CHAPTER 5 ENVIRONMENTAL IMPACTS OF STATION OPERATION

Chapter 5 presents the potential environmental impacts of operation of the Clinch River (CR) Small Modular Reactor (SMR) Project, which includes operation of two or more SMRs at the Clinch River Nuclear (CRN) Site.

In accordance with Title 10 of the Code of Federal Regulations (10 CFR) Part 51, impacts are analyzed, and a significance level of potential impact to each resource (i.e. SMALL, MODERATE, or LARGE) is assigned consistent with the criteria that U.S. Nuclear Regulatory Commission (NRC) established in 10 CFR Part 51, Appendix B, Table B-1, Footnote 3. Unless the impact is identified as beneficial, the impact is adverse. In the case of “SMALL,” the impact may be negligible. The definitions of significance are as follows:

SMALL — Environmental effects are not detectable or are so minor that they neither destabilize nor noticeably alter any important attribute of the resource. For the purposes of assessing radiological impacts, the NRC has concluded that those impacts that do not exceed permissible levels in the NRC’s regulations are considered SMALL.

MODERATE — Environmental effects are sufficient to alter noticeably, but not to destabilize important attributes of the resource.

LARGE — Environmental effects are clearly noticeable and are sufficient to destabilize important attributes of the resource.

This chapter is divided into 11 sections:

- Land Use Impacts (Section 5.1)
- Water-Related Impacts (Section 5.2)
- Cooling System Impacts (Section 5.3)
- Radiological Impacts of Normal Operation (Section 5.4)
- Environmental Impacts of Waste (Section 5.5)
- Transmission System Impacts (Section 5.6)
- Uranium Fuel Cycle and Transportation Impacts (Section 5.7)
- Socioeconomics Impacts (Section 5.8)
- Decommissioning Impacts (Section 5.9)
- Measures and Controls to Limit Adverse Impacts During Operation (Section 5.10)
- Cumulative Impacts Related to Station Operation (Section 5.11)

These sections present the potential environmental impacts of operation of the CR SMR Project. Impacts are analyzed and a significance level of potential impact to each resource is assigned. In addition, this section presents ways to avoid, minimize, or mitigate adverse impacts of CR SMR Project operations.

5.1 LAND USE IMPACTS

This section describes the potential impacts on land use of operating two or more small modular reactors (SMRs) at the Clinch River Nuclear (CRN) Site. For the purposes of this Environmental Report, the CRN Site, vicinity, and region are defined in Chapter 2. Subsection 5.1.1 describes the effects on land use at the CRN Site and vicinity. Subsection 5.1.2 describes effects that could occur along transmission lines and in offsite areas resulting from operation and maintenance activities. Subsection 5.1.3 describes potential effects on historic properties at the CRN Site and in the vicinity, along transmission corridors, and at offsite areas.

5.1.1 The Site and Vicinity

Adverse impacts to land use at the CRN Site and vicinity occur primarily during construction, as documented in Section 4.1.

5.1.1.1 The Site

Land use within and adjacent to the CRN Site is discussed in Subsection 2.2.1 and Table 2.2-1. Figure 2.2-2 illustrates land use. No new areas are expected to be disturbed after the construction phase ends, and no agricultural crop production is expected to occur on the CRN Site. Therefore, operations at the CRN Site are expected to have SMALL impacts on the pasture and developed land within the CRN Site.

Prime farmland at the CRN Site is discussed in Subsection 2.2.1.1. Figure 2.2-3 shows and Table 2.2-2 lists the soil types on the CRN Site and in the site vicinity. As described in Subsection 2.2.1.1, the modern prime farmland classification of soils should be similar to the first-class (good to excellent cropland) 1942 classification. There are no first-class soils within the CRN Site or in the immediate vicinity of the Oak Ridge Reservation (ORR). Therefore, the impact of the Clinch River (CR) SMR Project on the relative value of farmland would be SMALL.

The cooling systems that are used for the operation of two or more SMRs at the CRN Site are described in Subsection 3.4.1. Heat dissipation to the atmosphere from operation of the CR SMR Project cooling towers and the effects of the cooling tower plumes and drift are discussed in Subsection 5.3.3. The impacts of the cooling tower plume salts on the CRN Site area are also discussed in Subsection 5.3.3.

Transmission lines on the CRN Site are discussed in Subsection 2.2.3 and Section 3.7. During operations, actions associated with the onsite transmission lines would consist of routine maintenance and clearing activities. Impacts associated with routine maintenance and clearing activities are addressed in Section 5.6. Overall, the impact to land use associated with operation of the transmission lines on the CRN Site would be SMALL.

5.1.1.2 The Vicinity

Land use within the vicinity of the CRN Site is discussed in Subsection 2.2.1.2. Figure 2.2-4 illustrates land use within the vicinity. The majority of land located north and east in the vicinity of the CRN Site is federal land and is part of the ORR. No offsite land is expected to be disturbed after the construction phase, and operational land-use impacts of the CR SMR Project are confined to the CRN Site. Therefore, operations at the CRN Site would have a SMALL impact on the developed land and rural farmland in the vicinity of the CRN Site.

Land use impacts associated with CR SMR Project operation that may have social and economic effects in the region are discussed in Section 5.8. Housing is discussed in Subsection 2.5.2.6 and housing impacts related to the in-migrating plant operations workforce are discussed in Subsection 5.8.2.1. The effects of the cooling tower plumes and drift associated with the CR SMR Project are discussed in Subsection 5.3.3.

The CR SMR Project is expected to generate waste that requires disposal in permitted facilities and landfills. Discussions of impacts of non-radioactive waste as well as hazardous and mixed waste on land are provided in Section 5.5.

5.1.2 Transmission Corridors and Offsite Areas

Transmission lines at the CRN Site are discussed in Subsection 2.2.3 and Section 3.7. No additional transmission lines associated with the SMR Project in offsite areas are expected to be installed during the operations phase of the CR SMR Project. The impact to land use associated with offsite transmission lines during CR SMR Project operations would be SMALL.

The road and highway system in Roane, Loudon, Anderson, and Knox counties is shown in Figure 2.5.2-1 and discussed in Subsection 2.5.2.2. Information pertaining to the effects of operations workers on the local road and highway system is presented in Subsection 5.8.2.3. The land use impact on local roadways would be SMALL.

5.1.3 Historic Properties

This subsection focuses on the potential for the CR SMR Project to affect historic properties within the CRN Site and within a 0.5-mile (mi) radius surrounding the area in which vegetation clearing would take place. Archaeological sites and aboveground historic properties are among the properties that can be considered for listing on the National Register of Historic Places (NRHP). They are the principal historic properties of concern with regard to effects from CR SMR Project operations at the CRN Site along with traditional cultural properties. Additionally, Subsection 2.5.3, Tables 2.5.3-1 and 2.5.3-2, and Figures 2.5.3-1 and 2.5.3-2 present the site numbers, locations, and NRHP status of relevant historic properties within the 10-mi radius of the CRN Site center point. Direct effects from CR SMR Project operations to historic properties are possible within the CR SMR Project area of potential effect (CR SMR Project APE). The CR SMR Project APE is described in Subsection 2.5.3.

As described in Subsection 2.5.3, no NRHP-listed properties are listed on or immediately adjacent to the CRN Site. Fifty-nine recorded archaeological sites, four isolated finds, one non-site locality, and one cemetery have been identified within or immediately adjacent to the approximately 1305-acre CR SMR Project APE. Of these sites, one site is considered to be eligible for the NRHP, 16 sites are considered potentially eligible (or of undetermined eligibility) for the NRHP; and 42 are considered not eligible for the NRHP. Ten of the eligible and potentially eligible sites are avoidable.

As discussed in Subsection 4.1.3, Tennessee Valley Authority (TVA) has executed a Programmatic Agreement (PA) pursuant to Title 36 of the Code of Federal Regulations 800.14(b)(3).The PA provides for modifications to the CR SMR Project APE, evaluating the NRHP eligibility of unevaluated resources (archaeological sites and historic architectural resources), evaluating project effects to resources, and resolution of adverse effects. TVA would implement the provisions of the PA in the event of any changes to the CR SMR Project. The PA provides measures to mitigate impacts to historic properties associated with operations of the CR SMR Project.

5.1.3.1 Prehistoric and Historic Archaeological Sites

The highest potential for effects to archaeological sites would occur during the construction period as described in Subsection 4.1.3. Operations at the CR MR Project would occur in areas previously disturbed by CR SMR Project construction and preconstruction activities. A final assessment of effects to archaeological sites within the CR SMR Project APE and any required mitigation are dependent on the outcome of the Phase II testing/reporting as stipulated by the PA and conducted in consultation with the State Historic Preservation Officer (SHPO) and any federally recognized Native American Tribe that attaches religious and cultural significance to the historic property. Operational effects to archaeological sites determined in consultation to be eligible for listing in the NRHP would be treated pursuant to mitigation measures developed in consultation with the consulting parties as described in Subsection 4.1.3. Because most effects to archaeological properties would be anticipated during the construction period, impacts to archaeological sites on the CRN Site in association with CR SMR Project operations would be SMALL.

With preconstruction and construction activities, there is the possibility for the inadvertent discovery of previously unknown archaeological resources or human remains. The PA describes the measures that will be implemented in the event of such discoveries. Should previously unknown archaeological resources be discovered, sites will be protected and stabilized to prevent any further disturbance. Ground-disturbing work will stop within a 50-foot radius of the discovery. TVA, in consultation with the SHPO and federally recognized Native American tribes that attach religious and cultural significance to the property affected by the undertaking, would develop and implement a discovery plan to make an informed NRHP eligibility determination. TVA would continue to fulfill all stipulations of the PA and its obligations under Section 106. Ground-disturbing work would not resume at the previously unknown site until completion of the NRHP determination and PA signatory consultation. (Reference 5.1-1)

Subsection 4.1.3.1 describes the stipulations of the PA TVA would implement in the event of a discovery of previously unknown archaeological resources.

5.1.3.2 Historic Structures

As discussed in Subsection 2.5.3.7, no potentially eligible, eligible, or listed NRHP aboveground historic properties or districts were identified in the CRN Site during any previous survey. Within a 0.5-mi radius surrounding the area in which vegetation clearing would take place, there are no historic structures present within the CR SMR Project APE. Therefore, CR SMR Project operations have no direct effects on historic structures.

5.1.3.3 Cemeteries

One cemetery, the Hensley Cemetery, exists on the CRN Site. As discussed in Subsection 2.5.3.11, this cemetery is not eligible for the NRHP. TVA has determined that this cemetery would remain in place onsite, TVA would maintain the cemetery grounds and access road, and families would be able access the cemetery (Reference 5.1-2). Therefore, impacts to the Hensley Cemetery associated with CR SMR Project operations would be SMALL and beneficial resulting in greater preservation, upkeep, and access.

5.1.3.4 Traditional Cultural Properties

As discussed in Subsection 2.5.3.12, no traditional cultural properties have been identified in consultation with any federally recognized Native American tribe that attaches religious and cultural significance to an archaeological historic property, or any other interested parties on the CRN Site or within a 0.5-mi surrounding the area in which vegetation clearing would take place.

5.1.4 References

Reference 5.1-1. Tennessee Valley Authority and Tennessee State Historic Preservation Officer, "Programmatic Agreement between the Tennessee Valley Authority and the Tennessee State Historic Preservation Office regarding the management of historic properties affected by the Clinch River SMR Project," August 27, 2015.

Reference 5.1-2. AECOM, "Final Clinch River Site Land Use and Recreation Technical Report - Revision 2," Greenville, SC, Tennessee Valley Authority, October, 2014.

5.2 WATER-RELATED IMPACTS

This section provides information that describes the hydrological alterations, plant water supply, and water-related impacts of facility operations at the Clinch River Nuclear (CRN) Site. Water-related impacts from facility operations are addressed in the following subsections:

- Hydrologic Alterations and Plant Water Supply (5.2.1)
- Water-Use Impacts (5.2.2)

5.2.1 Hydrology Alterations and Plant Water Supply

This subsection presents an analysis of the impact of small modular reactor (SMR) operation on surface water and groundwater hydrology, as well as the sufficiency of the proposed water source to support facility operations.

5.2.1.1 Hydrologic Setting

5.2.1.1.1 Surface Water

A description of the hydrologic setting of surface water in the vicinity of the CRN Site is presented in Subsection 2.3.1.1. The CRN Site is located on the Clinch River arm of the Watts Bar Reservoir, which is the proposed water source and receiving water body for facility operations. The CRN Site is located on the reservoir between approximately Clinch River Mile (CRM) 14.5 and approximately CRM 19.0 (Reference 5.2-1). Within the CRN Site, the proposed surface water intake is located at approximately CRM 17.9, and the proposed discharge is located at approximately CRM 15.5.

Watts Bar Dam impounds the Watts Bar Reservoir. Watts Bar Dam is located on the Tennessee River at Tennessee River Mile (TRM) 529.9, approximately 52.4 river miles downstream of the CRN Site. The reservoir has approximately 722 miles (mi) of shoreline and over 39,090 acres (ac) of water surface (Reference 5.2-2). Water enters Watts Bar Reservoir from two primary sources: releases of water from the Melton Hill Dam on the Clinch River arm of the reservoir, and releases of water from Fort Loudoun Dam on the main body of the reservoir along the Tennessee River. Melton Hill Reservoir is located upstream of Melton Hill Dam, and releases water into Watts Bar Reservoir 4.1 mi upstream of the CRN Site. The Fort Loudoun Dam also releases water into Watts Bar Reservoir. Therefore, operations of both Melton Hill Dam and Fort Loudoun Dam can affect water levels and other characteristics on Watts Bar Reservoir. River flow direction at the CRN Site can be upstream, downstream, or quiescent, depending on the modes of operation of Melton Hill Dam, Watts Bar Dam, and Fort Loudoun Dam. For example, a flow reversal (upstream river flow) may occur from an abrupt shutdown of Melton Hill and Watts Bar Dams and by releasing water from Fort Loudoun Dam. (Reference 5.2-3)

The current operating policy of the Tennessee Valley Authority (TVA) river system, implemented in 2004, is defined by the TVA Reservoir Operations Study (ROS) (Reference 5.2-4). The daily average releases from Melton Hill Dam for 2004 through 2013 are shown in Figure 2.3.1-5. For this period, the overall average release from Melton Hill Dam, and consequently the expected approximate average river flow past the CRN Site during operations, is about 4670 cubic feet per second (cfs), equivalent to 2,095,896 gallons per minute (gpm). The maximum Melton Hill Dam daily average release observed for this period is about 21,700 cfs. The minimum single-day average release may be 0 cfs. The ROS guideline for the minimum daily average release over a 48-hour period from Melton Hill Dam is 400 cfs. The ROS guideline minimum daily average has been maintained since 2008, and, as discussed in Subsection 3.4.2.5, is ensured during SMR operations by installation of a continuous flow outlet (bypass) at Melton Hill Dam.

5.2.1.1.2 Groundwater

A description of the hydrogeological setting of groundwater in the vicinity of the CRN Site is presented in Subsection 2.3.1.2. The CRN Site is surrounded on three sides by the Clinch River arm of the Watts Bar Reservoir, which is likely to be the discharge area for CRN Site groundwater. The most likely pathway for groundwater flow is recharge in the upland areas with discharge to the Clinch River arm of the Watts Bar Reservoir. An alternate groundwater pathway is recharge in the upland areas with seepage to onsite drainages and surface water discharge into the Clinch River arm of the Watts Bar Reservoir. Natural discharge of the Valley and Ridge Province aquifers is primarily through streams, rivers, and springs. In the area of the CRN Site, the Clinch River arm of the Watts Bar Reservoir acts as a sink to which all groundwater migrates. Groundwater recharge is derived primarily from precipitation. Although periodic recharge from the Clinch River arm of the Watts Bar Reservoir during high stages of the reservoir may also be occurring, this is not considered to represent a significant part of the recharge to the aquifer.

5.2.1.2 Impacts of Facility Operations on Hydrology

5.2.1.2.1 Surface Water

Facility operations that could cause hydrological alterations to surface water include consumptive use of water from the reservoir, modification of shoreline stability, modification of wetlands or marshes by artificial fill, discharge of stormwater, and modification of flow or sedimentation characteristics as a result of Circulating Water System (CWS) intake and discharge flows.

The proposed water supply for makeup water to the CWS is surface water from the Clinch River arm of Watts Bar Reservoir. The water use from the reservoir is discussed in Section 3.3 and shown in Figure 3.3-1. The proposed intake withdraws an average of approximately 18,423 gallons per minute (gpm), and a maximum of approximately 30,708 gpm. Of this total, approximately 17,078 gpm average (approximately 25,608 gpm maximum) serves as makeup water for the CWS for the surrogate plant cooling towers. The proposed mechanical draft cooling towers consume some of this water through evaporation and drift. The average and maximum drift rate is 8 gpm, and the both the average and maximum evaporation rate is 12,800 gpm. For further explanation, see Subsection 3.4.1.4 for a discussion of average and maximum drift and evaporation rates. Of the water intake, 1345 gpm average (5100 gpm maximum) is directed to the plant and facilities, from which it is distributed to various auxiliary systems. The consumptive uses of water within these systems is negligible. The total blowdown rate for water which is proposed to be discharged to the holding pond from the CWS and auxiliary systems is an average of 4270 gpm, and a maximum of 12,800 gpm. Water from miscellaneous raw water uses and miscellaneous demineralized water uses are also discharged to the holding pond at an average rate of 445 gpm (maximum of 4200 gpm). Water from the holding pond along with water from the liquid radwaste treatment system is returned to the Clinch River arm of the Watts Bar Reservoir at an average rate of 5615 gpm and a maximum rate of 17,900 gpm.

Based on the average water withdrawal rate of 18,423 gpm discussed in the previous paragraph, and the average flow rate of 2,095,896 gpm in the portion of the reservoir adjacent to the CRN Site, the facility withdraws approximately 0.9 percent of the flow within the reservoir. Of this, the consumptive use of water is an average and a maximum of 12,808 gpm, which represents approximately 0.6 percent of the average flow rate. In the most conservative scenario, with a maximum water withdrawal rate of 30,708 gpm and a minimum daily average release of 400 cfs (179,520 gpm) from Melton Hill Dam, the facility withdraws approximately 17 percent of the daily average flow in the portion of the reservoir adjacent to the CRN Site, and approximately 7 percent of the daily average flow is consumed.

Considering Watts Bar Reservoir as a whole, these estimates are conservative, because the water released from Melton Hill Dam is not the only source of water for the reservoir. The Tennessee River below Fort Loudoun Dam comprises the main body of Watts Bar Reservoir and supports a much larger conveyance than that of the Clinch River arm of the reservoir. For example, for 2004 through 2013, the overall average release from Fort Loudoun Dam is about 18,310 cfs (compared to 4670 cfs for Melton Hill Dam). By comparison, the expected maximum consumptive use of water at the CRN Site, about 12,808 gpm (28.5 cfs), is essentially inconsequential compared to the combined average conveyances from Melton Hill Dam and Fort Loudoun Dam (0.1 percent). As such, hydrologic impacts of water consumption at the CRN Site on the overall flow and pool levels in Watts Bar Reservoir would be SMALL

As shown on Figure 3.4-3, the proposed intake system is constructed on the shoreline of the reservoir, along a length of approximately 50 feet (ft). Removal of sediment to maintain the intake during operations would be of a smaller scale than the shoreline excavation required for construction. In addition, removal of sediment to maintain the intake would be conducted following the same monitoring and consultation requirements as shoreline excavation during construction.

As discussed in Subsection 2.4.2.1.3, there are four perennial streams other than the Clinch River arm of the Watts Bar Reservoir, one intermittent stream, and 19 ephemeral steams/wet-weather conveyances (WWCs) on the CRN Site (Figure 2.4.1-2; (Reference 5.2-5)). As discussed in Subsection 4.3.2.1, the current footprint of the planned permanent facilities would directly impact one small perennial stream (S01) and six WWCs (Figure 2.4.1-2 and Figure 4.3-1). Stream S01 is within the area to be occupied by the cooling water intake and the pipeline from the intake to the CR SMR Project. Impacts from intake and pipeline installation potentially would result in the permanent loss of the entire length of stream S01, approximately 925 ft of stream. Stream S01 is a small tributary to the Clinch River arm of the Watts Bar Reservoir. It is fed by a spring and small pond (P04) and flows through a small wetland (W008). Stream S01 is expected to be subject to the U.S. Army Corps of Engineers (USACE) jurisdiction. A biological survey of S01 in 2015 sampled the stream's entire length and found no fish and only a few small crayfish. (Reference 5.2-6) The WWCs located on the CRN Site are ephemeral drainages that flow only in response to precipitation runoff and do not support communities of aquatic organisms. The USACE has not made a final jurisdictional determination concerning the WWCs.

Given the small size of these features, permanent removal would not result in substantial hydrological impacts. The impacts to the stream would be further reduced by mitigation that likely would be required in accordance with USACE guidelines. In addition, the hydrologic function of these features in conveying stormwater from the CRN Site would be incorporated into the stormwater management system for the CRN Site.

There are currently stormwater runoff/collection ponds and associated piping on the CRN Site remaining from the Clinch River Breeder Reactor Project. Modifications to these ponds and piping would be made, as needed, to support the CR SMR Project. Stormwater would be managed in accordance with a site-specific Integrated Pollution Prevention Plan (IPPP). Stormwater best management practices are employed in the IPPP to prevent or minimize the discharge of pollutants with stormwater in accordance with all relevant permits and licenses such as the National Pollutant Discharge Elimination System (NPDES) industrial stormwater permit.

The proposed technology for the discharge is a submerged, bottom-mounted multiport diffuser. The basic diffuser design includes circular conduits aligned approximately perpendicular to the daily average flow in the river. The diffusers contain circular outlet ports situated in the upper, downstream quadrant of the diffuser conduits. The velocity of the flow discharging from the ports typically varies between approximately 8 and 10 ft per second. This diffuser technology is used at TVA nuclear power plants. The diffuser design meets objectives of maximizing thermal and chemical mixing while limiting local scour and the possible formation of problematic water velocities and flow patterns in the reservoir.

5.2.1.2.2 Groundwater

There are no facility operations that could cause hydrogeological alterations to groundwater. There is no proposed withdrawal of groundwater for use during operations. The impacts of dewatering during construction were discussed in Subsection 4.2.1.2, and were found to be SMALL. Any additional dewatering required during operations would be expected to be of a smaller scale than that required for construction. As discussed in Subsection 2.3.1.2.2.1, because surface water is abundant in the area, U.S. Environmental Protection Agency's (EPA) Sole Source Aquifer Program has not identified any sole source aquifers in Tennessee, and therefore there is no potential to impact Sole Source Aquifers. Based on these factors, operational impacts to groundwater hydrogeology would be SMALL.

5.2.1.3 Sufficiency of Water Supply for Facility Operations

5.2.1.3.1 Surface Water

As discussed in Subsection 5.2.1.2.1, the proposed facility withdraws an average of 0.9 percent of the average flow rate within the portion of the reservoir adjacent to the CRN Site. Of this, the most conservative scenario results in a consumptive use of approximately 7 percent of the minimum release from Melton Hill Dam. These are conservative estimates, as the water released from Melton Hill Dam is not the only source of water for the Watts Bar Reservoir. Although the continuous minimum release rate of 400 cfs from Melton Hill Dam is intended to ensure mixing of the thermal plume from the SMR, it is not necessary to provide adequate water supply for the SMR intake. Therefore, the Clinch River arm of the Watts Bar Reservoir has sufficient water available to support facility operations.

5.2.1.3.2 Groundwater

Because there is sufficient availability of surface water and no proposed use of groundwater, there are no impacts related to availability of groundwater for facility operations.

5.2.2 Water Use Impacts

This subsection presents an analysis of the water use impacts of SMR operation. These include the impact of operational water use on the availability of water for other users, and the impact of operations on water quality which could affect the use of that water by other users.

5.2.2.1 Water Availability

5.2.2.1.1 Surface Water

As discussed in Subsection 5.2.1.2.1, proposed facility operations require withdrawal of surface water to support the CWS and other plant systems. A portion of that water is consumed through evaporation and drift from the CWS, resulting in a localized net loss of water from the Clinch River arm of the Watts Bar Reservoir, and a regional net loss of water from the Tennessee River watershed. This net loss was evaluated for the potential to reduce the amount of water available to other users, including municipal and industrial users, recreational and navigational purposes, and aquatic ecology.

To evaluate the availability of water to support facility operations and potential impacts on other users, a Regional Surface Water Use Study was performed. Basin-wide water use was discussed in Subsection 2.3.2.1.1, and water use in the vicinity of the CRN Site was discussed in Subsection 2.3.2.1.3.

Surface water is the primary water supply source for approximately 98.3 percent of the users in the Tennessee Valley watershed (Reference 5.2-3). Table 2.3.2-1 shows historical off-stream water use in the Tennessee River watershed from 1995 to 2010 and projected water use to 2035. Total water use peaked in 2005 and has decreased since then, mostly due to decline in water use for cooling at thermoelectric power plants.

TVA's current reservoir operating policy was designed to meet the off-stream water needs of the Tennessee Valley out to the year 2030. The forecast of 2030 water needs was based upon a water use estimate prepared using year 2000 data. The estimates used to develop the reservoir operating policy were a total withdrawal in 2030 of 13,990 million gallons per day (mgd) (21,647 cfs) with a return of 13,010 mgd (20,131 cfs), for a net water demand of 980 mgd (1516 cfs). For the portion of the Clinch River arm of the Watts Bar Reservoir upstream of the CRN Site, the assumption used for the operating plan development was a net water demand 63 mgd (97 cfs) for 2030. (Reference 5.2-3)

As shown in Table 2.3.2-1, total water withdrawals are projected to decline approximately 21 percent by 2035. The current projection of water demand for the watershed for 2035 indicates a total withdrawal of 9449 mgd with a return of 8737 mgd, for a net water demand of 712 mgd. By category, water withdrawals are projected to change as follows: industrial withdrawals increase 31 percent to 1502 mgd, public supply withdrawals increase 30 percent to 938 mgd, and irrigation withdrawals increase 35 percent to 46 mgd. The 31 percent decline in thermoelectric water withdrawal is projected based on the anticipated retirement of older power plants, which utilize once-through cooling, and the introduction of new plants using closed-cycle cooling. The current 2035 net water demand projection for the Clinch River arm of the Watts Bar Reservoir upstream of the CRN Site is 26 mgd. (Reference 5.2-3)

The proposed SMR withdraws an average of 26 mgd (40 cfs) (44 mgd [68 cfs] maximum), which would increase the current projected total withdrawal within the Tennessee River Watershed to 9475 mgd (14,661 cfs) (9493 mgd [14,698 cfs] maximum). The proposed SMR withdrawal represents approximately 0.27 percent (0.46 percent maximum) of the current projected total withdrawal within the Tennessee River Watershed. The projected maximum consumptive water use from the CRN Site is 18 mgd (28 cfs). This increases the estimated projected net water demand to 730 mgd (1130 cfs) within the watershed and to 44 mgd (68 cfs) for the Clinch River arm of the Watts Bar Reservoir upstream of the CRN Site.

This proposed increase of net water demand represents approximately 2.5 percent of the current projected net water demand in the Tennessee River watershed. Both of these revised projections are within the initial projection estimates that were used in the development of TVA's reservoir operation system policy. Based on the above, the potential impacts of operation on other surface water users, both locally in the Clinch River watershed and regionally in the Tennessee River watershed, would be SMALL.

5.2.2.1.2 Groundwater

Groundwater is not used for safety-related systems or non-safety-related water supply purposes at the proposed CR SMR Project. There are no anticipated facility operation impacts to local groundwater resources (Reference 5.2-3).

5.2.2.2 Water Quality

As discussed in NUREG-1437, Generic Environmental Impact Statement for License Renewal of Nuclear Plants Rev. 0, surface water quality impacts could occur from the concentration and discharge of chemicals added to the recirculating cooling water to prevent corrosion and biofouling, or from elevated temperatures in the discharge. The thermal impacts of the discharge are discussed in detail in Section 5.3. The other water quality impacts are discussed in this subsection.

Although cooling towers are considered to be closed-cycle cooling systems, concentrations of dissolved salts accumulate in the circulation system as a result of evaporative water loss. To maintain proper cooling, a certain percentage of the mineral-rich stream (blowdown) must be discharged and replaced with fresh water (makeup). In addition, cooling tower water chemistry must be maintained with anti-scaling compounds and corrosion inhibitors because cooling towers concentrate solids (minerals and salts) and organics that enter the system in makeup water. Similarly, a biocide must be added to the system to prevent the growth of fouling bacteria and algae.

The facility's wastewater discharges would be regulated by the Tennessee Department of Environment and Conservation (TDEC) through a NPDES permit. The anticipated constituents and their concentrations in the facility's non-radioactive liquid waste discharges are provided in Table 3.6-1, and the average and maximum flow rates for the discharges are discussed in Section 3.4 and Subsection 3.6.3.2. An NPDES permit includes discharge limits established to protect receiving waters, and monitoring to ensure compliance with those limits. Temperatures and chemical concentrations for all discharges would be in compliance with the terms and conditions of the NPDES permit. Biocides and chemicals used for water treatment are added in part per million concentrations, are used in accordance with a TDEC-approved Biocide/Corrosion Treatment Plan, and are largely consumed serving their purposes. TDEC takes the potential for these substances being in the discharge into consideration when establishing requirements for appropriate chemical parameter monitoring and acceptable limits in the NPDES permit. Therefore the impact from these discharges would be SMALL.

As shown in Figure 3.3-1, the projected blowdown flow rate for normal facility operations is an average of 4270 gpm, and a maximum of 12,800 gpm. An additional 445 gpm (average) and 4200 gpm (maximum) are discharged from miscellaneous power plant systems, and 900 gpm (average and maximum) are discharged from the liquid radioactive waste system. The total discharge flow rate from the facility to the Clinch River arm of the Watts Bar Reservoir is 5615 gpm (average) and 17,900 gpm (maximum).

Subsection 2.3.1.1.2.4 presents the historical flow rate information for the Clinch River arm of the Watts Bar Reservoir. The release of water from Melton Hill Dam is the main source of water for flow in the Clinch River arm of the Watts Bar Reservoir at the CRN Site. The daily average releases from Melton Hill Dam for 2004 through 2013 are shown in Figure 2.3.1-5. For this period, the overall average release, and consequently the expected approximate average reservoir flow past the CRN Site, is approximately 4670 cfs. The minimum daily average release is 0 cfs. However, the development of the CR SMR Project includes implementation of a bypass structure at Melton Hill Dam to ensure a continuous release of at least 400 cfs.

On average, the CRN plant discharge is about 0.3 percent of the expected average reservoir flow past the plant, and about 3 percent of the minimum release from Melton Hill Dam. In the most conservative scenario, the maximum plant discharge represents about 10 percent of the reservoir flow past the plant when the maximum discharge occurs coincidentally with the minimum daily average release from Melton Hill Dam. However, even in this conservative situation, the characteristics and constituents of the plant discharge still are proposed to be managed within the water quality criteria specified in the plant NPDES permit. As such, water quality impacts would be SMALL.

5.2.3 References

Reference 5.2-1. Tennessee Valley Authority, "Watts Bar Reservoir Land Management Plan, Panel 4 Map," February, 2009.

Reference 5.2-2. Tennessee Valley Authority, Watts Bar Reservoir Website, Website: http://www.tva.com/sites/wattsbarres.htm, 2015.

Reference 5.2-3. Tennessee Valley Authority, "Clinch River Small Modular Reactor Site Regional Surface Water Use Study - Revision 2," April 24, 2015.

Reference 5.2-4. Tennessee Valley Authority, "Programmatic Environmental Impact Statement, Reservoir Operations Study," May, 2004.

Reference 5.2-5. Howard, Charles S., Henderson, Andrew R., and Phillips, Craig L., "Clinch River Small Modular Reactor and Barge/Traffic Site Evaluation of Aquatic Habitats and Protected Aquatic Animals Technical Report - Revision 4," Tennessee Valley Authority, November 20, 2015.

Reference 5.2-6. Henderson, Andrew R. and Phillips, Craig L., "Clinch River Small Modular Reactor and Barge/Traffic Site Stream Survey Report - Revision 2," Tennessee Valley Authority, November 20, 2015.

5.3 COOLING SYSTEM IMPACTS

Section 5.3 describes the range of impacts on the environment and human health from the operation of the Clinch River (CR) Small Modular Reactor (SMR) Project cooling system. The cooling system includes the cooling water intake system (Subsection 5.3.1), the cooling water discharge system (Subsection 5.3.2), and the system for discharging heat to the atmosphere (Subsection 5.3.3). In addition to the evaluation of physical and ecological impacts from these three components, impacts to public health are evaluated (Subsection 5.3.4) based on potential effects from microorganisms and noise.

5.3.1 Intake System

The design of the cooling water intake structure is described in Subsection 3.4.2.1. The hydrodynamic and physical impacts from operation of the intake structure are described in Subsection 5.3.1.1. The impacts on aquatic ecosystems from operation of the intake are described in Subsection 5.3.1.2.

5.3.1.1 Hydrodynamic Description and Physical Impacts

The proposed location of the intake structure is on the shoreline of the Clinch River arm of the Watts Bar Reservoir at approximately Clinch River Mile (CRM) 17.9. As discussed in Subsection 3.4.2.1, the intake structure is proposed to be a common intake for all SMRs and contain pumps, trash racks, and appropriate water screen technology to minimize effects on aquatic biota. The front face of the structure is to be located at the existing river bank. The river bank is to be excavated to provide a short intake channel, approximately 50 feet (ft) wide, to ensure sufficient water depth to provide water under conditions of low flow (Figures 3.4-2 and 3.4-3).

Hydrological conditions in the reservoir adjacent to the Clinch River Nuclear (CRN) Site are discussed in Subsections 5.2.1.1.1 and 5.2.1.2.1. On the average, the design withdrawal rate for the facility is approximately 0.9 percent of the average flow rate in the portion of Watts Bar Reservoir adjacent to the CRN Site. In the most conservative scenario, assuming a maximum water withdrawal rate by the plant and a minimum release from Melton Hill Dam (400 cubic feet per second [cfs]), the facility withdrawal rate would be approximately 17 percent of the daily average reservoir flow past the plant. Considering all of Watts Bar Reservoir, these estimates are conservative because the water released from Melton Hill Dam is not the only source of water for the reservoir. The Tennessee River below Fort Loudoun Dam comprises the main body of Watts Bar Reservoir and supports a much larger conveyance than that of the Clinch River arm of the Watts Bar Reservoir. Based on a comparison of the volume of water to be withdrawn by the CRN facility and the overall volume of water available in Watts Bar Reservoir, CRN facility operations would not significantly affect water levels or flow rates within the reservoir.

As discussed in Subsection 3.4.2.1, the maximum intake inlet velocity, trash rack flow-through velocity, and water screens flow-through velocity are to be designed to be less than 0.5 ft per second (s), in accordance with Clean Water Act (CWA) Section 316(b) regulations for protection of aquatic life. As discussed in detail in Subsection 5.3.1.2, this intake velocity is sufficiently low so that the majority of fish or other swimming organisms can avoid being trapped on the intake screens. Given these limited intake velocities and flow rates, the withdrawal zone created by the intake is expected to be weak and limited to the area immediately in front of the intake structure. For this reason, related physical impacts from operation of the intake structure, including bottom scouring, induced turbidity, silt buildup, and alteration of thermal stratification patterns, are not expected to be significant. Therefore, hydrodynamic and physical impacts of water withdrawals during SMR operations would be SMALL.

5.3.1.2 Aquatic Ecosystems

This subsection discusses the potential impacts on the aquatic community of the Clinch River arm of the Watts Bar Reservoir from the operation of the intake structure for the CR SMR Project. The ecological characteristics of the potentially affected reservoir community adjacent to the CRN Site are described in Section 2.4. The operation of the cooling system and its use of the reservoir as the source of makeup water are described in Subsections 5.2.1.2.1 and 5.3.1.1. As noted in Subsection 5.3.1.1, operation of the CRN facility would not significantly affect water levels or flow rates in the reservoir. Thus, aquatic ecosystems and associated riparian habitats of the floodplain would not be affected by hydrological changes from facility operation.

For aquatic resources, the primary concerns related to the water intake are impacts associated with the relative amount of water drawn from the Clinch River arm of the Watts Bar Reservoir and the potential for organisms to be impinged on the intake screens of the intake structure or entrained within the circulating water system (CWS). Impingement occurs when organisms are trapped against the intake screens by the force of the water passing through the intake structure. Impingement can result in starvation, exhaustion, asphyxiation (water velocity forces may prevent proper gill movement or organisms may be removed from the water for prolonged periods of time), descaling, and other physical injuries. Entrainment occurs when organisms are incorporated into the intake water flow and drawn through the intake structure into the CWS. Organisms that become entrained normally are relatively small forms that float or swim freely in the water column, including plankton and early life stages of fish. As entrained organisms pass through the cooling system, they are subject to mechanical, thermal, and toxic stresses that often are lethal. (Reference 5.3-1)

As discussed in NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, Rev. 1, U.S. Nuclear Regulatory Commission (NRC) has determined that entrainment and impingement of fish and shellfish has not been a problem at operating nuclear facilities with cooling towers. This is due to the relatively low rates of water withdrawal required by facilities that utilize cooling towers in a closed-cycle cooling system. NRC did not identify any operating nuclear power plants with cooling towers operated in closed-cycle mode that reported reduced populations of aquatic organisms due to entrainment and impingement. Accordingly, NRC concluded that the effects of entrainment and impingement of aquatic organisms at nuclear facilities with a closed-cycle, cooling-tower-based heat dissipation system would be SMALL.

Closed-cycle, recirculating, cooling-water systems using fresh water can reduce water withdrawals by 96 percent to 98 percent of the amount that the facility would withdraw if it employed a once-through cooling system (Reference 5.3-1). This substantial reduction in water withdrawal capacity results in a corresponding reduction in entrainment and impingement of aquatic organisms.

The data from the U.S. Environmental Protection Agency (EPA) impingement studies suggested that a through-screen velocity of 0.5 feet per second (ft/s) would protect 96 percent of the fish tested. (Reference 5.3-1) The intake structure for the CR SMR Project is to be designed in accordance with Section 316(b) to limit through-screen velocity to no more than 0.5 ft/s and minimize the impact of the intake system on aquatic organisms. Thus, the design and construction of the intake structure is expected to prevent the impingement of the majority of fish or other swimming organisms that may come into contact with the intake structure.

The hydrological and ecological characteristics of the Clinch River arm of the Watts Bar Reservoir are additional factors limiting the potential for cooling system impacts on aquatic organisms from entrainment and impingement. As discussed in Subsection 5.2.1.2.1, based on the expected average water withdrawal through the intake structure, the design withdrawal rate for the facility is only approximately 0.9 percent of the annual average flow in the reservoir adjacent to the CRN Site. Under the most conservative scenario, based on the expected maximum withdrawal through the intake structure and a minimum daily average release from Melton Hill Dam, the facility withdrawal would be approximately 17 percent of the daily average flow in the reservoir adjacent to the CRN Site. Thus, the proportion of water withdrawn through the intake structure would be minimal under normal conditions and would be small even under the most conservative scenario. Also, the location of the intake structure on the shoreline of the reservoir is not near any known important spawning areas or other sensitive habitats. As discussed in Subsection 2.4.2, the reservoir adjacent to the CRN Site supports a community of relatively common species of aquatic organisms and is not known to provide habitat for listed species.

Subsection 2.4.2.1.1 includes a description of an investigation by Tennessee Valley Authority (TVA) in 2011 of ichthyoplankton in Watts Bar Reservoir adjacent to the CRN Site. The temporal occurrence, composition, and abundance of fish eggs and larvae in that part of the reservoir were characterized by data collected at an upstream location, immediately upstream of the location of the intake structure, and a downstream location.

The total numbers of fish eggs and larvae collected at the upstream and downstream locations and the percentage composition of the samples represented by each taxon are summarized in Table 2.4.2-3. The taxa identified in the samples are organized in the table by family. The families represented in the egg and larvae samples and the principal species from each family are discussed in Subsection 2.4.2.1.1. More than 53 percent of the eggs collected were from the freshwater drum (family Sciaenidae), followed by shad (Clupeidae), and temperate basses (Moronidae). More than 67 percent of the larvae collected were Clupeid species, followed by suckers (Catostomidae), temperate basses, sunfishes (Centrarchidae), and others contributing less than 2 percent (Table 2.4.2-3). The species abundance data were used with sample volume data to calculate species-specific densities of fish eggs and larvae in the water column. (Reference 5.3-2)

The data from the upstream location provide an indication of the ichthyoplankton densities at the proposed location of the intake structure. These density data are summarized in Table 5.3-1, which shows densities of fish eggs and larvae by family (in numbers/1000 cubic meter [m^3]) based on the locations across the channel where they were collected along the transect. The results are totaled and averaged for day and night and for a 24-hour (hr) period. The average annual density for a 24-hr period was 337.5 eggs/1000 m^3 and 91.0 larvae/1000 m^3. Thus, the average annual total density of both fish eggs and larvae for a 24-hr period was 428.5 organisms/1000 m^3.

