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Chapter 5 Environmental Impacts of Station Operation

This chapter presents the potential environmental impacts from the operation of new nuclear reactor units on the ESP site. In accordance with 10 CFR 51, impacts are analyzed, and a single significance level of potential adverse impacts (i.e., SMALL, MODERATE, or LARGE) has been assigned to each analysis. This is noted in respective topic discussions. Mitigation of adverse impacts is also presented, where appropriate. This chapter is divided into 11 sections:

- Land use impacts
- Water-related impacts
- Cooling system impacts
- Radiological impacts of normal operation
- Environmental impacts of waste
- Transmission system impacts
- Uranium fuel cycle impacts
- Socioeconomic impacts
- Decommissioning
- Measures and controls to limit adverse impacts during operation
- Cumulative Impacts

5.1 Land Use Impacts

The following subsections describe the impacts of operation of VCS units on land use at the VCS site, the 6-mile vicinity, and associated transmission line corridors, including impacts to historic and cultural resources. Operation of VCS is not anticipated to affect any current or planned land uses.

5.1.1 The Site and Vicinity

This subsection describes the impact of operation of VCS on land use at the VCS site and on the 6-mile vicinity.

5.1.1.1 The Site

Land use impacts from construction are described in Subsection 4.1. As described in Section 4.1, 6354 acres of the 11,532 acres proposed for the development of the VCS facility would be permanently disturbed during the operational life of the facility. The proposed units and associated buildings and switchyard/substation would occupy 420 acres. Approximately 149 acres within the site boundary would be associated with the transportation corridor, haul road, rail spur, and pipelines. The proposed cooling basin would occupy approximately 5785 acres, of which 4926 acres represent the size of the cooling basin at its normal high water level.

Exelon will enter into an agreement to purchase the proposed 11,532-acre site for construction of a nuclear power plant at the time of submission of the COL application. Under the purchase agreement for the site, Exelon will have the right to purchase the sellers' approximately 30 percent interest in the mineral rights underneath the power block and the right to purchase from the sellers a surface waiver within the exclusion area boundary and the area comprising the cooling basin. Based on advice from Exelon's oil and gas valuation experts, and their own oil and gas valuation experts, the current landowners have agreed that using the Mineral Valuation Formulas is a fair and reasonable method for calculating the value of the mineral interests to be acquired. Exelon will seek to obtain agreements to purchase the remaining mineral rights and associated oil and gas leases affecting the power block, and obtain surface waivers, within the exclusion area boundary and the area comprising the cooling basin from the remaining mineral owners and oil and gas lessees at the COL stage. For the mineral rights and associated oil and gas leases outside the power block, the exclusion area boundary, and the cooling basin, Exelon will evaluate, at the COL stage, the impact on operations of allowing the current land use or oil and gas exploration and development to continue. In cases where safety or other considerations indicate that the current land use or oil and gas exploration and development should not continue, Exelon will either purchase the mineral rights and associated oil and gas leases or obtain a waiver of the right to access the mineral rights through the surface. If necessary, Exelon will condemn the mineral interest rights and oil and gas leaseholds that it is unable to obtain through a negotiated purchase.

The only additional impacts to land use from operations will be the impacts of salt deposition and shadowing from mechanical draft cooling tower operation (Subsection 5.3.3.1). The cooling basin and mechanical draft cooling tower designs are described in Subsection 3.4.2. The impacts of the heat dissipation system, including deposition and shadowing from the mechanical draft cooling towers, are described in Subsections 5.3.3.1 and 5.3.3.2. The maximum predicted salt deposition outside of the immediate vicinity of the mechanical draft cooling towers is 0.10 pounds per acre per month and would occur in the summer months approximately 980 feet to the west-southwest from the centerpoint of the mechanical draft cooling towers. Annually, the salt deposition would average 0.043 pounds per acre per month, also in the west-southwest direction and 980 feet from the mechanical draft cooling towers. As described in Subsection 5.3.3.1.3, the predicted salt deposition is below the concentrations that could damage sensitive vegetation. Shadowing was predicted to occur for 380 hours annually, which is a small percentage of the total hours of daylight per year. Shadowing would primarily occur onsite. Exelon concludes that impacts to land use from VCS operations would be SMALL and would not warrant mitigation.

5.1.1.2 The Vicinity

As described in Section 2.5, the impact evaluation assumes that the residences of the in-migration operations employees would be distributed across the region but are expected to concentrate in the region of influence (ROI) comprised of the following six counties: Calhoun, DeWitt, Goliad, Jackson, Refugio and Victoria. Exelon estimates the operations work force at the VCS site would be 800 onsite employees (Subsection 3.10.3). Subsection 5.8.2 describes the impact of 800 new employees on the region’s housing market and the increases in tax revenues.

Exelon assumes no employees would live inside the vicinity of VCS as the land immediately adjacent to the site is owned by private parties and is unavailable for development. Therefore, it is likely that the new employees would choose to settle and purchase homes or acreage outside of the vicinity but in the ROI.

Exelon concludes that operations impacts to land use in the 6-mile vicinity would be SMALL and not warrant mitigation.

5.1.2 Transmission Corridors and Offsite Areas

Land proposed to be used for transmission corridors and offsite areas is described in Subsection 2.2.2. Land use impacts from the operation of VCS would be primarily evident in the ROI. Assuming the representative corridor described in Subsection 2.2.2, the new transmission corridors would require approximately 2809 acres of undeveloped land.

5.1.2.1 Transmission Corridors

American Electric Power (AEP) would own and operate the offsite transmission lines. Exelon expects that AEP would ensure that land use in the corridors and beneath the high-voltage lines is compatible with the reliable transmission of electricity. Vegetation communities in these corridors would be kept at an early successional stage by mowing and application of herbicides and growth-regulating chemicals. In some instances, AEP could allow farmers to grow feed (hay, wheat, corn) for livestock or graze livestock in these rights-of-way. AEP may also allow hunt clubs and individuals to plant wildlife foods for species such as quail, dove, wild turkey, and white-tailed deer. AEP would retain control and management of these rights-of-way that precludes virtually all residential and industrial uses of the transmission corridors. AEP would be expected to establish corridor vegetation management and line maintenance procedures for the proposed connector lines or incorporate the new lines under existing procedural plans. Access to transmission corridors is typically via public roads or through private property access locations where the transmission company has access agreements in place with the landowner.

Exelon concludes that operational impacts to land use in transmission corridors during operations would be SMALL and not require mitigation.

5.1.2.2 Cooling Basin Blowdown Line and Transportation Corridor

As described in Subsections 2.2.2 and 4.1.2.2, a 48-inch cooling basin blowdown discharge pipeline would be buried within the right-of-way of the heavy haul road built on the VCS site and the VCND transportation corridor. The offsite portion of the blowdown line would traverse Black Bayou through the Guadalupe River 100-year floodplain, terminating at the Guadalupe River. The transportation corridor would continue eastward across the Guadalupe river to the Victoria Barge Canal and eventually end at the Port of Victoria Turning Basin, which would be used for offloading large components needed for plant construction or operation.

Upon completion of the blowdown pipeline construction, the disturbed land would be recontoured and revegetated for possible future use. Exelon would maintain control over the right-of-way, but could allow this acreage to be used by current landowners for agricultural use. Exelon could access the discharge line right-of-way from the transportation corridor.

During the operations phase, Exelon’s use of the heavy haul road and transportation corridor would be infrequent. The land use changes effected during construction of the road (Section 4.1) would continue to exist into the operations phase. Given that the land use changes occurred during construction, Exelon concludes that operations phase land use changes from the heavy haul road would be SMALL.

5.1.2.3 Rail Spur Connection

The rail spur connecting the Union Pacific rail line to the VCS site would be left in place after construction for possible future use related to VCS operations. Exelon would maintain the rail spur. Because the rail spur is short (less than 0.25 mile offsite), Exelon concludes that impacts to land use due to the rail spur operations would be SMALL and would not warrant mitigation.

5.1.2.4 RWMU System and Intake Structure

As described in Subsection 4.1.2.4, a new raw water makeup (RWMU) system pumping station and canal would be located approximately 0.6 miles southwest of the GBRA Saltwater Barrier on the Guadalupe River and approximately 11 miles southeast of the VCS site. Three possible routes for the RWMU pipeline have been surveyed and the disturbed acreage ranges from 119 to 159 acres.

Upon completion of construction activities, the RWMU system and intake structure would be functional and permanent. VCS and/or the GBRA would operate and maintain the intake line. VCS and/or the GBRA would maintain control over the right-of-way, but could allow this acreage to be used by current landowners for agricultural use after construction activities were finished. VCS and/or the GBRA could access the right-of-way during operations for maintenance along public roads or through access agreements with adjacent landowners.

Due to the fact that the disturbance of land primarily occurs during construction, Exelon concludes that impacts to land use due to operation of the RWMU system would be SMALL and would not warrant mitigation.

5.1.2.5 Emergency Operations Facilities

Exelon will maintain an emergency operations facility (EOF) to assist with the management of off-normal events at VCS. The EOF will also serve to coordinate event response activities with federal, state and local emergency management agencies. The EOF will be located in Victoria, Texas. This facility is outside the VCS 10-mile emergency planning zone. Currently, this building provides office space for various city government functions; however, it will be refurbished and equipped to become a state-of-the-art EOF. There would be no impacts to land use.

5.1.2.6 Waste Disposal

VCS would generate low-level radioactive wastes that would require disposal in permitted radioactive waste disposal facilities and nonradioactive wastes that would require disposal in permitted landfills. Both types of waste are commonly generated, and permitted facilities are located throughout the country. As described in Subsection 5.5.1.2, there is adequate capacity in the vicinity of VCS to meet the projected demand for nonhazardous solid waste disposal for several decades. New construction of disposal facilities would not be required. Exelon concludes that impacts to offsite land use due to disposal of wastes generated at VCS would be SMALL and would not warrant mitigation.

5.1.3 Historic Properties and Cultural Resources

Exelon conducted Phase 1a and 1b investigations of the VCS site. The methodologies and results are described in detail in Subsection 2.5.3. The results of the Phase 1a and 1b investigations were described in reports that were submitted to the Texas Historical Commission (THC) for review. Phase 1b investigations identified no archaeological sites on the VCS site that are eligible or potentially eligible for listing on the National Register of Historic Places (NRHP). The VCS site is part of an NRHP-eligible rural historic landscape and numerous ranching and oil and gas-related features within the VCS site are contributing elements to this historic property. Fifty-three historic properties that are eligible for listing on the NRHP were identified within the visual effects area of potential effect (APE), a 10-mile radius surrounding the VCS site. Thirty-six of the 53 historic properties are part of a proposed historic district and are also contributing elements to the rural historic landscape.

Historic properties identified in the APE for physical disturbance could be adversely affected during construction of the VCS. Operational activities would occur in areas that were previously disturbed during construction of the VCS. Thus, operational activities would have a SMALL effect on these historic properties in the physical disturbance APE and would not require mitigation.

As described in Subsection 4.1.3, 38 of the 53 historic properties located in the visual effects APE could be adversely affected by the presence of the VCS through the introduction of a large, modern structure into the settings of the properties. Subsection 5.3.3.1 summarizes the predicted amount of pluming, fogging, icing, and salt deposition for the cooling basin and the mechanical draft cooling towers. No elevated plumes from the cooling basin would occur, and the ground level fog from the cooling basin would dissipate before reaching the site boundary. Fogging, icing, and salt deposition are predicted to be minimal or nonexistent for the mechanical draft cooling towers. Operation of the mechanical draft cooling towers would result in average plume heights ranging from 160 feet (in summer) to 544 feet (in winter) (Subsection 5.3.3.1.1). This plume would be visible from historic properties in the visual effects APE. The degree of visibility would depend on the season and resulting height of the plume. It would also depend on the weather, because even a partly cloudy sky would reduce the visibility of a plume. Overall, visibility of the plume would be intermittent during an average year. As described previously, construction of the VCS structures themselves would have an adverse effect on the settings of historic properties in the APE. While operation of the VCS and the resulting plume would be additive to this effect, the plume itself would have a SMALL effect on the historic properties and would not require additional mitigation.

With operational and maintenance activities, there is always the possibility for inadvertent discovery of previously unknown archaeological resources or human remains on the VCS site. The

Memorandum of Agreement between NRC, State Historic Preservation Office, Exelon, and the Advisory Council on Historic Preservation would include provisions to deal with these discovery situations, in compliance with the National Historic Preservation Act and the Texas Antiquities Code. As indicated in Section 4.1, Exelon would develop internal procedures to implement the discovery provisions in the Memorandum of Agreement.

Operational and maintenance activities for the RWMU and blowdown pipelines and the heavy haul road would be conducted within areas previously disturbed during construction. Because these portions of the project would either be buried or constructed near ground level, there is little potential for visual effects to historic properties. Thus, operation of the heavy haul road and pipelines would have a SMALL effect on historic properties and would not require mitigation.

Subsection 2.5.3.9 describes the cultural resources that have been previously recorded in the transmission line study area, which measures 10 miles wide. The specific location of the transmission line in the study corridor has not yet been determined. As indicated in Subsection 2.5.3.3, once a location has been determined, and before initiation of construction activities, cultural resource investigations would be expected to be conducted by the transmission service provider to identify historic properties and assess the effects of constructing the transmission line on them. Consultation would be conducted with the Texas Historical Commission and the State Historic Preservation Officer in accordance with the Texas Antiquities Code regarding the assessment of effects and to identify measures to avoid, minimize, or mitigate any adverse effects. Operation of the transmission lines would result in activities occurring in areas already disturbed through construction and would not result in physical disturbance of historic properties. Operation of the transmission lines would not result in visual impacts to the settings of historic properties located in the vicinity. Thus operation of the transmission lines would have a SMALL effect on historic properties and would not require mitigation.

With operational and maintenance activities in the offsite areas, there is always the possibility for inadvertent discovery of previously unknown archaeological resources or human remains. The Memorandum of Agreement for each of the offsite project elements (makeup water pipeline, cooling basin blowdown pipeline, and transmission line corridors) would include provisions to deal with these discovery situations, in compliance with the National Historic Preservation Act and the Antiquities Code of Texas. As indicated in Section 3.4, Exelon, AEP, and other applicable entities would develop internal procedures to ensure implementation of the discovery provisions for the project elements they are responsible for operating.

5.2 Water-Related Impacts

This section describes the hydrologic alterations that could affect the availability and quality of water resources and the plant water supply, as well as water use and water quality impacts associated with the operation of a proposed plant that would be built at the VCS site.

5.2.1 Hydrologic Alterations and Plant Water Supply

VCS would use both surface water and groundwater to meet the plant water demand. Section 3.3 details the plant's various uses and the associated amounts of water. Subsection 2.3.1 describes the hydrological resources from which this water would be withdrawn. Subsections 2.3.2 and 2.3.3 describe, respectively, the current demand on those hydrological resources and the quality of the water in those resources.

5.2.1.1 Surface Water

Surface water bodies integral to VCS operations would include the Guadalupe River and the plant's proposed cooling basin. Water bodies that could be affected by VCS and cooling basin operations would include Dry Kuy Creek and several of its unnamed intermittent tributaries, Kuy Creek and several of its unnamed intermittent tributaries, several unnamed intermittent tributaries to Black Bayou and Linn Lake, and the San Antonio Bay system.

The VCS closed-cycle cooling system would require makeup water supplied to the cooling basin from the Guadalupe River to replace water lost as evaporation, drift, seepage, and blowdown. The consumptive use of surface water by VCS would range from approximately 46,000 gallons per minute (gpm) under normal use conditions to approximately 68,300 gpm for maximum use conditions (sum of evaporation rates, seepage, and drift rates in Table 3.3-1–includes both cooling basin and mechanical draft cooling towers). (Blowdown would be returned to the Guadalupe River and is not considered consumptive loss.) Based on the average of approximately 1315 acre-feet per month of precipitation over a 60-year period (1947 to 2006), an estimated 9773 gpm of precipitation (Table 3.3-1) would be collected in the cooling basin. Rainfall collected in the cooling basin would reduce the demand on makeup water.

The cooling basin's emergency spillway would be designed such that there would be outflow to Kuy Creek only during storms that exceed the 100-year, 24-hour rain event. Overflows from the cooling basin during storms that exceed the 100-year, 24-hour rain event would increase the natural flow volume and velocity of Kuy Creek. A stilling basin would be installed at the end of the spillway to dissipate energy in the outflow to reduce the potential for downstream erosion.

As described in Subsection 4.2.1.1.4, the construction and resultant operation of the cooling basin would result in the loss of approximately 5000 acres of the drainage area to Dry Kuy Creek, Black

Bayou, Linn Lake, Kuy Creek, and their tributaries. The capture of precipitation could result in the loss of approximately 4277 acre-feet per year of runoff. This is equal to an average daily flow of approximately 5.9 cubic feet per second (cfs), which represents less than a 0.2 percent reduction in the average mean flow (4341 cfs) estimated in the Guadalupe River (Subsection 5.2.2.1) for the period 1997–2006. Additionally, cooling basin seepage would create a small base flow in tributaries within the Guadalupe-San Antonio River system. Hydrologic impacts of the cooling basin to surface water bodies during the operating life of the plant would be similar to the construction impacts described in detail in Section 4.2 and would be SMALL.

The impact of hydrologic alterations caused by VCS activities in offsite areas (Subsection 2.2.2) would be limited to operation and maintenance of the transmission lines, the raw water makeup (RWMU) system intake and cooling basin blowdown discharge pipelines. As described in Section 4.2, a heavy haul road (HHR) would be built on VCS property to connect the proposed plant site to the Victoria County Navigation District (VCND) transportation corridor and the barge facility. The RWMU system intake structure, located approximately 0.6 miles southwest of the GBRA Saltwater Barrier and Diversion Dam, would withdraw water from the Guadalupe River via an intake canal on the west bank of the river. Blowdown of the basin would be conveyed by a buried pipeline that follows the route of the HHR to the boundary of the VCS site and then parallels the VCND transportation corridor to its intersection with the Guadalupe River. Operation and maintenance of the VCS facilities would create minimal impacts in the floodplain, because the pipe would be buried.

5.2.1.2 Groundwater

5.2.1.2.1 Groundwater Withdrawal

All plant water systems, other than the service water and/or UHS mechanical draft cooling towers and circulating water system with its cooling basin, would use groundwater. This would include potable water, demineralized water, and fire protection water. Groundwater pumped from the VCS production wells would be a consumptive use because the groundwater would either be consumed or discharged to the cooling basin.

Groundwater would be supplied from onsite wells to meet an estimated operations demand of approximately 464 gpm (normal) to 1053 gpm (maximum) (Table 3.3-1 and Figure 3.3-1). As noted in Table 3.3-1, up to 1200 gpm (maximum) would be required from the onsite wells to refill the fire water storage tank(s) within the required 8-hour time frame. Groundwater would be withdrawn from the Evangeline Aquifer, as described in Subsections 2.3.1 and 2.3.2. The Evangeline Aquifer is not in communication with local surface water bodies in the vicinity of VCS site. Therefore, site groundwater withdrawals would not affect local surface water bodies.

Subsidence monitoring data from 1918 through 1973 indicates that during that time period, subsidence of less than 0.5 feet was observed in the site vicinity. The subsidence was attributed primarily to oil and gas production rather than groundwater pumping. (TDWR Nov 1982)

Between 1965 and 2002, seven groundwater-flow modeling studies were conducted in all or parts of the Texas Gulf Coast Aquifer System by the U.S. Geological Survey and others. Although several of the studies involved land-surface subsidence studies, most studies focused on the Houston/Galveston area, and none of the studies included a land-subsidence study of Victoria County (Kasmarek and Robinson 2004).

A 1992 *Regional Water Supply Plan for the City and County of Victoria* (Camp Dresser & McKee Jun 1992) estimated that historical pumping from the Evangeline Aquifer with a 90-foot drawdown observed in 1973 would result in a land-surface subsidence of 0.3 feet. Because specific unit-compaction coefficients for the Chicot and Evangeline Aquifers were not available for Victoria County, the plan estimates of land subsidence in Victoria County were made using a specific unit-compaction coefficient (1.0×10^{-4} per foot and 1.8×10^{-5} per foot, respectively) based on measurements in the Houston area. The specific unit-compaction coefficient relates the amount of land surface subsidence to the thickness of the clay and amount of water level decrease in the aquifer. The inelastic storage coefficient is the product of the specific unit-compaction coefficient and the clay layer thickness. Based on the thickness of the clay layers in the aquifer at the city of Victoria, the inelastic storage coefficients for the Chicot and Evangeline Aquifers were estimated at 1.0×10^{-2} and 5.4×10^{-3}, respectively. The inelastic storage coefficients were multiplied by the drawdown in water levels to yield an estimate of land surface subsidence. The plan's estimated land-surface subsidence of 0.3 feet is consistent with the observed subsidence information (less than 0.5 feet) provided in TDWR (Nov 1982). (Camp Dresser & McKee Jun 1992)

Although the *Regional Water Supply Plan for the City and County of Victoria* predicted that an additional 0.7 feet of land subsidence would occur between 1990 and 2040 as a result of an additional 70 feet of water level declines in the Evangeline Aquifer, those predictions are no longer valid. (Camp Dresser & McKee Jun 1992) As described in Subsection 2.3.2.2, the city of Victoria switched from a groundwater supply to a primarily surface water supply in 2001 with groundwater as a backup during drought conditions. Since 2001, water levels in a well screened in the Evangeline Aquifer at the Invista-DuPont facility have risen approximately 25 feet. Therefore, the land-surface subsidence at the VCS site is anticipated to be on the order of 0.3 feet, which is within the range of subsidence expected as a result of oil and gas production.

The depth of the proposed VCS groundwater production zone would minimize potential subsidence effects resulting from groundwater pumping. The impact of hydrologic alterations caused by VCS groundwater withdrawal would be SMALL.

5.2.1.2.2 Discharge to Groundwater

As described in Subsection 2.3.1.2.3.1, a three-dimensional, eleven layer numerical groundwater flow model was developed to evaluate potential impacts on the groundwater flow system from the construction and operation of the VCS site. Four specific areas of impact were assessed:

1. Seepage rate from the cooling basin into the site groundwater system
2. Post-construction groundwater level in the power block
3. Impacts on plant construction dewatering
4. Postulated, post construction groundwater accidental release pathway

The groundwater flow model is executed under the Visual MODFLOW version 4.3 environment developed by Schlumberger Water Services (Schlumberger Water Services 2008). The program consists of a series of pre- and post-processors that feed information to various numerical groundwater flow models developed by others. The groundwater flow model selected for the VCS site utilizes a three-dimensional finite-difference groundwater flow model known as MODFLOW-2000 (Harbaugh et al. 2000). A subsidiary program known as MODPATH (Pollock 1999) is used to perform particle tracking to identify the groundwater flow paths. A detailed description of the construction, calibration, and results of the model are included in Site Safety Analysis Report (SSAR) Appendix 2.4.12C.

Hydrogeologic information was used to develop a pre-construction model. Information was obtained from the site subsurface investigation program and regional publications and databases to develop a stratigraphic model of the Chicot Aquifer within the area of the VCS site.

Eleven layers were chosen to represent the components of the Chicot Aquifer: Sand 1, Upper Shallow, Lower Shallow, and Deep aquifers (model layers 2, 4, 6, 8, and 10 [layers 8 and 10 represent the Deep aquifer]) and the interfingerling clay layers (model layers 1, 3, 5, 7, 9, and 11) based on borehole data. The explicit method of representing a confining layer using a model layer was selected to represent the confining layers at the VCS site. A single value of hydraulic conductivity was selected to represent each of the sand geotechnical units. Hydraulic conductivity values were adjusted as part of the model calibration to match the observed heads. Other properties used to support model development include recharge rate, evapotranspiration, and effective porosity.

The primary zones of concern for the VCS cooling basin seepage and excavation dewatering are the Sand 1 aquifer and the Upper Shallow aquifer. The primary zones of concern for the VCS cooling basin seepage and excavation dewatering are Sand 1 and the Upper Shallow aquifer. Sand 1 is unsaturated in the pre-construction groundwater flow system.

Modifications to the calibrated pre-construction groundwater flow model were made to evaluate the effects of VCS operation. The post-construction, predictive simulations include estimation of cooling basin seepage, the amount of water removed during power block dewatering, and simulation of a post-construction accidental release of radioactive liquid effluent to groundwater. The following adjustments were made to the pre-construction model for the post-construction conditions:

- Surface elevations within the power block were set to an elevation of 95 feet NAVD 88 and within the cooling basin, the surface elevations were set to elevation 69 feet NAVD 88. Areas within the cooling basin where layer 1 was 1 foot in thickness (surficial clay absent as a result of excavation or erosion) were assigned a hydraulic conductivity of the underlying sand.
- Permeable backfill and inactive model cells were added to the power block area to represent backfill around buildings and the location of building foundations.

The post-construction simulations are summarized below.

5.2.1.2.2.1 Simulation of Cooling Basin

The post-construction, numerical groundwater model was used to simulate the changes to the groundwater system and impacts to the groundwater base flow to nearby surface water features as a result of cooling basin operation.

Cooling basin seepage was simulated using the river boundary condition to represent the basin. The river stage (cooling basin water level) for the boundary was set at an elevation of 90.5 feet NAVD 88 with the riverbed bottom (base of cooling basin) at an elevation of 69 feet NAVD 88. The riverbed conductance is based on a 2-foot thick sediment layer with a vertical hydraulic conductivity value equivalent to sand (34 feet per day) and a channel width equal to the entire model cell.

In addition to the cooling basin, the post-construction power block conditions were also simulated. Postulated buildings within the power block were represented by inactive model cells, which were surrounded by cells with permeable backfill. The power block backfill is assumed to be approximately 5 times more permeable than the natural sand units, however mitigating surface features such as finish grading to assure overland flow rather than ponding, storm drains to conduct surface drainage, and vegetation control are assumed to reduce the amount of infiltration through the backfill.

Cooling basin seepage was evaluated by looking at the flow budget in subareas of the model domain. The simulation results indicate an estimated 3930 gpm seepage rate from the cooling basin. The primary impacts of the cooling basin seepage appear to be restricted to the adjacent creeks and seeps. There appears to be minimal contribution to the base flows of the Black Bayou, Linn Lake, and Guadalupe River as a result of cooling basin seepage. Kuy Creek, Dry Kuy Creek, and the downgradient seeps show an increase in base flow (contribution from groundwater).

Subsection 2.3.1.2, Table 2.3.1.2-14 provides pre- and post- construction cooling basin seepage estimates.

Another impact of cooling basin seepage would be to raise groundwater levels beneath the power block. Subsection 2.3.1.2, Figure 2.3.1.2-25 presents a simulated potentiometric surface map in model layer 2 (geotechnical Sand 1) in the power block area. Subsection 2.3.1.2, Figure 2.3.1.2-26 presents the simulated potentiometric surface surrounding the cooling basin in layer 2. Geotechnical Sand 1 is represented as a vadose zone sand in the pre-construction groundwater model. The sand becomes saturated in the post-construction groundwater model within the immediate vicinity of the cooling basin. The figures indicate that groundwater levels are predicted to rise after filling the cooling basin. The predicted groundwater elevation in the power block area is at approximately an elevation of 85 feet NAVD 88.

A sensitivity analysis was performed on uncertain parameters associated with cooling basin seepage. The two primary uncertainties are the conductance of the cooling basin river boundary and the vertical hydraulic conductivity of the natural material underlying the cooling basin.

The vertical hydraulic conductivity of the sediment was assumed to be 34 feet per day for the base case, which represents a relatively clean sand. A more likely sediment composition would be that of a silty sand (due to sedimentation and chemical precipitation in the bottom of the operated basin), with a hydraulic conductivity approximately an order of magnitude lower (3.4 feet per day). The first sensitivity case uses this lower hydraulic conductivity to estimate seepage from the cooling basin.

A second sensitivity case involves uncertainty regarding the hydraulic conductivity of the clay in model layer 1. Exposure to repeated wetting and drying cycles could result in a higher hydraulic conductivity of the surficial materials. An order of magnitude increase in vertical hydraulic conductivity (0.6 feet per day) of the clay in layer 1 is assumed for the second sensitivity case.

Sensitivity case 1 appears to be sensitive to a change in the vertical hydraulic conductivity of sediment on the bottom of the cooling basin. An order-of-magnitude reduction in the vertical hydraulic conductivity of the sediment results in an approximately 14.5 percent reduction in the seepage rate from the cooling basin. Sensitivity case 2 appears to be insensitive to a change in the vertical hydraulic conductivity of the surficial clay layer. An order-of-magnitude increase in the vertical hydraulic conductivity of the clay results in only an approximately 2 percent increase in seepage from the cooling basin. The value selected for the hydraulic conductivity of the layer 1 clay in the base case represents the maximum value from the in-situ Guelph Permeameter testing performed during the site subsurface geotechnical investigation (Subsection 2.3.1.2.2.4.2) and therefore would provide an upper bound for the hydraulic conductivity in the clay.

5.2.1.2.2.2 Simulation of Power Block Dewatering Effects

Construction dewatering will be required when constructing the plant if the excavations for the deeper building foundations are expected to extend to an estimated elevation of –15 feet NAVD 88, which is in the Lower Shallow aquifer (model layer 6). The Lower Shallow aquifer was assumed to be dewatered to the approximate bottom of the aquifer at an elevation of approximately –20 feet NAVD 88. Two dewatering scenarios were considered:

1. Pre-construction groundwater conditions (cooling basin empty) with dewatering the entire power block area
2. Post-construction groundwater conditions (cooling basin full) with dewatering the entire power block area

These scenarios were evaluated because the scheduling of the construction activities is still in the planning stage and would not be final until a reactor technology is chosen at the COL stage. Dewatering would be required only for excavations beneath an elevation of approximately 50 feet NAVD 88 (Upper Shallow aquifer) prior to the basin being filled. Dewatering would be required at a much shallower depth (elevation of approximately 85 feet NAVD 88 if dewatering is performed while the basin is filled. All scenarios were simulated by assigning constant head boundaries representing the excavation for model layers 4 and 6 and in the post-construction scenario model layer 2.

Dewatering pumping (flow) rates ranged from approximately 990 to 1840 gpm. Figure 5.2-1 and Figure 5.2-2 present simulated potentiometric surface for dewatering Scenario 1 (pre-construction groundwater conditions (cooling basin empty) and Scenario 2 (post-construction groundwater conditions (cooling basin full) with dewatering the entire power block area) for model layer 6 (Lower Shallow aquifer), respectively. The finalization of a dewatering scheme will be evaluated once a reactor technology is selected at the COL stage.

5.2.1.2.2.3 Simulation of Accidental Release Pathway

The groundwater flow system downgradient of the power block was evaluated to identify potential exposure points from an accidental release of radionuclides to groundwater. The release is postulated to occur below the basement of a postulated radwaste building in the backfill present in model layer 4 (Upper Shallow aquifer). The release was simulated by placing particles in the power block backfill. The movement of these particles was calculated using MODPATH, which is a companion program to MODFLOW, that uses its output to perform the particle tracking. Four particle release scenarios are considered:

1. No pumping

2. With a hypothetical domestic well pumping on the north site boundary (approximately 4500 feet from the release)

3. With a hypothetical domestic well pumping on the west site boundary (approximately 3800 feet from the release)

4. With a hypothetical domestic well pumping on the east site boundary (approximately 11,000 feet from the release)

The hypothetical domestic wells are screened to fully penetrate model layer 6 (Lower Shallow aquifer), which is the uppermost aquifer used for water supply in the site area. For the northern well, the screened interval was from an elevation of –4 to –20 feet NAVD 88; for the western well, the screened interval was from an elevation of –4 to –31 feet NAVD 88; and, for the eastern well, the screened interval was from 8 to –31 feet NAVD 88. The hypothetical wells were pumped at a simulated rate of 50 gpm, which is considered the maximum practical pumping rate for the Lower Shallow aquifer within the site vicinity.

Subsection 2.3.1.2, Table 2.3.1.2-15 presents a summary of the travel times from the release point to the exposure point at the property boundary as derived from the particle tracking. The results of the particle tracking indicate a travel time of approximately 41,000 days (110 years) to the eastern site boundary. Modeling results indicate that when the particles are released into the fill they migrate down through the fill into model layer 6 (Lower Shallow aquifer) and then travel laterally toward the east or vertically to model layer 8 (Deep aquifer). None of the hypothetical pumping scenarios result in capture of particles by the pumping wells. The primary influence of the offsite pumping is to locally divert the particle tracks toward the north prior to the particle continuing to the eastern site boundary. Subsection 2.3.1.2, Figure 2.3.1.2-27 presents the particle track pathways for scenario 1 (without pumping). Additional discussions of the accidental release scenarios are presented in SSAR Appendix 2.4.12-C and SSAR Subsection 2.4.13.

5.2.1.2.2.4 Groundwater Model Summary and Conclusions

A summary of the specific findings of the three-dimensional eleven layer groundwater flow modeling effort used to evaluate groundwater level and flow changes associated with: the operation of a cooling basin at the VCS site; the dewatering of site excavations; and the assessment of post-construction groundwater flow paths are presented below.

- The groundwater levels in the power block area are predicted to be about elevation 85 feet NAVD 88 or about ten feet below the minimum finished grade elevation of 95 feet NAVD 88.

- The filling of the cooling basin to an elevation 90.5 feet NAVD 88 is predicted to raise groundwater levels beneath the site to a point where the currently unsaturated sand layer referred to as the Sand 1 geotechnical unit becomes saturated.

- Seepage from the cooling basin is predicted to increase groundwater contributions (base flow) to Kuy and Dry Kuy Creeks and seeps to the north and east of the VCS site. Seepage from the cooling basin is estimated to be approximately 3930 gpm. There appears to be minimal contribution to the base flows of Black Bayou, Linn Lake, and the Guadalupe River, as a result of cooling basin seepage. Kuy Creek, Dry Kuy Creek, and the downgradient seeps show an increase in base flow (contribution from groundwater).

- Seepage from the cooling basin is also predicted to alter the groundwater flow directions in the site area, particularly in the power block area, as the result of mounding beneath the basin.

