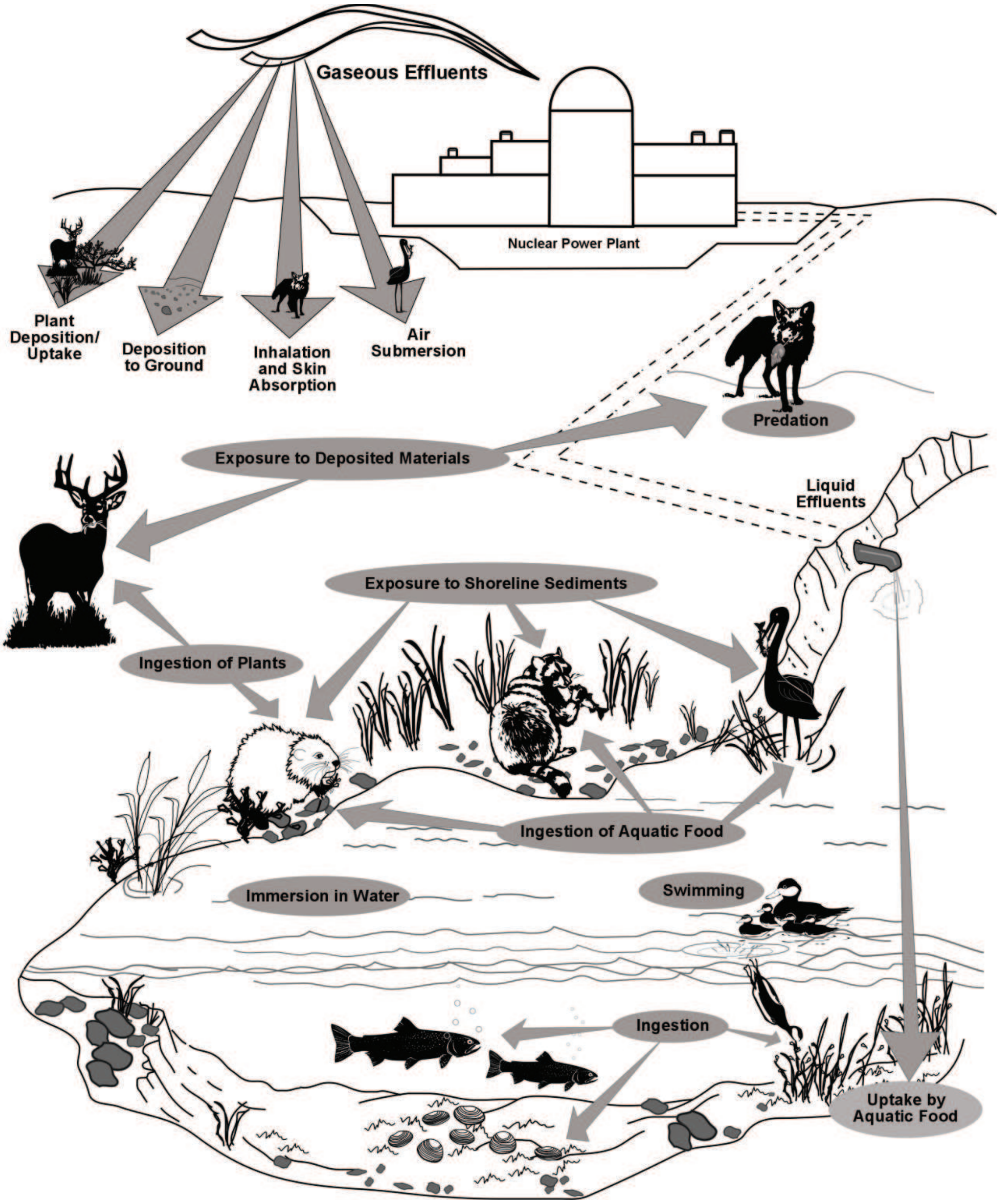

Figure 5-3. Exposure Pathways to Biota Other than Man (adapted from Soldat et al. 1974)

Detroit Edison calculated liquid pathway doses to the MEI; these dose estimates are shown in Table 5-24. The MEI is an adult for whom the majority of the dose comes from fish ingestion. The maximally exposed organ is the bone of a child, and the majority of the dose is from fish ingestion.

Table 5-24. Doses to the MEI for Liquid Effluent Releases from Fermi 3

Pathway	Total Body (mrem/yr)	Thyroid (mrem/yr)	Bone (mrem/yr)
Drinking water	0.000605	0.0263	0.000592
Fish	0.00541	0.00219	0.0827
Invertebrate	0.000571	0.000188	0.00449
Shoreline (includes water recreation)	0.000101	0.000101	0.000101
Total	0.00648	0.0263	0.0877
Age group receiving maximum dose	Adult	Infant	Child

Source: Table 12.2-20bR in Detroit Edison (2011b) and Table 5.4-4 in Detroit Edison (2011a)

The NRC staff recognizes the LADTAP II computer program as being an appropriate method for calculating the dose to the MEI for liquid effluent releases. The staff performed an independent evaluation of liquid pathway doses by using input parameters from the ER, and results were similar to those in the ER. The NRC staff judged all input parameters used in Detroit Edison's calculations to be appropriate. Results of the staff's independent evaluation are presented in Appendix G.

5.9.2.2 Gaseous Effluent Pathway

Gaseous pathway doses to the MEI were calculated by Detroit Edison by using the GASPAR II computer program (Strenge et al. 1987) at the nearest individual receptors in various directions (residence, garden, milk- and meat-producing animals, and the exclusion area boundary). The GASPAR II computer program was also used to calculate annual population doses. The following activities were considered in the dose calculations: (1) direct radiation from immersion in the gaseous effluent cloud and from particulates deposited on the ground, (2) inhalation of gases and particulates, (3) ingestion of contaminated meat and milk from animals eating contaminated grass, and (4) ingestion of garden vegetables contaminated by gases and particulates. The gaseous effluent releases used in the estimate of dose to the MEI and population are found in Table 12.2-16 of the DCD (GEH 2010a) for noble gases and other fission products and in Table 12.2-206 of the FSAR (Detroit Edison 2011b) for iodines. Other parameters used as inputs to the GASPAR II program – including population data, atmospheric dispersion factors, ground deposition factors, receptor locations, and consumption factors – are found in Tables 5.4-2 and 5.4-3 of the ER (Detroit Edison 2011a). Gaseous pathway doses to the MEI calculated by Detroit Edison are found in Table 5-25.

Table 5-25. Doses to the MEI for Gaseous Effluent Releases from Fermi 3

Pathway and Location	Age Group	Total Body Dose (mrem/yr)	Thyroid Dose (mrem/yr)	Bone Dose (mrem/yr)	Skin Dose (mrem/yr)
Plume (0.48 mi NNW)	All	1.42×10^{-1}	1.42×10^{-1}	1.42×10^{-1}	3.35×10^{-1}
Ground (0.59 mi NW)	All	4.95×10^{-1}	4.95×10^{-1}	4.95×10^{-1}	5.81×10^{-1}
Inhalation (0.59 mi NW)	Adult	2.81×10^{-3}	1.85×10^{-1}	1.74×10^{-3}	1.14×10^{-3}
	Teen	2.72×10^{-3}	2.40×10^{-1}	2.41×10^{-3}	1.16×10^{-3}
	Child	2.23×10^{-3}	2.93×10^{-1}	3.23×10^{-3}	1.02×10^{-3}
	Infant	1.29×10^{-3}	2.68×10^{-1}	2.20×10^{-3}	5.87×10^{-4}
Vegetable[(a)] (0.60 mi NW)	Adult	1.73×10^{-1}	3.89	4.81×10^{-1}	5.38×10^{-2}
	Teen	2.07×10^{-1}	5.41	6.96×10^{-1}	9.03×10^{-2}
	Child	3.37×10^{-1}	10.5	1.68	2.20×10^{-1}
Meat [(a)] (2.95 mi NNW)	Adult	1.61×10^{-3}	4.93×10^{-3}	6.67×10^{-3}	1.29×10^{-3}
	Teen	1.27×10^{-3}	3.72×10^{-3}	5.62×10^{-3}	1.09×10^{-3}
	Child	2.22×10^{-3}	6.02×10^{-3}	1.05×10^{-2}	2.05×10^{-3}
Goat milk (2.21 mi WNW)	Adult	1.68×10^{-2}	3.48×10^{-1}	2.38×10^{-2}	2.39×10^{-3}
	Teen	1.86×10^{-2}	5.53×10^{-1}	4.32×10^{-2}	4.34×10^{-3}
	Child	2.24×10^{-2}	1.10	1.05×10^{-1}	1.05×10^{-2}
	Infant	3.48×10^{-2}	2.67	1.88×10^{-1}	2.19×10^{-2}
Cow milk (2.09 mi WNW)	Adult	8.56×10^{-3}	2.84×10^{-1}	1.76×10^{-2}	2.53×10^{-3}
	Teen	1.13×10^{-2}	4.52×10^{-1}	3.22×10^{-2}	4.64×10^{-3}
	Child	1.86×10^{-2}	9.00×10^{-1}	7.80×10^{-2}	1.13×10^{-2}
	Infant	3.28×10^{-2}	2.18	1.46×10^{-1}	2.37×10^{-2}

Source: Detroit Edison 2011b

(a) No infant doses were calculated for the vegetable or meat pathway because the doses that infants receive from this diet would be bounded by the dose calculated for the child.

The NRC staff recognizes the GASPAR II computer program as an appropriate tool for calculating dose to the MEI and population from gaseous effluent releases. The staff performed an independent evaluation of gaseous pathway doses and obtained similar results to those in the ER. All input parameters used in Detroit Edison's calculations were judged by the staff to be appropriate. Results of the staff's independent evaluation are found in Appendix G.

5.9.3 Impacts on Members of the Public

This section describes the Detroit Edison's evaluation of the estimated impacts from radiological releases and direct radiation from Fermi 3. The evaluation addresses the dose from operations to the MEI located at the Fermi site boundary and the population dose (collective dose to the population within 50 mi) around Fermi 3.

5.9.3.1 Maximally Exposed Individual

Detroit Edison (2011a) states that total body and organ dose estimates to the MEI from liquid and gaseous effluents from Fermi 3 would be within the dose design objectives of 10 CFR Part 50, Appendix I. Total body doses and maximum organ doses at Lake Erie from liquid effluents were well within the Appendix I dose design objectives of 3 mrem/yr and 10 mrem/yr, respectively. Doses at the exclusion area boundary from gaseous effluents were well within the Appendix I dose design objectives of 10 mrad/yr air dose from gamma radiation, 20 mrad/yr air dose from beta radiation, 5 mrem/yr to the total body, and 15 mrem/yr to the skin. In addition, the dose to the thyroid was within the 15-mrem/yr Appendix I dose design objective. Table 5-26 compares the dose estimates for Fermi 3 to the Appendix I dose design objectives. The NRC staff completed an independent evaluation of the doses for comparison with Appendix I dose design objectives and found similar results, as shown in Appendix G.

Table 5-26. Comparisons of MEI Annual Dose Estimates from Liquid and Gaseous Effluents to 10 CFR Part 50, Appendix I, Dose Design Objectives

Radionuclide Releases/Doses	Detroit Edison Assessment	Appendix I Dose Design Objectives
Liquid effluents[(a)]		
Total body dose	0.006 mrem	3 mrem
Maximum organ dose (child bone)	0.088 mrem	10 mrem
Gaseous effluents (noble gases only)		
Beta air dose	0.26 mrad	20 mrad
Gamma air dose	0.22 mrad	10 mrad
Total body dose	0.98 mrem	5 mrem
Skin dose	1.15 mrem	15 mrem
Gaseous effluents (radioiodines and particulates)		
Maximum organ dose (child thyroid)	11.3 mrem	15 mrem

Source: Detroit Edison 2011a

(a) Total body dose is for an adult and maximum organ dose is for a child.

Detroit Edison (2011a) compared the combined dose estimates from direct radiation and gaseous and liquid effluents from the existing Fermi 2 and the proposed Fermi 3 against the 40 CFR Part 190 standards (Detroit Edison 2011a). Detroit Edison (2011a) states that the total body and organ dose estimates to the MEI from liquid and gaseous effluents for Fermi 3 are below the design objectives of 10 CFR Part 50, Appendix I. As stated in Section 5.9.2, exposure at the site boundary from direct radiation sources at Fermi 3 would not contribute significantly to the MEI dose. The routine thermoluminescent dosimeter (TLD) measurements (representative of direct radiation exposure) from operation of Fermi 2 at the site boundary are at background levels (Detroit Edison 2011a). Table 5-27 shows Detroit Edison's assessment that the total doses to the MEI from liquid and gaseous effluents at the Fermi site are well below the 40 CFR Part 190 standards. The staff completed an independent evaluation of the site total dose (cumulative dose) for comparison with 40 CFR Part 190 standards and found similar results, as shown in Appendix G.

Table 5-27. Comparison of MEI Doses (mrem/yr) to 40 CFR Part 190 Dose Standards

	Fermi 2	Fermi 3				
Dose Site	**Combined Liquid and Gaseous**	**Liquid**	**Gaseous**	**Combined**	**Fermi Site Total**	**40 CFR Part 190 Standards**
Total body	4.68	0.006	0.976	0.98	5.66	25
Thyroid	2.66	0.026	11.3	11.33	13.99	75
Other organ – child bone	0.05	0.088	2.18	2.27	2.32	25

Source: Detroit Edison 2011a

5.9.3.2 Population Dose

Detroit Edison estimated the collective total body dose within a 50-mi radius of the Fermi 3 site to be 14.9 person-rem from liquid effluents (Detroit Edison 2011a) and 6.7 person-rem/yr from gaseous effluents (Detroit Edison 2011a) using the population estimate for 2060. The estimated collective dose to the same population from natural background radiation is estimated to be 2,400,000 person-rem/yr. The dose from natural background radiation was calculated by multiplying the 50-mi population estimate for 2060 of approximately 7,710,000 people by the annual background dose rate of 311 mrem/yr (NCRP 2009).

The collective dose from the gaseous and liquid effluent pathways was estimated by using the GASPAR II and LADTAP II computer codes, respectively. The staff performed an independent evaluation of population doses and obtained similar results (see Appendix G).

Radiation protection experts conservatively assume that any amount of radiation may pose some risk of causing cancer or a severe hereditary effect and that the risk is higher for higher radiation exposures. Therefore, a linear, no-threshold dose response relationship is used to describe the relationship between radiation dose and detriments, such as cancer induction. The recent BEIR VII report by the National Research Council (2006) reconfirms the linear, no-threshold dose response model. Simply stated, any increase in dose, no matter how small, results in an incremental increase in health risk. This theory is accepted by the NRC as a conservative model for estimating health risks from radiation exposure, though it recognizes that the model probably overestimates those risks. On the basis of this method, the NRC staff estimated the risk to the public from radiation exposure by using the nominal probability coefficient for total detriment. The value of this coefficient is 570 fatal cancers, nonfatal cancers, and severe hereditary effects per 1,000,000 person-rem (10,000 person-Sv), which is equal to 0.00057 effect per person-rem. The coefficient is taken from International Commission on Radiological Protection (ICRP) Publication 103 (ICRP 2007).

Both the National Council on Radiation Protection and Measurements (NCRP) and ICRP suggest that when the collective effective dose is smaller than the reciprocal of the relevant risk detriment (i.e., less than 1/0.00057, which is less than 1754 person-rem), the risk assessment should note that the most likely number of excess health effects is zero (NCRP 1995; ICRP 2007). The estimated collective whole body dose to the population living within 50 mi of Fermi 3 is 21.6 person-rem/yr (Detroit Edison 2011a), which is less than the value of 1754 person-rem that the ICRP and NCRP suggest would most likely result in zero excess health effects (NCRP 1995; ICRP 2007).

In addition, at the request of the U.S. Congress, the National Cancer Institute (NCI) conducted a study and published the results in *Cancer in Populations Living near Nuclear Facilities* (NCI 1990). This report included an evaluation of health statistics around all nuclear power plants as well as several other nuclear-fuel-cycle facilities in operation in the United States in 1981. It found “no evidence that an excess occurrence of cancer has resulted from living near nuclear facilities” (NCI 1990).

5.9.3.3 Summary of Radiological Impacts on Members of the Public

The NRC staff evaluated the health impacts from routine gaseous and liquid radiological effluent releases from Fermi 3. On the basis of the information provided by Detroit Edison and NRC’s independent evaluation, the NRC staff concludes there would be no observable health impacts on the public from normal operation of Fermi 3, the health impacts would be SMALL, and additional mitigation is not warranted.

5.9.4 Occupational Doses to Workers

At the Fermi site, the annual occupational collective dose for 2006 through 2008 averaged 137 person-rem for the existing Fermi 2 (Lewis and Hagemeyer 2010). The estimated annual occupational collective dose for the GE-Hitachi ESBWR advanced reactor design, including the GE-Hitachi ESBWR at the Fermi 3 site, was 84.52 person-rem (GEH 2010a), which is less than the annual occupational collective dose of 129 person-rem for current boiling-water reactors (BWRs) for calendar year 2008 (Lewis and Hagemeyer 2010).

The licensee of a new plant would need to maintain individual doses to workers within 0.05 Sv (5 rem) annually, as specified in 10 CFR 20.1201, and incorporate as low as is reasonably achievable (ALARA) provisions to maintain doses below this limit.

The NRC staff concludes that the health impacts from occupational radiation exposure would be SMALL based on individual worker doses being maintained within 10 CFR 20.1201 limits and collective occupational doses being typical of doses found in current operating LWRs. Additional mitigation would not be warranted because the operating plant would be required to maintain doses ALARA.

5.9.5 Impacts on Biota Other than Humans

Detroit Edison estimated doses to biota in the environs of Fermi 3 by using surrogate species. The surrogates used in the ER are well-defined and provide an acceptable method for evaluating doses to the biota. Surrogate analyses were performed for aquatic species, such as fish, invertebrates, and algae, and for terrestrial species, such as muskrats, raccoons, herons, and ducks. Aquatic species on the site are represented by surrogates as follows: (1) various mussel and mollusk species and crayfish are represented by invertebrates; (2) darter, shiner, catfish, whitefish, yellow perch, largemouth bass, and striped bass are represented by fish; and (3) aquatic plants are represented by algae. Terrestrial species on the site are represented by surrogates as follows: (1) white-tailed deer, raccoon, gray squirrel, red squirrel, eastern cottontail rabbit, coyotes, red fox, striped skunk, prairie deer mouse, meadow vole, and muskrat are represented by raccoon and muskrat; (2) ducks and geese are represented by duck; and (3) bald eagle, shorebirds, and wading birds are represented by heron. Exposure pathways considered in evaluating dose to the biota were discussed in Section 5.9.1 and shown in Figure 5-3. The NRC staff reviewed the Detroit Edison (2011a) calculations and performed an independent evaluation of fish, invertebrates, algae, muskrat, raccoon, duck, and heron. The staff's independent evaluation found similar results, as shown in Appendix G.

5.9.5.1 Liquid Effluent Pathway

Detroit Edison (2011a) used the LADTAP II computer code to calculate doses to the biota from the liquid effluent pathway. In estimating the concentration of radioactive effluents in Lake Erie, Detroit Edison (2011a) used a transit dilution model. Liquid pathway doses were higher for biota than humans because of the bioaccumulation of radionuclides, ingestion of aquatic plants, ingestion of invertebrates, and increased time spent in water and shoreline associated with biota. The liquid effluent releases used in estimating the biota dose are given in Table 12.2-19b of the DCD (GEH 2010a). Estimates of the total body doses to the surrogate species from the liquid pathway are shown in Table 5-28.

Table 5-28. Detroit Edison Estimates of the Annual Dose (mrad/yr) to Biota from Fermi 3

	Detroit Edison Biota Dose Estimates		
Biota	**Liquid Pathway**	**Gaseous Pathway**	**Total Body Biota Dose All Pathways**
Fish	2.31	0	2.31
Invertebrate	7.65	0	7.65
Algae	11.9	0	11.9
Muskrat	14.8	11.2	26.0
Raccoon	0.43	11.2	11.6
Heron	6.87	11.2	18.0
Duck	14.8	11.2	26.0

Source: Detroit Edison 2011a

5.9.5.2 Gaseous Effluent Pathway

Gaseous effluents would contribute to the total body dose of the terrestrial surrogate species (i.e., muskrat, raccoon, heron, and duck). The exposure pathways include inhalation of airborne radionuclides, external exposure because of immersion in gaseous effluent plumes, and surface exposure from deposition of iodine and particulates from gaseous effluents. The dose calculated to the MEI from gaseous effluent releases in Table 5-25 would also be applicable to terrestrial surrogate species, but with a doubling of the ground deposition factor because terrestrial species are closer to the ground than humans. The gaseous effluent releases used in estimating the dose are found in Table 12.2-16 of the DCD (GEH 2010a) for noble gases and other fission products and in Table 12.2-206 of the FSAR (Detroit Edison 2011b) for iodines. Detroit Edison used doses calculated by the GASPAR II code at 0.25 mi from the proposed Fermi 3 site in estimating terrestrial species doses (Detroit Edison 2011a). Estimates of the total body doses to the surrogate species from the gaseous pathway are shown in Table 5-28.

5.9.5.3 Impact on Biota Other Than Humans

Radiological doses to nonhuman biota are expressed in units of absorbed dose (mrad) because the dose equivalent (mrem) applies only to human radiological doses. The ICRP (ICRP 1977, 1991, 2007) states that if humans are adequately protected, other living things are also likely to be sufficiently protected. The International Atomic Energy Agency (IAEA 1992) and the NCRP (1991) reported that a chronic dose rate of no more than 10 mGy/day (1000 mrad/day) to the MEI in a population of aquatic organisms would ensure protection of the population. IAEA (1992) also concluded that chronic dose rates of 1 mGy/day (100 mrad/day) or less do not appear to cause observable changes in terrestrial animal populations.

Table 5-29 compares estimated the total body dose rates to surrogate biota species that would be produced by releases from Fermi 3 to the IAEA/NCRP biota dose guidelines (IAEA 1992; NCRP 1991). None of the surrogate species had daily dose rates that exceeded the IAEA guidelines. Moreover, the biota dose estimates for Fermi 3 are conservative, because they do not consider decay of liquid effluents during transit. Actual doses to the biota are likely to be much less.

Table 5-29. Comparison of Biota Doses from Fermi 3 to IAEA/NCRP Guidelines for Biota Protection

Biota	Detroit Edison Estimate of Dose to Biota (mrad/day)[(a)]	IAEA/NCRP Guideline for Protection of Biota Populations (mrad/day)[(b)]
Fish	0.0063	1000
Invertebrate	0.021	1000
Algae	0.033	1000
Muskrat	0.071	100
Raccoon	0.032	100
Heron	0.049	100
Duck	0.071	100

Source: IAEA 1992

(a) Total dose from liquid and gaseous effluents in Table 5-25. For comparison purposes, Detroit Edison's reported dose in mrad/yr was converted to mrad/day by dividing by 365 days/yr. Published guidelines reported doses in mGy/day (1 mGy = 100 mrad).

(b) Guidelines in IAEA and NCRP reports expressed in Gy/day (1 mGy = 100 mrad).

The maximum total dose from both liquid and gaseous pathways from the bounding calculation is about 26.0 mrad/yr, or about 0.07 mrad/day. Thus, doses to biota calculated by Detroit Edison are far below the IAEA (1992) guidelines of 100 mrad/day (0.1 rad/day) for terrestrial biota and 1 rad/day for aquatic biota.

On the basis of the information provided by Detroit Edison and the NRC's independent evaluation, the NRC staff concludes that the radiological impact on biota from the routine operation of the proposed Fermi 3 would be SMALL and additional mitigation is not warranted.

5.9.6 Radiological Monitoring

An REMP has been in place for the Fermi site since Fermi 2 operations began in 1985, with preoperational sample collection activities beginning in 1978 (Detroit Edison 2011a). The REMP includes monitoring of the airborne exposure pathway, direct exposure pathway, water exposure pathway, aquatic exposure pathway from Lake Erie, and ingestion exposure pathway in a 5-mi radius of the station, with indicator locations near the plant perimeter and control locations at distances greater than 10 mi. An annual survey is conducted for the area surrounding the site to verify the accuracy of the assumptions used in the analyses. The REMP program includes the collection and analysis of samples of air particulates, precipitation, crops, milk, soil, well water, surface water, fish, and silt as well as the measurement of ambient gamma radiation. Radiological releases are summarized in an annual report, the most recent of which is *Fermi 2 – 2010 Radioactive Effluent Release Report* (Detroit Edison 2011b). The limits for all radiological releases are specified in the Offsite Dose Calculation Manual (ODCM) for Fermi 2, which is also provided in this report (Detroit Edison 2011b).

Fermi 3 construction would include a new protected area fence enclosing Fermi 2 and 3. Depending on the location of the new protected area fence, new near-field thermoluminescent dosimeter locations would be established to provide adequate monitoring for both Fermi 2 and Fermi 3 (Detroit Edison 2011a). To the greatest extent practical for other monitoring, the REMP for Fermi 3 would use the procedures and sampling locations used for Fermi 2. The staff reviewed the documentation for the existing REMP, the ODCM, and recent monitoring reports from the Fermi site and determined that the current operational monitoring program is adequate to establish the radiological baseline for comparison with the environmental impacts expected from the construction and operation of Fermi 3.

The annual radioactive effluent release report for 2010 summarized the results of the groundwater sampling performed by Detroit Edison in various locations around the plant under the NEI groundwater protection initiative (Detroit Edison 2011b). The sporadic and variable trace quantities of tritium (maximum concentration observed was 1950 pCi/L) were detected in the few shallow groundwater wells downwind from the Fermi 2 stack. Detroit Edison attributed this to the recapture of tritium in precipitation from the plant’s gaseous effluent (Detroit Edison 2009c). The detected tritium concentrations were far below the EPA drinking water standard of 20,000 pCi/L (41 FR 28402). Detroit Edison has indicated that any proposed changes in groundwater monitoring to support the NEI initiative for operation of Fermi 3 (see Section 2.11 for a description of the initiative) would be made prior to fuel loading for Fermi 3 (Detroit Edison 2009c).