This annual average total density was used with the average reservoir flow past the CRN Site and the average and maximum estimated water withdrawals through the intake structure to estimate the average and maximum rates of entrainment of fish eggs and larvae at the intake structure during operation of the CR SMR Project. The results predict an average entrainment rate of 0.88 percent and a maximum entrainment rate of 1.5 percent of the total number of fish eggs and larvae in the reservoir at the intake structure. This evaluation conservatively assumes that biotic entrainment equals hydraulic entrainment (calculated in Subsection 5.2.1.2.1 as an average of 0.9 percent) and does not account for any potential reductions in entrainment that may result from factors such as intake screens or larval behavior.

These results are consistent with the conclusion by NRC that the effects of entrainment of aquatic organisms at nuclear facilities with a closed-cycle, cooling-tower-based heat dissipation system are SMALL. Impingement would be minimized by the design of the intake structure. Entrainment of ichthyoplankton under normal conditions would be less than 1 percent, and it would not exceed 1.5 percent under the most conservative water withdrawal scenario. Based on the species present, the predominant fish eggs and larvae entrained would be common species. The minimal reductions in numbers of fish eggs and larvae associated with the operation of the intake structure would not reduce the populations of important species (listed species or those considered commercially or recreationally valuable) or of mussels that may depend on fish as hosts for their larvae. Based on the use of closed-cycle cooling, the proportion of water that would be withdrawn, the expected design and location of the intake, and the composition of the aquatic community, the impacts from entrainment, impingement, or other effects on fish and other organisms due to the operation of the cooling water intake system for the CR SMR Project would be SMALL.

5.3.2 Discharge System

This subsection describes the impacts of the discharge system during operation of the CR SMR Project. The hydrothermal discharge and its physical impacts are described in Subsection 5.3.2.1. The impacts on aquatic organisms from operation of the discharge are described in Subsection 5.3.2.2.

5.3.2.1 Thermal Discharges and Other Physical Impacts

The design of the discharge structure, described in Subsection 3.4.2.3, consists of a bottom-mounted, cylindrical, multi-port diffuser situated approximately perpendicular to the flow at approximately CRM 15.5. Plans are for ports located in the downstream, upper quadrant of the diffuser pipe to disperse the heated water into the flow of the reservoir. Discharges from the CR SMR Project will be permitted under the Tennessee Department of Environment and Conservation (TDEC) National Pollutant Discharge Elimination System (NPDES) program, which regulates the discharge of pollutants into waters of the state. Under NPDES regulations, waste heat is regarded as thermal pollution and is regulated, as are chemical pollutants.

Computer modeling was performed to evaluate the thermal effects of the discharge from the CR SMR Project on both a local and regional scale. The computer codes are commercially available software products which have been vetted by developers and are successfully applied on projects similar to the SMR project. The computer modeling simulated the geometry of the water body, the shapes of the SMR intake and discharge structures, the reservoir flow conditions, and the intake and discharge rates, to reproduce the transport and movement of mass, momentum, and thermal energy in the reservoir. The modeling included consideration of viscosity, buoyancy, flow advection, turbulent diffusion, and other physical parameters, and included site-specific calibration against actual field measurements.

The local-scale analysis focused on thermal effects in the immediate vicinity of the SMR discharge and included a computational model spanning the reach of reservoir from about CRM 13.5 to CRM 21.0. The regional-scale analysis focused on thermal effects in Watts Bar Reservoir at locations farther away from the SMR site. Of particular interest are potential impacts in the portion of the reservoir near the confluence of the Clinch River and Emory River (e.g., to assess potential impacts on the Kingston Fossil Plant), and the reach of the reservoir near the confluence of the Clinch River and the Tennessee River (e.g., to assess potential impacts on the main body of the reservoir). The regional-scale analysis included a computational model encompassing all of Watts Bar Reservoir.

Local-scale modeling was initially performed to evaluate alternatives for managing the SMR blowdown. The results of the analysis of those alternatives are presented in Subsection 9.4.2.2.2. The two preferred alternatives from the initial analysis each required installation of a new low-level outlet structure at Melton Hill Dam. The purpose of the bypass is to provide a continuous, minimum release from the dam during periods of idle operation of the existing hydroelectric generating units at the dam. With the bypass, sufficient flow is provided in the

Clinch River arm of the Watts Bar Reservoir at all times to assimilate blowdown from the CR SMR Project. The hydrothermal impacts of the CR SMR Project discharge are the same for both preferred alternatives; the only difference being in the type of hydraulic equipment used to control the bypass release from the dam. The initial analysis was based on a preliminary estimate of 3944 gallons per minute (gpm) for the SMR blowdown flowrate and a bypass flow rate of 200 cfs. Following further development of the plant parameter envelope (PPE), provided in Tables 3.1-1 and 3.1-2, a supplemental analysis of the preferred alternatives was performed. The supplemental analysis was based on a blowdown flow rate of 12,800 gpm and a bypass flow rate of 400 cfs.

The baseline temperature of water in the Clinch River arm of the Watts Bar Reservoir is summarized in Subsection 2.3.1.1.2.7. The flow conditions in the reservoir are summarized in Subsections 2.3.1.1.2.4 and 2.3.1.1.2.6. The local-scale analysis was conducted for both steady and unsteady flow conditions. As discussed in Subsection 2.3.1.1.2.4, flow rates and directions in the Clinch River arm of the Watts Bar Reservoir are a function of the relative release rates from Melton Hill, Fort Loudoun, and Watts Bar Dams. Although the Reservoir Operations Study (ROS) operating policy for Melton Hill Dam requires a minimum daily average release rate of 400 cfs, this may be achieved with a very short (less than 1 hr) period of operation of the hydro generating units at the dam, followed by up to 46 hr of no water release, before water is again released for another short period of operation. As discussed in Subsection 2.3.1.1.2.6, this manner of operation can lead to reversal of flow direction, or sloshing, of the reservoir. To address this behavior, the local-scale modeling analysis also examined the assimilation of the blowdown from the SMR plant for unsteady conditions in the Clinch River arm of Watts Bar Reservoir created by infrequent operation of the existing hydro units at Melton Hill Dam.

In the supplemental analysis, for the steady, minimum flow situation, the thermal plume from the SMR diffuser was evaluated using CORMIX, a water quality model used to assess and perform environmental impact assessment of mixing zones resulting from wastewater discharges from point sources. Modeling was conducted to evaluate worst-case scenarios under both extreme winter conditions and extreme summer conditions while the CRSMR Project is operating at 100 percent power (800 megawatts electric [MWe]). The steady flow rate was assumed to be 400 cfs, corresponding to the minimum daily average release from Melton Hill Dam as specified by the TVA ROS operating policy. The results suggest that for steady flow in the reservoir at or above 400 cfs, the thermal effluent from the SMR plant under PPE conditions could be assimilated within regulatory limits at a minimum distance of 50 ft from the diffuser.

For regulatory limits enforced on an hourly basis, the mixing zone for the diffuser discharge needs to be large enough to capture unsteady events wherein the thermal plume from the SMR billows laterally and upstream during sloshing events. To evaluate the thermal plume for these conditions, the model for local-scale analyses is capable of simulating the three dimensional, unsteady behavior of the SMR thermal discharge in the reservoir. The computational domain for the local-scale model included the natural geometry of the Clinch River arm of the Watts Bar Reservoir between approximately CRM 13.5 and CRM 21.0 (7.5 miles [mi]). The model inputs include the bathymetry of the reservoir and the basic configurations of the CR SMR Project intake and diffuser, as well as time histories for the ambient flow and temperature in the reservoir and the flow and temperature of the SMR blowdown.

In the supplemental analysis, two of the unsteady scenarios analyzed using the local-scale model included the behavior of the thermal plume for operation of the CR SMR Project at full power under extreme winter conditions and under extreme summer conditions. In terms of reservoir flow, operating conditions of Watts Bar Reservoir leading to perhaps the most challenging conditions for assimilation of the SMR thermal discharge are an extreme winter event and an extreme summer event, respectively, as presented in Figures 5.3-1 and 5.3-2. These diagrams show the flow rates from Melton Hill Dam (MHH), Watts Bar Dam (WBH), and Fort Loudoun Dam (FLH), and the flow rate in the reservoir at the CR SMR Project discharge location through a representative 48 hr period. Figures 5.3-1 and 5.3-2 show that Melton Hill Dam releases water for power generation through the hydroelectric plant at approximately 5000 cfs for 1 hr at the beginning of the first day, then releases a continuous flow of 400 cfs (through the bypass), and then releases flow through the hydroelectric plant at approximately 5000 cfs again for 1 hr at the end of the second day. In both scenarios, the flow in the reservoir increases immediately in reaction to the higher release volume during the first 2 hr. Once the release from the hydroelectric unit is completed, the flow rate at the discharge drops, and by hour 3 it reverses, flowing upstream in the reservoir. In the winter scenario (Figure 5.3-1), the sloshing in the reservoir continues for approximately 24 hr, decreasing in magnitude throughout that period until the reservoir reaches a steady flow rate of 400 cfs in the downstream direction. In the summer scenario (Figure 5.3-2), the sloshing continues for almost the entire 48-hr period.

The reversal of flow in the reservoir temporarily reduces downstream dispersion and transport of the discharge from the CR SMR Project. This causes the thermal plume to occupy a wider area of the reservoir as it is transported laterally and upstream from the discharge during the reverse flow event.

The behavior of the thermal plume must comply with the general water quality criteria for the State of Tennessee, which are provided by TDEC. For effluent entering the reservoir from the SMR discharge, the water quality criteria at the boundary of the mixing zone require that:

- The maximum change in river water temperature (ΔTR) caused by the effluent shall not exceed 5.4 degrees Fahrenheit (°F) relative to an upstream control point.
- The maximum river water temperature (TR) caused by the effluent shall not exceed 86.9°F.
- The maximum water temperature-rate-of-change (TROC) in the river shall not exceed ±3.6°F/hr.

The hydrothermal modeling results for the CR SMR Project indicate that these regulatory limits would be approached only under worst-case conditions. Extreme winter conditions would challenge regulatory limits for the river temperature rise (ΔTR) and the river TROC. Extreme summer conditions would challenge regulatory limits for the maximum river TR.

Spatially, the criteria for water temperature would be applied along the boundaries of an instream mixing zone surrounding the plant discharge. The water quality criteria do not outline any detailed procedures as to how the size and shape of mixing zones should be defined. Under these circumstances, the exact dimensions of mixing zones typically are determined on a case-by-case basis using analyses and recommendations provided by the permittee. Beyond this, some guidelines for the size and shape of mixing zones can be found in regulatory literature and correspondence from EPA. EPA would review any NPDES permit for the CR SMR Project issued by TDEC.

Because of the oscillation of flow within the reservoir due to the unsteady flow conditions, the shape and extent of the thermal plume, and the magnitude of ΔTR, TROC, and maximum TR all change throughout the 48-hr flow cycles depicted in Figure 5.3-1 and Figure 5.3-2. For winter conditions, the point in time with the most extreme temperature impact is hour 13. From results of the local-scale model, the configuration of the thermal plume at hour 13 is shown in Figure 5.3-3, along with configurations at other points in time, as identified in Figure 5.3-1. The figure shows the distribution of the change in temperature from ambient conditions within the plume (ΔTR), as well as the average ΔTR calculated around the perimeter of a 150 ft diameter mixing zone. For summer conditions, the point in time when ΔTR, and subsequently TR, is perhaps the most extreme is hour 46. The configuration of the thermal plume at hour 46 is shown in Figure 5.3-4, along with the configuration at other points in time, as identified in Figure 5.3-1.

The analysis also evaluated the maximum upstream travel distance of the thermal plume in both extreme winter and summer conditions to verify that the plume likely would not reach the SMR intake in any measureable amount. Figure 5.3-5 shows the approximate zone of influence of the thermal plume during extreme winter conditions. The most extreme condition occurs at hour 6 of the 48-hr cycle. Figure 5.3-5 shows that the maximum upstream extent of the plume would be to approximately CRM 16.3, more than 1.5 mi downstream of the SMR intake. Figure 5.3-6 shows the approximate zone of influence of the thermal plume during extreme summer conditions. The most extreme condition occurs at hour 38 of the 48-hr cycle. Figure 5.3-6 shows that the maximum upstream extent of the plume would be to approximately CRM 16.6, approximately 1.3 mi downstream of the SMR intake.

The result of the supplemental local-scale simulations suggest that the blowdown from the CR SMR Project operating at full power requires not only a bypass flow of about 400 cfs from Melton Hill Dam, but also a mixing zone commensurate to a circular area with a diameter of approximately 150 ft. The actual mixing zone would be established during the NPDES permitting process and is therefore deferred to the combined license application (COLA). However, a significant portion (more than half) of the Clinch River arm of the Watts Bar Reservoir is expected to remain hydrothermally unobstructed, allowing for the passage of fish and other aquatic life even during the relatively infrequent periods of extreme operating conditions. Although regulatory requirements based on compliance at the boundary of a 150-ft diameter mixing zone are satisfied, local pockets of warm water can slosh into regions beyond the mixing zone. For extreme winter conditions, the temperature rise in these pockets can be high. For PPE bounding conditions in Table 3.1-2, these are considered to fall within the range of acceptability for thermal compliance because they are brief and provide a zone of passage for aquatic life. The results also indicate that the intake for the CR SMR Project is far enough upstream that there is essentially no threat of blowdown being recirculated into the intake.

To assess potential water quality and hydrothermal impacts of the CR SMR Project at a regional-scale, a CE-QUAL-W2 (W2) water quality model was developed for Watts Bar Reservoir. W2 is formulated to simulate the behavior of rivers and reservoirs with traits that vary primarily throughout the depth and in the direction of flow. The parameters of primary concern for the Watts Bar model include flow, stage, water temperature, dissolved oxygen (DO), and algae biomass. The model includes the main body of Watts Bar Reservoir, major tributary inflows, and industrial discharges that potentially have a significant impact on reservoir water quality, including the withdrawal and thermal discharge for the CR SMR Project.

The calibrated W2 models for 2004, 2008, and 2013 were used to conduct simulations of the effects of SMR operation on temperature, algae, and DO in the Clinch River and Tennessee River portions of Watts Bar Reservoir. These years were selected to represent a normal flow year (2004), a low flow year (2008), and a high flow year (2013). The year 2013 also represented a year in which data were available; preapplication studies of the reservoir were conducted in 2013 to support the SMR evaluation.

W2 modeling results were summarized at the 1.5 meters (m; 5 ft) depth, the normal monitoring depth required by TDEC. TDEC's criteria for the Fish and Aquatic Life stream classification (Rule 1200-04-03-.03) are stated as follows:

- DO: In lakes and reservoirs, the DO concentrations shall be measured at mid-depth in waters having a total depth of 10 ft or less, and at a depth of 5 ft in waters having a total depth of greater than 10 ft and shall not be less than 5.0 milligrams per liter (mg/L).
- Temperature: The maximum water temperature change shall not exceed 3 degrees Celsius (°C; 3°F) relative to an upstream control point. The temperature of the water shall not exceed 30.5°C (86.9°F) and the maximum rate of change shall not exceed 2°C (35.6°F)/hr. The temperature of recognized trout waters shall not exceed 20°C (68°F). There shall be no abnormal temperature changes that may affect aquatic life unless caused by natural conditions. The temperature in flowing streams shall be measured at mid-depth.
- The temperature of impoundments where stratification occurs will be measured at mid-depth in the epilimnion (see definition in Rule 0400-40-03-.04) for warm water fisheries and mid-depth in the hypolimnion (see definition in Rule 0400-40-03-.04) for cold water fisheries.
- A successful demonstration as determined by TDEC conducted for thermal discharge limitations under Section 316(a) of the CWA, (33 USC 1326) shall constitute compliance with this section.

TDEC's criteria for the Domestic Water Supply stream classification is stated as follows:

- Temperature: The maximum water temperature change shall not exceed 3°C (5.4°F) relative to an upstream control point. The temperature of the water shall not exceed 30.5°C (86.9°F) and the maximum rate of change shall not exceed ±2°C (±3.6°F)/hr. The temperature of impoundments where stratification occurs will be measured at a depth of 5 ft or mid-depth, whichever is less, and the temperature in flowing streams shall be measured at mid-depth.

The results of the regional-scale modeling suggest that SMR effects would have de minimis impact on temperature, algae, and DO at sites further downstream in Watts Bar Reservoir. The modeling analyses suggest that the water temperature in these areas would perhaps be attenuated very slightly by the 400 cfs bypass at Melton Hill Dam (i.e., compared to the present conditions wherein there is no release).

In summary, hydrothermal modeling simulations were performed to evaluate impacts in the reservoir under various operational alternatives, including conditions with minimum, steady flow in the reservoir and conditions with unsteady flows in the reservoir. The results indicate that with a minimum steady flow of 400 cfs through the planned Melton Hill Dam bypass, the thermal effluent from the CR SMR Project operating under PPE conditions ideally could be assimilated within regulatory limits at a distance of about 50 ft from the diffuser. To allow for unsteady flow and PPE conditions, a mixing zone commensurate to a circular area of diameter of approximately 150 ft is expected to be sufficient. Because the discharge would be managed in accordance with requirements of the TDEC NPDES permit, and the modeling indicates compliance with the thermal water quality criteria, thermal impacts from operation of the CR SMR Project discharge would be SMALL, and mitigation beyond operation of the Melton Hill Dam bypass is not warranted.

5.3.2.2 Aquatic Ecosystems

Operation of the CR SMR CWS produces liquid effluent that is discharged to the Clinch River arm of the Watts Bar Reservoir and has thermal and chemical effects as described in Subsections 5.3.2.1 and 5.2.2.2, respectively. The majority of the waste heat produced by the SMRs would be discharged to the atmosphere through evaporation in the cooling towers. In a closed-cycle system, evaporation causes the accumulation of minerals in the water of the system. To limit this buildup of dissolved solids (minerals and salts), some water would be regularly removed from the system (blowdown) and replaced with makeup water from the reservoir. The discharge of this heated blowdown water can have thermal and chemical effects on biota in the receiving water body, the Clinch River arm of the Watts Bar Reservoir. This subsection discusses the potential impacts from the cooling water discharge on aquatic organisms in the reservoir. The ecological characteristics of the potentially affected reservoir community adjacent to the CRN Site are described in Section 2.4.

As discussed in NUREG-1437, Rev. 1, NRC has determined that thermal discharges from operating closed-cycle nuclear facilities with cooling towers have not been a problem with respect to heated effluents directly killing aquatic organisms. NRC studies also have evaluated other effects on biota resulting from cooling system discharges from operating closed-cycle nuclear facilities with cooling towers. The issues NRC evaluated included the following:

- Cold shock
- Thermal plume barriers to migrating fish
- Effects on the regional geographic distribution of aquatic organisms
- Premature emergence of aquatic insects
- Establishment and proliferation of nuisance species
- Low dissolved oxygen and gas supersaturation
- Accumulation of nonradiological contaminants in sediments or biota
- Exposure of aquatic organisms to radionuclides

For each of these issues, NRC determined that the effects of the cooling system discharge have been SMALL for operating closed-cycle nuclear facilities with cooling towers.

The results of the thermal discharge evaluation performed by TVA to evaluate the local and regional effects of the CR SMR Project discharge are consistent with the conditions assumed under NRC's evaluation. For example, as discussed in Subsection 5.3.2.1, modeling of the effects of the discharge from the CR SMR Project found that under worst-case conditions, the plant thermal effluent could be safely assimilated using a mixing zone commensurate to a circular area of diameter of approximately 150 ft. A 150-ft diameter mixing zone encompasses approximately 45 percent of the width of the Clinch River arm of the Watts Bar Reservoir in the area of the discharge, which leaves more than half of the width of the reservoir hydrothermally unobstructed for passage of fish. In extreme winter conditions, local pockets of warm water can slosh into regions beyond the mixing zone; however, these are of brief duration, and a zone of passage for fish would remain. Additional modeling was performed at a regional scale to evaluate the discharge in the context of the full extent of Watts Bar Reservoir, and it showed that the CR SMR Project discharge would have a negligible impact on temperature (outside of the area local to the mixing zone), algae, and dissolved oxygen in the reservoir. Accordingly, NRC's conclusions are applicable for the CRN Site, and the effects of the cooling system discharge would be SMALL.

Chemical impacts from the CR SMR Project cooling system discharge on water quality of the Clinch River arm of the Watts Bar Reservoir are discussed in Subsection 5.2.2.2. Because cooling towers concentrate minerals and salts as well as organic compounds that enter the system in makeup water, cooling tower water chemistry must be modified with the addition of anti-scaling compounds and corrosion inhibitors. Biocides are also added to the system to prevent the growth of bacteria and algae. It is anticipated that the facility's blowdown discharge would contain the nonradioactive liquid waste constituents and concentrations listed in Table 3.6-1. Radionuclides anticipated to occur in the discharge from the facility are discussed in Section 3.5 and listed in Table 3.5-1. The effluent from the liquid radioactive waste treatment system would be combined with the flow from the holding pond before entering the reservoir through the discharge structure. Chemical constituent levels in the cooling system discharge will be regulated by TDEC through an NPDES permit. The concentrations of constituents in the facility discharge would be limited by the NPDES permit to comply with state water quality standards for the protection of aquatic organisms.

On the basis of the NRC’s determination of insignificant biological impacts associated with thermal discharges from operating closed-cycle nuclear facilities with cooling towers, the results of the modeling of the thermal plume from the discharge at the CRN Site, the regulation of the temperature effects of the discharge in accordance with requirements of the NPDES permit and CWA Section 316(a), and the regulation of the chemical concentrations in the discharge in accordance with requirements of the NPDES permit, impacts on aquatic organisms from operation of the CR SMR cooling water discharge would be SMALL.

5.3.3 Heat Discharge System

This subsection describes the impacts from operation of the heat-discharge system for the CR SMR Project. Subsection 5.3.3.1 discusses the physical effects from the transfer of heat to the atmosphere, and Subsection 5.3.3.2 discusses the potential for theses physical effects to impact terrestrial ecosystems.

5.3.3.1 Heat Dissipation to the Atmosphere

The cooling system design for the CR SMR Project includes linear mechanical draft cooling towers (LMDCT) for the transfer and dissipation of heat from SMR cooling water to the atmosphere. The planned LMDCT use circulating makeup water from the Clinch River arm of the Watts Bar Reservoir. Releases from cooling towers consist of a vapor plume that is visible when water vapor released from the towers condenses in cooler ambient air. Small water droplets associated with the towers’ circulating water also are emitted and escape with the exhaust air. These droplets are referred to as drift and contain dissolved solids. Potential impacts from these releases on the CRN Site and immediate surroundings include:

- Aesthetics related to an elevated visible plume
- Ground level fogging and icing
- Deposition of dissolved solids in drift that escapes from the circulating water
- Cloud formation and shading
- Additional precipitation from the vapor plume
- An increase in humidity
- Interaction with other vapor plumes from existing sources in the vicinity of the CRN Site

Computer modeling of the CR SMR Project’s LMDCT used the Electric Power Research Institute’s (EPRI) Seasonal and Annual Cooling Tower Impact (SACTI) model for evaluating potential impacts to the CRN Site and its immediate surroundings. A description of the modeling and results of the study are presented below.

The SACTI model uses hourly meteorological data to calculate seasonal and annual impacts associated with the released vapor plume and drift deposition. Meteorological data used as input to the cooling tower model were from the CRN Site's meteorological monitoring program for the period from April 21, 2011 through July 9, 2013. Other SACTI model inputs include ceiling height and mixing height data, which were not collected as part of the onsite monitoring program. Ceiling height data used were from Lovell Field Airport in Chattanooga, as obtained from the National Climatic Data Center, which was determined to be the best source of available ceiling height data for the CRN Site. Mixing height data are not collected at all National Weather Service Stations. The Lovell Field Airport mixing height data are considered representative for the Appalachian Ridge and Valley Region of Tennessee. These data are provided by the EPA Support Center for Regulatory Atmospheric Modeling (SCRAM) database website for Tennessee. Ceiling height data used from Lovell Field were concurrent with the onsite meteorological data. The design of the facility's cooling towers is not yet final; thus, certain details, such as tower-specific performance curves and some design values, were not available. However, the current design for the CR SMR Project does use LMDCT. A representative set of cooling tower parameters was developed based on the required heat rejection for the CR SMR Project. Bounding cooling tower parameters were used where applicable. The representative data selected for the project's cooling tower evaluation were based on design parameters consistent with Case Study 1 of the SACTI User's Manual, as the heat rejection for Case Study 1 is similar to that of the CR SMR Project. SACTI Model Case Study 1 included two LMDCT with a total heat rejection of 1400 megawatts (MW). The CR SMR Project is designed for a total heat rejection of approximately 1640 MW. Where appropriate, cooling tower data for the project were prorated from the SACTI Model's Case Study 1 input data.

The cooling towers area on the site layout is located approximately 500 ft to the west of the power block area, at an elevation of approximately 810 ft above mean sea level (msl). The cooling towers are located 2950 ft (899 m) from the northern boundary of the CRN Site, 1400 ft (426 m) from the western boundary, 635 ft (193 m) from the southern boundary, and 2300 ft (701 m) from the eastern boundary. As shown in Table 3.1-2, Item 3.3.1, the design footprint of the cooling towers area occupies approximately 6 acres (ac).

Representative cooling tower parameters for the project are presented in Table 5.3-2. The modeled cooling tower configuration includes two towers consisting of nine cells each. Cooling tower cells are evenly spaced by 11.0 m. (Metric units are presented here to be consistent with the SACTI model input requirements.) Each tower modeled is 99.0 m long by 11.0 m wide. The release height of the cells above ground level is 19.8 m (65 ft, from Table 3.1-2, Item 3.3.8). The total cooling water flow rate would be up to 755,000 gpm (Table 3.1-2, Item 3.3.12). The circulating water system would operate at up to four cycles of concentration. Section 3.4 of this report provides additional information on the cooling system description, operating modes, and water intake and discharge characteristics.

Table 5.3-3 provides the drift droplet mass spectrum used for the SACTI modeling based on a Marley cooling tower, which is expected to have characteristics similar to the actual cooling towers that may be included in the eventual design. Excel drift eliminators are included to mitigate drift deposition and drift impacts. The two cooling tower housings were assumed to be 11.0 m apart, which is closer than the SACTI Model Case Study 1. Positioning the towers closer conservatively increases drift deposition by concentrating the releases from the towers. The cooling tower orientation was determined based on a sensitivity study of varying tower orientations and deposition rates. The sensitivity analysis demonstrated that an east-west lengthwise orientation generated the most conservative deposition rates.

Because the design of the cooling towers is not yet final, the density of total dissolved solids (TDS) in the CR SMR Project's cooling tower water is unknown. For the SACTI modeling, the TDS density was assumed equal to that of salt, 2.17 grams per cubic centimeter (gm/cm^3). This is considered an acceptable assumption given that an order-of-magnitude approach [in the SACTI Model] is utilized when analyzing depositions, so small differences in density are negligible with respect to the conclusions derived in the calculation." Other dissolved solids potentially found in the cooling water, such as ferric nitrate, ferric chloride, potassium nitrate, and magnesium nitrate are relatively comparable in density to salt.

SACTI modeling was performed using a polar receptor grid with radials at the 16 compass directions. Receptors along each radial were spaced at 10-m, 100-m, or 200-m increments depending on the parameter modeled. Modeling was conducted to evaluate the following:

- Groundlevel fogging and icing
- Additional precipitation and humidity
- Salt deposition
- Deposition of TDS
- Hours of plume shadowing
- Plume length frequencies

Results of the SACTI modeling are discussed below.

5.3.3.1.1 Groundlevel Fogging and Icing

Groundlevel fogging occurs when the visible vapor plume directly impacts groundlevel locations downwind of the tower. Icing is predicted under temperature conditions low enough for the freezing of plume water on groundlevel surfaces. The cooling tower analysis demonstrated that due to the relatively small size of these cooling towers in comparison to a cooling tower servicing a large power plant, and the temperature and climate of the area, there were no hours of fogging or icing calculated by the SACTI code at any distance from the towers. Therefore no fogging or icing impacts are expected on transportation areas around the CRN Site and impacts are categorized as SMALL.

5.3.3.1.2 Additional Precipitation and Humidity

Table 5.3-4 provides annual average water deposition rates from the SACTI model for distances out to 1000 m. The modeling predicted the greatest annual water deposition would occur at 100 m from the cooling towers for all directions. The greatest level of deposition on an annual average basis is 97,000 kilograms per square kilometer per month (kg/km2-mo), which occurs to the west of the towers. This value, which is equivalent to approximately 0.004 inches (in.) of water per month, is insignificant for the Oak Ridge area because the Oak Ridge National Weather Service Station reports approximately 3 in. of precipitation per month or more (Table 2.7.1-2). Thus, additional water deposition from the cooling towers would be negligible. No calculations for humidity levels are provided by the SACTI model. Some increase in relative humidity may occur close to the towers and in the elevated plume. However, with low levels of water deposition and no prediction of fogging or icing, impacts on groundlevel humidity are expected to be minimal. Based on this analysis, the effects of cooling tower operation on precipitation and humidity are expected to be SMALL.

5.3.3.1.3 Salt Deposition

The SMR project design includes efficient drift eliminators to mitigate the impacts of water droplets (drift) discharged from the top of the cooling towers. However, some water in the form of drift would still be discharged from the tower with the exhaust air. Once released, drift is carried downwind from the towers. Because drift consists of water originating from within the cooling towers, it has the same concentration of salts and other dissolved solids as the water circulating in the towers. As shown in Table 3.1-2, Item 3.3.6, the design of the cooling towers would utilize up to four cycles of concentration. Salt drift is of primary concern, because salt particles deposited in the surroundings may have adverse effects on the environment. Based on sodium (Na) and chloride (Cl) concentrations in the cooling tower's circulating water (as shown in Table 5.3-2), a salt (NaCl) concentration of 0.010086 grams of salt/gram of solution was modeled in the SACTI model.

NUREG-1555, *Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan,* provides a basis for interpreting salt deposition rates based on levels at which vegetation may be affected. Deposition rates of 1 to 2 kilograms per hectare per month (kg/ha/mo or kg/ha-mo), which is equivalent to 100 to 200 kg/km^2-mo, are generally not damaging to plants. Deposition rates of 10 to 20 kg/ha/mo (1000 to 2000 kg/km^2-mo) cause leaf damage in many species. These effects levels and the potential for impacts on terrestrial vegetation at the CRN Site are discussed further in Subsection 5.3.3.2.1.

Table 5.3-5 provides annual average downwind salt deposition rates from the SACTI model for distances out to 1000 m. The SACTI model predicted that the maximum salt deposition rate would occur at 100 m for all directions. At this distance, the greatest annual average deposition predicted is 6276 kg/km^2-mo to the west. The average salt deposition at 100 m based on all directions is predicted to be 2983 kg/km^2-mo.

At 200 m, annual average salt deposition rates are predicted by the model to be below 1000 kg/km^2-mo in all directions except for the west and west-northwest. At 300 m and beyond, annual average salt deposition rates are below 1000 kg/km^2-mo in all directions, and the greatest annual average deposition predicted is 605 kg/km^2-mo to the west of the towers. Salt deposition rates at 300 m also are below 1000 kg/km^2-mo in all seasons. At 600 m and beyond, the greatest annual average deposition rate is below 100 kg/ km^2-mo for all directions. A distance of 600 m from the cooling towers extends beyond the site boundary, to just over the other side of the river, in the south-southeast through northwest directions (clockwise).

Seasonal salt deposition values for distances out to 1000 m also are provided in Table 5.3-5. For the individual seasons at 600 m, salt deposition rates are below 100 kg/ km^2-mo except for the rate in the westerly direction from the tower during the summer season (111 kg/ km^2-mo). Based on this analysis, the effects of salt deposition from cooling tower operation are expected to be limited to the area of the cooling towers and would be SMALL.

5.3.3.1.4 TDS Deposition

Deposition of TDS other than salt was modeled and annual average values out to a distance of 1000 m are presented in Table 5.3-6. Maximum TDS deposition for all directions occurs at 100 m. At 100 m from the cooling towers, the greatest predicted deposition is 93,928 kg/km^2-mo to the west of the cooling towers, while the average deposition at 100 m is 44,972 kg/km^2-mo. At 300 m from the cooling towers, TDS deposition drops considerably. The maximum TDS deposition at 300 m is 5079 kg/km^2-mo, while the average at 300 m is 2545 kg/km^2-mo. Seasonal TDS deposition values for distances out to 1000 m also are provided in Table 5.3-6. Similar to the salt analysis, the greatest TDS deposition occurs adjacent to the cooling towers, and deposition drops off rapidly with distance. Thus, the effects of TDS deposition from cooling tower operation are expected to be limited to the area of the cooling towers and would be SMALL.

5.3.3.1.5 Plume Shadowing

The frequency of annual plume shadowing, or shading, in hours per year (hr/yr) out to a distance of 1000 m is presented in Table 5.3-7. SACTI model results predict a maximum of 634 hr/yr of plume shadowing at 200 m to the northeast of the cooling towers. At 200 m to the northeast, the cooling tower plume would be over the SMR facilities. The maximum number of hours of plume shadowing at 400 m is 283 hr to the west-southwest and is equivalent to just over 3 percent of the year. The nearest residences are located at approximately 500 m to 600 m to the west-southwest and southwest of the cooling towers. At 600 m, the maximum number of hours of plume shadowing to the west-southwest is 237 hr/yr, or 2.7 percent of the year.

The plume modeling evaluates the hours of shadowing per year based on plume sectors, where each sector consists of a 22.5 degree arc. Thus, any specific point within these 22.5 degree sectors is likely to experience plume shadowing less than the percentages given here. In addition, plume shadowing varies seasonally. At 600 m, for example, maximum plume shadowing is predicted to occur 3.9, 3.7, 5.8, and 2.7 percent of the time during the winter, spring, summer, and fall seasons, respectively. Seasonal hours of plume shadowing for distances out to 1000 m are presented in Table 5.3-7. Because the predicted frequencies of plume shadowing beyond the CRN Site are low, impacts would be SMALL.

5.3.3.1.6 Plume Length Frequency

Annual plume length frequencies calculated by the SACTI model are presented in Table 5.3-8 for plume lengths up to 1000 m. Predicted visible plumes extend no more than 3200 m from the towers. Plumes at this distance occur to the south, south-southwest, north-northwest, north, north-northeast, and south-southeast directions. However, the frequency of a visible plume at this distance is very low, with the greatest value being 0.09 percent of the time (annually) in the south-southeasterly direction. For other wind directions, the predicted plume does not extend beyond 2100 m. For these cases, a visible plume at 2100 m is also infrequent.

On an annual average basis, visible plumes occur up to 5.4 and 5.0 percent of the time out to a distance of approximately 200 m to the east and east-southeast directions of the towers, respectively. For other directions, a plume out to 200 m occurs less than 3.4 percent of the time annually. Table 5.3-8 also provides seasonal plume length frequencies for distances out to 3200 m. Visible plumes are more frequent in winter and fall than in spring and summer. In winter, predicted visible plumes occur 5 percent of the time out to approximately 800 m in the east direction and 300 m in the east-southeast direction from the cooling towers. During summer, the 5 percent visible plume frequency level extends to only between 100 m and 200 m for any direction.

At 300 m, a visible plume is expected less than 3 percent of the time annually for the east and east-southeast directions and less than 2 percent of the time for any of the other directions. Based on these distances and directions, locations with overhead visible plumes occurring more than 3 percent of the time annually are predicted to be restricted to the CRN Site on or adjacent to the CR SMR Project.

Visible plume frequency calculations evaluated all hours of the year including night-time hours and periods of poor visibility (e.g., periods of precipitation and fog). During night-time hours and weather conditions producing poor visibility, visible plumes from the cooling tower would be obscured or hidden. Cooler temperature conditions, such as during the night-time hours, create greater occurrences of condensation and the likelihood of a visible plume. In addition, modeling indicates long visible plumes can be generated during periods when atmospheric conditions are close to or at saturation, conditions often associated with precipitation that can obscure a predicted visible plume. As a result, the SACTI model produces conservative results, and the occurrence of visible plumes from the project’s cooling towers is expected to be less frequent than predicted by the model. Impacts on terrestrial ecosystems from the occurrence of visible plumes would be SMALL.

5.3.3.1.7 Plume Interaction with Existing Sources

The nearest large facility to the CRN Site is Hittman Transportation, located approximately 2 kilometers (km) north of the cooling towers. At this distance, the SACTI model results indicate that water and salt deposition decline significantly (Tables 5.3-4 and 5.3-5). This reduction in deposition rates is reflective of reduced concentrations of plume contaminants. Further, the frequency of a visible plume at 2 km in this direction is only about 15 hr/yr (Table 5.3-8). The impacts of the cooling towers on other facilities, as well their interaction with other nearby air pollution sources, will be addressed during consultation with TDEC regarding air quality permitting. Given the limited concentrations of salt and TDS in drift and the distance to other potential sources of vapor plumes, the potential for interaction of the SMR plume with other plumes would be negligible, and the impact would be SMALL.

5.3.3.1.8 Holding Pond

The planned CR SMR Project includes a holding pond to mix discharge streams from the cooling towers and miscellaneous demineralized water users for the facility. This provides that any discharge from the holding pond into the reservoir would be homogeneous in temperature and composition. The intent of the holding pond is not for heat removal from the facility discharge or for management of discharge flow rates, and cooling effects of the pond are not given credit in the hydrothermal analysis. The purpose of the pond is for discharge flow mixing only. Nevertheless, this mixing would act to further reduce temperatures and moderate flow rates, making this is a conservative modelling assumption for purposes of the hydrothermal analysis. Assuming the holding pond was to function under a “worst case” scenario as a cooling pond, NUREG-1555 states:

- The plume will exist as ground level fog, but will evaporate within 300 m or lift to become stratus for wind speeds greater than 2.2 meters per second (m/s).
- The plume will exist as fog over the pond, lifting to become stratus for winds less than or equal to 2.2 m/s.

An analysis of nearby areas of importance shows that the closest such area is Interstate 40, which is located 900 m from the CRN Site’s nearest boundary. Because this area is greater than 300 m from the location of the holding pond, potential “worst case” scenario impacts from the holding pond would be SMALL.

5.3.3.2 Terrestrial Ecosystems

The terrestrial ecosystems at the CRN Site that could be affected by operation of the SMR system for discharging heat to the atmosphere are described in Subsection 2.4.1. Heat dissipation systems at nuclear power facilities potentially can impact terrestrial ecological communities through effects such as those evaluated and discussed in Subsection 5.3.3.1 (salt deposition; increased precipitation, humidity, fogging, and icing; and plume shading), as well as noise, and bird collisions with cooling towers.

5.3.3.2.1 Salt Deposition

As discussed in NUREG-1437, Rev. 0, salts from cooling tower operation are deposited on plants by droplet and particulate fallout, rainfall, and wind. In most humid environments, rain would wash salts off of vegetation, but exposure can become substantial during periods between rainfall events. Plants damaged by salt drift and deposition may show acute symptoms, such as discolored or necrotic tissue, stunted growth, or deformities. Chronic symptoms are less apparent but may include reduced growth, chlorosis, or increased susceptibility to insects or disease. Foliar uptake of salt is affected by the characteristics of the leaves, salt concentration, temperature, humidity, and the length of time the leaf is wet. Salt on foliage is absorbed in solution, so rainfall, dew, and humidity can enhance salt uptake. Because moisture and other plant and environmental factors affect salt deposition, uptake, and injury to plants, exposures likely to cause effects are difficult to predict.

Salt deposition also can damage vegetation through salinization of soil. However, in areas where rainfall is sufficient to leach salts from the soil, salinization usually does not occur. Consequently, NRC generally considers the risk to vegetation from soil salinization to be low.