- Construction dewatering scenarios were simulated with the cooling basin empty and full with an estimated range of pumping rates between 990 (empty) and 1840 gpm (full).

- Particle tracking suggests that the closest receptor for an accidental release to groundwater from postulated radwaste buildings would be the eastern property boundary for the VCS site with a travel time of approximately 41,000 days (110 years) to the eastern site boundary.

Seepage from the operation of the cooling basin would increase infiltration to the underlying Chicot Aquifer, which would most likely alter the natural shallow groundwater flow direction and gradient near the cooling basin. Because any hydrologic alterations to groundwater would be local, the impact of hydrologic alterations of groundwater from the operation of the VCS cooling basin would be SMALL.

5.2.1.3 Summary of Hydrologic Alterations

As discussed in Section 4.2.1.1.4, the capture of precipitation within the cooling basin footprint could result in the loss of approximately 4277 acre-feet per year (2654 gpm) of inflow, mainly to Kuy Creek (1065 acre-feet per year or 659 gpm) and Dry Kuy Creek (2914 acre-feet per year or 1797 gpm). Seepage from the VCS cooling basin is estimated to contribute between 335 acre-feet per year (220 gpm) to Kuy Creek and approximately 742 acre-feet per year (460 gpm) to Dry Kuy Creek. Both creeks are intermittent/ephemeral and currently receive flows only as a result of rain events. The runoff flows from rain events are short-term, whereas the seepage flows to the creeks would be at a constant rate. Further, an additional 500 acre-feet per year (310 gpm) is estimated to occur as a result of post-construction groundwater flow to groundwater seeps.

Total seepage from the cooling basin to the subsurface is estimated to be approximately 6340 acre-feet per year (3930 gpm). The seepage would increase shallow groundwater contributions to the Victoria Barge Canal (Guadalupe River Valley), San Antonio River, and Kuy and Dry Kuy Creeks. Given that the seepage estimates reflect the amount of seepage lost from the entire base and perimeter of the cooling basin, the seepage volume and flow rate would be minimal at any one location. As such, erosion in and near the surface water bodies as a result of seepage would not likely occur. The seepage would increase infiltration to the underlying Chicot Aquifer, which would most likely alter the natural shallow groundwater flow direction and gradient; however, any hydrologic alterations to groundwater would be local.

5.2.2 Water-Use Impacts

This subsection describes the results of the analysis of operations that could affect water use, including water availability and the analysis of water quality changes that could affect water use.

5.2.2.1 Surface Water

The source of the plant's makeup water would be the Guadalupe River as described in Section 3.4. The RWMU system would deliver up to 75,000 acre-feet per year at a maximum rate of 217 cfs as makeup water to the cooling basin to replenish losses through evaporation, basin seepage, blowdown discharges, and cooling tower drift. The water would be diverted into an approximately 3150 feet long intake canal and an approximately 200-foot long intake basin located on the southwest side of the Guadalupe River.

The location, flow data, period of record, and drainage area for the U.S. Geological Survey (USGS) gaging stations on the Guadalupe and San Antonio Rivers near the VCS site are presented in Subsection 2.3.1.1.1. Long-term stream flow data is not available for the Guadalupe River at the location of the Exelon RWMU system, approximately 430 feet upstream of the saltwater barrier. The nearest upstream gaging stations with long-term records are the Victoria gage (USGS 08176500) on the Guadalupe River and the Goliad gage (USGS 08188500) on the San Antonio River. The drainage areas for the Victoria and Goliad gages are 5198 square miles and 3921 square miles, respectively. The drainage area for the abandoned gaging station on the Guadalupe River near Tivoli is 10,130 square miles. Based on these drainage areas, the Victoria and Goliad gages monitor flows from approximately 90 percent of the total drainage area that contributes to the flow in the Guadalupe River at the diversion to the RWMU system. Flows in the Guadalupe River at the point of diversion were estimated by summing the reported flows at the Victoria and Goliad gaging stations and multiplying that sum by the ratio of the drainage area of the Guadalupe River at Tivoli to the sum of the drainage areas of the Guadalupe River at Victoria and San Antonio River at Goliad (10,130 ÷ (5198 + 3921) = 1.11). Based on these estimates, the maximum VCS water use of 217 cfs represents

5 percent of the annual mean flow in the Guadalupe River (4341 cfs) based on 10 years (1997 through 2006) of flow data.

Water Use Evaluation

The potential water use impacts were evaluated as if the makeup water would be supplied to the VCS cooling basin under an assumed existing senior water right. This provides a conservative estimate of the potential impacts because under a senior water right, Exelon would have "first call" on diverting the water during periods when the Guadalupe River flows were low. The potential impact in terms of the volume of river flow being diverted would be higher than in the case of more junior water rights that would be restricted from using water during periods of low river flow.

Section 2.3.2.3.3 discusses the availability of water under the rights held either jointly or directly by the GBRA and Union Carbide Corporation (UCC). A surplus of more than 115,000 acre-feet per year is projected in 2060 under the GBRA/UCC water rights. Section 2.3.2.3.3 also discusses existing water rights in the Guadalupe and San Antonio river basins in addition to those held by GBRA/UCC. For the potentially available portions of these water rights, Exelon estimates a current surplus of approximately 39,000 acre-feet per year. The priority dates of these rights vary from 1895 to 1997. The largest portion of the unused water is associated with a senior right. Because the evaluation of VCS water use assumes a relatively senior water right, the impacts of obtaining water through any combination of the potentially available water rights or a new appropriation would be consistent with, and likely less than, those presented below. The regional water planning process described in Section 2.3.2.3.3 considers the use of water allocated under existing rights during a repeat of the 1950s drought of record and through the planning horizon, as well as projected demands, shortages, and potential water use conflicts.

Exelon could supply the makeup water demand at VCS via a new water right. The priority date assigned to a new water right would restrict diversions to the Exelon RWMU system to periods in which demands under the existing, more senior water rights could be met. Further, for a new water right the TCEQ may impose special conditions, including potential restrictions on withdrawals during periods of low river flow (e.g., environmental flow conditions). These considerations would constrain the VCS withdrawals during periods of low river flow. The diversion of water during periods of relatively high flow or low demand by other water users would reduce the impacts relative to acquisition of water under a more senior existing water right.

The daily makeup water withdrawals over the 60-year historical period (1947 through 2006) given the projected water availability under an existing senior water right were calculated based on the Guadalupe-San Antonio (GSA) River Basin Water Availability Model (WAM; TNRCC Dec 1999). To assess VCS surface water use impacts as a function of run-of-river flows, the estimated VCS daily makeup water withdrawal rates were compared with the range of daily river flow conditions estimated over the 60-year historical period. The frequency distribution of the daily VCS makeup water withdrawal as a percentage of the daily Guadalupe River flow for that 60-year period is shown in Table 5.2-1 and Figure 5.2-3. The estimated plant water withdrawal was less than 15 percent of the Guadalupe River flow 85 percent of the time. Approximately 17 percent of the time, the plant either needed no additional makeup water, or no water was available for plant use as the result of low flow conditions. The withdrawal rate exceeded 30 percent of the estimated river flow less than 3 percent of the time.

Historical data shows the Guadalupe River flows at the diversion to the GBRA canal system are lower during the summer and fall months, with the lowest flows typically occurring in August and October. Table 5.2-2 and Figure 5.2-4 provide a summary of the estimated VCS makeup water withdrawal as a percentage of the Guadalupe River flow by month and by season. Consistent with the trend observed in the river flows, the VCS surface water withdrawal as a percentage of the monthly and seasonal flow of the Guadalupe River would be typically higher in the summer and fall months.

The VCS makeup water withdrawal rate would depend on the flow rate of the Guadalupe River, the priority of the water right, the water level in the cooling basin, and the blowdown flow from the cooling basin. Variations in makeup water availability would be accommodated by allowing the cooling basin water level and quality to fluctuate within acceptable ranges.

The cooling basin would be designed to contain enough makeup water to support the operation of the plant for several months during potential low river flow periods. There is one authorized surface water diversion from the Guadalupe River downstream of the source of the VCS water supply. That water right authorizes diversion of 272 acre-feet per year for a crawfish farming operation near the outlet of the river into San Antonio Bay (Table 2.3.2-10).

Water rights totaling 175,501 acre-feet per year and authorized for municipal, industrial, and irrigation use (Table 2.3.2-12) are held either jointly or directly by the GBRA and UCC. As shown in Tables 2.3.2-9 and 2.3.2-10, the GBRA/UCC water rights are senior (priority) to most other permitted water rights on the Guadalupe River. The principle of priority appropriation or "first-in-time-first-in-right" is applied, which means that the most senior, or oldest, water right has first call on flows. Exelon continues to coordinate with the GBRA to ensure that ample water will be available for VCS in the future. As discussed previously, a significant volume of potentially available water rights exist in the Guadalupe and San Antonio Rivers. Exelon would finalize contractual agreements to withdraw water under one or more existing rights and/or a new water right(s) at the COL stage. The analysis of the projected water consumption concludes that Exelon would divert a small percentage of water that reaches the saltwater barrier and the San Antonio Bay system. The potentially available portions of existing water rights in the Guadalupe River indicate that an agreement could be reached to secure sufficient water to meet the VCS demand.

One of the fundamental elements of the South Central Texas (Region L) regional water planning process is the quantification of surface water and groundwater supplies reliably available during a repeat of the drought of record (1950–1957) and throughout the planning horizon. Surface water supplies available to each water right are computed using the Guadalupe-San Antonio River Basin Water Availability Model originally developed by the TCEQ and refined for regional water planning purposes subject to natural hydrology, prior appropriation, and hydrologic assumptions approved by the TWDB.

Although not specifically envisioned in the development of the 2006 Region L Water Plan, the proposed use of surface water by VCS under agreement with the GBRA is consistent with the plan assumptions. Legal use of existing surface water rights on a priority basis is a fundamental assumption in evaluating water supply. Hence, uses of all existing surface water rights are reflected in the water availability projections of the Region L Regional Water Plan, which include consideration of the drought of record conditions. Additionally, the 2011 South Central Texas (Region L) Regional Water Plan was approved by Region L on August 5, 2010, and submitted to the TWDB for review and inclusion in the 2012 State Water Plan in September 2010. The 2011 Region L Regional Water Plan includes updated regional water demand projections for steam-electric power generation including those projected for the VCS project. The 2011 Region L Regional Water Plan also includes a recommended project to supply water to VCS (i.e., the “GBRA-Exelon Project”). Analysis conducted for the Regional Water Planning Group using the state’s surface water availability model, as modified for regional planning purposes, concludes that sufficient water is available for the VCS project (SCTRWPG 2010).

As described previously, the frequency distribution of the daily VCS makeup water withdrawal as a percentage of the daily Guadalupe River flow for a 60-year historical period (which included the drought of record [1950–1957]) estimated that approximately 17 percent of the time either the plant needed no additional makeup water (i.e., the cooling basin water level was at or above the design pool elevation), or no water was available for plant use as the result of drought conditions. The VCS cooling basin is designed to sustain plant operation for several months during drought conditions.

Projected surface water demands, supplies, and needs for Victoria and Calhoun Counties, as presented in the 2006 Regional Water Plan, are summarized in Table 2.3.2-14. As shown in the table, after meeting the projected Calhoun County surface water demands and Victoria County surface water needs, a surplus of more than 115,000 acre-feet per year remains under the combined GBRA/UCC water rights in the time period during which the VCS units would be operating. Additionally, approximately 39,000 acre-feet per year of currently permitted water is estimated to potentially be available, and new water right applications are pending.

VCS Bio-statistical Study

Although VCS water withdrawals would generally represent a relatively small percentage of annual Guadalupe River flow, Exelon undertook an approximately year-long study to evaluate the potential effects of these water withdrawals on the ecological health of the San Antonio Bay system. The study reported in TPWD's 1998 document, Freshwater Inflow Recommendations for the Guadalupe Estuary of Texas (Pulich et al. 1998), sought to identify the hypothetical freshwater inflow patterns necessary to optimize fisheries harvests in the bay system. In contrast, the objective of the VCS analysis was to develop and use statistical relationships between freshwater inflows and surrogate representations of ecosystem health to identify potential effects associated with the proposed VCS water diversions.

In its guidance towards establishing relationships between freshwater inflows and estuarine health, the Science Advisory Committee (SAC, established through Senate Bill 3 of the 77th Texas Legislature) provided a brief summary discussion on estuarine ecosystems and their major physiochemical and biological variables. Figure 5.2-5 is a highly simplified diagram prepared by the SAC to represent causal relations among such estuarine processes. Despite the simplifications made in such a depiction, the diagram demonstrates that the estuarine ecosystem is highly dynamic and complex, being comprised of many variables and their interactions. The SAC has noted that it is not feasible to quantify each of the cause-and-effect relations diagrammed in Figure 5.2-5. Instead, the complexity of Figure 5.2-5 has been further distilled by the SAC to represent the most fundamental relations of inflow to the ecosystem in a form that may be feasible for determining inflow requirements. Figure 5.2-6 presents a conceptual schematic of the causal connection(s) between “inflow” and “biology.” (SAC 2009)

Inflows are one of the principal components contributing to estuarine ecology for which man exhibits some influence, and were hence of primary interest to the VCS bio-statistical study. Flow and salinity are known to exhibit strong correlations, a relationship that is strengthened in San Antonio Bay by the rather enclosed geomorphology of the bay system (Figure 5.2-7). Because the bay is somewhat sheltered from direct salinity intrusion from the Gulf of Mexico, Gulf salinities take a relatively long time to intrude into the system via the natural passes (e.g., Aransas Pass and Pass Cavallo). Accordingly, freshwater inflows typically have a longer lasting influence on San Antonio Bay salinities relative to other Texas Bays (e.g., Galveston Bay and Matagorda Bay), with salinities generally high, and the influences of tides and wind on water quality more noticeable, during periods of low freshwater inflow (Slack et al. 2009).

Rather than develop relationships between salinity and the biology of the system, the VCS bio-statistical study focused upon the relationship between representations of San Antonio Bay biology and freshwater inflow. While salinity exhibits a more direct relation to inflow, as noted in Figure 5.2-6, the ultimate target is a relation to the “biology.” SAC 2009 notes that it is possible to establish a direct relation of biology to inflow, though the data requirements and analytical methods to establish such a relation are demanding. Studies typically focus on salinity rather than abundance for the simple reason that salinity data are typically readily available, whereas biological data are not. In San Antonio Bay, however, there are ample biological data available to study biology directly. Secondly, inferring biological reactions through salinity can be misleading, as estuarine organisms generally function over a wide range of salinities. While these organisms exhibit preferences, they can exist outside of their preferred salinity conditions, complicating the relationship between salinity and biology and hampering the characterization of the organisms' dependence on inflow. For example, as explained by the Guadalupe, San Antonio, Mission, and Aransas Rivers and Mission, Copano, Aransas and San Antonio Bays Basin and Bay Expert Science Team (GSA BBEST), “[j]uvenile and adult blue crabs are tolerant of a wide range of environmental conditions, having been found in habitats…ranging from freshwater…to hypersaline lagoons with [salinities] up to 117 psu” (practical salinity unit: GSA BBEST March 2011). Lastly, salinity is but one of several pathways by which inflow can exert an influence on abundance (see Figure 5.2-5). Focusing entirely on salinity may result in overlooking other flow-modulated responses or wholly misinterpreting a non-salinity response to inflow. By analyzing directly the relation of organism abundance to freshwater inflows, there is a better chance of capturing all of the flow-modulated effects.

Thus, the primary interest in the VCS study was the bio-statistical analysis of organism density (abundance) and its relation to freshwater inflows. The methodology used in the VCS bio-statistical study is consistent with the present knowledge on developing relationships in highly dynamic systems described in the SAC's document to the Basin and Bay Expert Science Teams, Methodologies for Establishing a Freshwater Inflow Regime for Texas Estuaries (SAC 2009). As described in greater detail in the subsequent discussion, the VCS bio-statistical study was completed in the following major steps:

1. Identification of key estuarine species to evaluate (via average annual abundance) as a proxy for bay health.
2. Data retrieval from the Texas Parks and Wildlife Department (TPWD) Coastal Fisheries Database and preparation for use with statistical analysis tools.
3. Quantification of historical freshwater inflows to the San Antonio Bay system and characterization of these flows using annual and seasonal representations.

4. Identification and culling of statistical relationships between the average annual abundances of the selected species and freshwater inflows, including the assessment of the potential effects of other independent variables (namely fisheries harvest data and water temperature) on organism abundance.

5. Utilization of the TCEQ Water Availability Model (WAM) and the South Central Texas Regional Water Planning Group (Region L) Guadalupe-San Antonio (GSA) WAM to simulate “without-project” and “with-project” hydrological demand scenarios, as well as several potential future hydrological scenarios, such that the best-fit statistical relationships could be used to assess potential effects on the abundances of the selected organisms.

As noted above, the first study task was to select the estuarine species to be evaluated as a measure of present and potential future bay health. Brown shrimp *(Penaeus aztecus* or *Farfantepenaeus aztecus),* white shrimp *(Penaeus setiferus* or *Litopenaeus setiferus),* blue crab *(Callinectes sapidus),* and eastern oyster *(Crassostrea virqinica)* were chosen as important San Antonio bay species. These are four of the key organisms utilized during the application of the Texas Water Development Board (TWDB) and TPWD's “State Methodology for San Antonio Bay” (Longley, W.L., ed. 1994). As described in TPWD's 1998 report, Freshwater Inflow Recommendations for the Guadalupe Estuary of Texas, the selected species “are representative dominant fisheries organisms or ecologically important prey species common in the Guadalupe Estuary based on TPWD Coastal Fisheries Program surveys” (Pulich et al. 1998). Thus, the abundances of these organisms provide a measure of the ecological productivity of the San Antonio Bay system, including a partial measure of the availability of food for certain predatory species. Notably, as discussed in Subsection 2.4.1.5, blue crabs are one important food source for the federally endangered whooping crane *(Grus americana).* Accordingly, the average annual abundances of the four species listed above were chosen as the proxy for the ecological health of the San Antonio Bay system in the VCS bio-statistical study.

The next step was to retrieve San Antonio Bay abundance data for the selected species. The source of such biological data used in the VCS study, the TPWD Coastal Fisheries Database, is a compilation of data collected by the TPWD using various sample methodologies. This dataset contains data from 1976 to 2008, varying by the sample gear utilized. In contrast to San Antonio Bay fisheries harvest data, which were used by some previous efforts such as the above-referenced 1998 TPWD inflow recommendations study, the Coastal Fisheries Database information is obtained via random sampling; thus, the sampling schedule and locations are not subject to external factors like fuel and market seafood prices. Approximately 787,000 records (with up to 40 separate entries per record) were obtained from the TPWD database, representing all of the readily available data of this nature historically collected by the TPWD for the selected species. Once retrieved, abundance data for each organism were normalized by volume of water, area of sample, and sampling time depending on the geartype in which the organism was caught, to prepare for statistical analysis.

Ultimately, the development of biological parameters consisted of four phases: the initial development of database tools to process the Coastal Fisheries data; the analysis of the geographic distribution of sampling events; the detailed analysis of sampling data; and, finally, specific analyses of organism densities.

The task of quantifying freshwater inflows for use in the statistical analyses began with the development of the hydrologic data for the San Antonio Bay system watershed. These data were developed from a variety of sources, including the USGS and TWDB. Daily mean flow data were obtained for five USGS stream flow gages on the Guadalupe and San Antonio Rivers and Coleto Creek (a tributary to the Guadalupe River) for their entire periods of record. The TWDB provided modeled daily runoff values for 13 ungaged watersheds within the San Antonio Bay watershed for the period 1977–2008, as well as estimates of the diversions from and return flows to these ungaged watercourses. The TWDB and USGS data were compiled to develop a daily representation of total freshwater inflows to San Antonio Bay for the period 1977 through 2008 (i.e., the period of record for the historical biological data obtained for use in the study).

Using the daily data, parameters of freshwater inflow were developed to serve as independent variables in the statistical comparisons to average organism abundance. The most important aspect of the year-to-year variation in annual discharge is how it is manifested in the annual seasonal floods and the summer low-flow period (SAC 2009). Some years exhibit a pronounced and extended seasonal pulse (also known as a "freshet"), while in other years the spring freshet may be totally absent. Correspondingly, in some years the summer low-flow period may be shortened or even eliminated by unusual runoff, and in other years may be prolonged while the flows dwindle. The SAC indicates that preliminary statistical analyses (based on work performed in Matagorda Bay) using seasonal freshets as an independent variable have better explained the variation of abundance for several major species than similar analyses using calendar-period flows (i.e., bi-monthly or annual periods). The SAC recommends that, "If available, a freshet analysis may prove a useful characterization of estuarine inflows for purposes of assessing the response of biology (SAC 2009)." This representation of flow, and its suggested use by the SAC, represents the evolving thinking of the scientific community with respect to the relation of freshwater inflow to estuarine health.

Thus, while earlier efforts, such as the those reported for the TPWD's 1998 inflow recommendations study (Pulich et al. 1998), focused on gaged flow averaged temporally, either as annual means or as "seasonal" (i.e., bimonthly volumes), the flow component of the VCS bio-statistical analysis was based on the premise that substantial explanation of ecological response depends on the space-time variation of inflows. Accordingly, in addition to evaluating the relationships between annual freshwater inflow volumes and organism abundance, more refined representations of inflow were developed to recognize the importance of seasonal pulses (i.e., "freshets") and the intervening drier periods. Furthermore, the seasonal freshets (and the associated low-flow periods between them) were characterized by two methods, one assigning a 3-month timeframe after the onset of the freshet in the hydrological record, and the other with a varying freshet duration dictated by identifying both the freshet onset and ending in the hydrologic data via the application of a mathematical algorithm (termed the "FRESHET Methodology"). In all, eleven seasonal characterizations of freshwater inflow were used to develop the inflow-related independent variables for statistical analysis:

- Annual freshwater inflow
- 3-month spring freshet (3 calendar months starting with freshet onset)
- Summer dry period between 3-month freshets
- 3-month fall freshet (3 calendar months starting with freshet onset)
- Winter dry period between 3-month freshets
- Summer lowest 3-month flow (3 calendar months starting with low-flow onset)
- Winter lowest 3-month flow (3 calendar months starting with low-flow onset)
- Spring freshet using "FRESHET Methodology" (mathematically identified pulses of flow in the hydrologic record)
- Summer dry period between freshets identified with the FRESHET Methodology
- Fall freshet using FRESHET Methodology (mathematically identified pulses of flow in the hydrologic record)
- Winter dry period between freshets identified with the FRESHET Methodology

It should be noted that hydrologic data were temporally related to the biological data through the development of a relative timeframe referred to as an "effective hydrologic period." For each organism, the effective hydrologic period is that 12-month period in which the hydrology is considered to influence the given organism, considering its life cycle traits (e.g., moving in or out of the bay at a given time of year). In addition to the freshwater inflow-related parameters developed from the annual and seasonal inflow volume representations described above, parameters of water temperature and commercial fishing harvest data were developed for use in the statistical analyses.

With the dependent (i.e., average annual organism abundance for the selected key species) and independent (i.e., based on freshwater inflow representations, fisheries harvest data, and water temperature data) variables prepared, statistical regressions were developed to assess which, if any, relationships of organism abundance to freshwater inflow yielded statistically valid and meaningful tools for the subsequent analysis of potential effects on the ecological health of San Antonio Bay. Approximately 60,000 multivariate linear regressions were performed and subsequently analyzed (facilitated by statistical analysis tools developed for the project) to identify their capability in predicting average annual abundance. The regressions ultimately identified to relate organism abundance to fresh water inflow are presented below, wherein "Adj. R^2" represents the percent of variance explained by a regression and "A" represents the relative annual organism abundance in the bay. The adjusted R^2 is used, as an increased number of variables can cause an artificial increase in R^2. It should be noted that the descriptor "Whole Bay" indicates that organism abundance was aggregated across the San Antonio Bay system, rather than for a specific sampling location(s). This methodology was selected because the TPWD's program of random sampling leads to variation in the total number and frequency of sampling events at individual sampling locations that hinders the development of statistical relationships at a specific point(s) in the bay system. The identified regressions are as follows:

White Shrimp:

Whole Bay Otter Trawl White Shrimp related to Total San Antonio Bay 3-Month Summer Low-Flows

Adj. R^2= 0.586

$A = 0.433 + 1.97 \times 10^{-5}\ DQ3$

This equation relates average annual white shrimp abundance, as represented by sampling in San Antonio Bay using an otter trawl, to the magnitude of the lowest 3-month cumulative flow occurring between March and August (as represented in the above equation by DQ3). This equation explains approximately 59 percent of the variance of the data.

Eastern Oyster:

Whole Bay Oyster Dredge Eastern Oyster related to Total San Antonio Bay 3-Month Spring Freshet Flows

Adj. R^2 = 0.218

$A = 2285.44 - 5.59 \times 10^{-4}\ SQ3$

This equation relates average annual eastern oyster abundance, as represented by samples collected in San Antonio Bay using an oyster dredge, to the magnitude of the 3-month cumulative high flow occurring between January and June (as represented in the above equation by SQ3). This equation explains about 22 percent of the variance of the data.

Blue Crab:

Whole Bay Otter Trawl Blue Crab related to Colorado Total San Antonio Bay 3-Month Summer

Intervening Flows:

Adj. $R^2 = 0.280$

$A = 3.843 + 1.52 \times 10^{-5}$ SINTQ

This equation relates average annual blue crab abundance, as represented by sampling in San Antonio Bay using an otter trawl, to the average monthly magnitude of intervening flows occurring between the spring and fall 3-month freshets (as represented in the above equation by SINTQ). This equation explains approximately 28 percent of the variance of the data.

The explained variances offered by the eastern oyster and blue crab relationships to freshwater inflows are weak, suggesting other external factors unrelated to inflow, as currently represented, also contribute to variations in these organisms' average annual abundances. No discernable statistical relationship between average annual brown shrimp abundance and freshwater inflow variables resulted from this analysis.

To use the identified linear regressions to evaluate the potential effects on San Antonio Bay health resulting from the proposed VCS water withdrawals, the Region L WAM was chosen as an available and accepted means of modeling baseline and with-project hydrological scenarios. The following WAM simulations were used to evaluate potential project-specific impacts in the VCS bio-statistical study:

Present Conditions Without VCS Scenario (Present Conditions) — The Present Conditions Scenario uses results from a Region L WAM simulation that represents current conditions with respect to water availability for individual water rights. The Region L Present Conditions WAM used in the VCS bio-statistical study includes the following assumptions:

- The maximum diversion amount being sought by each individual water right is established as the actual maximum annual use in the 10 years before the WAM was originally developed (1990–1999) as reported by the individual water rights owners. Additionally, the Region L Present Conditions WAM has been updated to reflect changes in water use patterns for seven major water rights and reservoirs in the GSA watershed since 1999.
- The maximum storage capacity of all reservoirs specified as the actual year-2000 storage capacity (rather than the authorized maximum storage amount).

- Return flows associated with individual water rights and within the basin are set to 2006 reported levels, adjusted for San Antonio Water System (SAWS) direct recycled consumptive water use of about 24,900 acre-feet per year (based on contracts for consumptive use). The Region L Present Conditions WAM contains approximately 157,000 acre-feet per year of discharges, including 70,306 acre-feet per year of SAWS discharges (accounting for the aforementioned direct recycled water use).

- The model assumes a total use of 73,900 acre-feet per year of the Guadalupe-Blanco River Authority (GBRA) Lower Basin rights, including a diversion of 4,199 acre-feet per year under the most junior GBRA right, Certificate of Adjudication (COA) #18-5178. The total amount of 73,900 acre-feet per year is greater than the historical average cumulative use of approximately 50,000 acre-feet per year, as derived from GBRA's reported historical usage of its lower basin rights.

Present Conditions with VCS Scenario – The Present Conditions with VCS Scenario incorporates the data sets and assumptions from the Present Conditions without VCS Scenario, except that up to 75,000 acre-feet is annually diverted from the river under COA 18-5178 (proxy used to represent potential water supply for the proposed VCS) at a maximum instantaneous diversion rate of 217 cfs. As discussed earlier in Subsection 5.2.2.1, VCS makeup water withdrawals over the period 1947 through 2006 were modeled using the GSA WAM (TNRCC Dec 1999) and assuming withdrawals under an existing senior water right (COA 18-5178). These modeled withdrawals, adjusted to account for modeled cooling basin blowdown to the Guadalupe River, were added to the existing COA 18-5178 demand of 4,199 acre-feet per year at a monthly time-step. The remaining approximately 26,800 acre-feet per year of the 106,000 acre-feet per year permitted under COA 18-5178 are left unused. The bio-statistical study simulation extends from 1947 to 1989, representing the period of overlap between the Region L Present Conditions WAM (1934–1989) and modeled VCS withdrawals and blowdown flows (1947–2006). The Present Conditions Scenario with VCS uses conservative assumptions consistent with the Present Conditions without VCS Scenario and is intended to represent the incremental effect on freshwater inflows to the bay resulting from surface water diversions associated with VCS operation.

Comparison of the Present Condition without VCS and Present Conditions with VCS models indicates an average decrease in inflows to San Antonio Bay of approximately 5,300 acre-feet per month with VCS in operation, with a standard deviation of about 3,200 acre-feet per month. This reduction represents about 3.4 percent of the average monthly inflows to the bay system. The approximate inflow reduction at higher flows (i.e., at or above the 90th-percentile flow) is approximately 9,600 acre-feet per month, or about 2.6 percent of the inflow magnitude without VCS in operation. At the lowest flows (i.e., at or below the 10th-percentile), inflow to San Antonio Bay increases by about 1 percent with VCS in operation, due primarily to modeled blowdown from the VCS cooling basin.

Three additional comparative scenarios that were used to conservatively model potential future conditions in the basin are discussed in the cumulative impacts analysis presented in Section 5.11.

The hydrologic scenarios (i.e., Present Conditions without VCS and Present Conditions with VCS) were then used in conjunction with the previously described linear regressions relating average annual organism abundance to freshwater inflows to evaluate the potential effects on the health of the San Antonio Bay system (i.e., compared to the current health of the bay) associated with proposed VCS water withdrawals from the Guadalupe River. The results of the evaluation are summarized in Table 5.2-3.

Inspection of Table 5.2-3 indicates that the estimated potential reductions (relative to abundance predictions made using the Present Conditions without VCS model) in white shrimp abundance range from approximately 4 percent to 18 percent, with the larger potential changes predicted at lower abundances (i.e., occurrence frequencies exceeded 90 percent of the time). For blue crab, the estimated potential decrease in abundance relative to the modeled present conditions is approximately 3 percent at higher abundances (i.e., occurrence frequencies exceeded 10 percent of the time). Lower blue crab abundances are driven by the constant in the regression and therefore yield no apparent change between the hydrologic scenarios. No negative impacts are identified for eastern oyster, as all modeled scenarios result in increases in oyster abundance.

Given the wide range of variability in the historically (1977–2008) observed organism abundances of white shrimp, blue crab, and eastern oyster, the identified regressions relating average annual abundances for these organisms to freshwater inflow are relatively weak, with particularly low explained variance for blue crab and eastern oyster. Accordingly, a sensitivity analysis was performed to determine at what level of statistical confidence in the predictions potential impacts are determined. Statistical confidence (starting at $\alpha = 0.05$, or 95 percent confidence) was iteratively adjusted until a negative impact was discernible from the Present Conditions without VCS scenario. As one lowers the level of statistical confidence, the associated confidence bounds in the prediction constrict. Thus, the statistical confidence of a discernible potential impact has been characterized at the first identification of a negative impact exceeding the corresponding confidence level. As presented in Table 5.2-3, statistical confidence in the predicted abundance reductions for white shrimp and blue crab are at most 12 percent and 6 percent, respectively. There is at most 2 percent statistical confidence in the predicted increases in eastern oyster abundance.

It is standard to employ a 95 percent confidence level in statistical assessments of biology (McDonald 2009). At this level of confidence, none of the potential impacts of the various future hydrologic scenarios analyzed is statistically discernible. If the confidence level is reduced to that approximate to one standard deviation (approximately 68 percent), these potential impacts are still not statistically discernible. While the low confidences in the predictions are not surprising considering the relatively weak regressions, they underscore the fact that other external factors unrelated to freshwater inflow (as characterized in the bio-statistical evaluation) contribute to variations in organism abundances in San Antonio Bay.

Based on the analysis of the potential impacts to the key species assessed in this study, the following conclusions were drawn:

- No statistically significant relationships between key species abundance and annual freshwater inflows to San Antonio Bay were identified. However, a small number of statistical relationships associated with seasonal inflows were developed using the FRESHET and the 3-Month Freshet methodologies. Thus, the original hypothesis that pulses of flow, or the period between these pulses, are more significant to estuarine health than annual flows appears to be valid. Further, the 3-Month Freshet methodology provides a readily implementable means of evaluating flows using the South Central Texas Regional Water Planning Group's current tool for such an assessment, the Regional L GSA WAM.

- The identified statistical relationships between eastern oyster and blue crab abundances and freshwater inflow parameters are weak (i.e., there are small amounts of explained variance for these relationships). The results of the analyses conducted during this study indicate that other external factors unrelated to freshwater inflows (as represented within the VCS study) contribute to variations in oyster and blue crab abundances.

- Using the developed linear regressions and comparing abundances predicted by the Present Conditions without VCS hydrological model to those predicted by the Present Conditions with VCS hydrological model, there is the potential for decreases in white shrimp and blue crab abundances. However, the predicted changes in the abundances of these organisms due to VCS water withdrawals are not discernible at the 95 percent confidence level of the prediction, a standard biological assessment criterion. Specifically, there is at most 12 percent confidence in the predicted reductions (see Table 5.2-3).

Thus, with respect to freshwater inflows to San Antonio Bay, the project-specific scenario analyzed, and the methodologies employed therein, the study did not indicate that the VCS project would yield a statistically discernable impact (at the 95 percent confidence level) on the predicted future abundances' (i.e., as compared to the current abundances) of the key San Antonio Bay organisms evaluated. The study results are consistent with the conclusion that VCS water use impacts on the ecological health of San Antonio Bay would be small.