5.10 Nonradioactive Waste Impacts

This section describes the potential impacts on the environment that could result from the generation, handling, and disposal of nonradioactive waste and mixed waste during the operation of Fermi 3. As discussed in Section 3.4.4, the types of nonradioactive waste that would be generated, handled, and disposed of during operational activities at Fermi 3 include solid wastes, liquid effluents, and air emissions. Solid wastes include municipal waste, dredge spoils, sewage treatment sludge, and industrial wastes. Liquid waste includes NPDES-permitted discharges (such as effluents that contain chemicals or biocides), wastewater effluents, site stormwater runoff, and other liquid wastes (such as used oils, paints, and solvents that require offsite disposal). Air emissions would primarily be generated by vehicles, diesel generators, and combustion generators. In addition, small quantities of hazardous waste and of mixed waste, which is waste that has both hazardous and radioactive characteristics, may be generated during plant operations. The assessment of potential impacts resulting from these types of wastes is presented in the following subsections.

5.10.1 Impacts on Land

The operation of Fermi 3 would generate solid and liquid wastes similar to those already generated by the current operation of Fermi 2. Although the total volume of solid and liquid wastes would increase at the Fermi site, no new solid or liquid waste types are expected to result from the operation of the new Fermi 3 (Detroit Edison 2011a).

Detroit Edison has indicated it would continue to use recycling and waste minimization practices in place at the Fermi site for the nonradioactive solid waste that would be generated from the operation of Fermi 3. Solid wastes – such as used oils, antifreeze, scrap metal, lead-acid batteries, and paper – that could be recycled or reused would be managed through the approved and licensed contractor. The solid waste that could not be recycled or reused would be transported to the licensed offsite commercial disposal sites (Detroit Edison 2011a). Spoils from maintenance dredging of the water intake canal and cleaning of the pump house intakes would be accumulated in the onsite Spoils Disposal Pond. Subject to MDEQ and USACE review, dredged material from the disposal pond could be used as fill material or sold for use as topsoil (Detroit Edison 2011a). Debris collected on trash screens at the water intake structure would be disposed of offsite in accordance with State regulations.

The wastewater generated from the operation of Fermi 3 would be treated in a manner similar to that for the wastewater from existing Fermi 2 (Detroit Edison 2011a). Sanitary waste generated from the operation of Fermi 3 would be collected onsite and discharged to the Monroe Metropolitan Wastewater Treatment Facility for treatment under the site sanitary industrial use permit (Detroit Edison 2011a). Because effective practices for recycling and minimizing waste are already in place for Fermi 2 and because the plans are to manage Fermi 3 solid and liquid wastes in a similar manner in accordance with applicable Federal, State, and local requirements and standards, the review team expects that impacts on land from nonradioactive wastes generated during the operation of Fermi 3 would be minimal and that no further mitigation is warranted.

5.10.2 Impacts on Water

Effluents containing chemicals or biocides from the operation of Fermi 3 would be discharged mainly to Lake Erie. Discharge sources would include cooling tower blowdown, chemical and nonchemical metal-cleaning wastes, service water screen backwash, stormwater runoff, settled water from the Spoils Disposal Pond, and chemicals used to control zebra mussels (Detroit Edison 2011a).

Detroit Edison anticipates that it may be necessary to revise or apply for a new NPDES permit to accommodate increased discharges to Lake Erie resulting from the operation of Fermi 3 (Detroit Edison 2011a). In either case, discharges would be subject to limitations contained in the site's NPDES permit.

To properly manage stormwater flow, Detroit Edison would update its existing SWPPP to reflect the increase in impervious surfaces and changes in onsite drainage patterns (Detroit Edison 2011a). Sections 5.2.3.1 and 5.2.3.2 discuss impacts on the quality of the surface water and groundwater from operation of Fermi 3. Nonradioactive liquid effluents that would be discharged to Lake Erie would be regulated by MDEQ and subject to limitations contained in the site's NPDES permit.

Because there are regulated practices for managing liquid discharges containing chemicals or biocide and other wastewater and because there are plans for managing stormwater, the review team concludes that impacts on water from nonradioactive effluents during the operation of Fermi 3 would be minimal and that no further mitigation is warranted.

5.10.3 Impacts on Air

Operations of Fermi 3 would result in gaseous emissions from the intermittent operation of emergency diesel generators, an auxiliary boiler, and diesel fire pumps. In addition, increased vehicular traffic associated with the personnel needed to operate Fermi 3 would increase vehicle emissions in the area. Impacts on air quality are discussed in detail in Section 5.7.2. Increases in air emissions from operation of Fermi 3 would be in accordance with permits issued by MDEQ that would ensure compliance with the Federal, State, and local air quality control laws and regulations. Because there are regulated practices for managing air emissions from stationary sources, the review team concludes that impacts on air from nonradioactive emissions during the operation of Fermi 3 would be minor and that no further mitigation is warranted.

5.10.4 Mixed Waste Impacts

Mixed waste contains both low-level radioactive waste and hazardous waste. The generation, storage, treatment, and disposal of mixed waste is regulated by the Atomic Energy Act of 1964, the Solid Waste Disposal Act of 1965 as amended by the Resource Conservation and Recovery Act (RCRA) in 1976, and the Hazardous and Solid Waste Amendments (which amended RCRA in 1984).

Each reactor at the Fermi site is expected to produce on the order of 0.5 m^3/yr of mixed waste. Mixed waste generated at Fermi 2 in the last few years ranged from 200 to 2000 lb/yr (Detroit Edison 2011a). Mixed waste can be reduced through decay, stabilization, neutralization, filtration, or chemical decontamination or treatment. Detroit Edison stated that the mixed waste that cannot be treated onsite will be temporarily stored at a remote monitored structure until it is shipped for offsite disposal at an approved facility. Existing Detroit Edison procedures for the storage of mixed wastes would be used to limit any occupational exposure or accidental spill (Detroit Edison 2011a). Fermi 3 would also claim an exemption under a state of Michigan low-level mixed waste exemption (Fermi 2 currently operates under this exemption) that would allow Detroit Edison to store an unlimited quantity of mixed waste for a long time if the mixed waste exemption conditions are met.

Because effective practices for minimizing waste are already in place for Fermi 2 and because the plans are to manage Fermi 3 mixed wastes in a similar manner in accordance with all applicable Federal, State, and local requirements and standards, the review team concludes that impacts from the generation of mixed waste at Fermi 3 would be minimal and that no further mitigation is warranted.

5.10.5 Summary of Nonradioactive Waste Impacts

Solid, liquid, gaseous, and mixed wastes generated during the operation of Fermi 3 would be handled according to county, State, and Federal regulations. Required county, State, and Federal permits for the handling and disposal of dredged material and solid waste would be obtained. A revised SWPPP for surface-water runoff and NPDES permits for permitted releases of cooling and auxiliary system effluents would ensure compliance with the Federal Water Pollution Control Act (Clean Water Act) and MDEQ water quality standards. Wastewater discharge would be required to comply with NPDES limitations. Air emissions from Fermi 3 operations would be compliant with air quality standards as permitted by MDEQ. Impacts from the generation, storage, and disposal of mixed waste during operation of Fermi 3 would be compliant with requirements and standards. On the basis of (1) information provided by Detroit Edison, (2) effective practices for recycling, minimizing, managing, and disposing of wastes already in use at the Fermi site, (3) the review team's expectation that regulatory approvals will be obtained to regulate the additional waste that would be generated during Fermi 3 operations, and (4) the review team's independent evaluation, the review team concludes that the potential impacts from nonradioactive waste resulting from the operation of Fermi 3 would be SMALL and further mitigation is not warranted.

Cumulative impacts on water and air from nonradioactive emissions and effluents are discussed in Sections 7.2.2.1 and 7.5, respectively. For the purposes of Chapter 9, the staff concludes that (1) there would be no substantive differences between the impacts from nonradioactive waste at the Fermi site and those at the alternative sites, and (2) no substantive cumulative impacts warrant further discussion beyond those discussed for the alternative sites in Section 9.3.

5.11 Environmental Impacts of Postulated Accidents

The NRC staff considered the radiological consequences on the environment from potential accidents at the proposed Fermi 3. Detroit Edison based its COL application on the proposed installation of an ESBWR design for the proposed Fermi 3. Detroit Edison's application references Revision 9 of ESBWR DCD. The NRC staff issued a final design approval for the ESBWR on March 9, 2011 (76 FR 14437) and has begun the process of design certification rulemaking for the ESBWR (76 FR 16549).

The term "accident" as used in this section refers to any off-normal event not addressed in Section 5.9 that results in release of radioactive materials into the environment. This review focuses on events that could lead to releases substantially in excess of permissible limits for normal operations. Normal release limits are specified in 10 CFR Part 20, Appendix B, Table 2.

Numerous features combine to reduce the risk associated with accidents at nuclear power plants. Safety features in the design, construction, and operation of the plants, which make up the first line of defense, are intended to prevent the release of radioactive materials from the plant. The design objectives and the measures for keeping levels of radioactive materials in effluents to unrestricted areas ALARA are specified in 10 CFR Part 50, Appendix I. Additional measures are designed to mitigate the consequences of failures in the first line of defense. These measures include the NRC's reactor site criteria in 10 CFR Part 100, which require the site to have certain characteristics that reduce the risk to the public and reduce the potential impacts of an accident, and emergency preparedness plans and protective action measures for the site and environs, as set forth in 10 CFR 50.47, 10 CFR Part 50, Appendix E, and NUREG-0654/FEMA-REP-1 (NRC 1980). All these safety features, measures, and plans make up the defense-in-depth philosophy to protect the health and safety of the public and the environment.

On March 11, 2011, and for an extended period thereafter, several nuclear power plants in Japan experienced the loss of important equipment necessary to maintain reactor cooling after the combined effects of severe natural phenomena: an earthquake followed by a tsunami. In response to these events, the Commission established a task force to review the current regulatory framework in place in the United States and to make recommendations for improvements. On July 12, 2011, the task force reported the results of its review (NRC 2011) and presented the recommendations to the Commission on July 19, 2011. As part of the short-term review, the task force concluded that, while improvements are expected to be made as a result of the lessons learned, the continued operation of nuclear power plants and licensing activities for new plants do not pose an imminent risk to public health and safety. In addition, a number of areas were recommended to the Commission for long-term consideration.

Collectively, these recommendations are intended to clarify and strengthen the regulatory framework for protection against severe natural phenomena, for mitigation of the effects of such events, for coping with emergencies, and for improving the effectiveness of NRC programs. Because of the passive design and inherent 72-hour coping capability for core, containment, and spent fuel pool cooling with no operator action required, the ESBWR design has many of the design features and attributes necessary to address the Task Force Recommendations (NRC 2011).

On March 12, 2012, the NRC issued three Orders and a request for information (RFI) to holders of U.S. commercial nuclear reactor licenses and construction permits to enhance safety at U.S. reactors based on specific lessons learned from the event at Japan's Fukushima Dai-ichi nuclear power plant as identified in the task force report. The first and third Orders apply to every U.S. commercial nuclear power plant, including recently licensed new reactors. The first Order requires a three-phase approach for mitigating beyond-design-basis external events. Licensees are required to use installed equipment and resources to maintain or restore core, containment and spent fuel pool cooling during the initial phase. During the transition phase, licensees are required to provide sufficient, portable, onsite equipment and consumables to maintain or restore these functions until they can be accomplished with resources brought from off site. During the final phase, licensees are required to obtain sufficient offsite resources to sustain those functions indefinitely (77 FR 16091). The second Order requires reliable hardened vent systems at boiling water reactor facilities with “Mark I” and “Mark II” containment structures (77 FR 16098). The third Order requires reliable spent fuel pool level instrumentation (77 FR 16082). The RFI addressed five topics: (1) seismic reevaluations; (2) flooding reevaluations; (3) seismic hazard walkdowns; (4) flooding hazard walkdowns, and; (5) a request for licensees to assess their current communications system and equipment under conditions of onsite and offsite damage and prolonged station blackout and perform a staffing study to determine the number and qualifications of staff required to fill all necessary positions in response to a multi-unit event (NRC 2012b, c). The RFI requested reactor licensees to reevaluate seismic and flooding hazards using present day methods to determine if the plant's design basis needs to be changed.

The NRC staff issued RAIs to Detroit Edison requesting information to address the requirements of the first and third Orders, and information sought in the first and fifth RFI topics (NRC 2012d, e, f). The ESBWR containment design differs from those identified in the second Order; therefore, the actions addressed in this order are not applicable to Fermi 3. NRC's evaluation of Detroit Edison's responses is addressed in the NRC's Final Safety Evaluation Report, and any changes to the COL application that are deemed necessary will be incorporated into the applicant's FSAR.

The severe accident evaluation presented later in this section draws from the analyses developed in the staff's safety review, which includes consideration of severe accidents initiated by external events and those that involve fission product releases. The staff evaluation discusses the environmental impacts of severe accidents in terms of risk, which considers both the likelihood of a severe accident and its consequences. For several reasons discussed below, the staff has determined that the Fukushima accident and the NRC's subsequent Orders and requests for information do not change the staff's conclusions on the environmental impacts of design basis accidents or severe accidents.

Each new reactor application evaluates the natural phenomena that are pertinent to the site for the proposed reactor design by applying present-day regulatory guidance and methodologies. This includes the determination of the characteristics of the flood and seismic hazards. With respect to flooding, Detroit Edison documented the flood hazard in the FSAR consistent with present-day guidance and methodologies. This analysis sufficiently addressed the considerations involved in the second topic in the March 2012 RFI. The NRC staff performed a confirmatory review of the flood hazard analysis and has affirmed in Section 2.4 of the NRC's Final Safety Evaluation Report that the analysis was adequate and meets all applicable regulatory requirements (NRC 2012g). The staff evaluated all flood-causing mechanisms and concluded that none would exceed the referenced ESBWR standard plant site parameter for the maximum flood (or tsunami) level or affect the structures, systems, and components (SSCs) important to safety. This conclusion is based on the Fermi site topography, which shows that the SSCs important to safety are at elevations higher than maximum flood hazard. In addition, the staff concludes the likelihood of an extreme flooding event similar to what occurred at the Fukushima Dai-ichi site is low since neither the applicant nor the staff has identified any mechanisms for creating a flooding event at the Fermi site that is at all comparable with the extreme flooding event that occurred at the Fukushima Dai-ichi site.

With respect to the consideration of severe accidents initiated by seismic events, Detroit Edison is currently developing its response to the staff's seismic hazard RAI, which included the considerations of the first topic in the March 2012 RFI (NRC 2012d). In this RAI, the applicant was requested to evaluate the impacts of the newly released CEUS-SSC model, as documented in NUREG-2115, on the Fermi 3 site specific seismic hazard calculation. This model considers the latest seismic source information for the Central and Eastern United States. The applicant will need to demonstrate and the NRC staff will confirm that the ESBWR seismic design response spectra are acceptable at the Fermi 3 site. However, the applicant's accident analyses should not be affected because the applicant would be required to modify the plant design to assure any change in the seismic hazard can be accounted for without a reduction in design margin.

In addition to the above considerations for seismic and flooding, the safety features of the ESBWR design further support the conclusion that the Fukushima accident does not warrant a change in the environmental risks of severe accidents considered in the Fermi 3 FEIS analysis. In particular, the potential design-related vulnerabilities raised by the event at Fukushima, such as the impact of the extended loss of alternating and/or direct current electric power on core cooling systems, would not materially affect the analysis of severe accidents for Fermi 3 because the ESBWR has been designed to withstand such a loss of power and prevent and mitigate severe accidents. As previously noted in the task force report, the ESBWR passive safety systems would remove the decay heat from the reactor core on the loss of alternating and/or direct current electric power and operate to maintain adequate core cooling for a period of 72 hours without further operator action, unlike the facilities at the Fukushima site. This core cooling by the passive safety systems can be sustained for an extended period beyond 72 hours where the only operator action is to re-fill the internal pool that provides the source of water for the passive safety systems. Additional details are provided in the staff's Safety Evaluation Report for the ESBWR design certification. The NRC staff's design certification review (76 FR 14437) regarding the safety of the ESBWR design concluded that the design has a very high capacity to withstand beyond design basis events.

In sum, none of the information the staff has identified about the Fukushima accident or the steps taken by the NRC to date to implement the task force recommendations suggests that the seismic and flooding hazards or the available mitigation capability (i.e., passive safety systems) assumed in the Fermi EIS analysis of severe accidents would be affected. For these reasons, the NRC's analysis of the environmental impacts of design basis and severe accidents presented herein remains valid.

This section discusses the (1) types of radioactive materials, (2) paths to the environment, (3) relationship between radiation dose and health effects, and (4) environmental impacts of reactor accidents – both design-basis accidents (DBAs) and severe accidents. The environmental impacts from accidents during the transportation of spent fuel are discussed in Chapter 6.

The potential for dispersion of radioactive materials in the environment depends on the mechanical forces that physically transport the materials and on the physical and chemical forms of the material. Radioactive material exists in a variety of physical and chemical forms. The majority of the material in the fuel is in the form of nonvolatile solids. However, there is a significant amount of material that is in the form of volatile solids or gases. The gaseous radioactive materials include the chemically inert noble gases (e.g., krypton and xenon), which have a high potential for release. Radioactive forms of iodine, which are created in substantial quantities in the fuel by fission, are volatile. Other radioactive materials formed during the operation of a nuclear power plant have lower volatilities and therefore have lower tendencies to escape from the fuel than do the noble gases and isotopes of iodine.

Radiation dose to individuals is determined by their proximity to radioactive material, the duration of their exposure, the extent to which they are shielded from the radiation, and the extent to which radioactive material is ingested or inhaled. Pathways that lead to radiation dose include (1) external radiation from radioactive material in the air, on the ground, and in the water; (2) inhalation of radioactive material; and (3) ingestion of food or water containing material initially deposited on the ground and in water.

Radiation protection experts assume that any amount of radiation exposure may pose some risk of causing cancer or a severe hereditary effect and that the risk is higher for higher radiation exposures. Therefore, a linear, no-threshold response model is used to describe the relationship between radiation dose and detriments such as cancer induction. The recent BEIR VII report (National Research Council 2006) supports the linear, no-threshold dose response model as a basis for estimating the risks from low doses. This approach is accepted by the NRC as a conservative method for estimating health risks from radiation exposure, while it also recognizes that the model may overestimate those risks.

Physiological effects are clinically detectable if individuals receive radiation exposure resulting in a dose of more than about 25 rad over a short period of time (hours). Untreated doses of about 250 to 500 rad received over a relatively short period (hours to a few days) can be expected to cause some fatalities.

5.11.1 Design-Basis Accidents

Detroit Edison evaluated the potential consequences of postulated accidents to demonstrate that an ESBWR could be constructed and operated at the Fermi site without undue risk to the health and safety of the public (Detroit Edison 2011a). These evaluations used DBAs for the ESBWR design being considered for the Fermi site and site-specific meteorological data. The set of accidents covers events that range from those having a relatively high probability of occurrence with relatively low consequences to those having a relatively low probability of occurrence with high consequences.

The DBA review focuses on the ESBWR design at the Fermi site. The bases for analyses of postulated accidents for this design are well established because they have been considered as part of the NRC's reactor design certification process. Potential consequences of DBAs are evaluated following procedures outlined in regulatory guides and standard review plans. The potential consequences of accidental releases depend on the specific radionuclides released, amount of each radionuclide released, and meteorological conditions. The source terms for the ESBWR and methods for evaluating potential accidents are based on guidance in Regulatory Guide 1.183 (NRC 2000b).

For environmental reviews, consequences are evaluated by assuming realistic meteorological conditions. Meteorological conditions are represented in these consequence analyses by an atmospheric dispersion factor, which is also referred to as χ/Q. Acceptable methods of calculating χ/Q for DBAs from meteorological data are set forth in Regulatory Guide 1.145 (NRC 1983).

Table 5-30 lists χ/Q values pertinent to the environmental review of DBAs for the Fermi 3 site (Detroit Edison 2011a). Smaller χ/Q values are associated with greater dilution capability. The first column lists the time periods and boundaries for which χ/Q and dose estimates are needed.

Table 5-30. Atmospheric Dispersion Factors for Fermi 3 Site DBA Calculations

Time Period and Boundary	**χ/Q (s/m^3) (a)**
0 to 2 hr or worst 2-hr period, exclusion area boundary	5.7×10^{-5}
0 to 8 hr, low-population zone	3.1×10^{-6}
8 to 24 hr, low-population zone	2.7×10^{-6}
1 to 4 days, low-population zone	2.0×10^{-6}
4 to 30 days, low-population zone	1.3×10^{-6}

Source: Detroit Edison (2011a).
(a) Values are rounded to two significant digits

For the exclusion area boundary, the postulated DBA dose and its atmospheric dispersion factor are calculated for a short term (i.e., 2 hr). For the low-population zone, they are calculated for the course of the accident (i.e., 30 days, composed of four time periods). The second column lists the χ/Q values for the Fermi site, using the site-specific meteorological information discussed in ER Section 2.7.4-4, and the exclusion area boundary and low-population zonedistances (Detroit Edison 2011a). In ER Section 2.7.6.1, Detroit Edison calculated the χ/Q values listed in Table 5-30 by using 6 years of onsite meteorological data (2002 through 2007) for the Fermi site and assuming the release point is located at ground level.

The NRC staff reviewed the meteorological data used by Detroit Edison and the method used to calculate the atmospheric dispersion factors. Based on these reviews, the staff concludes that the atmospheric dispersion factors for the Fermi site are acceptable for use in evaluating potential environmental consequences of postulated DBAs for the ESBWR design at the Fermi site.

Detroit Edison calculated site-specific consequences of DBAs in the ER on the basis of analyses performed for design certification of an ESBWR design with adjustment for Fermi 3 site-specific χ/Q characteristics. Table 5-31 presents the list of DBAs considered by Detroit Edison and the estimate of the environmental consequences of each accident in terms of the total effective dose equivalent (TEDE). TEDE is estimated by the sum of the committed effective dose equivalent from inhalation and the effective dose equivalent from external exposure. Dose conversion factors from Federal Guidance Report 11 (Eckerman et al. 1988) were used to calculate the committed effective dose equivalent. Similarly, dose conversion factors from Federal Guidance Report 12 (Eckerman and Ryman 1993) were used to calculate the effective dose equivalent.

The staff reviewed Detroit Edison's selection of DBAs by comparing the accidents listed in the COL application with the DBAs considered in the ESBWR DCD (GEH 2010e), which has been reviewed and approved in the design certification process. The staff confirmed that the DBAs in the ER are the same as those considered in the design certification; therefore, the staff

Table 5-31. Design-Basis Accident Doses for an ESBWR at Fermi Site

	Total Effective Dose Equivalent (rem)(a)			
Accident	**Standard Review Plan Section(b)**	**Exclusion Area Boundary**	**Low Population Zone**	**Review Criterion**
Main steam line break	15.6.4			
Pre-incident iodine spike		0.074	0.0032	25 (c)
Equilibrium iodine spike		0.0057	0.0016	2.5(d)
Loss-of-coolant accident	15.6.5	0.64	0.89	2.5 (c)
Feedwater line break	15.2.8			
Pre-incident iodine spike		0.51	0.027	25(c)
Equilibrium iodine spike		0.031	0.0016	2.5 d)
Reactor water cleanup water line break				
Pre-incident iodine spike		0.20	0.011	25 (c),
Equilibrium iodine spike		0.011	0.0016	2.5 (d)
Failure of small lines carrying primary coolant outside containment	15.6.2			
Pre-incident iodine spike		0.0097	0.0043	2.5 (c)
Equilibrium iodine spike		0.0028	0.0043	2.5 (d)
Fuel handling	15.7.4	0.12	0.0064	6.3 (d)

(a) To convert rem to Sv, divide by 100. Values are rounded to two significant digits.
(b) NUREG-0800 (NRC 2007b).
(c) 10 CFR 52.79(a)(1), and 10 CFR 100.21 criteria.
(d) SRP criteria, Table 1 in SRP Section 15.0.3.

concluded that the set of DBAs is appropriate. In addition, the staff reviewed the calculation of the site-specific consequences of the DBAs and found the results of the calculations to be reasonable for use in the evaluation of environmental consequences of DBAs.

There are no environmental criteria related to the potential consequences of DBAs. Consequently, the review criteria used in the staff's safety review of DBA doses are included in Table 5-31 to illustrate the magnitude of the calculated environmental consequences (TEDE). In all cases, the calculated TEDE values are considerably smaller than the TEDE limits used as safety review criteria.

The NRC staff reviewed the Detroit Edison DBA analysis in the ER, which is based on analyses performed for design certification of the ESBWR design with adjustment for Fermi site-specific characteristics. The NRC staff also performed an independent DBA analysis. The results of the Detroit Edison and the NRC staff analyses indicate that the environmental consequences associated with DBAs, if an ESBWR design were to be located at the Fermi site, would be small. On this basis, the staff concluded that the environmental consequences of DBAs at the Fermi site would be SMALL for an ESBWR.

5.11.2 Severe Accidents

Section 7.2 of the ER (Detroit Edison 2010b, 2011a) considers the potential consequences of severe accidents for single ESBWR at the Fermi site. Three pathways are considered: (1) atmospheric pathway, in which radioactive material is released to the air; (2) surface-water pathway, in which airborne radioactive material falls out on open bodies of water; and (3) groundwater pathway, in which groundwater is contaminated by a basemat melt-through, with subsequent contamination of the surface water by the groundwater.