As noted by NRC in NUREG-1437, Rev. 0 and NUREG-1555, the tolerances of native plants, crops, and ornamentals to salt deposition from drift are not precisely known. Accordingly, NRC recommends an order-of-magnitude approach to evaluating such effects, and NUREG-1555 identifies the following salt (NaCl) deposition thresholds for evaluating the potential for effects on vegetation:

- <u>1 to 2 kg/ha/mo (100 to 200 kg/km^2-mo)</u>: salt deposition generally not damaging to plants
- <u>10 to 20 kg/ha/mo (1000 to 2000 kg/km^2-mo)</u>: threshold range for visible leaf damage from salt deposition on leaves in any month during the growing season
- <u>Hundreds or thousands of kg/ha/year</u>: could cause damage sufficient to suggest the need for changes of tower-basin salinities or a re-evaluation of tower design, depending on the extent of the area impacted and the uniqueness of the terrestrial ecosystems expected to be exposed to drift deposition

The distance at which the SACTI model predicts the greatest salt deposition rate from the cooling towers is 100 m; the greatest annual average deposition is 6276 kg/km^2-mo to the west (Table 5.3-5). The average salt deposition for all directions at 100 m is 2983 kg/km^2-mo. A radius of 100 m from the cooling towers is within the developed area of the facility immediately surrounding the cooling towers. Thus, salt deposition is predicted to exceed the 1000 to 2000 kg/ km^2-mo threshold range for effects within that radius. As a result, there is the possibility that vegetation on slopes established immediately adjacent to the cooling towers to the west and south may be adversely affected by salt deposition.

At 200 m from the cooling towers, annual average salt deposition rates are predicted by the model to be below 1000 kg/ km^2-mo in all directions except for the west and west-northwest

(Table 5.3-5). Thus, within this developed area of the facility, salt deposition is predicted to be within the threshold for adverse effects in almost all directions. However, the potential for impacts to vegetation on the slopes adjacent to the cooling towers may extend to the toe of the slope in the westerly direction.

At 300 m from the cooling towers and beyond, the model predicts that the maximum salt deposition drops below 1000 kg/km^2-mo (Table 5.3-5). The greatest annual average deposition predicted at 300 m is 605 kg/km^2-mo to the west of the towers. Seasonal salt deposition rates at 300 m are below 1000 kg/km^2-mo in all seasons. Thus, beyond 200 m from the cooling towers and throughout the remainder of the CRN Site, salt deposition is predicted to remain below the 1000 to 2000 kg/km^2-mo threshold range for adverse effects.

At 600 m and beyond, maximum annual average salt deposition for all directions is below 100 kg/km^2-mo, a level at which vegetation damage does not occur. For the individual seasons, salt deposition values also are below 100 kg/km^2-mo at 600 m except for the westerly direction from the towers during the summer season. In summer at 600 m to the west, the predicted salt deposition is 111 kg/ km^2-mo, which is within the 100 to 200 kg/ km^2-mo range where damage to vegetation generally does not occur.

Based on studies of operating nuclear power facilities with cooling towers, discussed in NUREG-1437, Rev. 1, most deposition of drift and salt from cooling towers occurs in relatively close proximity to the towers. Deposition rates generally have been below those known to cause measurable adverse effects on plants, and no deposition effects on plant communities or crops have been observed from the operation of cooling towers at most nuclear power facilities. The SACTI modeling for the operation of the cooling towers at the CRN Site similarly predicts only a minor potential for vegetation to be impacted, and the area potentially affected would be limited to the area between the cooling towers and the reservoir on the west side of the CRN Site. Whether localized impacts to vegetation occur in this area would be determined by the sensitivity to salt deposition of the vegetation established in the area and local climatic conditions, such as the frequency with which rainfall washes salt deposits from foliage. Given that the potentially affected vegetation would be vegetation established on slopes during facility development in a limited area adjacent to the cooling towers, and the minimal occurrence of deposition effects at other facilities operating cooling towers, the impacts of salt deposition at the CRN Site would be SMALL. Mitigation may be warranted if vegetation established on slopes to prevent soil erosion is adversely affected by salt deposition.

5.3.3.2.2 Increased precipitation, humidity, fogging, and icing

As discussed in Subsections 5.3.3.1.1 and 5.3.3.1.2, the SACTI model indicated that operation of the cooling towers would not produce additional fogging or icing at any distance from the towers, and additional water deposition from the cooling towers would be negligible. Some increase in relative humidity may occur close to the towers, but effects on groundlevel humidity are expected to be minimal. As discussed in NUREG-1437, Rev. 1, impacts from increased humidity at nuclear power facilities have not been observed. Thus, the effects of cooling tower operation on terrestrial vegetation or other biota at the CRN Site from precipitation, humidity, fogging, or icing are expected to be SMALL.

5.3.3.2.3 Noise

The principal source of noise associated with the heat discharge system is the operation of the mechanical draft cooling towers. Wildlife on the CRN Site and the adjacent Grassy Creek Habitat Protection Area would be exposed to elevated noise levels, which would have the potential to alter behavioral patterns. As discussed in Section 2.8, the ambient noise assessment performed prior to construction and preconstruction activities on the CRN Site concluded that sound levels onsite ranged between daytime levels of 46 to 48 A-weighted decibels (dBA) and nighttime levels of 41 to 49 dBA. As presented in Table 3.1-2, Item 3.3.10, the cooling towers at the CR SMR Project are expected to operate at less than 70 dBA at a distance of 1000 ft.

Subsection 4.3.1.4 discusses the potential effects of noise on wildlife in the context of noise generated by construction activities. As discussed in that section, construction-related noise is attenuated by natural factors such as vegetation, topography, and temperature, and it quickly decreases over relatively short distances. Prediction of the effects of noise on wildlife is limited by the paucity of information linking sound levels to effects on species. A study by the Federal Highway Administration that summarized information from the available literature on the effects of noise on wildlife populations indicated that birds have been studied the most. The review found that some studies indicated that bird numbers and breeding were adversely affected by proximity to roads and their associated noise, while other studies found the opposite effect, with reports of many bird species using roadside habitats despite the noise. The sensitivity of birds seems to vary by species, with some affected, some not affected, and others more common even near noisy interstate highways. For mammals, the review found that studies indicate large mammals may avoid noise, but the effect seems to be small to moderate, and small mammals occur in significant numbers in highway rights-of-way and do not seem to be adversely affected by road noise. (Reference 5.3-3) The threshold noise level at which birds and small mammals are frightened or startled is 80 to 85 dBA (893 NRC 2011). This noise level is expected to occur at less than 1000 ft from the cooling towers, and undeveloped areas of habitat potentially affected occur only in a small area immediately south and west of the cooling towers between the facility and the reservoir.

More sensitive species may be permanently displaced to more distant habitats as a result of elevated noise levels from cooling tower operation, while more tolerant species likely would remain nearby if available habitats are otherwise suitable. Wildlife displaced by noise can find refuge in available undisturbed habitats in the vicinity of the CRN Site. Based on the similarity of cooling tower operational noise and highway noise levels, the rapid attenuation of noise expected to occur beyond the cooling tower area, the ability of mobile wildlife to move away from the noise, and the habituation and limited sensitivity of many wildlife species to the noise levels likely to occur in habitat areas, the impacts of noise on wildlife from cooling tower operation are expected to be SMALL.

5.3.3.2.4 Bird Collisions with Cooling Towers

As shown in Table 3.1-2, Item 3.3.8, the height of the mechanical draft cooling towers is expected to be 65 ft above finished grade. As discussed in NUREG-1437, Rev. 1, NRC has determined that natural draft cooling towers, which are much taller (usually taller than 330 ft), cause some bird mortality from collisions. However, mechanical draft cooling towers are much smaller (usually less than 100 ft) and cause negligible mortality to birds. Therefore, adverse effects on bird populations from collisions with the mechanical draft cooling towers at the CR SMR Project would be SMALL.

5.3.4 Impacts to Members of the Public

This subsection describes two issues associated with operation of the cooling system for the CR SMR Project that potentially could impact human health: propagation of etiologic agents (pathogenic microorganisms) and noise.

5.3.4.1 Etiologic Agent (Microorganism) Impacts

As discussed in NUREG-1555, etiologic agents, including organisms formerly referred to as thermophilic microorganisms, can increase in occurrence and numbers due to the presence of heat in aquatic systems or can resist moderately high temperatures long enough to be released into a cooler water body where they can grow. When such microorganisms are etiologic agents capable of causing human disease (pathogens), they can pose a risk to public health if cooling towers and thermal discharges can harbor them or accelerate their growth once they are released into the environment.

Etiologic agents of concern in the context of cooling systems include bacteria such as *Vibrio* species (spp.), *Salmonella* spp., *Legionella* spp., *Shigella* spp., *Plesiomonas shigelloides*, and *Pseudomonas* spp.*;* thermophilic fungi; noroviruses; free-living amoebae of the genera *Naegleria and Acanthamoeba*; the protozoan *Cryptosporidium;* and toxin-producing algae such as *Karenia brevis*. Data from the Centers for Disease Control and Prevention (CDC) show that there were three outbreaks of waterborne illness from treated recreational waters and one from untreated recreational water in Tennessee between 2009 and 2010. The organisms responsible were *Cryptosporidium* spp., *Shigella* spp., *Escherichia coli*, and an unidentified species. (Reference 5.3-4) In the years 2011 to 2012, there were no reported waterborne illnesses in Tennessee (Reference 5.3-5). Data regarding waterborne pathogens and toxic algae were not available specifically for the Watts Bar Reservoir.

Characteristics of these etiologic agents associated with aquatic environments and cooling systems are described below:

> *Vibrio* spp., *V. cholerae* and *V. parahaemolyticus*, are human pathogens that cause severe diarrhea, but through different mechanisms. Cholera is transmitted to humans through water or food. *V. vulnificus* is an emerging pathogen of humans that causes wound infections, gastroenteritis, or primary septicemia. (Reference 5.3-6) V. cholerae

has an optimal growth temperature range of 18°C (64.4°F to 37°C (98.6°F) (Reference 5.3-7).

Salmonella spp. live in the intestinal tracts of humans and animals. *Salmonella* spp. are the cause of two types of salmonellosis: enteric fever (typhoid), resulting from bacterial invasion of the bloodstream, and acute gastroenteritis, resulting from a foodborne infection/intoxication. (Reference 5.3-8) *Salmonella* spp. enter the natural environment (water, soil, plants) through human or animal excretion. *Salmonella* spp. do not appear to multiply significantly in the natural environment, but they can survive several weeks in water and several years in soil if conditions are favorable. (Reference 5.3-9)

Shigella spp. can cause a gastrointestinal disease called shigellosis, with symptoms that include diarrhea, fever, and stomach cramps. *Shigella* spp. can occur in water or food. Infection can occur from eating contaminated food, swimming in or drinking contaminated water, or contact with flies that carry the bacterium. Water may become contaminated from sewage or an infected person swimming or bathing.(Reference 5.3-10)

Plesiomonas shigelloides has been found in many aquatic ecosystems, including freshwater (ponds, streams, rivers), estuarine, and marine. The pathogen has been isolated from warm-blooded and cold-blooded animals, including freshwater fish and shellfish, and from many types of animals, including cattle, goats, swine, cats, dogs, monkeys, vultures, snakes, and toads. Symptoms from an infection are usually mild, although a more severe, dysenteric form of gastroenteritis may occur. Under laboratory conditions, *P. shigelloides* is able to grow at temperatures between 8°C (46.4°F) and 45°C (113°F), with an optimal range from 25°C (77°F) to 35°C (95°F). (Reference 5.3-11)

All of the *Pseudomonas* spp. are free-living bacteria found in soil and water. They are also found on the surfaces of plants and animals. *P. aeruginosa* exploits an existing break in the host defenses in order to infect the compromised tissues. It can infect almost all tissues, causing urinary tract infections, respiratory system infections, dermatitis, soft tissue infections, bacteremia, bone and joint infections, gastrointestinal infections, and a variety of systemic infections. (Reference 5.3-12) Its optimum temperature for growth is 37°C (98.6°F), and it is able to grow at temperatures as high as 42°C (107.6°F).

Karenia brevis is a dinoflagellate responsible for red tides in the Gulf of Mexico. It is a marine species and would not be found in the Clinch River arm of the Watts Bar Reservoir. (Reference 5.3-13)

Legionella spp. can cause Legionnaire’s disease, which is contracted from inhaling infected water droplets. The bacteria can be found in hot tubs, hot water tanks, large plumbing systems, decorative fountains, and cooling towers. (Reference 5.3-14)

Symptoms of Legionnaire's disease are similar to pneumonia, including cough, shortness of breath, high fever, muscle aches and headaches (Reference 5.3-15). *L. pneumophila* can withstand temperatures of 50°C (122°F) for several hours, but it remains dormant below 20°C (68°F) (Reference 5.3-16).

Naegleria fowleri is an amoeba found in warm freshwater and soil. Specifically, it is usually found in bodies of warm freshwater, such as lakes and rivers, geothermal water such as hot springs, warm water discharge from industrial plants, swimming pools that are poorly maintained with minimal or no chlorination, and water heaters. An infection can occur if the amoeba is inhaled through the nose; it cannot be contracted by drinking contaminated water. *N. fowleri* causes primary amoebic meningoencephalitis, a brain infection that leads to the destruction of brain tissue. Initial symptoms include headache, fever, nausea, or vomiting. Later symptoms include stiff neck, confusion, lack of attention to people and surroundings, loss of balance, seizures, and hallucinations. The disease usually causes death within about 5 days (range 1 to 12 days). *N. fowleri* infections are rare. In the 10 years from 2005 to 2014, 35 infections were reported in the United States. Of those cases, 31 people were infected by contaminated recreational water, three people were infected after performing nasal irrigation using contaminated tap water, and one person was infected by contaminated tap water. *N. fowleri* grows best at higher temperatures of up to 115°F (46°C) and can survive for short periods at higher temperatures. (Reference 5.3-17)

Acanthamoeba can cause *Acanthamoeba* keritities, an eye infection that can result in permanent vision impairment or blindness. Other symptoms include eye pain, eye redness, blurred vision, sensitivity to light, sensation of something in the eye and excessive tearing. *Acanthamoeba* can be found in freshwater bodies, soil, and air. People who wear contact lenses are the most susceptible to this infection. (Reference 5.3-18)

Cryptosporidium parvum is an obligate intracellular parasite. It can cause cryptosporidiosis, with symptoms that include mild to severe diarrhea, with severity increasing in young, old, and immuno-compromised individuals. Human exposure usually occurs by the ingestion of water contaminated with fecal material from an infected animal or food that was irrigated or washed with contaminated water. Swimming pools and other recreational waters are another vehicle for transmission of *Cryptosporidium* oocysts. The oocysts are difficult to eliminate with disinfectants like chlorine and can remain infectious for up to a year in both freshwater and seawater. Treated human wastewater can contain oocysts and could contaminate recreational waters downstream of a sewage treatment plant. (Reference 5.3-11)

Freshwater algal blooms can be harmful either by creating toxins or by generally impacting water quality such that they degrade aesthetic, ecological, or recreational value. Harmful algal blooms (HABs) are most often caused by cyanobacteria, but other types of algae can also cause toxicity. In addition to the production of neurotoxic, hepatotoxic, dermatotoxic, or other bioactive compounds, HABs can cause fish kills by depleting the oxygen in the water column. HABs can be naturally occurring or result of human activity. HABS usually are associated with significant increases in nutrient levels. (Reference 5.3-19)

Subsection 5.3.2.1 describes the potential effects of the hydrothermal discharge from the cooling system on water temperatures in the Clinch River arm of the Watts Bar Reservoir. The discharge will be managed in accordance with requirements of the TDEC NPDES permit, and the modeling indicates compliance with the thermal water quality criteria; therefore, thermal impacts from operation of the CR SMR Project discharge would be SMALL.

The maximum temperature measured in the Clinch River arm of the Watts Bar Reservoir during monitoring activities was 31.3°C (88.3°F) (at the monitoring location near CRM 16, approximately 0.5 mi upstream from the discharge location). Due to the complexity of the human-manipulated hydrology of this portion of the reservoir, temperatures can at times exceed TDEC’s regulations without the additional discharge associated with the CR SMR Project. As discussed in Subsection 5.3.2.1, modeling of the effects of the discharge (incorporating a continuous 400 cfs bypass of the Melton Hill Dam) indicated that the thermal component of the discharge would be assimilated within 50 ft of the discharge structure.

No data are available concerning the occurrence of etiologic agents and thermophilic microorganisms in the Clinch River arm of the Watts Bar Reservoir near the CR SMR Site. As stated in NUREG-1437, Supplement 34, thermophilic microorganisms generally occur in water with temperatures between 77°F (25°C) and 176°F (80°C). Optimal growth has been reported at between 122°F (50°C) and 150°F (65.5°C). TDEC requires a water temperature of lower than 86.9°F (30.5°C); it is unlikely that populations of thermophilic or other etiologic agents would increase in the reservoir due to discharges from the CR SMR Project. Because the temperatures in the reservoir have at times exceeded TDEC’s criteria in the absence of a discharge from the CR SMR Project, etiologic agents would not experience conditions that are substantially different from those that have previously occurred without causing their proliferation. The mixing zone where elevated temperatures from the discharge would occur would be a small area within the reservoir, and its temperatures would be at the low end of the range preferred by thermophilic etiologic agents. In addition, the few incidences of disease from etiologic agents reported in Tennessee would suggest that hydrothermal discharges on multiple reservoirs has had little or no effect on the proliferation of these agents. Based on these lines of evidence, the potential for etiologic agents associated with cooling system operation to impact public health is SMALL.

5.3.4.2 Noise

This subsection is focused on the potential human health effects associated with operation of the cooling system for the CR SMR Project. NUREG-1555 notes that the principal sources of noise from nuclear power facility operations include natural draft and mechanical draft cooling towers. Other sources may include auxiliary equipment such as pumps to supply cooling water.

The main source of noise associated with the cooling system at the CR SMR Project is operation of the mechanical draft cooling towers.

The distance from the perimeter of the cooling tower block to the nearest property boundary is approximately 690 ft. The nearest offsite residence is located approximately 1900 ft southwest from the edge of the cooling tower block, across the Clinch River arm of the Watts Bar Reservoir from the CRN Site. The cooling towers are expected to produce noise levels of less than 70 dBA at a distance of 1000 ft during operation, as presented in Table 3.1-2, Item 3.3.10. For industrial and commercial areas, TVA uses a 60 dBA equivalent noise level as a design goal at the property line. NUREG-1437, Rev 1 indicates that noise levels below 65 dBA are considered acceptable outside a residence. It also notes that cooling towers emit noise of a broadband nature, which is largely indistinguishable from and is less obtrusive than noise of a specific tonal nature (such as transformer or loudspeaker noise). Noise produced by the cooling towers would be attenuated with distance and intervening vegetation. Considering that noise levels from the cooling towers are expected to be less than 70 dBA at 1000 ft from the towers and the nearest residence is almost twice that distance, noise levels at the nearest residence are expected to be attenuated to 65 dBA or less. Therefore, impacts to members of the public from noise associated with operation of the cooling system would be SMALL.

5.3.5 References

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Reference 5.3-17. Centers for Disease Control and Prevention, Naegleria Fowleri, Website: http://www.cdc.gov/parasites/naegleria/general.html, 2015.

Reference 5.3-18. Centers for Disease Control and Prevention, Acanthamoeba Keratitis, Website: http://www.cdc.gov/parasites/acanthamoeba/gen_info/acanthamoeba_keratitis.html, 2015.

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Table 5.3-1
Average annual densities of fish eggs and larvae (number/1000 m^3) collected at the upstream sample location (CRM 18.0) near the proposed intake for the CR SMR Project from February 2011 through January 2012

Fish Eggs								
	Day				Night			
Family	RDB	Midchannel	Midchannel (bottom tow)	LDB	RDB	Midchannel	Midchannel (bottom tow)	LDB
Sciaenidae	3.5	14.9	23.4	26.0	12.5	13.0	1671.1	6.3
Clupeidae	13.4	31.0	49.4	309.6	5.3	11.7	22.2	36.6
Moronidae	4.3	24.2	26.5	154.4	3.6	13.9	21.8	56.0
Unidentifiable	4.3	11.9	11.0	65.2	5.8	8.1	10.6	27.6
Total	25.6	82.0	110.3	555.7	27.1	46.7	1725.7	126.5
Avg	193.4				481.5			
24-hr Avg	337.5							
Fish Larvae								
Clupeidae	44.2	51.8	45.9	81.9	64.1	64.7	65.3	137.4
Catostomidae	0.9	0.4	0.0	0.9	0.9	1.3	0.0	1.8
Moronidae	8.7	11.0	11.5	21.7	6.2	9.4	8.3	13.6
Centrarchidae	5.6	5.1	0.9	2.6	4.5	2.7	2.8	22.1
Atherinopsidae	3.0	1.3	0.9	0.4	1.8	-	-	1.4
Cyprinidae	-	-	-	-	3.1	4.0	1.4	0.9
Sciaenidae	1.7	0.8	1.8	0.9	0.4	0.9	0.5	0.5
Percidae	-	-	-	0.9	-	0.4	-	0.9
Unidentifiable	-	0.4	0.4	-	0.9	-	-	-
Polyodontidae	-	-	-	0.4	-	-	-	-
Total	64.2	70.9	61.3	109.6	81.9	83.5	78.2	178.5
Avg	76.5				105.5			
24-hr Avg	91.0							

Notes:
Average Annual Density of Eggs and Larvae: 337.5 + 91.0 = 428.5/1000 m^3 = 0.4285/m^3
RDB = right descending bank
LDB = left descending bank
- = no fish eggs or larvae collected
Source: (470 Tennessee Valley Authority 2012)

Table 5.3-2
Cooling Tower Design Inputs for SACTI Model

Parameter	Design Value
Total Heat Rejection for All Units (MBtu/hr)	5593
Total Heat Rejection for All Units (MWt)	1640
Height of Cells Above Ground Level (m)	19.8
Cell Exit Diameter (m)	9.14
Cell Spacing (m)	11.0
Each Tower Length (m)	99.0
Each tower Width (m)	11.0
Maximum Number of Cells All Units	18
Sodium Concentration (ppm)	990
Chloride Concentration (ppm)	1527
Salt Concentration (g salt/g solution)[1]	0.010086
Total Dissolved Solids Concentration (g TDS/g solution)[1]	0.068
Salt Density (g/cm^3)	2.17
Cycles of Concentration	4
Air Flow Rate All Cells (kg/s)	16,186.8
Drift Rate All Cells (g/s)	200.7

[1] Based on four cycles of concentration

Notes:
cm^3 = cubic centimeter
g = grams
kg = kilograms
m = meters
MBtu/hr = million British thermal units per hour
MWt = megawatts thermal
ppm = parts per million
s = second
SACTI = Seasonal and Annual Cooling Tower Impact
TDS = total dissolved solids

Table 5.3-3
Cooling Tower Droplet Mass Spectrum[1]

Mass in Range Modeled	Droplet Size Provided by Marley (microns)	Droplet Size Used in SACTI (microns)
0.12	<10	5 - 10
0.08	10 - 15	10 - 15
0.20	15 - 35	15 - 35
0.20	35 - 65	35 - 65
0.20	65 - 115	65 - 115
0.10	115 - 170	115 - 170
0.05	170 - 230	170 - 230
0.04	230 - 375	230 - 375
0.008	375 - 525	375 - 525
0.002	>525	525 - 1000

[1] The size distribution provided by Marley (SPX Cooling Technologies) did not include bounding values at the upper and lower ends of the spectrum. Limits were added as needed for the SACTI modeling. Limits were set to half the lowest value and approximately twice the upper value as provided by Marley.

Table 5.3-4 (Sheet 1 of 3)
Water Deposition in kg/km^2-mo

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Annual Average																	
100	40000	28000	33000	49000	97000	75000	53000	35000	37000	22000	21000	32000	62000	53000	48000	31000	45000
200	5300	3800	4500	7400	14000	10000	7300	4500	5600	2800	2800	6600	12000	12000	8300	4600	7000
300	3400	2600	3200	4700	8100	5900	4000	3000	3800	1700	1700	4600	8800	8200	6200	3500	4600
400	2000	1500	2400	3000	4500	3300	3000	1800	2100	1000	1200	2900	5200	5000	4800	2000	2900
500	870	610	940	1200	2000	1400	1200	770	760	430	460	960	1800	1700	1600	800	1100
600	230	180	280	450	820	580	350	190	230	110	150	400	830	780	530	230	400
700	230	180	270	430	800	570	330	190	230	110	140	390	810	770	510	230	390
800	230	180	250	320	480	340	300	190	230	110	120	330	600	570	480	230	310
900	230	180	250	310	440	300	300	190	230	110	110	320	570	540	480	230	300
1000	220	180	240	230	320	230	280	180	220	110	110	220	390	370	430	230	250
Winter																	
100	12000	10000	16000	19000	40000	47000	44000	37000	35000	27000	22000	28000	45000	28000	24000	14000	28000
200	2600	2700	4300	7800	9900	10000	9200	6300	6800	3900	3900	9900	18000	13000	8300	3700	7600
300	2500	2700	3400	6100	7200	7600	6100	4900	5400	2500	2400	8600	16000	11000	7600	3400	6100
400	1300	1400	2900	3400	3600	4100	4900	2800	3000	1500	1600	5400	9000	6900	6100	1800	3700
500	300	310	910	970	1100	1300	1600	1100	870	590	610	1500	2600	2100	1900	540	1100
600	170	170	310	580	730	720	520	320	340	170	220	720	1400	1100	680	230	530
700	170	170	290	560	720	700	500	320	340	170	200	710	1400	1100	660	230	520
800	170	170	270	380	440	390	470	320	340	170	160	580	1000	860	630	230	410
900	160	170	270	360	410	340	470	320	330	170	160	560	980	830	630	230	400
1000	160	170	240	250	260	250	400	310	320	160	160	400	670	560	580	230	320

Table 5.3-4 (Sheet 2 of 3)
Water Deposition in kg/km^2-mo

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Spring																	
100	24000	22000	26000	46000	91000	79000	56000	38000	25000	21000	19000	31000	56000	42000	34000	30000	40000
200	4600	3800	3800	7100	16000	12000	6800	4300	5200	2400	2300	6500	12000	11000	7500	4300	6800
300	3000	2500	3100	4900	10000	7000	3600	2500	4000	1500	1400	4100	8200	8000	6000	3500	4600
400	1600	1400	1800	3100	5200	3500	2600	1500	1900	940	1100	2100	4700	4400	4300	1800	2600
500	530	540	710	1300	2100	1600	1100	700	540	380	430	810	1600	1500	1400	720	990
600	190	190	280	460	1000	740	300	150	200	100	120	410	770	770	490	220	400
700	190	190	270	450	970	720	290	150	200	100	110	400	750	760	480	220	390
800	190	190	250	350	530	390	270	150	200	100	91	310	610	590	450	220	310
900	190	190	240	340	460	330	270	150	200	99	89	300	580	570	450	220	290
1000	190	180	230	250	340	240	230	150	190	94	82	180	370	340	420	220	230
Summer																	
100	74000	48000	51000	79000	160000	94000	57000	30000	47000	20000	19000	31000	79000	85000	75000	48000	62000
200	6600	4500	4900	7600	16000	9400	5500	2900	4300	2200	2300	4300	8200	11000	7800	4900	6400
300	3300	2200	2700	3600	7400	3800	2000	1700	2600	1200	1400	2500	3800	5900	4000	2700	3200
400	2200	1400	2200	2600	4900	2600	1700	1100	1700	800	940	1600	2600	3500	3100	1700	2200
500	1300	840	1000	1400	2700	1500	940	610	850	360	370	630	1300	1600	1400	950	1100
600	230	160	220	290	760	390	190	100	160	72	100	180	380	490	340	180	260
700	230	160	210	280	750	380	180	100	160	72	100	170	370	480	330	180	260
800	230	160	200	240	480	270	160	100	160	72	95	150	240	290	300	180	210
900	220	160	200	230	440	250	160	100	160	72	94	150	220	260	290	180	200
1000	220	150	200	200	360	210	160	97	150	71	94	120	190	230	260	180	180

Table 5.3-4 (Sheet 3 of 3)
Water Deposition in kg/km^2-mo

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Fall																	
100	45000	28000	39000	45000	89000	74000	55000	34000	42000	22000	24000	36000	68000	55000	57000	31000	47000
200	7100	4400	5100	7000	12000	9500	8300	5000	6300	2700	3100	6200	13000	11000	10000	5500	7300
300	4700	3400	3700	4500	7000	5100	4700	3300	3400	1500	1600	4000	8700	8500	7500	4800	4800
400	2800	1900	2700	2800	4200	3100	3100	1900	2000	990	1200	2800	5200	5500	6200	2700	3100
500	1300	730	1100	1200	1700	1300	1200	730	810	430	450	1000	1700	1800	2100	970	1200
600	340	220	360	480	740	490	420	200	240	120	160	350	840	830	650	320	420
700	340	220	340	480	710	480	400	200	240	120	150	350	810	820	630	320	410
800	340	220	310	340	450	310	360	200	240	120	120	300	590	590	590	320	340
900	340	210	300	320	420	290	360	200	240	110	120	300	560	560	590	320	330
1000	330	210	290	220	300	230	350	190	240	110	110	220	400	410	500	320	280

Table 5.3-5 (Sheet 1 of 3)
Salt Deposition kg/km^2-mo

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Annual Average																	
100	2977	2067	2249	3259	6276	4781	3538	2593	2652	1634	1235	1950	3671	3334	3155	2364	2983
200	684	478	504	744	1425	1084	809	595	626	375	284	468	884	802	730	547	690
300	272.31	194.4	216.61	317.85	604.91	457.07	326.94	238.82	260.56	148.66	123.64	220.73	421.72	376.25	330.37	230.02	296.3
400	252.03	178.13	196.47	275.72	511.77	386.52	299.66	220.44	234.99	138.59	106.68	183.07	340.42	313.36	300.06	207.68	259.1
500	180.17	125.95	137.87	197.34	374.29	282.96	213.85	156.8	161.83	97.93	75.62	123.34	233.75	213.47	201.16	146.06	182.65
600	29.81	21.9	30.64	45.17	90.81	67.86	44.81	25.69	29.69	16.51	20.35	33.34	70.46	59.27	49.37	25.94	41.35
700	29.81	21.9	27.77	41.84	85.11	63.74	40.37	25.69	29.69	16.51	17.38	30.64	65.23	56.57	44.99	25.94	38.95
800	29.81	21.9	22.69	31.16	55.74	41.34	33.47	25.69	29.69	16.51	12.3	23.56	44.69	40.87	37.28	25.94	30.79
900	29.48	21.67	22.67	30.52	53.62	39.81	33.45	25.31	29.12	16.12	12.29	23.15	43.33	39.65	37.26	25.63	30.19
1000	28.79	21.2	22.19	28.11	50.26	37.74	32.38	24.52	27.97	15.34	12.1	20.32	38.19	34.69	35.32	25	28.38
Winter																	
100	733	709	721	626	1862	2474	2743	2569	2140	1797	1144	1477	2109	1342	1086	899	1527
200	189.89	182.55	201.11	222.67	494.75	619.48	686.32	626.19	552.19	432.56	288.36	408.33	634.79	411.73	313.73	239.86	406.53
300	99.09	97.37	115.26	156.99	276.78	321.27	308.33	273.99	262.64	181.7	138.18	247	406.09	269.04	207.14	125.61	217.9
400	82.75	78.56	99.36	100.24	189.21	239.44	279.11	246.07	226.49	166.59	110.3	191.79	296.2	204.35	176.33	101.4	174.26
500	49.29	47.71	59.66	59.42	129.47	164.97	187.09	166.2	142.06	112.75	77.84	111.33	175.22	118.48	99.41	63.51	110.28
600	14.26	12.97	25.19	39.13	61.38	62.82	50.76	35.06	37.65	23.76	28.6	43.13	83.07	55.67	45.41	17.45	39.77
700	14.26	12.97	21.8	34.14	57.09	57.11	45.39	35.06	37.65	23.76	23.52	40.27	77.37	54.95	40.63	17.45	37.09
800	14.26	12.97	16.31	20.27	30.34	32.06	38.07	35.06	37.65	23.76	15.28	30.32	52.75	39.98	32.39	17.45	28.06
900	13.68	12.62	16.27	19.25	28.74	30.18	38.02	34.48	36.15	22.95	15.28	29.62	50.74	38.67	32.39	17.1	27.26
1000	12.51	11.91	15.2	16.17	24.46	27.52	35.1	33.29	33.12	21.3	15.02	24.89	41.63	30.74	30.28	16.4	24.35

Table 5.3-5 (Sheet 2 of 3)
Salt Deposition kg/km^2-mo

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Spring																	
100	1651	1505	1659	3075	5636	4930	3797	2982	1654	1529	1125	1718	3352	2459	2116	2261	2590
200	417	373	373	705	1320	1132	845	665	422	347	252	424	806	627	510	522	609
300	177.73	156.19	172.66	304.72	591.65	481.04	335.64	256.63	196.87	138.78	110.41	201.12	383.46	307.78	252.31	220.67	267.98
400	156.23	141.03	146.97	265.74	481.7	403.27	310.66	238.66	163.94	129.72	96.49	156.12	312.6	246.45	221.2	197.02	229.24
500	104.44	96.28	102.55	189.03	348.5	295.42	222.76	174.45	104.89	90.96	67.87	110.53	213.31	164.63	141.22	138.73	160.35
600	22.32	21.02	26.69	43.48	94.39	72.77	41.88	24.63	23.4	15.7	18.32	36.1	60.46	52.03	39.47	24.11	38.55
700	22.32	21.02	23.97	39.52	85.91	67.68	38.32	24.63	23.4	15.7	15.49	31.01	55.37	48.06	36.14	24.11	35.79
800	22.32	21.02	18.85	31.24	55.48	44.54	32.47	24.63	23.4	15.7	10.37	22.85	42.56	37.1	30.29	24.11	28.56
900	22.14	20.74	18.83	30.71	52.71	42.12	32.46	24.35	22.85	15.05	10.34	22.19	41.45	36.05	30.27	23.92	27.89
1000	21.75	20.18	18.41	27.91	49.15	39.53	31.2	23.8	21.73	13.76	10.12	18.75	35.14	29.41	29.01	23.55	25.84
Summer																	
100	5931	3772	3827	5969	11270	6677	3962	2386	3746	1574	1237	2151	5384	6092	5426	3780	4574
200	1282	826	826	1289	2457	1455	869	521	811	350	272	482	1178	1351	1180	834	999
300	473.49	303.53	315.64	484.57	940.68	554.23	322.39	196.88	305.3	133.12	111.03	198.38	460.88	535.58	455.98	313.66	381.58
400	454.62	292.13	303.95	459.37	863.82	506.41	306.04	187.58	292.58	124.4	102.23	176.34	415.61	484.08	429.71	299.45	356.14
500	342.72	218.84	220.36	338.39	643.26	379.37	227.6	139.3	216.65	91.4	71.72	124.9	308.34	352.57	311.47	222.11	263.06
600	42.78	28.53	32.01	48.74	111.44	66.28	37.52	17.81	27.39	11.96	12.82	22.94	58.77	62.63	52.81	30.28	41.54
700	42.78	28.53	30.65	46.42	107.97	63.39	34.18	17.81	27.39	11.96	11.95	21.78	54.72	59.17	48.82	30.28	39.86
800	42.78	28.53	28.44	41.43	81.09	47.53	29.02	17.81	27.39	11.96	10.47	17.76	39.9	45.57	41.45	30.28	33.84
900	42.49	28.53	28.43	41.12	79.03	46.79	29	17.62	27.2	11.96	10.46	17.68	38.82	44.43	41.42	30.28	33.45
1000	41.91	28.51	28.42	40.12	76.68	45.62	28.99	17.23	26.82	11.95	10.46	16.57	37.8	43.28	40.13	30.28	32.8

Table 5.3-5 (Sheet 3 of 3)
Salt Deposition kg/km^2-mo

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Fall																	
100	3239	2032	2564	2799	5371	4574	3491	2394	3055	1675	1455	2452	3528	3034	3718	2222	2975
200	773	478	574	647	1224	1036	810	567	727	383	333	565	868	736	867	532	695
300	315.64	204.73	250.53	291.03	537.77	443.28	340.02	233.33	282.41	147.03	141	245.78	436.76	373.14	395.32	243.2	305.06
400	291.19	183.79	222.74	238.83	440.42	365.52	298.68	212.9	260.74	139.01	121	215.48	327.33	296.49	361.72	214.52	261.9
500	205.31	126.99	158.34	172.85	321.64	267.04	212.64	147.21	184.75	99.75	87.7	148.71	226.36	198.72	241.24	144.41	183.98
600	38.67	23.77	39.25	48.92	90.26	68.54	51.36	27.39	32.35	15.86	23.94	32.84	84.49	67.56	61.28	31.32	46.11
700	38.67	23.77	34.85	46.79	83.89	65.7	45.46	27.39	32.35	15.86	20.3	31.43	78.12	65.42	55.52	31.32	43.55
800	38.67	23.77	26.77	29.37	50.39	39.01	35.58	27.39	32.35	15.86	14.01	24.79	45.2	40.69	45.65	31.32	32.55
900	38.32	23.42	26.74	28.57	48.51	37.97	35.54	26.81	32.23	15.74	13.98	24.59	43.8	39.21	45.62	30.51	31.97
1000	37.61	22.72	26.21	25.61	45.04	36.05	35.26	25.66	31.99	15.51	13.7	22.26	39.04	34.66	42.2	28.89	30.15

Table 5.3-6 (Sheet 1 of 3)
TDS Deposition kg/km^2-mo

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Annual Average																	
100	45567	31660	33854	49028	93928	71518	53352	39631	40548	24927	18407	29266	54604	49715	47381	36160	44972
200	7091	4965	5447	7939	15752	12025	8816	6189	6632	3967	3317	5176	9939	8542	7927	5669	7462
300	2445	1753	1739	2613	5079	3854	2767	2138	2448	1376	1059	1886	3627	3176	2721	2037	2545
400	2030	1441	1658	2383	4549	3434	2593	1781	1926	1113	968	1645	3166	2857	2567	1700	2238
500	1141	823	977	1389	2623	1967	1450	1003	1118	624	568	1004	1970	1743	1565	986	1309
600	389.08	302	422.04	493.52	921.96	688.79	577.52	349.87	458.92	218.35	290	443.66	920.53	786.06	760.77	386.18	525.58
700	327.31	258.57	269.83	393.86	679.22	500.26	360.64	287.89	385.54	175.99	158.96	367.81	726.6	649.62	504.45	319.67	397.89
800	291.22	227.25	247.28	339.65	537.23	388.18	313.67	250.66	330.13	153.97	135.36	330.42	623.8	582.33	461.71	276.27	343.07
900	257.96	199.34	232.78	296.1	458.88	336.07	304	222.96	286.61	138	131.76	290.28	535.19	489.04	434.97	243.86	303.61
1000	176.15	136.59	194.81	217.28	353.65	267.48	266.46	155.71	192.26	95.25	112.01	208.35	377.5	335.12	360.95	177.82	226.71
Winter																	
100	11058	10748	10587	8584	26948	36256	41488	39366	32548	27406	16995	21648	30445	19237	15761	13711	22674
200	2176	1979	2515	2776	6151	7270	7656	6731	6357	4798	3700	4240	6644	4080	3826	2612	4594
300	1034	935	1054	1527	2551	2830	2715	2699	2807	1867	1256	2098	3578	2322	1839	1262	2023
400	748	708	983	1235	2079	2382	2587	2061	1954	1366	1140	1813	3069	2069	1716	918	1677
500	490	466	646	867	1415	1525	1495	1233	1254	807	684	1221	2129	1478	1220	597	1095
600	311	289	478	604	857	793	786	595	751	374	450	743	1353	991	939	373	668
700	246	241	320	493	616	604	532	476	571	281	238	646	1158	861	658	307	516
800	204	203	294	434	481	495	494	425	475	249	206	604	1074	810	613	257	457
900	174.89	165.25	270.94	356.34	397.63	404.61	472.53	382.32	411.05	229.48	200.31	505.61	872.43	667.02	555.96	223.83	393.14
1000	128.34	123.23	223.74	240.01	277	286.47	413.49	251.15	282.72	147.48	170.94	340.32	557.58	418.35	455	166.21	280.13