Summary

Surface water use impacts as a result of the VCS surface water withdrawals from the Guadalupe River would be SMALL based on the following findings:

- The maximum instantaneous diversion for VCS water use of 217 cfs represents 5 percent of the annual mean flow of the Guadalupe River at the proposed point of diversion, based on 10 years (1997–2006) of flow data.

- The cooling basin would be designed to contain enough water to support the operation of the plant for several months during low river flow periods. Variations in makeup water availability would be accommodated by allowing the cooling basin water level and quality to fluctuate within acceptable ranges. Additionally, as discussed in Subsection 5.2.1, the site groundwater model predicts that cooling basin seepage would create a small base flow in tributaries within the Guadalupe-San Antonio River System.

- The daily makeup water withdrawals over the 60-year historical period (1947 through 2006) assuming a senior priority date were calculated based on the Guadalupe-San Antonio River Basin Water Availability Model (TNRCC Dec 1999). To assess VCS surface water use impacts as a function of run-of-river flows, the estimated VCS daily makeup water withdrawal rates were compared to the range of daily river flow conditions estimated over the 60-year historical period. The frequency distribution of the daily VCS makeup water withdrawal as a percentage of the daily Guadalupe River flow for the 60-year period estimates that VCS water withdrawal would be less than 15 percent of the Guadalupe River flow 85 percent of the time; and the withdrawal rate would exceed 30 percent of the estimated river flow less than 3 percent of the time. Based on this evaluation, freshwater inflows to the San Antonio Bay system for the period of record would be relatively unaffected by VCS water use.

- The VCS water withdrawals would be obtained from one or more water rights. The surplus available under senior (priority) GBRA/UCC unallocated water rights or other existing water rights in the Guadalupe-San Antonio River Basin is sufficient to meet the VCS site demand.

- A bio-statistical study was conducted to evaluate the potential effects of VCS water withdrawals on the ecological health of the San Antonio Bay system, using the average annual abundances of four key estuarine species (brown shrimp, white shrimp, blue crab, and eastern oyster) as a representation of bay health. The TPWD Coastal Fisheries Database provided approximately 787,000 records for the selected species for the period 1977–2008. Freshwater inflow data were obtained from the TWDB and the USGS and aggregated to estimate daily inflows to the bay system over the same period, from which seasonal (i.e., "freshet") and annual representations of inflow were characterized. Roughly

60,000 multivariate linear regression analyses were performed and evaluated to identify their ability to relate freshwater inflows to the average annual abundances of the selected species, ultimately yielding a relationship for white shrimp and relatively weaker relationships for blue crab and eastern oyster. No relationship was identified for brown shrimp. The identified regressions were used in conjunction with hydrological scenarios developed using the Region L GSA WAM to assess current San Antonio Bay conditions and potential effects on the selected organisms' abundances associated with the proposed VCS water withdrawals from the Guadalupe River. With respect to freshwater inflows to San Antonio Bay, the project-specific scenario analyzed, and the methodologies employed therein, the study did not indicate that the VCS project would yield a statistically discernible impact (at the 95 percent confidence level) on the predicted future abundances (as compared to current abundances) of the key San Antonio Bay organisms evaluated. The study results are consistent with the conclusion that VCS water use impacts on the ecological health of San Antonio Bay would be small.

- The Present Conditions with VCS hydrological model used in the bio-statistical evaluation indicates that at lower flows (i.e., flows exceeded 90 percent of the time) there is a modeled net increase of approximately 1 percent in freshwater inflows to San Antonio Bay with VCS in operation, primarily due to modeled blowdown from the VCS cooling basin.

5.2.2.2 Groundwater

The VCS potable water system, demineralized water system, fire protection system, and miscellaneous onsite users would be supplied by groundwater wells. Groundwater would be withdrawn from the Evangeline Aquifer, as described in Subsections 2.3.1 and 2.3.2. The Evangeline Aquifer is not in communication with local surface water bodies. Therefore, site groundwater withdrawals would not affect local surface water bodies.

Groundwater would be supplied from onsite production wells to meet an estimated demand of 464 gpm (normal) to 1053 gpm (maximum) (Table 3.3-1). Additionally, as noted in Table 3.3-1, up to 1200 gpm (maximum) would be required from onsite wells to refill the fire water storage tank(s) within the required 8-hour time frame. The onsite production wells would be located to minimize interference between them and drawdown at planned reactor buildings. A groundwater drawdown analysis was performed for a conceptual layout of three proposed production wells at the site. The criteria for the well locations were: (1) at least 100 feet from the site boundary, (2) at least 4000 feet from the nearest assumed reactor containment, (3) at least 6000 feet from an adjacent onsite production well, and (4) screened in the Evangeline Aquifer between 450 and 1000 feet below existing grade. The analysis assumed the three onsite production wells would be placed in a triangular configuration around the power block. Two wells would be located to the east and west, approximately 9600 feet apart. A third well would be located to the north, approximately 6600 feet equal distance from the other two wells.

Various pumping scenarios ranging from 215 to 425 gpm (for normal operations) to 1200 gpm (peak demand required to refill the fire water storage tank(s) within 8 hours) were evaluated. These pumping rates envelope the predicted groundwater demands for operation of a proposed plant at the VCS site. The results indicate that the groundwater drawdown impacts due to the pumping from the site's production wells during plant operations would be SMALL. The groundwater drawdown analysis is summarized below.

Three pumping scenarios were evaluated for the normal operations groundwater demand: (1) pumping 425 gpm from a single well, (2) pumping 215 gpm from two adjacent production wells (6600 feet spacing), and (3) pumping 215 gpm from two wells at opposite ends of the site (9600 feet spacing). Hydraulic conductivity (K) values of 100 and 226 gallons per day per square foot (gpd/square feet) were used in the analysis. The estimated drawdown for each scenario at each production well and at the nearest reactor building (4000 feet from the well) is summarized below.

Pumping rate (gpm)	**Drawdown (ft) at Production Well**		**Drawdown (ft) at Nearest Reactor Building**	
	K = 100 gpd/ft^2	K = 226 gpd/ft^2	K = 100 gpd/ft^2	K = 226 gpd/ft^2
(1) 425	43.5	20.0	11.0	6.0
(2) 2 × 215 (6600 feet spacing)	27.0	12.5	11.0	6.0
(3) 2 × 215 (9600 feet spacing)	26.0	12.0	11.0	5.5

To be conservative, the drawdown of the Evangeline Aquifer was also estimated for a peak groundwater demand of 1200 gpm for a period greater than 1 year. The peak demand could be met by pumping two production wells at a rate of 600 gpm from each well (production well 1 or 2 could be pumped in conjunction with well 3 to produce the same drawdown pattern and well spacing). The estimated drawdown when pumping a two-well system at 600 gpm per well, with 6600 feet of well spacing, is summarized below:

Location	**Drawdown (ft) for K = 100 gpd/ft^2**	**Drawdown (ft) for K = 226 gpd/ft^2**
Well 1 or 2	75	35
Well 3	75	35
Nearest reactor building	31	16

The above drawdown predictions are based on pumping groundwater only at the VCS site from the Evangeline Aquifer. The predictions do not consider the effects of recharge or vertical leakage from the overlying Chicot Aquifer, both of which would tend to mitigate drawdown impacts in the Evangeline Aquifer from VCS production wells. However, given the depth of the Evangeline Aquifer, the distance to the aquifer outcrop area, and the presence of a thick confining layer separating the Evangeline and Chicot Aquifers, effects from recharge or vertical leakage would be minimal.

As described in Subsection 2.3.2.2, the current offsite wells in the VCS vicinity are screened in the shallow Chicot Aquifer, have low pumping rates, and are located well outside the site boundaries. It is unlikely that the proposed VCS production wells would impact the offsite well users. The groundwater use impacts due to pumping from the site's production wells during operation would be SMALL.

As described in Subsection 2.3.2, the Victoria County Groundwater Conservation District was created in 2005 and the district management plan (adopted by the VCGCD and TWDB during late 2008) established an estimated value of 35,000 acre-feet per year (based on the TWDB groundwater availability model) as the amount of groundwater that can be produced within the district and beneficially used. The projected groundwater supply available in the South Central Texas Region L water planning area from the Gulf Coast Aquifer during a drought of record condition is 132,348 acre-feet per year throughout the 2010 through 2060 projection period. Available and allocated groundwater supply projections for Victoria County, which are provided in Table 2.3.2-2, indicate that in 2040 and 2060, the county will have 7487 acre-feet per year and 8229 acre-feet per year, respectively, of unallocated groundwater supplies. Currently all new non-exempt wells to be located in Victoria County are required to obtain a permit prior to commencement of drilling and/or operation under the rules of VCGCD. As of April 2009, there were two permits, one for drilling and one for operating, under review. The estimated normal groundwater use for VCS is approximately 750 acre-feet per year (464 gpm). Because Victoria County will have a projected unallocated groundwater supply of 7487 acre-feet per year in 2040 and there are no current public water supply applications pending for the county, the impacts of the VCS groundwater demand on the regional groundwater supplies would be SMALL and would not warrant mitigation.

5.2.3 Water Quality Impacts

5.2.3.1 Surface Water

The proposed closed-cycle cooling system includes an approximately 4900-acre cooling basin for dissipation of waste heat. It will be necessary to blow down the cooling basin to control the accumulation of salts and solids in the reservoir. Cooling basin blowdown would be pumped to the Guadalupe River via a discharge pipeline. The blowdown flows are expected to range between 0 and 6500 (normal) or 40,000 (maximum) gpm. The characteristics of the plume associated with the blowdown discharge, including its physical and chemicals effects, are described in Subsection 5.3.2.

As described in Subsection 5.3.2, because the VCS cooling basin would be classified under TCEQ rules as an "industrial cooling impoundment" and would not support recreational or other public uses, discharges to the cooling basin are not anticipated to be subject to the Texas surface water quality standards. Discharges into the Guadalupe River would be subject to state water quality standards. Limits on VCS outfall concentrations, flow rates, and monitoring schedules would be determined through the Texas Pollutant Discharge Elimination System (TPDES) permitting process.

The water in the mechanical draft cooling tower basins (service water system) would be treated for pH control, biofouling, and scale control and dechlorination using appropriate chemicals. Biocides and chemical additives used in VCS plant systems would be consistent with those approved by the U.S. Environmental Protection Agency or the state of Texas. The effluents associated with these systems may contain low concentrations of some chemicals and/or biocides. The cooling basin water could contain low concentrations of chemicals and/or biocides introduced by the plant effluents or as constituents in the raw water makeup supply from the intake canal. The volume and concentration of each constituent discharged to the Guadalupe River as part of the blowdown would meet all requirements established in the TPDES permit issued by the TCEQ. Considering the anticipated amount of mixing and the limits that will be placed on the discharge in the TPDES permit, the effects of chemicals in the blowdown discharge on the Guadalupe River water quality would be SMALL.

The characteristics of the blowdown discharge plume, including its physical and chemical effects, are described in Subsection 5.3.2. Although the VCS RWMU system intake would be located downriver from the plant discharge, there is little risk of recycle. As described in Subsection 5.3.2.2.2, the blowdown discharge plume would become fully mixed with the Guadalupe River within 600 feet downstream of the discharge under the most restrictive river flow/blowdown discharge flow conditions. Concentrations of solids and chemicals in the blowdown discharge water would return to ambient river levels almost immediately downstream of the discharge diffuser. The discharge waters would continue to mix with Guadalupe and San Antonio River water and surface runoff along the approximately 20 river mile route to the RWMU system intake. Given the level of mixing associated with the VCS intake and discharge arrangement, the potential for recycle-related effects is minimal.

The cooling basin's passive emergency spillway would be designed such that there would be outflow only during storms that exceed the 100-year, 24-hour rain event. A stilling basin would be installed at the end of the spillway to dissipate energy in the outflow and to reduce the potential for downstream erosion.

Power generated from VCS would be transmitted over new circuits that would interconnect to substations at Hillje, Cholla, Coleto Creek, Whitepoint, Blessing, and STP (Figure 2.2-3). In order to fully deliver VCS-generated power to the regional transmission grid, additional transmission lines are expected to be built in the vicinity or colocated (where practicable) with the existing transmission lines in the area as discussed in Section 3.7.2. These corridors cross more than 120 (intermittent and perennial) stream drainages, including the Guadalupe, Lavaca, and Navidad rivers and the Victoria Barge Canal. The transmission line inspections and maintenance procedures are expected to be the same as in use today for similar high voltage lines. Chemicals, chiefly herbicides, would be used in the corridors, but use of chemicals is mitigated by the use of EPA-registered formulations that are approved for use in utility corridors. The transmission lines are expected to traverse mostly agricultural lands and there should be limited need for corridor maintenance. Because the transmission service provider would be expected to follow best management practices in the use of chemicals in maintaining the transmission corridors, the impacts to water quality associated with streams or rivers in or near the corridors are expected to be SMALL.

5.2.3.2 Groundwater

Groundwater supplied from onsite wells and used in the potable water system, demineralized water system, fire protection system, and miscellaneous onsite uses would be continuously fed a biocide such as sodium hypochlorite to prevent biological growth. Because the total suspended solids levels in the groundwater are low, no coagulate chemicals would be considered for treatment.

Spills of materials such as diesel fuel, hydraulic fluid, or lubricants would be unlikely during operations; however, should they occur, they would be cleaned up quickly in accordance with a developed VCS SPCC Plan. Although these plans are primarily intended to prevent spilled oil from moving into navigable waters, they also would mitigate impacts to local groundwater because spills are quickly attended to and not allowed to penetrate to groundwater.

Saltwater intrusion effects can occur either by lateral intrusion of the saltwater front or from upconing beneath a pumping well. Lateral intrusion of the saltwater front requires a significant drawdown of freshwater in the aquifer to allow saltwater to migrate laterally. The distance to the nearest saltwater source (the tidal segment of the Guadalupe River, which starts at the GBRA saltwater barrier) is approximately 12 miles. Although the Victoria Barge Canal is closer, the Guadalupe River provides a boundary between the VCS site and the tidally influenced canal. The distance to the nearest saltwater source and the absence of other large groundwater production wells between the site and the saltwater barrier indicate that lateral intrusion is not a likely mechanism. Upconing occurs when pumping from a production well lowers the head of freshwater above the fresh/saltwater interface (inferred to be at elevation 1500 feet below mean sea level for the VCS area). The density difference between the fresh and saltwater lifts the interface upward beneath the pumping well, and at a certain critical rise the fresh/saltwater interface accelerates upward and enters the well. Analysis for the range of hydraulic conductivity, distance to the fresh/saltwater interface, and the expected screened interval for the site wells indicates that upconing of saltwater is unlikely at the anticipated pumping rates for the VCS production wells.

Given that an SPCC Plan would be implemented and that saltwater intrusions are unlikely, the impacts of VCS operation on groundwater quality would be SMALL and would not warrant mitigation.

5.2.4 References

Camp Dresser & McKee Jun 1992. Regional Water Supply Plan for the City and County of Victoria.Texas Water Development Board Contracted Report 91483588, June 1992.

GSA BBEST March 2011. Environmental Flows Recommendations Report Final Submission to the Guadalupe, San Antonio, Mission, and Aransas Rivers and Mission, Copano, Aransas, and San Antonio Bays Basin and Bay Area Stakeholder Committee, Environmental Flows Advisory Group, and Texas Commission on Environmental Quality. Guadalupe, San Antonio, Mission, and Aransas Rivers and Mission, Copano, Aransas, and San Antonio Bays Basin and Bay Expert Science Team, March 1, 2011. Available at: http://www.tceq.state.tx.us/assets/public/permitting/watersupply/water_rights/eflows/20110301guadbbest_transmission.pdf, accessed September 30, 2011.

Harbaugh et al., 2000. Harbaugh, A.W., Banta, E.R., Hill, M.C., and McDonald, M.C., MODFLOW2000, The U.S. Geological Survey Modular Ground-Water Model-User Guide to Modularization Concepts and Ground-Water Flow Process, U.S. Geological Survey Open-File Report 00–92, Reston, Virginia, 2000.

Longley, W.L., ed. 1994. Freshwater inflows to Texas bays and estuaries: ecological relationships and methods of determination of needs. Texas Water Development Board and Texas Parks and Wildlife Department, Austin, TX. 386 pp. Available at http://midgewater.twdb.state.tx.us/bays_estuaries/Publications/FreshwaterInflows-%20Ecological%20Relationships%20and%20Methods%20for%20Determination%20of%20Needs%20-%201994.pdf, accessed May 17, 2010.

McDonald 2009. McDonald, J.H., Handbook of Biological Statistics (2nd ed.). Sparky House Publishing, Baltimore, Maryland. pp. 1-3. 2009.

Pollock, 1999. Pollock, D.W., User's Guide for MODPATH/MODPATH-PLOT, version 3: A Particle Tracking Post-Processing Package for MODFLOW, the U.S. Geological Survey Finite-Difference Ground-Water Flow Model, U.S. Geological Survey Open-File Report 94-464, Reston, Virginia, 1994.

Pulich et al. 1998. Pulich, Jr., W., W.Y. Lee, C. Loeffler, P. Eldridge, J. Hinson, M. Minto, and D. German. 1998. Freshwater inflow recommendation for the Guadalupe Estuary of Texas. Coastal Studies Technical Report No. 98-1. Texas Parks and Wildlife, Austin, Tx. 100 pp. Available at http://midgewater.twdb.state.tx.us/bays_estuaries/Publications/Freshwater%20Inflow%20Recommendation%20for%20the%20Guadalupe%20Estuary%20of%20Texas%20-%201998.pdf, accessed May 17, 2010.

SAC (Science Advisory Committee) 2009. Methodologies for Establishing a Freshwater Inflow Regime for Texas Estuaries Within the Context of the Senate Bill 3 Environmental Flows Process, Report # SAC-2009-03. Document Version Date: June 5, 2009. Austin, TX. Available at http://www.tceq.state.tx.us/assets/public/permitting/watersupply/water_rights/eflows/fwi20090605.pdf, accessed June 3, 2010.

Schlumberger Water Services, 2008. Schlumberger Water Services, Visual MODFLOW v. 4.3 User's Manual, Waterloo, Ontario, Canada, 2008.

Slack et al. 2009. Slack, R.D., W.E. Grant, S.E. Davis III, T.M. Swannack, J. Wosniak, D.M. Greer, and A.G. Snelgrove, Linking Freshwater Inflows and Marsh Community Dynamics in San Antonio Bay to Whooping Cranes, SAGES (San Antonio Estuarine System) Final Project Report to the Guadalupe-Blanco River Authority and the San Antonio River Authority, Texas A&M AgriLIFE, April 2009.

SCTRWPG 2010. South Central Texas Regional Water Planning Group, 2011 South Central Texas Regional Water Plan, September 2010. Available at http://www.regionltexas.org/2011_rwp2.php, accessed September 29, 2011.

TDWR Nov 1982. Texas Department of Water Resources, Land-Surface Subsidence in the Texas Coastal Region, Report 272, November 1982.

TNRCC Dec 1999. Texas Natural Resource Conservation Commission, Water Availability in the Guadalupe-San Antonio River Basin, December 1999.

TWDB Feb 2010. Texas Water Development Board, 2011 South Central Texas Regional Water Plan. DRAFT Initially Prepared Plan, February 2010.

Table 5.2-1
Frequency Distribution of Estimated VCS Water Withdrawal as a Percentage of the Historical 60-Year Daily Guadalupe River Flow

Plant Water Use as a Percentage of the Daily Guadalupe River Flow	Number of days (from a total of 21,915 days)	Percent of 60-Year Period (1947–2006)
0%[a]	3741	17%
0–5%	6662	30%
5–10%	5463	25%
10–15%	2821	13%
15–20%	1366	6.2%
20–25%	741	3.4%
25–30%	499	2.3%
30–35%	232	1.1%
35–40%	117	0.53%
40–45%	64	0.29%
45–50%	53	0.24%
50–55%	34	0.16%
55–60%	12	0.055%
60–65%	21	0.096%
65–70%	26	0.12%
70–75%	9	0.041%
75–80%	8	0.037%
80–85%	7	0.032%
85–90%	17	0.078%
90–95%	15	0.068%
95–100%	7	0.032%

(a) Represents when either the plant (1) needed no additional makeup water, due to the cooling basin water level being at or above the design pool elevation, or (2) no water was available for plant use as the result of low flow conditions.

Table 5.2-2
Estimated VCS Water Withdrawal as a Percentage of the Historical 60-Year Guadalupe River Flow

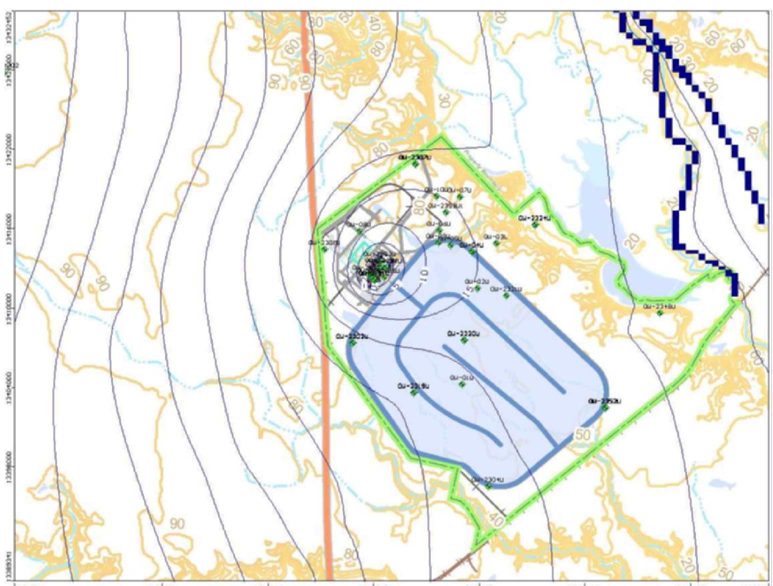
Season	Month	Estimated VCS Water Use as a Percent of Guadalupe River Flow (1947–2006)	Seasonal Percentage
Winter	December	3.3%	7.0%
	January	10%	
	February	7.3%	
Spring	March	7.3%	6.9%
	April	6.8%	
	May	6.5%	
Summer	June	7.4%	8.8%
	July	8.5%	
	August	11%	
Fall	September	8.5%	8.6%
	October	10%	
	November	7.0%	

Table 5.2-3
Organism Abundance Estimated using the Present Conditions with VCS Hydrological Model, Including Potential Changes Relative to Abundance Estimated using the Present Conditions without VCS Hydrological Model

Organism	Occurrence	Present Conditions without VCS Project-Abundance (number/ acre-foot)	Present Conditions with VCS Project-Abundance (number/ acre-foot)	Present VCS Project Impact on Present Conditions (number/ acre-foot)	Percent Change from Present Conditions with VCS Project	Statistical Confidence in the Predicted Change
White Shrimp	90% Exceedance	1.18	0.96	-0.22	-18.37%	At most 12%
	10% Exceedance	8.69	8.31	-0.38	-4.35%	
	Average	4.43	4.13	-0.30	-6.88%	
Eastern Oyster	90% Exceedance	1,380.16	1,391.47	11.31	0.82%	At most 2%
	10% Exceedance	2,181.07	2,188.34	7.27	0.33%	
	Average	1,868.01	1,878.16	10.15	0.54%	
Blue Crab	90% Exceedance	3.84	3.84	0.00	0.00%	At most 6%
	10% Exceedance	10.31	10.03	-0.29	-2.76%	
	Average	6.82	6.58	-0.25	-3.63%	

Red shaded areas are constant head boundaries
Blue-green shaded areas are inactive cells representing the open excavation
Contour Interval = 5 ft

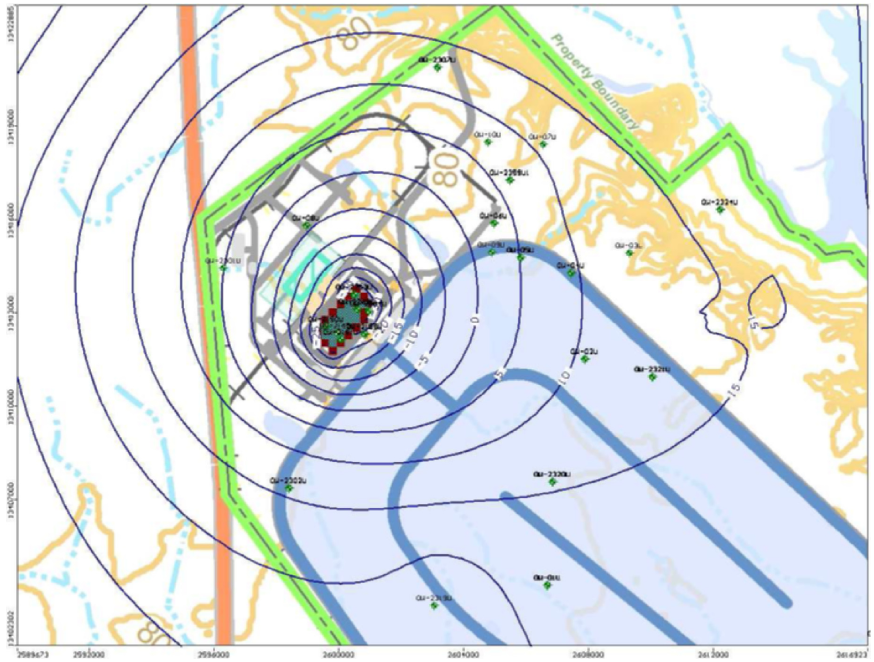
Detail View



Dark blue shaded areas are river boundaries
Contour Interval = 5 ft

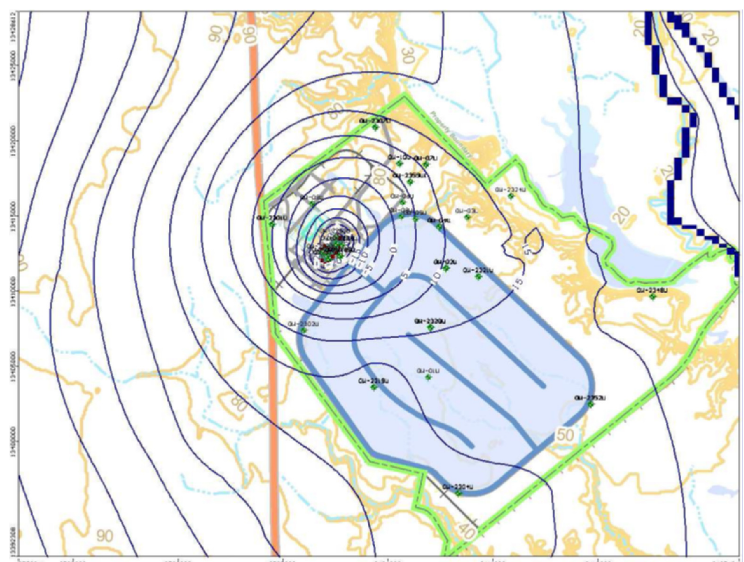
Overview

Figure 5.2-1 Simulated Potentiometric Surface for Dewatering Scenario 1 in Layer 6 (Basin Empty)



Red shaded areas are constant head boundaries
Blue-green shaded areas are inactive representing the open excavation
Contour Interval = 5 ft

Detail View



Dark blue shaded areas are river boundaries
Contour Interval = 5 ft

Overview

Figure 5.2-2 Simulated Potentiometric Surface for Dewatering Scenario 3 in Layer 6 (Basin Filled)

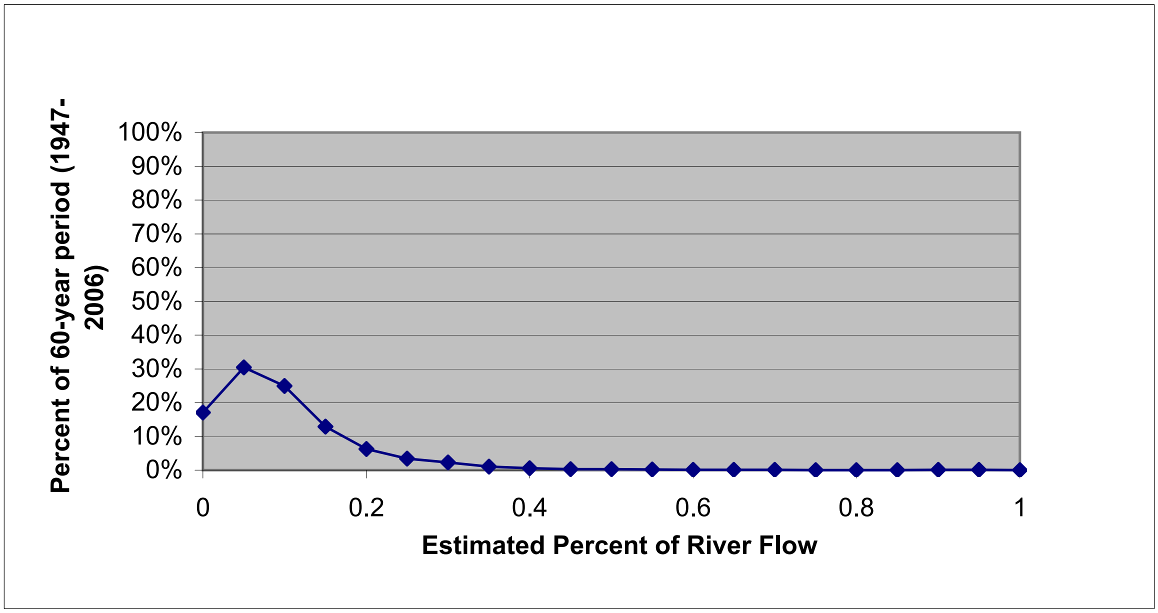


Figure 5.2-3 Frequency Distribution of Estimated VCS Water Withdrawal as a Percentage of the Historical 60-Year Guadalupe River Flow

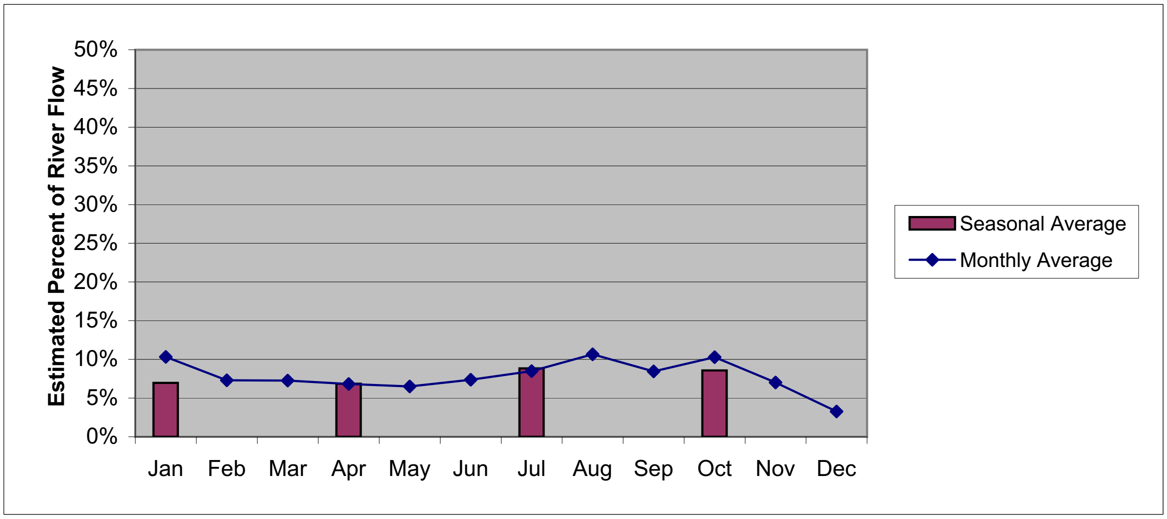


Figure 5.2-4 Estimated VCS Water Withdrawal as a Percentage of the Historical 60-Year Guadalupe River Flow (1947-2006)

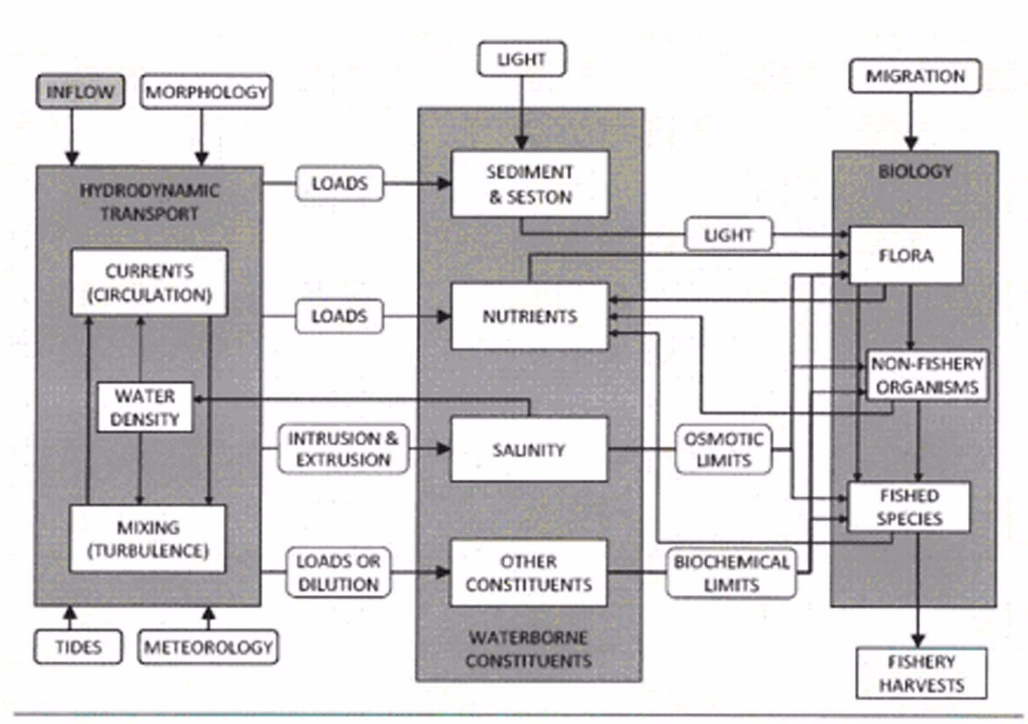


Figure 5.2-5 Schematic of Estuarine Ecosystem (SAC 2009)