Detroit Edison's consequence assessment is based on the Revision 4 of the probabilistic risk assessment (PRA) for the ESBWR design (GEH 2009). GEH subsequently updated the PRA model to Revision 6 (GEH 2010c). The NRC staff evaluated the current PRA model and its results, and concluded that the Revision 6 results are an acceptable basis for evaluating severe accidents and strategies for mitigating them. The applicant discussed the extent to which the ESBWR PRA bounds the effects of site-specific internal and external flooding in Appendix AA of Chapter 19 of the FSAR (Detroit Edison 2012e). The NRC staff has reviewed this information, and as discussed in its safety evaluation of the information in Chapter 19 of the FSAR, considers the certified design PRA results incorporated by reference to be bounding. Detroit Edison is required by regulation to upgrade and update the PRA before initial fuel loading. At that time, the NRC staff expects that the PRA will be site-specific and that it will no longer use the bounding assumptions of the design-specific PRA.

Detroit Edison's evaluation of the potential environmental consequences for the atmospheric and surface-water pathways incorporates the results of the MELCOR Accident Consequence Code System (MACCS2) computer code (Chanin et al. 1990; Chanin and Young 1998; Jow et al. 1990) run that used ESBWR source term information and site-specific meteorology, population, and land use data. Detroit Edison provided copies of the input and output files for the MACCS2 code runs (Detroit Edison 2011a). The NRC staff reviewed Detroit Edison's input and output files, made confirmatory calculations, and determined that Detroit Edison's results were reasonable.

The MACCS computer code was developed to evaluate the potential offsite consequences of severe accidents for the sites covered by NUREG-1150 (NRC 1990). The MACCS2 code evaluates the consequences of atmospheric releases of material following a severe accident. The pathways modeled include exposure to the passing plume, exposure to material deposited on the ground and skin, inhalation of material in the passing plume and resuspended from the ground, and ingestion of contaminated food and surface water.

Three types of severe accident consequences were assessed in the MACCS2 analysis: (1) human health, (2) economic costs, and (3) land area affected by contamination. Human health effects are expressed in terms of the number of early fatalities, latent cancers, and other diseases that might be expected if a severe accident were to occur. These effects are directly related to the cumulative radiation dose received by the general population. MACCS2 estimates both early fatalities and latent cancer fatalities. Early fatalities are related to high doses or dose rates and expected to occur within a year of exposure (Jow et al. 1990).

Latent fatalities are related to exposure of a large number of people to low doses and dose rates and expected to occur after a latent period of several (2 to 15) years. Population health-risk estimates are based on the population distribution within a 50-mi radius of the site. Economic costs of a severe accident include the costs associated with short-term relocation of people; decontamination of property and equipment; interdiction of food supplies, land, and equipment use; and condemnation of property. The affected land area is a measure of the areal extent of the residual contamination following a severe accident. Farm land decontamination is an estimate of the area that has an average whole body dose rate for the 4-year period following the release that would be more than 0.5 rem/yr if not reduced by decontamination and that would have a dose rate following decontamination of less than 0.5 rem/yr. Decontaminated land is not necessarily suitable for farming.

Risk is the product of the frequency and the consequences of an accident. For example, the probability of a severe accident resulting from internal events at power and without loss of containment for an ESBWR design at the Fermi site is estimated to be 1.5×10^{-8} per reactor-year (Ryr) (see Table 5-32). The cumulative population dose associated with a severe accident without loss of containment at the Fermi site is calculated to be about 146,700 person-rem (Detroit Edison 2011a). The population dose risk for this class of accidents is the product of 1.5×10^{-8} per Ryr and 146,700 person-rem, or 2.2×10^{-3} person-rem/Ryr (see Table 5-32).

The following sections discuss the estimated risks associated with each pathway. The risks presented in the tables that follow are risks per year of reactor operation.

5.11.2.1 Air Pathway

The MACCS2 code directly estimates consequences associated with releases to the air pathway. Detroit Edison used the MACCS2 code to estimate consequences to a projected population in 2060 on the basis of meteorological data for calendar years 2002 through 2007. The results of the MACCS2 runs are presented in Table 5-32 for an ESBWR at the Fermi site (Detroit Edison 2011a). The values presented in this table are based on using the 2002 meteorological data that resulted in the highest consequences. The core damage frequencies (CDFs) given in these tables are for internally initiated accident sequences while the plant is at power. Internally initiated accident sequences include sequences that are initiated by human error, equipment failures, loss of offsite power, etc. The CDFs used by Detroit Edison are those from Revision 4 of the ESBWR PRA submitted as part of the application for certification of the ESBWR design (GEH 2009). GEH has updated these frequencies in the ESBWR PRA Revision 6 (GEH 2010c). The core damage frequencies in ESBWR PRA Revision 6 are similar to those in Revision 4.

Table 5-32. Mean Environmental Risks from ESBWR Internal Events At-Power Severe Accidents at the Fermi Site

			Environmental Risk					
				Fatalities per Ryr				
Release Category Description (Accident Class)		Core Damage (frequency/ Ryr)[(a)]	Population Dose (person-rem/Ryr)[(b)]	Early[(c)]	Latent[(d)]	Cost[(e)] ($/Ryr)	Land Requiring Decontamination[(f)] (ac/Ryr)	Population Dose from Water Ingestion (person-rem/Ryr)[(b)]
TSL	Containment leakage at technical specification limit	1.5×10^{-8}	2.2×10^{-3}	0.0	1.3×10^{-6}	0.50	4.2×10^{-6}	4.8×10^{-3}
CCIW	Containment fails due to core concrete interaction; lower drywell debris bed covered	2.9×10^{-12}	2.5×10^{-5}	1.3×10^{-13}	1.5×10^{-8}	0.071	3.2×10^{-7}	3.9×10^{-7}
EVE	Ex-vessel steam explosion fails containment	1.1×10^{-9}	2.5×10^{-2}	3.4×10^{-9}	1.5×10^{-5}	92.0	2.2×10^{-4}	1.2×10^{-3}
FR	Release through controlled (filtered) venting from suppression chamber	9.2×10^{-11}	4.2×10^{-4}	1.5×10^{-14}	2.5×10^{-7}	0.47	3.3×10^{-6}	2.1×10^{-6}
CCID	Containment fails due to core concrete interaction; lower drywell debris bed uncovered	1.5×10^{-12}	3.2×10^{-5}	3.7×10^{-12}	2.0×10^{-8}	0.12	3.2×10^{-7}	3.9×10^{-7}
OPW2	Containment fails due to late (>24 hr) loss of containment heat removal	8.5×10^{-12}	1.2×10^{-5}	0.0	7.0×10^{-9}	0.0021	1.8×10^{-8}	3.6×10^{-8}
BOC	Break outside of containment	7.9×10^{-11}	2.6×10^{-3}	2.3×10^{-9}	1.8×10^{-6}	8.7	1.5×10^{-5}	1.5×10^{-4}
BYP	Containment bypassed because of containment isolation system failure with large (>12 in. hole) opening; lower drywell debris bed covered	5.7×10^{-11}	1.7×10^{-3}	5.4×10^{-10}	1.4×10^{-6}	3.5	9.9×10^{-6}	1.9×10^{-5}
OPVB	Containment fails due to failure of vapor suppression system (vacuum breaker) function	2.1×10^{-12}	1.3×10^{-5}	2.6×10^{-14}	7.6×10^{-9}	0.030	1.5×10^{-7}	1.2×10^{-7}
OPW1	Containment fails due to early (<24 hr) loss of containment heat removal	2.0×10^{-12}	1.2×10^{-5}	7.6×10^{-17}	7.3×10^{-9}	0.030	1.5×10^{-7}	1.3×10^{-7}
Total		$\mathbf{1.7 \times 10^{-8}}$	$\mathbf{3.2 \times 10^{-2}}$	$\mathbf{6.3 \times 10^{-9}}$	$\mathbf{2.0 \times 10^{-5}}$	$\mathbf{1.1 \times 10^{2}}$	$\mathbf{2.6 \times 10^{-4}}$	$\mathbf{1.3 \times 10^{-3}}$

Source: Detroit Edison 2011a

(a) Detroit Edison used core damage frequencies from ESBWR PRA Revision 4 (GEH 2009). GEH has updated these frequencies in the ESBWR PRA Revision 6 (GEH 2010c). The core damage frequencies in ESBWR Revision 6 are similar to those of Revision 4 values.

(b) To convert rem to Sv, divide rem by 100.

(c) Early fatalities are fatalities related to high doses or dose rates that generally can be expected to occur within a year of the exposure (Jow et al. 1990).

(d) Latent fatalities are fatalities related to low doses or dose rates that could occur after a latent period of several (2 to 15) years.

(e) Cost risk includes costs associated with short-term relocation of people, decontamination, interdiction, and condemnation. It does not include costs associated with health effects (Jow et al. 1990).

(f) Land risk is the area where the average whole body dose rate for the 4-year period following the accident exceeds 0.5 rem/yr but can be reduced to less than 0.5 rem/yr by decontamination. To convert acres to hectares, divide by 2.47.

Core damage frequencies for other at-power events (external events) and lower power or shutdown are discussed in the ESBWR PRA (GEH 2010c) and summarized in Section 19.2.3.2 of the ESBWR DCD (GEH 2010d). Detroit Edison incorporates by reference these analyses in the Fermi 3 COL application. Section 19.2.3.2.4 of the DCD discusses a seismic margins analysis in which PRA-based methods are used to identify potential vulnerabilities in the design so corrective measures can be taken to reduce risk. Similarly, Sections 19.2.3.2.1 through 19.2.3.2.3 address risks associated with external fires, external flooding, and high winds. Section 19.2.4 of the DCD addresses risks during plant shutdown. The total environmental risks from shutdown and power operations, including internal events, fires, high winds, and floods, are presented in Table 5-33.

Table 5-33 presents the probability-weighted consequences (i.e., the risks of severe accidents) for an ESBWR located on the Fermi site. This table shows the risks are small for all risk categories considered. The presented risks are for a projected population in calendar year 2060 in the surrounding 50-mi of the Fermi site. For perspective, Tables 5-34 and 5-35 compare the health risks from severe accidents for an ESBWR at the Fermi site with the risks for current-generation reactors at various sites.

In Table 5-34, the health risks estimated for an ESBWR at the Fermi site are compared with health risk estimates for the five reactors considered in NUREG-1150 (NRC 1990). Although risks associated with both internally and externally initiated events were considered for the Peach Bottom and Surry reactors in NUREG-1150, only risks associated with internally initiated events are presented in Table 5-34. The health risks shown for an ESBWR at the Fermi site are significantly lower than the risks associated with current-generation reactors presented in NUREG-1150.

The last two columns of Table 5-34 provide average individual fatality risk estimates. To put these estimated fatality risks into context for the environmental analysis, the NRC staff compared these estimates to the safety goals. The Commission has set safety goals for average individual early fatality and latent cancer fatality risks from reactor accidents in the Safety Goal Policy Statement (51 FR 30028). These goals are presented here solely to provide a point of reference for the environmental analysis and do not serve the purpose of a safety analysis. This statement expressed the Commission’s policy regarding the acceptance level of radiological risk from nuclear power plant operation as follows:

- Individual members of the public should be provided a level of protection from the consequences of nuclear power plant operation such that individuals bear no significant additional risk to life and health.
- Societal risks to life and health from nuclear power plant operation should be comparable to or less than the risks of generating electricity by viable competing technologies and should not be a significant addition to other societal risks.

Table 5-33. Total Environmental Risks from ESBWR Severe Accidents at the Fermi Site

		Environmental Risk					
			Fatalities per Ryr				
Event Types	**Core Damage Frequency (Ryr^{-1})[(a)]**	**Population Dose (person-rem/Ryr)[(b)]**	**Early[(c)]**	**Latent[(d)]**	**Cost[(e)] (\$/Ryr)**	**Land Requiring Decontamination[(f)] (ac/Ryr)**	**Population Dose from Water Ingestion (person-rem/Ryr)[(b)]**
At Power Internal Events (see Table 5-32)	1.7×10^{-8}	0.032	6.3×10^{-9}	2.0×10^{-5}	110	2.6×10^{-4}	1.3×10^{-3}
At Power Fire	1.2×10^{-8}	0.040	1.2×10^{-8}	3.2×10^{-5}	83	5.2×10^{-4}	2.4×10^{-4}
At Power High Wind	8.6×10^{-9}	0.032	1.0×10^{-8}	2.6×10^{-5}	65	3.8×10^{-4}	1.9×10^{-4}
At Power Internal Flood	6.9×10^{-9}	0.092	2.8×10^{-8}	7.5×10^{-5}	180	1.0×10^{-3}	5.5×10^{-4}
Shutdown Internal Events	1.7×10^{-8}	0.51	1.6×10^{-7}	4.2×10^{-4}	1100	5.7×10^{-3}	3.0×10^{-3}
Shutdown Fire	9.6×10^{-9}	0.29	9.1×10^{-8}	2.4×10^{-4}	590	3.2×10^{-3}	1.7×10^{-3}
Shutdown High Wind	4.0×10^{-8}	1.2	3.8×10^{-7}	9.8×10^{-4}	2400	1.3×10^{-2}	6.9×10^{-3}
Shutdown Flood	5.2×10^{-9}	0.16	5.0×10^{-8}	1.3×10^{-4}	320	1.7×10^{-3}	9.1×10^{-4}
Total	**1.2×10^{-7}**	**2.3**	**7.4×10^{-7}**	**1.9×10^{-3}**	**4900**	**2.7×10^{-2}**	**1.4×10^{-2}**

(a) Core damage frequencies from ESBWR PRA Revision 6, Tables 10.3-3a, 10.3-3b, and 10.3-3c (GEH 2010c).
(b) To convert rem to Sv, divide rem by 100.
(c) Early fatalities are fatalities related to high doses or dose rates that generally can be expected to occur within a year of the exposure (Jow et al. 1990).
(d) Latent fatalities are fatalities related to low doses or dose rates that could occur after a latent period of several (2 to 15) years.
(e) Cost risk includes costs associated with short-term relocation of people, decontamination, interdiction, and condemnation. It does not include costs associated with health effects (Jow et al. 1990).
(f) Land risk is the area where the average whole body dose rate for the 4-year period following the accident exceeds 0.5 rem/yr but can be reduced to less than 0.5 rem/yr by decontamination. To convert acres to hectares, divide by 2.47.

Table 5-34. Comparison of Environmental Risks for an ESBWR at the Fermi 3 Site with Risks for Current-Generation Reactors at Five Sites Evaluated in NUREG-1150(a)

	Core Damage (frequency/ Ryr)	50-mi Population Dose Risk (person-rem/Ryr)(b)	Fatalities per Ryr		Average Individual Fatality Risk per Ryr	
			Early	Latent	Early	Latent Cancer
Grand Gulf(c)	4.0×10^{-6}	$5 \times 10^{+1}$	8×10^{-9}	9×10^{-4}	3×10^{-11}	3×10^{-10}
Peach Bottom(c)	4.5×10^{-6}	$7 \times 10^{+2}$	2×10^{-8}	5×10^{-3}	5×10^{-11}	4×10^{-10}
Sequoyah(c)	5.7×10^{-5}	$1 \times 10^{+3}$	3×10^{-5}	1×10^{-2}	1×10^{-8}	1×10^{-8}
Surry(c)	4.0×10^{-5}	$5 \times 10^{+2}$	2×10^{-6}	5×10^{-3}	2×10^{-8}	2×10^{-9}
Zion(c)	3.4×10^{-4}	$5 \times 10^{+3}$	4×10^{-5}	2×10^{-2}	9×10^{-9}	1×10^{-8}
ESBWR(d) at Fermi 3 site	1.2×10^{-7}	$2.3 \times 10^{+0}$	7.4×10^{-7}	1.9×10^{-3}	2.8×10^{-11}	3.9×10^{-11}

(a) Source: NRC 1990

(b) To convert rem to Sv, divide by 100.

(c) Risks were calculated using the MACCS code presented in NUREG-1150 (NRC 1990).

(d) Total environmental risks for an ESBWR at the Fermi 3 site from Table 5-33.

Table 5-35. Comparison of Environmental Risks from Severe Accidents for an ESBWR at the Fermi Site with Risks Initiated by Internal Events for Current Plants Undergoing Operating License Renewal Review

Risk	Core Damage (frequency per Ryr)	50-mi Population Dose Risk (person-rem per Ryr)(a)
Current reactor maximum(b)	2.4×10^{-4}	69
Current reactor mean(b)	2.7×10^{-5}	16
Current reactor median(b)	1.6×10^{-5}	13
Current reactor minimum(b)	1.9×10^{-6}	0.34
ESBWR(c) at Fermi	1.2×10^{-7}	2.3

(a) To convert person-rem to person-Sv, divide by 100.
(b) Based on MACCS and MACCS2 calculations for 76 current plants at 44 sites.
(c) Total environmental risks for an ESBWR at the Fermi 3 site from Table 5-33.

The following quantitative health objectives are used to determine whether the safety goals are achieved:

- The risk to an average individual in the vicinity of a nuclear power plant of prompt fatalities that might result from reactor accidents should not exceed one-tenth of 1 percent (0.1 percent) of the sum of prompt fatality risks resulting from other accidents to which members of the U.S. population are generally exposed.
- The risk to the population in the area near a nuclear power plant of cancer fatalities that might result from nuclear power plant operation should not exceed one-tenth of 1 percent (0.1 percent) of the sum of cancer fatality risks resulting from all other causes.

These quantitative health objectives are translated into two numerical objectives as follows:

- The individual risk of a prompt fatality from all "other accidents to which members of the U.S. population are generally exposed," is about 4×10^{-4} per year, including a risk of 1.3×10^{-4} per year associated with transportation accidents (NSC 2010). One-tenth of 1 percent of these figures implies that the individual risk of prompt fatality from a reactor accident should be less than 4×10^{-7} per Ryr.
- "The sum of cancer fatality risks from all other causes" for an individual is taken to be the cancer fatality rate in the United States, which is about 1 in 500 or 2×10^{-3} per year (ACS 2008). One-tenth of 1 percent of this implies that the risk of cancer to the population in the area near a nuclear power plant because of its operation should be limited to 2×10^{-6} per Ryr.

MACCS2 calculates average individual early fatality and latent cancer fatality risks. The average individual early fatality risk is calculated by using the population distribution within 1 mi of the plant boundary. The average individual latent cancer fatality risk is calculated by using the population distribution within 10 mi of the plant. For the plants considered in NUREG-1150, these risks were well below the Commission's safety goals. Risks calculated for the ESBWR design at the Fermi site are lower than the risks associated with the current-generation reactors considered in NUREG-1150 and are well below the Commission's safety goals.

The NRC staff compared the CDF and population dose risk estimate for an ESBWR at the Fermi site with statistics summarizing the results of contemporary severe accident analyses performed for 76 reactors at 44 sites. The results of these analyses are included in the final site-specific Supplements 1 through 37 to the GEIS, NUREG-1437 (NRC 1996) and in the ERs included with license renewal applications for those plants for which supplements have not been published. All of the analyses were completed after publication of NUREG-1150 (NRC 1990), and the analyses for 72 of the reactors used MACCS2, which was released in 1997. Table 5-35 shows that the CDFs estimated for the ESBWR are significantly lower than those of current-generation reactors. Similarly, the population doses estimated for an ESBWR at the Fermi site are well below the mean and median values for current-generation reactors undergoing license renewal.

Finally, the total population dose risk (2.3 person-rem per Ryr, see Table 5-33) from an ESBWR severe accident at the Fermi site may be compared with its dose risk from normal operations at the site (see Section 5.9.3.2). The population dose risk from normal operation (doses from liquid and gaseous effluents) of an ESBWR at Fermi is about 22 person-rem/Ryr (see Subsection 5.9.3.2 of this EIS). Thus, the population dose risk associated with severe accidents is about one order of magnitude lower than the risk from the liquid and gaseous effluents during normal operations. Comparatively, the population dose risk for a severe accident is small.

5.11.2.2 Surface Water Pathways

Surface-water pathways are an extension of the air pathway. These pathways cover the effects of radioactive material deposited on open bodies of water and include ingestion of water, and aquatic foods as well as external radiation from submersion in water and activities occurring near the water. Of these surface-water pathways, the MACCS2 code evaluates only the ingestion of contaminated water. The risks associated with this surface-water pathway calculated for the Fermi site are included in the last column of Table 5-33. The total water-ingestion dose risk of about 1.4×10^{-2} person-rem per Ryr is small compared with the total dose risk of 2.3 person-rem per Ryr.

Although surface water pathways beyond water ingestion are not considered in the MACCS2 code, they have been examined in NUREG-1437. Detroit Edison relied on generic analyses in NUREG-1437 (NRC 1996) for surface water pathways related to swimming and shoreline activities, and to aquatic food consumption. NUREG-1437 reiterates the conclusions set forth in the final EIS for Fermi 2 operations, NUREG-0769 (NRC 1981), which indicate that doses from shoreline activities and swimming are much smaller than either water ingestion doses or aquatic food ingestion doses.

Surface-water bodies within the 50-mi region of the Fermi site that are accessible to the public include Lake Erie, River Raisin, Huron River, Maumee River, Lake St. Clair, Detroit River, and other smaller water bodies. In NUREG–1437, the NRC evaluated doses from the aquatic food pathway (fishing) for the current fleet of nuclear reactors, including Fermi 2 (NRC 1996). The cumulative population dose from the aquatic food pathway for Fermi 2 severe accidents was estimated to be approximately 1400 person-rem per Ryr.

If a severe accident occurred at a reactor located at the Fermi site, it is likely that Federal, State, and local officials would take various measures, including limiting access to contaminated areas and interdiction of drinking water and fishing to reduce exposures. Actual dose-risk values would be expected to be significantly reduced due to these actions (NRC 1996). Considering the likelihood of interdiction, NRC staff concluded that the population dose risk from the surface water pathways at the Fermi site would likely be small compared to air pathway dose risk.

5.11.2.3 Groundwater Pathway

The groundwater pathway involves a reactor core melt, reactor vessel failure, and penetration of the floor (basemat) below the reactor vessel. Ultimately, core debris reaches the groundwater where soluble radionuclides are transported with the groundwater. MACCS2 does not evaluate the environmental risks associated with severe accident releases of radioactive material to groundwater. In the NUREG-1437, NRC staff assumed that the probability of occurrence of a severe accident with a basemat penetration was 1×10^{-4} per Ryr and concluded that the groundwater contribution to risk is generally a small fraction of the risk attributable to the atmospheric pathway. The Detroit Edison ER (Detroit Edison 2011a) summarizes the discussion in NUREG–1437 and reaches the same conclusion.

NRC staff has reevaluated its assumption of a 1×10^{-4} per Ryr probability of a basemat melt-through. The staff believes that the 1×10^{-4} probability is too large for new reactor designs. New reactor designs include features to minimize the potential for core debris to reach groundwater in the event of a core melt accident. The ESBWR design includes a basemat internal melt arrest and coolability (BiMAC) device to cool the core debris and prevent basemat melt-through. Furthermore, the probability of core melt with basemat melt-through should be no larger than the total CDF estimate for the reactor.

Table 5-33 gives a total CDF estimate of 1.2×10^{-7} per Ryr for an ESBWR design. NUREG-1150 (NRC 1990) indicates that the conditional probability of a basemat melt-through ranges from 0.05 to 0.25 for current-generation reactors. The ESBWR severe-accident release sequences that might be expected to involve core-concrete interactions have frequencies on the order of 1×10^{-10} per Ryr. GEH has estimated a failure probability of 0.0003 for the BiMAC to function. On this basis, the NRC staff determined that a basemat melt-through probability on the order of 1×10^{-10} per Ryr is reasonable and still conservative.

The groundwater pathway is more tortuous and affords more time for implementing protective actions; it thus results in a lower risk to the public. As a result, the NRC staff concludes that the risks associated with releases to groundwater are sufficiently small that they would not have a significant effect on the overall plant risk.

5.11.2.4 Summary of Severe Accident Impacts

The NRC staff has reviewed the severe accident risk analysis in the ER and conducted a confirmatory analysis of the probability-weighted consequences of severe accidents for the proposed Fermi 3 using the MACCS2 code. The results of both Detroit Edison's analysis and the NRC staff's analysis indicate that the environmental risks associated with severe accidents if an ESBWR were to be located at the Fermi site would be small when compared with the risks associated with operation of the current-generation reactors at other sites. These risks are well within the NRC safety goals. On these bases, the staff concludes that the probability-weighted consequences of severe accidents at the Fermi site would be SMALL for an ESBWR reactor.

5.11.3 Severe Accident Mitigation Alternatives

Detroit Edison has applied for a license to construct and operate an ESBWR at the Fermi site. The ESBWR design incorporates many features intended to reduce severe accident CDFs and the risks associated with severe accidents. The effectiveness of ESBWR design features in reducing risk is evident in Tables 5-34 and 5-35, which compare CDFs and severe accident risks for the ESBWR with CDFs and risks for current-generation reactors. CDFs and risks have generally been reduced by a factor of 100 or more when compared to the currently operating nuclear power units.

The purpose of the evaluation of severe accident mitigation alternatives (SAMAs) is to determine whether there are severe accident mitigation design alternatives (SAMDAs) or procedural modifications or training activities that can be justified to further reduce the risks of severe accidents (NRC 2000b). Consistent with the direction from the Commission to consider the SAMDAs at the time of certification, GEH has considered 177 design alternatives for an ESBWR at a generic site (GEH 2010b).

The ESBWR design already has numerous plant features designed to reduce CDF and risk. As a result, the benefits and risk reduction potential of any additional plant improvements are significantly reduced from those of existing reactors. This is true for both internally and externally initiated events. The NRC staff does not expect that improvements in either modeling or data would change the conclusions.