Table 5.3-6 (Sheet 2 of 3)
TDS Deposition kg/km^2-mo

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Spring																	
100	25464	23146	24803	46300	83983	73295	57233	45535	25309	23167	16717	25471	49839	36383	31583	34623	38928
200	4462	4016	4108	7457	14538	12585	9028	6780	4587	3748	2970	5053	8870	6619	5554	5358	6608
300	1791	1595	1374	2492	5047	4170	2756	2153	1965	1302	923	1833	3288	2710	2119	1898	2339
400	1303	1178	1278	2292	4438	3714	2598	1884	1403	1057	847	1560	2912	2437	1951	1608	2029
500	781	700	796	1348	2592	2076	1436	1023	866	600	505	965	1800	1507	1235	936	1198
600	374.87	326.61	389.08	478.44	956.6	679.25	486.05	264.47	461.56	222.47	257.18	420.29	787.39	716.35	691.07	363.23	492.18
700	330.68	272.61	228.56	397.2	754.05	524.15	292.89	231.02	388.61	161.2	134.44	337.63	652.93	612.78	476.03	309.13	381.49
800	302.22	254.26	208.16	356.78	639.6	436.62	253.09	202.23	332.06	132.9	112.68	297.17	592.25	572.29	439.96	264.37	337.29
900	259.25	229.89	196.56	313.89	525.84	375.32	250.06	177.9	285.4	120.95	108.5	267.72	527.61	490.05	413.01	230.11	298.25
1000	150.02	137.25	168.02	225.34	391.87	297.67	226.94	131.94	189.43	90.94	94.05	196.18	370.03	324.41	332.75	168.6	218.46
Summer																	
100	90590	57771	58105	90664	170044	100891	59892	36386	57193	24086	18514	32821	81225	92137	82039	57931	69393
200	12894	8319	8388	13202	26019	15436	9302	5271	8152	3522	2848	5358	13151	14158	12401	8429	10428
300	3766	2492	2429	3784	7581	4456	2672	1584	2421	1096	906	1647	3802	4339	3616	2597	3074
400	3500	2250	2380	3617	7114	4153	2518	1473	2265	968	839	1441	3456	4009	3434	2325	2859
500	1833	1180	1266	1901	3795	2237	1321	788	1202	513	465	812	1886	2152	1904	1240	1531
600	313.35	217.92	297.67	331.25	859.55	520.47	361.36	176.47	245.96	114.52	161	250.35	482.77	521.41	542.28	270.55	354.18
700	272.6	207.98	220.85	283.26	637.06	366.82	223.74	147.93	220.82	113.39	110.6	200.72	350.91	430.55	319.44	248.61	272.2
800	241.45	188.62	211.15	256.07	501.45	271.91	179.21	119.03	187.62	97.29	99.04	173.6	269.51	376.26	272.87	226.56	229.48
900	227.2	177.32	202.92	232.62	453.58	255.6	178.56	107.27	162.23	82.41	97.47	155.71	246.26	312.52	268.98	210.03	210.67
1000	182.52	122.27	170.63	199.57	388.78	230.33	159.73	88.27	128.37	64.62	80	122.83	217.84	252.17	237.88	142.72	174.28

Table 5.3-6 (Sheet 3 of 3)
TDS Deposition kg/km^2-mo

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Fall																	
100	49710	31099	38497	41865	80049	68501	52347	36592	46948	25655	21726	37041	52056	44795	55892	33807	44786
200	8134	5010	6419	7255	14272	11881	9110	6051	7569	3954	3936	6012	10613	8502	9453	5724	7744
300	3038	1855	2027	2416	4577	3738	2946	2243	2722	1323	1218	2029	3878	3183	3246	2295	2671
400	2409	1506	1915	2134	4012	3252	2686	1752	2128	1106	1104	1828	3226	2756	3112	1829	2297
500	1390	891	1175	1337	2431	1937	1578	1015	1190	607	656	1071	2122	1801	1898	1124	1389
600	576	386	559	601	1017	800	746	425	427	185	330	413	1187	990	936	568	634
700	470.25	319.48	331.4	426.92	699.03	528.8	441.3	342.63	398.9	166.25	170.43	333.92	846.59	752.23	612.53	431.85	454.53
800	424.55	264.95	293.37	327.73	508.87	363.46	373.25	298.11	358.08	155.11	138.76	292.56	648.12	620.01	568.97	369.82	375.36
900	376.13	221.94	276.44	292.33	442.95	317.05	356.28	262.24	316.64	136.19	135.09	269.49	561.92	526.12	544.46	321.55	334.8
1000	248.37	166.39	229.06	206.83	339.51	256.16	299.57	173.01	184.13	86.11	115.41	197.11	402.5	366.68	452.65	243.26	247.92

Table 5.3-7
Hours of Plume Shadowing

Dist(m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Annual Average																	
200	40	65	125.4	421.4	618.5	505.1	419.9	361.4	393.3	469.7	633.7	541.6	535	218.1	71	37.7	341
400	16	22	59.1	282.6	241.8	205.9	134.1	104	114	141.3	216.9	200.6	163.6	187.5	30	18	133.6
600	12	16	41.1	237.1	134.1	139.6	56.8	50	58	72	131.9	133.2	103.9	57.7	22	16	80.1
800	7	12.1	33.1	169	101.5	96.6	39	36	49	52	104.9	111.2	74.6	48.9	19	12	60.4
1000	5	8	29.1	131.5	81.8	73.5	24	30	44	50	85.8	91.7	65.9	37.8	13	6	48.6
Winter																	
200	4	3	10.1	30.7	42.4	134.7	191	180.5	211.3	263.8	343.5	139.5	38.9	34.2	14.8	5.7	103
400	2	1	2	7.6	28.4	98.6	72.6	62	67	88.3	140	92.4	29.6	9	6	3	44.4
600	2	1	0	4.5	21.4	84.3	32.8	36	34	45	86	69.2	26.4	7	6	2	28.6
800	1	1	0	4.5	17.4	61.9	20	27	29	31	68	59.2	25.4	7	4	1	22.3
1000	0	0	0	4.5	17.4	48.8	11	24	29	31	56.8	54.2	23.2	7	2	0	19.3
Spring																	
200	20	31	60.6	142.7	246.7	152.8	72	70	67	75	86	179.5	265.3	83.7	37.1	16	100.3
400	7	10	27	104.2	106.9	32.7	18	12	19	23	24	39	81.3	58.4	15	9	36.7
600	6	8	18	80.1	50.2	12.7	7	4	11	10	12	24	50.4	30.3	9	8	21.3
800	2	5	15	57.2	36.2	9.7	8	4	9	10	9	20	33.2	27.2	9	6	16.3
1000	1	3	13	50.6	25.5	6.7	5	2	9	10	8	16	27.7	21.1	6	3	13
Summer																	
200	9	12.8	27.1	192.8	210.2	47.6	32.5	30	26	25	27	43.4	158.1	78.5	8	6	58.4
400	4	7	11.9	139.4	22.5	11.5	6.5	7	7	5	7	8	13	113.1	4	3	23.1
600	1	4	9.1	126	4	4.5	1	4	5	2	6	6	6	13.4	2	3	12.3
800	1	4.1	6.1	84.8	3	3.5	1	3	5	1	6	6	3	8.7	2	3	8.8
1000	1	3	6.1	57	1	2	1	3	3	1	5	5	2	4.7	2	2	6.2
Fall																	
200	7	18.2	27.5	55.1	119.3	170.1	124.4	81	89	105.9	177.2	179.3	72.7	21.8	11.1	10	79.3
400	3	4	18.2	31.5	83.9	63.1	37	23	21	25	45.9	61.2	39.7	7	5	3	29.5
600	3	3	14	26.5	58.4	38.1	16	6	8	15	27.9	34	21.2	7	5	3	17.9
800	3	2	12	22.5	44.9	21.5	10	2	6	10	21.9	26	13	6	4	2	12.9
1000	3	2	10	19.4	38	16	7	1	3	8	16	16.4	13	5	3	1	10.1

Table 5.3-8 (Sheet 1 of 6)
Annual Plume Length Frequency

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
Annual Average																	
100	4.49	3.88	5.34	5.77	7.94	6.21	5.28	3.73	5.94	3.43	4.94	9.14	12.24	9.44	8.23	4	100
200	1.53	1.35	1.71	2.57	2.95	1.94	1.29	1.23	1.73	0.82	0.85	3.1	5.44	4.99	3.3	1.71	36.51
300	0.74	0.7	0.61	1.33	1.44	0.9	0.22	0.47	0.65	0.39	0.34	1.72	2.97	2.6	1.31	0.99	17.38
400	0.61	0.54	0.61	0.78	0.66	0.32	0.22	0.39	0.55	0.31	0.34	1.21	1.88	1.71	1.31	0.86	12.29
500	0.37	0.31	0.61	0.78	0.66	0.32	0.22	0.2	0.29	0.23	0.34	1.21	1.88	1.71	1.31	0.49	10.93
600	0.37	0.31	0.61	0.78	0.66	0.32	0.22	0.2	0.29	0.23	0.34	1.21	1.88	1.71	1.31	0.49	10.93
700	0.32	0.24	0.61	0.78	0.66	0.32	0.22	0.13	0.19	0.16	0.34	1.21	1.88	1.71	1.31	0.39	10.46
800	0.32	0.24	0.61	0.78	0.66	0.32	0.22	0.13	0.19	0.16	0.34	1.21	1.88	1.71	1.31	0.39	10.46
900	0.32	0.24	0.56	0.69	0.42	0.16	0.13	0.13	0.19	0.16	0.32	1.16	1.73	1.52	1.14	0.39	9.26
1000	0.27	0.21	0.56	0.69	0.42	0.16	0.13	0.07	0.17	0.15	0.32	1.16	1.73	1.52	1.14	0.33	9.04
1200	0.27	0.21	0.56	0.69	0.42	0.16	0.13	0.07	0.17	0.15	0.32	1.16	1.73	1.52	1.14	0.33	9.04
1300	0.27	0.21	0.56	0.69	0.42	0.16	0.13	0.07	0.17	0.15	0.32	1.16	1.73	1.52	1.14	0.33	9.04
1400	0.27	0.21	0.56	0.69	0.42	0.16	0.13	0.07	0.17	0.15	0.32	1.16	1.73	1.52	1.14	0.33	9.04
1500	0.27	0.21	0.56	0.69	0.42	0.16	0.13	0.07	0.17	0.15	0.32	1.16	1.73	1.52	1.14	0.33	9.04
1600	0.27	0.21	0.56	0.69	0.42	0.16	0.13	0.07	0.17	0.15	0.32	1.16	1.73	1.52	1.14	0.33	9.04
1700	0.27	0.21	0.56	0.69	0.42	0.16	0.13	0.07	0.17	0.15	0.32	1.16	1.73	1.52	1.14	0.33	9.04
1800	0.27	0.21	0.36	0.48	0.29	0.09	0.07	0.07	0.17	0.15	0.24	0.95	1.22	1.03	0.66	0.33	6.59
1900	0.27	0.21	0.36	0.48	0.29	0.09	0.07	0.07	0.17	0.15	0.24	0.95	1.22	1.03	0.66	0.33	6.59
2000	0.27	0.21	0.36	0.48	0.29	0.09	0.07	0.07	0.17	0.15	0.24	0.95	1.22	1.03	0.66	0.33	6.59
2100	0.27	0.21	0.14	0.19	0.08	0.05	0.03	0.07	0.17	0.15	0.12	0.4	0.59	0.48	0.41	0.33	3.7
2200	0.27	0.21	0	0	0	0	0	0.07	0.17	0.15	0	0	0	0	0	0.33	1.2
2300	0.17	0.14	0	0	0	0	0	0.03	0.12	0.09	0	0	0	0	0	0.19	0.73
2400	0.17	0.14	0	0	0	0	0	0.03	0.12	0.09	0	0	0	0	0	0.19	0.73
2500	0.17	0.14	0	0	0	0	0	0.03	0.12	0.09	0	0	0	0	0	0.19	0.73
2600	0.06	0.04	0	0	0	0	0	0.01	0.08	0.05	0	0	0	0	0	0.09	0.33
2700	0.06	0.04	0	0	0	0	0	0.01	0.08	0.05	0	0	0	0	0	0.09	0.33
2800	0.06	0.04	0	0	0	0	0	0.01	0.08	0.05	0	0	0	0	0	0.09	0.33
2900	0.06	0.04	0	0	0	0	0	0.01	0.08	0.05	0	0	0	0	0	0.09	0.33

Table 5.3-8 (Sheet 2 of 6)
Annual Plume Length Frequency

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
3000	0.06	0.04	0	0	0	0	0	0.01	0.08	0.05	0	0	0	0	0	0.09	0.33
3100	0.06	0.04	0	0	0	0	0	0.01	0.08	0.05	0	0	0	0	0	0.09	0.33
3200	0.06	0.04	0	0	0	0	0	0.01	0.08	0.05	0	0	0	0	0	0.09	0.33
Winter																	
100	2.82	2.47	4.7	6.07	6.35	5.5	5.98	4.23	5.43	2.92	3.79	10.44	14.9	11.57	9.54	3.29	100
200	1.69	1.62	2.42	4.35	3.69	3.17	2.63	2.4	2.73	1.25	1.53	7.14	11.44	9	6.51	2.16	63.74
300	0.99	0.99	0.92	2.47	2.02	1.36	0.56	1.11	1.46	0.61	0.61	4.32	6.98	5.33	3.22	1.53	34.48
400	0.85	0.75	0.92	1.81	1.13	0.59	0.56	0.92	1.25	0.52	0.61	3.31	5.07	3.92	3.22	1.41	26.82
500	0.49	0.45	0.92	1.81	1.13	0.59	0.56	0.49	0.75	0.35	0.61	3.31	5.07	3.92	3.22	0.94	24.61
600	0.49	0.45	0.92	1.81	1.13	0.59	0.56	0.49	0.75	0.35	0.61	3.31	5.07	3.92	3.22	0.94	24.61
700	0.42	0.31	0.92	1.81	1.13	0.59	0.56	0.35	0.56	0.28	0.61	3.31	5.07	3.92	3.22	0.78	23.83
800	0.42	0.31	0.92	1.81	1.13	0.59	0.56	0.35	0.56	0.28	0.61	3.31	5.07	3.92	3.22	0.78	23.83
900	0.42	0.31	0.82	1.62	0.89	0.28	0.31	0.35	0.56	0.28	0.59	3.17	4.58	3.64	3.03	0.78	21.63
1000	0.42	0.31	0.82	1.62	0.89	0.28	0.31	0.21	0.49	0.23	0.59	3.17	4.58	3.64	3.03	0.7	21.3
1100	0.42	0.31	0.82	1.62	0.89	0.28	0.31	0.21	0.49	0.23	0.59	3.17	4.58	3.64	3.03	0.7	21.3
1200	0.42	0.31	0.82	1.62	0.89	0.28	0.31	0.21	0.49	0.23	0.59	3.17	4.58	3.64	3.03	0.7	21.3
1300	0.42	0.31	0.82	1.62	0.89	0.28	0.31	0.21	0.49	0.23	0.59	3.17	4.58	3.64	3.03	0.7	21.3
1400	0.42	0.31	0.82	1.62	0.89	0.28	0.31	0.21	0.49	0.23	0.59	3.17	4.58	3.64	3.03	0.7	21.3
1500	0.42	0.31	0.82	1.62	0.89	0.28	0.31	0.21	0.49	0.23	0.59	3.17	4.58	3.64	3.03	0.7	21.3
1600	0.42	0.31	0.82	1.62	0.89	0.28	0.31	0.21	0.49	0.23	0.59	3.17	4.58	3.64	3.03	0.7	21.3
1700	0.42	0.31	0.82	1.62	0.89	0.28	0.31	0.21	0.49	0.23	0.59	3.17	4.58	3.64	3.03	0.7	21.3
1800	0.42	0.31	0.56	1.24	0.59	0.16	0.14	0.21	0.49	0.23	0.42	2.51	3	2.56	1.97	0.7	15.54
1900	0.42	0.31	0.56	1.24	0.59	0.16	0.14	0.21	0.49	0.23	0.42	2.51	3	2.56	1.97	0.7	15.54
2000	0.42	0.31	0.56	1.24	0.59	0.16	0.14	0.21	0.49	0.23	0.42	2.51	3	2.56	1.97	0.7	15.54
2100	0.42	0.31	0.21	0.49	0.16	0.07	0.09	0.21	0.49	0.23	0.26	1.08	1.48	1.32	1.36	0.7	8.91
2200	0.42	0.31	0	0	0	0	0	0.21	0.49	0.23	0	0	0	0	0	0.7	2.37
2300	0.21	0.12	0	0	0	0	0	0.07	0.38	0.12	0	0	0	0	0	0.4	1.29
2400	0.21	0.12	0	0	0	0	0	0.07	0.38	0.12	0	0	0	0	0	0.4	1.29
2500	0.21	0.12	0	0	0	0	0	0.07	0.38	0.12	0	0	0	0	0	0.4	1.29
2600	0.07	0.05	0	0	0	0	0	0.05	0.26	0.07	0	0	0	0	0	0.24	0.73

Table 5.3-8 (Sheet 3 of 6)
Annual Plume Length Frequency

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
2700	0.07	0.05	0	0	0	0	0	0.05	0.26	0.07	0	0	0	0	0	0.24	0.73
2800	0.07	0.05	0	0	0	0	0	0.05	0.26	0.07	0	0	0	0	0	0.24	0.73
2900	0.07	0.05	0	0	0	0	0	0.05	0.26	0.07	0	0	0	0	0	0.24	0.73
3000	0.07	0.05	0	0	0	0	0	0.05	0.26	0.07	0	0	0	0	0	0.24	0.73
3100	0.07	0.05	0	0	0	0	0	0.05	0.26	0.07	0	0	0	0	0	0.24	0.73
3200	0.07	0.05	0	0	0	0	0	0.05	0.26	0.07	0	0	0	0	0	0.24	0.73
Spring																	
100	3.65	3.28	4.92	5.84	8.44	6.96	5.15	3.82	6.75	3.93	5.42	9.18	12	8.88	8.1	3.69	100
200	1.37	1.33	1.55	2.73	3.4	1.89	0.9	0.95	1.68	0.75	0.73	2.09	4.97	4.72	2.99	1.66	33.7
300	0.51	0.62	0.58	1.48	1.81	1.03	0.22	0.28	0.43	0.39	0.3	0.97	2.45	2.22	1.04	0.82	15.15
400	0.37	0.47	0.58	0.78	0.91	0.43	0.22	0.17	0.34	0.34	0.3	0.56	1.49	1.45	1.04	0.75	10.19
500	0.21	0.3	0.58	0.78	0.91	0.43	0.22	0.09	0.11	0.22	0.3	0.56	1.49	1.45	1.04	0.32	9.02
600	0.21	0.3	0.58	0.78	0.91	0.43	0.22	0.09	0.11	0.22	0.3	0.56	1.49	1.45	1.04	0.32	9.02
700	0.15	0.21	0.58	0.78	0.91	0.43	0.22	0.04	0.07	0.19	0.3	0.56	1.49	1.45	1.04	0.2	8.63
800	0.15	0.21	0.58	0.78	0.91	0.43	0.22	0.04	0.07	0.19	0.3	0.56	1.49	1.45	1.04	0.2	8.63
900	0.15	0.21	0.54	0.71	0.47	0.17	0.11	0.04	0.07	0.19	0.28	0.52	1.42	1.31	0.93	0.2	7.31
1000	0.13	0.17	0.54	0.71	0.47	0.17	0.11	0.04	0.06	0.19	0.28	0.52	1.42	1.31	0.93	0.17	7.19
1100	0.13	0.17	0.54	0.71	0.47	0.17	0.11	0.04	0.06	0.19	0.28	0.52	1.42	1.31	0.93	0.17	7.19
1200	0.13	0.17	0.54	0.71	0.47	0.17	0.11	0.04	0.06	0.19	0.28	0.52	1.42	1.31	0.93	0.17	7.19
1300	0.13	0.17	0.54	0.71	0.47	0.17	0.11	0.04	0.06	0.19	0.28	0.52	1.42	1.31	0.93	0.17	7.19
1400	0.13	0.17	0.54	0.71	0.47	0.17	0.11	0.04	0.06	0.19	0.28	0.52	1.42	1.31	0.93	0.17	7.19
1500	0.13	0.17	0.54	0.71	0.47	0.17	0.11	0.04	0.06	0.19	0.28	0.52	1.42	1.31	0.93	0.17	7.19
1600	0.13	0.17	0.54	0.71	0.47	0.17	0.11	0.04	0.06	0.19	0.28	0.52	1.42	1.31	0.93	0.17	7.19
1700	0.13	0.17	0.54	0.71	0.47	0.17	0.11	0.04	0.06	0.19	0.28	0.52	1.42	1.31	0.93	0.17	7.19
1800	0.13	0.17	0.35	0.49	0.37	0.11	0.06	0.04	0.06	0.19	0.26	0.5	1.06	0.88	0.48	0.17	5.32
1900	0.13	0.17	0.35	0.49	0.37	0.11	0.06	0.04	0.06	0.19	0.26	0.5	1.06	0.88	0.48	0.17	5.32
2000	0.13	0.17	0.35	0.49	0.37	0.11	0.06	0.04	0.06	0.19	0.26	0.5	1.06	0.88	0.48	0.17	5.32
2100	0.13	0.17	0.06	0.15	0.13	0.09	0.04	0.04	0.06	0.19	0.11	0.17	0.5	0.26	0.24	0.17	2.49
2200	0.13	0.17	0	0	0	0	0	0.04	0.06	0.19	0	0	0	0	0	0.17	0.75
2300	0.09	0.11	0	0	0	0	0	0	0.04	0.15	0	0	0	0	0	0.09	0.49

Table 5.3-8 (Sheet 4 of 6)
Annual Plume Length Frequency

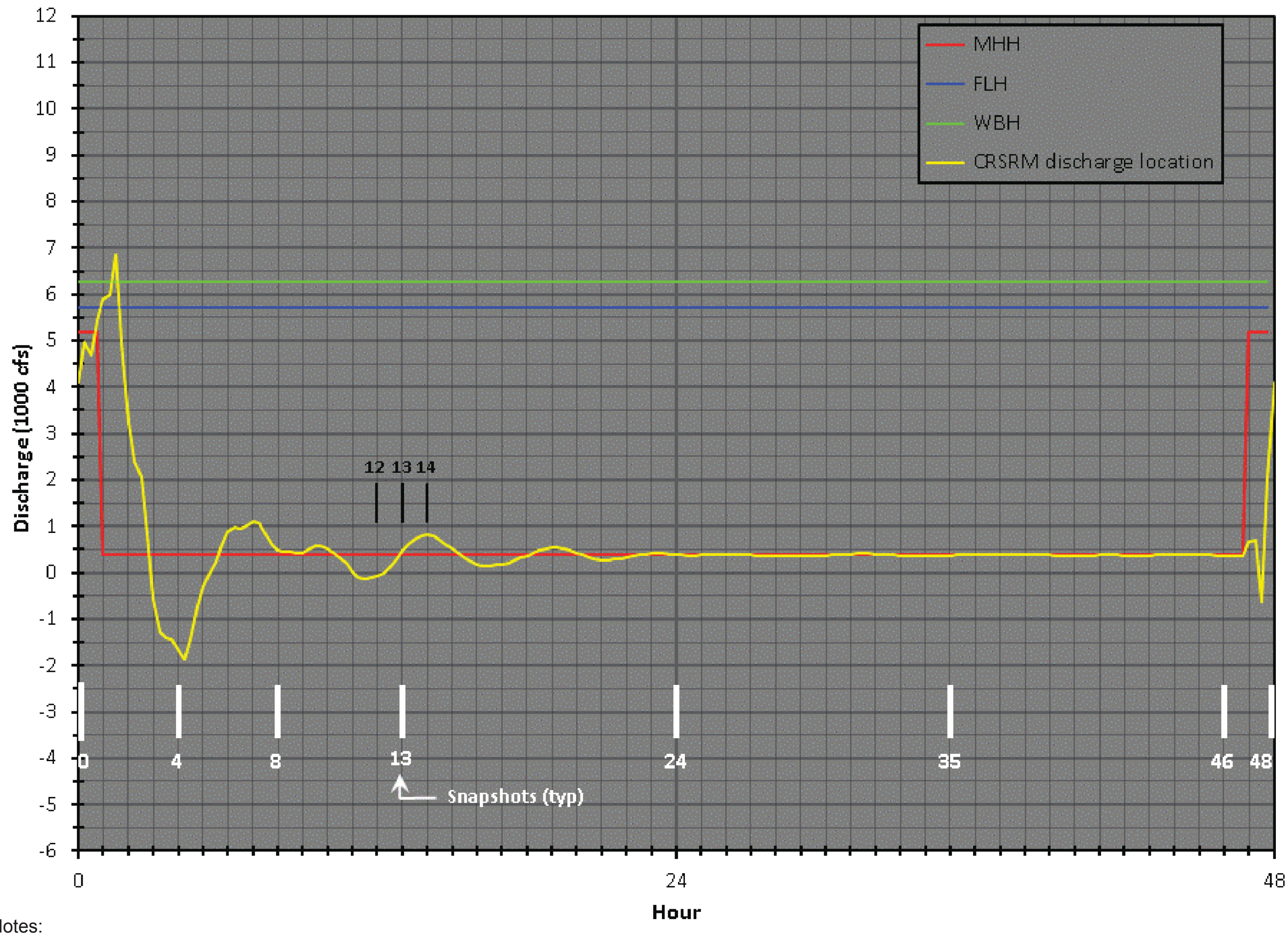
Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
2400	0.09	0.11	0	0	0	0	0	0	0.04	0.15	0	0	0	0	0	0.09	0.49
2500	0.09	0.11	0	0	0	0	0	0	0.04	0.15	0	0	0	0	0	0.09	0.49
2600	0.04	0.02	0	0	0	0	0	0	0.02	0.06	0	0	0	0	0	0.04	0.17
2700	0.04	0.02	0	0	0	0	0	0	0.02	0.06	0	0	0	0	0	0.04	0.17
2800	0.04	0.02	0	0	0	0	0	0	0.02	0.06	0	0	0	0	0	0.04	0.17
2900	0.04	0.02	0	0	0	0	0	0	0.02	0.06	0	0	0	0	0	0.04	0.17
3000	0.04	0.02	0	0	0	0	0	0	0.02	0.06	0	0	0	0	0	0.04	0.17
3100	0.04	0.02	0	0	0	0	0	0	0.02	0.06	0	0	0	0	0	0.04	0.17
3200	0.04	0.02	0	0	0	0	0	0	0.02	0.06	0	0	0	0	0	0.04	0.17
Summer																	
100	6.43	5.72	6.12	5.94	8.98	5.69	4.02	3.15	5.62	3.58	5.53	8.86	10.6	8.09	7.31	4.34	100
200	0.91	0.87	0.84	0.98	1.7	0.9	0.46	0.6	0.91	0.48	0.38	1.07	1.13	1.55	0.8	0.89	14.47
300	0.29	0.2	0.21	0.19	0.65	0.42	0.08	0.15	0.27	0.17	0.1	0.39	0.36	0.52	0.17	0.21	4.38
400	0.17	0.12	0.21	0.04	0.21	0.1	0.08	0.15	0.21	0.1	0.1	0.19	0.1	0.27	0.17	0.17	2.38
500	0.08	0.04	0.21	0.04	0.21	0.1	0.08	0.1	0.06	0.1	0.1	0.19	0.1	0.27	0.17	0.1	1.92
600	0.08	0.04	0.21	0.04	0.21	0.1	0.08	0.1	0.06	0.1	0.1	0.19	0.1	0.27	0.17	0.1	1.92
700	0.06	0.04	0.21	0.04	0.21	0.1	0.08	0.08	0.04	0.04	0.1	0.19	0.1	0.27	0.17	0.1	1.81
800	0.06	0.04	0.21	0.04	0.21	0.1	0.08	0.08	0.04	0.04	0.1	0.19	0.1	0.27	0.17	0.1	1.81
900	0.06	0.04	0.21	0.02	0.08	0.06	0.08	0.08	0.04	0.04	0.1	0.19	0.08	0.08	0.06	0.1	1.29
1000	0.04	0.04	0.21	0.02	0.08	0.06	0.08	0.04	0.04	0.04	0.1	0.19	0.08	0.08	0.06	0.06	1.2
1100	0.04	0.04	0.21	0.02	0.08	0.06	0.08	0.04	0.04	0.04	0.1	0.19	0.08	0.08	0.06	0.06	1.2
1200	0.04	0.04	0.21	0.02	0.08	0.06	0.08	0.04	0.04	0.04	0.1	0.19	0.08	0.08	0.06	0.06	1.2
1300	0.04	0.04	0.21	0.02	0.08	0.06	0.08	0.04	0.04	0.04	0.1	0.19	0.08	0.08	0.06	0.06	1.2
1400	0.04	0.04	0.21	0.02	0.08	0.06	0.08	0.04	0.04	0.04	0.1	0.19	0.08	0.08	0.06	0.06	1.2
1500	0.04	0.04	0.21	0.02	0.08	0.06	0.08	0.04	0.04	0.04	0.1	0.19	0.08	0.08	0.06	0.06	1.2
1600	0.04	0.04	0.21	0.02	0.08	0.06	0.08	0.04	0.04	0.04	0.1	0.19	0.08	0.08	0.06	0.06	1.2
1700	0.04	0.04	0.21	0.02	0.08	0.06	0.08	0.04	0.04	0.04	0.1	0.19	0.08	0.08	0.06	0.06	1.2
1800	0.04	0.04	0.15	0.02	0.06	0.04	0.06	0.04	0.04	0.04	0.06	0.16	0.06	0.06	0.04	0.06	0.95
1900	0.04	0.04	0.15	0.02	0.06	0.04	0.06	0.04	0.04	0.04	0.06	0.16	0.06	0.06	0.04	0.06	0.95

Table 5.3-8 (Sheet 5 of 6)
Annual Plume Length Frequency

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
2000	0.04	0.04	0.15	0.02	0.06	0.04	0.06	0.04	0.04	0.04	0.06	0.16	0.06	0.06	0.04	0.06	0.95
2100	0.04	0.04	0.11	0	0	0	0	0.04	0.04	0.04	0	0.02	0.02	0	0	0.06	0.4
2200	0.04	0.04	0	0	0	0	0	0.04	0.04	0.04	0	0	0	0	0	0.06	0.25
2300	0.04	0.04	0	0	0	0	0	0.02	0.02	0.02	0	0	0	0	0	0.04	0.18
2400	0.04	0.04	0	0	0	0	0	0.02	0.02	0.02	0	0	0	0	0	0.04	0.18
2500	0.04	0.04	0	0	0	0	0	0.02	0.02	0.02	0	0	0	0	0	0.04	0.18
2600	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0.02
2700	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0.02
2800	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0.02
2900	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0.02
3000	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0.02
3100	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0.02
3200	0	0	0	0	0	0	0	0	0.02	0	0	0	0	0	0	0	0.02
Fall																	
100	4.82	3.78	5.56	5.19	7.63	6.59	6.27	3.8	5.81	3.13	4.73	8.16	11.9	9.69	8.24	4.68	100
200	2.34	1.69	2.27	2.55	3.17	2.06	1.48	1.18	1.8	0.9	0.9	2.85	5.34	5.53	3.54	2.34	39.92
300	1.32	1.13	0.82	1.39	1.34	0.88	0.07	0.46	0.6	0.42	0.42	1.72	2.83	2.92	1.14	1.62	19.08
400	1.18	0.93	0.82	0.65	0.44	0.19	0.07	0.44	0.53	0.35	0.42	1.16	1.4	1.61	1.14	1.27	12.6
500	0.81	0.53	0.82	0.65	0.44	0.19	0.07	0.16	0.35	0.28	0.42	1.16	1.4	1.61	1.14	0.72	10.75
600	0.81	0.53	0.82	0.65	0.44	0.19	0.07	0.16	0.35	0.28	0.42	1.16	1.4	1.61	1.14	0.72	10.75
700	0.75	0.47	0.82	0.65	0.44	0.19	0.07	0.07	0.14	0.16	0.42	1.16	1.4	1.61	1.14	0.61	10.09
800	0.75	0.47	0.82	0.65	0.44	0.19	0.07	0.07	0.14	0.16	0.42	1.16	1.4	1.61	1.14	0.61	10.09
900	0.75	0.47	0.77	0.56	0.33	0.14	0.05	0.07	0.14	0.16	0.4	1.14	1.3	1.47	0.84	0.61	9.18
1000	0.56	0.4	0.77	0.56	0.33	0.14	0.05	0.02	0.14	0.16	0.4	1.14	1.3	1.47	0.84	0.49	8.76
1100	0.56	0.4	0.77	0.56	0.33	0.14	0.05	0.02	0.14	0.16	0.4	1.14	1.3	1.47	0.84	0.49	8.76
1200	0.56	0.4	0.77	0.56	0.33	0.14	0.05	0.02	0.14	0.16	0.4	1.14	1.3	1.47	0.84	0.49	8.76
1300	0.56	0.4	0.77	0.56	0.33	0.14	0.05	0.02	0.14	0.16	0.4	1.14	1.3	1.47	0.84	0.49	8.76

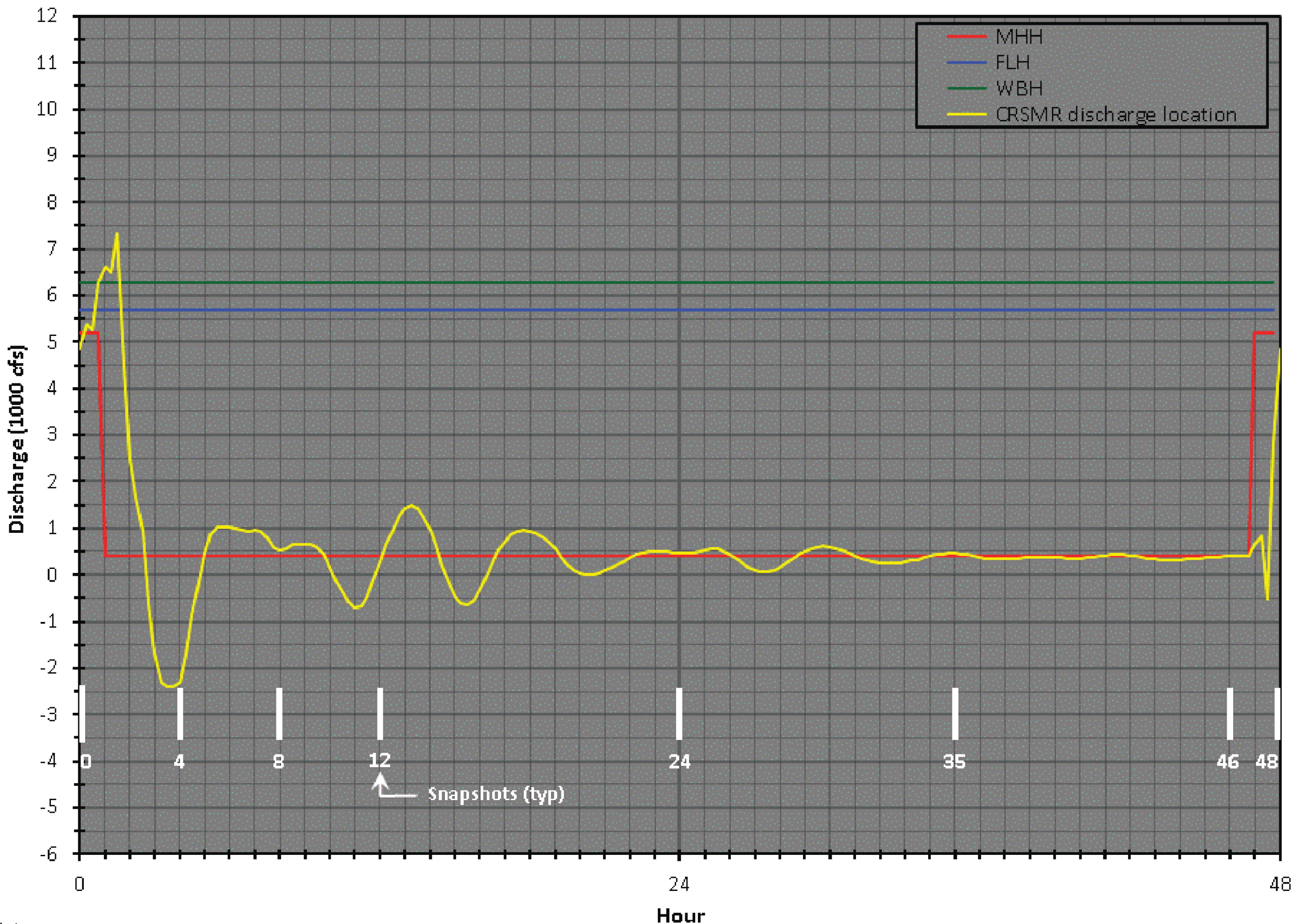
Table 5.3-8 (Sheet 6 of 6)
Annual Plume Length Frequency

Dist (m)	S	SSW	SW	WSW	W	WNW	NW	NNW	N	NNE	NE	ENE	E	ESE	SE	SSE	AVG
1400	0.56	0.4	0.77	0.56	0.33	0.14	0.05	0.02	0.14	0.16	0.4	1.14	1.3	1.47	0.84	0.49	8.76
1500	0.56	0.4	0.77	0.56	0.33	0.14	0.05	0.02	0.14	0.16	0.4	1.14	1.3	1.47	0.84	0.49	8.76
1600	0.56	0.4	0.77	0.56	0.33	0.14	0.05	0.02	0.14	0.16	0.4	1.14	1.3	1.47	0.84	0.49	8.76
1700	0.56	0.4	0.77	0.56	0.33	0.14	0.05	0.02	0.14	0.16	0.4	1.14	1.3	1.47	0.84	0.49	8.76
1800	0.56	0.4	0.42	0.28	0.19	0.05	0.02	0.02	0.14	0.16	0.26	0.93	1.04	0.9	0.35	0.49	6.2
1900	0.56	0.4	0.42	0.28	0.19	0.05	0.02	0.02	0.14	0.16	0.26	0.93	1.04	0.9	0.35	0.49	6.2
2000	0.56	0.4	0.42	0.28	0.19	0.05	0.02	0.02	0.14	0.16	0.26	0.93	1.04	0.9	0.35	0.49	6.2
2100	0.56	0.4	0.21	0.18	0.05	0.02	0	0.02	0.14	0.16	0.14	0.46	0.53	0.51	0.18	0.49	4.06
2200	0.56	0.4	0	0	0	0	0	0.02	0.14	0.16	0	0	0	0	0	0.49	1.77
2300	0.37	0.3	0	0	0	0	0	0.02	0.09	0.09	0	0	0	0	0	0.28	1.16
2400	0.37	0.3	0	0	0	0	0	0.02	0.09	0.09	0	0	0	0	0	0.28	1.16
2500	0.37	0.3	0	0	0	0	0	0.02	0.09	0.09	0	0	0	0	0	0.28	1.16
2600	0.16	0.12	0	0	0	0	0	0	0.07	0.07	0	0	0	0	0	0.12	0.53
2700	0.16	0.12	0	0	0	0	0	0	0.07	0.07	0	0	0	0	0	0.12	0.53
2800	0.16	0.12	0	0	0	0	0	0	0.07	0.07	0	0	0	0	0	0.12	0.53
2900	0.16	0.12	0	0	0	0	0	0	0.07	0.07	0	0	0	0	0	0.12	0.53
3000	0.16	0.12	0	0	0	0	0	0	0.07	0.07	0	0	0	0	0	0.12	0.53
3100	0.16	0.12	0	0	0	0	0	0	0.07	0.07	0	0	0	0	0	0.12	0.53
3200	0.16	0.12	0	0	0	0	0	0	0.07	0.07	0	0	0	0	0	0.12	0.53



Notes:
Snapshots are provided in Figure 5.3-3
MHH = Melton Hill Hyrdo plant
FLH = Fort Loudoun Hydro plant
WBH = Watts Bar Hydro plant
CR SMR = Clinch River Small Modular Reactor