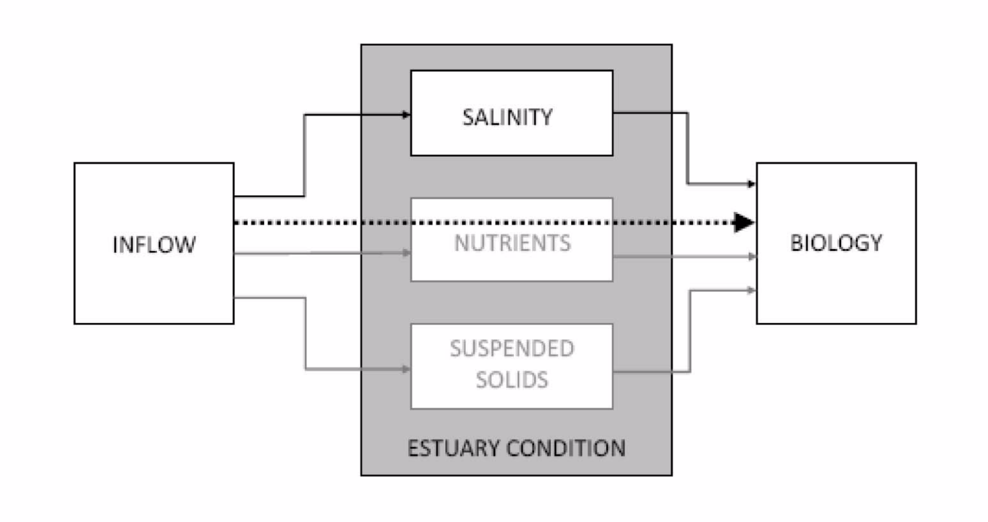


Figure 5.2-6 Schematic of Estuarine Ecosystem Simplified to Show Relation of Freshwater Inflow to Estuary Biology (SAC 2009)

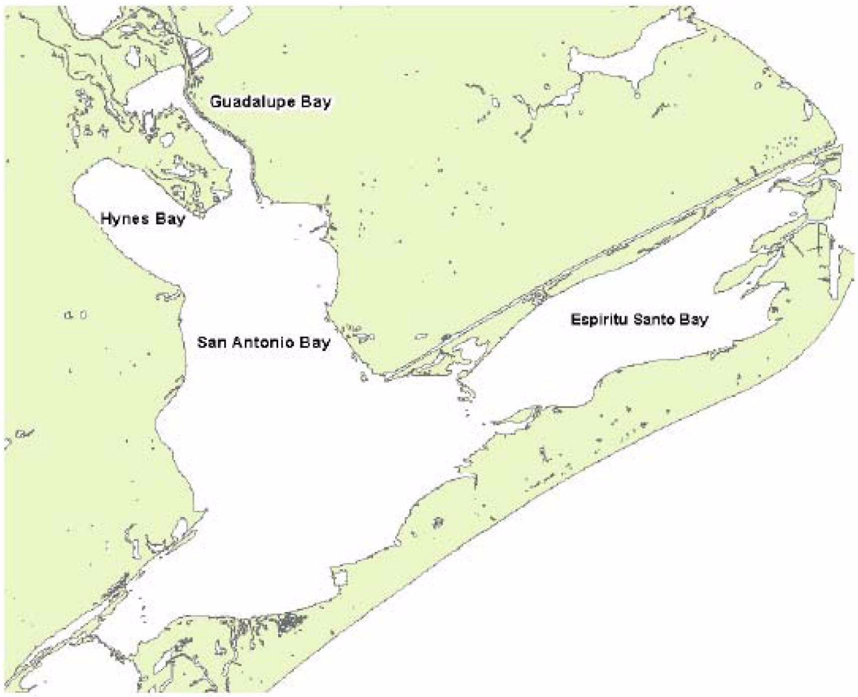


Figure 5.2-7 San Antonio Bay System

5.3 Cooling System Impacts

This section discusses and evaluates potential impacts of cooling system operation on the Guadalupe River aquatic communities. Individual parts of the cooling system are addressed separately in the following sections:

- Cooling Water Intake system
- Cooling Water Discharge system
- Heat Discharge system (cooling basin)

5.3.1 Intake System

5.3.1.1 Hydrological Descriptions and Physical Impacts

Section 3.4 describes the VCS proposed closed-cycle cooling system, which would include a raw water makeup (RWMU) system pumphouse on a 0.6 mile-long intake canal (3150-foot-long canal and 200-foot-long intake basin) that extends south from the Guadalupe River, as shown in Figure 5.3.1-1. Freshwater would be pumped from this canal to the VCS cooling basin via an approximately 8.5 to 11-mile-long pipeline (depending upon the route selected). The water from the canal would replace water lost to evaporation, blowdown, and seepage. The RWMU system pumphouse, a three-bay structure, would provide a maximum of 267 cubic feet per second (cfs) (120,000 gpm). As described in Section 3.4, a maximum of 217 cfs (97,500 gpm) would be supplied to the VCS cooling basin and a maximum of 50 cfs (22,500 gpm) would be reserved for future use by another non-VCS entity or entities. Although designed to supply as much as 217 cfs to the VCS cooling basin, the average pumping rate would be approximately 103.5 cfs (46,500 gpm).

The RWMU system intake structure would be constructed of reinforced concrete. Its layout would include a three-bay pumphouse with through-flow traveling water screens in each bay, provisions for stop logs or stop gates, spray wash pumps for the traveling water screens, fish return pumps, RWMU system pumps, and all necessary support facilities for operation of the RWMU system intake structure. The intake face would be perpendicular to the intake basin/canal and would occupy approximately 93 feet of shoreline. The intake structure would be equipped with steel trash racks (grates) with 1.0-inch openings to prevent heavy debris from entering the intake and damaging the traveling screens. The maximum flow (velocity) through the trash racks would be 0.26 feet per second (fps). After passing through the trash racks, intake water would flow through vertical traveling screens of a modified Ristroph design. Maximum through-screen velocity would be 0.5 fps.

Limiting the volume of water withdrawn at the RWMU system pumphouse for VCS cooling basin makeup to no more than 5 percent of the calculated annual mean flow (1997–2006) of the source water body (Guadalupe River) and limiting through-screen velocities to 0.5 fps or less at the intake structure trash racks and traveling screens are “technology-based performance standards” established in the EPA’s Phase I rule addressing cooling water intake structures (CWIS) for new facilities (66 FR 243). Ristroph-style traveling screens and fish handling (return) systems are listed in the Phase I rule as potentially effective design and construction technologies available for installation at CWIS for minimizing adverse impacts.

5.3.1.2 Aquatic Ecosystems

5.3.1.2.1 Impingement

The EPA’s regulations for CWIS for new facilities (66 FR 243) established technology-based requirements for the location, design, construction, and operation of CWIS at new industrial facilities. More specifically, the regulations present a two-track approach (two options) for demonstrating compliance with Section 316(b) of the Clean Water Act and minimizing adverse environmental impacts associated with operation of CWIS.

The EPA’s Track I approach establishes national intake capacity and velocity requirements, as well as location and capacity requirements, to ensure that CWIS flows are a small proportion of flow of the source water body. Track II allows permit applicants to conduct site-specific studies to demonstrate that adverse impacts are comparable to those that would be achieved under the Track I requirements. Exelon used the Track I requirements to guide the design of the VCS cooling system generally and the RWMU system pumphouse specifically. The Track I requirements are as follows:

- Cooling water intake flow must be at a level commensurate with that of a closed-cycle, recirculating cooling system.
- Through-screen intake velocity must be less than or equal to 0.5 fps.
- Cooling water intake flow must be less than or equal to 5 percent of the annual mean flow of the source water.
- Design and construction technologies for minimizing impingement must be selected and implemented if (1) there are threatened, endangered, or otherwise protected federal, state, or tribal species or critical habitat for these species within the hydraulic zone of influence of the cooling water intake structure; or (2) there are migratory, sport, and/or commercial species that pass through the hydraulic zone of influence and are of impingement concern to the EPA or fishery management agency(ies).

Under the design capacity peak flow rate of 267 cfs, the approach velocity would be 0.5 fps or less at the trash racks, intake apertures, and traveling screens. The maximum velocity through the bar grill would be 0.26 fps. The maximum through-screen velocity would be 0.5 fps. Intake velocities of this magnitude are rarely a threat to healthy adult and juvenile fishes, but they do have the potential to impinge younger, smaller, and unhealthy individuals.

The cooling water intake structure would be designed to minimize impingement mortality. After passing through the trash racks, intake water would flow through vertical traveling screens of a modified Ristroph design. Each traveling screen would be a continuous steel belt of framed mesh panels approximately 12.5 feet wide and composed of smooth screen-wire with 3/8-inch openings. Each panel would have a trough (fish bucket) on the lower lip designed to prevent re-impingement of fish and provide the mechanism to return fish to the Guadalupe River downstream of the intake canal opening. The fish buckets would allow organisms to remain in the water while being lifted to the fish return trough. As the traveling screen panel travels over the head sprocket of the traveling screen, low pressure sprays (10 pounds per square inch nominal) would gently wash the organisms into the fish return trough. As the traveling screen panel traverses further, high-pressure sprays (90 pounds per square inch nominal) would wash the remaining debris into the debris trough.

In the absence of an operating cooling water intake structure, it is impossible to observe impingement or measure impingement mortality. The maximum intake and through-screen velocities at the proposed RWMU system intake would be so low that impingement losses at the intake would be minor. In addition, Exelon conducted a review of swimming performance of resident fish species to assess their relative vulnerability to impingement.

Differences among fish species in their response to water flow changes have been attributed to life history traits and physical characteristics (Scott and Magoulick 2008). As described in Subsection 2.4.2, the fish assemblages of the Guadalupe River and its tributaries have been shaped by historical cycles of flood and drought. Fish populations that persist in areas that experience high flows, such as the Guadalupe River and its tributaries, must have either the ability to remain in place during floods or the capacity to rapidly recolonize following a flood. Some species, or particular size-classes of fish, may be more flood tolerant because they have better swimming ability (Scott and Magoulick 2008). Weaker swimmers may stay in place by seeking refuge from the current (Scott and Magoulick 2008). Both swimming speed and the ability to find refuge in a stream may provide protection during high flows, whether those flows result from flood waters or from intake pumps serving industrial facilities. Thus, either morphology or behavior adapted for an intermittent flood regime may provide fish a measure of protection from impingement on cooling water intake screens.

Both maximum and typical swim speeds are measured and reported in the literature. Maximum speeds, also known as critical or burst speeds, represent the sprinting ability of a fish. Typical swim speeds represent the prolonged or sustained speed. Swim speeds available in the literature for the species known to occur near the VCS site are presented in Table 5.3.1-1. Neither duration criteria for defining swim speeds nor test protocols are standardized. Study methods vary greatly from one experiment to the next. Studies of swim speed have been conducted for various purposes, such as (1) predicting impingement on intake screens (Hartwell and Otto 1991), (2) designing culverts to allow fish ingress and egress (FishXing Feb 2006), (3) comparing the abilities of native and nonnative fishes to withstand floods (Ward et al. 2003, Scott and Magoulick 2008), and (4) optimizing dispersal opportunities for desired fish species, and others (Adams et al. 2000; Hoover and Killgore May 2002). Each type of study focuses on particular aspects of swim speed and endurance and reports data that can be used in the evaluation of the proposed RWMU system intake structure. Despite the variety of study types, some general trends have been shown.

Some morphological features are reliably associated with fast swimming and resistance to displacement during high flows. For example, the elongated and slender body form of shiners (*Cyprinellus*, *Notropis*) indicates an efficient swimmer able to cope with fast currents (Scott and Magoulick 2008). The red shiner has a burst swim speed of more than 2.5 fps (Table 5.3.1-1). Large schools of cardinal shiners have been seen swimming in the water column within or adjacent to areas of high flow, feeding on drifting invertebrates (Robinson and Buchanan 1992), as cited in (Scott and Magoulick 2008). Shiners in other swimming speed experiments have also shown relatively high critical swimming speeds (Scott and Magoulick 2008, Ward et al. 2003).

In contrast, fish with short, round bodies experience more friction and thus must expend more energy to swim quickly. Fin placement and shape also affect swim speed. Pool dwellers such as gars (*Lepisosteus* spp.) and topminnows (*Fundulus* spp.) have rearward-placed dorsal fins, cylindrical bodies, flat heads, thick caudal peduncles, and broad round tails. Although no swim speed data was found for these fishes, this general body form is associated with rapid acceleration (Hoover and Killgore May 2002). In contrast, sunfishes (*Lepomis* spp.) have centrally located dorsal fins and compressed, deeper bodies, with symmetrical dorsal and ventral contours. Sunfishes are known for extreme maneuverability rather than fast swimming (Hoover and Killgore May 2002).

Sunfish tend to be cover-oriented, and associated with rocks, limbs, and other physical habitat features (Scott and Magoulick 2008), which may compensate for their relatively slower swim speeds. Ward et al. (2003) measured swimming performance of 12 common Arizona stream fishes, several of which are found in the lower Guadalupe River. The green sunfish ranked ninth out of 12 species, with a critical swimming speed of only 1.52 fps, yet this species persists in flood-prone environments, including the Guadalupe River. Lower critical swim speeds for green sunfish were reported by (Scott and Margoulick 2008) than by (Ward et al. 2003), owing in part to the experimental protocol. (Scott and Margoulick 2008) also reported substantially lower critical speeds for the longear sunfish, even lower than the prolonged swim speeds reported by other authors (Table 5.3.1-1). The explanation for these anomalies lies in the experimental design and study objectives. (Scott and Margoulick 2008) acknowledge that they “did not attempt to define stream velocity threshold levels for each species, but [their] study does provide some insight into the advantages and disadvantages each species may have during high-flow events.” Nevertheless, the critical swim speeds reported in this study are higher than the design face velocity at the RWMU system intake trash racks (0.26 fps) and traveling screens (0.5 fps) (Table 5.3.1-1).

In the vicinity of VCS, the Guadalupe River is muddy and large amounts of dead wood provide fish cover and refuge from flows. Some fish, particularly benthic species and weaker swimmers, are known to use structures in the habitat to provide shelter from flow and to actively select lower velocity patches within a larger stream flow. Habitat availability and behavior appear to be more important than swimming ability in preventing displacement of sunfish by high flows. For example, green sunfish and orangethroat darters (*Etheostoma spectabile*) chose lower-velocity patches in an experimental flume when habitat complexity was provided. Even when the habitat was simple and cover was absent, cardinal shiners and longear sunfish actively chose lower-velocity flume patches (Scott and Magoulick 2008).

For some fish species found in the vicinity of the VCS site, no swim speed data was found. Taxonomically and morphologically similar species may provide reasonable surrogate estimates of swim speed. For example, a single study of the red shiner is augmented by data on other shiners (Table 5.3.1-1). Reports on congeneric species are provided whenever possible; the swim speed of the fathead minnow (*Pimephales promelas*) may be an acceptable substitute for that of the bullhead minnow, *P. vigilax,* and data on the Atlantic silverside (*Menidia menidia*) is offered in place of the inland silverside *M. beryllina* (Table 5.3.1-1).

Other species near the VCS site are not represented even by congeneric surrogates. No swim speed data on any gar or sciaenid (drum) was located. For these species, knowledge of general morphological features and behavioral traits that support predictions of swim speed must be relied upon. In addition to the generalities discussed above, it is well documented that small fish experience less turbulence over their bodies—and thus less drag from the water—than larger fish of the same shape (Matthews 1998). Smaller fish have relatively faster critical swim times than larger fish. Small fish (0.1 meter) can reach speeds up to 25 body lengths per second, whereas larger fish (1 meter) seem unable to exceed 4 body lengths per second (Wardle 1975). Smaller fish are capable of higher tail beat frequencies than larger fish and forward motion resulting from one complete tail beat cycle is generally between 0.6 and 0.8 times the length of the fish (Wardle 1975).

Gars are among the most primitive fishes and are native to the Mississippi River basin (Berra 1981). Larval gars are weak swimmers, but are equipped with adhesive discs on their snouts that allow them to hold position until their swimming ability improves (Mettee et al. 1996). Spotted gar (*Lepisosteus oculatus*) and alligator gar (*Atractosteus spatula*) prefer backwater riverine areas with little or no current. In contrast, longnose gar (*L. osseus*) are more common in faster flowing waters

(Mettee et al. 1996). As expected based on morphological trends, the longnose gar is more slender and fusiform than the spotted gar or alligator gar, and it feeds on faster swimming prey such as anchovies and menhaden. In contrast, the alligator gar feeds on crabs, mullet, and water birds, and the spotted gar eats primarily crustaceans and bony fish (McEachran and Fechhelm 1998).

No swim speed data on the freshwater drum (*Aplodinotus grunniens*) was found. However, Alabama observations of this widespread species indicate that although juveniles are found in backwaters and marginal riverine habitats, adults prefer the fast-moving waters below dams (Mettee et al. 1996). The freshwater drum is a bottom-oriented fish, with a flattened ventral surface and a downward-facing mouth. It feeds on slow-moving benthic organisms such as aquatic insects, crayfish, and mollusks (Mettee et al. 1996). Based on morphology and the fact that freshwater drum in rivers are more robust (higher relative weights) than those in reservoirs, it appears that this species is best adapted (at least in the southeastern United States) to large rivers and lotic conditions (Rypel et al. 2006). This preference for flowing waters suggests that the freshwater drum is, at a minimum, a capable swimmer.

In summary, an examination of swimming performance of fish found in the vicinity of the VCS site suggests that healthy adults and juveniles would not be susceptible to impingement. Even the species that would seem most at risk are easily capable of escaping design intake flows. For example, fragile, smaller-bodied species such as the inland silverside and the mosquitofish, which are common in the Guadalupe River and its tributaries, are capable of burst speeds that are five to eight times the design approach velocity of the RWMU system pumphouse. Most of the minnow-like fishes are strong swimmers, as their fusiform (streamlined) shape is an adaptation for life in flowing water. The laterally compressed body shape of the Lepomids and crappies is more prevalent in quiet water habitats, particularly those with dense cover, where maneuverability is important. Although not known as strong swimmers, all of the Lepomids and the white crappie are capable of escaping the design intake flows of the RWMU system pumphouse.

The RWMU system pumphouse intake would be designed to minimize impingement mortality. Maximum design intake velocities would be too low to impinge most juvenile and adult fish in good condition. The Ristroph traveling screens and associated fish return system would further reduce impingement mortality, as any fish impinged would be gently washed from the traveling screens and sluiced back into the Guadalupe River at a point far enough removed from the RWMU system intake canal to prevent re-impingement. Impacts from impingement would be SMALL and would not require any mitigation beyond the measures (including Ristroph traveling screens and fish return system) discussed earlier in this section.

5.3.1.2.2 Entrainment

As indicated previously in the discussion of impingement, there is no way to accurately measure entrainment at a CWIS before it is built and operated. In the absence of an operating CWIS, conservative estimates of maximum potential entrainment can be made using densities of fish eggs and larvae in the source water body and design cooling water withdrawal rates. This approach is simplistic, as it assumes a relatively uniform horizontal distribution of eggs and larvae in the source water body, but it is more than adequate to support a comparative assessment of impacts.

Exelon surveyed fish, including ichthyoplankton (eggs and larvae), in the Guadalupe River immediately upstream of the Saltwater Barrier (Station GR-05), Goff Bayou, and the GBRA main canal in 2008. Ichthyoplankton samples were collected at Station GR-05 to characterize the lower Guadalupe River ichthyofauna and determine what groups are most likely to be transported into the intake canal and entrained at the RWMU pumphouse. Ichthyoplankton were collected at Goff Bayou and the GBRA main canal to support the assessment of an RWMU system intake on the GBRA main canal in Section 9.4 (Alternate Plant Systems). The cumulative impact of pumping 217 cfs to the VCS cooling basin and 50 cfs for another entity at some point in the future is analyzed in Section 5.11.

Exelon's analysis of entrainment assumed 100 percent mortality of eggs and larvae entrained in pumping systems. This is conservative. Some eggs and larvae pumped from the Guadalupe River to the cooling basin would survive, but the survival rate would be low owing to the distance traveled. Once eggs or larvae are transported into the cooling basin, all but the most thermally tolerant species would not persist in high summer temperatures. Eggs and larvae pumped into the cooling basin early in the spawning season would be more likely to survive than those pumped into the cooling basin in summer, when water temperatures are high.

To estimate the total number of fish that would be entrained at the proposed RWMU system intake, the density of larvae in the lower Guadalupe River (number per cubic meter) was multiplied by the withdrawal rate (cubic meters per second). This yielded estimates of numbers of larvae entrained per second, which were extrapolated to monthly entrainment estimates by adjusting for the number of days in the month. Table 5.3.1-2 shows the estimated number of larvae that would have been entrained at the RWMU system intake over the February–October 2008 spawning period had the pumps been operating at the maximum withdrawal rate.

Ichthyoplankton collections from the lower Guadalupe River in 2008 were dominated by three species: common carp (*Cyprinos carpio,* 60 percent of total), inland silverside (*Menidia beryllina,* 15.6 percent), and red shiner (*Cyprinella lotrensis*, 14.6 percent).

Most larvae collected were common carp, a nonnative nuisance species. Carp were only collected in one month, March 2008, but spawning almost certainly continued, at a lower intensity, into early summer. Based on densities of larvae in the water column and design pumping rates, an estimated 244,881 carp larvae would have been entrained in 2008 under the maximum pumping scenario (Table 5.3.1-2). A single large female carp can produce several million eggs per season, but the more typical range is 100,000 to 500,000 eggs. These eggs would develop into 10,000–50,000 larvae, according to the species- and age-specific mortality table in the case study analysis for the Phase II Cooling Water Intake Structures [Section 316(b)] rule (U.S. EPA Dec 2006). Thus, the number of larvae that would have been entrained over the February–October 2008 spawning period represents the production of approximately 5–24 female carp. Losing the production of 5–24 fish could have a small impact on carp in the immediate vicinity of the intake canal, but would have negligible impact on the lower Guadalupe River carp population. Proportionately fewer larvae would be entrained under the average pumping scenario (Table 5.3.1-3), making the impact even smaller.

This evaluation assumes that carp have some intrinsic value, and their losses would adversely affect the fish community of the Guadalupe River. Many fisheries managers regard the common carp, a nonnative species introduced to the United States in the middle of the 19th century, as a nuisance. The common carp is considered a pest in the Gulf states and much of the United States because it roots along the bottom searching for food and stirs up bottom sediments. These suspended sediments increase turbidity, reduce photosynthetic growth in submerged vascular plants, and may settle out in the spawning beds of more valuable fish species, smothering their eggs. Carp also eat the eggs and larvae of other fishes including those of native fish and more highly-esteemed sport fishes.

Smaller numbers of inland silverside larvae were collected at the lower Guadalupe River sampling station. The calculated density of inland silverside larvae in the river translated into the loss of 27,873 larvae in April 2008 and 35,836 larvae in May 2008 under the maximum withdrawal case (Table 5.3.1-2), and 13,294 larvae in April 2008 and 17,092 larvae in May 2008 under the average withdrawal case (Table 5.3.1-3). The inland silverside is a short-lived schooling fish, rarely living past its first breeding season. Inland silversides develop rapidly, and may reach sexual maturity in their first year of life (Hassan-Williams and Bonner 2009). In Lake Texoma, which lies on the Texas-Oklahoma border, fecundity of inland silverside ranged from 200 to 2000 eggs per female, with average-sized females producing around 835 eggs daily (Hassan-Williams and Bonner 2009). Along the Gulf Coast, spawning commences in March and extends into July, with multiple peaks of high spawning activity (Weinstein 1986). Females may produce from 20,000 to 170,000 eggs during their reproductive lifetime (Weinstein 1986), which equates to 10,000 to 85,000 eggs per year per individual, as fish normally live for 1 to 2 years. Assuming 10 percent of inland silverside eggs hatch into larvae (U.S. EPA Dec 2006), the 63,709 larvae lost under the maximum withdrawal case represent the production of from 8 to 64 inland silverside.

The total number of inland silverside larvae lost under the maximum withdrawal case, 63,709, would develop into 8199 reproducing adults according to the mortality table in the (U.S. EPA Dec 2006) case study. A single school of inland silversides may contain tens of thousands of fish. These projected losses would be insignificant for the inland silverside, a species with a very high reproductive potential.

A prototypical "r-selected" species, the inland silverside matures early (generally as a 1-year-old), spawns over an extended period, and produces many young. This ensures that some offspring survive in an unstable environment. Inland silversides in Texas and Florida spawn over the February–August period, with activity peaking in spring and late summer. Inland silversides spawned in February or March are capable of spawning as 5-month-old fish in July and August. Fish species like the inland silverside, with virtually unlimited reproductive potential, are genetically programmed to produce large numbers of young when conditions are favorable to compensate for high mortality rates when conditions are bad. Populations can sustain catastrophic losses as a result of droughts and floods and rebound in a matter of months when auspicious conditions lead to a successful spawning season and higher-than-normal survival of eggs and larvae.

Small numbers of red shiner larvae were also collected at the lower Guadalupe River sampling station. A hardy species that thrives in unstable environments (waterbodies subject to extreme temperature and dissolved oxygen fluctuations and high turbidity), the red shiner is found across the Great Plains and is locally abundant in low-gradient streams and rivers in Texas. This species spawns over the April–October period, with peak spawning activity in summer months. However, all red shiner larvae were collected late in the spawning season, in August and October 2008. Based on observed densities of larval red shiners at Station GR-05 and assuming a withdrawal rate of 217 cfs, an estimated 59,727 larvae would have been entrained at the RWMU system intake in 2008 (Table 5.3.1-2). A mature female red shiner produces 2,925–11,115 eggs per spawning season (Hassan-Williams 2009), which translates into 293–1112 larvae per spawning season, based on a typical eggs-to-larvae survival rate of 10 percent for shiners and minnows (U.S. EPA Dec 2006). Thus, the estimated number of larvae that would have been entrained in 2008 under the maximum withdrawal case represents the annual production of 54–204 mature female red shiners. Based on the life-stage-specific survival rates for a surrogate species, the emerald shiner (no data is provided in EPA 2006 for the red shiner), the 59,727 larvae that would have been entrained in 2008 would develop into approximately 1493 reproducing adults. Losses of this magnitude would have a negligible impact on the lower Guadalupe River population.

Very small numbers of sunfish and shad larvae also appeared in lower Guadalupe River ichthyoplankton collections. Based on larval densities, an estimated 27,873 sunfish (*Lepomis* species) larvae would have been entrained at the RWMU system based on 2008 data under the maximum withdrawal case (Table 5.3.1-2). Four *Lepomis* species were collected from Station GR-05 during monthly surveys of adult and juvenile fish, but the overwhelming majority were three species: bluegill (*Lepomis macrochirus*), warmouth (*Lepomis gulosus*), and longear sunfish (*Lepomis megalotis*). The reproductive behavior of these three sunfish is quite similar. All three are nest builders and nest guarders. All three spawn over the spring and summer, with the bluegill spawning period extending into September. Lepomids normally reach sexual maturity in their second or third year of life, as 1- and 2-year old fish. Fecundity is determined by body size and ranges from 4,500 (small warmouth) to 80,000 (large bluegill) eggs per female (Hassan-Williams and Bonner 2009). Based on known fecundity rates and mortality rates (U.S. EPA 2006), the maximum estimated entrainment loss (27,873 larvae) represents the production of 2 to 34 female sunfish. Losses of this magnitude would have virtually no effect on lower Guadalupe River sunfish populations.

Because adult gizzard shad (*D. cepedianum*) were almost ten times more abundant than adult threadfin shad (*D. petenense*) at Station GR-05 (see Subsection 2.4.2), the analysis that follows assumes that these shad larvae were predominantly gizzard shad. Based on the observed densities of shad in the lower Guadalupe River, an estimated 11,945 larvae would have been entrained at the RMWU intake in 2008 under the maximum withdrawal case (Table 5.3.1-2). Gizzard shad make use of a range of spawning habitats, including large rivers, backwaters of rivers, ponds, lakes, and reservoirs (Jenkins and Burkhead Feb 1994). Females broadcast eggs near the surface; eggs sink to the bottom or adhere to vegetation. A single female may produce from 22,000 to 540,000 eggs per spawning season, depending on its age and size (Carlander 1969). Given that approximately 10 percent of gizzard shad eggs survive and hatch into larvae (U.S. EPA Dec 2006), the maximum estimated entrainment over the February–October 2008 spawning period at the RWMU system intake represents the production of less than six mature female shad. Losses of this magnitude would have virtually no effect on lower Guadalupe River shad populations.

Entrainment losses under the maximum withdrawal rate (217 cfs) would be small and minimally affect fish populations in the lower Guadalupe River. Entrainment losses associated with the more typical "average use" pumping rate of 103.5 cfs would have correspondingly less effect on local fish populations. Table 5.3.1-3 shows estimated entrainment losses at a withdrawal rate of 103.5 cfs, which would be roughly half of the entrainment losses expected under the design basis peak flow rate of 217 cfs.

In summary, small numbers of fish larvae were collected by biologists from sampling station GR-05 on the lower Guadalupe River over the February–October 2008 spawning period. Densities of larvae in the river were used to estimate the total number of larvae that would have been entrained over the same period if Guadalupe River water were being withdrawn and pumped to the VCS cooling basin at a rate of 103.5 cfs (average rate) or 217 cfs (maximum rate). Only five ichthyoplankton taxa were collected, and the bulk of these specimens were common carp, a nonnative nuisance species. An estimated 244,881 carp larvae would have been entrained in 2008, an ecologically insignificant number. Smaller and ecologically insignificant numbers of inland silverside, red shiner, sunfish (*Lepomis* species), and shad (*Dorosoma* species) larvae were also collected. These data suggest that densities of larval fish in this reach of the Guadalupe River are very low, and entrainment losses would be correspondingly small. Entrainment losses of this magnitude would have no detectable impact on fish populations. The species most likely to be affected are common to ubiquitous in the river, are of no value as food or sport fish, and have high reproductive potential, thus can easily replace any losses.

The low densities of ichthyoplankton in the lower Guadalupe River may stem from the fact that the main channel of the lower Guadalupe River offers limited spawning habitat for resident fishes. Many river species in the southern U.S. spawn in sheltered areas (e.g., sloughs, backwaters, and oxbow lakes) or tributary streams outside of the main river channel where spawning fish and young can avoid strong currents and predators. Centrarchids (especially *Micropterus* and *Lepomis* species) in rivers move into shallow sloughs, backwaters, oxbow lakes, and tributaries to spawn, often in association with cover (aquatic plants, logs, or stumps). Other river species, including most suckers (*Moxostoma* species) and hogsuckers (*Hypentelium* species), migrate upstream to spawn in riffle and shoal areas over gravel and rocks or to enter tributaries that offer these kinds of substrates. Still others, especially catfish, spawn in protected locations that can range from holes in streambanks to abandoned appliances and automobile tires. Red shiners, which were by far the most abundant species in adult/juvenile samples (see Section 2.4.2), broadcast adhesive eggs over rocks, stumps, roots, and vegetation, or parasitize nests built by sunfish. As a consequence, their eggs and larvae are concentrated in shallow, off-channel areas, whereas ichthyoplankton were collected from the middle of the river at sampling station GR-05. The lower Guadalupe River above the Saltwater Barrier is often muddy and discolored, with a mud-silt substrate. The main channel at sampling stations GR-04 and GR-05 is 13–20 feet deep (at a river discharge of 1100 cfs) and currents can be strong, particularly when the river is running high. As a consequence, relatively few larvae are found in the main channel of the lower river, where they would be vulnerable to entrainment.

In conclusion, impacts from entrainment at the RWMU system pumphouse would be SMALL because (1) the CWIS has been designed to mitigate impacts of cooling water intake structures on aquatic ecosystems, (2) entrainment losses would be very low in comparison to reproductive potential, (3) species that would be affected are common-to-ubiquitous in the Guadalupe River drainage, and (4) no sensitive or special-status species are present. As a consequence, no mitigation beyond the design features discussed earlier in this section (including Ristroph traveling screens and a fish return system) is warranted.

5.3.1.3 References

Adams et al. 2000. Adams, S.R., J.J. Hoover, and K.J. Killgore, *Swimming Performance Of The Topeka Shiner (Notropis Topeka), An Endangered Midwestern Minnow*, American Midland Naturalist, 144(1): 178–186.

Beecham et al. 2007. Beecham, R.V., C.D. Micchew, and G.R. Parsons, *Comparative Swimming Performance Of Juvenile Pond-Cultured And Wild-Caught Channel Catfish*, North American Journal of Fisheries Management, 27 (3): 729–734.

Berra 1981. Berra, T.M., *An Atlas of Distribution of the Freshwater Fish Families of the World,* 1981, University of Nebraska Press.

FishXing Feb 2006. *FishXing Swim Speed Table*, February 2006. Available at http://www.fsl.orst.edu/geowater/FX3/help/FX3_Help.html#SwimData/swimtable.htm, accessed May 9, 2008.

Froese and Pauly Feb 2008. Froese, R. and D. Pauly, Editors, *FishBase*, February 2008. Available at http://www.fishbase.org/Physiology/SpeedSummary.php?genusname=Mugil&speciesname=cephalus&autoctr=200, accessed May 9, 2008.

Hartwell and Otto 1991. Hartwell, S.I. and R.G. Otto, *Critical Swimming Capacity of the Atlantic Silverside, Menidia menidia L*, Estuaries, Vol. 14, No. 2. pp. 218–221.

Hassan-Williams and Bonner 2009. Texas State University San Marcos Department of Biology, Hassan-Williams, C., and T.H. Bonner, *Texas Freshwater Fishes*, 2009. Available at http://www.bio.txstate.edu/~tbonner/txfishes/, accessed June 3, 2009.

Hocutt 1973. Hocutt, C. H., *Swimming Performance of Three Warmwater Fishes Exposed to a Rapid Temperature Change*, Chesapeake Science Vol. 14, No. 1, pp. 11–16.