In Section 7.3 of the ER, Detroit Edison references the SAMDAs that were considered in the ESBWR (GEH 2007).[a] Detroit Edison reasserts the reactor vendor's claim that there are no SAMDAs that will be cost-beneficial. In order to reassess this claim, Detroit Edison reevaluated the potential monetary values for averted costs of eliminating total CDF by using the Fermi site-specific dose and consequence risk information. Using procedures set forth in NUREG/BR-0184 (NRC 1997), Detroit Edison determined that the maximum averted cost risk for a single ESBWR reactor at the Fermi site is so low that none of the SAMDAs are cost-beneficial. A more realistic assessment would show that the potential reductions in cost risk are substantially less than the maximum averted cost risk because no single SAMDA can reduce the remaining risk to zero.

SAMDAs are a subset of the SAMA review. The other attributes of the SAMA review – namely, procedural modifications and training activities – have not been addressed by Detroit Edison or the GEH for design certification (GEH 2010b). However, Detroit Edison is committed (COM ER-7.3-002) to addressing these procedural modifications as stated below (Detroit Edison 2011a):

> A SAMA analysis to comply with 40 CFR 1502.16(h) shall be conducted of the administrative and procedural measures applicable to Fermi 3 and considered for implementation prior to fuel load if the associated cost does not exceed the maximum value associated with averting all risk of severe accidents.

Appendix I contains a detailed review of the GEH and Detroit Edison's SAMA analyses, and it presents the NRC staff's conclusions related to Fermi's site-specific analysis. After reviewing the Detroit Edison analysis (Detroit Edison 2011a), the NRC staff concluded that there are no ESBWR SAMDAs that would be cost-beneficial at the Fermi site.

As discussed in Appendix I, because the maximum attainable benefit is so low, a SAMA based on procedures or training for an ESBWR at the Fermi site would have to reduce the CDF or risk to near zero to become cost-beneficial. Based on its evaluation, the NRC staff concludes that it is unlikely that any of the SAMAs based on procedures or training would reduce the CDF or risk that much. Therefore, the NRC staff further concludes it is unlikely that these SAMAs would be cost-effective. In addition, based on statements by Detroit Edison (Detroit Edison 2011a), the NRC staff expects that the applicant will consider risk insights in the development of procedures and training. However, this expectation is not crucial to the NRC staff's conclusions because the staff already concluded procedural and training SAMAs would be unlikely to be cost effective. Therefore, the NRC staff concludes that SAMAs have been appropriately considered.

(a) The conclusion remained unchanged in the ESBWR SAMDA Report Revision 4 (GEH 2010b).

5.11.4 Summary of Postulated Accident Impacts

The NRC staff evaluated the environmental impacts from DBAs and severe accidents for an ESBWR design at the Fermi site. On the basis of the information provided by GEH, Detroit Edison, and NRC's own independent review, the staff concluded that the potential environmental impacts (risks) from a postulated accident from the operation of the proposed Fermi 3 would be SMALL and that no further mitigation is warranted.

5.12 Measures and Controls to Limit Adverse Impacts during Operation

In its evaluation of the environmental impacts of operating the proposed Fermi 3 reactor at the Fermi site, the review team relied on Detroit Edison's compliance with the following measures and controls that would limit adverse environmental impacts:

- Compliance with applicable Federal, State, and local laws, ordinances, and regulations intended to prevent or minimize adverse environmental impacts (e.g., solid waste management, erosion and sediment control, air emissions, noise control, stormwater management, spill response and cleanup, and hazardous material management)
- Compliance with applicable requirements of permits or licenses required for operation of Fermi 3 (e.g., Section 10 of the Rivers and Harbors Appropriation Act of 1899 [RHAA] and CWA Section 404 permits, NPDES permit)
- Compliance with existing Fermi 2 processes and/or procedures applicable to Fermi 3 operational environmental compliance activities for the Fermi site (e.g., solid waste management, hazardous waste management, and spill prevention and response)
- Incorporation of environmental requirements into construction contracts
- Implementation of BMPs.

Table 5-36 summarizes the measures and controls for limiting adverse impacts during operation of Fermi 3 at the Fermi site, based on the table supplied by Detroit Edison (2011a), as adjusted by the review team when considered to be appropriate. Some measures apply to more than one impact category. Fuel cycle impacts, including the radioactive waste system impacts, transportation of radioactive materials, and decommissioning, are discussed in Chapter 6 of this EIS.

5.13 Summary of Operational Impacts

The staff's evaluation of the environmental impacts of operations is summarized in Table 5-37. Impact level categories are denoted in the table as SMALL, MODERATE, or LARGE as a

Table 5-36. Summary of Measures and Controls Proposed by Detroit Edison to Limit Adverse Impacts When Operating Fermi 3

Affected Environment/Resource Area	Specific Measures and Control
Land Use Impacts	
The site and vicinity	• Adhere to applicable zoning regulations of Frenchtown Charter Township as well as Monroe County land use plans. • Minimize potential impacts through use of BMPs and compliance with SWPPP requirements. • Detroit Edison designed the onsite facilities to minimize the need for new roads; however, some new roads must unavoidably be built. • Incorporate drift eliminators into the design of the cooling towers to minimize the potential for salt deposition, especially on nearby agricultural lands. Salt drift mitigation beyond the proposed drift eliminators is not required. • Monitor natural draft and mechanical draft cooling towers and the heat dissipation system during operation under rules and regulations governing these systems.
Transmission line corridors and offsite areas	• The 345-kV transmission system and associated corridors would be exclusively owned and operated by ITC*Transmission*. Detroit Edison has no control over building or operation of the transmission system. The operational impacts are based on publicly available information and reasonable expectations on the configurations and practices that ITC*Transmission* is likely to use based on standard industry practice. Such efforts are assumed to include industry-standard BMPs that would minimize the operational effects on land use.
Water-Related Impacts	
Hydrologic alterations	• Develop and implement the SWPPP to manage stormwater runoff and prevent erosion. Surface water would be routed away from the nuclear plant through subgrade storm drains and off the slopes of the elevated area, as needed.
Water use and quality	• Comply with MDEQ Large Quantity Water Withdrawal Permit requirements. • Use Best Available Technology to reduce evaporative losses from cooling towers. • Develop and implement the SWPPP to manage stormwater runoff and prevent erosion. • Develop and implement a Pollution Incident Prevention Plan (PIPP).

Table 5-36. (contd)

Affected Environment/Resource Area	Specific Measures and Control
	• Comply with requirements of CWA Section 404 permit, Section 402(p) NPDES permit, RHAA Section 10 permit, and MDEQ Act 451 Part 303 and 325 permit. • CWA Section 401 water quality certification and Coastal Zone Management Act certification. • Design cooling water discharge diffuser to minimize the size of the thermal mixing zone, in both lateral and vertical extent. • Design the cooling water discharge diffuser to minimize bottom scour and associated turbidity. Riprap may be required to reduce bottom scour. • Locate and orient the discharge structure to minimize siltation resulting from turbidity at the diffuser ports. Diffuser design would reduce concentrated silt buildup through discharge points spaced approximately 17 ft apart.
Ecological Impacts	
Terrestrial and wetland resources	• Implement Operational Conservation and Monitoring Plan to mitigate operational impacts on the eastern fox snake, including measures to reduce traffic-induced mortality. • Implement measures in the SWPPP, PIPP, and permits for RHAA Section 10, CWA Section 404, and MDEQ Act 451 Parts 303 and 325 to minimize and mitigate impacts on aquatic resources, including jurisdictional wetlands. Wetland mitigation would be developed in consultation with MDEQ and USACE (Appendix K). • Develop and implement the SWPPP to manage stormwater runoff and prevent erosion. • Develop and implement a PIPP. • Use drift eliminators to keep solids deposition (assumed as salt) from cooling towers below NUREG-1555 significance level. • Develop NDCT lighting plans in coordination with the FAA and FWS to minimize avian impacts. • Although not under Detroit Edison's control, ITC*Transmission* would be expected to conform to industry-standard BMPs for transmission ROW maintenance to reduce impacts on terrestrial and wetland systems.
Aquatic resources	• Implement measures in the SWPPP, PIPP, and permits for RHAA Section 10, CWA Section 404, and MDEQ Act 451 Parts 303 and 325. • Use a closed cycle cooling system to reduce impingement and entrainment of aquatic organisms. • Maintain a low intake velocity (≤0.5 fps).

Table 5-36. (contd)

Affected Environment/Resource Area	Specific Measures and Control
	• Design intake screens with appropriate mesh size and include a trash rack. Regular washing of the intake screens will minimize impingement mortality. • Use a backwash system that would remove impinged organisms from intake screens and return them to the lake alive using a fish return system to Lake Erie outside the intake bay area. • If a shutdown of the proposed facility is planned during winter months, reduce the discharge of cooling water gradually in order to reduce the potential for cold shock to aquatic organisms. • Design cooling water discharge diffuser to minimize the size of the thermal mixing zone in both lateral and vertical extent. • Compliance with NPDES permit effluent limits and use of one Lake Erie outfall for Fermi 3 would minimize chemical impacts. • Avoid the use of phosphorus-containing corrosion and scale inhibitors in order to reduce nutrient loading that could contribute to algal blooms. • Minimize scouring through the use of riprap around the submerged discharge port, if necessary, and use an upward orientation of discharge ports. • Although not under Detroit Edison’s control, ITC*Transmission* would be expected to conform to industry-standard BMPs that are protective of aquatic systems for transmission ROW maintenance. • Design transmission lines to avoid wetlands or other water bodies to the maximum extent possible. Any unavoidable impacts would be subject to regulatory permit conditions.
Socioeconomic Impacts	• Sound attenuation measures as part of the standard mechanical draft cooling tower should be sufficient to limit the noise impact. Infrequent operation of the mechanical draft cooling towers would further reduce noise impacts. • Although most operational noise is expected to be similar to ambient noise levels, employees would be trained and appropriately protected to reduce their risk of noise exposure. Comply with all relevant OSHA regulations during operations of Fermi 3
Environmental Justice	• No mitigating measures or controls required.

Table 5-36. (contd)

Affected Environment/Resource Area	Specific Measures and Control
Historic Properties and Cultural Resources	• Operations are unlikely to affect archaeological sites. Appropriate controls would be used during post-construction excavation activities to ensure compliance with the NHPA. • Formal inadvertent discovery procedures would be in place to minimize impacts on potential onsite historic resources. • The closest offsite above-ground historic resource in the indirect area of potential effect is located approximately 1 mi from the proposed location of Fermi 3, and all others are located approximately 1.5 to 4.5 mi distant. Visual impacts are not substantial, and no measures or controls are necessary. • The Fermi site contains an existing power plant with two cooling towers. Operations would not introduce a new element that would contribute to the loss of historic integrity of historic above-ground resources in the site vicinity, and no measures or controls are necessary. • Although not under Detroit Edison's control, ITC*Transmission* would be expected to conform to regulatory requirements pertaining to historic and cultural resources that could be affected by transmission line operations.
Air Quality and Meteorology	• Comply with Federal, State, and local air permits; use cooling-tower drift eliminators; water, reseed, or pave areas used for construction. • Treat cooling water prior to discharge to reduce salt released into the atmosphere.
Nonradiological Health	• Use of biocides to reduce the levels of microbial populations in the cooling tower and condenser. • Comply with OSHA standards for Fermi 3 operational workers. • Control vehicle emissions by regularly scheduled maintenance. • Use standard sound attenuation measures for mechanical draft cooling towers. These should be sufficient to limit the noise impact. Infrequent operation of the mechanical draft cooling towers would further reduce noise impacts. • Monitor the release of nonradiological waste emissions and effluents.
Radiological Impacts of Normal Operations	
Radiation doses to members of the public	• Calculated radiation doses to members of the public within NRC and EPA standards (10 CFR Part 20, Appendix I of 10 CFR Part 50, and 40 CFR Part 190). • Radiological effluent and environmental monitoring programs would be implemented.

Table 5-36. (contd)

Affected Environment/Resource Area	Specific Measures and Control
Occupational radiation doses	• Estimated occupational doses are within NRC standards (10 CFR Part 20) • Program would be implemented to maintain occupational doses ALARA (10 CFR Part 20).
Radiation doses to biota other than humans	• Calculated doses to biota are well within NCRP and IAEA guidelines. • Radiological environmental monitoring program would be implemented.
Nonradioactive Wastes	• All releases from Fermi 3, including discharges to waste and discharges to air, would be in compliance with applicable regulations, permits, and procedures. • All wastes transferred offsite would be managed in licensed facilities in compliance with applicable regulations, permits, and procedures. • All hazardous wastes would be accumulated onsite in accordance with all applicable regulations and transferred offsite to licensed/permitted facilities in compliance with applicable regulations, permits, and procedures. • A recycling and waste minimization program would be implemented.
Impacts of Postulated Accidents	
Design-basis accidents	• Calculated dose consequences of design-basis accidents for the ESBWR at the Fermi site were found to be within regulatory limits.
Severe accidents	• Calculated probability-weighted consequences of severe accidents for the ESBWR at the Fermi site were found to be lower than the probability-weighted consequences for currently operating reactors.

Source: Detroit Edison 2011a

Table 5-37. Summary of Fermi 3 Operational Impacts

Resource Area	Comments	Impact Level
Land Use		
Site and vicinity	Permanent dedication of approximately 155 ac of onsite land for operation of one new onsite unit. Possible new housing and retail space in the vicinity.	SMALL
Offsite transmission line corridors	Permanent dedication of unused 10.8-mi, 393-ac ROW to transmission line use and unused 19 ac to expanded Milan substation. The remainder of offsite transmission line will occupy approximately 676 ac of existing transmission line ROW (total of approximately 1069 ac of transmission line ROW).	SMALL
Water Resources		
Water use		
Surface water	Average consumptive use of approximately 7.6 billion gal/yr from Lake Erie.	SMALL
Groundwater	No groundwater use or dewatering during operations.	SMALL
Water quality		
Surface water	Discharge of thermal, chemical, and radiological wastes from normal operations. Physical changes in Lake Erie resulting from stormwater runoff, blowdown discharge, and maintenance dredging.	SMALL
Groundwater	No unavoidable adverse impacts on groundwater quality are anticipated during operations.	SMALL
Ecological Resources		
Terrestrial and wetlands resources	Potential impact on eastern fox snake (State-listed as threatened) from vehicle-related mortality could be mitigated with implementation of Operational Conservation and Monitoring Plan. Salt drift and fogging from operation of cooling towers would have only a minimal impact on terrestrial species and habitats. Long-term maintenance of transmission line ROWs as early successional habitat.	SMALL to MODERATE (potential for MODERATE limited to eastern fox snake)
Aquatic resources	Cooling system impacts on Lake Erie related to thermal discharges, impingement, and entrainment.	SMALL

Table 5-37 (contd)

Resource Area	Comments	Impact Level
Socioeconomics		
Physical impacts	Small increase in noise levels; cooling tower and associated condensate plume would be visible offsite.	SMALL
Demography	Minor increase in population resulting from in-migrating operations workforce.	SMALL beneficial
Economy and taxes	Economic and tax impacts would be beneficial but SMALL in all areas in the 50-mi region, except for Monroe County, where economic impacts would be SMALL and property tax impacts would be LARGE and beneficial.	SMALL beneficial in the region to LARGE beneficial in Monroe County
Infrastructure and community services	Minor impacts on traffic, recreation, housing, public services, and education associated with population increase offset by increase in tax revenue. Local traffic would increase during operations resulting in increased congestion especially during outages.	SMALL (during normal operations) to MODERATE (outages)
Environmental Justice	No environmental pathways or preconditions exist that could lead to disproportionately high and adverse impacts on minorities or low-income populations.	SMALL
Historic and Cultural Resources	Minor impacts on offsite historic properties associated with visible condensate plume from cooling towers. Impacts from operating the proposed transmission lines would be minor if there are no new significant alterations to the cultural environment.	SMALL
Air Quality and Meteorology	Slight increase in certain criteria pollutants and CO_2 from plant auxiliary combustion equipment (e.g., diesel generators); plumes and drift from cooling towers.	SMALL
Nonradiological Health	Operational activities would not have significant nonradiological health impacts on the public and workers.	SMALL
Radiological Impacts of Normal Operations		
Members of the public	Doses to members of the public would be below NRC and EPA standards, and there would be no observable health impacts (10 CFR Part 20, Appendix I to 10 CFR Part 50, 40 CFR Part 190).	SMALL

Table 5-37 (contd)

Resource Area	Comments	Impact Level
Plant workers	Occupational doses to plant workers would be below NRC standards, and program to maintain doses ALARA would be implemented.	SMALL
Biota other than humans	Dose to biota other than humans would be below NCRP and IAEA guidelines.	SMALL
Nonradioactive Wastes	Solid, liquid, gaseous, and mixed wastes generated during operations would be handled according to county, State, and Federal regulations.	SMALL
Impacts of Postulated Accidents		
Design-basis accidents	Impacts of design-basis accidents would be well below regulatory criteria.	SMALL
Severe accidents	Probability-weighted consequences of severe accidents would be lower than the Commission's safety goals and probability-weighted consequences for currently operating reactors.	SMALL

measure of their expected adverse impacts, if any. The bases for these determinations are provided in detail in Sections 5.1 through 5.11 of this EIS; a brief statement explaining the basis for the impact level for each major resource category is provided in the table. Some impacts, such as the addition of tax revenue from Detroit Edison for the local economies, are likely to be beneficial to the community.

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6.0 Fuel Cycle, Transportation, and Decommissioning

This chapter addresses the environmental impacts from (1) the uranium fuel cycle and solid waste management, (2) the transportation of radioactive material, and (3) the decommissioning of the proposed new nuclear unit Enrico Fermi Unit 3 (Fermi 3) at the Detroit Edison Enrico Fermi Atomic Power Plant (Fermi) site.

In its evaluation of uranium fuel cycle impacts from the new unit at the Fermi site, Detroit Edison used the Economic Simplified Boiling Water Reactor (ESBWR) advanced light-water reactor (LWR) design, assuming a capacity factor of 93 percent (Detroit Edison 2011a) for the ESBWR reactor design.

This chapter presents the U.S. Nuclear Regulatory Commission (NRC) staff's assessment of the environmental impacts from fuel cycle, transportation, and decommissioning activities in relation to the GE-Hitachi ESBWR design that Detroit Edison is proposing for Fermi 3.

6.1 Fuel Cycle Impacts and Solid Waste Management

This section discusses the environmental impacts from the uranium fuel cycle and solid waste management for the ESBWR reactor design. The environmental impacts of this design are evaluated against specific criteria for LWR designs in Title 10 of the Code of Federal Regulations (CFR) 51.51.

The regulations in 10 CFR 51.51(a) state the following:

> "Under §51.50, every environmental report prepared for the construction permit stage or early site permit stage or combined license stage of a light-water-cooled nuclear power reactor, and submitted on or after September 4, 1979, shall take Table S-3, Table of Uranium Fuel Cycle Environmental Data, as the basis for evaluating the contribution of the environmental effects of uranium mining and milling, the production of uranium hexafluoride, isotopic enrichment, fuel fabrication, reprocessing of irradiated fuel, transportation of radioactive materials and management of low-level wastes and high-level wastes related to uranium fuel cycle activities to the environmental costs of licensing the nuclear power reactor. Table S-3 shall be included in the environmental report and may be supplemented by a discussion of the environmental significance of the data set forth in the table as weighed in the analysis for the proposed facility."

The ESBWR proposed for Unit 3 at the Fermi site is an LWR that would use uranium dioxide (UO_2) fuel; therefore, Table S-3 (10 CFR 51.51(b)) can be used to assess the environmental impacts of the uranium fuel cycle. Table S-3 values are normalized for a reference

1000-megawatt electrical (MW(e)) LWR at an 80 percent capacity factor. The 10 CFR 51.51(a) Table S-3 values are reproduced in Table 6-1. The power rating for the proposed Fermi 3 ESBWR is 4500 megawatts thermal (MW(t)) (Detroit Edison 2011a). With a capacity factor of 93 percent, Fermi 3 would produce an average of 1428 MW(e) (Detroit Edison 2011a).

Specific categories of environmental considerations are included in Table S-3 (see Table 6-1). These categories relate to land use, water consumption and thermal effluents, radioactive releases, burial of transuranic and high-level waste (HLW) and low-level waste (LLW), and radiation doses from transportation and occupational exposures. In developing Table S-3, the NRC staff considered two fuel cycle options that differed in the treatment of spent fuel removed from a reactor. The “no-recycle” option treats all spent fuel as waste to be stored at a Federal waste repository, whereas the “uranium-only recycle” option involves reprocessing spent fuel to recover unused uranium and return it to the system. Neither cycle involves the recovery of plutonium. The contributions in Table S-3 resulting from reprocessing, waste management, and transportation of wastes are maximized for both of the two fuel cycles (uranium-only and no-recycle); that is, the identified environmental impacts are based on the cycle that results in the greater impact. The uranium fuel cycle is defined as the total of those operations and processes associated with provision, utilization, and ultimate disposition of fuel for nuclear power reactors.

The Nuclear Nonproliferation Act of 1978 (22 USC 3201 *et seq.*) significantly affected the disposition of spent nuclear fuel by deferring indefinitely the commercial reprocessing and recycling of spent fuel produced in the U.S. commercial nuclear power program. While the ban on the reprocessing of spent fuel was lifted during the Reagan administration, economic circumstances changed, reserves of uranium ore increased, and the stagnation of the nuclear power industry in the United States provided little incentive for industry to resume reprocessing. During the 109th Congress, the Energy Policy Act of 2005 (119 Statute 594) was enacted. It authorized the U.S. Department of Energy (DOE) to conduct an advanced fuel recycling technology research and development program to evaluate proliferation-resistant fuel recycling and transmutation technologies that minimize environmental or public health and safety impacts. Consequently, while Federal policy does not prohibit reprocessing, additional governmental and commercial efforts would be needed before commercial reprocessing and recycling of spent fuel produced in the U.S. commercial nuclear power plants would commence.

The no-recycle option is presented schematically in Figure 6-1. Natural uranium is mined in either open-pit or underground mines or by an in situ leach solution mining process. In situ leach mining, currently the primary form of mining in the United States, involves injecting a lixiviant solution into the uranium ore body to dissolve uranium and then pumping the solution to the surface for further processing. The ore or in situ leach solution is transferred to mills where it is processed to produce “yellowcake” uranium oxide (U_3O_8). A conversion facility prepares the U_3O_8 by converting it to uranium hexafluoride (UF_6), which is then processed by an enrichment

Table 6-1. Uranium Fuel Cycle Environmental Data[(a)]

Environmental Considerations	Total	Maximum Effect per Annual Fuel Requirement or Reference Reactor Year of Model 1000-MW(e) LWR
Natural Resource Use		
Land (acres)		
Temporarily committed[(b)]	100	
Undisturbed area	79	
Disturbed area	22	Equivalent to a 100-MW(e) coal-fired power plant.
Permanently committed	13	
Overburden moved (millions of MT)	2.8	Equivalent to a 95-MW(e) coal-fired power plant.
Water (millions of gallons)		
Discharged to air	160	Equal to 2 percent of model 1000-MW(e) LWR with cooling tower.
Discharged to water bodies	11,090	
Discharged to ground	127	
Total	11,377	Less than 4 percent of model 1000 MW(e) with once-through cooling.
Fossil fuel		
Electrical energy (thousands of MW-hr)	323	Less than 5 percent of model 1000-MW(e) LWR output.
Equivalent coal (thousands of MT)	118	Equivalent to the consumption of a 45-MW(e) coal-fired power plant.
Natural gas (millions of standard cubic feet)	135	Less than 0.4 percent of model 1000 MW(e) energy output.
Effluents – Chemical (MT)		
Gases (including entrainment)[(c)]		
SO_x	4400	
NO_x[(d)]	1190	Equivalent to emissions from a 45-MW(e) coal-fired plant for a year.
Hydrocarbons	14	
CO	29.6	
Particulates	1154	
Other gases:		
F	0.67	Principally from uranium hexafluoride (UF_6) production, enrichment, and reprocessing. The concentration is within the range of State standards – below level that has effects on human health.
HCl	0.014	

Table 6-1. (contd)

Environmental Considerations	Total	Maximum Effect per Annual Fuel Requirement or Reference Reactor Year of Model 1000-MW(e) LWR
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: NH_3 – 600 cfs, NO_3 – 20 cfs, Fluoride – 70 cfs.
NO_3^-	25.8	
Fluoride	12.9	
Ca^{++}	5.4	
Cl^-	8.5	
Na^+	12.1	
NH_3	10	
Fe	0.4	
Tailings solutions (thousands of MT)	240	From mills only – no significant effluents to environment.
Solids	91,000	Principally from mills – no significant effluents to environment.
Effluents – Radiological (curies)		
Gases (including entrainment)		
Rn-222		Presently under reconsideration by the Commission.
Ra-226	0.02	
Th-230	0.02	
Uranium	0.034	
Tritium (thousands)	18.1	
C-14	24	
Kr-85 (thousands)	400	
Ru-106	0.14	Principally from fuel reprocessing plants.
I-129	1.3	
I-131	0.83	
Tc-99		Presently under consideration by the Commission.
Fission products and transuranics	0.203	
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	0.0034	From UF_6 production.
Th-230	0.0015	
Th-234	0.01	From fuel fabrication plants – concentration 10 percent of 10 CFR Part 20 for total processing 26 annual fuel requirements for model LWR.
Fission and activation products	5.9×10^{-6}	

Table 6-1. (contd)

Environmental Considerations	Total	Maximum Effect per Annual Fuel Requirement or Reference Reactor Year of Model 1000-MW(e) LWR
Solids (buried onsite)		
Other than high-level (shallow)	11,300	9100 Ci comes from low-level reactor wastes and 1500 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 Btus)	4063	Less than 5 percent of model1000-MW(e) LWR.
Transportation (person-rem):		
Exposure of workers and general public	2.5	
Occupational exposure (person-rem)	22.6	From reprocessing and waste management.