Figure 5.3-1. River Flows for PPE Extreme Winter Conditions, Full Power



Note:
Snapshots are provided in Figure 5.3-4

Figure 5.3-2. River Flows for PPE Extreme Summer Conditions, Full Power

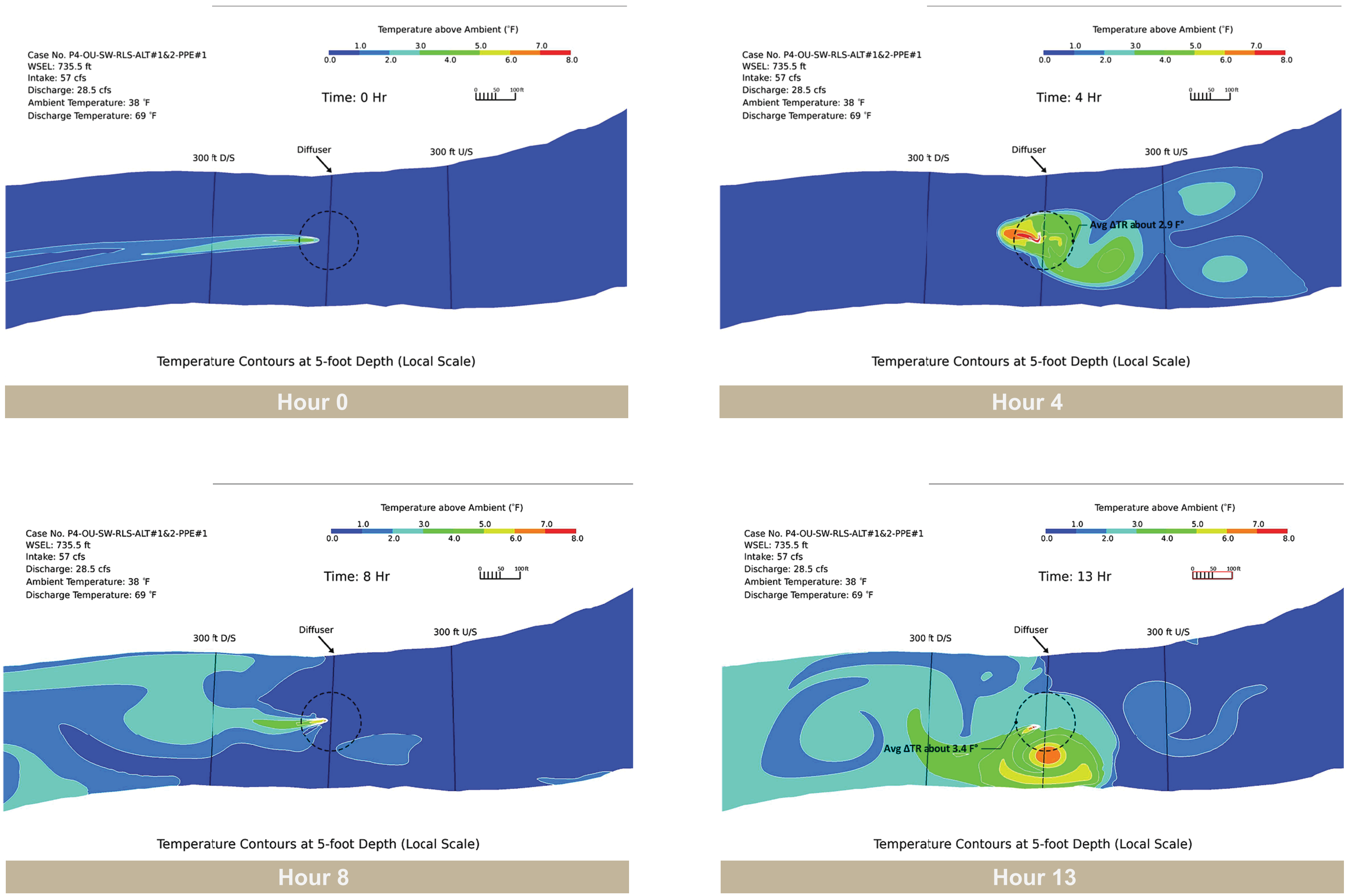


Figure 5.3-3. Temperatures at 5-Foot Depth for PPE Extreme Winter Conditions, Full Power (Sheet 1 of 2)

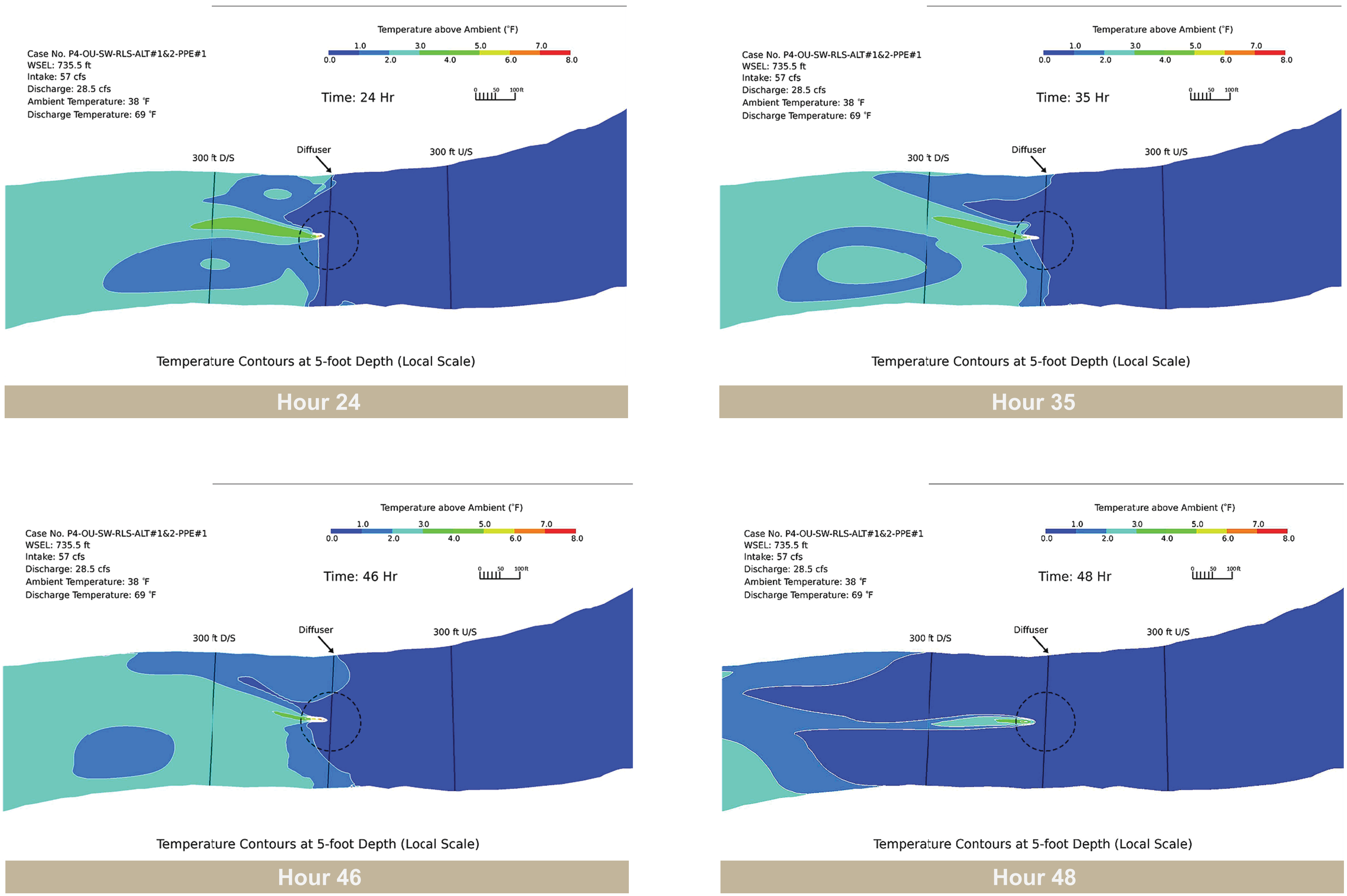


Figure 5.3-3. Temperatures at 5-Foot Depth for PPE Extreme Winter Conditions, Full Power (Sheet 2 of 2)

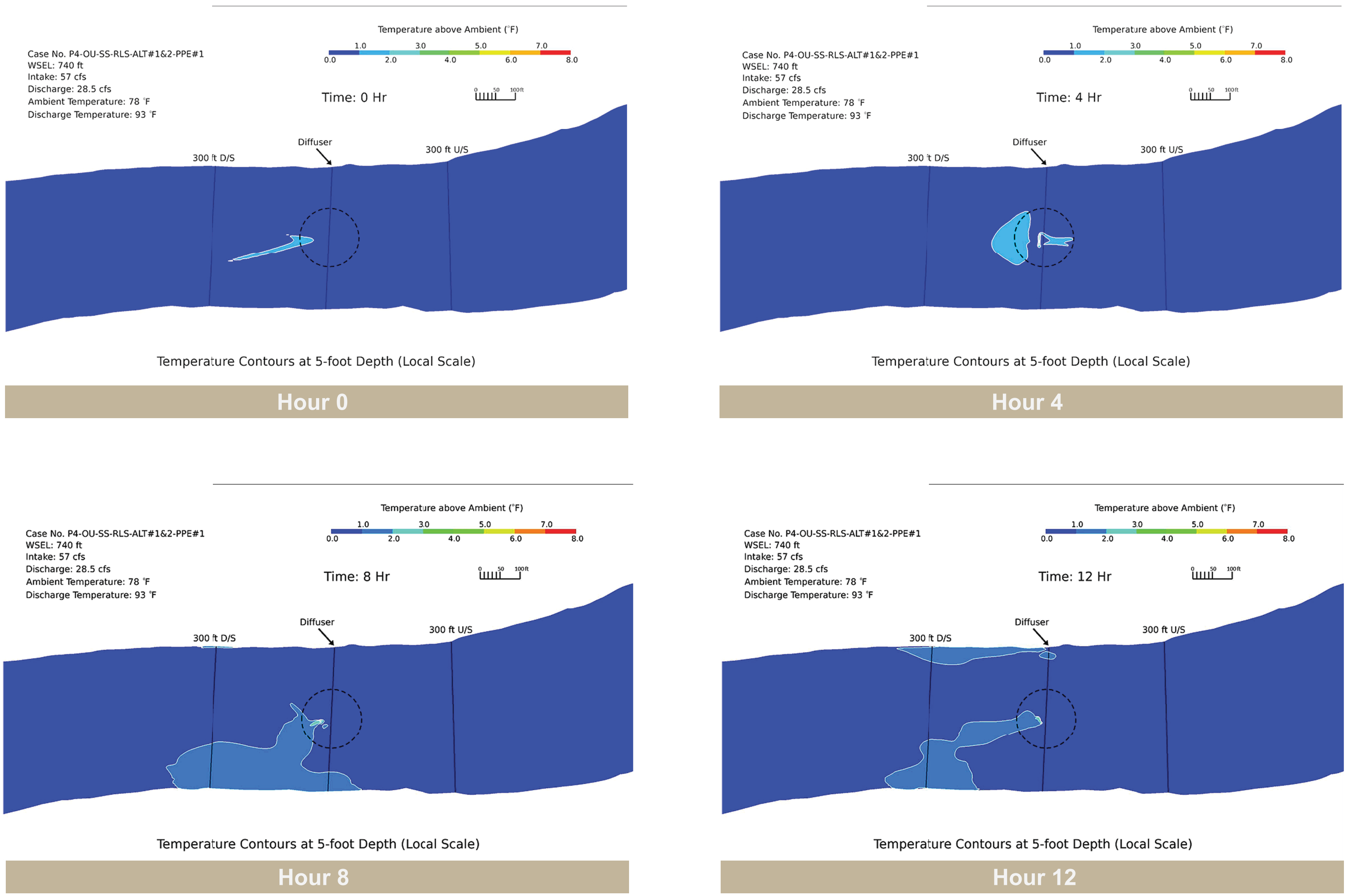


Figure 5.3-4. Temperatures at 5-Foot Depth for PPE Extreme Summer Conditions, Full Power (Sheet 1 of 2)

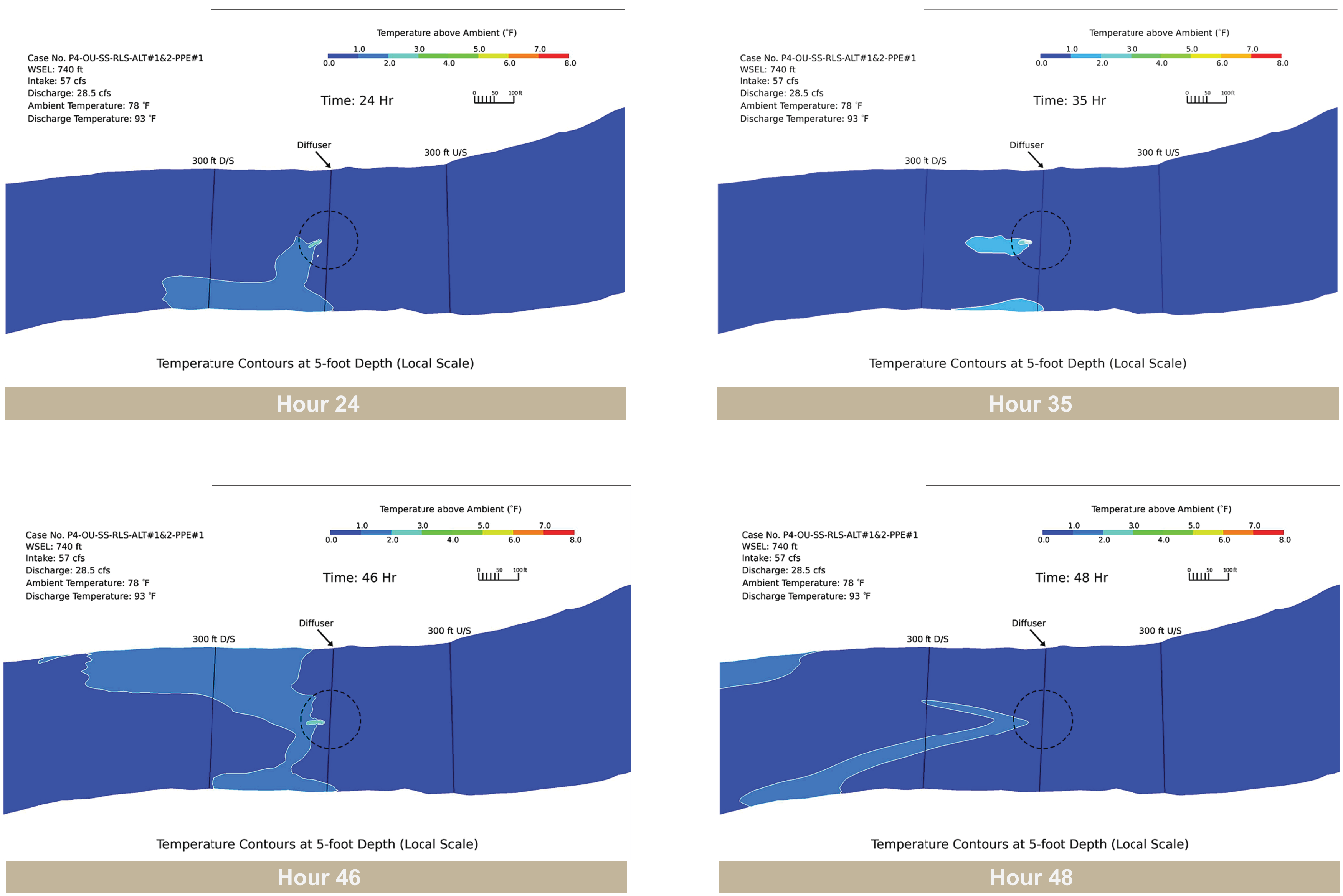


Figure 5.3-4. Temperatures at 5-Foot Depth for PPE Extreme Summer Conditions, Full Power (Sheet 2 of 2)

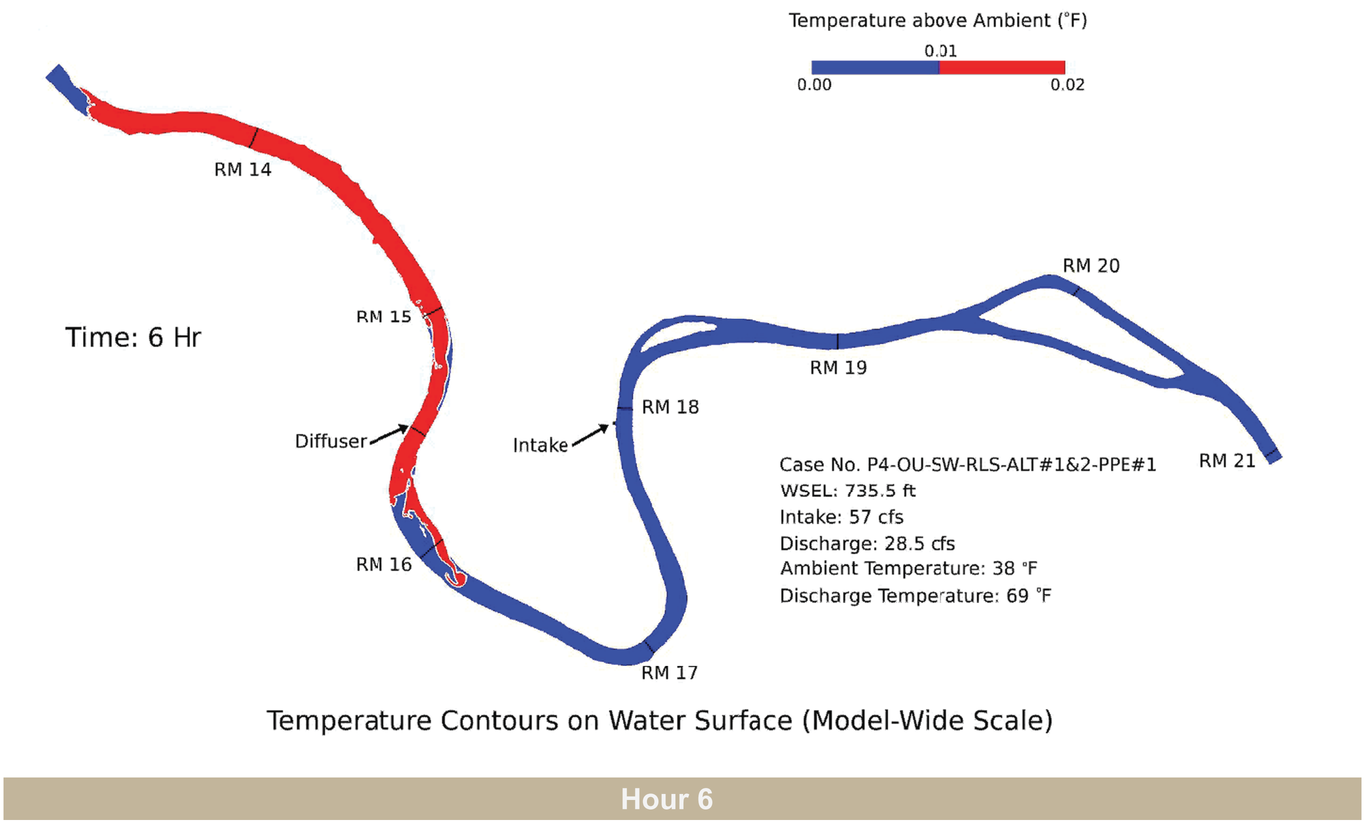


Figure 5.3-5. Approximate Zone of Influence of SMR Thermal Effluent at Water Surface for PPE Extreme Winter Conditions, Full Power

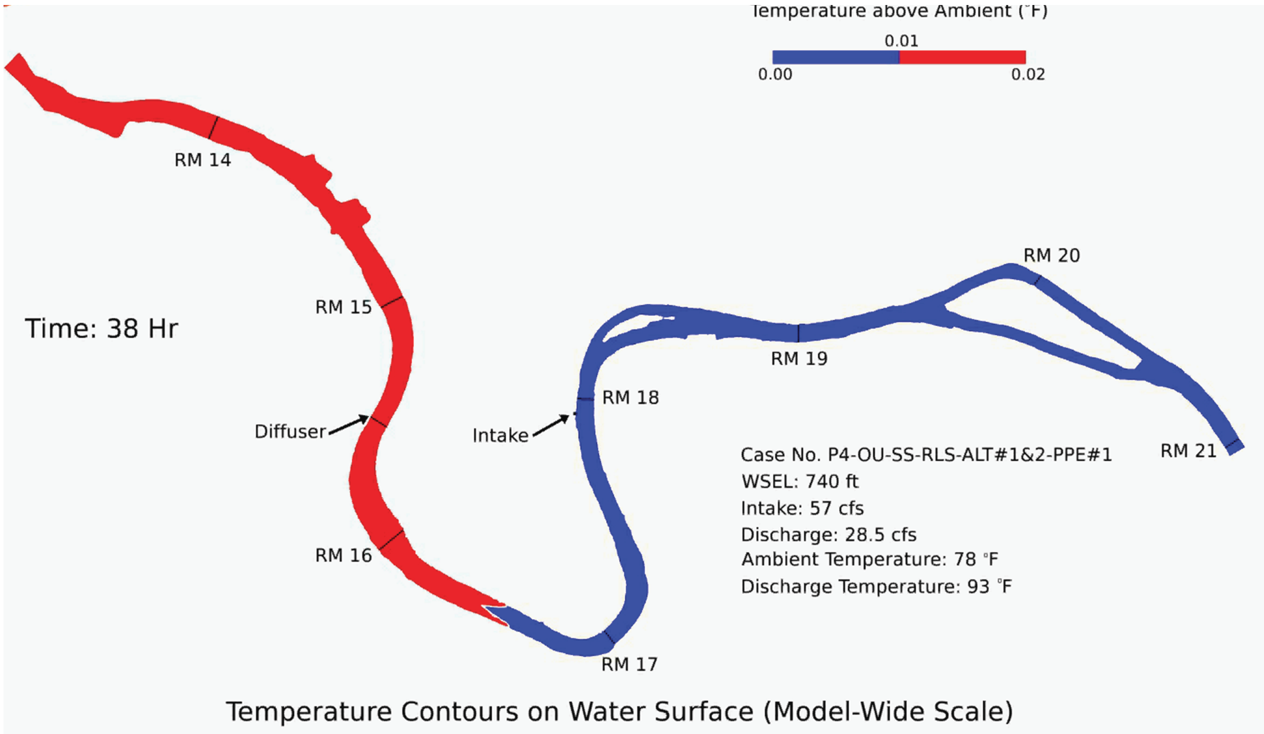


Figure 5.3-6. Approximate Zone of Influence of SMR Thermal Effluent at Water Surface for PPE Extreme Summer Conditions, Full Power

5.4 RADIOLOGICAL IMPACTS OF NORMAL OPERATION

This section describes the radiological impacts of normal operations of the Clinch River (CR) Small Modular Reactor (SMR) Project on members of the public and the biota of terrestrial and aquatic ecosystems. As discussed in Section 3.9, the SMRs would be manufactured in a factory and shipped to the Clinch River Nuclear (CRN) Site. The number of SMR units would vary depending on the SMR design selected. In most SMR designs, the reactor containment vessel is underground. Because a final SMR design has not yet been selected, a plant parameter envelope, described in Section 3.1, was developed for use in evaluating potential environmental impacts from normal operations of the CR SMR Project.

Subsection 5.4.1 describes the environmental pathways by which radiation and radiological effluents from the facility may be transmitted to living organisms in and around the CRN Site. Subsection 5.4.2 estimates individual and collective doses to members of the public from gaseous and liquid effluents from normal SMR operations, as well as from increased ambient background radiation levels from the facility. Subsection 5.4.3 evaluates the impacts of these doses by comparing them to regulatory limits. Subsection 5.4.4 evaluates the impact to non-human biota.

5.4.1 Exposure Pathways

Living organisms in the vicinity of the CR SMR Project may be exposed to radiological releases from normal facility operations. Small quantities of radioactive gases and liquids are expected to be released to the environment during normal operation of SMRs at the CRN Site. Radiological exposure due to operation of the SMRs is highly dependent on the pathways by which a receptor may become exposed to radiological releases from the facility. The major pathways of concern are those that could result in the highest offsite radiological dose. The relative importance of a pathway depends on the type and amount of radioactivity released, its environmental transport mechanism, and usage of the land surrounding the CRN Site (e.g., residence, gardens, etc.). Factors such as the relative location of homes and the local production of milk cattle and vegetable gardens are taken into consideration when evaluating pathways of radiological exposure. In addition, the environmental transport mechanisms for gaseous effluents are dependent on the meteorological characteristics of the area.

Radioactive gaseous effluent pathways include direct radiation, deposition on plants and soil, and inhalation by humans and animals. Radioactive liquid effluent pathways include consumption of fish, drinking of water from downstream sources, and direct exposure from radionuclides that may be deposited in the Clinch River arm of Watts Bar Reservoir. An additional exposure pathway is direct radiation from the SMRs during normal operation.

Radiation doses to humans from the potential release of radionuclides during operation of the SMRs have been evaluated for gaseous emissions released to the atmosphere and for liquid effluents released into the Clinch River arm of the Watts Bar Reservoir. The critical pathways to humans for routine releases at the CRN Site are radiation exposure from submersion in air, inhalation of contaminated air, drinking milk from an animal that feeds on open pasture near the CRN Site, eating vegetables and meat raised near the CRN Site, eating fish caught in the Clinch River arm of Watts Bar Reservoir, and drinking water from downstream sources. Other less significant pathways considered include: external irradiation from radionuclides deposited on the ground surface, activities on the shoreline of the Clinch River arm of the Watts Bar Reservoir, and direct radiation from the SMRs. The relative importance of the potential pathways to humans has been evaluated by calculating the doses from routine operations for each pathway. Calculation assumptions, methodology, results, and conclusions are presented in the following subsections.

The release of small amounts of radioactive effluents is permitted as long as releases comply with the requirements in Title 10 of the Code of Federal Regulations (10 CFR) Part 20 and 40 CFR Part 190. The design and operation of the SMRs at the CRN Site will also limit gaseous and liquid effluent releases such that doses to the public would be as low as reasonably achievable (ALARA) in accordance with the objectives of 10 CFR 50, Appendix I.

The exposure pathways considered and the calculation methods used to estimate doses to the maximally exposed individual (MEI) and to the population surrounding the CRN Site were based on U.S. Nuclear Regulatory Commission (NRC) Regulatory Guide (RG) 1.109, *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR 50*, Appendix I and on NRC RG 1.111, *Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors*. The MEI is defined as a member of the general public at an assumed location that results in the maximum possible calculated dose. The exposure pathway parameters are provided in Tables 5.4-1, 5.4-2, and 5.4-3 for the liquid pathways and Table 5.4-4 for the gaseous pathways. The projected population distribution in the year 2067 within 50 mile (mi) of the CRN Site is provided in Table 5.4-5. The source terms used in estimating exposure pathway doses were based on the total projected bounding site release activity levels provided in Tables 3.5-1 and 3.5-2 releases for all units and individual units, respectively. The source terms for gaseous releases are provided in Tables 3.5-3 and 3.5-4 for all units and individual units, respectively. There are no unusual animals, plants, agricultural practices, game harvests, or food processing operations within the surrounding region requiring special consideration.

5.4.1.1 Liquid Pathways

The pathways evaluated for exposure to liquid effluents from normal facility operations include ingestion of contaminated fish or invertebrates and ingestion of contaminated drinking water. Exposure to liquid effluents from normal operations also may occur through shoreline, swimming, and boating activities occurring downstream of the facility discharge location on the Clinch River arm of the Watts Bar Reservoir.

Liquid effluent discharge is assumed to be fully mixed with the flow in the Clinch River arm of the Watts Bar Reservoir. As described in Subsection 5.2.1.1.1, the overall average release from

Melton Hill Dam for 2004 through 2013, and consequently the expected approximate average river flow past the CRN Site during operations, is approximately 4670 cubic feet per second (cfs). For the purpose of this analysis, the mean flow rate over the course of a year is assumed to be 4000 cfs. The use of this flow is conservative because mixing the discharge into a smaller volume yields higher activity concentrations. In addition, transit time from liquid discharge to receptor is conservatively assumed to be zero. Thus, other than the distribution times built into the LADTAP II computer code, no decay time is applied to reduce the activity of the radioactive liquid effluent between discharge and exposure.

5.4.1.2 Gaseous Pathways

The exposure pathways evaluated for gaseous effluents from normal facility operations include external exposure to (submersion in) gases in the air, external exposure to ground contaminated by gaseous deposition, and inhalation of airborne activity. Exposure to gaseous effluents also may occur through ingestion of contaminated milk, meat, and vegetables.

5.4.1.3 Direct Radiation from SMRs

An NRC evaluation of operating nuclear plants in NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, Rev. 1, states:

> “Direct radiation from sources within a light water reactor (LWR) plant is due primarily to nitrogen-16, a radionuclide produced in the reactor core by neutron activation of oxygen-16 from the water. Because the primary coolant of an LWR is contained in a heavily shielded area, dose rates in the vicinity of LWRs are generally undetectable and less than 1 mrem/year at the site boundary.”

Thus, data from operating reactors indicate that direct radiation doses from large operating pressurized water reactors are negligible. The statement from NUREG-1437, Rev. 1 can be extrapolated to conclude that direct radiation doses from multiple SMRs with a total electric power generation not greater than 1000 megawatts electric are also expected to be less than 1 millirem per year (mrem/yr). Similarly, based on dose rate modeling results for the AP1000, a reactor much larger in size than the SMRs, direct radiation from the containment and other buildings would be negligible at the site boundary (Reference 5.4-1).

5.4.2 Radiation Dose Modeling

This subsection describes the methodology, data, and results of the evaluation of radiation doses to members of the public. LADTAP II and GASPAR II are the computer models used to evaluate doses to members of the public from liquid and gaseous effluents, respectively, released from normal operations of the SMRs at the CRN Site. The annual consumption and usage rates for the average individual and the MEI were taken from NRC RG 1.109 Tables E-4 and E-5, respectively. LADTAP II and GASPAR II use the maximum rates in calculating individual doses and the average rates in calculating population doses.

Production rates for agricultural commodities within 50 mi of the CRN Site were determined for use in the LADTAP II and GASPAR II models. Vegetable production rates within 50 mi of the CRN Site are assumed to be equal to the state production rates multiplied by the fraction of the state harvested land area that falls within the 50-mi radius. Similarly, milk and meat production rates within 50 mi of the CRN Site are assumed to be equal to the state production rates multiplied by the respective fractions of the state milk and meat animals that reside within the 50-mi radius. Food production rates are assumed to increase proportionally with population increases within 50 mi of the CRN Site. This is conservative because the guidance in NUREG-1555, Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan, requires the use of only present production rates for calculating population doses. Table 5.4-6 shows the annual production rate of foods in Tennessee, and Table 5.4-7 shows the vegetable, milk and meat production rates within 50 mi of the facility.

No dose modeling was conducted to evaluate the dose from the direct radiation pathway. As discussed in Subsection 5.4.1.3, the direct radiation doses from the SMRs are expected to be negligible. However, it was conservatively assumed that the total direct radiation dose from all SMR units on the CRN Site would be 1 mrem/yr at the site boundary.

5.4.2.1 Liquid Pathways

The LADTAP II computer program, as described in NUREG/CR-4013, LADTAP II – Technical Reference and User Guide, was used to calculate doses to the MEI and to the general population surrounding the CRN Site from normal operations of the SMRs at the CRN Site. This program implements the radiological exposure models described in NRC RG 1.109 to estimate the dose resulting from radioactive releases in liquid effluents.

LADTAP II was used to evaluate both internal and external doses to the MEI and the general population from radionuclides in liquid effluents based on the following pathways:

- Internal exposure from ingestion of aquatic foods
- Internal exposure from ingestion of drinking water
- Internal exposure from ingestion of milk and meat from livestock consuming water and pasture feed from farms irrigated by contaminated water
- Internal exposure from ingestion of vegetables and fruits from farms irrigated by contaminated water
- External exposure to shoreline sediments
- External exposure from boating and swimming

Input parameters for LADTAP II are detailed in Tables 5.4-1 through 5.4-3. Table 5.4-1 presents the fish and invertebrate consumption rates and aquatic recreation usage rates used for the average individual and the MEI. The values are taken from NRC RG 1.109 Tables E-4 and E-5, respectively.

Table 5.4-2 provides population consumption rates of aquatic food obtained from the Clinch River arm of Watts Bar Reservoir for the projected 2067 population within 50 mi of the CRN Site. These consumption rates are based on the assumption that 50 percent of the fish and invertebrate consumed by the population within 50 mi comes from the Clinch River arm of Watts Bar Reservoir. Table 5.4-2 identifies the portion of the consumption that represents aquatic food obtained by sport fishers and the portion that represents commercially caught aquatic food, and it provides details on how these values were calculated.

Table 5.4-3 identifies the primary liquid pathway parameters used in the LADTAP II program to estimate radioactive exposures due to liquid effluents from the SMRs at the CRN Site. An explanation of each of the parameters is provided in the table footnotes.

5.4.2.2 Gaseous Pathways

The GASPAR II computer program was used to calculate doses from gaseous pathways to offsite receptors from normal operations of the SMRs at the CRN Site. This program, described in NUREG/CR-4653, *GASPAR II – Technical Reference and User Guide,* implements the radiological exposure models described in NRC RG 1.109 for radioactivity releases in gaseous effluents. As discussed in Subsection 2.7.6, routine dilution and deposition estimates were calculated using the XOQDOQ-82 modeling program, which is the dispersion model for evaluating routine releases recommended by NRC in NUREG/CR-2919, *XOQDOQ: Computer Program for the Meteorological Evaluation of Routine Effluent Releases at Nuclear Power Stations*. Site-specific, validated meteorological data for June 2011 through May 2013 were used as input to the model. The site-specific dilution and deposition estimates were used by the GASPAR II computer program to calculate radiation doses.

By using projections of food production and consumption rates coupled with the projected population within a 50-mi radius of the CRN Site, GASPAR II evaluated both external and internal exposures to gaseous effluents from the operation of SMRs at the CRN Site based on the following pathways:

- External exposure to gases
- External exposure to ground contaminated by gases
- Inhalation of gases
- Ingestion of milk contaminated from the grass-to-cow-to-milk pathway
- Ingestion of contaminated vegetables and meats

Table 5.4-4 identifies the gaseous pathway parameters used in the GASPAR II computer program, including current and projected milk, meat, and vegetable production within 50 mi of the CRN Site. Annual consumption rates for the average individual and the MEI were obtained from NRC RG 1.109 Tables E-4 and E-5, respectively. Table 5.4-5 presents the projected total 2067 population within a 50-mi radius of the CRN Site as a function of direction and distance.

5.4.3 Impacts to Members of the Public

This subsection summarizes the impacts to individuals from radioactive effluents released in the course of normal operation of the SMRs at the CRN Site. Impacts to the public are evaluated by comparing estimated dose to regulatory acceptance criteria. Doses to the MEI and collective doses to the public were evaluated.

Doses to the MEI from liquid effluent from all units are shown in Table 5.4-8 (per SMR unit) and 5.4-9 (all units), and doses from gaseous effluent are shown in Tables 5.4-10 (per SMR unit) and 5.4-11 (all units). Collective doses to the population from liquid and gaseous effluents are shown in Tables 5.4-12 and 5.4-13, respectively. Gaseous effluent doses to the thyroid of the MEI from iodines and particulates are shown in Table 5.4-14.

Table 5.4-15 summarizes the estimated doses to the MEI per operating unit of the CR SMR Project and compares them to the ALARA design objectives from 10 CFR Part 50, Appendix I to determine compliance with dose rates protective of the general public. All of the doses are less than or equal to the corresponding regulatory dose limits in 10 CFR Part 50, Appendix I; thus, the criteria are met.

Annual doses to the MEI from the SMRs at the CRN Site are summarized in Table 5.4-16. The sum of the direct radiation dose, liquid effluent dose, and gaseous effluent dose yields an annual total body dose of 11.0 mrem/yr. (As discussed in Subsections 5.4.1.3 and 5.4.2, the direct radiation dose would be negligible but is assumed to be 1 mrem/yr.) Similarly, the sum of direct, liquid, and gaseous contributions for the thyroid and the bone pathways yields a total dose of 25 mrem/yr and 24 mrem/yr respectively. The U.S. Environmental Protection Agency (EPA) radiation protection standards in 40 CFR Part 190 provide criteria that apply to the annual dose equivalent received by members of the general public exposed to planned discharges of radioactive materials from the operation of nuclear power plants. The most restrictive portion of the standards specified in this regulation states that the annual dose equivalent shall not exceed 25 mrem/yr to the whole body. The regulation also provides standards limiting the annual dose equivalent to the thyroid (75 mrem/yr) and any other organ (25 mrem/yr). As shown in Table 5.4-16, the total body annual dose, estimated to be 11.0 mrem/yr, is below the limit of 25 mrem/yr. Similarly, total doses to the thyroid and bone also are below their respective limits. This annual dose was compared to EPA's environmental radiation protection standards for individual members of the public from 40 CFR 190.10 to determine compliance. All of the doses are less than the corresponding regulatory dose limits; thus the criteria are met. As indicated in NUREG-1555, demonstration of compliance with the limits of 40 CFR 190 is considered to also indicate compliance with the 100 mrem limit in 10 CFR 20.1301.

Annual collective doses to the public based on the population within 50 mi of the CRN Site also were estimated based on the operation of all SMR units. Table 5.4-17 shows the total body and thyroid doses from all liquid and gaseous pathways expressed in units of person-rems per year (person-rem/yr). For comparison, Table 5.4-17 also includes the annual collective background radiation dose calculated from the estimated population within 50 mi of the CRN Site in 2067 and the average natural background dose in the United States of approximately 311 mrem/yr. The total of the doses to the population for the total body (68 person-rem/yr) and thyroid (100 person-rem/yr) are negligible compared to the background dose of 820,000 person-rem/yr.

Because the doses to members of the public from operation of the SMRs at the CRN Site are calculated to be within the regulatory limits for protection of the MEI and the contribution to the collective population dose is estimated to be negligible compared to background, the radiological impacts to members of the public from normal operation of the CR SMR Project would be SMALL.

5.4.4 Impacts to Biota Other than Members of the Public

This subsection examines radiation exposure pathways to biota other than members of the public to determine if these pathways could result in doses to biota greater than the doses predicted for humans. This assessment uses surrogate biota species that provide representative information on the various dose pathways potentially affecting broader classes of living organisms, including the important terrestrial and aquatic species identified in Section 2.4. Surrogates are used because important attributes are well defined and are accepted as a method for judging doses to biota. As described in NUREG/CR-4013 the use of surrogate biota in this analysis includes the use of algae as a surrogate for aquatic plants and the use of invertebrates as a surrogate for freshwater mollusks and crayfish. Other surrogates used in this analysis include fish, muskrat, raccoon, heron, and duck. There are no unusual plants, animals, or pathways in the vicinity of the CRN Site that would require specific evaluation.

Doses to surrogate biota from liquid effluents were calculated using the LADTAP II program and the parameters included in the computer program. As described in NUREG-CR/4013, pathways evaluated for aquatic biota include internal exposure from bioaccumulation and external exposure from swimming and the shoreline. Exposure pathways for terrestrial biota include ingestion of aquatic biota and external exposure from swimming and the shoreline. Liquid effluent doses to biota from the operation of SMRs at the CRN Site are shown in Table 5.4-18. Doses range from 1.3 millirad per year (mrad/yr) for the raccoon to 8.9 mrad/yr for the heron.

Because the GASPAR II program does not perform biota dose calculations, the human doses calculated for the gaseous pathway were assumed to be applicable to biota. Because biota are closer to the ground than are humans, the ground deposition doses calculated by the GASPAR II computer program were doubled. This is consistent with the approach used for biota in LADTAP II. The nearest terrestrial biota were assumed to be exposed to gaseous effluents at a distance of 0.25 mi from the SMR release point. It was also assumed that the internal dose and the external plume dose received by the biota are the same as the doses received by humans.

This is reasonable because the plume dose is independent of the size of the receptor, and it is conservative because the internal dose for humans is based on a much longer retention period than would be expected for biota. As shown in Table 5.4-19, the highest of the total body doses for the child, teen, and adult was identified as the biota dose for the inhalation, vegetable consumption, plume immersion, and ground deposition pathways. The total biota dose from all four pathways is 84 millirads per year (mrad/yr).

The total doses to surrogate biota from liquid and gaseous effluents released from normal operations of the SMRs at the CRN Site are shown in Table 5.4-20. The total dose to each of the biota was calculated by summing the annual doses from gaseous and liquid pathways in mrad/yr. The total doses also were converted to units of mrad/day for comparison to criteria for the protection of biota.

Use of exposure guidelines, such as 40 CFR Part 190, which apply to members of the public in unrestricted areas, is considered very conservative when evaluating calculated doses to biota. As noted in NUREG-1555, Subsection 5.4.4, the International Council on Radiation Protection states "… if man is adequately protected then other living things are also likely to be sufficiently protected" and uses human protection to infer environmental protection from the effects of ionizing radiation.

As stated in NUREG-1555, "species in most ecosystems experience rather high mortality rates from natural causes." From an ecological viewpoint, population stability is considered more important to the survival of a species than individual mortality. In addition, no biota have been discovered that show significant changes in morbidity or mortality due to radiation exposures predicted for nuclear power plants.