Hoover and Killgore May 2002. U.S. Army Corps of Engineers, Hoover, J.J., and K.J. Killgore, *Small Floodplain Pools As Habitat For Fishes And Amphibians: Methods For Evaluation*, ERDC TNEMRRP-EM-03, May 2002.

Jenkins and Burkhead Feb 1994. Jenkins, R.E. and N.M. Burkhead, *Freshwater Fishes of Virginia,* 1993, February 1994, American Fisheries Society.

Matthews 1998. Matthews, W. J., *Patterns in Freshwater Fish Ecology*, 1998, Kluwer Academic Publishers.

McEachran and Fechhelm 1998. McEachran, J.D. and J.D. Fechhelm, *Fishes of the Gulf of Mexico. Volume I: Myxiniformes to Gasterosteiformes*, 1998, University of Texas Press.

Mettee et al. 1996. Mettee, M.F., P.E. O'Neil, and J.M. Pierson, *Fishes of Alabama and the Mobile Basin,* 1996, Oxmoor House.

Parsons 1993. Parsons, G.R., *Comparisons of Triploid and Diploid White Crappies*, Transactions of the American Fisheries Society, Volume 122, Issue 2: 237–243.

Rypel et al. 2006. Rypel, A.L., D.R. Bayne, and J.B. Mitchell. *Growth Of Freshwater Drum From Lotic And Lentic Habitats In Alabama*, Transactions of the American Fisheries Society, 135: 987–997.

Scott and Magoulick 2008. Scott, M. K. and D. D. Magoulick, *Swimming Performance In Five Warmwater Stream Fish Species*, Transactions of the American Fisheries Society, 137 (1): 209-215.

Taylor et al. 2007. Taylor, J. C., P. S. Rand, and J. Jenkins, *Swimming Behavior Of Juvenile Anchovies (Anchoa Spp.) In An Episodically Hypoxic Estuary: Implications For Individual Energetics And Trophic Dynamics*, Marine Biology, 152: 939–957.

U.S. EPA Dec 2006. U.S. Environmental Protection Agency, *Phase II — Large Existing Electric Generating Plants: Case Study Analysis*, December 1, 2006. Available at http://www.epa.gov/waterscience/316b/phase2/casestudy/, accessed on May 30, 2008.

Ward et al. 2003. Ward, D.L., A.A. Schultz, and P.G. Matson, *Differences In Swimming Ability And Behavior In Response To High Water Velocities Among Native And Nonnative Fishes*, Environmental Biology of Fishes, 68:87-92.

Wardle 1975. Wardle, C.S., Limit Of Fish Swimming Speed, Nature 255, 725–727.

Weinstein 1986. Weinstein, M. P., *Habitat Suitability Models: Inland Silverside*, 1986.

Table 5.3.1-1 (Sheet 1 of 2)
Swimming Speed of Fish Near VCS

Source	Common Name	Scientific Name	Burst Speed (cm/s)	Burst Speed (f/s)	Prolonged Speed (cm/s)	Prolonged Speed (f/s)	Fish Length (cm)
5	Anchovy	*Anchoa* spp.	32.6	1.07	—	—	37
4	Spotfin shiner	Cyprinella spilopterus	67.07	2.20	—	—	7.5–8.4
7	Red shiner	Cyprinella lutrensis	77.50	2.54	—	—	7
6	Cardinal shiner	Luxilus cardinalis	31.70	1.04	—	—	4.6–7.2
1	Bigeye shiner	Notropis boops	—	—	26.00	0.85	62.3
1	Bigeye shiner	Notropis boops	—	—	33.00	1.08	60.6
1	Bigeye shiner	Notropis boops	—	—	36.00	1.18	62.3
1	Bigeye shiner	Notropis boops	—	—	39.00	1.28	63.3
10	Topeka shiner	Notropis topeka	75.00	2.46	40.00	1.31	4.4–5.5
1	Common carp	Cyprinus carpio	140.00	4.59	—	—	15.3
1	Common carp	Cyprinus carpio	426.70	14.00	—	—	15.3
1	Common carp	Cyprinus carpio	—	—	140.00	4.59	15.3
1	Common carp	Cyprinus carpio	—	—	121.90	4.00	15.3
7	Fathead minnow	Pimephales promelas	69.1	2.27	—	—	6.5–7.3
4	Channel catfish	Ictalurus punctatus	61.26	2.01	—	—	14–15.4
8	Channel catfish	Ictalurus punctatus	120.00	3.94	—	—	—
3	Striped mullet	Mugil cephalus	430.50	14.12	—	—	21
2	Atlantic silverside	Menidia menidia	61.50	2.02	—	—	—
7	Mosquitofish	Gambusia affinis	38.50	1.26	—	—	4.2
7	Green sunfish	Lepomis cyanellus	46.20	1.52	—	—	7
6	Green sunfish	Lepomis cyanellus	13.89	**0.46**	—	—	5.5–6.4
1	Pumpkinseed	Lepomis gibbosus	—	—	37.20	1.22	12.7
1	Longear sunfish	Lepomis megalotis	—	—	19.00	0.62	94.7
1	Longear sunfish	Lepomis megalotis	—	—	22.00	0.72	93.9
1	Longear sunfish	Lepomis megalotis	—	—	33.00	1.08	81.6
1	Longear sunfish	Lepomis megalotis	—	—	39.00	1.28	88.9
6	Longear sunfish	Lepomis megalotis	14.40	**0.47**	—	—	5.1–6.3
1	Largemouth bass	Micropterus salmoides	—	—	50.00	1.64	10.4
1	Largemouth bass	Micropterus salmoides	—	—	47.40	1.56	10.4
1	Largemouth bass	Micropterus salmoides	—	—	39.90	1.31	10.4

Table 5.3.1-1 (Sheet 2 of 2)
Swimming Speed of Fish Near VCS

Source	Common Name	Scientific Name	Burst Speed (cm/s)	Burst Speed (f/s)	Prolonged Speed (cm/s)	Prolonged Speed (f/s)	Fish Length (cm)
1	Largemouth bass	Micropterus salmoides	—	—	35.40	1.16	10.4
4	Largemouth bass	Micropterus salmoides	49.68	1.63	—	—	5.2–6.4
3	Largemouth bass	Micropterus salmoides	88.00	2.89	—	—	21
9	White crappie	Pomoxis annularis	34.70	1.14	—	—	not given

Sources:
1. FishXing Feb 2006
2. Hartwell and Otto 1991
3. Froese and Pauly Feb 2008
4. Hocutt 1973
5. Taylor et al. 2007
6. Scott and Magoulick 2008
7. Ward et al. 2003
8. Beecham et al. 2007
9. Parsons 1993
10. Adams et al. 2000

Notes:
Bold values are **less than** the maximum allowable approach velocity of 0.5 ft/s, but **greater than** the design velocities at the trash racks (0.26 fps).
Swim speeds that were available in the literature for the species found near VCS are presented in this table. For some fish species, no swim speed data was found.
cm/s = centimeters per second
f/s = feet per second
cm = centimeters

Table 5.3.1-2
Estimated Number of Larvae Entrained per Month (2008), Maximum Withdrawal Case (217 cfs)

Species	February	March	April	May	June	July	August	September	October	Annual Total
Shad spp										
Day	0	11,945	0	0	0	0	0	0	0	
Night	0	0	0	0	0	0	0	0	0	
Monthly Total	0	11,945	0	0	0		0	0	0	11,945
Inland silverside										
Day	0	0	0	35,836	0	0	0	0	0	
Night	0	0	27,873	0	0	0	0	0	0	
Monthly Total	0	0	27,873	35,836	0	0	0	0	0	63,709
Common carp										
Day	0	55,745	0	0	0	0	0	0	0	
Night	0	189,136	0	0	0	0	0	0	0	
Monthly Total	0	244,881	0	0	0	0	0	0	0	244,881
Red shiner										
Day	0	0	0	0	0	0	0	0	31,854	
Night	0	0	0	0	0	0	27,873	0	0	
Monthly Total	0	0	0	0	0	0	27,873	0	31,854	59,727
Sunfish spp.										
Day	0	0	0	0	0	0	0	0	0	
Night	0	0	0	0	0	0	27,873	0	0	
Monthly Total	0	0	0	0	0	0	27,873	0	0	27,873

Table 5.3.1-3
Estimated Number of Larvae Entrained per Month (2008), Normal Withdrawal Case (103.5 cfs)

Species	February	March	April	May	June	July	August	September	October	Annual Total
Shad spp										
Day	0	5,697	0	0	0	0	0	0	0	
Night	0	0	0	0	0	0	0	0	0	
Monthly Total	0	5,697	0	0	0	0	0	0	0	5,697
Inland silverside										
Day	0	0	0	17,092	0	0	0	0	0	
Night	0	0	13,294	0	0	0	0	0	0	
Monthly Total	0	0	13,294	17,092	0	0	0	0	0	30,386
Common carp										
Day	0	26,588	0	0	0	0	0	0	0	
Night	0	90,210	0	0	0	0	0	0	0	
Monthly Total	0	116,798	0	0	0	0	0	0	0	116,798
Red shiner										
Day	0	0	0	0	0	0	0	0	15,193	
Night	0	0	0	0	0	0	13,294	0	0	
Monthly Total	0	0	0	0	0	0	13,294	0	15,193	28,487
Sunfish spp.										
Day	0	0	0	0	0	0	0	0	0	
Night	0	0	0	0	0	0	13,294	0	0	
Monthly Total	0	0	0	0	0	0	13,294	0	0	13,294

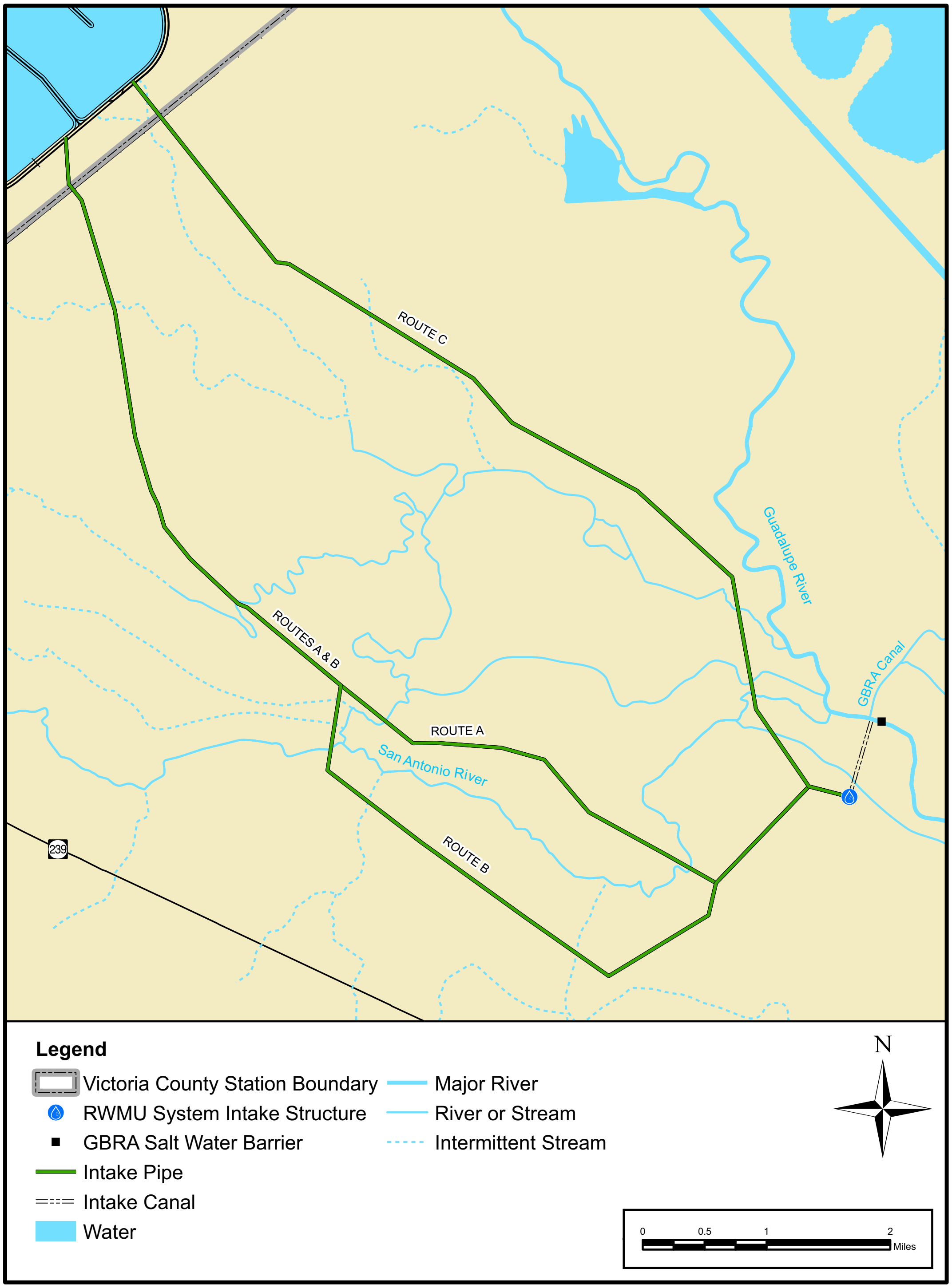


Figure 5.3.1-1 RWMU System Canal, Intake Structure, and Pipelines

5.3.2 Discharge Systems

Section 3.4 describes the proposed closed cycle cooling system for VCS, which includes an approximately 4900-acre cooling basin for dissipation of waste heat. After leaving the main condenser, heated water would flow into the cooling basin, where the bulk of the heat would be transferred to the atmosphere by evaporative cooling. After moving through the cooling basin circuitously by way of a series of interior dikes (see Figure 3.4-1), the cooled water would be recirculated back to the condenser by pumps in the cooling basin intake structure. As described in Section 3.4, it would be necessary to blow down the cooling basin to limit the accumulation of dissolved solids in the reservoir. Cooling basin blowdown would be pumped from the cold side of the cooling basin, where the condenser cooling and blowdown pumps would be located, to the Guadalupe River via a 48-inch-diameter blowdown discharge line. The blowdown line would terminate in a shoreline surface diffuser designed to promote mixing with the receiving water and rapidly disperse waste heat (Figure 3.4-4). Blowdown flows are expected to range between 0 and 40,000 gpm (Table 3.3-1). A range of approximately 7000 gpm to 40,000 gpm (the design maximum) was evaluated.

Under the Texas Surface Water Quality Standards (Title 30, Texas Administrative Code, Chapter 307), the cooling basin would be classified as an “industrial cooling impoundment,” which is defined as “[a]n impoundment which is owned or operated by, or in conjunction with, the water rights permittee, and which is designed and constructed for the primary purpose of reducing the temperature and removing heat from an industrial effluent.” The only references to cooling water impoundments in the Texas Surface Water Quality Standards are with respect to temperature. The Standards provide that "temperature in industrial cooling lake impoundments and all other surface water in the state shall be maintained so as to not interfere with the reasonable use of such waters. Numerical temperature criteria have not been specifically established for industrial cooling lake impoundments, which in most areas of the state contribute to water conservation and water quality objectives.” Additionally, cooling water impoundments are expressly exempted from the temperature requirements set forth in the Texas Surface Water Quality Standards.

Based on the VCS cooling basin's classification as an industrial cooling impoundment, and because it will not support recreational or other public uses, the cooling basin is not anticipated to be subject to the Texas Surface Water Quality Standards, including temperature limitations on discharges into the basin. This interpretation is supported by the Texas Commission on Environmental Quality’s (TCEQ’s) designation of the South Texas Project main cooling reservoir (MCR) as an "industrial cooling impoundment,” and the fact that there are no thermal limitations imposed on discharges into the MCR by that facility's Texas Pollutant Discharge Elimination System (TPDES) permit.

The final discharge (blowdown) that flows into the Guadalupe River would be subject to state surface water quality standards. The reach of the river into which the blowdown would flow, designated

Stream Segment 1803 by the TCEQ, has been classified as supporting contact recreation and “high” aquatic life use (Title 30, Texas Administrative Code, Section 307.10, Appendix A, *Site-Specific Uses and Criteria for Classified Segments*). Stream segments with the “high” aquatic life use sub-category are expected to support highly diverse assemblages of aquatic species with some sensitive species present (TCEQ Jul 2000).

Segment 1803 has been assigned a site-specific, absolute maximum temperature criterion, 93°F, but the general criterion for temperature rise over ambient (ΔT) in freshwater streams, 5°F, applies to this segment of the Guadalupe River (Title 30, Texas Administrative Code, Section 307.4, *General Criteria*). No TPDES permit has yet been obtained for VCS, but Exelon assumes that these criteria would be included in the permit, and therefore designed the discharge system to comply with them.

The following subsections describe the modeling efforts that support the design of the discharge system (Subsection 5.3.2.1) and evaluate the potential effects of the discharge on aquatic resources in the Guadalupe River (Subsection 5.3.2.2).

5.3.2.1 Thermal Discharges and Other Physical Impacts

Cooling basin blowdown temperatures and discharges to the Guadalupe River were modeled based on simulated cooling basin temperatures. Cooling basin temperatures were simulated using plant and cooling basin design parameters and historical (1947–2006) meteorology. All calculations assumed a 100 percent plant load factor. Cooling basin temperatures on the cold side of the basin (in the area of the cooling basin intake structure) were calculated for high (water depth of 21 feet) and low (water depth of 8 feet) elevation cases. Blowdown temperatures and temperature differences (blowdown temperature minus river temperature) were based on 60-year simulations using low-elevation conditions. For any given year and month, maximum blowdown temperatures were approximately 1.2°F higher for the low-elevation case than for the high-elevation case. The maximum temperature difference was 3.5°F less under the high-elevation case than the low-elevation case.

The low-elevation, maximum, blowdown temperature, of approximately 97°F, occurred in August; blowdown temperature under the low-elevation case exceeded 93°F for 2.9 percent of the 60-year period. Cooling basin temperatures were simulated over the period 1990 to 2006 for a lower pond elevation (water depth of 4 feet). These simulations resulted in a maximum cold side basin temperature of 98.4°F that also occurred in August. A maximum blowdown temperature of 100°F was assumed for the thermal analysis to account for differences in the potential reactor technology. Temperature predictions from the cooling basin simulation were compared with grab sample ambient temperatures at two proximate gaging stations, U.S. Geological Survey (USGS) 08176500 and TCEQ 12590, on the Guadalupe River at Victoria. River temperature measurements corresponded with the days of the cooling basin simulation for 148 days of the 60-year period. The maximum ambient river temperature upstream of VCS was 89.6°F, which has been measured only three times in the last 60 years. The largest temperature difference (blowdown temperature minus river temperature) predicted was 14.7°F. In order to bound all reactor technologies, a factor of 10 percent was added to the maximum blowdown temperature difference of 14.7°F. These simulations resulted in a maximum cold side basin temperature of 98.4°F that also occurred in August.

The CORMIX Version 5.0 model was used to simulate the temperature distribution in the Guadalupe River downstream of the discharge (blowdown diffuser). CORMIX is an EPA-supported mixing zone model that emphasizes the role of boundary interactions to predict steady-state mixing behavior and plume geometry. It is widely used and recognized as a state-of–the-art-tool for discharge mixing zone analyses.

The simulations were based on 60 years of regional historic meteorological data for establishing cooling basin temperatures and more than 30 years of ambient river temperature data. Long-term daily river flow records in the Guadalupe River were available from USGS gaging station 08176500 on the Guadalupe River at Victoria. A continuous record of these daily flows from 1935 through 2006 was analyzed and low-flow statistics calculated. The 7Q2 and 7Q10 (seven-day two-year and seven-day ten-year low flows) were found to be 552 and 110 cfs. Discharge thermal plume modeling was performed for river flows as low as the 7Q10 low flow of 110 cfs. At the 7Q10 flow, the elevation of the river surface at the discharge structure was estimated at 9.63 feet NAVD 88. The elevation of the top of the discharge pipes would be at the 7Q10 river elevation. The discharge flow direction would be offshore, perpendicular to the river flow. River flow rates (both low and average) are generally greatest from the late winter through the spring and lowest during the summer.

The discharge structure would be on the Guadalupe River, whereas cooling (makeup) water would be pumped to the cooling basin via an 8.5 to 11-mile-long pipeline from the Guadalupe River at a diversion point approximately 430 feet upstream of the Saltwater Barrier. Therefore, recirculation of heated effluent could not occur. The multi-port diffuser would create rapid mixing of the effluent with flowing river water.

Blowdown would be discharged whenever the river flow is adequate: (1) river flow of 7Q10 or more and (2) river flow at least seven times the discharge flow. Therefore, for the purpose of calculating impacts, the minimum river flows during which blowdown could be discharged were assumed. The flow specification sought to determine at what flow the maximum discharge ΔT would be reduced to 2.5°F (one-half the allowable amount under the assumed permit guidelines). Addition of a safety factor to accommodate thermal discharges from the Invista-DuPont plant located approximately 3 river-miles downstream resulted in a multiplier of 7, meaning that blowdown would only be discharged to the river when the natural flow of the river was at least seven times the discharge volume. For example, the river flow must be a minimum of 623.84 cfs in order to allow discharge at maximum blowdown flow of 40,000 gpm (89.12 cfs). The maximum allowable blowdown flow for 7Q10 river flow is 7,053 gpm (15.71 cfs, or 110 cfs divided by 7).

The thermal distribution resulting from discharging maximum (40,000 gpm) and 7Q10/7 (7053 gpm) blowdown flow into 623.84 cfs of river flow are presented in Table 5.3.2-1. The maximum (7053 gpm) blowdown flow into the 7Q10 river flow of 110 cfs is also presented. Two cases are presented: Max-ΔT for the largest discharge temperature excess over ambient (16.17°F) and Max-T for the maximum blowdown discharge temperature (100°F). The Max-ΔT case corresponds to the largest discharge excess temperature over ambient and thus the largest excess temperature isotherms. Even for the most restrictive case (7Q10/7 discharge flow into 7Q10 river flow with maximum ΔT), the downstream plume distances are within the typical TCEQ mixing zone extent of 300 feet. No more than 40 percent of the river cross-section would be impacted by the plume temperatures (ΔT of 5°F or temperature of 93°F) of interest.

5.3.2.2 Aquatic Ecosystems

Aquatic resources can be impacted by thermal, chemical, and physical characteristics of the discharge stream. Each of these is evaluated below.

5.3.2.2.1 Thermal Effects

Thermal analysis indicates that the blowdown from the cooling basin would affect a minor part of the river in the immediate area of the discharge diffuser. Because most of the water column is unaffected by the blowdown, even under extreme (worst-case) conditions, the thermal plume would not create a barrier to upstream or downstream movement of important fish species, including largemouth bass, bluegill, blue catfish, and channel catfish (Subsection 2.4.2).

Observations of fish in the wild have identified patterns of fish occurrence in response to temperature around the world, leading to the general categorization of fishes as “warm-water” or “cold-water” species. Concern about thermal pollution during the past few decades has led to formal investigation of thermal tolerances and preferences in fishes (Walford and Merriman 1969; Beitinger et al. 2000). Streams in southeast Texas, including the Guadalupe River, are typical warm-water bodies.

Although several methods exist for determining the maximum temperature a fish can withstand before perishing, recent reviews have suggested that the critical thermal maximum (CTM), with an endpoint of loss of equilibrium, is the most robust and repeatable measure of upper thermal tolerance in fishes (Beitinger et al. 2000). The CTM represents a nonlethal exposure to temperature; fish can recover and live normally if returned to lower temperature water following exposure to the CTM (Beitinger et al. 2000). Variability in CTM measured in the laboratory as well as in actual responses of fishes to thermal stress in natural habitats results from differences in acclimation and seasonal acclimatization to temperature (Matthews 1998, Beitinger et al. 2000).

Adult fish generally can tolerate higher temperatures than can eggs or larvae of the same species (Matthews 1998). No fish is known to withstand water temperatures much higher than 44°C (111°F), when proteins begin to denature; in fact, few fish survive in water with temperatures higher than 40°C (104°F). For many North American freshwater fish, the CTM is between 32 and 38°C (90 and 100°F) (Matthews 1998). The presence of heat shock proteins in fish that experience thermal extremes in their native habitats affords some protection to fish from sudden increases in water temperature (Matthews 1998).

Critical thermal maxima for fish occurring in the Guadalupe River near the proposed discharge diffuser are shown in Table 5.3.2-2, along with the associated acclimation temperature. When no CTMs were available in the published literature, other indicators of thermal tolerance are provided. All of the important fish for which CTMs have been determined at VCS are well able to withstand the maximum river temperature that would be allowed at the discharge point (93°F) or a 5°F increase in ambient river temperature. The fish for which the reported CTMs were lower than 93°F had all been acclimated to temperatures of less than 61°F, which is an increase in temperature approximately six times what is allowed by the TCEQ. With the exception of the smallmouth buffalo and inland silverside, all of the species (or congener, in the case of warmouth) that had CTMs lower than 93°F at low acclimation temperatures, also had higher CTMs when acclimation temperatures were more representative of field conditions (Table 5.3.2-2). No corroborating data is available for the smallmouth buffalo or the inland silverside; their responses to river temperatures of 93°F are presently unknown.

The thermal discharge modeling assumed worst-case conditions: maximum ΔT, minimum and maximum discharge flows, and minimum specified Guadalupe River flow (7Q10 or seven times the discharge flow). Under these conditions, no thermal impacts are expected beyond some thermally sensitive species possibly avoiding the area in the vicinity of the discharge outlet. Impacts to aquatic communities would be SMALL and would not warrant mitigation.

5.3.2.2.2 Chemical Impacts

Chemicals in the discharge that may affect aquatic resources would include biocides to limit fouling of the cooling water system, dissolved and suspended solids, and other chemical agents to limit scaling. Discharge concentrations of these constituents would comply with applicable state water quality standards, which would be specified in a TPDES permit. Discharge pumps would be sized so that the blowdown flow rate could be varied up to a maximum design flow rate of 40,000 gpm.

Section 3.6 (Table 3.6-1) provides estimates of chemical concentrations in the blowdown discharged to the Guadalupe River. Blowdown would only occur when river flows are at least seven times the blowdown flow. CORMIX modeling shows that the discharge plume would become fully mixed with the river within approximately 600 feet downstream of the discharge for the most restrictive river flow/ discharge flow ratio of seven. Once the discharge is mixed with the river, the resulting concentrations of chloride, sulfate, and total dissolved solids would not exceed the applicable ambient water quality standards, as shown in Table 5.3.2-3.

Concentrations of solids and chemicals in the discharge water would return to ambient levels almost immediately downstream of the discharge pipe. Any impacts to aquatic biota would be SMALL and would not warrant mitigation.

5.3.2.2.3 Physical Impacts

A multi-port diffuser was chosen as the generic blowdown discharge design. In order to maintain reasonable discharge velocities while also maintaining acceptable thermal performance, four 1.5-foot-diameter pipes discharging at the shoreline are proposed. The blowdown discharge of 7053 gpm (7Q10/ 7, 15.71 cfs) through the four pipes would result in an average discharge velocity of 2.22 fps. The average flow of the Guadalupe River measured at Victoria (USGS gaging station 08176500) for the period of record, 1935–2009, is 1980 cfs. The average river velocity is 3.21 fps during average river flow of 1980 cfs. Consequently, no scour would be expected at the discharge velocities typical of the blowdown flows.

A maximum blowdown flow rate of 40,000 gpm (89.12 cfs) results in a discharge velocity of 12.61 fps. Localized scour could occur during periods of maximum blowdown flow. Under the Max-ΔT case (Table 5.3.2-1), including the minimum river flow (623.84 cfs) for which the maximum blowdown rate would be allowed, the plume quickly becomes vertically fully mixed thus impacting the river bottom. The discharge velocity would be quickly attenuated as it is diluted by the slower moving river. Plume velocities within approximately 70 feet (down and cross-stream from the discharge) would approximate those during average river flow and, thus, bottom scour would not extend beyond that point.

The area directly affected by scouring may not provide good quality benthic habitat for invertebrates or fishes. However, the scour is not expected to be any more severe than what occurs during periodic floods in the river. Ample benthic habitat of similar quality occurs upstream and downstream of the small area affected by scouring. Other than a local redistribution of benthic organisms, the discharge would not be expected to affect Guadalupe River benthic invertebrates or fish. No important aquatic species or critical habitat would be affected. Physical impacts to aquatic communities would therefore be SMALL and would not warrant mitigation.

5.3.2.3 References

Beitinger et al. 2000. Beitinger T. L., W. A. Bennett, and R. W. McCauley, *Temperature Tolerances of North American Freshwater Fishes Exposed to Dynamic Changes in Temperature, Environmental Biology of Fishes*, Volume 58, Number 3, pp. 237–275, 2002.

Matthews 1998. Matthews, W. J., *Patterns in Freshwater Fish Ecology*, 1998, Kluwer Academic Publishers, 1998.

Matthews and Heins 1987. Matthews, W.J. and D.C. Heins, *Community and Evolutionary Ecology of North American Stream Fishes*, 1987, University of Oklahoma Press, 1987.

Moyle 2002. Moyle, P.B., *Inland Fishes of California: Revised and Expanded,* 2002, University of California Press, 2002.

Patillo et al. 1997. Patillo, M.E., T.E. Czapla, D.M. Nelson, and M.E. Monaco, *Distribution and Abundance of Fish and Invertebrates in Gulf of Mexico Estuaries, Volume II: Species Life History Summaries*, ELMR Rep. No. 11, 1997, NOAA/NOS Strategic Environmental Assessments Division, 1997.

TCEQ Jul 2000. Texas Commission on Environmental Quality, *2000 Texas Surface Water Quality Standards*, July 2000.

Walford and Merriman 1969. Walford, L. and D. Merriman, *Report from Fishery Workshop*, Chesapeake Science Volume 10, Number 3-4, pp. 289-291, 1969.

Table 5.3.2-1
Proposed Discharge Mixing Zone Statistics

Discharge Flow Case	Furthest Downstream Extent, ft from Discharge[(a)]	Maximum Plume Width, ft[(b)]	Maximum Plume Depth, ft[(c)]	River Cross Section, Width (ft) x Depth (ft)	Maximum Plume Cross Section/ River Cross Section
5°F Temperature Increase Above Ambient River Temperature, Q_d = 7053 gpm (one-seventh of Q_r), Q_r = 110 cfs (49,370 gpm, 7Q10).[(d)] Max-ΔT (16.17°F) case.					
7Q10/7	264.73	54.13	1.02	75.31 × 1.81	0.40
5°F Temperature Increase Above Ambient River Temperature, Q_d = 7053 gpm (7Q10/ 7) or 40,000 gpm (max.), Q_r = 623.84 cfs (280,000 gpm, or Q_d (max) * 7). Max-ΔT (16.17°F) case.					
7Q10/7	22.01	14.72[(e)]	2.21	89.55 × 3.78	0.10
Max.	15.16	24.52[(f)]	3.78	89.55 × 3.78	0.40[(g)]
93°F Ambient River Temperature, Q_d = 7053 gpm (one-seventh of Q_r), Q_r = 110 cfs (49,370 gpm, 7Q10). Max-T (100°F) case.					
7Q10/7	237.97	43.36	1.21	75.31 × 1.81	0.39
93°F Ambient River Temperature, Q_d = 7053 gpm (7Q10/ 7) or 40,000 gpm (max.), Qr = 623.84 cfs (280,000 gpm, Q_d (max) * 7). Max-T (100°F) case.					
7Q10/7	18.80	14.24[(h)]	2.19	89.55 × 3.78	0.09
Max.	11.36	23.74[(i)]	3.78	89.55 × 3.78	0.38[(j)]

(a) From center of discharge.
(b) Maximum width typically extends from near shore. Notes are included for other locations.
(c) Measured from river/plume surface.
(d) Q_r and Q_d are river and discharge flow rate.
(e) Centered 9.29 feet from near shore.
(f) Centered 36.12 feet from near shore.
(g) CORMIX calculates 0.27. 0.40 presented here based on heat balance considerations.
(h) Centered 8.82 feet from near shore.
(i) Centered 31.69 feet from near shore.
(j) CORMIX calculates 0.27. 0.38 presented here based on heat balance considerations.