(a) 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 (AEC 1974); the "Environmental Survey of the Reprocessing and Waste Management Portion of the LWR Fuel Cycle," NUREG-0116 (Supp. 1 to WASH-1248) (NRC 1976); 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) (NRC 1977b); 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 Sec. 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.

(b) The contributions to temporarily committed land from reprocessing are not prorated over 30 years, because the complete temporary impact accrues regardless of whether the plant services 1 reactor for 1 year or 57 reactors for 30 years.

(c) Estimated effluents based upon combustion of equivalent coal for power generation.

(d) 1.2 percent from natural gas use and process.

facility to increase the percentage of the more fissile isotope uranium-235 and decrease the percentage of the non-fissile isotope uranium-238. At a fuel fabrication facility, the enriched uranium, which is approximately 5 percent uranium-235, is then converted to UO_2. The UO_2 is pelletized, sintered, and inserted into tubes to form fuel assemblies, which are placed in a reactor to produce power. When the content of the uranium-235 reaches a point at which the nuclear reactor has become inefficient with respect to neutron economy, the fuel assemblies are withdrawn from the reactor. After onsite storage for sufficient time to allow for short-lived fission product decay and to reduce the heat generation rate, the fuel assemblies would be transferred to a waste repository for internment. Disposal of spent fuel elements in a repository constitutes the final step in the no-recycle option.

The following assessment of the environmental impacts of the fuel cycle as related to the operation of the proposed project is based on the values given in Table S-3 (Table 6-1) and the NRC staff's analysis of the radiological impact from radon-222 and technetium-99. In NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*

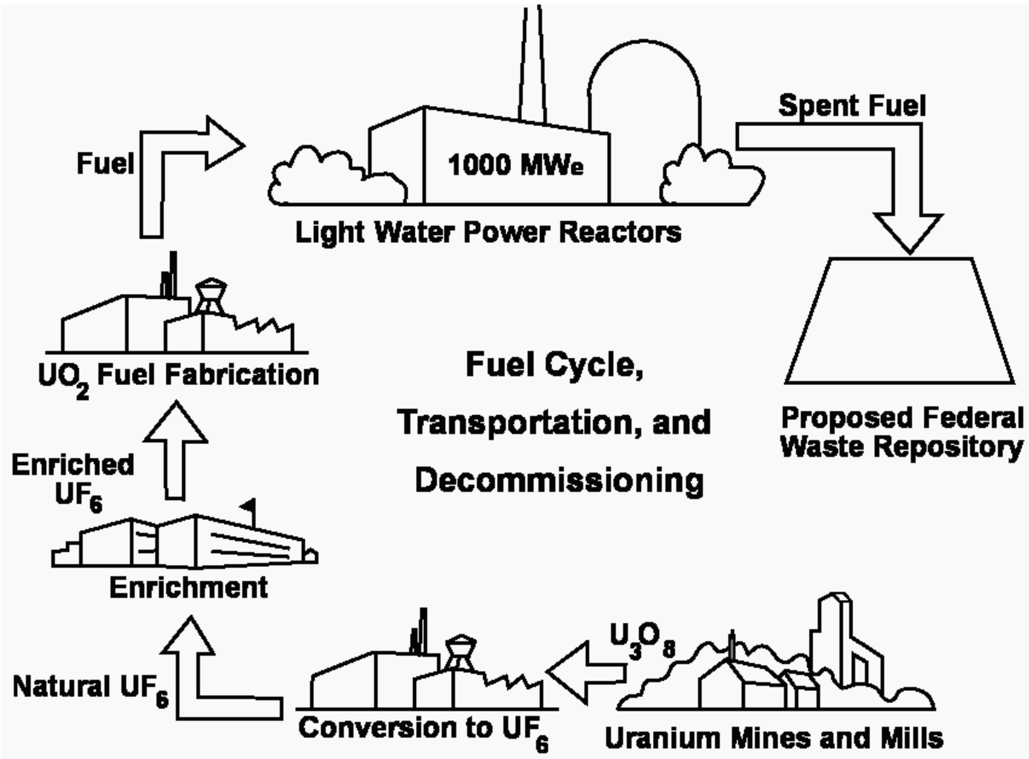

Figure 6-1. The Uranium Fuel Cycle: No-Recycle Option (derived from NRC 1996)

(GEIS) (NRC 1996, 1999),[(a)] the NRC staff provides a detailed analysis of the environmental impacts from the uranium fuel cycle. Although NUREG-1437 is specific to the impacts related to license renewal, the information is relevant to this review, because the advanced LWR design considered here uses the same type of fuel; the NRC staff's analyses in Section 6.2.3 of NUREG-1437 are summarized and set forth here.

The fuel cycle impacts in Table S-3 are based on a reference 1000-MW(e) LWR operating at an annual capacity factor of 80 percent for a net electric output of 800 MW(e). As explained above, the total net electric output from Fermi 3 is 1428 MW(e), which is about 1.79 times (i.e., 1428 MW(e) divided by 800 MW(e) yields 1.79) the impact values in Table S-3 (see Table 6-1). For simplicity and added conservatism in its review and evaluation of the environmental impacts of the fuel cycle, the NRC staff multiplied the impact values in Table S-3 by a factor of 2, rather than 1.79, thus scaling the impacts upward to account for the increased electric generation of the proposed unit. Throughout this chapter, scaling by a factor of 2 will be referred to as the 1000-MW(e) LWR-scaled model.

(a) NUREG-1437 was originally issued in 1996. Addendum 1 to NUREG-1437 was issued in 1999. Hereafter, all references to NUREG-1437 include NUREG-1437 and its Addendum 1.

Recent changes in the fuel cycle may have some bearing on environmental impacts; however, as discussed below, the NRC staff is confident that the contemporary fuel cycle impacts are below those identified in Table S-3. This is especially true in light of the following recent fuel cycle trends in the United States:

- Increasing use of in situ leach uranium mining, which does not produce mine tailings.
- Transitioning of U.S. uranium enrichment technology from gaseous diffusion (GD) to gas centrifuge (GC). The latter centrifuge process uses only a small fraction of the electrical energy per separation unit compared to GD. (U.S. GD plants relied on electricity derived mainly from the burning of coal.)
- Current LWRs use nuclear fuel more efficiently due to higher fuel burnup. Therefore, less uranium fuel per year of reactor operation is required than in the past to generate the same amount of electricity.
- Fewer spent fuel assemblies per reactor-year are discharged; hence, the waste storage/repository impact is lessened.

The values in Table S-3 were calculated from industry averages for the performance of each type of facility or operation within the fuel cycle. Recognizing that this approach meant that there would be a range of reasonable values for each estimate, the NRC staff followed the policy of choosing the assumptions or factors to be applied so that the calculated values would not be underestimated. This approach was intended to ensure that the actual environmental impacts would be smaller than the quantities shown in Table S-3 for all LWR nuclear power plants within the widest range of operating conditions. The NRC staff recognizes that many of the fuel cycle parameters and interactions vary in small ways from the estimates in Table S-3; the staff concludes that these variations would have no impacts on the Table S-3 calculations.

For example, to determine the quantity of fuel required for a year’s operation of a nuclear power plant in Table S-3, the NRC staff defined the model reactor as a 1000-MW(e) LWR operating at 80 percent capacity with a 12-month fuel reloading cycle and an average fuel burnup of 33,000 megawatt-days per metric ton of uranium (MWd/MTU). This is a “reactor reference year” or “reference reactor-year” depending on the source (either Table S-3 or NUREG-1437), but it has the same meaning.

If approved, the combined license (COL) for Fermi 3 would allow 40 years of operation. In NUREG-1437, the sum of the initial fuel loading plus all of the reloads for the lifetime of the reactor can be divided by the 60-year lifetime (40-year initial license term and 20-year license renewal term) to obtain an average annual fuel requirement. This approach was followed in NUREG-1437 for both boiling water reactors and pressurized water reactors; the higher annual requirement, 35 metric tons (MT) of uranium made into fuel for a boiling water reactor, was chosen in NUREG-1437 as the basis for the reference reactor-year (NRC 1996). The average annual fuel requirement presented in NUREG-1437 would be increased by only 2 percent if a 40-year lifetime was evaluated. However, a number of fuel management improvements have been adopted by nuclear power plants to achieve higher performance and to reduce fuel and separative-work (enrichment) requirements. Since Table S-3 was promulgated, these improvements have reduced the annual fuel requirement; this means the Table S-3 assumptions remain bounding as applied to the proposed unit.

Another change supporting the bounding nature of the Table S-3 assumptions is the elimination of U.S. restrictions on the importation of foreign uranium. Until recently, the economic conditions in the uranium market favored utilization of foreign uranium at the expense of the domestic uranium industry. From the mid-1980s to 2004, the price of U_3O_8 remained below $20 per pound. These market conditions forced the closing of most U.S. uranium mines and mills, substantially reducing the environmental impacts in the United States from uranium-mining activities. However, the spot price of uranium increased dramatically, from $24 per pound in April 2005 to $135 per pound in July 2007, and has decreased to near $52 per pound as of July 2011 (UxC 2011). As a result, there is a renewed interest in uranium mining and milling in the United States, and the NRC anticipates receiving multiple license applications for uranium mining and milling in the next several years. The majority of these applications are expected to be for in situ leach solution mining that does not produce tailings. Factoring in changes to the fuel cycle suggests that the environmental impacts of mining and tail millings could drop to levels below those given in Table S-3; however, Table S-3 estimates remain bounding for the proposed unit.

In summation, these reasons highlight why Table S-3 is likely to overestimate impacts from Fermi 3 and, therefore, remains a bounding approach for this analysis.

Section 6.2 of NUREG-1437 discusses, in greater detail, the sensitivity to changes in the fuel cycle since issuance of Table S-3 on the environmental impacts.

6.1.1 Land Use

The total annual land requirement for the fuel cycle supporting the 1000-MW(e) LWR-scaled model is about 230 ac. Approximately 26 ac are permanently committed land, and 200 ac are temporarily committed. A “temporary” land commitment is a commitment for the life of the specific fuel cycle plant (e.g., a mill, enrichment plant, or succeeding plants). Following completion of decommissioning, such land can be released for unrestricted use. “Permanent” commitments represent land that may not be released for use after plant shutdown and decommissioning, because decommissioning activities do not result in removal of sufficient radioactive material to meet the limits in 10 CFR Part 20, Subpart E, for release of that area for unrestricted use. Of the 200 ac of temporarily committed land, 160 ac are undisturbed and 44 ac are disturbed. In comparison, a coal-fired power plant using the same MW(e) output as the LWR-scaled model and using strip-mined coal requires the disturbance of about 360 ac/yr for fuel alone. The NRC staff concludes that the impacts on land use to support the 1000-MW(e) LWR-scaled model would be SMALL.

6.1.2 Water Use

The principal water use for the fuel cycle supporting a 1000-MW(e) LWR-scaled model is that required to remove waste heat from the power stations supplying electrical energy for the enrichment step of this cycle. Scaling from Table S-3, of the total annual water use of 2.3×10^{10} gal, about 2.2×10^{10} gal are required for the removal of waste heat, assuming that a new unit uses once-through cooling. Also, scaling from Table S-3, other water uses involve the discharge to air (e.g., evaporation losses in process cooling) of about 3.2×10^{8} gal/yr and water discharged to the ground (e.g., mine drainage) of about 3.0×10^{8} gal/yr.

On a thermal-effluent basis, annual discharges from the nuclear fuel cycle are about 4 percent of the 1000-MW(e) LWR-scaled model using once-through cooling. The consumptive water use is about 2 percent of the 1000-MW(e) LWR-scaled model using cooling towers. The maximum consumptive water use (assuming that all plants supplying electrical energy to the nuclear fuel cycle use cooling towers) would be about 4 percent of the 1000-MW(e) LWR-scaled model using cooling towers. Under this condition, thermal effluents would be negligible. The NRC staff concludes that the impacts on water use for these combinations of thermal loadings and water consumption would be SMALL.

6.1.3 Fossil Fuel Impacts

Electric energy and process heat are required during various phases of the fuel cycle process. The electric energy is usually produced by the combustion of fossil fuel at conventional power plants. Electric energy associated with the fuel cycle represents about 5 percent of the annual electric power production of the reference 1000-MW(e) LWR. Process heat is generated primarily by the combustion of natural gas. This gas consumption, if used to generate electricity, would be less than 0.4 percent of the electrical output from the model plant. The NRC staff concludes that the fossil fuel impacts from the direct and indirect consumption of electric energy for fuel cycle operations would be SMALL relative to the net power production of the proposed project.

The largest use of electricity in the fuel cycle comes from the enrichment process. It appears that GC technology is likely to eventually replace GD technology for uranium enrichment in the United States. The same amount of enrichment from a GC facility uses less electricity and therefore results in lower amounts of air emissions such as carbon dioxide (CO_2) than a GD facility. Therefore, the NRC staff concludes that the values for electricity use and air emissions in Table S-3 continue to be appropriately bounding values.

As indicated in Appendix L, the largest source of carbon dioxide (CO_2) emissions associated with nuclear power is from the fuel cycle, not operation of the plant. The largest source of CO_2 in the fuel cycle is production of electric energy from the combustion of fossil fuel in conventional power plants. This energy is used to power components of the fuel cycle such as the enrichment process. The CO_2 emissions from the fuel cycle are about 5 percent of the CO_2 emissions from an equivalent fossil-fuel-fired plant.

In Appendix L, the NRC staff estimates that the carbon footprint of the fuel cycle to support a reference 1000-MW(e) LWR operating at an 80 percent capacity factor for a 40-year plant life is on the order of 17,000,000 MT of CO_2, including a very small contribution from other greenhouse gases (GHGs). Scaling this footprint to the power level of Fermi 3 with the scaling factor of 2 discussed earlier, the NRC staff estimates the carbon footprint for 40 years of fuel cycle emissions to be 34,000,000 MT of CO_2 (average annual emissions rate of 850,000 MT, averaged over the period of operation) as compared to a total U.S. annual emission rate of 5.5 billion MT of CO_2 (EPA 2011).

On this basis, the NRC staff concludes that the fossil fuel impacts, including GHG emissions, from the direct and indirect consumption of electric energy for fuel cycle operations, would be SMALL.

6.1.4 Chemical Effluents

The quantities of gaseous and particulate effluents from fuel cycle processes are given in Table S-3 (Table 6-1) for the reference 1000-MW(e) LWR and, according to WASH-1248 (AEC 1974), result from the generation of electricity for fuel cycle operations. The principal effluents are sulfur oxides, nitrogen oxides, and particulates. Table S-3 states that the fuel cycle for the reference 1000-MW(e) LWR requires 323,000 MW-hr of electricity. The fuel cycle for the 1000-MW(e) LWR-scaled model would therefore require 6.5×10^5 MW-hr of electricity, or 0.016 percent of the 4.1 billion MW-hr of electricity generated in the United States in 2008 (DOE/EIA 2009). Therefore, the gaseous and particulate emissions would add about 0.016 percent to the national gaseous and particulate chemical effluents for electricity generation.

Liquid chemical effluents produced in fuel cycle processes are related to fuel enrichment and fabrication 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 within established standards. Table S-3 (Table 6-1) specifies the amount of dilution water required for specific constituents. In addition, all liquid discharges into the navigable waters of the United States from plants associated with the fuel cycle operations would be subject to requirements and limitations set by the appropriate Federal, State, Tribal, and local agencies.

Tailings solutions and solids are generated during the milling process, but as Table S-3 indicates, effluents are not released in quantities sufficient to have a significant impact on the environment.

On the basis of the discussions above, the NRC staff concludes that the impacts of these chemical effluents would be SMALL.

6.1.5 Radiological Effluents

Radioactive effluents estimated to be released to the environment from waste management activities and certain other phases of the fuel cycle process are set forth in Table S-3 (Table 6-1). NUREG-1437 (NRC 1996) provides the 100-year environmental dose commitment to the U.S. population from fuel cycle activities for 1 year of operation of the model 1000-MW(e) LWR using the radioactive effluents in Table S-3. Excluding reactor releases and dose commitments because of exposure to radon-222 and technetium-99, the total overall whole body gaseous dose commitment and whole body liquid dose commitment from the fuel cycle were calculated to be approximately 400 person-rem and 200 person-rem, respectively. Scaling these dose commitments by a factor of 2 for the 1000-MW(e) LWR-scaled model results in whole body dose commitment estimates of 800 person-rem for gaseous releases and 400 person-rem for liquid releases. For both pathways, the estimated 100-year environmental dose commitment to the U.S. population would be approximately 1,200 person-rem for the 1000-MW(e) LWR-scaled model.

Currently, the radiological impacts associated with radon-222 and technetium-99 releases are not addressed 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 GD facilities. Detroit Edison provided an assessment of radon-222 and technetium-99 in its Environmental Review (ER) (Detroit Edison 2011a). This evaluation relied on the information discussed in NUREG-1437 (NRC 1996).

In Section 6.2 of NUREG-1437 (NRC 1996), the NRC staff estimated the radon-222 releases from mining and milling operations and from mill tailings for each year of operation of the reference 1000-MW(e) LWR. The estimated releases of radon-222 for the reference reactor year for the 1000-MW(e) LWR-scaled model are approximately 10,400 curies (Ci). Of this total, about 78 percent would be from mining, 15 percent from milling operations, and 7 percent from inactive tails before stabilization. For radon releases from stabilized tailings, the NRC staff assumed that the LWR-scaled model would result in emissions of 2 Ci per site year (i.e., 2 times the NUREG-1437 [NRC 1996] estimate for the reference reactor year). The major risks from radon-222 are from exposure to the bone and the lungs, although there is a small risk from exposure to the whole body. The organ-specific dose-weighting factors from 10 CFR Part 20 were applied to the bone and lung doses to estimate the 100-year dose commitment from radon-222 to the whole body. The estimated 100-year environmental dose commitment from mining, milling, and tailings before stabilization for each reactor-year (assuming the 1000-MW(e) LWR-scaled model) would be approximately 1,840 person-rem to the whole body. From stabilized tailings piles, the estimated 100-year environmental dose commitment would be approximately 36 person-rem to the whole body. Additional insights regarding Federal policy/resource perspectives concerning institutional controls comparisons with routine radon-222 exposure and risk and long-term releases from stabilized tailing piles are discussed in NUREG-1437 (NRC 1996).

Also as discussed in NUREG-1437, the NRC staff considered the potential doses associated with the releases of technetium-99. The estimated releases of technetium-99 for the reference reactor year for the 1000-MW(e) LWR-scaled model are 14 millicuries (mCi) from chemical processing of recycled UF_6 before it enters the isotope enrichment cascade and 10 mCi into the groundwater from a HLW repository. The major risks from technetium-99 are from exposure to the gastrointestinal tract and kidney, although there is a small risk from exposure to the whole body. Applying the organ-specific dose-weighting factors from 10 CFR Part 20 to the gastrointestinal tract and kidney doses, the total-body 100-year dose commitment from technetium-99 to the whole body was estimated to be 200 person-rem for the 1000-MW(e) LWR-scaled model.

Radiation protection experts assume that any amount of radiation may pose some risk of causing cancer or a severe hereditary effect, and that the risk is higher for higher radiation exposures. Therefore, a linear, no-threshold dose-response relationship is used to describe the relationship between radiation dose and detriments such as cancer induction. A recent report by the National Research Council (2006), the Biological Effects of Ionizing Radiation (BEIR) VII report, uses the linear, no-threshold dose-response model as a basis for estimating the risks from low doses. This approach is accepted by the NRC as a conservative method for estimating health risks from radiation exposure, recognizing that the model may overestimate those risks. Based on this method, the NRC staff estimated the risk to the public from radiation exposure using the nominal probability coefficient for total detriment. This coefficient has the value of 570 fatal cancers, nonfatal cancers, and severe hereditary effects per 1,000,000 person-rem (10,000 person-sievert [Sv]), equal to 0.00057 effect per person-rem. The coefficient is taken from Publication 103 of the International Commission on Radiological Protection (ICRP) (ICRP 2007).

The nominal probability coefficient was multiplied by the sum of the estimated whole body population doses from gaseous effluents, liquid effluents, radon-222, and technetium-99 discussed above (approximately 3300 person-rem/yr) to calculate that the U.S. population would incur a total of approximately 1.9 fatal cancers, nonfatal cancers, and severe hereditary effects annually.

Radon-222 releases from tailings are indistinguishable from background radiation levels at a few miles distance from the tailings pile (at less than 0.6 mi in some cases) (NRC 1996). The public dose limit issued by the U.S. Environmental Protection Agency (EPA) (40 CFR Part 190) is 25 millirem per year (mrem/yr) to the whole body from the entire fuel cycle, but most NRC licensees have airborne effluents resulting in doses of less than 1 mrem/yr (61 FR 65120).

In addition, at the request of the U.S. Congress, the National Cancer Institute (NCI) conducted a study and published *Cancer in Populations Living Near Nuclear Facilities* in 1990 (Jablon et al. 1990). This report included an evaluation of health statistics around all nuclear power plants, as well as several other nuclear fuel cycle facilities, in operation in the United States in 1981, and found "no evidence that an excess occurrence of cancer has resulted from living near nuclear facilities." The contribution to the annual average dose received by an individual from fuel-cycle-related radiation and other sources as reported in a report published by the National Council on Radiation Protection and Measurements (NCRP) (NCRP 2009) is listed in Table 6-2. The contribution from the nuclear fuel cycle to an individual's annual average radiation dose is extremely small (less than 0.1 mrem/yr) compared to the annual average background radiation dose (311 mrem/yr).

Based on the analyses presented above, the NRC staff concludes that the environmental impacts of radioactive effluents from the fuel cycle are SMALL.

Table 6-2. Comparison of Annual Average Dose Received by an Individual from All Sources

Source		Dose (mrem/yr)[a]	Percentage of Total
Ubiquitous background	Radon and thoron	228	37
	Space	33	5
	Terrestrial	21	3
	Internal (body)	29	5
	Total background sources	**311**	**50**
Medical	Computed tomography	147	24
	Medical x-ray	76	12
	Nuclear medicine	77	12
	Total medical sources	**300**	**48**
Consumer	Construction materials, smoking, air travel, mining, agriculture, fossil fuel combustion	13	2
Other	Occupational	0.5[b]	0.1
	Nuclear fuel cycle	0.05[c]	0.01
Total		**624**	**100**

Source: NCRP 2009

(a) NCRP Report 160 expresses doses in mSv/yr (1 mSv/yr equals 100 mrem/yr).

(b) Occupational dose is regulated separately from public dose and is provided here for informational purposes.

(c) Calculated using 153 person-Sv/yr from Table 6.1 of NCRP 160 and a 2006 U.S. population of 300 million.

6.1.6 Radiological Wastes

The quantities of buried radioactive waste material (low-level, high-level, and transuranic wastes) generated by the reference 1000-MW(e) LWR are specified in Table S-3 (Table 6-1). For LLW disposal at land burial facilities, the Commission notes in Table S-3 that there would be no significant radioactive releases to the environment.

Detroit Edison can currently ship Class A LLW to the Energy Solutions site in Clive, Utah and has done so (Detroit Edison 2011b); however, it cannot dispose of Class B and C LLW at the Energy Solutions site in Barnwell, South Carolina. The Waste Control Specialists, LLC, site in Andrews County, Texas, is licensed to accept Class A, B, and C LLW from the Texas Compact (Texas and Vermont). As of May 2011, Waste Control Specialists, LLC, may accept Class A, B, and C LLW from outside the Texas Compact for disposal, subject to established criteria, conditions, and approval processes. Michigan is not currently affiliated with any compact. Other disposal sites may also be available by the time Fermi 3 could become operational.

Detroit Edison has committed to implementing a waste minimization program for Fermi 3 (Detroit Edison 2011a); however, additional waste minimization measures could be implemented by the licensee to specifically reduce or eliminate the generation of Class B and C waste. These measures could include reducing the service run length for resin beds, short-loading media volumes in ion-exchange vessels, and other techniques discussed in the Electric Power Research Institute (EPRI) *Class B/C Waste Reduction Guide* (EPRI 2007a) and *EPRI Operational Strategies to Reduce Class B/C Wastes* (EPRI 2007b). These measures would provide time for offsite disposal capability to be developed or onsite interim storage capacity to be added. Measures to reduce the generation of Class B and C wastes, such as reducing the service run length of resin beds, could increase the volume of LLW, but would not increase the total activity (in curies) of radioactive material in the waste. The volume of waste would still be bounded by or very similar to the estimates in Table S-3, and the environmental impacts would not be significantly different.

Detroit Edison has proposed a Solid Waste Management System for Fermi 3 that provides enough storage space to hold the total combined volume of 3 months of packaged Class A and 10 years of packaged Class B and Class C LLW generated during plant operations. If additional storage capacity for Class B and C LLW is required, Detroit Edison could elect to construct additional temporary storage facilities. Detroit Edison could also enter into an agreement with a third-party contractor to process, store, own, and ultimately dispose of LLW from Fermi 3.

The NRC staff anticipates that licensees would temporarily store Class B and C LLW onsite until offsite storage locations are available. Several operating nuclear power plants have successfully increased onsite storage capacity in the past in accordance with existing NRC regulations. This extended waste storage onsite resulted in no significant increase in dose to the public. In addition, the NRC issued Regulatory Issue Summary 2008-12 (NRC 2008), which included guidance for the extended onsite interim storage of LLW. This guidance addressed the storage of waste in a manner that minimizes potential exposure to workers, which may require adding shielding and storing waste in packaging compatible with the waste composition (e.g., chemical and thermal properties).

In most circumstances, the NRC's regulations (10 CFR 50.59) allow licensees operating nuclear power plants to construct and operate additional onsite LLW storage facilities without seeking approval from the NRC. Licensees are required to evaluate the safety and environmental impacts before constructing the facility and make those evaluations available to NRC inspectors. A number of nuclear power plant licensees have constructed and currently operate such facilities in the United States. Typically, these additional facilities are constructed near the power block inside the security fence, on land that has already been disturbed during initial plant construction. Therefore, the impacts on environmental resources (e.g., land use and aquatic and terrestrial biota) would be very small. All of the NRC (10 CFR Part 20) and EPA (40 CFR Part 190) dose limits would apply both for public and occupational radiation exposure.