The National Academy of Sciences-National Research Council's Committee on the Biological Effects of Ionizing Radiation concludes that the evidence indicates that no other living organisms have been identified that are likely to be significantly more radiosensitive than members of the public (Reference 5.4-2). The Department of Energy (DOE) Order 458.1, Radiation Protection of the Public and the Environment, identifies dose rate criteria to protect aquatic and terrestrial biota from adverse effects due to radiation released from DOE operations (Reference 5.4-3). These criteria, provided in DOE Standard 1153-2002, are 1 rad/day for aquatic animals and 0.1 rad/day for terrestrial animals. Existing effects data support the application of these dose limits to representative individuals within the population of animals (Reference 5.4-4). As shown in Table 5.4-20, total doses to the surrogate aquatic animals are 0.0045 mrad/day for fish and 0.021 mrad/day for invertebrates. For surrogate terrestrial biota, total body doses range from 0.23 mrad/day for the raccoon to 0.25 mrad/day for the heron. The highest of these doses (0.021 mrad/day for aquatic biota and 0.25 mrad/day for terrestrial biota) are significantly less than their respective dose rate criteria (1 rad/day and 0.1 rad/day). The permissible dose rates given in 40 CFR Part 190 are considered screening levels and higher species-specific dose rates could be acceptable with additional study or data. Because the doses to surrogate biota presented in Table 5.4-20 are significantly below the dose rate criteria specified by DOE, the impact to biota other than members of the public due to operation of the CR SMR Project would be SMALL.

5.4.5 Occupational Doses

The annual occupational dose to operational workers, including outage activities, is dependent on the specific plant design chosen, and is determined in accordance with applicable criteria in 10 CFR 20 and 10 CFR 50 Appendix I. The occupational dose is provided at COLA once the design has been selected.

5.4.6 References

Reference 5.4-1. U.S. Nuclear Regulatory Commission, Westinghouse AP1000 Design Control Document Rev. 19 (Chapter 12), Website: http://pbadupws.nrc.gov/docs/ML1117/ML11171A500.html, June 21, 2011.

Reference 5.4-2. National Research Council, "The Effects on Populations of Exposure to Low Levels of Ionizing Radiation. Report of the Advisory Committee on the Biological Effects of Ionizing Radiation," INIS-XA-N--248, Washington, DC, November, 1972.

Reference 5.4-3. U.S. Department of Energy, "Radiation Protection of the Public and the Environment," DOE O 458.1, February 11, 2011.

Reference 5.4-4. U.S. Department of Energy, "DOE Standard: A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota," DOE-STD-1153-2002, Washington, DC, 2002.

Table 5.4-1
Liquid Pathway Parameters – Aquatic Food and Activities

Parameter	MEI			Average			
	Child	Teen	Adult	Child	Teen	Adult	Average Rate
Fish consumption[1] (kg/yr)	6.9	16	21	2.2	5.2	6.9	5.9[2]
Invertebrate consumption[1] (kg/yr)	1.7	3.8	5	0.33	0.75	1.0	0.85[2]
Shoreline recreation[3] (hr/yr)	14	67	12	9.5	47	8.3	12.8[4]
Swimming recreation[3] (hr/yr)	14	67	12	9.5	47	8.3	12.8[4]
Boating recreation[3] (hr/yr)	14	67	12	9.5	47	8.3	12.8[4]
Population distribution[5]	NA	NA	NA	0.18	0.11	0.71	NA

1 MEI rates from NRC RG 1.109 Table E-5. Average individual rates from NRC RG 1.109 Table E-4.
2 Average rate of fish and invertebrate consumption calculated by weighting age-specific consumption by population distribution and summing across the age groups.
3 Water recreation from NRC RG 1.109 Tables E-4 and E-5 as listed for shoreline activities. Time spent swimming and boating is assumed for each to be identical to time spent on shoreline activities.
4 Average rate of recreational shoreline, swimming, and boating activities calculated by weighting age-specific recreational rates by population distribution and summing across the age groups.
5 NRC RG 1.109 Page 1.109-33.

Notes:
hr/yr = hours per year
kg/yr = kilograms per year
MEI = maximum exposed individual
NA = not applicable

Table 5.4-2
Aquatic Food Consumption from Clinch River arm of Watts Bar Reservoir for 2067 Population within 50 Miles (kg/yr)

Parameter	Fish	Invertebrate
Average person[1]	5.9[1]	0.85[1]
50-mi population - total[2]	7,800,000	1,130,000
50-mi population - sport[3]	1,870,000	271,000
50-mi population - commercial[4]	5,930,000	861,000

1 Aquatic food consumption for the average person from NRC RG 1.109 Table E-4. Average rate of fish and invertebrate consumption calculated by weighting age-specific consumption by population distribution and summing across the age groups.
2 Total consumption of fish by the 2067 population within 50 mi of the CRN Site. As source of 50% of fish and invertebrate consumed by the population within 50 mi of the site is Clinch River arm of the Watts Bar Reservoir, the total population consumption is determined by multiplying the average person rate (5.9 and 0.85) by the 2067 50-mi population and by 50%.
3 Population consumption of food obtained by sport is determined by multiplying the total consumption by the percentage of the population that eats sport food, estimated at 24 percent.
4 Commercial population consumption is the remaining consumption rate (total minus sport population value).

Notes:
kg/yr = kilograms per year

Table 5.4-3
Liquid Pathway Parameters

Parameter	Value
Release source terms	Tables 3.5-1 and 3.5-2
Discharge rate (Clinch River flow)[1]	4000 cfs[1]
Dilution factor for discharge	1[1]
Transit time to receptor	0[2]
Impoundment reconcentration model	None[3]
50-mi population in 2010	1,723,327[4]
50-mi population in 2067[5]	2,658,157[4]
50-mi shoreline usage	34,000,000 person-hours/yr[6]
50-mi swimming usage	34,000,000 person-hours/yr[6]
50-mi boating usage	34,000,000 person-hours/yr[6]
Fish and invertebrate consumption	Table 5.4-2
Drinking water consumption	730 liters per year[7]
Current – 50-mi drinking water population	162,000[8]
2067 – 50-mi drinking water population	249,000[8]
2067 – milk production using Clinch River as Irrigation	30,800 kilograms per year[9]
2067 – meat production using Clinch River as Irrigation	26,200 kilograms per year[9]
2067 – produce production using Clinch River as Irrigation	113,000 kilograms per year[9]

1 Liquid discharge from the surrogate plant is assumed to be fully mixed with Clinch River arm of Watts Bar Reservoir. A conservative mean flow rate of 4000 cfs is assumed. It is conservative because it is lower than the flow data collected over 47 years for the Clinch River arm of Watts Bar Reservoir near Oak Ridge and at Melton Hill Dam.

2 Transit time to the liquid effluent receptor is conservatively assumed to be zero; no decay is assumed other than the distribution times built into LADTAP II.

3 Liquid effluent is released directly into Clinch River Arm of the Watts Bar Reservoir. Effluent is assumed to be immediately, completely mixed.

4 The total population within 50 mi of the CRN Site is projected to increase from the current 1,723,327 to 2,658,157 in 2067. This is a projected increase of 54 percent.

5 Permanent population is projected to 40 years beyond the projected 2027 commencement of operation date for the last unit.

6 Time spent by the average individual on shoreline activities taken from NRC RG 1.109 Table E-4. The time spent boating and swimming each is assumed identical to that spent on shoreline activities. Person-hours per year was determined by multiplying the average rate of 12.8 hours per year (hr/yr) by the projected 2067 population of 2,658,157.

7 Adult maximum exposed individual annual drinking water consumption from NRC RG 1.109 Table E-5.

8 Current and 2067 drinking water populations determined by multiplying the 50-mi population by the percentage of persons served by Clinch River arm of Watts Bar Reservoir (9.4 percent).

9 Irrigated food production within 50 mi determined by multiplying the projected 2067 food production within 50 mi by the percentage of irrigated state land within 50 mi (2.41 percent) and by the percentage of irrigation occurring with water from the Clinch River arm of Watts Bar Reservoir within 50 mi (0.67 percent).

Table 5.4-4
Gaseous Pathway Parameters – GASPAR II Information

Parameter	Value
Release source terms	Tables 3.5-3 and 3.5-4
Population distribution - current	Tables 2.5.1-2 and 2.5.1-4
Population distribution – projected 2067	Table 5.4-5
Dispersion and deposition factors	Section 2.7
Meteorology	Section 2.7
Maximum dispersion direction	WNW
Current - 50-mi milk production[1] (kg/yr)	124,000,000
Current - 50-mi meat production[1] (kg/yr)	106,000,000
Current - 50-mi vegetable/fruit production[1] (kg/yr)	454,000,000
Projected 2067 - 50-mi milk production[2,3] (kg/yr)	191,000,000
Projected 2067 - 50-mi meat production[2,3] (kg/yr)	163,000,000
Projected 2067 - 50-mi vegetable/fruit production[2,3] (kg/yr)	700,000,000

1 Current production: Production in Tennessee multiplied by percent of Tennessee food produced within 50 mi.
2 Permanent population is projected to 40 years beyond the projected 2027 commencement of operation date for the last unit.
3 Projected 2067 production: Current production within 50 mi multiplied by the population ratio of 1.54 (ratio of 2067 population/current population).

Notes:
kg/yr = kilograms per year
WNW = west northwest

Table 5.4-5
Total Population Distribution Within 50 Miles of the CRN Site in 2067[1,2]

Direction	0-1	1-2	2-3	3-4	4-5	5-10	10-20	20-30	30-40	40-50
N	0	0	0	0	110	2850	2594	570	5499	12,272
NNE	0	0	0	0	0	8678	10,509	12,234	35,396	11,082
NE	5	0	0	0	0	1555	51,540	30,575	25,463	12,290
ENE	8	9	1	0	0	1670	104,860	711,355	81,037	31,999
E	8	14	130	57	116	9101	130,456	207,087	67,225	108,807
ESE	6	39	112	203	475	12,098	26,220	229,719	32,360	14,583
SE	8	42	85	307	357	22,492	11,132	21,153	4038	10,641
SSE	7	59	67	234	396	3916	35,921	17,961	2693	707
S	13	29	38	150	213	2446	14,716	24,197	19,100	10,242
SSW	14	31	41	150	147	1242	5357	26,006	49,143	21,631
SW	13	51	69	132	265	965	3895	5502	12,679	44,254
WSW	16	68	172	151	373	7989	4829	7185	7015	9876
W	18	107	161	183	742	18,819	15,343	5587	52,483	12,930
WNW	21	89	248	87	220	5303	6069	8407	11,606	13,108
NW	20	25	50	14	84	1771	7498	4907	3914	24,543
NNW	0	1	0	0	156	2077	8465	840	11,546	35,117
Total	157	564	1174	1668	3654	102,972	439,404	1,313,285	421,197	374,082
								Grand Total	2,658,157	

1 Projected total 2067 population distribution; sum of transient and permanent projected populations.
2 Permanent population is projected to 40 years beyond the projected 2027 commencement of operation date for the last unit.

Notes:
E = East
N = North
S = South
W = West

Table 5.4-6
Food Production in Tennessee

Food	State Production	Max Year
Red Meat	6.76E+08 lbm	2012
Broilers	1.02E+09 lbm	2008
Milk	9.48E-08 lbm	2008
Tomatoes	8.50E+05 cwt	2012
Snap Beans	1.95E+05 cwt	2012
Soybeans	4.67E+07 bu	2012
Corn	1.28E+08 bu	2012
Wheat	2.14E+07 bu	2012
Apples	6.40E+06 lbm	2012

Table 5.4-7
Vegetable, Milk, and Meat Production within 50 Miles in 2067

Food	Production in TN (kg/yr)[1]	Percent of TN Food Produced within 50 mi		Production within 50 mi (Kg/yr)		
				Present	2067	Irrig 2067[2]
Milk	4.30E+08	Milk Cows	28.81%	1.24E+08	1.91E+08	3.08E+04
Red Meat	3.06E+08	Beef Cows	12.75%	3.91E+07	-	-
Broilers	4.62E+08	Broilers	41.39%	6.65E+07	-	-
Meat Total	-	-	-	1.06E+08	1.63E+08	2.62E+04
Vegetables/Fruit[3]	5.17E+09	Harvested Land	8.79%	4.54E+08	7.00E+08	1.13E+05

1 Production in TN –State values are from Table 5.4-1.
2 Production within 50 mi (Irrig 2067) – the percentage of state irrigation occurring within 50 mi and by 0.67%, the percentage of irrigation occurring with water from the Clinch River.
3 Vegetable production rates are for non-leafy vegetables only. Although there is no significant production of leafy vegetables, the same production rates are conservatively assumed to be applicable to leafy vegetables.

Table 5.4-8
Liquid Effluent Doses per Unit Units to MEI (mrem/yr)

Pathway	Total Body	GI-LLI	Liver	Kidney	Lung	Skin	Thyroid	Bone
Fish	8.5E-03	1.3E-02	1.1E-02	7.0E-03	1.1E-03	0	3.0E-03	2.2E-02
Invertebrate	2.6E-03	4.6E-02	5.4E-03	1.5E-02	1.8E-04	0	1.9E-03	6.5E-03
Drinking	2.9E-03	4.3E-03	4.2E-03	4.6E-03	3.7E-03	0	1.8E-02	2.0E-03
Shoreline activities	1.2E-05	1.2E-05	1.4E-05	1.4E-05	1.4E-05	7.9E-05	1.4E-05	1.4E-05
Swimming	1.4E-06	1.4E-06	1.7E-06	1.7E-06	1.7E-06	0	1.7E-06	1.7E-06
Boating	7.2E-07	7.2E-07	8.4E-07	8.4E-07	8.4E-07	0	8.4E-07	8.4E-07
Irrigated Vegetables	3.4E-03	7.2E-03	8.5E-03	8.3E-03	4.5E-03	0	1.8E-02	1.9E-02
Irrigated Milk	2.0E-03	2.1E-03	6.0E-03	4.0E-03	2.8E-03	0	2.3E-02	9.1E-03
Irrigated Meat	6.5E-04	2.5E-04	6.8E-04	2.9E-03	3.4E-04	0	7.6E-04	2.0E-03
Total Dose	2.0E-02	9.7E-02	3.5E-02	4.2E-02	1.3E-02	7.9E-05	6.4E-02	6.0E-02
Age group[1]	Adult	Adult	Child	Child	Child	Teen	Child	Child

[1] The age group receiving the maximum dose for each organ shown.

Notes:
GI-LLI = Gastrointestinal – Lower Large Intestine
mrem/yr = millirems per year
MEI = maximum exposed individual

Table 5.4-9
Liquid Effluent Doses from All Units to MEI (mrem/yr)

Pathway	Total Body	GI-LLI	Liver	Kidney	Lung	Skin	Thyroid	Bone
Fish	9.2E-02	4.5E-02	1.1E-01	3.2E-02	1.2E-02	0	3.2E-02	1.6E-01
Invertebrate	2.3E-02	2.3E-01	5.2E-02	7.7E-03	2.0E-03	0	7.7E-03	3.4E-02
Drinking	1.3E-02	1.7E-02	2.1E-02	1.8E-01	1.5E-02	0	1.8E-01	1.9E-02
Shoreline activities	1.1E-04	1.1E-04	1.3E-04	1.3E-04	1.3E-04	7.0E-04	1.3E-04	1.3E-04
Swimming	8.8E-06	8.8E-06	1.0E-05	1.0E-05	1.0E-05	0	1.0E-05	1.0E-05
Boating	4.4E-06	4.4E-06	5.1E-06	5.1E-06	5.1E-06	0	5.1E-06	5.1E-06
Irrigated Vegetables	2.2E-02	3.2E-02	6.8E-02	1.8E-01	2.2E-02	0	1.8E-01	2.1E-01
Irrigated Milk	1.4E-03	1.5E-02	5.1E-02	2.5E-01	1.4E-02	0	2.5E-03	1.1E-02
Irrigated Meat	3.5E-02	9.9E-02	4.2E-02	5.0E-03	1.7E-03	0	5.0E-01	1.4E-01
Total Dose	1.7E-01	4.4E-01	3.1E-01	6.6E-01	6.8E-02	7.0E-04	6.6E-01	5.4E-01
Age group[1]	Adult	Adult	Child	Child	Child	Teen	Child	Child

[1] The age group receiving the maximum dose for each organ shown.

Notes:
GI-LLI = Gastrointestinal – Lower Large Intestine
mrem/yr = millirems per year
MEI = maximum exposed individual

Table 5.4-10 (Sheet 1 of 2)
Gaseous Effluent Doses per Unit to MEI

Location	Pathway		Dose per Unit (mrem/yr)							
			Total Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
Site Boundary (0.21 mi WNW)	External	Plume	6.2E+00	6.2E+00	6.2E+00	6.2E+00	6.2E+00	6.2E+00	6.3E+00	1.4E+01
		Ground	8.5E-01	8.5E-01	8.5E-01	8.5E-01	8.5E-01	8.5E-01	8.5E-01	1.0E+00
		Total	7.1E+00	7.1E+00	7.1E+00	7.1E+00	7.1E+00	7.1E+00	7.2E+00	1.5E+01
	Inhalation	Adult	1.5E+00	1.5E+00	2.9E-01	1.5E+00	1.5E+00	1.2E+01	2.0E+00	0
		Teen	1.5E+00	1.5E+00	3.5E-01	1.6E+00	1.6E+00	1.5E+01	2.4E+00	0
		Child	1.3E+00	1.3E+00	4.3E-01	1.4E+00	1.4E+00	1.8E+01	2.1E+00	0
		Infant	7.6E-01	7.5E-01	2.1E-01	8.5E-01	8.3E-01	1.6E+01	1.3E+00	0
	All	Adult	8.5E+00	8.6E+00	7.3E+00	8.6E+00	8.6E+00	1.9E+01	9.2E+00	1.5E+01
		Teen	8.5E+00	8.6E+00	7.4E+00	8.6E+00	8.7E+00	2.2E+01	9.5E+00	1.5E+01
		Child	8.4E+00	8.4E+00	7.5E+00	8.5E+00	8.5E+00	2.5E+01	9.2E+00	1.5E+01
		Infant	7.8E+00	7.8E+00	7.3E+00	7.9E+00	7.9E+00	2.3E+01	8.5E+00	1.5E+01
Residence (0.66 mi WNW)	External	Plume	7.8E-01	7.8E-01	7.8E-01	7.8E-01	7.8E-01	7.8E-01	7.9E-01	1.8E+00
		Ground	1.3E-01	1.3E-01	1.3E-01	1.3E-01	1.3E-01	1.3E-01	1.3E-01	1.5E-01
		Total	9.0E-01	9.0E-01	9.0E-01	9.0E-01	9.0E-01	9.0E-01	9.2E-01	1.9E+00
	Inhalation	Adult	1.8E-01	1.9E-01	3.5E-02	1.9E-01	1.9E-01	1.5E+00	2.5E-01	0
		Teen	1.9E-01	1.9E-01	4.2E-02	2.0E-01	2.0E-01	1.8E+00	2.9E-01	0
		Child	1.6E-01	1.6E-01	5.2E-02	1.8E-01	1.8E-01	2.2E+00	2.5E-01	0
		Infant	9.5E-02	9.4E-02	2.6E-02	1.1E-01	1.0E-01	1.9E+00	1.6E-01	0
Vegetable Garden (1.15 mi WNW)	Veg	Adult	5.7E-01	5.7E-01	2.3E+00	5.8E-01	5.6E-01	1.5E+00	5.5E-01	0
		Teen	8.5E-01	8.5E-01	3.7E+00	8.7E-01	8.5E-01	2.1E+00	8.3E-01	0
		Child	1.9E+00	1.9E+00	8.9E+00	1.9E+00	1.9E+00	4.2E+00	1.9E+00	0
Meat Animal (0.70 mi WNW)	Meat	Adult	4.4E-01	4.6E-01	2.0E+00	4.4E-01	4.4E-01	5.1E-01	4.4E-01	0
		Teen	3.6E-01	3.7E-01	1.6E+00	3.6E-01	3.6E-01	4.1E-01	3.6E-01	0
		Child	6.5E-01	6.6E-01	3.1E+00	6.6E-01	6.5E-01	7.3E-01	6.5E-01	0

Table 5.4-10 (Sheet 2 of 2)
Gaseous Effluent Doses per Unit to MEI

Location	Pathway		Dose per Unit (mrem/yr)							
			Total Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
MEI	All	Adult	2.1E+00	2.1E+00	5.2E+00	2.1E+00	2.1E+00	4.4E+00	2.2E+00	1.9E+00
		Teen	2.3E+00	2.3E+00	6.3E+00	2.3E+00	2.3E+00	5.2E+00	2.4E+00	1.9E+00
		Child	3.6E+00	3.6E+00	1.3E+01	3.7E+00	3.6E+00	8.0E+00	3.7E+00	1.9E+00
		Infant	1.0E+00	1.0E+00	9.3E-01	1.0E+00	1.0E+00	2.8E+00	1.1E+00	1.9E+00
		Max	3.6E+00	3.6E+00	1.3E+01	3.7E+00	3.6E+00	8.0E+00	3.7E+00	1.9E+00
		Group	Child	Child	Child	Child	Child	Child	Child	All

Note: In the first four rows for the MEI, MEI doses are obtained by conservatively summing the residence total external dose with the residence inhalation, vegetable, and meat maximum doses even though they are not all at the same location.

Table 5.4-11 (Sheet 1 of 2)
Gaseous Effluent Doses from All Units to MEI

Location	Pathway		Dose for All Units (mrem/yr)							
			Total Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
Site Boundary (0.21 mi WNW)	External	Plume	4.0E+01	4.0E+01	4.0E+01	4.0E+01	4.0E+01	4.0E+01	4.1E+01	8.4E+01
		Ground	2.9E+00	2.9E+00	2.9E+00	2.9E+00	2.9E+00	2.9E+00	2.9E+00	3.3E+00
		Total	4.3E+01	4.3E+01	4.3E+01	4.3E+01	4.3E+01	4.3E+01	4.3E+01	8.8E+01
	Inhalation	Adult	4.8E+00	5.0E+00	9.4E-01	5.0E+00	5.1E+00	4.1E+01	6.6E+00	0
		Teen	4.9E+00	5.0E+00	1.2E+00	5.2E+00	5.3E+00	5.2E+01	7.7E+00	0
		Child	4.3E+00	4.3E+00	1.4E+00	4.7E+00	4.7E+00	6.2E+01	6.7E+00	0
		Infant	2.5E+00	2.5E+00	7.3E-01	2.8E+00	2.8E+00	5.5E+01	4.2E+00	0
	All	Adult	4.8E+01	4.8E+01	4.4E+01	4.8E+01	4.8E+01	8.4E+01	5.0E+01	8.8E+01
		Teen	4.8E+01	4.8E+01	4.4E+01	4.8E+01	4.8E+01	9.5E+01	5.1E+01	8.8E+01
		Child	4.7E+01	4.7E+01	4.4E+01	4.8E+01	4.8E+01	1.0E+02	5.0E+01	8.8E+01
		Infant	4.5E+01	4.5E+01	4.4E+01	4.6E+01	4.6E+01	9.8E+01	4.8E+01	8.8E+01
Residence (0.66 mi WNW)	External	Plume	5.0E+00	5.0E+00	5.0E+00	5.0E+00	5.0E+00	5.0E+00	5.1E+00	1.1E+01
		Ground	4.3E-01	4.3E-01	4.3E-01	4.3E-01	4.3E-01	4.3E-01	4.3E-01	5.1E-01
		Total	5.4E+00	5.4E+00	5.4E+00	5.4E+00	5.4E+00	5.4E+00	5.4E+00	1.1E+01
	Inhalation	Adult	6.0E-01	6.2E-01	1.1E-01	6.3E-01	6.4E-01	5.1E+00	8.2E-01	0
		Teen	6.1E-01	6.3E-01	1.4E-01	6.5E-01	6.6E-01	6.4E+00	9.6E-01	0
		Child	5.4E-01	5.4E-01	1.7E-01	5.8E-01	5.9E-01	7.6E+00	8.2E-01	0
		Infant	3.1E-01	3.1E-01	8.9E-02	3.5E-01	3.4E-01	6.8E+00	5.2E-01	0
Vegetable Garden (1.15 mi WNW)	Veg	Adult	1.1E+00	1.1E+00	3.7E+00	1.1E+00	1.0E+00	4.0E+00	1.0E+00	0
		Teen	1.5E+00	1.5E+00	5.8E+00	1.6E+00	1.5E+00	5.2E+00	1.4E+00	0
		Child	3.1E+00	3.0E+00	1.4E+01	3.2E+00	3.1E+00	1.0E+01	3.0E+00	0
Meat Animal (0.70 mi WNW)	Meat	Adult	7.0E-01	7.5E-01	2.7E+00	7.0E-01	6.9E-01	9.0E-01	6.8E-01	0
		Teen	5.5E-01	5.8E-01	2.3E+00	5.6E-01	5.5E-01	7.0E-01	5.4E-01	0
		Child	9.6E+00	9.8E+00	4.3E+00	9.8E+00	9.6E+00	1.2E+00	9.6E-01	0

Table 5.4-11 (Sheet 2 of 2)
Gaseous Effluent Doses from All Units to MEI

Location	Pathway		Dose for All Units (mrem/yr)							
			Total Body	GI-Tract	Bone	Liver	Kidney	Thyroid	Lung	Skin
MEI	All	Adult	7.8E+00	7.9E+00	1.2E+01	7.9E+00	7.8E+00	1.5E+01	8.0E+00	1.1E+01
		Teen	8.1E+00	8.1E+00	1.4E+01	8.2E+00	8.1E+00	1.8E+01	8.4E+00	1.1E+01
		Child	1.0E+01	1.0E+01	2.3E+01	1.0E+01	1.0E+01	2.4E+01	1.0E+01	1.1E+01
		Infant	5.8E+00	5.8E+00	5.5E+00	5.8E+00	5.8E+00	1.2E+01	6.0E+00	1.1E+01
		Max	1.0E+01	1.0E+01	2.3E+01	1.0E+01	1.0E+01	2.4E+01	1.0E+01	1.1E+01
		Group	Child	Child	Child	Child	Child	Child	Child	All

Note: In the first four rows for the MEI, MEI doses are obtained by conservatively summing the residence total external dose with the residence inhalation, vegetable, and meat maximum doses even though they are not all at the same location.

Table 5.4-12
Liquid Effluent Doses Per Unit to Population Within 50 Miles[1] (person-rem/yr)

Pathway	Total Body	Thyroid
Sport fish	7.1E-01	1.7E-01
Commercial fish	7.8E-01	1.5E-01
Sport invertebrate	1.3E-01	6.3E-02
Commercial invertebrate	3.9E-01	1.7E-01
Drinking water	3.8E-01	1.2E+00
Shoreline activities	3.4E-02	3.4E-02
Swimming	4.1E-03	4.1E-03
Boating	2.0E-03	2.0E-03
Irrigated milk	2.2E-04	9.3E-04
Irrigated meat	1.7E-04	2.1E-04
Irrigated non-leafy vegetables	5.3E-04	4.0E-04
Irrigated leafy vegetables	6.7E-05	3.2E-04
Total Dose	2.4E+00	1.8E+00

[1] Annual liquid effluent dose for the 50-mi population determined by LADTAP II.

Notes:
person-rem/yr = person-rems per year

Table 5.4-13
Gaseous Effluent Dose Per Unit to Population Within 50 Miles[1] (person-rem/yr)

Pathway	Total Body	Thyroid
Plume	8.0E-01	8.0E-01
Ground	5.7E-01	5.7E-01
Inhalation	1.4E+00	8.1E+00
Vegetable	7.7E+00	7.6E+00
Cow milk	1.8E+00	4.7E+00
Meat	2.6E+00	2.8E+00
Total Dose	1.5E+01	2.5E+01

1 Annual gaseous effluent dose for the 50-mi population determined by GASPAR II.

Notes:
person-rem/yr = person-rems per year

Table 5.4-14
Gaseous Effluent Thyroid Doses Per Unit to MEI from Iodines and Particulates[1] (mrem/yr)

Pathway	Adult	Teen	Child	Infant
Plume	0	0	0	0
Ground	1.3E-01	1.3E-01	1.3E-01	1.3E-01
Inhalation	1.3E+00	1.7E+00	2.0E+00	1.8E+00
Vegetable	9.9E-01	1.2E+00	2.3E+00	0
Meat	7.2E-02	5.3E-02	7.9E-02	0
Total Dose	2.5E+00	3.1E+00	4.5E+00	2.0E+00

1 Annual gaseous effluent thyroid doses for the MEI determined by GASPAR II.

Notes:
mrem/yr = millirems per year
MEI = maximum exposed individual

Table 5.4-15
Compliance of MEI Annual Doses Per Unit with 10 CFR 50, Appendix I Criteria

Type of Dose	Location	Annual Dose	Limit[5]
Liquid Effluent[1]			
Total Body (mrem)	Clinch River	2.0E-02	3
Maximum Organ – GI-LLI (mrem)	Clinch River	9.7E-02	10
Gaseous Effluent			
Gamma Air[2] (mrad)	Site Boundary	9.5E+00	10
Beta Air[2] (mrad)	Site Boundary	1.2E+01	20
Total Body[3] (mrem)	Residence	9.0E-01	5
Skin[3] (mrem)	Residence	1.9E+00	15
Iodines and Particulates[4]			
Maximum Organ – Thyroid (mrem)	Residence/Garden/Meat	4.5E+00	15

1 Annual liquid effluent doses for the MEI determined by LADTAP II; the MEI is the adult receptor.
2 Annual gaseous effluent doses for the MEI determined by GASPAR II; dose for a receptor at the site boundary, near ground level.
3 Annual gaseous effluent external doses for the MEI determined by GASPAR II.
4 Annual gaseous effluent total thyroid doses from iodines and radioactive material in particulate form for the MEI determined by GASPAR II.
5 Dose limits in 10 CFR 50, Appendix I.

Notes:
mrem = millirem
mrad = millirad
MEI = maximum exposed individual

Table 5.4-16
Compliance of MEI Doses from All Units with 40 CFR 190.10 Criteria (mrem/yr)

Pathway	Liquid[1]	Gaseous[2]	Direct[3]	Total[4]	Limit[5]
Total Body	1.7E-01	1.0E+01	1.0E+00	1.1E+01	25
Thyroid	6.6E-01	2.4E+01	0.0E+00	2.5E+01	75
Other Organ - Bone	5.4E-01	2.3E+01	0.0E+00	2.4E+01	25

1 Annual liquid effluent doses for the MEI determined by LADTAP II; the MEI is the adult receptor for total body dose and the child for thyroid and bone dose.
2 Annual gaseous effluent doses for the MEI determined by GASPAR II; the MEI is the child receptor.
3 Annual direct dose is assumed to be 1 mrem per year.
4 Site totals are summed across receptors and locations to provide a conservative site total.
5 Dose limits in 40 CFR 190.10.

Notes:
mrem/yr = millirems per year
MEI = maximum exposed individual

Table 5.4-17
Doses from All Units to Population Within 50 Miles (person-rem/yr)[1]

Pathway	Total Body	Thyroid
Liquid	9.6E+00	7.2E+00
Gaseous		
Noble gases	3.2E+00	3.2E+00
Iodines	8.0E-02	4.0E+01
Particulates	2.9E+00	2.3E+00
C-14	4.0E+01	4.0E+01
H-3	1.3E+01	1.3E+01
Gaseous Total	6.0E+01	1.0E+02
Pathways Total	6.8E+01	1.0E+02
Background Radiation[2]	8.3E+05	

1 Doses per unit multiplied by 4 to approximate doses from all units
2 The background dose is obtained by multiplying the average natural background dose rate in the United States of 311 mrem/yr (0.311 rem/yr) by the 2067 population of2.66E6 persons.

Table 5.4-18
Liquid Effluent Doses from All Units to Biota

Biota	Dose for All Units (mrad/yr)
Fish	1.6E+00
Invertebrates	7.6E+00
Algae	2.5E+00
Muskrat	3.4E+00
Raccoon	1.3E+00
Heron	8.9E+00
Duck	3.2E+00

Notes:
mrad/yr = millirad per year

Table 5.4-19
Gaseous Effluent Doses from All Units to Biota

Pathway	Child TBD[1] (mrem/yr)	Teen TBD[1] (mrem/yr)	Adult TBD[1] (mrem/yr)	Biota Dose (mrad/yr)
Inhalation	3.2E+00	3.7E+00	3.6E+00	3.7E+00[2]
Vegetable consumption	4.6E+01	2.2E+01	1.6E+01	4.6E+01[2]
Plume immersion	3.0E+01	3.0E+01	3.0E+01	3.0E+01[2]
Ground deposition	2.2E+00	2.2E+00	2.2E+00	4.3E+00[3]
Total				8.4E+01[4]

1 Total body dose (TBD) determined from GASPAR II for human receptors located 0.25 mi from the reactor release point was used as biota dose.
2 Biota dose from gaseous effluent through inhalation, vegetable consumption, and plume immersion pathways is estimated as the maximum total body dose determined for human receptors located 0.25 mi of the SMR facility.
3 Because biota are closer to the ground, biota dose from the ground deposition pathway is determined as twice the ground deposition dose determined for humans to compensate for the height differential.
4 The total gaseous effluent dose to biota is estimated as the sum of inhalation, vegetable consumption, plume immersion, and ground deposition doses.

Notes:
mrad/yr = millirads per year
mrem/yr = millirems per year
TBD = total body dose

Table 5.4-20
Doses from All Units to Biota

Biota	Gaseous[1] (mrad/yr)	Liquid[2] (mrad/yr)	Total[3] (mrad/yr)	Total[4] (mrad/day)
Algae	0	2.5E+00	2.5E+00	6.7E-03
Invertebrate	0	7.6E+00	7.6E+00	2.1E-02
Fish	0	1.6E+00	1.6+00	4.5E-03
Muskrat	8.4E+01	3.4E+00	8.7E+01	2.4E-01
Raccoon	8.4E+01	1.3E+00	8.5E+01	2.3E-01
Heron	8.4E+01	8.9E+00	9.3E+01	2.5E-01
Duck	8.4E+01	3.2E+00	8.7E+01	2.4E+-01

1 Total body dose determined from GASPAR II for human receptors located 0.25 mi from the reactor release point was used to model biota dose.
2 Biota dose from liquid effluent as modeled from LADTAP II.
3 Annual total body dose for biota from gaseous and liquid effluent.
4 Daily total body dose for biota from gaseous and liquid effluent as determined by dividing the annual dose by 365 days per year.

Notes:
mrad/yr = millirads per year
mrad/day = millirads per day

5.5 ENVIRONMENTAL IMPACTS OF WASTE

The following subsections discuss the environmental impacts of nonradioactive waste from the operation of two or more small modular reactor (SMR) units at the Clinch River Nuclear (CRN) Site. Regulations for generating, managing, handling, storing, treating, protecting, and disposing of these wastes are contained in federal regulations issued and overseen by the U.S. Nuclear Regulatory Commission (NRC) and the U.S. Environmental Protection Agency (EPA), and in Tennessee regulations overseen by the Tennessee Department of Environment and Conservation (TDEC). These regulations include the Clean Air Act, Clean Water Act, Atomic Energy Act, Resource Conservation and Recovery Act (RCRA), and others.

In NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, , Volume 1, NRC assembled several years of data from operating nuclear power stations and their effects on the environment. Station operations, and the regulatory requirements for protection of the environment, show that the impact of nonradioactive waste discharges from nuclear power operations is considered to be SMALL.

5.5.1 Nonradioactive-Waste-System Impacts

Descriptions of the SMR nonradioactive waste systems and chemical parameters are presented in Section 3.6. Nonradioactive wastes are managed in accordance with applicable federal, state, and local laws, regulations, and permit requirements, as well as Tennessee Valley Authority (TVA) Procedures. TVA expects to construct and operate a permanent onsite landfill for construction, site clearing, and grading debris. The construction/demolition landfill would be sized to accommodate the anticipated materials and would be located in the permanently cleared laydown area north of the main plant area. The landfill would be constructed in accordance with all relevant permit and licenses. No hazardous or municipal waste would be disposed of in this landfill. The landfill would be closed at the end of the construction period. The assessment of potential impacts resulting from the discharge of nonradioactive wastes is presented in the following subsections.

5.5.1.1 Impacts of Discharges to Water

Nonradioactive wastewater discharges to surface water from the facility are described in Subsection 3.6.3.2. Wastewater discharges include cooling tower blowdown; wastewater from the demineralized water system; wastewater from floor drains, sinks, and laboratories; and stormwater runoff. Additional aqueous waste streams may include raw cooling water, air conditioning condensate, steam generator blowdown, and high pressure fire protection water.

Chemicals such as biocides and corrosion inhibitors are used to treat intake or process waters. The quantities of chemicals to be used are determined during development of a Biocide/Corrosion Treatment Plan, which will be submitted as part of the application for a National Pollution Discharge Elimination System (NPDES) permit.

The preliminary site grading plan includes a holding pond on the western side of the CRN Site, which serves as the collection point for most process waste streams except for sanitary wastes and some stormwater discharges. The holding pond discharges to Watts Bar Reservoir through one or more diffusers located at approximately Clinch River Mile 15.5.

Wastewater discharges are regulated by the TDEC through a NPDES permit. The anticipated constituents and their concentrations in the facility's non-radioactive liquid waste discharges are provided in Table 3.6-1, and the average and maximum flow rates for the discharges are discussed in Section 3.4 and Subsection 3.6.3.2. A NPDES permit includes discharge limits established to protect receiving waters, and monitoring to ensure compliance with those limits. Temperatures and chemical concentrations for all discharges are also conditions of the NPDES permit. Biocides and chemicals used for water treatment are added to discharges in part per million concentrations and are largely consumed serving their purposes. TDEC takes the potential for these substances being in the discharge into consideration when establishing requirements for appropriate chemical parameter monitoring and acceptable limits in the NPDES permit. Therefore the impact from these discharges would be SMALL.

The CRN Site currently has a stormwater management system, designed for the Clinch River Breeder Reactor Project, consisting of stormwater runoff/collection ponds and piping. There are currently no known areas of significant erosion on the CRN Site that require controls. The existing stormwater management system would be modified, as needed, to support the CR SMR Project. Modifications may include one or more stormwater retention ponds for settling of solids, but no need has been identified for other treatment or oil/water separators. As part of the application for a NPDES permit, TVA is required to submit a Notice of Intent for Construction Activity Stormwater Discharges and an associated Stormwater Pollution Prevention Plan (SWPPP) to the TDEC. The NPDES permit will be obtained before any construction activities take place. Stormwater discharges are managed in accordance with a SWPPP during construction. Permanent stormwater management systems are designed and constructed to support operations and a NPDES permit requires monitoring of the discharges during operations. Therefore, impacts from stormwater discharge would be SMALL.

In conclusion, because engineering controls which prevent or minimize the release of harmful effluents would be used, and effluent concentrations would be maintained at levels below permitted limits established to be protective of water quality and aquatic life, potential impacts of discharges to water would be SMALL.

5.5.1.2 Impacts of Discharges to Land

Nonradioactive solid waste expected to be generated from the facility are described in Subsection 3.6.3.3. TVA maintains multiple procedures related to the management of non-radioactive solid waste, including used oil wastes, hazardous wastes, non-hazardous solid wastes, construction and demolition wastes (including spoils), and Universal Wastes (lamps, batteries, and pesticides). Nonradioactive solid wastes are disposed using a TVA-approved vendor. TVA complies with applicable federal, state, and local requirements and standards for handling, transporting, and disposing of solid waste. These include the 1976 RCRA, which amended the 1965 Solid Waste Disposal Act. TVA expects to construct and operate an onsite landfill for construction, site clearing, and grading debris. The construction/demolition landfill would be sized to accommodate the anticipated materials and would be located in the permanently cleared laydown area north of the main plant area. The landfill would be constructed in accordance with all relevant permits and licenses. Therefore, potential impacts from land disposal of nonradioactive wastes would be SMALL.

5.5.1.3 Impacts of Discharges to Air

As described in Subsection 2.7.2, Roane County is considered in attainment with the National Ambient Air Quality Standards, except that the county is a partial nonattainment area for particulate matter with a diameter less than 2.5 microns ($PM_{2.5}$) (part of the Knoxville-Sevierville- La Follette, Tennessee 2006 nonattainment area and part of Knoxville 1997 $PM_{2.5}$ nonattainment area). The CRN Site, however, does not lie within the partial nonattainment area for $PM_{2.5}$ in Roane County. Thus the CRN Site is considered in attainment with the air quality standards for all criteria pollutants. The CRN Site is located near the boundaries of Roane County with Knox and Loudon Counties. Knox and Loudon counties, in their entirety, are also within the Knoxville- Sevierville- La Follette, Tennessee $PM_{2.5}$ 2006 nonattainment area and within the Knoxville, Tennessee 1997 $PM_{2.5}$ nonattainment area. (Reference 5.5-1) TVA will consult with TDEC regarding the need for a TDEC Title V Operating Permit under the Clean Air Act following selection of the reactor design.