Table 5.3.2-2 (Sheet 1 of 2)
Critical Temperatures of Selected Freshwater Fish

Source	Common Name	Scientific Name	Critical Thermal Maximum (°C)	Critical Thermal Maximum (°F)	Other Measure of Upper Temperature Tolerance	Acclimation Temperature (°C)
B	Anchovy	*Anchoa* spp.	39.80	103.64	Larvae, juveniles, and adults were collected from waters at this temperature	
B	Gizzard shad	Dorosoma cepedianum	34.90	94.82	Juveniles and adults were collected from waters at this temperature	
A	Red shiner	Cyprinella lutrensis	39.00	102.20	—	25
A	Red shiner	Cyprinella lutrensis	32.00	**89.60**	—	15
A	Red shiner	Cyprinella lutrensis	36.20	97.16	—	22
A	Red shiner	Cyprinella lutrensis	36.50	97.70	—	25
A	Red shiner	Cyprinella lutrensis	35.00	95.00	—	20
A	Red shiner	Cyprinella lutrensis	34.50	94.10	—	20
A	Red shiner	Cyprinella lutrensis	34.10	93.38	—	20
A	Red shiner	Cyprinella lutrensis	39.60	103.28	—	30
A	Red shiner	Cyprinella lutrensis	38.10	100.58	—	26
A	Red shiner	Cyprinella lutrensis	34.00	93.20	—	10
A	Bullhead minnow	Pimephales vigilax	39.30	102.74	—	30
A	Smallmouth buffalo	Ictiobus bubalus	31.30	**88.34**	—	10
A	Channel catfish[(a)]	Ictalurus punctatus	34.50	94.10	—	12
A	Channel catfish[(a)]	Ictalurus punctatus	41.00	105.80	—	32
A	Channel catfish	Ictalurus punctatus	38.00	100.40	—	20
A	Channel catfish	Ictalurus punctatus	36.40	97.52	—	20
A	Channel catfish	Ictalurus punctatus	38.70	101.66	—	25
A	Channel catfish	Ictalurus punctatus	40.30	104.54	—	30
A	Channel catfish[(a)]	Ictalurus punctatus	30.90	**87.62**	—	10
A	Channel catfish[(a)]	Ictalurus punctatus	42.10	107.78	—	35
A	Channel catfish	Ictalurus punctatus	33.30	**91.94**	—	10
A	Slender madtom	Noturus exilis	36.50	97.70	—	26
D	Blue catfish	Ictalurus furcatus	37.00	98.60	Observed survival in waters of this temperature	
D	Flathead catfish	Pylodictus olivaris	34.00	93.20	Typical water temperature in native rivers	
B	Striped mullet	Mugil cephalus	37.00	98.60	Juveniles and adults were collected from waters at this temperature	
A	Inland silverside	Menidia beryllina	31.60	**88.88**	—	10
C	Blackstripe topminnow	Fundulus notatus	36.75	98.15	—	Not Given
A	Blackstripe topminnow	Fundulus notatus	41.60	106.88	—	**30**
A	Blackstripe topminnow	Fundulus notatus	38.30	100.94	—	**26**
A	Mummichog[(a)]	Fundulus heteroclitus	32.20	**89.96**	—	**7**
A	Mummichog[(a)]	Fundulus heteroclitus	44.10	111.38	—	**36**
A	Blackspotted topminnow	Fundulus olivaceous	38.80	101.84	—	**26**

Table 5.3.2-2 (Sheet 2 of 2)
Critical Temperatures of Selected Freshwater Fish

Source	Common Name	Scientific Name	Critical Thermal Maximum (°C)	Critical Thermal Maximum (°F)	Other Measure of Upper Temperature Tolerance	Acclimation Temperature (°C)
A	Plains topminnow	Fundulus sciadicus	37.00	98.60	—	**26**
A	Mosquitofish[(a)]	Gambusia affinis	32.50	**90.50**	—	**5**
A	Mosquitofish[(a)]	Gambusia affinis	43.50	110.30	—	**35**
A	Sheepshead minnow	Cyprinodon variegatus	45.10	113.18	—	**37–42**
A	Green sunfish	Lepomis cyanellus	35.80	96.44	—	**20**
A	Warmouth	Lepomis gulosus	32.90	**91.22**	—	**10**
A	Orangespotted sunfish	Lepomis humilis	36.40	97.52	—	**26**
A	Longear sunfish	Lepomis megalotis	37.80	100.04	—	**26**
A	Longear sunfish	Lepomis megalotis	34.10	93.38	—	**10**
A	Bluegill	Lepomis macrochirus	37.00	98.60	—	**25**
A	Bluegill	Lepomis macrochirus	39.60	103.28	—	**30**
A	Bluegill	Lepomis macrochirus	41.40	106.52	—	**35**
A	Bluegill	Lepomis macrochirus	36.60	97.88	—	**26**
A	Bluegill	Lepomis macrochirus	37.50	99.50	—	**26**
A	Bluegill	Lepomis macrochirus	37.90	100.22	—	
A	Bluegill[(a)]	Lepomis macrochirus	31.40	**88.52**	—	
A	Bluegill[(a)]	Lepomis macrochirus	41.40	106.52	—	
A	Spotted bass	Micropterus punctulatus	34.20	93.56	—	
A	Largemouth bass[(a)]	Micropterus salmoides	29.20	**84.56**	—	
A	Largemouth bass[(a)]	Micropterus salmoides	40.90	105.62	—	
A	Largemouth bass[(a)]	Micropterus salmoides	35.40	95.72	—	
A	Largemouth bass[(a)]	Micropterus salmoides	38.50	101.30	—	
D	Black crappie	Pomoxis nigromaculatus	31.00	**87.80**	Observation that temperatures higher than 31°C are stressful.	
D	White crappie	Pomoxis annularis	31.00	**87.80**	Observation that temperatures higher than 31°C are avoided.	

(a) The minimum and maximum acclimation and CTM for a given study are given; intermediate test conditions are not given.
Bold = Bold values are **CTM lower than** the maximum river temperature following discharge (93°F).
Sources:
(A) Beitinger et al. 2000 (all data is from Table 2), (B) Patillo et al. 1997, (C) Matthews and Heins 1987, (D) Moyle 2002.

Table 5.3.2-3
Effects of VCS Blowdown Discharges on Guadalupe River Quality

Constituent	30 TAC §307.10 Limit	VCS Discharge Concentration	Downstream Total Concentration[a]	Percent of TCEQ Limit
Cl^{-1} (chloride)[b]	100 mg per liter	235 mg per liter	54 mg per liter	54
SO_4^{-2} (sulfate)[b]	100 mg per liter	181 mg per liter	47 mg per liter	47
TDS (total dissolved solids)[c]	500 mg per liter	1948 mg per liter	500 mg per liter	100

(a) Downstream concentrations were estimated assuming the blowdown discharge is fully mixed with the river in the ratio of seven parts river water to one part blowdown.

(b) The average chloride and sulfate concentrations in the Guadalupe River were estimated using TCEQ data for Station 12590 (January 2004 through April 2007) and the results for two Guadalupe River samples taken by Exelon (November 2007 and April 2008) in support of the ESP application.

(c) The average total dissolved solids concentration was estimated from the results for two samples collected by Exelon (November 2007 and April 2008). The samples were collected at Highway 59, the same location used for the chloride and sulfate samples.

5.3.3 Heat Dissipation Systems

5.3.3.1 Heat Dissipation to the Atmosphere

As described in Section 3.4, a closed-cycle condenser cooling system would be used for VCS, with a cooling basin that functions as the normal power heat sink. Additionally, as discussed in Subsection 3.4.1.2, an external ultimate heat sink may be required for some reactor technologies. That ultimate heat sink may consist of mechanical draft cooling towers. Mechanical draft cooling towers could also be used for heat load dissipation of auxiliary plant systems. For this analysis, a representative system of mechanical draft cooling towers was evaluated. Heat rejection resulting from plant operations would be to the cooling basin and to the mechanical draft cooling towers. During normal operating conditions, most of the heat load would be to the cooling basin.

5.3.3.1.1 Cooling Basin

The Coleto Creek Plant and the South Texas Project (STP) are two power plants located in the region that use cooling ponds to dissipate heat resulting from plant operations. An increase in fogging in the vicinity has not been reported as a result of the operation of these plants and cooling ponds. It is expected that the impacts from the cooling basin would be similar to the other cooling ponds in the region. Therefore, the plume from the cooling basin would either exist as a ground-level fog over the pond that would evaporate close to the edge of the pond or would lift to become stratus, under moderate to calm wind conditions. The ground-level fog from the cooling basin would not be expected to reach the site boundary in any direction and would not noticeably increase fogging in the vicinity of the site over naturally occurring fog. Elevated plumes and the associated shadowing would also not be expected from the operation of the cooling basin.

Impacts from heat dissipation to the atmosphere from the operation of the cooling basin would be SMALL and would not warrant mitigation.

5.3.3.1.2 Mechanical Draft Cooling Towers

Cooling towers evaporate water to dissipate heat to the atmosphere. Evaporation is followed by partial recondensation, which creates a visible mist or plume. The plume creates the potential for shadowing, fogging, icing, and localized increases in humidity. In addition, small water droplets are blown out of the tops of the cooling towers. These water droplets are referred to as drift and can be deposited, along with any dissolved salts, on vegetation and surfaces surrounding the cooling towers.

For VCS, the impacts from fogging, icing, shadowing, and drift deposition were modeled using the Electric Power Research Institute's Seasonal/Annual Cooling Tower Impact (SACTI) prediction code. This code incorporates the modeling concepts presented by (Policastro et al.1994), which were endorsed by the NRC in NUREG-1555. The model provides predictions of seasonal and annual cooling tower impacts from mechanical or natural draft cooling towers. It predicts average plume length, rise, drift deposition, fogging, icing, and shadowing, providing results that have been validated with experimental data (Policastro et al. 1994).

The SACTI code simulated four identical mechanical draft cooling towers, two for each assumed unit. Each cooling tower has a maximum heat rejection rate of 90 megawatts and a maximum mechanical draft cooling tower water flow of 40,000 gpm. The cooling tower height was set at 56 feet above grade level. The meteorological data was from the National Weather Service meteorological station located at the Victoria Regional Airport for the years 2003–2007, purchased from the National Climatic Data Center (NCDC 2008). As described in Subsection 6.4.6.1, the meteorological data from the Victoria Regional Airport is representative of the meteorological conditions at VCS. The five most recent years of meteorological data available from the Victoria Regional Airport were input into the SACTI code. Additional physical and performance characteristics of the mechanical draft cooling towers, based on a representative ESBWR case, would be as follows:

Parameter	Value
Number of cooling towers	4
Width of cooling tower	63 feet
Length of cooling tower	129 feet
Diameter of individual fan outlet	32.8 feet
Number of fans per cooling tower	2
Cooling tower height	56 feet
Heat released (per tower)	90 MW
Maximum drift rate (percentage of circulating water flow rate)	0.001%
Water flow rate (per tower)	40,000 gpm
Cooling range	15.4°F
Approach	6.7°F
Dry bulb temperature	90.4°F
Wet bulb temperature	79.3°F
Air flow rate per fan	1,628,300 cubic feet per minute
Cycles of concentration	1.19
Salt (NaCl) concentration in the cooling tower basin makeup water	550 milligrams per liter

5.3.3.1.3 Length and Frequency of Elevated Plumes for Mechanical Draft Cooling Towers

The SACTI code calculated the expected plume lengths by direction for each season for the combined effect of the cooling towers. The plumes would occur in all compass directions. The average plume length and height were calculated from the frequency of occurrence for each plume based on the distance from the centerpoint of the cooling towers. The median plume length and height are the distances where half of all the plumes occurring would be expected to be less than that distance.

The average plume length would range from 0.23 mile in the summer season to 0.88 mile in the winter season. The annual prediction for the average plume length is 0.45 mile from the cooling towers. The median plume length would be 0.12 mile for each season and annually. The average plume height ranges from 160 feet in the summer season to 544 feet in the winter season. The annual prediction for the average plume height is 295 feet. The median plume height would be 98 feet in every season and annually. A small percentage of the plumes would extend beyond the site boundary. The maximum amount of time that a plume would extend beyond the site boundary at any one location would be 69 hours during the winter season and 159 hours annually. These values represent a small portion of 2190 hours, the total hours in a single normal season, and a smaller portion of 8760 hours, the total hours in a normal year.

As modeled, plumes from the mechanical draft cooling towers would be as follows:

	Winter	Spring	Summer	Fall	Annual
Predominant direction (true north)	south	north-northwest	north	south	north
Average plume length (miles)	0.88	0.31	0.23	0.40	0.45
Median plume length (miles)	0.12	0.12	0.12	0.12	0.12
Average plume height (feet)	544	209	160	272	295
Median plume height (feet)	98	98	98	98	98
Maximum time plume extends beyond site boundary in any one direction (hours)	69	23	23	44	159
Direction of maximum time plume extends beyond site boundary	west-southwest	west-southwest	west-southwest	west-southwest	west-southwest

The average plume lengths would be short and would not reach the site boundary in most directions. Plumes extending beyond the site boundary would have a shorter duration. Due to the varying directions, short average plume height and length, and limited time the plume would extend beyond the site boundary, impacts from elevated plumes would be SMALL and would not warrant mitigation.

5.3.3.1.4 Ground-Level Fogging and Icing

Fogging from the mechanical draft cooling towers occurs when the visible plume intersects with the ground, appearing like fog to an observer. The SACTI code predicted a total of 2 hours of fogging to occur from the operation of the cooling towers during the winter season in the southerly direction. Each of the other seasons would have less than an hour of fogging. The annual prediction for fogging would be almost 3 hours per year in the southerly direction. Fogging is predicted to occur offsite for a total of 6 minutes during the winter season to the west of the cooling towers at U.S. Highway 77. Impacts from fogging would be SMALL and would not warrant mitigation.

Icing from the cooling towers would be the result of ground-level fogging when ambient temperatures are below freezing. Icing is also not predicted to occur from the operation of the cooling towers because the climate of the region is typically too warm for frequent freezing temperatures.

As modeled, fogging from the mechanical draft cooling towers would be as follows:

	Winter	Spring	Summer	Fall	Annual
Maximum Hours of Fogging	2.0	0.46	0.64	0.22	2.8
Direction to Maximum Fogging Location	south	south	west-southwest	south	south
Hours of Fogging at U.S. Highway 77	0.10	(a)	(a)	(a)	0.10

(a) Not predicted to occur.

5.3.3.1.5 Salt Deposition

Water droplets blown from the mechanical draft cooling towers would have the same concentration of salts as the water in the cooling tower basins. As the water droplets blown from the towers evaporate, either in the air or on vegetation or equipment, salts are deposited.

The maximum predicted salt deposition is to the west-southwest of the cooling towers, 980 feet from the centerpoint of the cooling towers. The maximum deposition is 0.10 pounds per acre per month and occurs during the summer season. Annually, the salt deposition is 0.043 pounds per acre per month, also in the west-southwest direction and 980 feet from the cooling towers. This is much smaller than the NUREG-1555 significance level for possible visible effects to vegetation of 8.9 pounds per acre per month.

As modeled, salt deposition from the mechanical draft cooling towers would be as follows:

	Winter	Spring	Summer	Fall	Annual[(a)]
Maximum Salt Deposition (pounds per acre per month)	0.045	0.022	0.10	0.032	0.043
Distance to Maximum (feet)	980	980	980	660	980
Direction to Maximum	east-northeast	west-southwest	west-southwest	west-southwest	west-southwest
Maximum Salt Deposition at the WHY Substation (pounds per acre per month)	0.0064	0.016	0.011	0.0064	0.010

(a) The maximum annual salt deposition is the highest salt deposition for any one location over the course of a year. As the locations of the maximum salt depositions for each of the seasons vary, the maximum annual salt deposition is not the average of that for the individual seasons.

The NRC (U.S. NRC May 1996) reports that visible damage from salt deposition to terrestrial vegetation at operating nuclear power plants with mechanical draft cooling towers has not been observed. The impacts from the mechanical draft cooling towers are not expected to be different from the impacts of the currently operating nuclear power plants.

The WHY Substation is assumed to be located approximately 1450 feet north of the mechanical draft cooling towers of the first unit and 1700 feet northwest of the mechanical draft cooling towers of the second unit. The assumed distances are representative of a dual-unit advanced LWR site layout. A maximum predicted salt deposition of 0.016 pounds per acre per month would be expected at this location during the spring season and 0.010 pounds per acre per month annually.

The predicted salt deposition from the operation of the mechanical draft cooling towers would be less than the NUREG-1555 significance level where visible effects to vegetation may be observed. Salt deposition in other potentially sensitive areas, including at the VCS switchyard, are not expected to impact these facilities. Therefore, the impact from salt deposition from the mechanical draft cooling towers would be SMALL and would not require mitigation.

5.3.3.1.6 Cloud Formation, Cloud Shadowing, and Additional Precipitation

Vapor from cooling towers can create clouds or contribute to existing clouds. The SACTI code predicted the precipitation expected from the mechanical draft cooling towers. The maximum precipitation would occur during the summer season, with less than an inch of precipitation 980 feet west-southwest of the centerpoint of the towers. The precipitation annually would be 0.0003 inch of rain monthly. As described in Section 2.7 and Table 2.7-2, the average annual rainfall for Victoria County is 40 inches. The annual precipitation from the cooling towers would be very small compared to the average annual rainfall for Victoria County. Impacts from precipitation would be SMALL and would not require mitigation.

As modeled, precipitation from the mechanical draft cooling towers would be as follows:

	Winter	Spring	Summer	Fall	Annual
Maximum Water Deposition (inches per month)	0.00029	0.00014	0.00063	0.00019	0.00027
Distance to Maximum (miles)	0.19	0.19	0.19	0.12	0.19
Direction to Maximum Water Deposition	east-northeast	west-southwest	west-southwest	west-southwest	west-southwest

The formation of clouds could also prevent sunlight from reaching the ground, a phenomenon referred to as cloud shadowing. This is especially important for agricultural areas or other sensitive areas. Shadowing in the vicinity of the mechanical draft cooling towers was predicted to occur for 147 hours or less per season and 381 hours annually. Shadowing in offsite areas was predicted to occur less than 53 hours per season and 138 hours annually. These values for shadowing in offsite areas represent a small percentage of the total daylight hours of each season and per year. The impacts from cloud shadowing would be SMALL and would not require mitigation.

As modeled, shadowing from the mechanical draft cooling towers would be as follows:

	Winter	Spring	Summer	Fall	Annual
Maximum Hours of Shadowing Onsite	147	95	67	82	381
Direction to Maximum Onsite Shadowing Location	west-southwest	west	west-southwest	west-southwest	west-southwest
Maximum Hours of Shadowing Offsite	53	27	24	33	138
Direction to Maximum Offsite Shadowing Location	west-southwest	west-southwest	west-southwest	west-southwest	west-southwest

Note: Values are for the area outside of the immediate cooling tower vicinity (greater than 1000 feet from the tower)

5.3.3.1.7 Interaction with Existing Pollution Sources

There are no sources of pollution within 2 miles of the VCS site that could interact with the mechanical draft cooling tower plume. Some emissions sources, such as diesel generators and auxiliary boilers, would be located onsite as part of VCS. As described in Subsection 3.6.3.1, these emissions sources would only operate intermittently. The onsite sources would not be significant enough to have a distinguishable interaction with the cooling tower plume. Therefore, there would be no interaction of the cooling tower plume with existing pollution sources.

5.3.3.1.8 Ground-Level Humidity Increase

Increases in the absolute and relative humidity could result from the operation of the mechanical draft cooling towers. The vapor plume emitted from the cooling towers is buoyant and dissipates into the atmosphere as it rises and travels downwind. Occasionally, this elevated vapor plume can be brought to ground under strong wind conditions due to aerodynamic building wake effect. Consequently, ambient moisture content where the cooling tower plume touches the ground would increase. However, any noticeable increase is expected to be localized because of rapid mixing of the cooling tower plume with surrounding ambient air caused by the strong winds. The humidity in the region is typically high, and increases in the humidity would not be noticeable. The impacts from increases in absolute and relative humidity would be SMALL and mitigation would not be warranted.

5.3.3.2 Terrestrial Ecosystems

The VCS site is generally rangeland, a mixture of bluestem grasslands, encroaching shrubs, ephemeral streams and wetland depressions, and a few patches of trees (Subsection 2.4.1). The only protected species observed on or near this site are white-tailed hawks, wood storks, and a bald eagle. The hawks likely forage at the site, particularly in the winter/nonbreeding period, whereas the eagle was observed flying from the direction of Linn Lake. A lone wood stork was observed in the area of Linn Lake on two occasions. In addition, a flock of 30 storks was observed flying over Linn Lake in October of 2008. Additional “important” species, as defined in NUREG-1555 (U.S. NRC Oct 1999), found on the site include game animals common to this region: white-tail deer, feral pigs, northern bobwhite, turkey, dove, rabbits, and squirrels.

Cooling tower operational impacts on terrestrial biota can result from salt deposition, vapor plumes, icing, precipitation modifications, noise, and avian collisions with structures (e.g., the cooling towers). Each potential impact is discussed in Subsection 5.3.3.2.2. As discussed above, protected and other “important” species observed in the area of mechanical draft cooling tower construction include white-tailed hawks, a bald eagle, wood storks, and common game animals. Many animals in this area would likely shift to similar habitats nearby although some mortality of the smaller species incapable of such travel may occur.

5.3.3.2.1 Cooling Basin

The construction of the VCS facility would include an approximately 4900-acre cooling basin on a greenfield site composed primarily of grass and shrub rangeland. Impacts relative to the construction of this basin and subsequent loss of existing rangeland habitat are discussed in Subsection 4.3.1.

A similar type of cooling reservoir was built at STP in nearby Matagorda County, Texas. The STP cooling reservoir is now used as foraging, roosting and watering habitat for multiple waterfowl and water bird species during the winter months (Baker and Greene Mar 1989). Several seabird and shorebird species now nest along the dikes of the STP reservoir during the spring and summer months (USFWS 2008). The VCS cooling basin would be structurally similar to the reservoir at STP. Given erosion reducing construction within the proposed cooling basin, shoreline vegetation is not anticipated (nor does vegetation occur within the basin at STP). Assuming the colonization of the new VCS cooling basin by fish through the makeup water line, use of the basin as foraging habitat by piscivorous birds would eventually be expected. Potential use of the new basin by wintering waterfowl is likely, given the location of VCS near the confluence of multiple avian migration pathways. There are no uses proposed for this basin, other than cooling and a source of makeup water to and blowdown from the mechanical draft cooling towers.

5.3.3.2.2 Mechanical Draft Cooling Towers

5.3.3.2.2.1 Salt Drift

For this analysis, a dual unit plant was assumed. Two adjacent mechanical draft cooling towers are associated with each proposed VCS unit, with one pair in the eastern corner of the power block and the second pair in the western corner of the power block area. Habitat surrounding each set of cooling towers consists of site facilities and rangeland, primarily bluestem grasslands. Vegetation near the cooling towers could be subjected to salt deposition attributable to drift from the towers. Salt deposition could possibly cause vegetative stress, either directly by salts onto foliage or indirectly from accumulation of salts in the soil.

To evaluate salt deposition on plants, an order-of-magnitude approach was used since some plant species are more sensitive to salt deposition than others, and tolerance levels of most species are not well known. Deposition of sodium chloride at rates of approximately 1 to 2 pounds per acre per month is typically not damaging to plants, while deposition rates approaching or exceeding 9 pounds per acre per month in any month during the growing season could cause leaf damage in many species (U.S. NRC Oct 1999). An alternate approach for evaluating salt deposition is to use 9 to 19 pounds per acre per month of sodium chloride deposited on leaves during the growing season as a general threshold for visible leaf damage (U.S. NRC Oct 1999).

As presented in Subsection 5.3.3.1.5, the maximum expected salt deposition rate from the combination of all four towers would be 0.10 pounds per acre per month during the summer, 980 feet west-southwest of the centerpoint of the towers. This is a much smaller rate than the NUREG-1555 significance level (8.9 pounds per acre per month) for possible visible effects to vegetation. Any impacts from salt drift on local terrestrial ecosystems would therefore be SMALL and would not warrant mitigation.

5.3.3.2.2.2 Vapor Plumes and Icing

As discussed in Subsection 5.3.3.1.3, the expected average plume length would range from 0.23 (predominantly to the north) to 0.88 miles (predominantly to the south) and the median plume length would be approximately 0.12 miles (all seasons). As discussed in Subsection 5.3.3.1.4, ground level fogging as a result of mechanical draft cooling tower operation is predicted to occur for only 3 hours per year in a southerly direction (toward the cooling basin). Icing resulting from mechanical draft cooling tower operation is not predicted to occur. Thus, the impacts of vapor plumes, fogging, and icing on terrestrial ecosystems would be SMALL and would not warrant mitigation.

5.3.3.2.2.3 Clouds and Precipitation Modification

As discussed in Subsection 5.3.3.1.6, the predicted annual precipitation from the mechanical draft cooling towers would be approximately 0.0003 inch of rainfall monthly. This amount is very small when compared to the 40-inch average annual rainfall for Victoria County (NWS Apr 2008). Cloud shadowing due to tower operation is predicted to occur less than 381 hours annually compared to a total of 4440 hours of daylight at VCS during a year. Any impacts from cloud and/or precipitation modification on local terrestrial ecosystems would therefore be SMALL and would not warrant mitigation.

5.3.3.2.2.4 Noise

Noise generated from mechanical draft cooling tower operations would be approximately 52 decibels adjusted (dBA) at 400 feet from the tower (Subsection 5.8.1). This is below the 80 to 85 dBA level known to startle or frighten some birds and small mammals (Golden et al. 1980). Thus, it is unlikely that noise from the towers would disturb wildlife at distances greater than 400 feet from the towers. Additionally, the estimated noise level (52 dBA) associated with the new cooling towers is below the 60-65 dBA level the NRC considers of small significance (U.S. NRC May 1996). Noise impacts to terrestrial ecosystems would be SMALL and not warrant mitigation.

5.3.3.2.2.5 Avian Collisions

The mechanical draft cooling towers would rise less than 70 feet above grade. Tall, natural draft cooling towers have been associated with bird kills, but the lower height of mechanical draft cooling towers should pose little risk to birds and cause minimal mortality (U.S. NRC May 1996). Thus, impacts to birds from collisions with cooling towers would be SMALL and would not warrant mitigation.

In conclusion, there would be SMALL impacts to terrestrial ecosystems resulting from operation of the heat dissipation systems.

5.3.3.3 References

Baker and Greene Mar 1989. Baker, W. B., and G. N. Greene, *Final Report: 1987–1988 Special Ecological Studies for the South Texas Project, Matagorda County, Texas*, Houston Lighting and Power Company, March 1989.

Golden et al. 1980. Golden, J., Ouellette, R. P., Saari, S., and P. N. Cheremisinoff, *Environmental Impact Data Book, 1980*, Chapter 8, Noise, Ann Arbor Science Publishers, Inc.

NCDC 2008. National Climactic Data Center, *Hourly Surface Meteorological Observations from the Victoria Regional Airport*. Available at http://www.ncdc.noaa.gov/oa/ncdc.html, accessed January 16, 2008.

NWS Apr 2008. National Weather Service, Normals, Victoria County, April 3, 2008.

Policastro et al. 1994. Policastro, A. J., W. E. Dunn, and R. A. Carhart, *A Model for Seasonal and Annual Cooling Tower Impacts*, Atmospheric Environment Vol. 28, No. 3, Pages 379-395, Elsevier Science Ltd.

U.S. FWS 2008. U.S. Fish and Wildlife Service, *Texas Colonial Waterbird Census: Most Recent Texas Colonial Waterbird Database*. Available at http://www.fws.gov/texascoastalprogram/TCWC.htm, accessed April 9, 2008.

U.S. NRC May 1996. U.S. Nuclear Regulatory Commission, Generic Environmental Impact Statement for License Renewal of Nuclear Plants Volume 1, NUREG-1437, May 1996.

U.S. NRC Oct 1999. U.S. Nuclear Regulatory Commission, Standard Review Plans for Environmental Reviews of Nuclear Power Plants, NUREG-1555, October 1999.

5.3.4 Impacts to Members of the Public

This subsection describes the potential health impacts associated with the cooling system for the proposed VCS units. Specifically, impacts to human health from thermophilic microorganisms and from noise resulting from operation of the cooling system are addressed.

As described in Section 3.4, a cooling basin would be used as a closed-cycle cooling system for VCS. Mechanical draft cooling towers would be constructed to assist in heat load dissipation. Discharges with elevated temperatures would result from the following:

- Circulating water system discharge to the cooling basin
- Mechanical draft cooling tower blowdown to the cooling basin
- Cooling basin blowdown to the Guadalupe River

5.3.4.1 Etiological Agent Impacts

Consideration of the impacts of etiological agents such as microorganisms, parasites, and thermostable viruses on public health is important for facilities using cooling ponds, lakes, canals, or small rivers, because discharge into such water bodies may significantly increase the presence and numbers of microorganisms. Etiological agents associated with cooling ponds or towers and thermal discharges can have negative impacts on human health. Their presence and concentration can be increased by the addition of heat. These etiological agents include the enteric pathogens *Vibrio* spp., *Salmonella* spp., *Shigella* spp., and *Plesiomonas shigelloides*, as well as *Pseudomonas aeruginosa*, thermophilic fungi, noroviruses, and toxin-producing algae such as *Karenia brevis*, which causes red tide when present in high concentrations. They also include the bacteria *Legionella* spp., which causes Legionnaires' disease, and free-living amebae of the genera *Naegleria*, *Acanthamoeba*, and *Cryptosporidium*. Exposure to these etiological agents—or, in some cases, the endotoxins or exotoxins they produce—can cause illness or death.

These etiological agents are the cause of potentially serious human infections, the most serious of which is attributed to *Naegleria fowleri*. *Naegleria fowleri* is a free-living ameba that occurs worldwide. It is present in soil and practically all natural surface waters such as lakes, ponds, and rivers. *Naegleria fowleri* grows and reproduces well at high temperatures (104ºF to 113ºF) and has been isolated from waters with temperatures as low as 79.7°F. Naegleria fowleri thrives in warm, fresh water, particularly if the water is stagnant or slow moving. These protozoa are found in a variety of water bodies, including lakes, ponds, and poorly-maintained swimming pools and hot tubs. Because a primary food source for the amebae is coliform bacteria, the presence of significant numbers of coliform bacteria will promote growth of this ameba. Although exposure to this organism is very common, the chance is less than 1 in 100 million that a person exposed to water inhabited by

Naegleria will become infected. The few cases reported in Texas have occurred in the months of May through September. Symptoms include changes in the ability to taste or smell, rapidly followed by headache, fever, nausea, and vomiting. Although the disease is not transmissible from person to person, it is usually fatal (GBRA May 2006).

On a routine frequency, the Centers for Disease Control and Prevention compile statistical data regarding waterborne disease and outbreaks in the United States. A review of reported data from 1997 through the most recent reporting cycle (2004) indicates that there have been seven reported cases of primary amebic meningoencephalitis associated with recreational waters in Texas (CDC May 2000, CDC Nov 2002, CDC Oct 2004, CDC Dec 2006). Four additional cases were reported in the state of Texas in 2005 and 2007 (TDSHS Sep 2005, TDSHS Sep 2007, CDC May 2008). All cases were from water bodies in the central and northwestern portions of the state. None of the reported cases were in the vicinity of VCS.

The Texas Parks and Wildlife Department collects data on fish kills from harmful algal blooms, including golden alga, brown tide, and red tide. The brown tide is unique to the Gulf of Mexico and was first noted in the Laguna Madre, near Corpus Christi. The Laguna Madre was home to what is believed to be the longest continual algal bloom in history, from 1989 to 1997. However, there is no evidence that brown tide poses any harm to people. Golden alga blooms have been reported in the Red, Brazos, Colorado, and Rio Grande River Basins as recently as March 2008. Golden alga has not been reported in the river basins located in Victoria County: the Colorado-Lavaca Coastal; Lavaca River and Lavaca-Guadalupe Coastal Basin; and the Guadalupe River, San Antonio River, and San Antonio-Nueces Coastal Basin. There is no evidence that the toxins produced by golden alga pose any harm to people (TPWD 2008).

There are no regulations that could be tied to microorganisms associated with cooling ponds or towers or thermal discharges. Currently, no Occupational Safety and Health Administration or other legal standards for exposure to microorganisms exist.

Personnel and public access to the cooling basin would be controlled by administrative controls and security patrols. The cooling basin would be located within the fenced site boundary, precluding access by members of the public. Exelon would have a procedure in place to reduce the risk associated with exposure to etiological agents by providing work practices to eliminate routes of exposure to etiological agents that may produce illnesses. This procedure could include engineering and process controls such as ventilation and impermeable barriers. When engineering and process controls are not sufficient, respiratory protection would be prescribed. In addition, personal hygiene precautions would be required such as washing hands, tools, and exposed skin areas, wearing safety glasses, using disposable coveralls and booties, or using faceshields, gloves and hoods where splashing is anticipated. The risk to public health from etiological agents associated with the discharge of the circulating water system and the blowdown from the mechanical draft cooling towers to the cooling basin would be small and would not warrant mitigation.

Because etiological agents are ubiquitous in nature, the presence of etiological agents in the Guadalupe River would be expected. Subsection 5.3.2 describes the blowdown of the cooling basin to the Guadalupe River. Blowdown from the cooling basin to the Guadalupe River would be within limits set in the Texas pollutant discharge elimination system wastewater discharge permit for the proposed VCS. The effluent associated with the blowdown of the cooling basin would be released from a structure on the shoreline of the Guadalupe River. The effluent would be rapidly mixed with the flowing river water. The maximum temperature of the effluent would be 100°F, which is less than the temperature at which etiological agents reproduce well. An increase in the number of etiological agents in the small discharge and mixing zone of the thermal effluent is possible, but it would be limited by the flowing water that rapidly mixes the thermal plume and carries the etiological agents downstream away from the thermal effluent. Downstream of the proposed discharge at the end of the mixing zone, the temperature of the Guadalupe River would return to normal ambient conditions. Recreational activities on the Guadalupe River that could expose a member of the public to the etiological agents would likely only include swimming or the use of personal watercraft. The discharge structure would be in a difficult-to-access section of the Guadalupe River, and it is unlikely that a member of the public would be swimming in its vicinity. Personal watercraft users would be moving along the river and would not be near the discharge structure for very long. The risk to public health from etiological agents associated with the potential discharge of cooling basin water to the Guadalupe River would be small and would not warrant mitigation.

The risk to public health from etiological agents associated with the cooling system for the new units would be SMALL and would not warrant mitigation.

5.3.4.2 Noise Impacts

The proposed VCS units would produce noise from the operation of pumps, cooling towers, transformers, turbines, generators, switchyard equipment, and loudspeakers. The highest levels of noise from VCS would be associated with the operation of the mechanical draft cooling towers. Noise from the mechanical draft cooling towers would be attenuated by the distance to the VCS site boundary. The exclusion area boundary is greater than 4000 feet in all directions from the power block reference point, and the nearest full-time residence is approximately 4.5 miles from the site. The noise level generated by the cooling towers would be about 52 dBA at 400 feet from the towers and would be even lower at the exclusion area boundary. This noise level would be consistent with the existing background noise levels at the site. As reported in NUREG-1437 and referenced in NUREG-1555, noise levels below 65 dBA are considered of small significance. In addition, there are no applicable state or local noise regulations for unincorporated areas of Victoria County, where VCS is located. Thus, the impacts due to noise would be SMALL and would not warrant mitigation.

5.3.4.3 References

CDC May 2000. Centers for Disease Control and Prevention, *Morbidity and Mortality Weekly Report Surveillance for Waterborne-Disease Outbreaks—United States 1997–1998*, Volume 49 Number SS-4, May 26, 2000.

CDC Nov 2002. Centers for Disease Control and Prevention, *Morbidity and Mortality Weekly Report Surveillance for Waterborne-Disease Outbreaks-United States 1999–2000*, Volume 51 Number SS-8, November 22, 2002.