In addition, NUREG-1437 assessed the impacts of LLW storage onsite at currently operating nuclear power plants and concluded that the radiation doses to offsite individuals from interim LLW storage are insignificant (NRC 1996). The radiological environmental monitoring programs around nuclear power plants that operate such facilities show that the increase in radiation dose at the site boundary is not significant; the doses continue to be below 25 mrem/yr, the dose limit of 40 CFR Part 190. The types and amounts of LLW generated during operations of the proposed Fermi 3 reactor would be very similar to those generated by currently operating nuclear power plants, and the construction and operation of these interim LLW storage facilities would be very similar to the construction and operation of the currently operating facilities. In addition, in NUREG-1437 (Section 6.4.4.2), the NRC staff concluded that there should be no significant issues or environmental impacts associated with interim storage of LLW generated by nuclear power plants. Interim storage facilities would be used until these wastes could be shipped safely to licensed disposal facilities. Detroit Edison's resolution of LLW disposal issues for the existing Fermi 2 facility could also be implemented for the proposed Fermi 3 facility.

Current national policy, as found in the Nuclear Waste Policy Act (42 USC 10101 *et seq.*), mandates that high-level and transuranic wastes be buried at a deep geologic repository, such as the proposed repository at Yucca Mountain, Nevada. No release to the environment is expected to be associated with deep geologic disposal, because it has been assumed that all of the gaseous and volatile radionuclides contained in the spent fuel are released to the atmosphere before the disposal of the waste. In NUREG-0116 (NRC 1976), which provides background and context for the Table S-3 values established by the Commission, the NRC staff indicates that these high-level and transuranic wastes will be buried and will not be released to the environment.

As part of the Table S-3 rulemaking, the NRC staff evaluated, along with more conservative assumptions, this zero-release assumption associated with waste burial in a repository, and the NRC reached an overall generic determination that fuel cycle impacts would not be significant. In 1983, the Supreme Court affirmed the NRC's position that the zero-release assumption was reasonable in the context of the Table S-3 rulemaking to address generically the impacts of the uranium fuel cycle in individual reactor licensing proceedings (*Baltimore Gas & Electric v. National Resources Defense Council* 1983). In January 2012, the Blue Ribbon Commission on America's Nuclear Future (a Federal advisory committee to the U.S. Department of Energy) provided recommendations on nuclear energy policy issues, including the storage and disposal of spent nuclear fuel (BRC 2012). Although focused primarily on addressing national policy issues, the conclusions of this report are consistent with the assessment in Table S-3 regarding the environmental impact of high-level radioactive waste disposal.

Since 1984, NRC has considered the environmental impacts of spent nuclear fuel storage following the licensed lifetime of reactor operations to be a generic issue that is best addressed through rulemaking. Thus, the Commission's Waste Confidence Decision and Rule, 10 CFR Part 51.23, undergirds many agency licensing decisions involving the management of spent nuclear fuel after the licensed life of a reactor. In 2010, the Commission completed its most recent update of the Waste Confidence Decision and Rule, to reflect information gained from experience in the storage of spent nuclear fuel and high-level waste (75 FR 81032). On June 8, 2012, the U.S. Court of Appeals for the District of Columbia Circuit (the Court) vacated the 2010 Waste Confidence Decision and Rule, finding that it did not comply with the National Environmental Policy Act (NEPA). The Court decision held that (1) the Waste Confidence rulemaking is a major Federal action necessitating either an environmental impact statement (EIS) or a finding of no significant environmental impact, and (2) the Commission's evaluation has several deficiencies in considering the environmental impacts of spent nuclear fuel storage after the licensed life of reactor operation (*New York v. NRC* 2012).

In response to petitions subsequently filed under multiple NRC hearing dockets that requested suspension of final licensing decisions for applications relying on the vacated rule, on August 7, 2012, the Commission stated that "…in recognition of our duties under the law, we will not issue licenses dependent upon the Waste Confidence Decision or the Temporary Storage Rule until the court's remand is appropriately addressed. This determination extends just to final license issuance; all current licensing reviews and proceedings should continue to move forward" (NRC 2012a). On September 6, 2012, the Commission directed the NRC staff to proceed with the development of an EIS to support publication of an updated Waste Confidence Decision and Rule by September 7, 2014 (NRC 2012b). The updated Rule and supporting EIS must address the deficiencies identified in the Court's remand and provide the necessary NEPA assessment of the environmental impacts from long-term storage of spent nuclear fuel following the licensed lifetime of reactor operations.

As directed by the Commission in CLI-12-16 (NRC 2012a), NRC will not issue licenses dependent on the Waste Confidence Decision or Temporary Storage Rule prior to resolution of waste confidence-related issues. This action will ensure that there would be no irretrievable or irreversible resource commitments or potential harm to the environment before waste confidence impacts have been addressed. In the meantime, however, the NRC staff will follow the Commission's instructions to move forward with current licensing reviews and proceedings. To do so, the NRC staff will rely on long-standing Commission conclusions in the Waste Confidence rulemaking regarding storage of spent fuel for the period following the licensed life of the proposed Fermi Unit 3 reactor, while recognizing that further information may be obtained in the development of the updated Rule and supporting EIS.

In Commission Memorandum and Order CLI-12-16 (NRC 2012a), the Commission reflects on the extensive information NRC has used to develop previous Waste Confidence determinations and recognized that current rulemaking efforts should build on this information. Previously, this information indicated there would be no significant environmental impacts from the long-term storage of spent nuclear fuel following cessation of reactor operations. In the context of operating license renewal, Sections 6.2 and 6.4 of NUREG-1437 (NRC 1996) also provide additional descriptions of the generation, storage, and ultimate disposal of LLW, mixed waste, and HLW, including spent fuel from power reactors, concluding that environmental impacts from these activities are either small or acceptable. This information supported the conclusion that the environmental impacts from radioactive waste storage associated with an individual reactor would be small.

The NRC staff recognizes, however, that the Court's remand of the Waste Confidence Decision and Rule introduces additional uncertainties that might impact the results of these previous environmental analyses. The Court did not indicate that it disagreed with the overall conclusion of the Commission that a repository was the most likely disposal alternative. However, the confirmation of expected impacts from storage, plus the discussion of alternative impacts as required by the court, must await the completion of the EIS for Waste Confidence currently under development.

Based on these considerations, the NRC staff has reached a conclusion that the impacts of storage of spent fuel after the operational lifetime of proposed Fermi Unit 3 are small. The staff also concludes, based on Table S-3 and the above conclusions regarding storage of low level waste and spent fuel, that the environmental impacts from radioactive waste storage and disposal associated with Fermi Unit 3 would be SMALL. This conclusion is conditional in the sense that the NRC recognizes that information— with respect to storage of spent fuel— is subject to the results of the ongoing rulemaking to update the Waste Confidence Decision and Rule, which could develop information that might require a supplemental EIS. The NRC staff will continue to evaluate information developed in the Waste Confidence rulemaking, including the results of the EIS being developed to support this rulemaking. That EIS will also be informed by public participation in the NEPA process. If the results of the Waste Confidence

EIS identify information that requires a supplement to the Fermi Unit 3 EIS, the NRC staff will perform any necessary additional NEPA reviews for those issues before the NRC makes a final licensing decision.

6.1.7 Occupational Dose

The annual occupational dose attributable to all phases of the fuel cycle for the 1000-MW(e) LWR-scaled model is about 1200 person-rem. This is based on a 600 person-rem occupational dose estimate attributable to all phases of the fuel cycle for the model 1000-MW(e) LWR (NRC 1996). The NRC staff concludes that the environmental impact from this occupational dose is SMALL because the dose to any individual worker is maintained within the limits of 10 CFR Part 20, which is 5 rem/yr.

6.1.8 Transportation

The transportation dose to workers and the public related to the uranium fuel cycle is about 2.5 person-rem annually for the reference 1000-MW(e) LWR per Table S-3 (Table 6-1). This corresponds to a dose of 5.0 person-rem for the 1000-MW(e) LWR-scaled model. For purposes of comparison, the population within 50 mi of the Fermi 3 site is estimated to be 7,713,709 people (Detroit Edison 2011a). By using 0.311 rem/yr as the average dose to a U.S. resident from natural background radiation (NCRP 2009), the collective dose to that population is estimated to be 2.4×10^6 person-rem/yr. On the basis of this comparison, the NRC staff concludes that environmental impacts of transportation would be SMALL.

6.1.9 Conclusions

The NRC staff evaluated the environmental impacts of the uranium fuel cycle, as given in Table S-3 (Table 6-1), considered the effects of radon-222 and technetium-99, and appropriately scaled the impacts for the 1000-MW(e) LWR-scaled model. The NRC staff also evaluated the environmental impacts of GHG emissions from the uranium fuel cycle and appropriately scaled the impacts for the 1000-MW(e) LWR-scaled model. Based on this evaluation, the NRC staff concludes that the impacts would be SMALL.

6.2 Transportation Impacts

This section addresses both the radiological and nonradiological environmental impacts during normal operating and accident conditions resulting from (1) shipment of unirradiated fuel to the Fermi 3 site and alternative sites, (2) shipment of irradiated (spent) fuel to a monitored retrievable storage facility or a permanent repository, and (3) shipment of low-level radioactive waste and mixed waste to offsite disposal facilities. Alternative sites evaluated in this EIS include the existing Fermi site (proposed site), Petersburg, South Britton, Greenwood Energy Center, and Belle River (see Section 9.3). There is no meaningful differentiation among the proposed and the alternative sites regarding the radiological and nonradiological environmental impacts from normal operations and accident conditions, and thus such impacts are not discussed further in Chapter 9.

The NRC performed a generic analysis of the environmental effects of transportation of fuel and waste to and from LWRs in the *Environmental Survey of the Transportation of Radioactive Materials to and from Nuclear Power Plants*, WASH-1238 (AEC 1972) and in a supplement to WASH-1238, NUREG-75/038 (NRC 1975), and found the impact to be SMALL. These documents provided the basis for Table S-4 in 10 CFR 51.52 that summarizes the environmental impacts of transportation of fuel and waste to and from one LWR of 3000 to 5000 MW(t) (1000 to 1500 MW(e)). Impacts are provided for normal conditions of transport and accidents in transport for a reference 1100-MW(e) LWR. The transportation impacts associated with the Fermi 3 site were normalized for a reference 1100-MW(e) LWR at an 80 percent capacity factor for comparisons to Table S-4.(a) Dose to transportation workers during normal transportation operations was estimated to result in a collective dose of 4 person-rem per reference reactor-year. The combined dose to the public along the route and dose to onlookers were estimated to result in a collective dose of 3 person-rem per reference reactor-year.

Environmental risks of radiological effects during accident conditions, as stated in Table S-4, are small. Nonradiological impacts from postulated accidents were estimated as 1 fatal injury in 100 reactor-years and 1 nonfatal injury in 10 reference reactor-years. Subsequent reviews of transportation impacts in NUREG-0170 (NRC 1977a) and NUREG/CR-6672 (Sprung et al. 2000) concluded that impacts were bounded by Table S-4 in 10 CFR 51.52.

In accordance with 10 CFR 51.52(a), a full description and detailed analysis of transportation impacts are not required when an LWR is licensed (i.e., impacts are assumed bounded by Table S-4) if the reactor meets the following criteria:

- The reactor has a core thermal power level not exceeding 3800 MW(t).
- Fuel is in the form of sintered uranium dioxide pellets having a uranium-235 enrichment not exceeding 4 percent by weight; and pellets are encapsulated in zircalloy-clad fuel rods.
- Average level of irradiation of the fuel from the reactor does not exceed 33,000 MWd/MTU, and no irradiated fuel assembly is shipped until at least 90 days after it is discharged from the reactor.
- With the exception of irradiated fuel, all radioactive waste shipped from the reactor is packaged and in solid form.

(a) Note that the basis for Table S-4 is an 1100-MW(e) LWR at an 80 percent capacity factor (AEC 1972; NRC 1975). The basis for Table S-3 in 10 CFR 51.51(b), which was discussed in Section 6.1 of this EIS, is a 1000-MW(e) LWR with an 80 percent capacity factor (NRC 1976). However, because fuel cycle and transportation impacts are evaluated separately, this difference does not affect the results and conclusions in this EIS.

- Unirradiated fuel is shipped to the reactor by truck; irradiated (spent) fuel is shipped from the reactor by truck, rail, or barge; and radioactive waste other than irradiated fuel is shipped from the reactor by truck or rail.

The environmental impacts of the transportation of fuel and radioactive wastes to and from nuclear power facilities were resolved generically in 10 CFR 51.52, provided that the specific conditions in the rule (see above) are met; if not, then a full description and detailed analysis are required for initial licensing. The NRC may consider requests for licensed plants to operate at conditions above those in the facility's licensing basis; for example, higher burnups (above 33,000 MWd/MTU), enrichments (above 4 percent uranium-235), or thermal power levels (above 3800 MW(t)). Departures from the conditions itemized in 10 CFR 51.52(a) must be supported by a full description and detailed analysis of the environmental effects, as specified in 10 CFR 51.52(b). Departures found to be acceptable for licensed facilities cannot serve as the basis for initial licensing for new reactors.

In its application, Detroit Edison requested a COL for an additional reactor at its Fermi site in Monroe County, Michigan. The proposed new reactor would be a GE-Hitachi ESBWR. The ESBWR has a thermal power rating of 4500 MW(t), with a gross electrical rating of 1605 MW(e). This thermal power rating exceeds the 3800-MW(t) limit considered in 10 CFR 51.52. The net electrical output is expected to be approximately 1535 MW(e) as the Fermi 3 power consumption is expected to be 70 MW(e) (Detroit Edison 2011a). Fuel for the plant would be enriched up to about 4.6 weight percent uranium-235, which exceeds the 10 CFR 51.52(a) condition. In addition, the expected irradiation level of about 46,000 MWd/MTU exceeds the 10 CFR 51.52(a) condition. Therefore, a full description and detailed analysis of transportation impacts is required.

In its ER (Detroit Edison 2011a), Detroit Edison provided a full description and detailed analyses of transportation impacts. In these analyses, radiological impacts of transporting fuel and waste to and from the Fermi site and alternative sites were calculated by Detroit Edison using the RADTRAN 5.6 computer code (Weiner et al. 2008). For this EIS, the NRC staff estimated the radiological impacts of transporting fuel and waste to and from the Fermi site and alternative sites using the RADTRAN 5.6 computer code. RADTRAN 5.6 is the most commonly used transportation impact analysis computer code in the nuclear industry, and the NRC staff concludes that the code is an acceptable analysis method.

Based on comments on previous nuclear power plant EISs, an explicit analysis of the nonradiological impacts of transporting workers and construction materials to/from the Fermi site and alternative sites is now included. Nonradiological impacts of transporting construction workers and materials and operations workers are addressed in Sections 4.8.3 and 5.8.6, respectively. Publicly available information about traffic accidents, injury, and fatality rates was used to estimate nonradiological impacts. In addition, the radiological impacts on maximally exposed individuals (MEIs) are evaluated.

6.2.1 Transportation of Unirradiated Fuel

The NRC staff performed an independent analysis of the environmental impacts of transporting unirradiated (i.e., fresh) fuel to the Fermi site and alternative sites. Radiological impacts of normal operating conditions and transportation accidents as well as nonradiological impacts are discussed in this section. Radiological impacts on populations and MEIs are presented. Because the specific fuel fabrication plant for Fermi 3 unirradiated fuel is not known at this time, the staff's analysis assumes a “representative” route between the fuel fabrication facility and the Fermi site or alternative sites. This means that one analysis was done using a “representative” route with one set of route characteristics (distances and population distributions), and that analysis was used to conclude that the impact from radiation dose would be small for the Fermi site and each of the alternative sites. Once the location of the fuel fabrication site is known, there will likely be small differences in the route and dose estimates for the Fermi site and the alternative sites. However, the radiation doses from transporting unirradiated fuel to the Fermi site and alternative sites will still likely be small.

6.2.1.1 Normal Conditions

Normal transportation conditions, sometimes referred to as “incident-free” transportation, are transportation activities in which shipments reach their destination without releasing any radioactive material to the environment. Impacts from these shipments would be from the low levels of radiation that penetrate the unirradiated fuel shipping containers. Radiation exposures at some level would occur to the following individuals: (1) persons residing along the transportation corridors between the fuel fabrication facility and the Fermi site; (2) persons in vehicles traveling on the same route as an unirradiated fuel shipment; (3) persons at vehicle stops for refueling, rest, and vehicle inspections; and (4) transportation crew workers.

Truck Shipments

Table 6-3 provides the NRC staff's estimate of the number of truck shipments of unirradiated fuel for the ESBWR compared to those of the reference 1100-MW(e) reactor specified in WASH-1238 (AEC 1972) operating at 80 percent capacity (880 MW(e)). After normalization, the number of truck shipments of unirradiated fuel to the proposed Fermi site is slightly smaller (about 15 percent) than the number of truck shipments of unirradiated fuel estimated for the reference LWR in WASH-1238.

Shipping Mode and Weight Limits

In 10 CFR 51.52(a)(5), a condition is identified that states all unirradiated fuel is shipped to the reactor by truck. Detroit Edison specifies that unirradiated fuel would be shipped to the proposed reactor site by truck (Detroit Edison 2011a). Section 10 CFR 51.52 includes a condition that the truck shipments not exceed 73,000 lb as governed by Federal or State gross

Table 6-3. Numbers of Truck Shipments of Unirradiated Fuel for the Reference LWR and the ESBWR

Reactor Type	Number of Shipments per Reactor Unit: Initial Core[(a)]	Number of Shipments per Reactor Unit: Annual Reload[(a)]	Number of Shipments per Reactor Unit: Total[(a, b)]	Unit Electric Generation, MW(e)[(c)]	Capacity Factor[(c)]	Normalized, Shipments per 1100 MW(e)[(d)]
Reference LWR (WASH-1238)	18	6	252	1100	0.8	252
Fermi 3 ESBWR	38	8.5	361	1605	0.93	213

(a) Shipments of the initial core and for every 2-year refueling period have been rounded up to the next highest whole number.

(b) Total shipments of unirradiated fuel over a 40-year plant lifetime (i.e., initial core load plus 38 years of average annual reload quantities). Refueling occurs every 24 months. No unirradiated fuel shipments anticipated during the last 2 years of operation.

(c) Unit capacities and capacity factors were taken from WASH-1238 for the reference LWR and the ER (Detroit Edison 2011a) for the ESBWR.

(d) Normalized to net electric output for WASH-1238 reference LWR (i.e., 1100-MW(e) plant at 80 percent or net electrical output of 880 MW(e)).

vehicle weight restrictions. Detroit Edison states in its ER that the unirradiated fuel shipments to the proposed Fermi site would comply with applicable weight restrictions (Detroit Edison 2011a).

Radiological Doses to Transport Workers and the Public

Table S-4 includes conditions related to radiological dose to transport workers and members of the public along transport routes. These doses are a function of many variables, including the radiation dose rate emitted from the unirradiated fuel shipments, the number of exposed individuals and their locations relative to the shipment, the time in transit (including travel and stop times), and number of shipments to which the individuals are exposed. For this EIS, the NRC staff independently calculated the radiological dose impacts to transport workers and the public from the transportation of unirradiated fuel using the RADTRAN 5.6 computer code (Weiner et al. 2008).

One of the key assumptions in WASH-1238 (AEC 1972) for the reference LWR unirradiated fuel shipments is that the radiation dose rate at 3.3 ft from the transport vehicle is about 0.1 mrem/hr, which is 1 percent of the regulatory limit. This assumption was also used in the NRC staff's analysis of the ESBWR unirradiated fuel shipments. This assumption is reasonable because the ESBWR fuel materials would be low-dose-rate uranium radionuclides and would be packaged similarly to that described in WASH-1238 (i.e., inside a metal container that provides little radiation shielding). The numbers of shipments per year were obtained by dividing the normalized shipments in Table 6-3 by 40 years of reactor operation. Other key input parameters used in the radiation dose analysis for unirradiated fuel are shown in Table 6-4.

Table 6-4. RADTRAN 5.6 Input Parameters for Unirradiated Fuel Shipments

Parameter	RADTRAN 5.6 Input Value	Source
Shipping distance (km)	3600	AEC (1972).[a]
Travel fraction – rural	0.90	NRC (1977a).
Travel fraction – suburban	0.05	
Travel fraction – urban	0.05	
Population density – rural (persons/km^2)	10	DOE (2002a).
Population density – suburban (persons/km^2)	349	
Population density – urban (persons/km^2)	2260	
Vehicle speed (km/hr)	88.49	Conservative in transit speed of 55 mph assumed; predominantly interstate highways used.
Traffic count – rural (vehicles/hr)	530	DOE (2002a).
Traffic count – suburban (vehicles/hr)	760	
Traffic count – urban (vehicles/hr)	2400	
Dose rate at 1 m from vehicle (mrem/hr)	0.1	AEC (1972).
Shipment length (m)	7.3	Approximate length of two LWR fuel assemblies placed end to end.
Number of truck crew	2	AEC (1972), NRC (1977a), and DOE (2002a).
Stop time (hr/trip)	4.5	Based on one 30-minute stop per 4 hr of driving time (Johnson and Michelhaugh 2003).
Population density at stops (persons/km^2)	See Table 6-8 for truck stop parameters.	

(a) AEC (1972) provides a range of shipping distances between 25 and 3000 mi for unirradiated fuel shipments. A 2240-mi “representative” shipping distance was assumed in this EIS. While Detroit Edison intends to obtain its fresh fuel from the GE-Hitachi fuel fabrication facility in Wilmington, NC (Detroit Edison 2011a), a distance of approximately 771 mi, the analysis in this EIS bounds the potential shipping distance from other fuel fabrication facilities in the United States.

The RADTRAN 5.6 results for this “generic” unirradiated fuel shipment are as follows:

- Worker dose: 1.92×10^{-3} person-rem/shipment
- General public dose (onlookers/persons at stops and sharing the highway): 3.29×10^{-3} person-rem/shipment
- General public dose (along route/persons living near a highway or truck stop): 3.36×10^{-5} person-rem/shipment.

These values were combined with the number of average annual shipments of unirradiated fuel for the ESBWR to calculate annual doses to the public and workers. Table 6-5 presents the annual radiological impacts calculated by the NRC staff to workers, public onlookers (persons at stops and sharing the road), and members of the public along the route (i.e., residents within 0.5 mi of the highway) for transporting unirradiated fuel to the Fermi site and alternative sites. The cumulative annual dose estimates in Table 6-5 were normalized to 1100 MW(e) (880 MW(e) net electrical output). The NRC staff performed an independent review and determined that all dose estimates are bounded by the Table S-4 conditions of 4 person-rem/yr to transportation workers, 3 person–rem/yr to onlookers, and 3 person-rem/yr to members of the public along the route.

Table 6-5. Radiological Impacts under Normal Conditions of Transporting Unirradiated Fuel to the Fermi Site and Alternative Sites

Plant Type	Normalized Average Annual Shipments	Cumulative Annual Dose; person-rem/yr per 1100 MW(e)[a] (880 MW(e) net)		
		Workers	Public – Onlookers	Public – along Route
Reference LWR (WASH-1238)	6.3	1.2×10^{-2}	2.1×10^{-2}	2.1×10^{-4}
Fermi 3 ESBWR	5.3	1.0×10^{-2}	1.8×10^{-2}	1.8×10^{-4}
10 CFR 51.52, Table S-4 condition	<1 per day	4	3	3

(a) Multiply person-rem/yr times 0.01 to obtain doses in person-Sv/yr.

Radiation protection experts assume that any amount of radiation may pose some risk of causing cancer or a severe hereditary effect and that the risk is higher for higher radiation exposures. Therefore, a linear, no-threshold dose-response relationship is used to describe the relationship between radiation dose and detriments such as cancer induction. A recent report by the National Research Council (2006), the BEIR VII report, uses the linear, no-threshold dose-response model as a basis for estimating the risks from low doses. This approach is accepted by the NRC as a conservative method for estimating health risks from radiation exposure, recognizing that the model may overestimate those risks. Based on this method, the NRC staff estimated the risk to the public from radiation exposure using the nominal probability coefficient for total detriment. This coefficient has the value of 570 fatal cancers, nonfatal cancers, and severe hereditary effects per 1,000,000 person-rem (10,000 person-Sv), equal to 0.00057 effects per person-rem. The coefficient is taken from ICRP Publication 103 (ICRP 2007).

Both the NCRP and ICRP suggest that when the collective effective dose is smaller than the reciprocal of the relevant risk detriment (i.e., less than 1/0.00057, which is less than 1754 person-rem), the risk assessment should note that the most likely number of excess health effects is zero (NCRP 1995; ICRP 2007). The largest annual collective dose estimate for transporting unirradiated fuel to the Fermi site and alternative sites was 1.8×10^{-2} person-rem, which is less than the 1754 person-rem value that the ICRP and NCRP suggest would most likely result in zero excess health effects.

To place these impacts in perspective, the average U.S. resident receives about 311 mrem/yr effective dose equivalent from natural background radiation (i.e., exposures from cosmic radiation, naturally occurring radioactive materials such as radon, and global fallout from testing of nuclear explosive devices) (NCRP 2009). By using this average effective dose, the collective population dose from natural background radiation to the population along this representative route would be about 2.5 × 10^5 person-rem. Therefore, the radiation doses from transporting unirradiated fuel to the proposed Fermi site and alternative sites are minimal compared to the collective population dose to the same population from exposure to natural sources of radiation.