Nonradioactive gaseous effluents expected to be generated from the facility are described in Subsection 3.6.3.1. Operation of the nuclear power units increase gaseous and particulate emissions to the air by a small amount, primarily from equipment associated with the cooling towers and facility auxiliary systems. The primary sources of emissions from auxiliary systems are auxiliary boilers (Table 3.6-2), diesel generators (Table 3.6-3), and gas turbine generators (Table 3.6-4). The auxiliary boilers are used for heating the facility buildings, primarily during the winter months, and for process steam during reactor startups. The diesel generators/gas turbines and engine driven emergency equipment are used intermittently and for brief durations. Cooling tower impacts on terrestrial ecosystems are discussed in Subsection 5.3.3.2.

Air emission sources associated with the SMR units would be managed in accordance with federal, state, and local air quality control laws and regulations. Accordingly, air quality impacts from operation of the CR SMR Project would be SMALL for the surrounding communities and the nearest residents.

5.5.1.4 Sanitary Waste

During construction and operation, the facility will discharge sanitary wastewaters to the City of Oak Ridge Public Works Department. The projected effluent flow of an average of 50 gallons per minute (gpm) from the facility’s potable/sanitary water system to the City of Oak Ridge sanitary treatment system is included in Table 3.1-2, Item 5.1.1. This equates to an average daily flow of 72,000 gallons per day (gpd). The maximum flow rate, included in Table 3.1-2, Item 5.1.2, is estimated to be 100 gpm, or a maximum daily flow of 144,000 gpd. The maximum flow rate represents a small proportion (approximately 2.6 percent) of the 5.6 million gallon per day capacity of the City of Oak Ridge sanitary treatment system (Reference 5.5-2). Potential impacts associated with disposal of sanitary waste from operation of the SMR would be SMALL.

5.5.2 Hazardous and Mixed Waste Impacts

It is anticipated that the facility would be a Small Quantity Generator of Hazardous Wastes. These wastes are disposed using a TVA-approved vendor. TVA maintains procedures for management of hazardous and mixed waste at their facilities.

The term "mixed waste" refers specifically to waste that contains both hazardous waste and source, special nuclear, or byproduct material. Because radioactive materials at nuclear power facilities are regulated by NRC and hazardous wastes are regulated by EPA, nuclear power facilities managing mixed waste must meet the requirements of both regulatory agencies. The radioactive component of mixed waste must satisfy the definition of low-level waste in the Low-Level Radioactive Waste Policy Amendments Act of 1985. The hazardous component must exhibit at least one of the hazardous waste characteristics identified in Title 40 of the Code of Federal Regulation (40 CFR) 261, Subpart C, or be listed as a hazardous waste under 40 CFR 261, Subpart D.

Additionally, entities that generate, treat, store, or dispose of mixed wastes are subject to the requirements of the Atomic Energy Act, the Solid Waste Disposal Act of 1965, as amended by the RCRA in 1976, and the Hazardous and Solid Waste Amendments, which amended RCRA in 1984. In the State of Tennessee, the EPA has authorized the state to regulate those portions of the Federal act under RCRA.

5.5.2.1 Plant Systems Producing Hazardous and Mixed Waste

Nuclear power facilities typically do not generate large volumes of hazardous or mixed waste due to industry-wide, ongoing efforts to reduce mixed-waste generation. A 1990 survey conducted by NRC identified the types of hazardous and potentially mixed low-level waste listed below as common to reactor facilities (NUREG-1437, Rev. 0). The types of hazardous and potentially mixed waste that would be generated by the reactor selected for the CRN Site is expected to be consistent with the types identified by the survey. Types of hazardous or mixed waste may include:

- Waste oil from pumps and other equipment
- Chlorinated fluorocarbons resulting from cleaning, refrigeration, degreasing, and decontamination activities
- Organic solvents, reagents, compounds, and associated materials such as rags and wipes
- Metals such as lead from shielding applications and chromium from solutions and acids

- Metal-contaminated organic sludge and other chemicals
- Aqueous corrosives consisting of organic and inorganic acids

5.5.2.2 Hazardous and Mixed Waste Storage and Disposal

Specific hazardous and mixed waste management practices, treatment methods, and storage areas have not been established for the CRN Site. However, industry standard and regulatory compliant hazardous chemical control and radiological control measures would be applied during testing, handling, and storage (accumulation area) of hazardous and mixed wastes. In accordance with hazardous material management regulations in 40 CFR 261 and 265, onsite storage of hazardous and mixed wastes are limited. Therefore, hazardous and mixed wastes would be shipped offsite for treatment or disposal after a short accumulation period.

Examples of best management practices (BMPs) for hazardous and mixed waste storage and disposal include:

- Development of an emergency response plan
- Segregation of hazardous and mixed wastes from nonhazardous wastes
- Securing waste accumulations areas
- Posting accumulation areas with signs containing language similar to the following: “MIXED/HAZARDOUS WASTE AREA” and “DANGER-UNAUTHORIZED PERSONNEL-KEEP OUT”
- Use of secondary containment and the presence of spill kits for liquid hazardous and mixed waste storage
- Compliant container labeling
- Routine inspections of waste accumulation areas

5.5.2.3 Waste Minimization Plan

Pursuant to the regulations cited in Subsection 5.5.2 regarding hazardous and mixed waste management, TVA develops and implements Waste Minimization Plans for nuclear power facilities. The following industry BMPs are elements of the Waste Minimization Plan:

- Inventory identification and control that utilizes a tracking system to manage waste generation data and waste minimization opportunities
- Work planning to reduce mixed waste generation (An example of work planning is pre-task planning to determine what materials and equipment are needed to perform the anticipated work.)
- Mixed waste reduction, recycling, and reuse methods that maximize opportunities for reclamation and reuse of waste materials are used whenever feasible

- Training and education of employees on the principles and benefits of the waste minimization

5.5.2.4 Environmental Impacts of Hazardous and Mixed Waste

The development and implementation of hazardous and mixed waste management BMPs and the Waste Minimization Plan as described above in Subsections 5.5.2.2 and 5.5.2.3 would ensure that generation of hazardous and mixed wastes is minimized by the SMR units at the CRN Site. Due to the project small volume of hazardous and mixed waste, no significant emissions or releases of hazardous materials are expected as a result of mixed waste management practices. Therefore, environmental impacts of hazardous and mixed waste would be SMALL.

5.5.3 References

Reference 5.5-1. U.S. Environmental Protection Agency, Nonattainment Status for Each County by Year for Tennessee, Website: http://www.epa.gov/oaqps001/greenbk/anay_tn.html, December 5, 2013.

Reference 5.5-2. City of Oak Ridge, Welcome to the City of Oak Ridge, Tennessee, Website: http://www.oakridgetn.gov/department/PublicWorks/Divisions/Wastewater-Treatment, 2015.

5.6 TRANSMISSION SYSTEM IMPACTS

This section describes the impacts of transmission system operation for the Clinch River (CR) Small Modular Reactor (SMR) Project. As discussed in Section 3.7, the final design of the transmission infrastructure to support operation of two or more SMRs at the Clinch River Nuclear (CRN) Site, including corridors and switchyards, has not yet been finalized. Section 3.7 describes a general concept of the interconnection components and activities necessary to complete the connection between the CRN Site and the existing power transmission systems. As described in Subsection 3.7.1, activities related to the transmission system on the CRN Site include the construction of proposed switchyards, looping in transmission lines, and relocation of an existing transmission line within the site boundary. Transmission line upgrades in conjunction with the CR SMR Project are expected to include reconductoring, uprating, and rebuilding of some segments within the existing lines on and off the CRN Site. These upgrades, which would increase the electrical capacity of the existing transmission system, include activities such as moving features that interfere with clearance, replacing and/or modifying existing structures, installing intermediate structures, and modifying or replacing some of the existing conductors in order to increase ground clearance.

Additionally, Tennessee Valley Authority (TVA) plans to install an underground transmission line within an existing overhead transmission line right-of-way (ROW) which spans the CRN Site and ties into the Bethel Valley substation. As described in Subsection 3.7.3.4, the proposed underground transmission line would be installed approximately 36 inches (in.) below the ground surface. Impacts associated with construction in transmission line ROWs are discussed in Sections 4.1 and 4.3.

Subsections 5.6.1 and 5.6.2 discuss potential environmental impacts to terrestrial and aquatic ecosystems, respectively. Subsection 5.6.3 addresses potential operational impacts of the existing and proposed transmission lines to members of the public.

As described in greater detail in Section 3.7, two TVA transmission lines currently traverse the CRN Site, the east-west 500-kilovolt (kV) Watts Bar NP – Bull Run FP line and the north-south 161-kV Kingston FP – Fort Loudoun HP #1 line. Additional interconnection components and activities would be necessary to complete the connection between the CRN Site and existing power transmission systems and ensure that National Electrical Safety Code (NESC) standards are met. These components, based on an SMR surrogate plant at a generating output of 800 MWe, include onsite switchyards, loops in the two existing lines, various uprating activities, and relocation of an onsite portion of the Kingston FP – Fort Loudoun HP #1 161-kV transmission line. TVA also plans to install a 69-kV underground transmission line (approximately 5 miles [mi] in length) within the existing ROW of the Watts Bar NP – Bull Run FP 500-kV line on U.S. Department of Energy (DOE) property. The 69-kV line would tie into the Bethel Valley substation, also on DOE property. Figure 3.7-2 shows the existing transmission system on and adjacent to the CRN Site and the approximate proposed 161-kV transmission line relocation route. Figure 3.7-2 shows the route of the proposed underground 69-kV transmission line from the CRN Site to the Bethel Valley substation. It is expected that transmission system construction activities would be completed within the CRN Site and/or existing transmission line ROWs.

5.6.1 Impacts to Terrestrial Ecosystems

TVA manages transmission corridors to prevent woody growth from encroaching on energized transmission lines and potentially causing disruption in service or becoming a general safety hazard. In addition to maintaining an adequate distance between transmission line conductors and vegetation, management of vegetation along the ROWs is necessary to ensure access to structures.

TVA has procedures in place for use during ongoing transmission line ROW maintenance activities. In addition, TVA transmission line maintenance activities are subject to periodic National Environmental Policy Act review where resources within the ROW are assessed and characterized. TVA procedural documents such as *Right-Of-Way Vegetation Management Guidelines* and *A Guide for Environmental Protection and Best Management Practices for Tennessee Valley Authority Transmission Construction and Maintenance Activities* provide guidance to TVA personnel conducting maintenance activities in transmission line ROWs (Reference 5.6-1; Reference 5.6-2). Activities addressed include such operations as re-clearing of vegetation, maintenance of access roads, and erosion control. Best management practices (BMPs) are provided for re-clearing methods such as cutting of trees and herbicide application, and for protection of sensitive resources. Structural controls, standards, and specifications are identified to maintain physical components within ROWs such as riprap and culverts.

Periodic inspections of TVA's transmission lines would continue to be performed by aerial surveillance on a regular basis. These inspections are conducted to locate damaged equipment; in addition, any conditions that may interfere with normal operation of the line or adversely impact the surrounding area are reported. During these inspections, the condition of the vegetation within and adjacent to the ROW are noted. These observations are then used to plan corrective maintenance or routine vegetation maintenance.

Vegetation management along the ROW consists of two principal activities: felling of invasive trees adjacent to the cleared ROW, and vegetation control within the cleared ROW. Management of vegetation within the cleared ROW uses an integrated vegetation management approach based on BMPs designed to encourage low-growing plant species and discourage tall-growing plant species.

A vegetation re-clearing plan is developed for each transmission line segment based on the results of the periodic inspections described above. The two principal management techniques are mechanical mowing and herbicide application. Herbicides are applied in accordance with applicable state and federal laws and regulations. Only herbicides registered with the U.S. Environmental Protection Agency are used.

In NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, Rev. 1, the U.S. Nuclear Regulatory Commission (NRC) evaluated transmission line ROW management (cutting and herbicide application) during the license renewal term at all nuclear power plants. NRC concluded that continued ROW management would not lower habitat quality or cause significant changes in wildlife populations in the surrounding habitat, and that the impact on terrestrial resources would be SMALL for all nuclear power plants.

As described in Subsection 3.7.3.4, the proposed location of the underground transmission line is 36 in. below ground surface within the existing 500-kV ROW. The heat from underground transmission lines dissipates through the surrounding soil. Thus, operation of the proposed line is expected to increase the soil temperature adjacent to the line. However, this thermal effect is very localized and limited. Modeling of temperature effects from an underground 380-kV line under full load conditions indicated that the temperature increase at the surface directly above the line would not exceed 1 to 2 degrees Celsius (33.8 to 35.6 degrees Fahrenheit [°F]), and at a distance of 5 meters from this point, a soil temperature increase would not be detectable. (Reference 5.6-3) Similarly, soil temperature increases from the operation of a 69-kV underground line and the area affected are expected to be localized and limited. Soil temperature increases potentially could slightly alter the composition of the terrestrial vegetation and associated wildlife habitat directly above the line, but any effects would quickly decline with distance, and the affected area would be limited to the transmission line ROW, where vegetation is controlled.

Transmission lines generate coupled electric and magnetic fields, referred to together as electromagnetic fields (EMF). The voltage on the conductors of the transmission line generates an electric field that occupies the space between the conductors and other conducting objects such as the ground, transmission line structures, or vegetation. A magnetic field is generated by the current (movement of electrons) in the conductors. Electric fields from underground transmission lines are limited by insulation, and no electric field would be detected outside the cable. The strength of the magnetic field that surrounds the conductor decreases rapidly with distance. (Reference 5.6-3) Studies have found that magnetic and electric fields from transmission lines do not cause adverse behavioral, health, or reproductive effects in wildlife or other animals (Reference 5.6-4). Thus, EMF effects on terrestrial wildlife from operation of the underground 69-kV line would be negligible.

In summary, TVA has methods in place to protect terrestrial habitats from potential adverse effects associated with ongoing transmission line ROW maintenance activities. Potential thermal and EMF effects of the proposed underground transmission line on terrestrial habitats are expected to be negligible. Therefore, impacts to terrestrial ecosystems resulting from the operation and maintenance of transmission lines would be SMALL.

5.6.2 Impacts to Aquatic Ecosystems

Transmission lines within the vicinity of the CRN Site span several aquatic habitats, including a reservoir, creeks, and streams. The proposed location of the underground transmission line is within an existing 500-kV transmission line ROW. As discussed in Subsection 4.3.2.5, construction of the 69-kV line includes installation under short segments of several streams within the 500-kV ROW. The potential effects of transmission lines on aquatic ecosystems arise mainly from water quality effects associated with maintaining ROWs. TVA is responsible for many miles of transmission lines that span several aquatic habitats and, therefore, has procedures for ROW maintenance to protect aquatic resources. As described in Subsection 5.6.1, TVA has developed procedures for ROW maintenance activities such as erosion control and herbicide application, which are designed to maintain water quality in surface water bodies and wetlands in and near transmission line ROWs.

Streamside management zones (SMZs) refer to TVA-specified buffer areas surrounding bodies of water, including ponds, streams, and rivers. The size of the SMZ is specified depending on the slope of the surrounding area, the type of stream, and the particular resource that may be present in the stream. TVA follows established BMPs specifically directed toward avoiding or minimizing adverse impacts to SMZs and the associated waterbodies during maintenance activities. Use of hand held equipment for clearing trees reduces soil and shoreline disturbance. Applications of herbicides (except those labeled for aquatic use) are conducted so that chemicals are not applied directly or allowed to drift into intermittent or perennial streams or other water bodies. (Reference 5.6-1) Due to the use of these technologies when working near aquatic environments, adverse effects on aquatic ecosystems would be minimal.

As discussed for terrestrial ecosystems in Subsection 5.6.1, thermal effects from the 69-kV underground line potentially could occur in sediment and water of the stream segments that cross over the buried line. Such effects on aquatic systems were evaluated by the DOE in an Environmental Impact Statement (EIS) for a proposed 300-kV direct current underground transmission line, which would extend from Canada to New York City and would be installed largely beneath bodies of water. This EIS estimated that sediment temperature increases associated with the operation of that underground line would be less than 2°F at the sediment surface, not accounting for further temperature reductions that would result from advective heat losses to flowing water. Temperature changes in the water itself were estimated to be less than 0.01°F. Such changes in sediment or water temperatures would be negligible in comparison to seasonal fluctuations. As discussed for terrestrial ecosystems, EMF may be higher directly above an underground transmission line than below an overhead line, but electric fields are limited by insulation, magnetic fields weaken rapidly with distance, and such fields have not been found to cause adverse effects in wildlife or other animals. EMF effects on aquatic wildlife from operation of the underground 69-kV line would be negligible. (Reference 5.6-4)

TVA routinely implements measures to minimize potential adverse effects on aquatic habitats from ongoing transmission line ROW maintenance activities. Potential thermal and EMF effects of the proposed underground transmission line on aquatic habitats are expected to be negligible. Therefore, impacts to aquatic ecosystems resulting from the operation and maintenance of the transmission lines would be SMALL.

5.6.3 Impacts to Members of the Public

The possible effects from electrical transmission systems on members of the general public include exposure to EMF, electrical shock, exposure to noise, radio and television interference, and visual effects. Existing transmission lines currently connected to the energy distribution system are available for use by the CR SMR Project. As described in Section 3.7, existing line characteristics indicate the highest voltage line associated with the CRN Site is 500 kV. Also, a new 69-kV underground transmission line is proposed for installation within the existing Watts Bar NP – Bull Run FP 500-kV ROW.

5.6.3.1 Electromagnetic Field Exposure

Transmission lines and other types of electrical wiring generate EMF. The strength of the field depends on the current, design of the line, and distance from the line. Most of this energy is dissipated in the ROW and the very low residual amount is reduced to background levels near the ROW or energized equipment. (Reference 5.6-5) Existing offsite transmission lines are available to connect the CR SMR Project to the energy distribution system. Construction of new offsite overhead transmission lines is not proposed. However, as discussed in Section 3.7, some existing lines would be reconductored, uprated, or rebuilt to upgrade the transmission system as needed for the operation of the CR SMR Project. The EMF generated by the existing transmission lines would not be affected by operation of the CR SMR Project.

Installation of one new underground transmission line is proposed. Exposure to EMF is different for underground transmission lines. Electric fields from underground transmission lines are limited by insulation, and no electric field would be detected outside the cable. The strength of the magnetic field that surrounds the conductor decreases rapidly with distance. EMF strength may be higher directly above an underground line than under an overhead transmission line, but the width of the underground line EMF corridor is much less because the underground line occupies a narrower area. Mitigation measures can decrease the EMF fields related to underground transmission lines to negligible levels. (Reference 5.6-3)

Because public exposure to EMF from existing offsite transmission lines would not change and EMF fields associated with the new underground transmission line would be localized and can be decreased to negligible levels, impacts to the public resulting from EMF exposure would be SMALL.

5.6.3.2 Electrical Shock

In NUREG-1437, Rev 1, NRC indicates that the greatest electrical shock hazard from a transmission line is direct contact with the conductors and that tower designs preclude direct public access to the conductors. However, electrical shocks can occur without physical contact. Secondary shock can happen when humans make contact with either capacitively charged bodies (such as a vehicle parked near a transmission line) or magnetically linked metallic structures (such as fences near transmission lines). The shock received by the person could be painful. The intensity of the shock would depend on the EMF strength, the size of the object, and the degree of insulation between the object, the person, and the ground.

The NESC is the basis for design criteria that are intended to limit the risk of shock and other hazards due to transmission lines. The NESC calls for transmission lines to be designed with minimum vertical clearances to the ground so that the short-circuit current to ground produced from the largest anticipated vehicle or object is limited to less than 5 milliamperes. In NUREG-1437, Rev. 1, NRC indicated that the electrical shock issue is of small significance for transmission lines that are operated in adherence with the NESC. As described in Subsection 3.7.1, TVA plans to upgrade transmission lines in conjunction with the CR SMR Project. These upgrades (e.g., moving features that interfere with clearance, replacing and/or modifying existing structures, and modifying or replacing some existing conductors so as to increase ground clearance) would be needed to increase the electrical capacity of the existing transmission system. Maintaining the required clearance to meet NESC design criteria reduces the risk of electrical shock.

For underground transmission lines, no electrical fields are detected outside the cable. The electric field extending from an underground transmission line is limited by insulation, and outside the cable no electrical field would be detected. (Reference 5.6-3) Therefore, the most likely potential for electric shock from an underground transmission line is associated with direct contact, such as digging.

Given that TVA maintains the transmission lines in compliance with NESC guidelines, impacts to members of the public due to electrical shock would be SMALL.

5.6.3.3 Noise

As discussed in NUREG-1437, Rev. 1, transmission lines can generate a small amount of sound energy during corona activity, which is a partial discharge of electrical energy. During corona events, the ionization of the air that surrounds conductors of the high-voltage transmission lines, which is caused by electrostatic fields in these lines, generates impulse corona currents. When the voltage on a particular phase is high enough, a corona burst occurs, and a noise is generated. This audible noise from the line can barely be heard in fair weather on higher-voltage lines. During wet weather, water drops collect on the conductor and increase corona activity so that a crackling or humming sound may be heard near the line. This noise is caused by small electrical discharges from the water drops.

For 500-kV transmission lines, this corona noise, when present, is usually approximately 40-55 A-weighted decibels (dBA). The maximum recorded corona noise has been 60-61 dBA. (Reference 5.6-5) As discussed in Subsection 4.4.1.1, noise levels below 65 dBA outside a residence are generally considered to be acceptable Therefore, the corona-related noise potentially generated by transmission lines would be acceptable.

As described in Subsection 3.7.3.4, the depth of the proposed underground transmission line would be 36 in. below the ground surface. Corona discharge is not an issue with underground lines except at aboveground components such as substations, since the energized conductors are fully enclosed in a semi-conducting layer within the insulated cables that serve to equalize the electrical gradient at the surface of the components (Reference 5.6-6). The underground line is not expected to generate noise that would be audible from above the ground surface.

The 500-kV and 161-kV lines that would serve the CR SMR Project are already operating and the noise levels they produce are expected to continue to remain acceptable. The underground transmission line planned for construction is not expected to generate audible noise. Therefore, there are no anticipated increases to the current ambient noise levels associated with the operation of the transmission system, and the effect on noise would be SMALL.

5.6.3.4 Radio and Television Interference

Corona activity from transmission lines can also generate EMF noise at frequencies used for radio and television signals. If interference were to occur with radio or television reception, it would be due to unusual failures of power line insulators or poor alignment of the radio or television antenna and the signal source. Both conditions are correctable and would be repaired if reported to TVA. (Reference 5.6-5) As described in Subsection 5.6.3.3, corona discharge and the associated interference is not an issue with underground transmission lines. Therefore, there are no anticipated increases in corona activity associated with operation of the transmission system and the impact of the transmission lines on radio and television signals would be temporary and SMALL.

5.6.3.5 Visual Impacts

Continued operation of the existing transmission lines associated with the CR SMR Project would not affect the visual character of the area. The transmission towers and cleared corridors are already in place. The location of the proposed new 69-kV transmission line is underground within the existing 500-kV transmission line ROW. However, a portion of the existing 161-kV line located on the CRN Site would be re-routed to the east, along the Clinch River arm of the Watts Bar Reservoir. The new towers and cleared corridor would be visible from the reservoir and several residences across from the CRN Site. Given the presence of the other transmission lines on the CRN Site and in the area, and the industrial nature of the proposed project, the effect of the re-located transmission line would not noticeably alter important attributes of the area’s visual character. Therefore, although the re-located transmission line would alter viewscapes in the immediate vicinity of the CRN Site, the overall impact of the transmission system on visual resources would be SMALL.

5.6.4 References

Reference 5.6-1. Muncy, J. A., "A Guide for Environmental Protection and Best Management Practices," 2012.

Reference 5.6-2. Tennessee Valley Authority, "Right-Of-Way Vegetation Management Guidelines; Energy Delivery Environmental Protection Procedures," Revision 3, September 23, 2013.

Reference 5.6-3. Golder Associates, "Study on the Comparative Merits of Overhead Electricity Transmission Lines Versus Underground Cables," PPSMDE081295, May, 2008.

Reference 5.6-4. U.S. Department of Energy, "Champlain Hudson Power Express Transmission Line Project Environmental Impact Statement," September, 2013.

Reference 5.6-5. Tennessee Valley Authority, "Power Supply Improvement Project," 2005-107, April, 2008.

Reference 5.6-6. Aspen Environmental Group, Final Mitigated Negative Declaration and Supporting Initial Study for PG&E's Embarcader-Potrero 230 kV Transmission Project (Section 5.18), Website: http://www.cpuc.ca.gov/Environment/info/aspen/embarc-potrero/toc-fmnd.htm, October, 2013.

5.7 URANIUM FUEL CYCLE AND TRANSPORTATION IMPACTS

This section describes the environmental impacts from the uranium fuel cycle (UFC) for operation of two or more small modular reactors (SMR) at the Clinch River Nuclear (CRN) Site. Subsection 5.7.1 describes the impacts of the UFC using Table S-3, “Table of Uranium Fuel Cycle Environmental Data,” in Title 10 of the Code of Federal Regulations (10 CFR) 51.51. The subsections below 5.7.1 assess individual resources impact by the UFC. Subsection 5.7.2 describes the transportation of radioactive materials to and from the CRN Site.

The subsections under 5.7.2.1, Transportation Assessment, address the conditions for use of Table S-4, “Environmental Impact of Transportation of Fuel and Waste To and From One Light-Water-Cooled Nuclear Power Reactor,” in 10 CFR 51.52 to characterize the impacts of radioactive materials transportation to and from the CRN Site. 10 CFR 51.52(a) provides a list of conditions that a planned reactor must meet to fully apply Table S-4 to assess the impacts from transportation of fuel and radioactive waste. However, the SMRs at the CRN Site do not meet the conditions for average fuel enrichment or average fuel burnup provided in 10 CFR 51.52(a)(2) and 10 CFR 51.52(a)(3), respectively. Therefore, detailed analyses of fuel transportation effects for normal conditions and for accidents are presented in Subsection 5.7.2.2 and Section 7.4, respectively.

5.7.1 Uranium Fuel Cycle Impacts

The environmental effects from the UFC to support operation of SMRs at the CRN Site using Table S-3 are described and assessed in this subsection. The UFC is defined as the total of those options and processes associated with the provision, utilization, and ultimate disposition of fuel for nuclear power reactors. The evaluation in this subsection addresses the following stages of the UFC:

- Uranium mining and milling
- Conversion to uranium hexafluoride
- Enrichment of uranium-235
- Fabrication of reactor fuel
- Reprocessing of irradiated fuel
- Transportation and management of radioactive wastes
- Disposal of the spent fuel

Natural uranium is extracted from the earth through either open-pit or underground mining or by an in-situ leaching (ISL) process. ISL involves injecting an acidic solution into the groundwater aquifer to partition uranium from a solid to aqueous phase and then pumping the uranium-rich solution to the surface for further processing. The ore or leaching solution is processed to produce uranium oxide (U_3O_8). The uranium oxide is then converted to uranium hexafluoride (UF_6) in preparation for the enrichment process.

The UF_6 is transported to a separate facility for uranium enrichment. Uranium enrichment involves increasing the percentage of the more fissile isotope uranium-235 (U-235) and decreasing the percentage of the isotope uranium-238 (U-238). The enrichment process exploits the slight differences in atomic weights of the two isotopes. A feature common to large-scale enrichment schemes is that they employ a number of identical stages which use a cascading process to produce successively higher concentrations of U-235. Each stage concentrates the product of the previous stage further before the product is sent to the next stage. Similarly, the tailings from each stage are returned to the previous stage for further processing.

At a fuel-fabrication facility, the enriched uranium is converted from UF_6 to uranium dioxide (UO_2). In Table 3.1-2, Item 18, the fuel for the SMRs at the CRN Site is assumed to be UO_2. The UO_2 is formed into pellets, inserted into hollow rods, and loaded into fuel assemblies. The fuel assemblies are placed in the reactor to produce power. After a significant amount of the U-235 contained within a fuel assembly has been depleted, the nuclear fission process becomes inefficient, and spent fuel assemblies are then replaced. Spent fuel assemblies are placed in an onsite, interim, wet storage to allow for short-lived fission product decay and to reduce the heat generation rate. Afterward, the fuel assemblies are transferred to dry storage casks and stored onsite while awaiting transportation to a spent fuel storage facility or a waste repository.

The Nuclear Non-proliferation Act of 1978 effectively banned any reprocessing or recycling of spent fuel from United States commercial nuclear power. The ban on reprocessing spent fuel was lifted in 1981, but the combination of economics, uranium ore stockpiles, and nuclear industry stagnation provided little incentive for the industry to pursue reprocessing. The Energy Policy Act of 2005 authorized the U.S. Department of Energy (DOE) to research and develop proliferation-resistant fuel recycling and transmutation technologies that minimize environmental or public health and safety effects. Therefore, federal policy does not prohibit reprocessing, but there are currently no mature projects pursuing commercial reprocessing or recycling of spent fuel in the United States.

Table S-3 of 10 CFR 51.51 provides estimates of the environmental effects of the UFC. The effects are calculated for a reference 1000-megawatt-electric (MWe) light water reactor (LWR) operating at an annual capacity factor of 80 percent for an effective electric output of 800 MWe. This LWR design is referred to as the reference plant throughout this section. Data are calculated and presented in tables for land use, water consumption, thermal effluents, radioactive releases, waste burial, and radiation doses. 10 CFR 51.51 requires that the data in Table S-3 be used as the basis for evaluation of a proposed project.

In developing the reference plant data, the U.S. Nuclear Regulatory Commission (NRC) staff considered two UFC options. The “no recycle” and “uranium-only recycle” options differ only in the resting place of spent fuel. The “no recycle” option assumes that all spent fuel would be stored at a federal waste repository. The “uranium-only recycle” option assumes that spent fuel would be reprocessed to recover unused uranium, which would be returned to the UFC. The reference plant values provided for reprocessing, waste management, and transportation are from the UFC option resulting in the larger environmental effect.

The reference plant values provided in Table S-3 were derived from industry averages for each type of facility or operation associated with the UFC. Recognizing that this approach results in a range of values for each estimate, the NRC staff defined the assumptions or factors to be applied so the calculated values are not underestimated. This approach was intended to ensure that the actual environmental effects are less than the quantities shown for the reference plant and envelop the widest range of operating conditions for LWRs.

The NRC regulation recommends evaluating UFC parameters, nuclear plant characteristics, and impacts to the environment based on a reference plant. To determine the annual fuel requirement, the NRC staff defined the “reference plant” as a 1000-MWe LWR. The characteristics of the reference plant include an 80 percent capacity factor, a 12-month fuel reloading cycle, and an average fuel burnup rate of 33,000 megawatt-days (MWd) per metric ton (MT) of uranium (MTU). The expected lifetime of a newly constructed nuclear plant is approximately 60 years (yr; the 40-yr initial licensing plus one 20-yr license renewal term). The sum of the initial fuel loading and all of the expected reloads for the lifetime of the reactor is divided by the 60-yr expected lifetime to obtain an average annual fuel requirement. This quantity of fuel was determined for both boiling water reactors (BWRs) and pressurized water reactors (PWR); the higher annual requirement, a BWR using 35 MTU, was chosen in Subsection 6.2.3, paragraph 3, of NUREG-1437, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, Rev. 0 as the basis for the reference plant.

In NUREG-1437, Rev. 0, the NRC staff provided a detailed analysis of the environmental effects of the UFC. NUREG-1437, Rev. 1, provides a less detailed analysis and often references NUREG-1437, Rev. 0 for additional details. Although NUREG-1437, Rev. 0 and Rev. 1, are specific to license renewal, the information is relevant because the SMRs described by the plant parameter envelope (PPE) in Table 3.1-2 use the same fuel cycle process and the same type of fuel as the reference plant. Section 6.2 of NUREG-1437, Rev. 0 discusses the sensitivity to changes in the UFC on the environmental effects in detail.

In the past, uranium market conditions led to the closing of most domestic uranium mines and mills, and substantially reduced the environmental effects in the United States from these activities. According to the U.S. Energy Information Administration (EIA), Uranium Marketing Annual Report for 2013, the majority of uranium [as uranium oxide equivalent (U_3O_8e)] purchased by the United States reactors has historically been imported. In 2013, 83 percent of uranium purchased by owners and operators of United States commercial nuclear power reactors was of foreign origin. (Reference 5.7-1)

Domestic production of uranium has been showing an upward trend since 2003 to meet increasing demand and projected demand from new plants involved in licensing and construction (Reference 5.7-2). However, purchases decreased slightly from 58 million pounds of U_3O_8e in 2012 to 57 million pounds U_3O_8e in 2013 (Reference 5.7-1). EIA conducted an additional analysis in 2014 examining the potential impacts of excess uranium offered into the market from inventories at the DOE's Portsmouth and Paducah gaseous diffusion plants. During the period from 2014 to 2033, the EIA reports that 129 million pounds the U_3O_8e would enter the market from the DOE stockpiles (Reference 5.7-3).

The slight decrease in U_3O_8e purchases in 2013 and DOE uranium coming on to the market suggest that the environmental effects of mining and milling could temporarily drop to levels below those given for the reference plant. However, the effects are still bounded by the reference numbers in NUREG-1437, Rev. 0 and Rev. 1. Therefore, for the purposes of this analysis, the reference plant estimates have not been reduced.

As provided in Table 3.1-2, Item 16.6, the maximum net power output of the SMRs at the CRN Site is 800 MWe. Table 3.1-2, Item 16.4, provides a station capacity factor of 98 percent resulting in an effective net power output 784 MWe. The ratio of the effective net power output value for the SMRs described by the PPE (784 MWe) to the net electrical output for the 1000 MWe reference plant (800 MWe) provides a scaling factor of 0.98 to convert reference plant values to project-specific values at the CRN Site (Table 5.7-1).

The environmental effects of the UFC from operating SMRs at the CRN Site were evaluated to assess qualitative effects to the environment. This assessment is based on the values calculated in Tables 5.7-1 and 5.7-2[1]; an analysis of the radiological effects from radiological emissions from the UFC including radon-222 (Rn-222) and technetium-99 (Tc-99) provided in Tables 5.7-3 and 5.7-4; and average doses to the United States population from UFC and non-UFC sources of radiation provided in Table 5.7-5.

5.7.1.1 Land Use

The total annual land requirement for the UFC supporting SMRs at the CRN Site is presented in Table 5.7-2. The table lists values for both permanently and temporarily committed land. Permanent land commitments are those that may not be released for use after plant shutdown and/or decommissioning. This limitation on land use is because decommissioning activities on the pertinent land may not remove sufficient radioactive material to meet the limits in 10 CFR 20, Subpart E, for release of land for unrestricted use. Temporary land commitments are for the life of the specific UFC plant (e.g., a mill, enrichment plant, or succeeding plants). Following completion of decommissioning, such land can be released for unrestricted use.

[1] As scaled off the UFC impacts for the 1000-MWe reference plant in 10 CFR 51.51, Table S-3 using the ratio provided in Table 5.7-1.

As provided in Table S-3 for the reference plant, Table 5.7-2 equates the UFC disturbed land area and overburden requirements for the SMRs at the CRN Site to an equivalently-sized (in electrical power production) coal-fired power plant using strip-mined coal as a fuel and requiring the same area of disturbed land and overburden movement. The comparison shows that UFC land requirements for SMRs at the CRN Site producing 800 MWe are equivalent to the coal mining land use requirements (disturbed land) for a coal-fired plant producing only approximately 88 MWe. Therefore, an equivalent area of disturbed land for coal production yields about 89 percent less electrical output than an equivalent amount of land disturbed for electrical production with uranium fuel or, for an equivalent amount of energy produced with coal, the land use requirements would be nine times greater.

Due to the recent increase in natural gas production in the United States, the net electrical output associated with natural gas production was compared to the net electrical output from SMRs at the CRN Site based on an equivalent area of disturbed land. It is estimated that natural gas production in Marcellus shale disturbs about 8.8 acres (ac) per well pad (cleared lands for pad and infrastructure). (Reference 5.7-4) Each well pad contains on average two natural gas wells and each well typically produces 10 million cubic feet (ft^3) of natural gas per day (Reference 5.7-4). Using conversion factors of 1021 British thermal units (Btu) per cubic foot of natural gas and an assumed power plant heat rate of 8152 Btu per kilowatt-hour, the resulting net electrical output from natural gas production in the Macellus shale is about 11.8 MWe per ac (Reference 5.7-5). For comparison, if the 21.6 ac of disturbed land required to support the fuel needs for SMRs at the CRN Site (Table 5.7-2) were dedicated to natural gas production, the land would only produce enough fuel for a gas-fired plant producing approximately 255 MWe. Therefore, an equivalent area of disturbed land for natural gas fuel production yields 68 percent less net electrical output that an equivalent amount of land disturbed for electrical production with uranium fuel.

If the quality and opportunity costs of the land are equivalent, then it is reasonable to state that land requirements for nuclear power are SMALL compared to coal-fired power plants and natural gas production. Therefore, it is concluded that the effect on land use to support the UFC for SMRs at the CRN Site is considered to be SMALL.

5.7.1.2 Water Use

Power stations supply electrical energy to the enrichment stage of the UFC. The primary water requirement of the UFC is waste heat removal from these power stations. Table S-3 of 10 CFR 51.51 provides a total water discharge (usage) within the UFC for the reference plant as 11,377 x 10^6 gallons per year, less than 4 percent of the actual water used to cool the 1000 MWe reference plant. Applying the 0.98 scaling factor, the water use within the UFC to support SMRs at the CRN Site is estimated to be approximately 11,149 million gallons per year. Therefore, like the water average and maximum net water demands for the reactors themselves described in Subsection 5.2.2.1.1, the impact from the water used to manage power needs to support the SMRs at the CRN Site are also SMALL assuming similar water sources.

According to Table S-3, the annual thermal discharge of power plants used within the UFC to support the 1000-MWe reference plant is approximately 4063 billion Btu; this usage is less than 5 percent of the actual thermal discharge of the 1000 MWe reference plant. The expected thermal effluent value for SMRs at the CRN Site is approximately 3982 billion Btu as presented in Table 5.7-2. Similarly, because the thermal effluent value for the proposed plants is less than the thermal effluent value for the reference plant, the thermal discharge from the UFC for the SMRs at the CRN Site would also be SMALL.

From 10 CFR 51.51, Table S-3 states that the consumptive water use of the UFC in support of the 1000-MWe reference plant, i.e., water discharged to air from cooling towers, is 2 percent of the water consumption of the plant itself. Therefore, considering the scaling factor of 0.98, the water consumption from the UFC supporting the SMRs at the CRN Site would have a SMALL effect with respect to water use.

5.7.1.3 Fossil Fuel Effects

Electrical energy and process heat are consumed during various phases of the UFC. The electrical energy is often produced by combustion of fossil fuels (coal and/or natural gas) at conventional power plants. From 10 CFR 51.51, Table S-3, the electrical energy needs associated with the UFC associated with the reference plant are 323,000 MW-hours (MWh) and represents less than 5 percent of the annual electrical power production of the reference plant. For SMRs at the CRN Site, the UFC electrical energy needs would be approximately 316,540 MWh, which is equivalent to 115,640 MT of coal or 132 million ft^3 of natural gas (Table 5.7-2).

In NUREG-1437, Rev. 0, the NRC concludes that the effects of direct and indirect consumption of electric power for fuel cycle operations produced using fossil fuels are small and appropriate for the electric power being produced from uranium fuel by the reference plant. NUREG-1437, Rev. 1, does not provide any additional information that would alter this conclusion. Since the power output and UFC demands for the SMRs at the CRN Site are less than those for the reference plant, it is concluded that environmental effects from the combustion of fossil fuels associated with UFC operations is also considered to be SMALL.

The NRC estimates that the carbon footprint of the UFC to support the 1000-MWe reference plant for the 40-yr plant life is about 17,000,000 MT of carbon dioxide (Reference 5.7-6). Scaling the 10 CFR 51.51 reference plant's UFC carbon footprint to obtain a UFC carbon footprint for the SMRs at the CRN Site, the carbon footprint for 40 yr of UFC emissions would be approximately 16,660,000 MT. The average annual emission rate would then be approximately 416,000 MT. This rate compares to a total annual emissions of 5,500,000,000 MT in 2011 for the entire United States (Reference 5.7-7). Therefore, it is concluded that the carbon footprint associated with UFC operations is also considered to be SMALL.

5.7.1.4 Chemical Effluents

The quantities of gaseous, liquid, and solid effluents needed to support the UFC for the 10 CFR 51.51 reference plant and for the SMRs at the CRN Site are presented in Table 5.7-2.

Gaseous effluents include the entrainment of the pollutants provided in Table 5.7-2. The effluent quantities from the UFC for the reference plant are from 10 CFR 51.51, Table S-3. The 0.98 scaling factor is applied to estimate the effluent quantities for the UFC supporting the SMRs at the CRN Site provided in Table 5.7-2. According to 10 CFR 51.51, Table S-3, the gaseous effluents from the UFC supporting the reference plant are equivalent to the gaseous effluents from a 45 MWe coal power plant. Applying the 0.98 scaling factor to each of the gaseous effluents and summing them, the gaseous effluents from the UFC supporting the SMRs at the CRN Site are equivalent to the gaseous effluents from a 44 MWe coal power plant.