CDC Oct 2004. Centers for Disease Control and Prevention, *Morbidity and Mortality Weekly Report Surveillance for Waterborne-Disease Outbreaks Associated with Recreational Water-United States 2001–2002* and *Surveillance for Waterborne-Disease Outbreaks Associated with Drinking Water United States 2001–2002*, Volume 53 Number SS-8, October 22, 2004.

CDC Dec 2006. Centers for Disease Control and Prevention, *Morbidity and Mortality Weekly Report Surveillance for Waterborne Disease and Outbreaks Associated with Recreational Water—United States 2003–2004 and Surveillance for Waterborne Disease and Outbreaks Associated with Drinking Water and Water not Intended for Drinking–United States 2003–2004*, Volume 55 Number SS-12, December 22, 2006.

CDC May 2008. Centers for Disease Control and Prevention, *Morbidity and Mortality Weekly, Primary Amebic Meningoencephalitis—Arizona, Florida, and Texas, 2007*, Volume 57, May 30, 2008.

GBRA May 2006. Guadalupe-Blanco River Authority, *GBRA Emphasizes Importance of Water Quality in Water Recreation*, Guadalupe-Blanco River Authority News Release, May 17, 2006.

TDSHS Sep 2005. Texas Department of State Health Services, *Rare Amebic Illness Confirmed*, News Release, September 14, 2005.

TDSHS Sep 2007. Texas Department of State Health Services, *Confirmatory Tests Show PAM Caused Lubbock County Man's Death*, News Release, September 24, 2007.

TPWD 2008. Texas Parks and Wildlife Department, *Harmful Algal Blooms*. Available at http://www.tpwd.state.tx.us/landwater/water/environconcerns/hab/, accessed April 12.

U.S. NRC Oct 1999. U.S. Nuclear Regulatory Commission, Standard Review Plans for Environmental Reviews of Nuclear Power Plants, NUREG-1555, October 1999.

5.4 Radiological Impacts of Normal Operation

This section describes the radiological impacts of normal plant operation on members of the public, plant workers, and biota. Subsection 5.4.1 describes the exposure pathways by which radiation and radioactive effluents can be transmitted from the proposed units to organisms living near the plant. Subsection 5.4.2 estimates the maximum doses to the public from the operation of each new unit. Subsection 5.4.3 evaluates the impacts of these doses by comparing them to regulatory limits. Subsection 5.4.4 considers the impact to nonhuman biota that are present along the exposure pathways. Finally, Subsection 5.4.5 addresses the radiation doses to plant workers from the new units.

5.4.1 Exposure Pathways

Small quantities of radioactive liquids and gases will be discharged to the environment during normal operation of the proposed units. The impact of these releases and any direct radiation to individuals, population groups, and biota in the vicinity of the new units are evaluated by considering the most important pathways from the release points to the receptors of interest. The major pathways are those that could yield the highest radiological doses for a given receptor. The relative importance of a pathway is based on the type and amount of radioactivity released, the environmental transport mechanism, and the consumption or usage factors of the receptor.

The exposure pathways considered and the analytical methods used to estimate doses to the maximally exposed individual (MEI) and to the population within 50 miles of the new units are based on RGs 1.111 (U.S. NRC 1977a) and 1.109 (U.S. NRC 1977b). An MEI is a hypothetical member of the public located to receive the maximum possible calculated dose. Use of the MEI allows comparisons with established dose criteria for the public.

Population doses are calculated for the year 2080, the assumed end of plant life, when the population is projected to be at its peak during the assumed 60 years of plant operation. In 2080, food production rates within 50 miles of the plant are projected to increase at the same rate as population growth. Population doses are calculated considering the following 12 counties that have at least 10 percent of their land areas within 50 miles of the plant: Aransas, Bee, Calhoun, DeWitt, Goliad, Jackson, Karnes, Lavaca, Matagorda, Refugio, San Patricio, and Victoria.

5.4.1.1 Liquid Pathways

As discussed in Section 3.5, the proposed units would release radioactive liquid effluents to the Guadalupe River and eventually to the San Antonio Bay system. There are no radioactive liquid effluent release pathways to the cooling basin; this body of water will be monitored and sampled as indicated in Subsection 6.2.2.1.

The NRC-endorsed LADTAP II computer program (PNL 1986) is used to calculate the doses to the MEI, the population, and biota, with parameters specific to the Guadalupe River. Since further dilution occurs before the effluents reach the bays, the river doses are bounding. LADTAP II implements the radiological exposure models described in RG 1.109 for radioactivity releases in liquid effluent, as well as exposure models for boating and swimming as described in NUREG/CR-4013 (PNL 1986). The following exposure pathways are considered in LADTAP II:

- Ingestion of aquatic foods
- Ingestion of drinking water
- External exposure to shoreline sediments
- External exposure to water through boating and swimming
- Use of irrigated water

The input parameters for the liquid pathway are presented in Table 5.4-1. The discharge from the plant is assumed to be fully mixed within the river flow in accordance with the discharge system design. Doses to the MEI, the population, and biota are calculated based on the activity concentrations in the river at the point of discharge from the plant into the Guadalupe River.

5.4.1.2 Gaseous Pathways

The NRC-endorsed GASPAR II computer program (PNL 1987) is used to calculate the doses to the MEI, the population, and biota from gaseous effluents. This program implements the radiological exposure models described in RG 1.109 to estimate the radioactivity releases in gaseous effluent and the subsequent doses. The following exposure pathways are considered in GASPAR II:

- External exposure to airborne plume
- External exposure to contaminated ground
- Inhalation of airborne activity
- Ingestion of contaminated meat and milk
- Ingestion of contaminated garden vegetables

The input parameters for the gaseous pathway are presented in Table 5.4-2, and the receptor locations are shown in Table 5.4-3.

5.4.1.3 Direct Radiation

The direct radiation dose is assumed to be 2.5 mrem/yr outside the controlled area, corresponding to the shielding criteria for the ABWR and representing the largest direct dose component for the reactor technologies being evaluated. As indicated in Section 2.7, the distance from the power block area of the new units to the site boundary is 0.62 mile or approximately 3274 feet. Because the site boundary is the nearest receptor in an uncontrolled area, the direct radiation dose rate at the site boundary is assumed to be 2.5 mrem/yr.

5.4.2 Radiation Doses to Members of the Public

In this subsection, MEI doses from liquid and gaseous effluents from one new unit are estimated using the methodologies and parameters specified in Subsection 5.4.1.

5.4.2.1 Liquid Pathway Doses

Based on the parameters shown in Table 5.4-1, the LADTAP II computer program is used to calculate doses to the MEI via the following activities:

- Eating fish and invertebrates caught in the Guadalupe River
- Drinking water from the Guadalupe River, assuming it is a source of potable water
- Boating, swimming, and using the shoreline for recreational purposes
- Consuming meats, vegetables, and milk irrigated with contaminated water

The liquid activity releases (source terms) are shown in Table 3.5-1. Annual doses to the maximally exposed adult, teenager, child, and infant are calculated. The maximum total body and organ doses are presented in Table 5.4-4, with the age group receiving the dose also identified.

5.4.2.2 Gaseous Pathway Doses

Based on the parameters in Table 5.4-2 and 5.4-3, the GASPAR II computer program is used to calculate doses to the maximally exposed adult, teenager, child, and infant at the following locations:

- Nearest site boundary
- Nearest residence
- Nearest vegetable garden
- Nearest meat cow

There are no milk animals within 5 miles of the plant. The gaseous activity releases (source terms) are shown in Table 3.5-2. Annual doses to the maximally exposed adult, teenager, child, and infant are calculated. The maximum total body and organ doses are presented in Table 5.4-5. In this table, the contributions from viable pathways are summed to obtain a total dose for each organ and age group.

5.4.3 Impacts to Members of the Public

In this subsection, the radiological impacts to individuals and population groups from liquid and gaseous effluents are estimated using the methodologies and parameters specified in Subsection 5.4.1.

Table 5.4-6 shows the total body and organ doses to the MEI from liquid and gaseous effluents from a new unit. The calculated doses for both types of effluent are within the design objectives of 10 CFR 50 Appendix I. Table 5.4-7 shows that the total site direct and liquid and gaseous effluent doses from the proposed new units are well within the regulatory limits of 40 CFR 190. Since the dose limits for members of the public in 40 CFR 190 are more restrictive than those in 10 CFR 20.1301, demonstration of compliance with the limits of 40 CFR 190 is also considered to be a demonstration of compliance with the 0.1 rem limit of 10 CFR 20.1301. Table 5.4-8 shows that the collective doses from the new units to the population within 50 miles of the VCS site are negligible compared to natural background radiation. Based on the estimated doses from the new units, impacts to members of the public will be SMALL and will not warrant mitigation.

5.4.4 Impacts to Biota Other than Members of the Public

Radiation exposure pathways to biota, other than members of the public, are examined to determine if these pathways could result in doses to biota greater than those predicted for humans. This assessment uses surrogate species that provide representative information about the various dose pathways potentially affecting broader classes of living organisms. Surrogates are used since important attributes of these species are well defined and are accepted as a method for estimating doses to biota.

5.4.4.1 Liquid Pathway

The LADTAP II computer program is used to calculate doses to the biota via the following exposure pathways:

- Fish and Invertebrates — Internal exposure from bioaccumulation of radionuclides and external exposure from swimming and shoreline activities

- Algae — Internal exposure from bioaccumulation of radionuclides and external exposure from immersion in water
- Muskrat and Duck — Internal exposure from ingestion of aquatic plants and external exposure from swimming and shoreline activities
- Raccoon — Internal exposure from ingestion of invertebrates and external exposure from shoreline activities
- Heron — Internal exposure from ingestion of fish and external exposure from swimming and shoreline activities

Parameters used to calculate biota doses, such as food consumption rates, body masses, effective body radii, and residence times for swimming and shoreline exposure, are taken from RG 1.109 and NUREG/CR-4013 (PNL 1986).

5.4.4.2 Gaseous Pathway

Gaseous effluents contribute to the terrestrial doses. Immersion and ground deposition doses are largely independent of organism size, and the doses for the MEI, as described in Subsection 5.4.2, can be applied to biota. However, the external ground deposition doses, as calculated by GASPAR II, are increased by a factor of two to account for the closer proximity of terrestrial organisms to the ground, similar to the adjustments made for biota exposures to shoreline sediments in LADTAP II.

5.4.4.3 Biota Doses

Use of exposure guidelines, such as 40 CFR 190, which apply to members of the public in unrestricted areas, is considered very conservative when evaluating calculated doses to biota. The International Council on Radiation Protection states that “if man is adequately protected, then other living things are also likely to be sufficiently protected,” (ICRP 1977), and the National Council on Radiation Protection concurs with this conclusion (NCRP 1991). This assumption is appropriate in cases where humans and other biota inhabit the same environment and have common paths of exposure. It is less appropriate in cases where human access is restricted or pathways exist that are much more important for biota than for humans. Conversely, it is also known that biota with the same environment and exposure pathways as man can experience higher doses without adverse effects.

Species in most ecosystems experience dramatically higher mortality rates from natural causes than man. From an ecological viewpoint, population stability is considered more important to the survival of the species than the survival of individual organisms. Thus, higher dose limits could be permitted. In addition, no biota has been discovered that show significant changes in morbidity or mortality due to radiation exposures predicted from nuclear power plants. The International Atomic Energy Agency

(IAEA) concludes that there is no scientific evidence that chronic dose rates below 100 mrad/day are harmful to plants and animals (IAEA 1992).

Maximum annual doses to biota from liquid and gaseous effluents are shown in Table 5.4-9, which also shows the daily doses. It is seen that all biota doses are well within the IAEA guideline. Hence, impacts to biota other than members of the public will be SMALL and will not warrant mitigation.

5.4.5 Occupational Doses

The annual occupational dose to operational workers, including outage activities, will be dependent on the specific plant design chosen, and will be in accordance with applicable 10 CFR 20 and 10 CFR 50 Appendix I criteria. Based on the information available for the reactor designs being considered, the maximum annual occupational dose is 99 person-rem for the ABWR (GE 1997). The dose to construction workers from the operation of the first unit during the construction of subsequent unit(s) is addressed in Section 4.5. The impact on occupational doses will be SMALL and no new mitigation measures or controls are warranted.

5.4.6 References

GE 1997. GE Nuclear Energy, *ABWR Design Control Document, Tier 1*, Revision 4, March 1997.

IAEA 1992. International Atomic Energy Agency, *Effects of Ionizing Radiation on Plants and Animals at Levels Implied by Current Radiation Protection Standards*, Technical Reports Series No. 332, 1992.

ICRP 1977. International Council on Radiological Protection, *Recommendations of the International Council on Radiological Protection*, Publication 26, 1977.

NCRP 1987. National Council on Radiation Protection and Measurements, *Exposure of the Population in the United States and Canada from Natural Background Radiation*, NCRP Report No. 94, 1987.

NCRP 1991. National Council on Radiation Protection and Measurements, *Effects of Ionizing Radiation on Aquatic Organisms*, NCRP Report No. 109, 1991.

PNL 1986. Pacific Northwest Laboratory, *LADTAP II — Technical Reference and User Guide*, NUREG/CR-4013, April 1986.

PNL 1987. Pacific Northwest Laboratory, *GASPAR II — Technical Reference and User Guide*, NUREG/CR-4653, March 1987.

TWDB 2004. Texas Water Development Board, *Water Use Estimates by Location of Use*. Available at http://www.twdb.state.tx.us/wushistorical/DesktopDefault.aspx?PageID=1, accessed June 9, 2008.

U.S. Census Bureau 2006. *State and County Quick Facts*. Available at http://quickfacts.census.gov/qfd/states/48000.html.

USDA 2007. National Agricultural Statistics Service, *2007 Texas Agricultural Statistics*. Available at www.nass.usda.gov/Statistics_by_State/Texas/Publications/Annual_Statistical_Bulletin.

USDA 2009. *2007 Census of Agriculture,* Texas State and County Data, Volume 1. Available at www.agcensus.usda.gov/Publications/2007/Full_Report/Volume_1._Chapter_2_County_Level/Texas/index.asp.

U.S. Fish & Wildlife Service 2006. *2006 National Survey of Fishing, Hunting, and Wildlife-Associated Recreation – Texas*. Available at http://www.census.gov/prod/2008pubs/fhw06-tx-pdf.

U.S. NRC 1977a. U.S. NRC, *Methods for Estimating Atmospheric Transport and Dispersion of Gaseous Effluents in Routine Releases from Light-Water-Cooled Reactors*, RG 1.111, Revision 1, July 1977.

U.S. NRC 1977b. U.S. NRC, *Calculation of Annual Doses to Man from Routine Releases of Reactor Effluents for the Purpose of Evaluating Compliance with 10 CFR Part 50, Appendix I*, RG 1.109, Revision 1, October 1977.

**Table 5.4-1 (Sheet 1 of 3)
Liquid Pathway Parameters**

Parameter	Value	Basis/Source(s)
Release Source Terms	See Table 3.5-1	Table 3.5-1 shows the activity releases by isotope, assumed for one conventional or six mPower units.
Impoundment Reconcentration Model	None	This model does not apply to the river discharge scenario.
Individual Consumption/ Exposure Rates	See RG 1.109	The values from Tables E-5 and E-4 of RG 1.109 are used for the MEI and the average person within the population, respectively.
Site Water Type	River	Guadalupe River.
Flow Rate in Receiving Water Body	480 cfs	This is a conservative flow rate that represents 95th percentile of all observed annual average flow rates in the Guadalupe River from 1935 to 2008. Effluent activity is assumed to be released directly into the river without any prior dilution.
Shore-Width Factor	0.2	This is the appropriate value for a river (RG 1.109, Table A-2).
Dilution factor for Discharge	1	No dilution is assumed beyond mixing in the river flow rate.
Transit Time to Receptor	See RG 1.109	The default transit times from RG 1.109, Table D-1 are used.
Irrigation Rate	110 l/m^2 per month	Based on an assumed value of 1 inch per week.
50-Mile Population	4.15×10^5	This is the projected population for the year 2080, the end of plant life. It is used to conservatively maximize population doses. This projection represents an increase of a factor of 1.7 over the 2000 population.
50-Mile Drinking Water Population	7.08×10^4	Of the municipal water usage in the 12 counties within 50 miles of the plant, 17% comes from the Guadalupe River (TWDB 2004). Based on this, it is assumed that 17% of the population in 2080 receives its drinking water from Guadalupe River.
50-Mile Sport Fishing Harvest	6.69×10^4 kg/yr	Based on RG 1.109, Appendix D and Table E-4, the average individual consumes 5.9 kg/yr of fish. Multiplying this by the 2080 population yields the total annual consumption of fish within 50 miles of 2.43×10^6 kg/yr. Of the state population of 20.9 million (U.S. Census Bureau 2006), 0.574 million (U.S. Fish & Wildlife Service 2006) or about 2.75% engages in sport fishing in rivers. It is assumed that 2.75% of the fish consumption within 50 miles is due to sport fishing from Guadalupe River.
50-Mile Commercial Fishing Harvest	1.15×10^6 kg/yr	As the previous entry indicates, of the total fish consumption within 50 miles of 2.43×10^6 kg/yr, 2.75% is due to sport fishing. It is assumed that Guadalupe River is the source of 50% of the fish consumed within 50 miles, with the remaining 47.25% coming from commercial fishing.
50-Mile Sport Invertebrate Harvest	9.71×10^3 kg/yr	Based on RG 1.109, Appendix D and Table E-4, the average individual consumes 0.85 kg/yr of invertebrate. Multiplying this by the 2080 population yields the total annual consumption of invertebrate within 50 miles of 3.53×10^5 kg/yr. As with sport fishing, it is assumed that 2.75% of the invertebrate consumption within 50 miles is due to sport invertebrate harvest from the Guadalupe River.

Table 5.4-1 (Sheet 2 of 3)
Liquid Pathway Parameters

Parameter	Value	Basis/Source(s)
50-Mile Commercial Invertebrate Harvest	1.67×10^5 kg/yr	As the previous entry indicates, of the total invertebrate consumption within 50 miles of 3.53×10^5 kg/yr, 2.75% is due to sport invertebrate harvest. It is assumed that Guadalupe River is the source of 50% of the invertebrate consumed within 50 miles, with the remaining 47.25% coming from commercial harvest.
50-Mile Shoreline Usage	5.30×10^6 hr/yr	Based on RG 1.109, Appendix D and Table E-4, the average individual spends 12.8 hr/yr on shoreline recreation. This is multiplied by the 2080 population to yield the shoreline usage within 50 miles.
50-Mile Swimming Usage	5.30×10^6 hr/yr	Based on 12.8 hr/yr, same as shoreline usage.
50-Mile Boating Usage	5.30×10^6 hr/yr	Based on 12.8 hr/yr, same as shoreline usage.
50-Mile Leafy Vegetable Production	9.65×10^6 kg/yr	The harvested land area in the 12 counties within 50 miles represents about 3.5% of the state total (USDA 2009). The annual production of leafy vegetables in the state (USDA 2007) is multiplied by 3.5% to estimate the production within 50 miles. Assuming production to increase with the population, the production is also multiplied by the population growth factor of 1.7 to project the production in 2080.
50-Mile Leafy Vegetable Production with Irrigated Water	9.49×10^3 kg/yr	Within the 12 counties within 50 miles, 5.7% of the harvested land is irrigated (USDA 2009). Of the water used for irrigation in the 12 counties, 1.7% comes from the Guadalupe River (TWDB 2004). The 50-mile leafy vegetable production is multiplied by these two fractions to estimate the production using irrigated water from the Guadalupe River.
50-Mile Vegetable Production	5.18×10^7 kg/yr	The harvested land area in the 12 counties within 50 miles represents about 3.5% of the state total (USDA 2009). The annual production of vegetables in the state (USDA 2007) is multiplied by 3.5% to estimate the production within 50 miles. Assuming production to increase with the population, the production is also multiplied by the population growth factor of 1.7 to project the production in 2080.
50-Mile Vegetable Production with Irrigated Water	5.09×10^4 kg/yr	Within the 12 counties within 50 miles, 5.7% of the harvested land is irrigated (USDA 2009). Of the water used for irrigation in the 12 counties, 1.7% comes from the Guadalupe River (TWDB 2004). The 50-mile vegetable production is multiplied by these two fractions to estimate the production using irrigated water from the Guadalupe River.
50-Mile Milk Production	1.41×10^7 l/yr	Milk cows in the 12 counties within 50 miles represent about 0.24% of the state total (USDA 2009). The annual production of milk in the state (USDA 2007) is multiplied by 0.24% to estimate the production within 50 miles. Assuming production to increase with the population, the production is also multiplied by the population growth factor of 1.7 to project the production in 2080.

Table 5.4-1 (Sheet 3 of 3)
Liquid Pathway Parameters

Parameter	Value	Basis/Source(s)
50-Mile Milk Production with Irrigated Water	1.60×10^{5} l/yr	Within the 12 counties within 50 miles, 5.7% of the harvested land is irrigated (USDA 2009). Of the water used for livestock in the 12 counties within 50 miles, 20% comes from the Guadalupe River (TWDB 2004). The 50-mile milk production is multiplied by these two fractions to estimate the production using irrigated water from the Guadalupe River.
50-Mile Meat Production	2.23×10^{8} kg/yr	Beef cows and broilers in the 12 counties within 50 miles represent about 5.6% and 0.20%, respectively, of the state totals (USDA 2009). The annual productions of red meat and broiler in the state (USDA 2007) are multiplied by these percentages and summed to estimate the total meat production within 50 miles. Assuming production to increase with the population, the production is also multiplied by the population growth factor of 1.7 to project the production in 2080.
50-Mile Meat Production with Irrigated Water	2.52×10^{6} kg/yr	Within the 12 counties within 50 miles, 5.7% of the harvested land is irrigated (USDA 2009). Of the water used for livestock in the 12 counties within 50 miles, 20% comes from the Guadalupe River (TWDB 2004). The 50-mile meat production is multiplied by these two fractions to estimate the production using irrigated water from the Guadalupe River.

Table 5.4-2
Gaseous Pathway Parameters

Parameter	Value	Basis/Source(s)
Release Source Terms	See Table 3.5-2	Table 3.5-2 shows the activity releases by isotope, assumed for one conventional or six mPower units.
Atmospheric Dispersion and Deposition Factors	See Tables 2.7-14, 2.7-17, 2.7-19, 2.7-21, 2.7-23, and 2.7-25	Table 2.7-14 shows the dispersion and deposition data for the nearest site boundary, residence, vegetable garden, and meat animal. Tables 2.7-19, 2.7-21, 2.7-23, and 2.7-25 show dispersion and deposition data for 160 sectors representing 16 directions and 10 distance segments out to 50 miles. The dispersion and deposition data at the assumed biota location at a distance of 0.25 mile are obtained from Table 2.7-17.
Individual Consumption Rates	See RG 1.109	The values from Tables E-5 and E-4 of RG 1.109 are used for the MEI and the average person within the population, respectively.
50-Mile Population	4.15×10^5	This is the projected population for the year 2080, the end of plant life. It is used to conservatively maximize population doses.
50-Mile Population Distribution	See Table 2.5.1-1	Table 2.5.1-1 shows the population distribution in 2080 for 160 sectors representing 16 directions and 10 distance segments out to 50 miles.
50-Mile Milk Production	1.41×10^7 l/yr	This is the projected production for 2080. See comment on milk production in Table 5.4-1.
50-Mile Meat Production	2.23×10^8 kg/yr	This is the projected production for 2080. See comment on meat production in Table 5.4-1.
50-Mile Vegetable Production	5.18×10^7 kg/yr	This is the projected production for 2080. See comment on vegetable production in Table 5.4-1.
Fraction of year leafy vegetables grown	1	This is the most conservative value.
Fraction of year milk cows on pasture	1	This is the most conservative value.
Fraction of maximum individual's vegetable intake from own garden	0.76	This is the default value from RG 1.109, Table E-15.
Fraction of milk-cow feed from pasture	1	This is the most conservative value.
Average absolute humidity for growing season	8 g/m^3	This is the default value in GASPAR II (PNL 1987). It is used when a value of zero is input.
Fraction of year goats at pasture	1	This is the most conservative value.
Fraction of goat feed from pasture	1	This is the most conservative value.
Fraction of year beef cattle at pasture	1	This is the most conservative value.
Fraction of beef cattle feed from pasture	1	This is the most conservative value.

Table 5.4-3
Gaseous Pathway Receptor Locations

Receptor	Direction	Distance (mi)
Site Boundary	SW	0.62
Residence	NNW	1.40
Vegetable Garden	NW	1.65
Meat Animal	NNW	1.40
Biota	NW	0.25

Note: The site boundary and residence, garden, and meat animal locations are shown in Figure 6.2-6. The distance to the receptor location is from the edge of the power block.

Table 5.4-4
Liquid Pathway Doses for Maximally Exposed Individuals

Pathway	Dose (mrem/yr) per Unit[a]							
	Total Body	GI-LLI[b]	Bone	Liver	Kidney	Thyroid	Lung	Skin
Fish	0.33	0.15	1.0	0.41	0.13	0.026	0.044	0
Invertebrate	0.044	0.15	0.077	0.068	0.024	0.0027	0.0064	0
Drinking	0.17	0.19	0.016	0.24	0.23	0.35	0.22	0
Shoreline	0.00053	0.00053	0.00062	0.00062	0.00062	0.00062	0.00062	0.0035
Swimming	0.000015	0.000015	0.000017	0.000017	0.000017	0.000017	0.000017	0
Boating	0.0000075	0.0000075	0.0000087	0.0000087	0.0000087	0.0000087	0.0000087	0
Irrigated Vegetables	0.17	0.31	0.14	0.36	0.29	0.27	0.25	0
Irrigated Meat	0.031	1.4	0.038	0.023	0.064	0.018	0.018	0
Total	0.74	2.2	1.3	1.1	0.74	0.67	0.54	0.0035
Maximum Dose Age Group	Adult	Adult	Child	Child	Child	Child	Child	Teen

(a) "Unit" refers to one conventional unit or six modular mPower reactors.
(b) GI-LLI — Gastrointestinal Tract — Lower Large Intestine.

Table 5.4-5 (Sheet 1 of 2)
Gaseous Pathway Doses for Maximally Exposed Individuals

	Dose (mrem/yr) per Unit[(a)]							
Pathway	**Total Body**	**GI-Tract**	**Bone**	**Liver**	**Kidney**	**Thyroid**	**Lung**	**Skin**
Site Boundary								
External								
Plume	1.9	1.9	1.9	1.9	1.9	1.9	2.0	6.7
Ground	0.85	0.85	0.85	0.85	0.85	0.85	0.85	1.0
Total	2.8	2.8	2.8	2.8	2.8	2.8	2.8	7.7
Inhalation								
Adult	0.11	0.13	0.029	0.13	0.14	3.2	0.17	0
Teen	0.12	0.13	0.037	0.14	0.16	4.1	0.21	0
Child	0.11	0.11	0.047	0.13	0.14	5.0	0.18	0
Infant	0.062	0.060	0.030	0.084	0.085	4.6	0.12	0
Total								
Adult	2.9	2.9	2.8	2.9	2.9	5.9	3.0	7.7
Teen	2.9	2.9	2.8	2.9	2.9	6.9	3.1	7.7
Child	2.9	2.9	2.8	2.9	2.9	7.8	3.0	7.7
Infant	2.8	2.8	2.8	2.9	2.9	7.4	3.0	7.7
Residence								
External								
Plume	0.54	0.54	0.54	0.54	0.54	0.54	0.55	1.7
Ground	0.23	0.23	0.23	0.23	0.23	0.23	0.23	0.27
Total	0.77	0.77	0.77	0.77	0.77	0.77	0.78	2.0
Inhalation								
Adult	0.025	0.028	0.0062	0.029	0.032	0.70	0.038	0
Teen	0.026	0.029	0.0080	0.031	0.035	0.90	0.046	0
Child	0.024	0.024	0.010	0.028	0.032	1.1	0.039	0
Infant	0.014	0.013	0.0065	0.019	0.019	1.0	0.026	0
Vegetable								
Adult	0.24	0.24	1.2	0.25	0.23	4.3	0.20	0
Teen	0.35	0.35	1.8	0.39	0.36	5.4	0.31	0
Child	0.75	0.73	4.2	0.84	0.78	10	0.70	0
Meat								
Adult	0.10	0.16	0.45	0.11	0.10	0.39	0.094	0
Teen	0.083	0.11	0.38	0.089	0.083	0.29	0.078	0
Child	0.15	0.16	0.71	0.16	0.15	0.46	0.14	0

Table 5.4-5 (Sheet 2 of 2)
Gaseous Pathway Doses for Maximally Exposed Individuals

	Dose (mrem/yr) per Unit[a]							
Pathway	**Total Body**	**GI-Tract**	**Bone**	**Liver**	**Kidney**	**Thyroid**	**Lung**	**Skin**
Total MEI Dose[b]								
Adult	1.1	1.2	2.4	1.2	1.1	6.1	1.1	2.0
Teen	1.2	1.3	2.9	1.3	1.2	7.4	1.2	2.0
Child	1.7	1.7	5.6	1.8	1.7	13	1.7	2.0
Infant	0.78	0.78	0.77	0.79	0.79	1.8	0.81	2.0

(a) "Unit" refers to one conventional unit or six modular mPower reactors.
(b) Total MEI dose is the sum of the residence, vegetable, and meat pathways.

Table 5.4-6
Comparison of Maximally Exposed Individual Doses with 10 CFR 50, Appendix I Criteria

Type of Dose	Location	Annual Dose per Unit[a]	
		VCS	Limit
Liquid Effluent			
Total Body (mrem)	Guadalupe River	0.74	3
Maximum Organ — GI-LLI (mrem)	Guadalupe River	2.2	10
Gaseous Effluent			
Gamma Air (mrad)	Site Boundary	3.0	10
Beta Air (mrad)	Site Boundary	7.5	20
Total Body (mrem)	Site Boundary	2.8	5
Skin (mrem)	Site Boundary	7.7	15
Iodines and Particulates, Maximum Organ — Thyroid (mrem)	Residence/Garden/ Meat Cow	11	15

(a) "Unit" refers to one conventional unit or six modular mPower reactors.

Table 5.4-7
Comparison of Maximally Exposed Individual Doses with 40 CFR 190 Criteria

	Site[a][b] Dose (mrem/yr)				
	Liquid	Gaseous	Direct	Total	Limit
Total Body	1.5	5.8	5.0	12	25
Thyroid	1.3	25	5.0	32	75
Other Organ — Bone	2.6	11	5.0	19	25

(a) "Site" refers to two conventional units or 12 modular mPower reactors.

(b) Site doses for two units are obtained by doubling the doses from a single unit. Liquid effluent doses are obtained from doubling the doses in Table 5.4-4. Gaseous effluent doses are obtained by doubling the higher of the site boundary and MEI doses in Table 5.4-5. The direct radiation dose is obtained by doubling 2.5 mrem/yr, the dose outside the controlled area corresponding to the shielding criteria for the ABWR (GE 1997, Table 3.2a); this is the largest direct dose component for the reactor technologies being evaluated.

Table 5.4-8
Collective Doses Within 50 Miles

Source	Dose (person-rem/yr) per Unit[a]		Site[b] Dose (person-rem/yr)	
	Total Body	**Thyroid**	**Total Body**	**Thyroid**
Liquid Effluents	8.7	8.4	17	17
Gaseous Effluents				
Noble Gases	0.29	0.29	0.58	0.58
Iodines	0.0066	2.6	0.013	5.2
Particulates	0.14	0.11	0.28	0.21
C-14	0.59	0.59	1.2	1.2
H-3	0.10	0.10	0.21	0.21
Total Gaseous Effluents	1.1	3.7	2.3	7.4
Total	9.9	12	20	24
Natural Background[c]	1.2×10^5			

(a) "Unit" refers to one conventional unit or six modular mPower reactors.
(b) "Site" refers to two conventional units or 12 modular mPower reactors.
(c) Based on dose rate of 300 mrem/yr (NCRP 1987).

Table 5.4-9
Biota Doses from Liquid and Gaseous Effluents

Biota	Site[a] Dose (mrad/yr)			Total Dose (mrad/day)
	Liquid	Gaseous	Total	
Fish	21	0	21	0.059
Invertebrate	50	0	50	0.14
Algae	55	0	55	0.15
Muskrat	39	130	170	0.46
Raccoon	6.3	130	140	0.37
Heron	67	130	200	0.54
Duck	39	130	170	0.46

(a) "Site" refers to two conventional units or 12 modular mPower reactors.

5.5 Environmental Impacts of Waste

Plant operation at the proposed VCS will result in the generation of several waste streams. These wastes will be regulated, as appropriate, during generation, management, handling, treatment, storage, transportation, and disposal. This section describes the potential environmental impacts associated with these wastes and is divided into a subsection addressing nonradioactive wastes and one addressing mixed wastes.

5.5.1 Nonradioactive Waste System Impacts

Descriptions of the VCS nonradioactive waste systems and chemical parameters are presented in Section 3.6. Nonradioactive wastes generated at the site will be managed in accordance with applicable federal, Texas, and local laws and regulations, and permit requirements. Management practices will include the following:

- Nonradioactive petroleum and hazardous wastes (e.g., used oil and antifreeze) will be collected and stored temporarily onsite until disposed of at offsite licensed commercial waste disposal facilities or recovered at an offsite permitted recycling or recovery facility.
- Water discharges from cooling and auxiliary systems (e.g., cooling tower blowdown, sanitary wastewater treatment effluent and other treated wastewater effluent streams) will be discharged via cooling basin blowdown through the outfall to the Guadalupe River, permitted by the Texas Commission on Environmental Quality (TCEQ).
- Waste sludge generated at the water treatment plant and sanitary wastewater treatment plant will be disposed of offsite via contract with a licensed waste transportation and disposal company. Offsite sludge disposal methods could include landfilling, incineration, land application, and/or further treatment at licensed facilities. Septic tank sludge will be removed periodically by a licensed contractor and disposed of offsite.
- Debris (e.g., vegetation) collected on trash screens at the water intake structure(s) will be disposed of either onsite or offsite in accordance with TCEQ regulations.
- Scrap metal, lead acid batteries, and paper collected at the Victoria County Station will be recycled offsite at an approved recycle facility, to the extent practicable.