Maximally Exposed Individuals under Normal Transport Conditions

The NRC staff conducted a scenario-based analysis to develop estimates of incident-free radiation doses to MEIs for fuel and waste shipments to and from the Fermi site. An MEI is a person who may receive the highest radiation dose from a shipment to and/or from the Fermi site. The following discussion also applies to shipments of unirradiated fuel, spent fuel, and radioactive waste to and from any of the alternative sites. The analysis is based on DOE data (2002b) and incorporates data about exposure times, dose rates, and the number of times an individual may be exposed to an offsite shipment. Adjustments were made where necessary to reflect the normalized fuel and waste shipments addressed in this EIS. In all cases, the NRC staff assumed that the dose rate emitted from the shipping containers is 10 mrem/hr at 6.6 ft from the side of the transport vehicle. This assumption is conservative, in that the assumed dose rate is the maximum dose rate allowed by U.S. Department of Transportation (DOT) regulations (49 CFR 173.441). Most unirradiated fuel and radioactive waste shipments would have much lower dose rates than the regulations allow (AEC 1972; DOE 2002a). The analysis is described below.

Truck Crew Member

Truck crew members would receive the highest radiation doses during incident-free transport because of their proximity to the loaded shipping container for an extended period. The NRC staff's analysis assumed that crew member doses are limited to 2 rem/yr, which is the DOE administrative control level presented in DOE-STD-1098-2008, *DOE Standard, Radiological Control*, Chapter 2, Article 211 (DOE 2008). This limit is anticipated to apply to spent nuclear fuel shipments to a disposal facility, because DOE would take title to the spent fuel at the reactor site. There will be more shipments of spent nuclear fuel from the Fermi site and alternative sites than there will be shipments of unirradiated fuel and radioactive waste other than spent fuel from these sites. This is because the capacities of spent fuel shipping casks are limited due to their substantial radiation shielding and accident-resistance requirements. Spent fuel shipments also have significantly higher radiation dose rates than unirradiated fuel and radioactive waste (DOE 2002b). As a result, crew doses from unirradiated fuel and radioactive waste shipments would be lower than the doses from spent nuclear fuel shipments. The DOE administrative limit of 2 rem/yr (DOE 2009) is less than the NRC limit for occupational exposures of 5 rem/yr (10 CFR Part 20).

The DOT does not regulate annual occupational exposures. It does recognize that air crews are exposed to elevated cosmic radiation levels and recommends dose limits to air crew members from cosmic radiation (DOT 2003). Air passengers are less of a concern because they do not fly as frequently as air crew members. The recommended limits are a 5-year effective dose of 2 rem/yr, with no more than 5 rem in a single year (DOT 2003). As a result, a 2-rem/yr MEI dose to truck crews is a reasonable estimate to apply to shipments of fuel and waste from the Fermi site and alternative sites.

Inspectors

Radioactive shipments are inspected by Federal or State vehicle inspectors, for example, at State ports of entry. The Yucca Mountain Final EIS (DOE 2002b) assumed that inspectors would be exposed for 1 hr at a distance of 3.3 ft from the shipping containers. The dose rate at 3.3 ft is conservatively assumed to be at the regulatory limit and equivalent to about 14 mrem/hr; therefore, the dose per shipment is about 14 mrem. This is independent of the location of the reactor site. Based on this conservative value and the assumption that the same person inspects all shipments of fuel and waste to and from the proposed Fermi site and alternative sites, the annual doses to vehicle inspectors were calculated to be about 2.2 rem/yr, based on a combined total of 160 shipments of unirradiated fuel, spent fuel, and radioactive waste per year. This value is greater than the DOE administrative control level (DOE 2009) on individual doses and is less than the 5-rem/yr NRC occupational dose limit.

Resident

The analysis assumed that a resident lives adjacent to a highway where a shipment would pass and would be exposed to all shipments along a particular route. Exposures to residents on a per-shipment basis were obtained from the NRC staff's RADTRAN 5.6 output files. These dose estimates are based on an individual located 100 ft from the shipments that are traveling 15 mph. The potential radiation dose to the maximally exposed resident is about 0.095 mrem/yr for shipments of fuel and waste to and from the proposed Fermi site and alternative sites.

Individual Stuck in Traffic

This scenario addresses potential traffic interruptions that could lead to a person being exposed to a loaded shipment for 1 hr at a distance of 4 ft. The NRC staff's analysis assumed this exposure scenario would occur only one time to any individual, and the dose rate was at the regulatory limit of 10 mrem/hr at 6.6 ft from the shipment. The dose to the MEI was calculated to be 16 mrem in DOE's Yucca Mountain Final EIS (DOE 2002b).

Person at a Truck Service Station

This scenario estimates doses to an employee at a service station where all truck shipments to and from the proposed Fermi site and alternative sites are assumed to stop. The NRC staff's analysis assumed this person would be exposed for 49 minutes at a distance of 52 ft from the loaded shipping container (DOE 2002b). The exposure time and distance were based on the observations discussed by Griego et al. (1996). This results in a dose of about 0.34 mrem/shipment and an annual dose of about 54 mrem/yr for the Fermi site and alternative sites, assuming that a single individual services all unirradiated fuel, spent fuel, and radioactive waste shipments to and from the Fermi site and alternative sites.

6.2.1.2 Radiological Impacts of Transportation Accidents

Accident risks are a combination of accident frequency and consequence. Accident frequencies for transportation of unirradiated fuel to the proposed Fermi site and alternative sites are expected to be lower than those used in the analysis in WASH-1238 (AEC 1972), which forms the basis for Table S-4 of 10 CFR 51.52, because of improvements in highway safety and security and an overall reduction in traffic accident, injury, and fatality rates since WASH-1238 was published. There is no significant difference between the ESBWR and current-generation LWRs in the consequences of transportation accidents severe enough to result in a release of unirradiated fuel particles to the environment, because fuel form, cladding, and packaging are similar to those analyzed in WASH-1238. Consequently, consistent with the conclusions of WASH-1238 (AEC 1972), the impacts of accidents during transport of unirradiated fuel for the ESBWR on the Fermi site and alternative sites are expected to be smaller than those listed in Table S–4 for current-generation LWRs.

6.2.1.3 Nonradiological Impacts of Transportation Accidents

Nonradiological impacts are the human health impacts projected to result from traffic accidents involving shipments of unirradiated fuel to the Fermi site and alternative sites; the analysis does not consider radiological or hazardous characteristics of the cargo. Nonradiological impacts include the projected number of traffic accidents, injuries, and fatalities that could result from shipments of unirradiated fuel to the site and return shipments of empty containers from the site.

Nonradiological impacts are calculated by using accident, injury, and fatality rates from published sources. The rates (i.e., impacts per vehicle-kilometer traveled) are then multiplied by estimated travel distances for workers and materials. The general formula for calculating nonradiological impacts is:

Impacts = (unit rate) × (roundtrip shipping distance) × (annual number of shipments)

In this formula, impacts are presented in units of the number of accidents, number of injuries, and number of fatalities per year. Corresponding unit rates (i.e., impacts per vehicle-km traveled) are used in the calculations.

Accident, injury, and fatality rates were taken from Table 4 in ANL/ESD/TM-150, *State-Level Accident Rates for Surface Freight Transportation: A Reexamination* (Saricks and Tompkins 1999). Nationwide median rates were used for shipments of unirradiated fuel to the site. The data are representative of traffic accident, injury, and fatality rates for heavy truck shipments similar to shipments of unirradiated fuel to the Fermi site and alternative sites. In addition, the DOT Federal Motor Carrier Safety Administration evaluated the data underlying the Saricks and Tompkins (1999) rates, which were taken from the Motor Carrier Management Information System, and determined that the rates were underreported. Therefore, the accident, injury, and fatality rates in Saricks and Tompkins (1999) were adjusted using factors derived from data provided by the University of Michigan Transportation Research Institute (UMTRI) (UMTRI 2003). The UMTRI data indicate that accident rates for 1994 to 1996, the same data used by Saricks and Tompkins (1999), were underreported by about 39 percent. Injury and fatality rates were underreported by 16 and 36 percent, respectively. As a result, the accident, injury, and fatality rates were increased by factors of 1.64, 1.20, and 1.57, respectively, to account for the underreporting.

The nonradiological accident impacts calculated by the NRC staff for transporting unirradiated fuel to (and empty shipping containers from) the Fermi site and alternative sites are shown in Table 6-6. The nonradiological impacts associated with the WASH-1238 reference LWR are also shown for comparison. Note that there are only small differences between the impacts calculated for an ESBWR at the Fermi site and alternative sites and the reference LWR in WASH-1238, due entirely to the estimated annual number of shipments.

Table 6-6. Nonradiological Impacts of Transporting Unirradiated Fuel to the Proposed Fermi Site and Alternative Sites, Normalized to Reference LWR

Plant Type	Annual Shipments Normalized to Reference LWR	One-Way Shipping Distance, km	Roundtrip Distance, km per year	Annual Impacts		
				Accidents per Year	Injuries per Year	Fatalities per Year
Reference LWR (WASH-1238)	6.3	3600	4.5×10^4	2.1×10^{-2}	1.1×10^{-2}	6.5×10^{-4}
Fermi and alternative sites ESBWR	5.3	3600	3.8×10^4	1.8×10^{-2}	8.9×10^{-3}	5.5×10^{-4}

6.2.2 Transportation of Spent Fuel

The NRC staff performed an independent analysis of the environmental impacts of transporting spent fuel from the proposed Fermi site and alternative sites to a spent fuel disposal repository. For the purposes of these analyses, the staff considered the proposed geologic HLW repository at the Yucca Mountain site in Nevada as a surrogate destination. Currently, the NRC Yucca Mountain adjudicatory proceeding is suspended, and there are Yucca Mountain-related matters pending in federal court. However, the NRC staff considers an estimate of the impacts of the transportation of spent fuel to a possible repository in Nevada to be a reasonable bounding estimate of the transportation impacts on a storage or disposal facility because of the distances involved and the representativeness of the distribution of members of the public in urban, suburban, and rural areas (i.e., population distributions) along the shipping routes. Radiological and nonradiological environmental impacts of normal operating conditions and transportation accidents, as well as nonradiological impacts, are discussed in this section. As noted above, the NRC Yucca Mountain adjudicatory proceeding is suspended, and there are Yucca Mountain-related matters pending in federal court. Regardless of the outcome of these proceedings, the NRC staff concludes that transportation impacts are roughly proportional to the distance from the reactor site to the repository site, in this case Michigan to Nevada.

This NRC staff analysis is based on shipment of spent fuel by legal-weight trucks in shipping casks with characteristics similar to casks currently available (i.e., massive, heavily shielded, cylindrical metal pressure vessels). Because of the large size and weight of spent fuel shipping casks, each shipment is assumed to consist of a single shipping cask loaded on a modified trailer. These assumptions are consistent with those made in the evaluation of the environmental impacts of transportation of spent fuel in Addendum 1 to NUREG-1437 (NRC 1999). Because the alternative transportation methods involve rail transportation or heavy-haul trucks, which would reduce the overall number of spent fuel shipments (NRC 1999), thereby reducing impacts, these assumptions are conservative. In addition, the use of current shipping cask designs for this analysis results in conservative impact estimates, because the current designs are based on transporting short-cooled spent fuel (approximately 120 days out of reactor). Future shipping casks would be designed to transport longer-cooled fuel (more than 5 years out of reactor) and would require much less shielding to meet external dose limitations. Therefore, future shipping casks are expected to have higher cargo capacities, thus reducing the numbers of shipments and associated impacts.

The NRC staff calculated the radiological impacts of transportation of spent fuel using the RADTRAN 5.6 computer code (Weiner et al. 2008). Routing and population data used in RADTRAN 5.6 for truck shipments were obtained from the Transportation Routing Analysis Geographic Information System (TRAGIS) routing code (Johnson and Michelhaugh 2003). The population data in the TRAGIS code are based on the 2000 Census. Nonradiological impacts were calculated using published traffic accident, injury, and fatality data (Saricks and

Tompkins 1999), in addition to route information from TRAGIS. Traffic accident rates input to RADTRAN 5.6 and nonradiological impact calculations were adjusted to account for underreporting, as discussed in Section 6.2.1.3.

6.2.2.1 Normal Conditions

Normal conditions, sometimes referred to as “incident-free” conditions, are transportation activities in which shipments reach their destination without an accident occurring en route. Impacts from these shipments would be from the low levels of radiation that penetrate the heavily shielded spent fuel-shipping cask. Radiation exposures would occur to the following populations: (1) persons residing along the transportation corridors between the Fermi site and alternative sites and the proposed repository location; (2) persons in vehicles traveling on the same route as a spent fuel shipment; (3) persons at vehicle stops for refueling, rest, and vehicle inspections; and (4) transportation crew workers (drivers). For this analysis, the NRC staff assumed that the destination for the spent fuel shipments is the proposed geologic HLW repository at Yucca Mountain in Nevada. This assumption is conservative because it tends to maximize the shipping distance from the Fermi site and alternative sites.

Shipping casks have not been designed for the spent fuel from advanced reactor designs such as the ESBWR. Information in *Early Site Permit Environmental Report Sections and Supporting Documentation* (INEEL 2003) indicated that advanced LWR fuel designs would not be significantly different from existing LWR designs; therefore, current shipping cask designs were used for the analysis of ESBWR spent fuel shipments. The NRC staff assumed that the capacity of a truck shipment of ESBWR spent fuel was 0.5 MTU per shipment, the same capacity as that used in WASH-1238 (AEC 1972). In its ER (Detroit Edison 2011a), Detroit Edison assumed a shipping cask capacity of 0.5 MTU per shipment.

Input to RADTRAN 5.6 includes the total shipping distance between the origin and destination sites and the population distributions along the routes. This information was obtained by running the TRAGIS computer code (Johnson and Michelhaugh 2003) for highway routes from the Fermi site and alternative sites to the proposed geologic HLW repository at Yucca Mountain. The resulting route characteristics information, generated by the NRC staff, is shown in Table 6-7. Note that for truck shipments, all the spent fuel is assumed to be shipped to the proposed geologic HLW repository at Yucca Mountain over designated highway-route controlled quantity routes. In addition, TRAGIS data were loaded into RADTRAN 5.6 on a State-by-State basis, which increases precision and allows results to be presented for each State along the route between the Fermi site or alternative sites and the proposed geologic HLW repository at Yucca Mountain, if desired.

Table 6-7. Transportation Route Information for Shipments from the Fermi Site and Alternative Sites to the Proposed Geologic HLW Repository at Yucca Mountain, Nevada[(a)]

	One-Way Shipping Distance, km				Population Density, persons/km^2			Stop Time per Trip, hr
Alternative Site	**Total**	**Rural**	**Suburban**	**Urban**	**Rural**	**Suburban**	**Urban**	
Fermi 3 Site	3480	2843	558	79	10.2	311.6	2384	4.5
Petersburg	3457	2829	549	79	10.1	314.5	2368	4.5
South Britton	3510	2864	564	82	10.2	312.7	2382	4.5
Greenwood Energy Center	3564	2860	630	74	10.3	309.0	2362	4.5
Belle River	3585	2827	652	106	10.2	328.0	2393	4.5

Source: Johnson and Michelhaugh 2003

(a) This table presents aggregated route characteristics provided by TRAGIS (Johnson and Michelhaugh 2003), including estimated distances from the alternative sites to the nearest TRAGIS highway node. Input to the RADTRAN 5.6 computer code was disaggregated to a State-by-State level.

Radiation doses are a function of many parameters, including vehicle speed, traffic count, dose rate, packaging dimensions, number in the truck crew, stop time, and population density at stops. The values for these parameters and others used in the NRC staff’s analysis and the sources of the information are provided in Table 6-8.

For this analysis, the transportation crew for spent fuel shipments delivered by truck is assumed to consist of two drivers. Escort vehicles and drivers were considered, but they were not included in the analysis, because their distance from the shipping cask would reduce the dose rates to levels well below the dose rates experienced by the drivers and would be negligible. Stop times for refueling and rest were assumed to accrue at the rate of 30 minutes per 4 hr of driving time. TRAGIS outputs were used to estimate the number of stops. Doses to the public at truck stops have been significant contributors to the doses calculated in previous RADTRAN 5.6 analyses. For this analysis, doses to the public at refueling and rest stops (“stop doses”) are the sum of the doses to individuals located in two annular rings centered at the stopped vehicle, as illustrated in Figure 6-2. The inner ring represents persons who may be at the truck stop at the same time as a spent fuel shipment and extends 1 to 10 m from the edge of the vehicle. The outer ring represents persons who reside near a truck stop and extends from 10 to 800 m from the vehicle. This scheme is similar to that used by Sprung et al. (2000). Population densities and shielding factors were also taken from those of Sprung et al. (2000), which were based on the observations of Griego et al. (1996).

Table 6-8. RADTRAN 5.6 Normal (Incident-free) Exposure Parameters

Parameter	RADTRAN 5.6 Input Value	Source
Vehicle speed (km/hr)	88.49	Based on average speed in rural areas given in DOE (2002a). Conservative in-transit speed of 55 mph assumed; predominantly interstate highways used.
Traffic count – rural (vehicles/hr)	530	DOE (2002a).
Traffic count – suburban (vehicles/hr)	760	
Traffic count – urban (vehicles/hr)	2400	
Vehicle occupancy (persons/vehicle)	1.5	DOE (2002a).
Dose rate at 1 m from vehicle (mrem/hr)	14	DOE (2002a, b) – approximate dose rate at 1 m that is equivalent to maximum dose rate allowed by Federal regulations (i.e., 10 mrem/hr at 2 m from the side of a transport vehicle).
Packaging dimensions (m)	Length – 5.2 Diameter – 1.0	DOE (2002b).
Number of truck crew	2	AEC (1972), NRC (1977a), and DOE (2002a, b).
Stop time (hr/trip)	Route-specific	See Table 6-7.
Population density at stops (persons/km^2)	30,000	Sprung et al. (2000). Equivalent to nine persons within 10 m of vehicle. See Figure 6-1.
Min/max radii of annular area around vehicle at stops (m)	1 to 10	Sprung et al. (2000).
Shielding factor applied to annular area surrounding vehicle at stops (dimensionless)	1 (no shielding)	Sprung et al. (2000).
Population density surrounding truck stops, persons/km^2	340	Sprung et al. (2000).
Min/max radius of annular area surrounding truck stop (m)	10 to 800	Sprung et al. (2000).
Shielding factor applied to annular area surrounding truck stop (dimensionless)	0.2	Sprung et al. (2000).

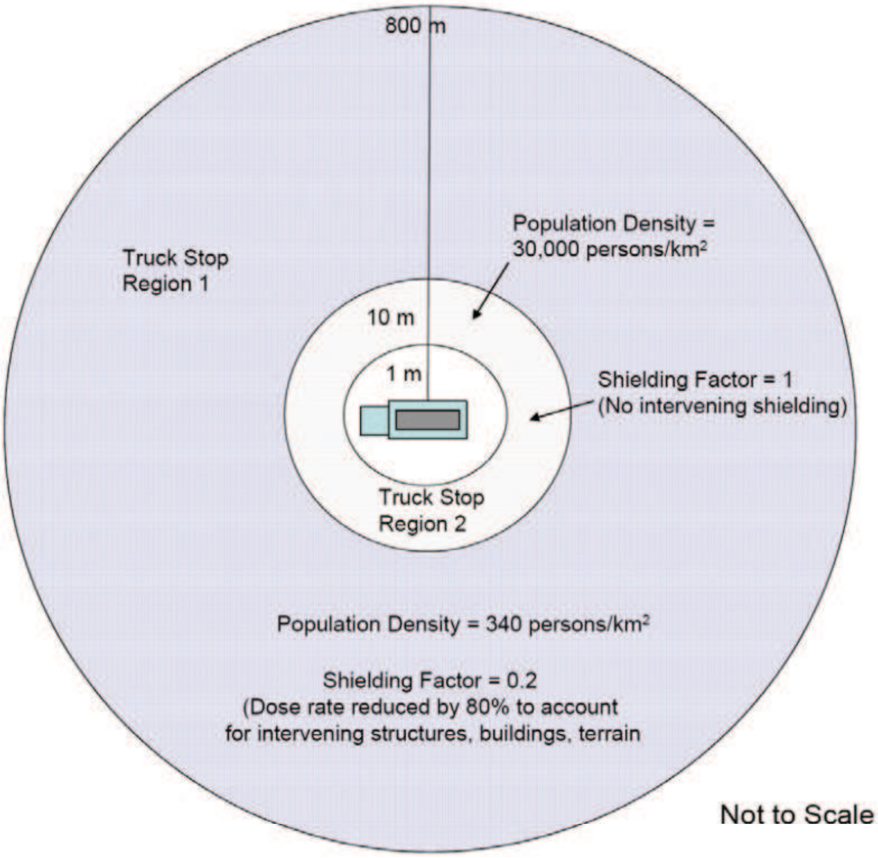

Figure 6-2. Illustration of Truck Stop Model

The results calculated by the NRC staff for these normal (incident-free) exposure calculations are shown in Table 6-9 for the proposed Fermi site and alternative sites. Population dose estimates are given for workers (i.e., truck crew members), onlookers (doses to persons at stops and persons on highways exposed to the spent fuel shipment), and persons along the route (persons living near the highway). Shipping schedules for spent fuel generated by Fermi 3 have not been determined. The NRC staff concluded it was reasonable to calculate annual doses assuming the annual number of spent fuel shipments is equivalent to the annual refueling requirements. Each refuel cycle is anticipated to reload 68.2 MTU of fresh fuel (Detroit Edison 2011a) every 2 years. It was assumed that the same corresponding amount of spent fuel was to be removed from the reactor and sent to a spent fuel storage facility or repository. With a truck capacity of 0.5 MTU/shipment, a minimum of 137 shipments would be required for transport of spent fuel after each refuel cycle. This level of activity would lead to an annual average of 68.5 spent fuel shipments.

Table 6-9. Normal (Incident-Free) Radiation Doses to Transport Workers and the Public from Shipping Spent Fuel from the Fermi Site and Alternative Sites to the Proposed Geologic HLW Repository at Yucca Mountain

Location	Worker (Crew)	Along Route	Onlookers
Reference LWR (WASH-1238) (person-rem/yr)[(a)]	9.5	0.37	19
ESBWR at Fermi site (person-rem/yr)	6.4	0.25	13
Petersburg (person-rem/yr)	6.3	0.25	13
South Britton (person-rem/yr)	6.5	0.26	13
Greenwood Energy Center (person-rem/yr)	6.5	0.28	13
Belle River	6.6	0.30	13
Table S-4 condition (person-rem/yr)	4	3	3

(a) To convert person-rem to person-Sv, divide by 100.

Population doses were normalized to the reference LWR in WASH-1238 (880 net MW(e)). This corresponds to an 1100-MW(e) LWR operating at 80 percent capacity. The normalized number of annual spent fuel shipments is 40.3, compared to 60 for the reference LWR. This difference in annual shipment numbers is solely responsible for the differences in the radiation doses for the reference LWR and the ESBWR at the proposed Fermi site as reported in Table 6-9.

There are only small differences in transportation impacts among the Fermi site and the four alternative sites. In general, the proposed Fermi site has the same impacts as the alternative sites, primarily because all routes have approximately the same shipping distance to the proposed geologic HLW repository at Yucca Mountain. However, the differences among sites are minor and are less than the uncertainty in the analytical results.

The bounding cumulative doses to the exposed population given in Table S-4 are:

- 4 person-rem/reactor-year to transport workers
- 3 person-rem/reactor-year to general public (onlookers) and members of the public along the route.

The calculated population doses to the crew and onlookers for the reference LWR and the Fermi and alternative site shipments exceed Table S-4 values. A key reason for the higher population doses relative to Table S-4 is the longer shipping distances assumed for this analysis (i.e., to a repository in Nevada) than the distances used in WASH-1238. WASH-1238 assumed that each spent fuel shipment would travel a distance of 1000 mi, whereas the shipping distances used in this assessment were about 2150 to 2230 mi. If the shorter distance was used to calculate the impacts for the Fermi spent fuel shipments, the doses could be reduced by more than 50 percent. Other important differences are the model related to vehicle stops described above and the additional precision that results from incorporating State-specific route characteristics.

Where necessary, the NRC staff made conservative assumptions to calculate impacts associated with the transportation of spent fuel. Some of the key conservative assumptions are as follows.

- ***Use of the regulatory maximum dose rate (10 mrem/hr at 2 m) in the RADTRAN 5.6 calculations***. The shipping casks assumed in the EIS prepared by DOE in support of the application for the proposed geologic HLW repository at Yucca Mountain (DOE 2002b) were designed to transport spent fuel that has cooled for a minimum of 5 years (see 10 CFR 961, Subpart B). Most spent fuel would have cooled for much longer than 5 years before being shipped to a possible geologic repository. Shipments from the Fermi site and alternative sites are also expected to be cooled for longer than 5 years. Consequently, the estimated population doses in Table 6-9 could be further reduced if more realistic dose rate projections and shipping cask capacities are used.
- ***Use of 30 minutes as the average time at a truck stop in the calculations***. Many stops made for actual spent fuel shipments are of short duration (i.e., 10 minutes) for brief visual inspections of the cargo (e.g., checking the cask tie-downs). These stops typically occur in minimally populated areas, such as an overpass or freeway ramp in an unpopulated area. Furthermore, empirical data provided in Griego et al. (1996) indicate that a 30-minute duration is toward the high end of the stop-time distribution. Average stop times observed by Griego et al. (1996) are on the order of 18 minutes.