Because of the gaseous effluents from the UFC needed to support the SMRs at the CRN Site are equivalent to the effluents from a small 44 MWe coal-fired power plant or, for an equivalent amount of energy produced with coal, the chemical effluents would be about 2.3 times greater. Therefore, it is concluded that the effects to the degradation of air quality from the power generation needed to support the UFC is SMALL.

Liquid chemical effluents produced during the UFC are associated with the fuel enrichment, fuel fabrication, and fuel reprocessing steps. While fuel reprocessing is not currently performed commercially in the United States, the effluent amounts provided in 10 CFR 51.51, Table S-3, and Table 5.7-2 include potential reprocessing activities. In Table 5.7-2 the 0.98 scaling factor is used to estimate the quantities of liquid chemical effluents from the UFC needs of the SMRs at the CRN Site. Because the effluents at these quantities require only small amounts of dilution by the receiving bodies of water to achieve concentrations that are below established standards, the effects to the degradation of water quality from the power generation needed to support the UFC is SMALL. Additionally, any liquid discharges into the navigable waters of the United States from power plants associated with UFC operations are subject to requirements and limitations set in National Pollutant Discharge Elimination System permits issued by an appropriate federal, state, regional, local, or affected Native American tribal regulatory agency.

Tailings solutions and solids are generated during the milling process; however, these materials are not released in quantities that would have a significant effect on the environment. Amounts of tailings and solids for the reference plant and the SMRs at the CRN Site are provided in Table 5.7-2. The effect of all effluent waste streams (gaseous, liquid, and solid) associated with the UFC needs for the SMRs at the CRN Site are considered to be SMALL.

5.7.1.5 Radioactive Effluents

The estimates of radioactive effluent releases from the UFC to the environment from one year of operation for the 10 CFR 51.51 reference plant and the SMRs at the CRN Site are presented in Table 5.7-2. Radioactive effluents from the UFC include gaseous and liquid effluents. However,

Table 5.7-2 does not address Rn-222 and its progeny (herein after referred to as Rn-222) from the UFC activity or Tc-99 released from waste management or reprocessing activities.

The 100-yr involuntary environmental dose commitment to the United States population from the reference plant's impact on the UFC is provided in Table 5.7-3. From NUREG-1437, Rev 1, Table 4.12.1.1-1, "Population Doses from Uranium Fuel Cycle Facilities Normalized to One Reference Reactor Year," the portion of dose commitment from radioactive gaseous effluents is 400 person-rem per year and the portion of dose commitment from radioactive liquid effluents per year due to all UFC operations is 200 person-rem. Applying the ratio of effective electric output values from Table 5.7-1 and the 0.98 scaling factor for the SMRs at the CRN Site, the dose commitment from radioactive gaseous and liquid effluents provided in Table 5.7-3 would be approximately 392 person-rem and 196 person-rem, respectively. Thus, the total 100-yr environmental dose commitment to the United States population from radioactive gaseous and liquid releases resulting from these portions of the UFC provided in Table 5.7-3 is 588 person-rem per year for the SMRs at the CRN Site.

Currently, the radiological effects associated with Rn-222 and Tc-99 releases are not addressed in the reference plant data in 10 CFR 51.51. Most Rn-222 releases are from mining and milling operations and emissions from mill tailings, and most Tc-99 releases are from gaseous diffusion enrichment facilities. Although the gaseous diffusion plants in the United States have been shut down, the following assessment is based on the assumption that gaseous diffusion plants are in operation.

In Table 6.2 of NUREG-1437, Rev. 0, the NRC staff estimated the Rn-222 releases from mining plus milling and emanating from mill tailings required to support each year of operations of the 1000-MWe reference plant to total 5200 curies (Ci). The major risks from Rn-222 are bone and lung cancer, and there is a small risk from whole body exposure. The organ-specific dose weighting factors from 10 CFR Part 20 are applied to the bone and lung doses to estimate the 100-yr dose commitment from Rn-222 to the whole body, which is estimated to be 140 person-rem for the reference plant. Using the 0.98 scaling factor, the Rn-222 releases from the UFC associated with SMRs at the CRN Site are estimated to be 5096 Ci and the estimated population dose commitment from mining, milling, and tailings before stabilization for each year of operation of SMRs at the CRN Site is estimated to be 136 person-rem (Table 5.7-4).

In NUREG-1437, Rev. 0, the NRC staff also considered the potential health effects associated with the release of Tc-99 as part of UFC operations. It was found that the releases of Tc-99 are from chemical reprocessing of recycled UF_6 before it enters the isotope enrichment cascade. The annual Tc-99 releases (in Ci) from the reference plant (0.012 Ci) and scaled releases from the SMRs at the CRN Site (0.012 Ci) are presented in Table 5.7-4.

The major risks from Tc-99 are from exposure of the gastrointestinal tract and kidney; additionally, there is a small risk from whole-body exposure. Using the organ-specific dose weighting factors from 10 CFR 20, these individual organ risks were converted to a whole-body

100-yr dose commitment per year of operation. These values are presented in Table 5.7-4 for the reference plant (100 person-rem) and for the SMRs at the CRN Site (98 person-rem).

Many 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. The Biological Effects of Ionizing Radiation (BEIR) VII report by the National Research Council, uses the linear, no-threshold dose response model as a basis for estimating the risks from low doses (Reference 5.7-8). 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 risk to the public from radiation exposure using the nominal probability coefficient for total detriment can be estimated. This coefficient has the value of 570 fatal cancers, nonfatal cancers, and severe hereditary effects per 1,000,000 person-rem. From Table 5.7-3, the total whole body population doses (including Rn-222 and Tc-99) would be 840 person-rem/yr for the 1000-MWe reference plant and 822 person-rem/yr for the SMRs at the CRN Site. The estimated number of fatal cancers, nonfatal cancers, and severe hereditary effects would be less than one per year for both the 1000-MWe reference plant and the new plant.

In addition, at the request of the U.S. Congress, the National Cancer Institute conducted a study and published "Cancer in Populations Living near Nuclear Facilities: A Survey of Mortality Nationwide and Incidence in Two States" in 1991 (Reference 5.7-9). 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 the UFC-related radiation and other sources is presented in Table 5.7-5. (Reference 5.7-10)

Based on the information presented above, it is concluded that the environmental effect (population dose) from radioactive effluents from the UFC demands for the SMRs at the CRN Site is considered to be SMALL.

5.7.1.6 Radioactive Wastes

The quantities (in Ci) of radioactive waste material generated as part of the UFC (low-level waste [LLW], high-level waste [HLW], and transuranic [TRU] waste) are shown in 10 CFR 51.51(a), Table S-3, and Table 5.7-2. For LLW disposal, the NRC indicates in Table S-3 that no significant radioactive releases to the environment are expected.

Pursuant to 10 CFR 51.23(b) and 10 CFR 51.50(b)(2), this Environmental Report does not discuss the environmental impacts of spent nuclear fuel storage in a spent fuel pool or an interim spent fuel storage installation (ISFSI) for the period following the term of the reactor operating license, reactor combined license, or ISFSI license. Rather, the impact determination in NUREG-2157, *Generic Environmental Impact Statement for Contained Storage of Spent Nuclear Fuel,* regarding continued storage is deemed incorporated into the environmental impact statement.

5.7.1.7 Occupational Dose

As provided in Subsection 6.2.2.3 of NUREG-1437, Rev. 0, the annual occupational dose for the reference 1000 MWe reactor attributable to all phases of the fuel cycle is 600 person-rem. The fuel cycle for the SMRs would be similar to the fuel cycle for the reference plant. Individual occupational doses are maintained to meet the dose limits in 10 CFR Part 20, which is 5 rem/yr. Therefore, the environmental effects from this occupational dose is considered to be SMALL.

5.7.1.8 Transportation

As shown in Table 5.7-2, the annual transportation dose from exposure to workers and the general public for the 10 CFR 51.51 reference plant is approximately 2.5 person-rem. Applying the scaling ratio, the total annual occupational dose attributable to all phases of the UFC needs for the SMRs at the CRN Site is estimated to be approximately 2.4 person-rem. For comparative purposes, the estimated annual dose from natural background radiation to a person living within 50 miles (mi) of the CRN Site is 0.36 rem per person (Reference 5.7-11). Given the size of the total population (worker and general public) exposed during transportation, it is concluded that the dose from transportation is considered to be SMALL.

5.7.1.9 Summary

Using the federal evaluation process in NUREG-1437, Rev. 0 and Rev. 1, the evaluation subsection has examined the environmental effect of the UFC, including the dose from Rn-222 and Tc-99, as it relates to the operation of SMRs at the CRN Site. Based on this evaluation, it is concluded that the environmental effects of the contributions to the UFC from the operation of SMRs at the CRN Site is considered to be SMALL.

5.7.2 Transportation of Radioactive Materials

The public dose from the transportation of all radioactive waste (LLW, HLW, and TRU waste) is discussed in the preceding Subsection 5.7.1.8. The following information supports the assessment of spent nuclear fuel transportation:

- Reactor type and rated core thermal power (Section 3.2)
- Fuel assembly description (Subsection 3.8.1)
- Average irradiation level of irradiated fuel (Subsection 3.2.1)
- Capacity of on-site storage facilities and minimum fuel storage time (Subsection 3.8.2)
- Transportation distances (Section 7.4)

5.7.2.1 Transportation Assessment

As detailed in the following subsections, the SMRs at the CRN Site do not meet all of the conditions for the reactor and fuel provided in 10 CFR 51.52(a). Specifically, the SRM fuel enrichment can be greater than 4 percent by weight and SMR fuel burnup can be greater than 33,000 megawatt-days per metric ton. Therefore, the analyses of fuel transportation effects for normal conditions and for accidents are presented in Subsection 5.7.2.2 and Section 7.4, respectively.

Nonradiological effects from the transportation of fuel (new and spent) and other radiological wastes are traffic density, weight of the loaded truck or railcar, heat from the fuel cask, and transportation accidents. The NRC evaluated the environmental effects of transportation of fuel and waste for LWRs and found the impacts to be SMALL. The NRC analyses provided the basis for Table S-4 in 10 CFR 51.52, which summarizes the environmental effects of transportation of fuel and radioactive wastes to and from a reference plant (Table 5.7-6 and Table 5.7-7). Table S-4 addresses two categories of environmental consideration: (1) normal conditions of transport, and (2) accidents during transport.

Subparagraphs 10 CFR 51.52(a)(1) through (5) delineate specific conditions the reactor licensee must meet to use Table S-4 as part of its environmental report. For reactors not meeting all of the conditions in paragraph (a) of 10 CFR 51.52, paragraph (b) of 10 CFR 51.52 requires further analysis of the transportation effects.

The conditions in paragraph (a) of 10 CFR 51.52 establishing the applicability of Table S-4 are reactor core thermal power, fuel form, fuel enrichment, fuel encapsulation, average fuel irradiation, time after discharge of irradiated fuel before shipment, mode of transport for unirradiated fuel, mode of transport for irradiated fuel, radioactive waste form and packaging, and mode of transport for radioactive waste other than irradiated fuel. The following subsections describe the characteristics of the SMRs at the CRN Site relative to the conditions of 10 CFR 51.52 for use of Table S-4. If the conditions of Table S-4 are not met, detailed transportation accident analyses are required.

5.7.2.1.1 Reactor Core Thermal Power

Subparagraph 10 CFR 51.5(a)(1) requires that for comparison to the reference plant, the new reactor must have a core thermal power level not exceeding 3800 Megawatt thermal (MWt). In Table 3.1-2, Item 16.1, the SMRs on the CRN Site have a combined maximum thermal power level of 2420 MWt. Therefore the sum of the thermal power for all new SMRs at the CRN Site meets this condition.

The initial core loading of the reference plant is 100 MTU. In Table 3.1-2, Item 18.0.2, the surrogate SMR core contains 96 fuel assemblies. The mass of the uranium in the fuel assemblies is 0.304 MTU per fuel assembly, resulting in an initial core loading of about 30 percent of the 100 MTU assumed for the reference plant.

5.7.2.1.2 Fuel Form

Subparagraph 10 CFR 51.52(a)(2) requires that the reactor fuel be in the form of sintered uranium dioxide pellets. In Table 3.1-2, Item 18.0.1, fuel for the SMRs at the CRN site would be a sintered UO_2 fuel. Therefore, the requirement is met.

5.7.2.1.3 Fuel Enrichment

Subparagraph 10 CFR 51.52(a)(2) requires that the reactor fuel have a U-235 enrichment not exceeding 4 percent by weight. AIn Table 3.1-2, Item 18.1, the SMR fuel would have an enrichment of less than 5 percent which can exceed this condition. However, NUREG/CR-6703, *Environmental Effects of Extending Fuel Burnup Above 60 GWd/MTU,* supported the conclusion that the environmental impacts of enrichments up to 5 percent were bounded by the impacts reported in Table S-4.

5.7.2.1.4 Fuel Encapsulation

Subparagraph 10 CFR 51.52(a)(2) requires that the reactor fuel pellets be encapsulated in Zircaloy rods. In Table 3.1-2, Item 18.7, the SMR fuel would use Zircaloy cladding and, therefore, meets the requirement.

5.7.2.1.5 Average Fuel Irradiation

Subparagraph 10 CFR 51.52(a)(2) requires that the average fuel burnup not exceed 33,000 MW-days per MTU. In Table 3.1-2, Item 18.2, average burnup for the SMR fuel assembly would be less than or equal to 51,000 MW-days per MTU which exceeds the limits of Table S-4. However, NUREG/CR-6703 supports the conclusion that the environmental impacts of higher fuel burnup rates were bounded by the impacts reported in Table S-4.

5.7.2.1.6 Time After Discharge of Irradiated Fuel Before Shipment

Subparagraph 10 CFR 51.52(a)(3) requires that no irradiated fuel assembly be shipped until at least 90 days after it is discharged from the reactor. The analysis provided by the NRC and referenced in Table S-4 assumes 150 days of decay time before shipment of any irradiated fuel assemblies (Reference 5.7-12). NUREG/CR-6703 assumes a minimum of 5 yr between removal from the reactor and shipment. NUREG-1437, Rev. 1, indicates that the NRC specifies 5 yr as the minimum cooling period when it issues certificates of compliance for casks used for shipment of power reactor fuel. Therefore, five years is considered the minimum decay time expected before shipment of irradiated fuel assemblies. In Table 3.1-2, 18.0.4, SMRs at the CRN Site would have a 6-yr storage capacity, which exceeds that needed to accommodate 5-yr cooling of irradiated fuel before removal from the spent fuel pool and either transferred to onsite dry storage or transport offsite. Therefore, the requirement is met.

5.7.2.1.7 Mode of Transport for Unirradiated Fuel

Subparagraph 10 CFR 51.52(a)(5) requires that unirradiated fuel be shipped to the reactor site by truck. Fuel is expected to be shipped to the CRN Site by truck from a fuel fabrication facility as far away as Washington State. Table S-4 includes a condition that truck shipment would not exceed 73,000 pounds. Fuel shipments to the CRN Site would comply with this and other state and federal requirements. Therefore, the criterion is met.

5.7.2.1.8 Mode of Transport for Irradiated Fuel

Subparagraph 10 CFR 51.52(a)(5) allows irradiated fuel to be shipped by truck, rail or barge. Irradiated fuel is expected to be shipped from the CRN Site by truck. Currently, the DOE is responsible for spent fuel transportation from reactor sites.

5.7.2.1.9 Radioactive Waste Form and Packaging

Subparagraph 10 CFR 51.52(a)(4) requires that radioactive waste be shipped from the reactor in packages and in a solid form (with the exception of irradiated fuel). As described in Subsection 3.8.3, the LLW generated by the SMRs at the CRN Site would be prepared, packaged, and shipped according to the U.S. Department of Transportation regulations. Therefore, the requirement is met.

5.7.2.1.10 Mode of Transport for Radioactive Waste

Subparagraph 10 CFR 51.52(a)(5) requires that the mode of transportation of LLW be either by truck or rail. LLW is expected to be shipped from the CRN Site by truck in accordance with state and federal requirements, including limiting shipments to 73,000 pounds. Therefore, the requirement is met.

5.7.2.1.11 Number of Truck Shipments

The NRC references the “Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants,” also referred to as “WASH-1238,” for transportation impacts from the 10 CFR 51.52 (Table S-4) reference reactor. Table S-4 specifies the following conditions for traffic density: less than one truck shipment per day or less than three rail cars per month. The number of truck shipments of unirradiated fuel, irradiated fuel, and solid radioactive waste to and from the CRN Site was calculated using the same truck loading rates as used in WASH-1238 or based on information provided in Table 3.1-2. The WASH-1238 truck shipments per year (traffic density) are compared to the CRN Site shipments in Table 5.7-7.

TVA estimates that 492 shipments of unirradiated fuel would be required for operating SMRs described by the PPE over 40 yr. In WASH-1238, the NRC assumed 18 shipments of new fuel would be made for the initial reactor loading of the 10 CFR 51.52 Table S-4 reference reactor and an additional 6 shipments per year for 39 yr resulting in a total of 252 shipments (Reference 5.7-12). The annual number of shipments of new fuel to the reference plant and the SMRs at the CRN Site are provided in Table 5.7-6. While the maximum number of fuel shipments for initial loading is 40, because the SMR design has not been selected and the initial loading scheme is not known, the average annual number assumes the same number of fuel shipments over the 40-yr lifetime of the SMRs.

TVA estimates that there would be 46 annual shipments of irradiated fuel from the SMRs at the CRN Site. As provided in Table 5.7-7, the normalized number of annual shipments is 57. The number of annual shipments of irradiated fuel from the reference reactor is 60 (Reference 5.7-12).

The number of solid radioactive waste shipments from the CRN Site is based on a volume of 5000 ft^3 per year as provided in Table 3.1-2, Item 11.2.3. As shown in Table 5.7-7, the number of solid radioactive waste shipments from the CRN Site would be about 61 truck shipments per year normalized to 75 shipments per year.

As shown in Table 5.7-8, the sum of the number of yearly truck shipments of fuel and radioactive waste to and from the CRN Site is estimated to be 147 trucks per year, or less than one truck shipment per day. Table S-4 from 10 CFR 50.52 also states that the reference reactor would have less than one truck shipment per day. Therefore the traffic density from the CRN Site would be comparable to the traffic density from the reference reactor.

5.7.2.1.12 Summary

Although the SMRs at the CRN Site meet most of the conditions in 10 CFR 51.51 and 51.52, the conditions for fuel burnup and fuel enrichment are not met. Therefore, TVA provided additional transportation analyses. These analyses are presented in Subsection 5.7.2.2 and Section 7.4, respectively.

5.7.2.2 Incident-Free Transportation Impact Analysis

The environmental impacts of radioactive materials transportation were estimated using the most recent version of the RADTRAN 6.5 computer code. RADTRAN is a nationally accepted standard program and code for calculating the risks of transporting radioactive materials. RADTRAN was used in estimating the radiological doses and dose risks to populations and transportation workers resulting from incident-free transportation and to the general population from accident scenarios. For the analysis of incident-free transportation risks, the code used scenarios for persons who would share transportation routes with shipments, persons who live along the route of travel, and persons exposed at stops. Environment impacts of incident-free transportation of fuel are discussed in this subsection. Transportation accidents are discussed in Section 7.4.

5.7.2.2.1 Transportation of Unirradiated Fuel

Table S-4 of 10 CFR 51.52 includes conditions related to radiological doses to transport workers and members of the public along transport routes. These doses, based on calculations in

WASH-1238 (Reference 5.7-12), are a function of the radiation dose rate emitted from the unirradiated fuel shipments, the number of exposed individuals and their locations relative to the shipment, the time of transit (including travel and stop times), and the number of shipments to which the individuals are exposed.

Calculation of worker and public doses associated with annual shipments of unirradiated fuel were performed using the WebTRAGIS and RADTRAN computer codes. One of the key assumptions in WASH-1238 for the reference LWR unirradiated fuel shipments is that the radiation dose rate at 3 feet from the transport vehicle is 0.1 millirem/hour (hr). This assumption is reasonable for the new plant technologies because the fuel materials would be low-dose rate enriched uranium and would be packaged similarly to the fuel analyzed in WASH-1238 (inside a metal container that provides sufficient radiation shielding).

For unirradiated fuel shipments, highway routes are analyzed using the routing computer code WebTRAGIS. It is assumed that all unirradiated fuel shipments come from Richland, Washington. The commercial route setting was used to generate highway routes generally used by commercial trucks. The distance from the CRN Site to Richland, Washington is 2281.9 mi. The population summary module of the WebTRAGIS computer code is used to determine the exposed populations within a half-mile band on either side of the route.

The per trip dose values are combined with the average annual number of shipments of unirradiated fuel to calculate annual doses to the public and workers for comparison to Table S- 4 dose values. The number of shipments per year is obtained from Table 5.7-6. The incident-free dose rates (in person-rem per shipment) were calculated by RADTRAN and are provided in Table 5.7-9. The dose rates ranged from 1.47E-02 person-rem per year for the transportation crew to 1.04E-03 person-rem per year for the public along the transportation route.

5.7.2.2.2 Transportation of Irradiated Fuel

The environmental impacts of transporting spent fuel from the CRN Site to a spent fuel disposal facility assume Yucca Mountain, Nevada as a possible location for a geologic repository. The impacts of the transportation of spent fuel to a possible repository in Nevada provides a reasonable determination of the transportation impacts to a monitored retrievable storage facility because of the distances involved and the representative exposure of members of the public in urban, suburban, and rural areas.

Incident-free transportation refers to transportation activities in which the shipments reach their destination without releasing any radioactive cargo to the environment. Impacts from these shipments are from the low levels of radiation that penetrate the heavily shielded spent fuel shipping cask. Radiation doses occur to the following:

- Persons residing along the transportation corridors between the CRN Site and the potential repository

- Persons in vehicles passing a spent fuel shipment
- Persons at vehicle stops for refueling, rest, and vehicle inspections
- Transportation crew workers

This analysis is based on shipment of spent fuel by legal-weight trucks in casks with characteristics similar to casks currently available (i.e., massive, heavily shielded, cylindrical metal pressure vessels). Each shipment is assumed to consist of a single shipping cask loaded on a modified trailer. These assumptions are consistent with assumptions made in evaluating environmental impacts of spent fuel transportation in Addendum 1 to NUREG-1437, Rev. 0. As discussed in NUREG-1437, Rev. 0, these assumptions are conservative because the alternative assumptions involve rail transportation or heavy-haul trucks that reduce the overall number of spent fuel shipments.

The transportation route selected for a shipment determines the total potentially exposed population and the expected frequency of transportation-related accidents. For truck transportation, the route characteristics most important to the risk assessment include the total shipping distance between each origin-destination pair of sites and the population density along the route.

For irradiated fuel, it is assumed that all irradiated fuel is sent to the potential Yucca Mountain repository. The distance from the CRN Site to the repository was determined to be 2265.4 mi by the WebTRAGIS (Reference) computer code for a highway route-controlled quantity. Routing and population data used in RADTRAN for truck shipments were obtained from the WebTRAGIS computer code. The population data in the WebTRAGIS computer code is based on the 2010 United States census.

The population doses are calculated by multiplying the number of spent fuel shipments per year by the per-shipment doses. The numbers of shipments per year are obtained from Table 5.7-7. The incident-free dose rates (in person-rem per shipment) were calculated by RADTRAN and are provided in Table 5.7-9. The dose rates ranged from 7.64 person-rem per year for the transportation crew to 0.482 person-rem per year for the public along the transportation route.

5.7.2.2.3 Transportation of Radioactive Waste

Incident-free transportation refers to transportation activities in which shipments reach their destination without releasing any radioactive cargo to the environment. Impacts from these shipments are from the low levels of radiation that penetrate the radioactive waste shipping containers. Radiation doses occur to the following:

- Persons residing along the transportation corridors between the CRN Site and the potential repository
- Persons in vehicles passing a radioactive waste shipment

- Persons at vehicle stops for refueling, rest, and vehicle inspections
- Transportation crew workers

This analysis is based on shipment of radwaste by legal-weight trucks in either sea-land containers or high-integrity containers similar to those currently available. Each shipment is assumed to consist of a single shipping container from the CRN Site to Andrews, Texas.

The transportation route selected for a shipment determines the total potentially exposed population and the expected frequency of transportation-related accidents. For truck transportation, the route characteristics most important to the risk assessment include the total shipping distance between each origin-destination pair of sites and the population density along the route.

For radioactive waste, WebTRAGIS selected a commercial route of Interstate highways through Tennessee, Arkansas, and Texas. The route is 1162.0 mi with an elapsed time of about 27.5 hr.

Routing and population data used in RADTRAN for truck shipments was obtained from the WebTRAGIS computer code. The population data in the TRAGIS computer code is based on the 2010 United States census. All radioactive waste shipments are transported by legal-weight trucks to the Texas site over commercial truck routes.

The population doses are calculated by multiplying the number of radioactive waste shipments per year by the per-shipment doses. The numbers of shipments per year are identified in Table 5.7-7. The incident-free dose rates (in person-rem per shipment) were calculated by RADTRAN and are provided in Table 5.7-9. The dose rates ranged from 4.78 person-rem per year for the transportation crew to 0.422 person-rem per year for the public along the transportation route.

5.7.2.2.4 Comparison to 10 CFR 51.52 Table S-4

For an equal comparison to the reference reactor in 10 CFR 51.52 Table S-4, the number of shipments in Table 5.7-8 for the SMR must be normalized. For each technology, the number of shipments is normalized based on net electric generation relative to the 1100 MWe and 80 percent capacity factor reference reactor analyzed in WASH-1238 (NUREG-1555, *Standard Review Plans for Environmental Reviews for Nuclear Power Plants: Environmental Standard Review Plan*). Additionally, the unirradiated fuel shipments are adjusted to account for the initial core loading in the annual number of shipments for each reactor technology. The spent fuel shipments are scaled to reflect the capacity of 0.5 MTU/container used for the reference reactor. The radioactive waste shipments are scaled to reflect a capacity of 82.6 ft^3 per shipment (2.34 cubic meters (m^3) per shipment) for high activity waste used for the reference reactor. The radioactive waste shipments reflect a capacity of 28.32 m^3 per shipment. This container size is based on a 20-ft shipping container. The resulting annual truck shipments normalized to the reference reactor are summarized in Table 5.7-8. Annual doses provided in Table 5.7-9 are based on the normalized number of shipments.

Table 5.7-9 provides a total transportation worker dose of 12.4 person rem per reactor year. This compares against the Table S-4 value of 4 person-rem per reactor year. While the estimate is more than four times the Table S-4 value, it is still considered small given the increased number of normalized shipments, and the greater assumed transportation distances (WASH-1238 uses 1000 mi for unirradiated fuel shipments, 1000 mi for irradiated fuel shipments, and 500 mi for radioactive waste shipments (Reference 5.7-12)). The doses provided in Table 5.7-9 also assume the maximum dose rate for all shipment types, and the use of 30 minutes as the average time for a truck stop in the calculations.

Table 5.7-9 also provides a total onlooker dose of 4.36 person rem per reactor year. Onlookers are members of the public exposed to a shipping container for a short duration during periods when the transportation vehicle is stopped. This compares against the Table S-4 value of 3 person-rem per reactor year. While the estimate is slightly more the Table S-4 value, it is still considered small given the increased number of normalized shipments, the greater assumed transportation distances, and the increased populations along the transportation routes. Table S-4 does not provide a cumulative dose for the population exposed along the transportation routes for direct comparison.

5.7.2.3 Summary

A detailed analysis of the environmental impacts for the transportation of unirradiated fuel, irradiated fuel, and radioactive waste transported to and from the CRN Site was performed in accordance with 10 CFR 51.52(b). An evaluation of the environmental impact due to transportation of unirradiated fuel, irradiated fuel, and radioactive waste at alternative indicates that the alternative sites are not obviously superior to the CRN Site.

The new plant would have sufficient fuel pool storage capacity to enable a minimum cooling period of five years and sufficient storage capacity to permit irradiated fuel to cool sufficiently to meet the requirements of shipping casks available at the time the fuel is shipped.

In the analysis it was assumed that all shipments of unirradiated fuel, irradiated fuel, and radioactive waste are by truck. The shipping weights would comply with federal, state, local, and tribal government restrictions as appropriate. The total number of shipments for the CRN Site are outlined in Table 5.7-8, is 147 per year (normalized) which meets the Table S-4 requirement of less than one per day.

The radiological effects of incident-free conditions of transport are summarized in Table 5.7-9. The radiological effects of accidents in transport are provided in Section 7.4. The values obtained from these analyses represent the impacts from incident-free transportation of radioactive materials to and from the CRN Site. The population doses to the transport crew and onlookers resulting from the new plant normalized to the reference reactor exceed Table S-4 values. However, these increases are reasonable given the different exposure parameters between WASH-1238 and the CRN Site RADTRAN model. Therefore, based on the analyses and above discussion, the environmental impacts of transportation of unirradiated fuel, irradiated fuel, and radioactive waste would be SMALL.

5.7.3 References

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Reference 5.7-6. U.S. Nuclear Regulatory Commission, "Final Environmental Impact Statement for Combined Licenses for Virgil C. Summer Nuclear Station Units 2 and 3," NUREG-1939, Vol. 1, Washington, DC, April, 2011.

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Reference 5.7-9. National Cancer Institute, No Excess Mortality Risk Found in Counties with Nuclear Facilities - Fact Sheet, Website: http://www.cancer.gov/cancertopics/factsheet/Risk/nuclear-facilities, April 19, 2011.

Reference 5.7-10. U.S. Nuclear Regulatory Commission, Sources of Radiation, Website: http://www.nrc.gov/about-nrc/radiation/around-us/sources.html, June 28, 2013.

Reference 5.7-11. U.S. Nuclear Regulatory Commission, Personal Annual Radiation Dose Calculator, Website: http://www.nrc.gov/about-nrc/radiation/around-us/calculator.html, June 28, 2013.

Reference 5.7-12. U.S. Atomic Energy Commission, "Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants (WASH-1238)," December, 1972.

Table 5.7-1
Scaling Factor- Reference Plant and CRN SMRs

Parameter	10 CFR 51.51 Reference Plant (1000 MWe LWR)	CRN Site SMRs
Net Electric Output	1000 MWe	800 MWe
Capacity Factor	80 percent	98 percent
Effective Electric Output	1000 MWe x 80 percent = 800 MWe	800 MWe x 98 percent = 784 MWe
Ratio of Effective Electric Output Values	1	0.98[1]

[1] This scale factor is used to calculate the Standard Plants values in the remaining tables of this section.

Table 5.7-2 (Sheet 1 of 4)
Uranium Fuel Cycle Environmental Data

Environmental Considerations	Annual Fuel Requirement Impacts 10 CFR 51.51 Reference plant		Annual Fuel Requirement Impacts CRN Site SMRs	
	Reference plant Data	Maximum effect per annual fuel requirement or RRY	Reference Reactor Data multiplied by scale factor = 0.98	Maximum effect per annual fuel requirement or RRY multiplied by scale factor
Natural Resource Use				
Land (ac)				
Temporarily committed	100		98	
Undisturbed area	79		77.4	
Disturbed area	22	This is equivalent to a 110 MWe coal-fired power plant.	21.6	This is equivalent to an 88 MWe coal-fired power plant; 89% less energy per ac than the SMR option
Permanently committed	13		12.7	
Overburden moved, million MT	2.8	This is equivalent to a 95 MWe coal-fired power plant.	2.74	This is approximately equivalent to a 93 MWe coal-fired power plant; 88% less energy per ac than the SMR option
Water (millions of gal)				
Discharged to air	160	= 2 percent of model 1000 MWe LWR with cooling tower	157	< 2 percent of model 1000 MWe LWR with cooling tower
Discharged to water bodies	11,090		10,868	
Discharged to ground	127		124	
Total	11,377	< 4 percent of the water needs of the 1000 MWe LWR with once-through cooling.	11,149	< 4 percent of the water needs of the 1000 MWe LWR with once-through cooling.

Table 5.7-2 (Sheet 2 of 4)
Uranium Fuel Cycle Environmental Data

Environmental Considerations	Annual Fuel Requirement Impacts 10 CFR 51.51 Reference plant		Annual Fuel Requirement Impacts CRN Site SMRs	
	Reference plant Data	Maximum effect per annual fuel requirement or RRY	Reference Reactor Data multiplied by scale factor = 0.98	Maximum effect per annual fuel requirement or RRY multiplied by scale factor
Fossil fuel				
Electrical energy, MW hour (MWh)	323,000 MWh	< 5 percent of model 1000 MWe output	316,540 MWh	< 5 percent of model 1000 MWe output
Equivalent coal (MT)	118,000	This is equivalent to the consumption of a 45 MWe coal-fired power plant.	115,640	This is equivalent to the consumption of a 44 MWe coal-fired power plant.
Natural gas (standard cubic feet [scf])	135 million		132 million	
Chemical Effluents (MT)				
Gases, incl. entrainment				
SO_x	4400	These values are equivalent to the emissions from a 45 MWe coal-fired plant for a year.	4312	These values are equivalent to the emissions from a 44 MWe coal-fired plant for a year.
NO_x	1190		1166	
Hydrocarbons	14		13.7	
CO	29.6		29.0	
Particulates	1154		1131	
Other gases				
F	0.67		0.66	
HCl	0.014		0.014	
Liquids				
SO^-_4	9.9		9.7	
NO^-_3	25.8		25.3	

Table 5.7-2 (Sheet 3 of 4)
Uranium Fuel Cycle Environmental Data

Environmental Considerations	Annual Fuel Requirement Impacts 10 CFR 51.51 Reference plant		Annual Fuel Requirement Impacts CRN Site SMRs	
	Reference plant Data	Maximum effect per annual fuel requirement or RRY	Reference Reactor Data multiplied by scale factor = 0.98	Maximum effect per annual fuel requirement or RRY multiplied by scale factor
Fluoride	12.9		12.6	
Ca^{++}	5.4		5.3	
Cl^{-}	8.5		8.33	
Na^{+}	12.1		11.9	
NH_3	10.0		9.8	
Fe	0.4		0.4	
Tailings solutions	240,000		235,200	
Solids	91,000		89,180	
Radiological Effluents, Ci				
Gases, incl. entrainment				
Rn-222	-		-	
Ra-226	0.02		0.02	
Th-230	0.02		0.02	
U	0.034		0.033	
H-3 (thousands)	18.1		17.7	
C-14	24		23.52	
Kr-85 (thousands)	400		392	
Ru-106	0.14		0.13	
I-129	1.3		1.3	
I-131	0.83		0.81	

Table 5.7-2 (Sheet 4 of 4)
Uranium Fuel Cycle Environmental Data

Environmental Considerations	Annual Fuel Requirement Impacts 10 CFR 51.51 Reference plant		Annual Fuel Requirement Impacts CRN Site SMRs	
	Reference plant Data	**Maximum effect per annual fuel requirement or RRY**	**Reference Reactor Data multiplied by scale factor = 0.98**	**Maximum effect per annual fuel requirement or RRY multiplied by scale factor**
Tc-99	-		-	
Fission products and transuranics (TRU)	0.203		0.199	
Liquids				
Uranium and daughters	2.1		2.06	
Ra-226	0.0034		0.0033	
Th-230	0.0015		0.0015	
Th-234	0.01		0.0098	
Fission and Activation	5.9×10^6		5.8×10^6	
Solids (buried onsite)				
Other than high level waste (HLW) (shallow)	11,300		11,074	
TRU and HLW (deep)	11,000,000		10,780,000	
Other Environmental Considerations				
Thermal Effluents, (Billions of British thermal units [Btu])	4063 billion Btu	< 5 percent of the model 1000 MWe LWR	3982 billion Btu	< 5 percent of the model 1000 MWe LWR
Transportation				
Exposure of workers and the general public	2.5 person-rem		2.4 person-rem	
Occupational exposure	22.6 person-rem	From reprocessing and waste management	22.1 person-rem	From reprocessing and waste management

Table 5.7-3
Whole Body 100-Year Dose Commitment Estimate

Uranium Fuel Sources	10 CFR 51.51 Reference Plant (person-rem)	CRN Site SMRs (person-rem)
From radioactive gaseous effluents (all fuel operations excluding reactor releases and the dose commitment due to Rn-222 & Tc-99)	400	392
From radioactive liquid effluents (all fuel-cycle operations excluding reactor operation)	200	196
Subtotal	600	588
Total Rn-222 (see Table 5.7-4)	140	136
Total Tc-99 (see Table 5.7-4)	100	98
Total with Rn-222 and Tc-99	840	822

Table 5.7-4
Estimated 100-Year Environmental Dose Commitment from Mining and Milling for Each Year of Operation

	1000 MWe Reference plant NUREG-1437, Rev. 0, Subsection 6.2.2.1		Facility CRN Site SMRs	
	Annual Release (Ci)	100-year Committed Dose (person-rem)	Annual Release (Ci)	100-year Committed Dose (person-rem)
Radon-222				
Mining	4100	110	4018	108
Milling and tailings (other than stabilized)	1100	29	1078	28
Total for Rn-222	5200	140	5096	136
Technetium-99				
Chemical reprocess	0.007	100	0.007	98
Groundwater	0.005		0.005	
Total for Tc-99	0.012	100	0.012	98

Table 5.7-5
Radiation Exposure to the United States Population

Exposure Source	Average Dose Equivalent to United States Population (mrem/yr)
Natural:	
Radon/Thoron	229
Cosmic	31
Other	50
Occupational	0.62
Consumer Products	12
Medical:	
Medical Procedures	223
Nuclear medicine	74
Approximate Total	620

Source: (Reference 5.7-10)

Table 5.7-6
Number of Truck Shipments of Unirradiated Fuel

Reactor Type	Number of Fuel Shipments		
	Initial Load[1]	Annual Reload[2]	Total
Reference LWR	18[2]	6	252
SMRs at the CRN Site	40 (maximum)	12 (assumed even loading over 40 years)	492
Normalized	NA	15	600

1 Shipments of the initial core have been rounded up to the next highest whole number.
2 The initial core load for the reference PWR in WASH-1238 was 100 MTU with 18 truck shipments (Reference 5.7-12).

Notes:
NA = Not Applicable

Table 5.7-7
Number of Radioactive Waste Shipments

Reactor Type	Waste Generation Rate	Number of Shipments per reactor-yr	Normalized Shipments per reactor-yr
Irradiated Fuel			
Reference LWR	30 MTU per year	60	NA
SMRs at the CRN Site	10.6 MTU per year	46	57
Solid Radioactive Waste			
Reference LWR	3800 cubic feet per year	46	-NA
SMRs at the CRN Site	5000 cubic feet per year	61	75

Note:
NA = Not Applicable

Table 5.7-8
CRN Site SMR Comparisons to 10 CFR 51.52 Reference Conditions

Characteristic	Reference Reactor 10 CFR 51.52/WASH-1238[1]	CRN Site SMRs
Thermal Power Rating (MWt)	3800 MWt	2420 MWt
Fuel Form	Sintered uranium dioxide pellets	Sintered uranium dioxide pellets
U-235 Enrichment (%)	< 4	< 5
Fuel Rod Cladding	Zircaloy rods	Zircaloy rods
Average Fuel Irradiation (MWd per MTU)	≤ 33,000	≤ 51,000
Unirradiated Fuel		
Transport Mode	Truck	Truck
Irradiated Fuel		
Transport Mode	Truck, rail, or barge	Truck, rail, or barge
Decay time before shipment	> 5 years per contract with DOE	> 5 years per contract with DOE
Radioactive Waste		
Transport Mode	Truck or rail	Truck or rail
Waste Form	Solid	Solid
Packaged	Yes	Yes
Traffic Density (shipments)		
Unirradiated Fuel – Initial Loading	12	40
Unirradiated Fuel - Reload	15/year	12.3/year 15/year normalized
Irradiated Fuel	60/year	46/year 57/year - normalized
Radioactive Waste	46/year	61/year (75/year normalized)
Total	121/year	119.3/year (147 – normalized)
Trucks per day	< 1/day	< 1/day

1 (Reference 5.7-12)

Table 5.7-9
Total Shipment Cumulative Dose Summary

Exposed Population	Dose (Person – rem/yr)			
	Unirradiated Fuel	Irradiated Fuel	Radioactive Waste	Total
Transportation Workers (Crew)	1.47E-02	7.64E+00	4.78E+00	1.24E+01
General Public				
Along Route (Off Link)	1.04E-03	4.82E-01	4.22E-01	9.05E-01
Onlookers (On link & Stops	5.39E-03	2.70E+00	1.65E+00	4.36E+00