A sensitivity study was performed to demonstrate the effects of using more realistic dose rates and stop times for the incident-free population dose calculations. For this sensitivity study, the dose rate was reduced to 5 mrem/hr, the approximate 50-percent confidence interval of the dose rate distribution estimated by Sprung et al. (2000) for future spent fuel shipments. The stop time was reduced to 18 minutes per stop. All other RADTRAN 5.6 input values were unchanged. The result is that the annual crew doses were reduced to 3.7 person-rem/yr, or about 58 percent of the annual dose shown in Table 6-9. The annual onlooker doses were reduced to 3.1 person-rem/yr (24 percent), and the annual doses to persons along the route were reduced to 0.097 person-rem/yr (39 percent). The NRC staff concludes that using more realistic parameters for shipment capacities, stop times, and dose rates would reduce the annual doses in Table 6-9 to below the Table S-4 values.

In its ER (Detroit Edison 2011a), Detroit Edison described the results of a RADTRAN 5.6 analysis of the impacts of incident-free transport of spent fuel to the proposed geologic HLW repository at Yucca Mountain. Although the overall approaches are the same (e.g., use of TRAGIS and RADTRAN 5.6), there are some differences in the modeling details. For example, the NRC staff's analysis used State-by-State route characteristics, whereas Detroit Edison elected to use aggregated route information). The NRC staff concludes that the results produced by Detroit Edison are similar to those calculated by the NRC staff in this EIS.

Using the linear no-threshold dose-response relationship discussed in Section 6.2.1.1, the annual public dose impact for transporting spent fuel from the proposed Fermi site and alternative sites to the proposed geologic HLW repository at Yucca Mountain is about 20 person-rem, which is less than the 1754 person-rem value the ICRP (ICRP 2007) and NCRP (NCRP 1995) suggest would most likely result in zero excess health effects. This dose is very small compared to the estimated 1.6×10^5 person-rem that the same population along the route from the proposed Fermi site to Yucca Mountain would incur annually from exposure to natural sources of radiation. Note that the estimated population doses along the route from the Fermi site-to-Yucca-Mountain route from natural background radiation are different than the natural background dose calculated by the NRC staff for unirradiated fuel shipments in Section 6.2.1.1 of this EIS, because the route characteristics are different. A generic route was used in Section 6.2.1.1 for unirradiated fuel shipments, and an actual highway route was used in this section for spent fuel shipments.

Dose estimates to the MEI from transport of unirradiated fuel, spent fuel, and wastes under normal conditions are presented in Section 6.2.1.1.

6.2.2.2 Radiological Impacts of Accidents

As discussed previously, the NRC staff used the RADTRAN 5.6 computer code to estimate impacts of transportation accidents involving spent fuel shipments. RADTRAN 5.6 considers a spectrum of postulated transportation accidents, ranging from those with high frequencies and low consequences (e.g., “fender benders”) to those with low frequencies and high consequences (i.e., accidents in which the shipping container is exposed to severe mechanical and thermal conditions).

Radionuclide inventories are important parameters in the calculation of accident risks. The radionuclide inventories used in this analysis were from the applicant’s ER (Detroit Edison 2011a). Spent fuel inventories used in the NRC staff analysis are presented in Table 6-10. The list of radionuclides set forth in the table includes all of the radionuclides that were included in the analysis conducted by Sprung et al. (2000). The NRC staff’s analysis also included the inventory of crud, or radioactive material deposited on the external surfaces of LWR spent fuel rods. Because crud is deposited from corrosion products generated elsewhere in the reactor cooling system and the complete reactor design and operating parameters are uncertain, the quantities and characteristics of crud deposited on ESBWR spent fuel are not available at this time. The Fermi 3 ESBWR spent fuel transportation accident impacts were calculated by assuming the cobalt-60 inventory in the form of crud is 169 Ci/MTU, based on information in Sprung et al. (2000).

Robust shipping casks are used to transport spent fuel because of the radiation shielding and accident resistance required by 10 CFR Part 71. Spent fuel shipping casks must be certified Type B packaging systems, meaning they must withstand a series of severe postulated accident

Table 6-10. Radionuclide Inventories Used in Transportation Accident Risk Calculations for an ESBWR[(a)(b)]

Radionuclide	Ci/MTU	Bq/MTU	Physical-Chemical Group
Am-241	1.30×10^{3}	4.81×10^{13}	Particulate
Am-242m	2.79×10^{1}	1.03×10^{12}	Particulate
Am-243	3.26×10^{1}	1.21×10^{12}	Particulate
Ce-144	1.35×10^{4}	5.00×10^{14}	Particulate
Cm-242	4.86×10^{1}	1.80×10^{12}	Particulate
Cm-243	3.47×10^{1}	1.28×10^{12}	Particulate
Cm-244	4.96×10^{3}	1.84×10^{14}	Particulate
Cm-245	6.75×10^{-1}	2.50×10^{10}	Particulate
Co-60 (crud)(c)	3.38×10^{2}	1.25×10^{12}	Crud
Co-60 (activation)(c)	2.86×10^{3}	1.06×10^{14}	Particulate
Cs-134	5.19×10^{4}	1.92×10^{15}	Cesium
Cs-137	1.27×10^{5}	4.70×10^{15}	Cesium
Eu-154	1.04×10^{4}	3.85×10^{14}	Particulate
Eu-155	5.40×10^{3}	2.00×10^{14}	Particulate
I-129	4.24×10^{-2}	1.57×10^{9}	Cesium
Kr-85	9.27×10^{3}	3.43×10^{14}	Gas
Pm-147	3.53×10^{4}	1.31×10^{15}	Particulate
Pu-238	6.15×10^{3}	2.28×10^{14}	Particulate
Pu-239	3.86×10^{2}	1.43×10^{13}	Particulate
Pu-240	6.22×10^{2}	2.30×10^{13}	Particulate
Pu-241	1.22×10^{5}	4.51×10^{15}	Particulate
Pu-242	2.24×10^{0}	8.29×10^{10}	Particulate
Ru-106	1.86×10^{4}	6.88×10^{14}	Ruthenium
Sb-125	4.81×10^{3}	1.78×10^{14}	Particulate
Sr-90	9.08×10^{4}	3.36×10^{15}	Particulate
Y-90	9.09×10^{4}	3.36×10^{15}	Particulate

(a) Divide Becquerel (Bq) per Metric Ton Uranium (Bq/MTU) by 3.7×10^{10} to obtain curies per MTU (Ci/MTU).

(b) The source of the spent fuel inventories is Detroit Edison (2011a), Table 3.8-12, except as noted in footnote (c).

(c) Co-60 exists both as an activation product in spent fuel and is the primary radioactive constituent in fuel assembly crud, or radioactive material deposited on the external surfaces of fuel assemblies. The Co-60 inventory in crud was calculated using information in NUREG/CR-6672 (Sprung et al. 2000).

conditions with essentially no loss of containment or shielding capability. These casks are also designed with fissile material controls to ensure the spent fuel remains subcritical under normal and accident conditions. According to Sprung et al. (2000), the probability of encountering accident conditions that would lead to shipping cask failure is less than 0.01 percent (i.e., more than 99.99 percent of all accidents would result in no release of radioactive material from the shipping cask). The NRC staff assumed that shipping casks approved for transportation of spent fuel from an ESBWR would provide equivalent mechanical and thermal protection of the spent fuel cargo.

Accident frequencies were calculated in RADTRAN 5.6 by using user-specified accident rates and conditional shipping cask failure probabilities. State-specific accident rates were taken from Saricks and Tompkins (1999) and used in the RADTRAN 5.6 calculations. The State-specific accident rates were adjusted to account for underreporting, as described in Section 6.2.1.3. Conditional shipping cask failure probabilities (i.e., the probability of cask failure as a function of the mechanical and thermal conditions applied in an accident) were taken from Sprung et al. (2000).

The RADTRAN 5.6 accident risk calculations were performed by using the radionuclide inventories given in Table 6-10. The resulting risk estimates were then multiplied by assumed annual spent fuel shipments to derive estimates of the annual accident risks associated with spent fuel shipments from the proposed Fermi site or alternative sites to the proposed geologic HLW repository at Yucca Mountain in Nevada. As was done for routine exposures, the NRC staff assumed that the numbers of shipments of spent fuel per year are equivalent to the annual discharge quantities.

For this assessment, release fractions for current-generation LWR fuel designs (Sprung et al. 2000) were used to approximate the impacts from the ESBWR spent fuel shipments. This assumes that the fuel materials and containment systems (i.e., cladding, fuel coatings) behave similarly to current LWR fuel under applied mechanical and thermal conditions.

The NRC staff used RADTRAN 5.6 to calculate the population dose from the released radioactive material from four of five possible exposure pathways.[a] These pathways are as follows:

- External dose from exposure to the passing cloud of radioactive material (cloudshine).
- External dose from the radionuclides deposited on the ground by the passing plume (groundshine). The NRC staff's analysis included the radiation exposure from this pathway,

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(a) Internal dose from ingestion of contaminated food was not considered, because the staff assumed evacuation and subsequent interdiction of foodstuffs following a postulated transportation accident.

even though the area surrounding a potential accidental release would be evacuated and decontaminated, thus preventing long-term exposures from this pathway.

- Internal dose from inhalation of airborne radioactive contaminants (inhalation).
- Internal dose from resuspension of radioactive materials that were deposited on the ground (resuspension). The NRC staff's analysis included the radiation exposures from this pathway, even though evacuation and decontamination of the area surrounding a potential accidental release would prevent long-term exposures.

Table 6-11 presents the environmental consequences calculated by the NRC staff for transportation accidents when spent fuel from the Fermi site and alternative sites is shipped to the proposed geologic HLW repository at Yucca Mountain. The shipping distances and population distribution information for the routes were the same as those used for the normal "incident-free" conditions (see Section 6.2.2.1). The results are normalized to the WASH-1238 reference reactor (880-MW(e) net electrical generation, 1100-MW(e) reactor operating at 80 percent capacity) to provide a common basis for comparison to the impacts listed in Table S-4. Note that the impacts for all site alternatives are less than the reference LWR impacts. Also, although there are slight differences in impacts among the alternative sites, none of the alternative sites would be clearly favored over the proposed Fermi site.

Table 6-11. Annual Spent Fuel Transportation Accident Impacts for an ESBWR at the Proposed Fermi Site and Alternative Sites, Normalized to Reference 1100-MW(e) LWR Net Electrical Generation

Location	Normalized Population Impacts, person-rem/yr[a]
Reference LWR (WASH-1238)	4.6×10^{-6}
Fermi site	3.1×10^{-6}
Petersburg site	3.1×10^{-6}
South Britton site	3.2×10^{-6}
Greenwood site	3.2×10^{-6}
Belle River-St. Clair site	4.3×10^{-6}

(a) Multiply person-Sv/yr times 100 to obtain person-rem/yr.

By using the linear no-threshold dose-response relationship discussed in Section 6.2.1.1, the annual collective public dose estimates for transporting spent fuel from the Fermi and alternative sites to the proposed geologic HLW repository at Yucca Mountain are on the order of 3×10^{-6} person-rem, which is less than the 1754 person-rem value that the ICRP (ICRP 2007) and NCRP (NCRP 1995) suggest would most likely result in zero excess health effects. This risk is very minute compared to the estimated 1.6×10^{5} person-rem that the same population along the route from the proposed Fermi site to the proposed geologic HLW repository at Yucca Mountain would incur annually from exposure to natural sources of radiation. Note that the estimated population dose to persons along the Fermi-to-Yucca-Mountain route is different than the population dose calculated by the NRC staff for unirradiated fuel shipments in Section 6.2.1.1, because the route characteristics are different.

The NRC staff performed a confirmatory evaluation of Detroit Edison's spent fuel transportation accident risk analysis. It noted that Detroit Edison used a different, though valid, methodology for the ER calculations. The primary difference was that Detroit Edison assumed aggregated route parameters, whereas in this EIS, the NRC staff used State-by-State shipping distances and population densities. The staff concluded that Detroit Edison's analysis was reasonable and comprehensive and meets the intent of 10 CFR 51.52(b).

6.2.2.3 Nonradiological Impacts of Spent Fuel Shipments

The general approach used to calculate nonradiological impacts of spent fuel shipments is the same as that used for unirradiated fuel shipments. The main difference is that the spent fuel shipping route characteristics are better defined, so the State-level accident statistics in Saricks and Tompkins (1999) may be used. State-by-State shipping distances were obtained from the TRAGIS output file and combined with the annual number of shipments and accident, injury, and fatality rates by State from Saricks and Tompkins (1999) to calculate nonradiological impacts. In addition, the accident, injury, and fatality rates from Saricks and Tompkins (1999) were adjusted to account for underreporting (see Section 6.2.1.3). The results calculated by the NRC staff are shown in Table 6-12.

Table 6-12. Nonradiological Impacts of Transporting Spent Fuel from the Proposed Fermi Site and Alternative Sites to the Proposed Geologic HLW Repository at Yucca Mountain, Normalized to Reference LWR

Site	One-Way Shipping Distance (km)	Nonradiological Impacts per Year		
		Accidents/yr	Injuries/yr	Fatalities/yr
Fermi (proposed site)	3481	1.5×10^{-1}	6.8×10^{-2}	4.6×10^{-3}
Petersburg	3457	1.5×10^{-1}	6.7×10^{-2}	4.5×10^{-3}
South Britton	3510	1.5×10^{-1}	6.8×10^{-2}	4.6×10^{-3}
Greenwood Energy Center	3564	1.5×10^{-1}	7.3×10^{-2}	4.9×10^{-3}
Belle River	3585	1.6×10^{-1}	7.4×10^{-2}	4.9×10^{-3}

Note: The number of shipments of spent fuel assumed in the calculations is 40.3 shipments/yr after normalizing to the reference LWR. Estimates are for roundtrip travel.

6.2.3 Transportation of Radioactive Waste

This section discusses the environmental effects of transporting radioactive waste other than spent fuel from the proposed Fermi site and alternative sites. The environmental conditions listed in 10 CFR 51.52 that apply to shipments of radioactive waste are as follows.

- Radioactive waste (except spent fuel) would be packaged and in solid form.

- Radioactive waste (except spent fuel) would be shipped from the reactor by truck or rail.
- The weight limitation of 73,000 lb per truck and 100 tons per cask per railcar would be met.
- Traffic density condition would be less than the one truck shipment per day or three railcars per month.

Radioactive waste (other than spent fuel from the Fermi 3 ESBWR) is expected to be capable of being shipped in compliance with Federal or State weight restrictions. Table 6-13 presents the NRC staff's estimates of annual waste volumes and annual waste shipment numbers for an ESBWR, normalized to the reference 1100-MW(e) LWR defined in WASH-1238 (AEC 1972). The expected annual waste volumes for the ESBWR are estimated at 15,900 ft^3/yr. By using the same packaging assumptions as WASH-1238 (2.34 m^3/shipment), the annual number of waste shipments was estimated at 114 shipments per year after normalization to the reference LWR in WASH-1238.

Table 6-13. Summary of Radioactive Waste Shipments from the Proposed Fermi Site and Alternative Sites

Reactor Type	Waste Generation Information	Annual Waste Volume, m^3/yr per Unit	Electrical Output, MW(e) per Unit	Normalized Rate, m^3/1100 MW(e) Unit (880 MW(e) Net)[(a)]	Shipments/ 1100 MW(e) (880 MW(e) Net) Electrical Output[(b)]
Reference LWR (WASH-1238)	3800 ft^3/yr per unit	108	1100	108	46
Fermi 3 and alternative sites ESBWR	15,859 ft^3/yr per unit[(c)]	449[(c)]	1605	265	114

Conversions: 1 m^3 = 35.31 ft^3. Drum volume = 210 liters (0.21 m^3).

(a) Capacity factors used to normalize the waste generation rates to an equivalent electrical generation output are 80 percent for the reference LWR (AEC 1972) and 93 percent for the Fermi 3 ESBWR (Detroit Edison 2011a). Waste generation for the ESBWR is normalized to 880 MW(e) net electrical output (1100-MW(e) unit with an 80-percent capacity factor).

(b) The number of shipments per 1100 MW(e) was calculated by dividing the normalized rate by the assumed shipment capacity used in WASH-1238 (2.34 m^3/shipment).

(c) This value was taken from DCD Revision 9 (GEH 2010).

The annual waste volume and annual number of shipments are greater than those for the 1100-MW(e) reference reactor that was the basis for Table S-4. However, by using currently available shipping packages and practices, the annual shipment estimates could be reduced below those for the reference LWR if higher shipment capacities were considered for certain types of radioactive waste from the Fermi 3 site. For example, if all of the dry active waste, approximately 12,827 ft^3 of the 15,859 ft^3/yr LLRW projected (GEH 2010), were to be shipped in standard 20-ft Sealand containers (1,000 ft^3, 1 container per truck), approximately 50 shipments per year to a disposal site would be required, assuming a shipment capacity of 2.34 m^3 of waste per shipment for the remaining waste as was assumed in WASH-1238. For comparison to the 46 annual shipments of radioactive waste for the reference reactor, the normalized number of shipments required for Fermi 3 radioactive waste would then be 30 shipments, rather than the 114 shipments identified in Table 6-13.

The sum of the daily shipments of unirradiated fuel, spent fuel, and radioactive waste for an ESBWR located at the Fermi site and alternative sites is less than the one-truck-shipment-per-day condition given in 10 CFR 51.52, Table S-4.

Dose estimates to the MEI from transport of unirradiated fuel, spent fuel, and waste under normal conditions are presented in Section 6.2.1.1.

Nonradiological impacts of radioactive waste shipments were calculated by using the same general approach as unirradiated and spent fuel shipments. For this EIS, the shipping distance was assumed to be 500 mi one way (AEC 1972). Because the actual destination is uncertain, national median accident, injury, and fatality rates were used in the calculations (Saricks and Tompkins 1999). These rates were adjusted to account for underreporting, as described in Section 6.2.1.3. The results are presented in Table 6-14. As shown, the calculated nonradiological impacts for transportation of radioactive waste other than spent fuel from the Fermi site and alternative sites to waste disposal facilities are greater than the impacts calculated for the reference LWR in WASH-1238. As noted above, the calculated impacts would be less than those calculated for the reference reactor, if currently available shipping packages and practices were used.

Table 6-14. Nonradiological Impacts of Radioactive Waste Shipments from an ESBWR at the Proposed Fermi Site

Location	Normalized Shipments per Year	One-Way Distance (km)	Accidents per Year	Injuries per Year	Fatalities per Year
Reference LWR (WASH-1238)	46	800	3.4×10^{-2}	1.7×10^{-2}	1.1×10^{-3}
Fermi 3 ESBWR	114	800	8.5×10^{-2}	4.2×10^{-2}	2.6×10^{-3}

Note: The shipments and impacts have been normalized to the reference LWR.

6.2.4 Conclusions

The NRC staff conducted a confirmatory analysis and performed independent calculations of the potential impacts under normal operating and accident conditions of transporting fuel and wastes to and from an ESBWR to be located at the Fermi site and alternative sites. For comparison with Table S-4, the environmental impacts were adjusted (i.e., normalized) to the environmental impacts associated with the reference LWR in WASH-1238 (AEC 1972), by multiplying the ESBWR impact estimates by the ratio of the total electric output for the reference reactor to the electric output of the proposed reactor.

Because of the conservative approaches and data used to calculate impacts, the actual environmental effects are not likely to exceed those calculated in this EIS. Thus, the NRC staff concludes that the environmental impacts of transportation of fuel and radioactive wastes to and from the Fermi site and alternative sites would be SMALL and would be consistent with the environmental impacts associated with transportation of fuel and radioactive wastes to and from current-generation reactors presented in Table S-4 of 10 CFR 51.52.

On March 3, 2010, DOE submitted a motion to the Atomic Safety and Licensing Board to withdraw with prejudice its application for a permanent geologic repository at Yucca Mountain, Nevada (DOE 2010). Currently the NRC Yucca Mountain adjudicatory proceeding is suspended, and there are Yucca Mountain-related matters pending in federal court. Regardless of the outcome of these proceedings, the NRC staff concludes that transportation impacts are roughly proportional to the distance from the reactor site to the repository site, in this case Michigan to Nevada. The distance from the Fermi site or any of the alternative sites to any new planned repository in the contiguous United States would be no more than double the distance from the Michigan site to Yucca Mountain. Doubling the environmental impact estimates from the transportation of spent reactor fuel, as presented in this section, would provide a reasonable bounding estimate of the impacts for NEPA purposes. The NRC staff concludes that the environmental impacts of these doubled estimates would still be SMALL.

6.3 Decommissioning Impacts

At the end of the operating life of a power reactor, NRC regulations require that the facility be decommissioned. The NRC defines decommissioning as the safe removal of a facility from service and the reduction of residual radioactivity to a level that permits termination of the NRC license. The regulations governing decommissioning of power reactors are found in 10 CFR 50.75 and 10 CFR 50.82. The radiological criteria for termination of the NRC license are in 10 CFR Part 20, Subpart E. Minimization of contamination and generation of radioactive waste requirements for facility design and procedures for operation are addressed in 10 CFR 20.1406.

An applicant for a COL is required to certify that sufficient funds will be available to provide for radiological decommissioning at the end of power operations. As part of its COL application for the Fermi 3 on the Fermi site, Detroit Edison included a Decommissioning Funding Assurance Report in its COL Application Part 1 (Detroit Edison 2010), which stated that Detroit Edison would establish an external sinking funds account to accumulate funds for decommissioning.

Environmental impacts from the activities associated with the decommissioning of any reactor before or at the end of an initial or renewed license are evaluated in the *Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities: Supplement 1, Regarding the Decommissioning of Nuclear Power Reactors*, NUREG-0586, Supplement 1 (NRC 2002) (referred to as the GEIS-DECOM). Environmental impacts of the DECOM, SAFSTOR, and ENTOMB decommissioning methods are evaluated in the GEIS-DECOM. A COL applicant is not required to identify a decommissioning method at the time of the COL application. The NRC staff's evaluation of the environmental impacts of decommissioning presented in the GEIS-DECOM identifies a range of impacts for each environmental issue for a range of different reactor designs. Based on a DOE study (DOE 2004), it is expected that the ESBWR design would have lower physical plant inventories, less accumulated radioactivity, and fewer disposal and transportation costs than current operating reactors. Therefore, the NRC staff concludes that the impacts discussed in GEIS-DECOM remain bounding for reactors deployed after 2002, including the ESBWR.

The GEIS-DECOM does not specifically address the carbon footprint of decommissioning activities. However, it does list the decommissioning activities and states that the decommissioning workforce would be smaller than the operational workforce and that the decontamination and demolition activities could take up to 10 years to complete. Finally, it discusses SAFSTOR, in which decontamination and dismantlement are delayed for a number of years. Given this information, the NRC staff estimated the CO_2 footprint of decommissioning to be approximately 70,000 MT without SAFSTOR. This footprint is about equally split between decommissioning workforce transportation and equipment usage. The details of the estimate are presented in Appendix L. A 40-year SAFSTOR period would increase the footprint of decommissioning by about 40 percent. These CO_2 footprints are roughly three orders of magnitude lower than the CO_2 footprint presented in Section 6.1.3 for the uranium fuel cycle.

Therefore, the NRC staff relies upon the bases established in GEIS-DECOM and concludes the following with respect to the decommissioning of proposed Fermi 3:

1. Doses to the public would be well below applicable regulatory standards, regardless of which decommissioning method considered in the GEIS-DECOM is used.
2. Occupational doses would be well below applicable regulatory standards during the license term.
3. The quantities of Class C or greater than Class C wastes generated would be comparable or less than the amounts of solid waste generated by reactors licensed before 2002.
4. Air quality impacts of decommissioning are expected to be negligible at the end of the operating term.
5. Measures are readily available to avoid potential significant water quality impacts from erosion or spills. The liquid radioactive waste system design includes features to limit the release of radioactive material to the environment, such as pipe chases and tank collection basins. These features will minimize the amount of radioactive material in spills and leakage that would have to be addressed at decommissioning.
6. Ecological impacts of decommissioning are expected to be negligible.

7. Socioeconomic impacts would be short term and could be offset by decreases in population and economic diversification.

On the basis of the GEIS-DECOM and the evaluation of air quality impacts from GHG emissions above, the NRC staff concludes that, as long as the regulatory requirements on decommissioning activities to limit the impacts of decommissioning are met, the decommissioning activities would result in a SMALL impact.

6.4 References

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10 CFR Part 50. Code of Federal Regulations, Title 10, *Energy*, Part 50, “Domestic Licensing of Production and Utilization Facilities.”

10 CFR Part 51. Code of Federal Regulations, Title 10, *Energy*, Part 51, “Environmental Protection Regulations for Domestic Licensing and Related Regulatory Functions.”

10 CFR Part 71. Code of Federal Regulations, Title 10, *Energy*, Part 71, “Packaging and Transportation of Radioactive Material.”

10 CFR Part 961. Code of Federal Regulations, Title 10, *Energy*, Part 961, “Standard Contract for Disposal of Spent Nuclear Fuel and/or High-Level Radioactive Waste.”

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11. ABSTRACT (200 words or less)

This environmental impact statement (EIS) has been prepared in response to an application submitted to the U.S. Nuclear Regulatory Commission (NRC) by Detroit Edison for a construction permit and operating license (combined license or COL). The proposed actions related to the Detroit Edison application are (1) NRC issuance of a COL for a new power reactor unit at the Detroit Edison Enrico Fermi Atomic Power Plant (Fermi) site in Monroe County, Michigan; and (2) U.S. Army Corps of Engineers (USACE) permit action to perform certain regulated activities on the site. The USACE is participating with the NRC in preparing this EIS as a cooperating agency and participates collaboratively on the review team.

After considering the environmental aspects of the proposed action, the staff's recommendation to the Commission is that the COL be issued as proposed. This recommendation is based on (1) the application, including the Environmental Report (ER) submitted by Detroit Edison; (2) consultation with Federal, State, Tribal, and local agencies; (3) the staff's independent review; (4) the staff's consideration of comments related to the environmental review that were received during the public scoping process and on the draft EIS; and (5) the assessments summarized in this EIS, including the potential mitigation measures identified in the ER and this EIS. The USACE permit decision would be made following issuance of this final EIS and completion of its permit application review process and permit decision documentation.

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