Further descriptions of plant systems containing nonradioactive wastes can be found in Section 3.6. 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

Nonradiological wastes from routine plant operations include those from mechanical draft cooling tower blowdown, plant auxiliary system wastewater, and stormwater runoff. As identified in Section 1.2, a Texas Pollutant Discharge Elimination System (TPDES) permit will identify the limits on various chemical constituents, so that the water quality of the Guadalupe River is protected.

Although there will be several discharge locations to the cooling basin, there will only be one discharge outfall that releases industrial effluents to the Guadalupe River. Surface water runoff will be directed to two retention ponds, one on the east side of the plant and the other on the west. Overflow to these ponds will be directed to Linn Lake and Kuy Creek, for the east and west ponds, respectively. The stormwater retention ponds are shown in Figure 3.1-1.

Ambient or baseline water quality characteristics are described in Section 2.3, and Table 3.6-1 provides the expected cooling water blowdown concentrations. The cooling basin blowdown discharge system will be designed so that the concentrations of constituents at the discharge outfall will be mixed and will reach concentrations upon entering the Guadalupe River not significantly different from those of the river. Concentrations in the outfall plume are estimated in Section 5.3.

Considering that the anticipated amount of mixing will achieve compliance with the limits that will be placed on discharges by the TPDES permit, the potential impacts from constituents in the cooling water and plant auxiliary system discharges from the VCS on the Guadalupe River will be SMALL.

In addition, a Stormwater Pollution Prevention Plan (SWPPP) will be developed to (1) prevent or minimize the discharge of pollutants with the stormwater, and (2) reflect the addition of new paved areas and facilities and changes in drainage patterns. The impacts of the addition of impervious surfaces are expected to be negligible because best management practices initiated through the SWPPP will be employed to control stormwater runoff. Thus, environmental impacts from stormwater discharges will be SMALL.

5.5.1.2 Impacts of Discharges to Land

Operation of the units will result in generation of solid wastes. The types of solid waste generated are addressed in Subsection 3.6.3.5. Applicable federal, Texas, and local requirements and standards will be met with regard to the handling, transporting, and disposal of solid wastes offsite. Any onsite waste disposal (e.g., uncontaminated sediment) will be performed in accordance with the appropriate TCEQ guidelines.

Hazardous wastes are addressed in Subsection 3.6.3.4. There are two hazardous waste disposal facilities in Texas:

- The nearest hazardous waste disposal facility is U.S. Ecology Texas, located in Robstown near Corpus Christi, Texas. The facility has a rated capacity of approximately 1.5 million cubic yards (TNRCC Feb 2000).
- The other hazardous waste disposal facility is Waste Control Specialists, LLC, located in Andrews, Texas. The existing capacity of the facility is over 5 million cubic yards (TCEQ Oct 2005).

The available disposal capacity in the state far exceeds the projected demands for hazardous waste disposal associated with VCS operations. The annual quantity of hazardous waste generated in Texas exceeds 15 million tons (U.S. EPA 2005). As indicated in Subsection 3.6.3.4, VCS would be expected to operate as a small quantity generator and generate less than 27,000 pounds (13 tons) of hazardous waste on an annual basis. This amount is small in comparison to the hazardous waste generated in the state. Based on the low VCS generation rate and disposal capacity in the state, the impacts associated with disposal of the VCS hazardous waste would be SMALL.

VCS would generate nonhazardous waste that would be classified as municipal solid waste and disposed of in accordance with TCEQ regulations at landfills permitted to receive such wastes. Municipal solid waste planning in Texas is the responsibility of 24 councils of governments. The VCS site is located in the Golden Crescent Regional Planning Commission. This area has one landfill, City of Victoria Landfill, a municipal solid waste landfill with 22 years of remaining capacity based on 2006 data (TCEQ Nov 2007). Municipal solid waste landfills in adjacent council areas include the El Centro Landfill in Nueces County, which has 57 years of remaining capacity, and the Fort Bend Regional Landfill in Fort Bend County, which has 147 years of remaining capacity (TCEQ Nov 2007). A construction and demolition debris landfill is located in Fort Bend County, Sprint Fort Bend County Landfill, and has 52 years of remaining capacity (TCEQ Nov 2007).

The TCEQ (Title 30, Texas Administrative Code, Sections 330.3 and 330.173) defines nonhazardous industrial waste in three classes—Class 1, 2, and 3—and establishes which landfills are acceptable for disposal of the classes. The U.S. Ecology Texas landfill in Robstown in Nueces County accepts industrial solid waste in Classes 1, 2, and 3 (TCEQ Dec 2006). This facility has nonhazardous waste-rated disposal capacity of 93,000 cubic yards (TNRCC Feb 2000).

There is adequate capacity in the vicinity of VCS to meet the projected demand for nonhazardous solid waste disposal for several decades. Therefore, the impacts of disposal of all types of nonhazardous solid wastes from VCS operations would be SMALL.

Recycling and waste minimization programs will be employed at VCS. Nonradioactive solid waste will be reused or recycled to the extent practicable. Solid wastes appropriate for recycling will be managed through use of approved and appropriately licensed commercial waste disposal facilities.

Therefore, the potential impacts from land disposal of nonradioactive solid wastes will be SMALL and will not warrant mitigation.

5.5.1.3 Impacts of Discharges to Air

Operation of the units at the site will result in small amounts of gaseous emissions to the air, from equipment associated with plant auxiliary systems (e.g., diesel generators, combustion turbines, and auxiliary boilers). This equipment normally operates only periodically (e.g., during startup/shutdown or testing), and thus the related emissions are infrequent. Projected bounding values for emissions from this equipment are provided in Tables 3.6-2, 3.6-3, and 3.6-4.

Based on an initial estimate of the amount of potential air emissions, and the infrequent nature of the potential emissions, impacts to air quality will be SMALL and will not warrant mitigation.

5.5.1.4 Sanitary Waste Impacts

Sanitary waste will be treated in an onsite sewage treatment plant. The sanitary treatment generated sludge will be disposed of offsite via contract with a licensed waste transportation and disposal company. Offsite sludge disposal methods could include landfilling, incineration, land application, and/or further treatment at licensed facilities. The sanitary system will discharge to the cooling basin, which ultimately discharges to the Guadalupe River at the discharge outfall. The large volume of water available for mixing contained in the cooling basin will result in an insignificant buildup of sewage-related constituents. Therefore, the mixing volume provided by the cooling basin for treated sanitary effluent, as well as the disposal of sanitary treatment sludge at licensed offsite facilities, will ensure that potential impacts associated with sanitary waste from the operation of the units will be SMALL and will not warrant mitigation.

5.5.1.5 Impacts of Dredging and Disposal

It is anticipated that periodic dredging will be required as part of maintenance activities associated with the RWMU system intake canal. Dredging activities and the management and disposal of the resulting spoils would be conducted in accordance with a US Army Corp of Engineers (USACE) issued permit, as well as other applicable permits and regulations. The disposal site(s) would be selected in coordination with the USACE to avoid sensitive areas (e.g., wetlands or waterways), to maximize the effectiveness of water quality best management practices (BMPs), and to ensure adequate disposal area for the life of the VCS facility. The implemented BMPs could include the installation of silt fence or vegetative filter strips, the use of filter bags or other decanting techniques, and/or the placement of disposal areas to promote the return of managed dewatering runoff to the source water body (i.e., rather than another water body that could have different water quality characteristics). Considering that dredging and disposal activities will be conducted in accordance with applicable permits and regulations, utilizing BMPs for site selection and water quality protection, the impacts associated with the disposal of RWMU canal dredge spoils will be SMALL.

5.5.2 Mixed Waste Impacts

The term "mixed waste" refers specifically to waste that is regulated as both radioactive waste and hazardous waste. Radioactive materials at nuclear power plants are regulated by the NRC under the Atomic Energy Act (AEA 1954). Hazardous wastes are regulated by the state of Texas, which is an EPA-authorized state (i.e., a state authorized by the EPA to regulate those portions of the Federal act) under the Resource Conservation and Recovery Act (RCRA).

Mixed waste generated on site is assessed based on the following laws and regulations. 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 40 CFR 261, Subpart C, or be listed as a hazardous waste under 40 CFR 261, Subpart D. 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 the RCRA in 1984. The Federal agencies responsible for ensuring compliance with these statutes are the NRC and the EPA.

5.5.2.1 Plant Systems Producing Mixed Waste

A 1990 survey conducted by the NRC identified the following types of mixed low-level waste at reactor facilities (U.S. NRC May 1996):

- 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

Specific types and quantities of mixed wastes that could be generated in new operating reactors are not available. However, the types of mixed waste generated by the reactor selected for the VCS site are expected to be consistent with the types identified by the survey.

5.5.2.2 Mixed Waste Storage and Disposal Plans

The volume of mixed waste will be reduced or eliminated by one or more of the following methods before disposal: decay, stabilization, neutralization, filtration, or chemical or thermal destruction by an offsite vendor. Some small quantities of mixed waste, if generated, will be treated on site, or disposed of offsite, as applicable. Occupational chemical and radiological exposures could occur during the testing of mixed wastes to determine if the constituents are chemically hazardous. Appropriate hazardous chemical control and radiological control measures will be applied during testing, handling, and storage (accumulation area) of mixed wastes and will include the following:

- Segregate mixed wastes from nonhazardous wastes.
- Designate and use an area only for storage of mixed waste and excluding its use for storage of unrelated materials or equipment or for other functions.
- Provide a secondary containment for liquid mixed wastes being stored (for example, berm and line areas where drums are stored).
- Label the containers properly and in accordance with regulatory requirements.
- Post and/or provide applicable material safety data sheets, emergency spill response procedures, and a spill kit in the area.
- Fence and lock the gate to the accumulation area when authorized personnel are not present.
- Post signs at the entrance to the storage area with language similar to the following: “MIXED HAZARDOUS WASTE AREA” and “DANGER-UNAUTHORIZED PERSONNEL-KEEP OUT.”

5.5.2.3 Waste Minimization Plan

A waste minimization program will be developed and implemented. The following will be key elements of such a program:

- Maintenance Program — Equipment maintenance programs will be periodically reviewed to establish improvements in corrective and preventive maintenance that will reduce equipment failures that could generate mixed waste. Maintenance procedures will be reviewed to determine which were contributing to the production of waste in the form of process materials, scrap, and cleanup residue. In addition, the need for revising operational procedures, modifying equipment, and segregating and recovering the mixed waste source will be determined.

- Recycling and Reuse — Opportunities for reclamation and reuse of waste materials will be used whenever feasible. Tools, equipment, and materials will be decontaminated for reuse or recycle whenever possible to minimize the amount of waste for disposal.

- Segregation — If radiological or hazardous waste is generated, proper handling, containerization, and separation techniques will be employed. This will minimize cross contamination and the unnecessary generation of mixed waste.

- Decay in Storage — Some portion of the mixed waste will be radionuclides with relatively short half-lives. The NRC generally allows facilities to store waste containing radionuclides with half-lives of less than 120 days until 10 half-lives have elapsed and the radiation emitted from the unshielded surface of the waste is indistinguishable from background levels. The waste could then be disposed of as a nonradioactive waste. Radioactive waste could also be stored for decay under certain circumstances in accordance with 10 CFR 20. For mixed waste, storage for decay will be particularly advantageous, because the waste could be managed solely as a hazardous waste after the radionuclides decayed to background levels, thus simplifying the management and regulation of these wastes.

- Work Planning — Pre-job planning will be performed to determine what materials and equipment will be needed to perform the anticipated work. One objective of this planning will be to prevent pollution and minimize the amount of mixed waste that may be generated and to use only the materials necessary to accomplish the work. Planning will also prevent mixing of materials or waste types.

- Tracking Systems — A tracking system will be developed, if required, to identify waste generation data and waste minimization opportunities. This will provide essential feedback to successfully guide future efforts. The data collected by the system will be used for internal reporting. The tracking system will provide feedback on the progress of the waste minimization program, including the results of the implementation of pollution prevention technologies.

- Training and Awareness Programs — By educating employees in the principles and benefits of the waste minimization plan, solutions to current and potential environmental management problems could be found.

5.5.2.4 Environmental Impacts of Mixed Waste

Industry accepted chemical handling techniques, pre-job planning, and compliance with a facility waste minimization plan (as presented in Subsection 5.5.2.3) will ensure that only small quantities of mixed wastes will be generated by the new units. Therefore, environmental impacts of mixed waste will be SMALL.

5.5.3 Conclusions

Minimal chemical constituents will be discharged to the water and air from operation of the new units. Air emissions will be infrequent, and liquid effluent discharges to the Guadalupe River and the cooling basin will be sufficiently mixed to be protective of the receiving waters. Cooling basin discharges to the Guadalupe River and stormwater discharges will be compliant with the facility's TPDES permits. Waste minimization programs will reduce the amount of wastes, including mixed wastes, generated by operation of the new units. To the extent possible, solid wastes will be recycled. For wastes that cannot be recycled, applicable federal, Texas, and local requirements and standards will be met with regard to the handling, transporting, and disposal of solid wastes offsite. Therefore, the impacts of waste generation will be SMALL and will not warrant mitigation.

5.5.4 References

AEA 1954. *Atomic Energy Ac*t, 42 USC 2011 et seq.

RCRA 1976. *Resource Conservation Recovery Act*, 42 USC 6901 et seq.

TCEQ Oct 2005. Texas Commission on Environmental Quality, Renewal of Hazardous Waste Permit No. 50358 for Waste Control Specialists LLC, Permit renewal issued October 5, 2005.

TCEQ Dec 2006. Texas Commission on Environmental Quality, *Commercial Management Facilities for Hazardous and Industrial Solid Wastes*, GI-225, December 2006.

TCEQ Nov 2007. Texas Commission on Environmental Quality, *Municipal Solid Waste in Texas: A year in Review*, AS-187/07, November 2007.

TNRCC Feb 2000. Texas Natural Resource Conservation Commission, Permit No. HW-50052-0001 for Texas Ecologists, Inc., Permit issued February 8, 2000.

U.S. EPA 2005. U.S. Environmental Protection Agency, *State Detail Analysis, The National Biennial RCRA Hazardous waste Report (based on 2005 Data)*, 2005.

U.S. NRC May 1996. U.S. Nuclear Regulatory Commission, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, NUREG-1437, Vol. 1, May 1996.

5.6 Environmental Impacts of Transmission Systems

This section describes the possible environmental impacts of transmission lines during system operation. Potential impacts from transmission system operation, including corridor maintenance and transmission line use, are described relative to terrestrial and aquatic ecosystems and members of the public.

5.6.1 Terrestrial Ecosystems

Power generated from VCS site would be transmitted over circuits in both new and existing transmission corridors (Subsection 2.2.2), including rights-of-way and access roads. These corridors would connect VCS with the existing Coleto Creek, Hillje, Blessing, Whitepoint, and South Texas Project (STP) substations and a new Cholla substation. The routes and lengths of these transmission corridors have not been finalized, but the associated corridors would service areas in the Houston, Corpus Christi, San Antonio, and Austin regions.

Exelon conducted a seven-county macrocorridor study to identify transmission corridor locations that would limit impact on human populations and ecological resources. The resulting proposed transmission corridor locations (Subsection 2.2.2) would use existing corridors (transmission and otherwise) to the extent possible to minimize impacts. Land cover types in the recommended corridors are typical of the region. Approximately 62 percent of the land cover is cultivated fields/pasture/rangeland, approximately 25.7 percent is forest/shrublands/herbaceous, 7.5 percent is open water/wetlands, and 5 percent is urban.

The transmission corridor system would be owned and maintained by American Electric Power (AEP) Texas Central Company, which surveys and maintains woody vegetation in the corridors every 3–5 years to allow continuous and safe transmission of power in accordance with its management plan. This plan includes procedures for the removal of rapidly-growing trees and trees that might otherwise interfere with power transmission, the pruning of trees near transmission lines, and maintenance of travel routes in the corridors, all employing best management practices to limit environmental impacts. Tree removal is accomplished by manual and mechanical methods, as well as by application of herbicides. Herbicide applicators involved in this process are trained and licensed for these activities and follow local, state, and federal guidelines, as well as the requirements of their pesticide application permit from the Texas Department of Agriculture. Much of the VCS transmission system traverses croplands, pastures, and rangeland and would require limited corridor maintenance.

As indicated in Subsection 2.4.1.5, federal- and state-listed endangered or threatened species (“important” under NUREG-1555) occur or have historically occurred in the counties containing the transmission system. AEP has established procedures in the event that endangered or threatened species are found in the corridors, including a process for communicating with the U.S. Fish and Wildlife Service.

No areas designated as “critical habitat” for endangered or threatened species by the U.S. Fish and Wildlife Service occur on or adjacent to the proposed or existing transmission corridors. None of the proposed or existing corridors cross federal or state parks, wildlife refuges, wildlife management areas, or recreation areas.

Other “important” species likely to use these corridors are game species common to this region: white-tailed deer, northern bobwhite, turkey, rabbit, squirrel, and dove (U.S. NRC Oct 1999). Given the predominance of crop, pasture, and rangeland in the proposed and existing corridors and land covers that typically require limited and infrequent vegetation maintenance, corridor maintenance is unlikely to disturb these species for periods longer than the duration of the activity.

The impacts of transmission corridor maintenance and/or vegetation management on terrestrial resources were evaluated in the Generic Environmental Impact Statement (GEIS) for License Renewal of Nuclear Plants (U.S. NRC May 1996). The GEIS determined that transmission corridor maintenance activities would not lower habitat diversity or result in significant changes in surrounding habitats. Potential impacts on wildlife species as a result of these activities were determined to be of SMALL significance for operating nuclear power plants. Based on AEP procedures, the NRC determination of the SMALL impacts of existing corridor maintenance, and the plan for most of the VCS transmission system to use or expand existing lines with minimal construction of new corridor, Exelon does not anticipate significant impacts.

The impacts of transmission corridor maintenance and/or vegetation management on floodplains and wetlands were also evaluated in the GEIS (U.S. NRC May 1996). Potential impacts were determined to be of SMALL significance for operating nuclear power plants. Based on AEP procedures, the NRC determination of the SMALL impacts of existing corridor maintenance, and the plan for most of the VCS transmission system to use or expand existing lines with minimal construction of new corridor, Exelon does not anticipate significant impacts.

Avian mortality resulting from collision with transmission lines was evaluated in the GEIS (U.S. NRC May 1996). The impacts were determined to be of SMALL significance at operating nuclear power plants. Given that most of the VCS transmission system would involve using or expanding existing lines (with existing management activities) with limited construction of new corridors, Exelon concludes that impacts as a result of avian collisions would be SMALL. Provisions or devices for preventing avian collisions would be similar on new transmission lines to those in existing lines and/or as determined by regulatory agencies.

No significant impacts of electromagnetic fields associated with transmission lines have been identified for terrestrial biota (U.S. NRC May 1996), so these impacts would be of SMALL significance. Because these proposed lines are 345 kV, there would be no adverse impacts from ozone formation (U.S. NRC Oct 1999).

Based on review of the established AEP procedures regarding corridor maintenance, the NRC's analysis of maintenance activities in the GEIS (U.S. NRC May 1996), and the fact that most of the corridors traverse, or would traverse, relatively open lands (row crops, pasture, rangelands), potential impacts associated with routine corridor maintenance activities on terrestrial resources would be SMALL.

5.6.2 Aquatic Ecosystems

Operation and maintenance of the new and proposed transmission system and corridors have the potential to affect important aquatic habitats and species. Subsection 2.2 describes the eight new circuits that would connect VCS to the regional electric grid and would be designed to service the Houston, Corpus Christi, San Antonio, and Austin areas. Subsection 4.3.2 addresses potential impacts to aquatic ecosystems of constructing the new transmission lines and associated corridors. Subsection 5.6.2 describes potential impacts of operating and maintaining these transmission lines and managing vegetation in the associated corridors.

5.6.2.1 Important Habitats

As described in Subsection 2.2.2, the specific routes for the new lines would be determined under the Public Utility Regulatory Act of 2001, which requires electric utilities to obtain a certificate of convenience and necessity before providing electric service to the public. AEP, which would own, operate, and maintain the transmission lines and corridors, would submit a detailed transmission routing study to the Public Utility Commission of Texas (PUCT) that includes preferred and alternative routes along with an environmental impact assessment of the project. The PUCT would make the final route selection based on the routing study, the impact assessment, and input received from the public and stakeholders.

Because the PUCT's final determination on the best route for the transmission lines would not be available for several years, a macrocorridor study was undertaken to identify alternative transmission corridor routes based on (1) engineering and cost constraints, (2) environmental considerations (e.g., locations of streams and wetlands, wildlife habitat), and (3) the "built environment" (i.e., locations of residential areas, schools, churches, and parks). The study also identified a "recommended corridor" that took all these factors into consideration. Identification of this recommended corridor has made it possible to assess potential ecological impacts of constructing (in Section 4.3) and maintaining (in Section 5.6) these transmission corridors. However, the recommended corridor (and representative route, which is a 200-foot-wide subset of the recommended corridor) was delineated to provide a basis for assessing representative impacts of the project. The corridor routes ultimately selected by the PUCT may be different than those recommended in the macrocorridor study, but it is unlikely the routes would be outside the 3-mile-wide macrocorridor.

Based on the locations of proposed substations and the assumed configuration of the transmission corridors (see Figures 2.2-3 and 2.4-3), none of the new lines would cross any state parks, national parks, state conservation areas, state or national wildlife refuges, or critical habitat for any federal-listed species. There are very few such parks and conservation areas in this part of Texas, and AEP would solicit input from state and federal resource agencies to ensure agency concerns would be considered in selection of final route(s). Under normal circumstances, new transmission lines would be routed around state and federal parks, state conservation areas, and wildlife refuges.

The proposed transmission lines would cross numerous waterways, perennial or intermittent streams, and associated floodplains or wetlands. The recommended corridor crosses major waterways, including the Guadalupe River, Victoria Barge Canal and Lavaca River, as well as numerous smaller streams, both perennial and intermittent, in seven Texas counties. These counties are Calhoun, DeWitt, Goliad, Jackson, Matagorda, Victoria, and Wharton. AEP has right-of-way vegetation management programs and procedures intended to minimize impacts to water quality and to protect wetlands and stream crossings. AEP's procedures for line clearance of distribution and transmission lines requires vegetation management contractors to "promptly" remove limbs or trees that fall into waterways during tree cutting operations. The same procedure establishes strict guidelines for use of herbicides: application according to label instructions; application according to federal, state, and local regulations; accurate and up-to-date recordkeeping; and notification of landowners when possible. The GEIS (U.S. NRC May 1996) concludes that impacts of transmission system operation and maintenance to surface water quality and aquatic communities is of SMALL significance when utilities employ "proper management practices" with respect to vegetation management, soil erosion, and application of herbicide impacts.

Impacts of transmission lines on important aquatic habitats during operations would, therefore, be SMALL and would not warrant mitigation.

5.6.2.2 Important Species

AEP's transmission maintenance and vegetation management practices have been designed to minimize impacts to water quality of downgradient streams, ponds, and impoundments, and thus to the associated aquatic populations. Furthermore, as noted in the previous subsection, much of the VCS-transmission system would cross croplands, pastures, and rangeland and should require limited corridor maintenance.

As shown in Table 2.4-4, two protected aquatic species are known to occur in the seven counties through which the new VCS-connected lines and corridors would extend. The opossum pipefish (*Microphis brachyurus*), designated as “threatened” by the state of Texas, occurs in coastal portions of Calhoun County (TPWD 2005; TPWD 2007). This species spawns in fresh and low-salinity estuarine waters along the coast of Texas and could be present in lower reaches of rivers and streams flowing into Matagorda Bay and San Antonio Bay (TPWD 2005). The smalltooth sawfish (*Pristis pectinata*), the only member of the elasmobranch group that has been afforded protection under the Endangered Species Act, was listed as endangered on April 1, 2003 (68 FR 15674). As noted in Section 2.4.2.2.1, since 1971, there have been only three (in 1978, 1979, and 1984) published or museum reports of smalltooth sawfish collected from this region, all from Texas. TPWD has placed the smalltooth sawfish on its lists of rare species for most coastal counties, including Calhoun, Jackson, Matagorda, and Refugio Counties; however, these listings are clearly based on historical records rather than up-to-date information on the species' range.

Practices and procedures would be adopted to prevent impacts to surface waters and wetlands. As a consequence, impacts to aquatic populations, including the opossum pipefish and smalltooth sawfish, from operation and maintenance of transmission lines would be SMALL and would not warrant mitigation measures beyond the actions already identified in this section.

5.6.3 Impacts to Members of the Public

As described in Subsection 3.7.2, the transmission system for VCS would consist of the following transmission lines:

- Double circuit 345 kV line from VCS to Coleto Creek substation
- Double circuit 345 kV line from VCS to Hillje substation
- Single circuit 345 kV line from VCS to Blessing substation
- Single circuit 345 kV line from VCS to Whitepoint substation
- Single circuit 345 kV line from VCS to STP substation
- Single circuit 345 kV line from VCS to Cholla substation

The construction of transmission lines to Coleto Creek, Hillje, Blessing, and Cholla substations would require temporary land disturbance and would affect sparsely populated land mainly used for agriculture and ranching. Right-of-ways would be routed away from densely populated areas when possible. Transmission lines to Whitepoint and STP would use an existing line and would require much less land disturbance than the other four lines.

Impacts to members of the public resulting from the operation and maintenance of the transmission system may occur in the forms of visual impacts, electric shock hazards, electromagnetic field exposure, noise impacts, or radio and television interference.

5.6.3.1 Visual Impacts

The new transmission lines for VCS would be owned, constructed, operated, and maintained by AEP. According to Texas Administrative Code (Title 16, Part 2, Chapter 25 §25.195(c), AEP is subject to regulations that require consideration of alternative means of providing the transmission service that is less costly, as operationally sound, and as effective as building new transmission facilities. In accordance with PUCT and Electric Reliability Council of Texas requirements, a routing study would be prepared by AEP to identify transmission construction options that would consider impacts to the natural and built environment, as well as engineering concerns. Long-standing procedures that take into consideration the environmental and visual values of the surrounding area would be used during the selection process.

Tower maintenance, tree pruning, and other aesthetic operations would be done periodically by the transmission service provider. AEP would attempt to maintain important viewscapes. When possible to do so safely, natural vegetation would be retained along transmission corridors to minimize ground-level visual impacts.

Consequently, the visual impacts to members of the public from the transmission system would be SMALL.

5.6.3.2 Electric Shock

Objects located near transmission lines can become electrically charged due to their immersion in the lines' electric field. This charge results in a current that flows through the object to the ground. The current is called “induced” because there is no direct connection between the line and the object. The induced current can also flow to the ground through the body of a person who touches the object. An object that is insulated from the ground can store an electrical charge, becoming “capacitively charged.” A person standing on the ground and touching a vehicle or a fence could receive an electrical shock because of the sudden discharge of the capacitive charge through the person's body to the ground. After the initial discharge, a steady-state current can develop, the magnitude of which depends on several factors, including:

- Strength of the electric field, which depends on the voltage of the transmission line
- Height and geometry of the individual transmission wires
- Size of the object on the ground

- Extent to which the object is grounded

The National Electrical Safety Code (NESC) describes how to establish minimum vertical clearances to the ground for electric lines having voltages exceeding 98 kV. The clearance must limit the induced current due to electrostatic effects to 5 milliamperes if the largest anticipated truck, vehicle, or equipment were short-circuited to ground (IEEE Aug 2006). By way of comparison, the setting of ground fault circuit interrupters used in residential wiring (special breakers for outside circuits or those with outlets around water pipes) is 4 to 6 milliamperes. Analysis of this issue, detailed in the GEIS (U.S. NRC May 1996), concludes that “potential electrical shock impacts are of SMALL significance for transmission lines that are operated in adherence with the NESC.”

As described in Subsection 3.7.2, new 345 kV lines are proposed to service the new generation considered for the VCS site. These lines would be built in compliance with the NESC limit. All transmission lines constructed by AEP would conform to standards given by the American National Standards Institute, NESC, and other applicable codes and standards that are generally accepted by the industry, except as modified by PUCT. The examination of the PUCT regulatory compliance services database did not identify any complaints about electric shock associated with AEP transmission lines in the past years. Therefore, the impacts to the public from induced electric shock would be SMALL, and no mitigation measures would be needed.

5.6.3.3 Electromagnetic Field Exposure

Available evidence regarding the effects of exposure to extremely low frequency (ELF) electric and magnetic fields is inconclusive; it continues to suggest that the impact is insignificant.

In 1996, after 17 years of research that examined more than 500 studies, the National Research Council released the results of a study that stated, “the conclusion of the committee is that the current body of evidence does not show that exposure to these fields presents a human-health hazard.” The report added there is no conclusive evidence that the electromagnetic field (EMF) plays a role in the development of cancer, or reproductive or other abnormalities in humans (NRC 1996).

As part of The World Health Organization (WHO) International EMF Project in 1997, a working group of 45 scientists from around the world surveyed the evidence for adverse EMF health effects. The WHO scientists reported that the epidemiological studies “do not provide sufficient evidence to support an association between extremely-low-frequency magnetic-field exposure and adult cancers, pregnancy outcome, or neurobehavioral disorders” (NIEHS Jun 2002).

The American Physical Society represents thousands of U.S. physicists. In response to the National Institute of Environmental Health Sciences Working Group’s conclusion that EMF is a possible human carcinogen, the American Physical Society's executive board voted in 1998 to reaffirm its 1995 opinion that there is "no consistent, significant link between cancer and power line fields."

A 1999 NIEHS report (NIEHS May 1999) contains the following conclusion:

> The NIEHS concludes that ELF-EMF exposure cannot be recognized as entirely safe because of weak scientific evidence that exposure may pose a leukemia hazard. In our opinion, this finding is insufficient to warrant aggressive regulatory concern. However, because virtually everyone in the United States uses electricity and therefore is routinely exposed to ELF-EMF, passive regulatory action is warranted such as a continued emphasis on educating both the public and the regulated community on means aimed at reducing exposures. The NIEHS does not believe that other cancers or non-cancer health outcomes provide sufficient evidence of a risk to currently warrant concern.

Although studies continue to be conducted and additional information is published regarding the effects of exposure to EMF (WHO 2005), there continues to be no conclusive evidence of a link between EMF and the development of cancer, or reproductive or other abnormalities in humans. Thus, impacts to the public attributable to EMF exposure from transmission system operations will be SMALL. No mitigation measures or controls are warranted.

5.6.3.4 Noise

High-voltage transmission lines can emit noise when the electric field strength surrounding them is greater than the breakdown threshold of the surrounding air, creating a discharge of energy. This energy loss, known as corona discharge, is affected by ambient weather conditions such as humidity, air density, wind, and precipitation and by irregularities on the energized surfaces. The transmission lines would be expected to be designed with hardware and conductors that have features to minimize corona discharge. Nevertheless during wet weather, the potential for corona loss increases, and corona loss could occur if insulators or other hardware have any defects. The GEIS (U.S. NRC May 1996) concluded that corona discharge resulting in audible noise, radio, and television interference, energy losses, and the production of ozone is generally not a problem with 345 kV transmission lines.

Corona-induced noise from existing transmission lines is very low or inaudible, except directly below the line on a quiet, humid day. Such noise does not pose a risk to humans. PUCT and AEP monitor complaints on transmission line noise; should such complaints occur, AEP would investigate the cause and, if necessary, replace the defective component to correct the problem. The examination of the PUCT regulatory compliance services database did not identify any complaints about corona noise associated with AEP transmission lines in the past years. Therefore, Exelon does not expect complaints on nuisance noise from the proposed transmission lines and concludes impacts would be SMALL.

5.6.3.5 Radio and Television Interference

Generally, the cause of radio or television interference from transmission lines is attributable to corona discharge from defective insulators or hardware. PUCT and AEP monitor for complaints about radio or television interference. Should such complaints occur, AEP would be expected to investigate the cause and, if necessary, correct the problem. As described in Subsection 5.6.3.4, the transmission lines used by VCS would be designed to minimize corona discharge up to their maximum operating voltage. The examination of the PUCT regulatory compliance services database did not identify any complaints about radio and television interference associated with AEP transmission lines in past years. Therefore, it is expected that radio and television interference from the proposed transmission lines would be SMALL.

5.6.4 References

IEEE Aug 2006. Institute of Electrical and Electronics Engineers, *National Electrical Safety Code*, C2-2007, August 2006.

NIEHS Jun 2002. National Institute of Environmental Health Sciences, *EMF Electric and Magnetic Fields Associated with the Use of Electric Power Questions & Answers*, June 2002.

NIEHS May 1999. National Institute of Environmental Health Sciences, *NIEHS Report on Health Effects from Exposure to Power-Line Frequency Electric and Magnetic Fields*, Publication No. 99-4493, May 1999.

TPWD 2005. Texas Parks and Wildlife Department, *Rare, Threatened, and Endangered Species of Texas: Opossum pipefish (Microphis brachyurus)*, 2005, available at http://gis.tpwd.state.tx.us/TpwEndangeredSpecies/DesktopDefault.aspx, accessed April 22, 2008.

TPWD 2007. Texas Parks and Wildlife Department, *Endangered and Threatened Fish in Texas and United States*, 2007, available at http://www.tpwd.state.tx.us/huntwild/wild/species/endang/animals/fish/, accessed May 4, 2008.

NRC 1996. National Research Council, Possible Health Effects of Exposure to Residential Electric and Magnetic Fields, October 1996.

U.S. NRC May 1996. U.S. Nuclear Regulatory Commission, Division of Regulatory Applications, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, NUREG-1437, May 1996, Volume 1.

U.S. NRC Oct 1999. U.S. Nuclear Regulatory Commission, Office of Nuclear Reactor Regulation, *Standard Review Plans for Environmental Reviews of Nuclear Power Plants*, NUREG-1555, October 1999.

WHO 2005. World Health Organization, *Electromagnetic Fields and Public Health—Electromagnetic Hypersensitivity*, Fact Sheet No. 296, December 2005, available at www.who.int/mediacentre/factsheets/fs296/en/print.html, accessed June 19, 2008.

5.7 Uranium Fuel Cycle and Transportation Impacts

Subsection 5.7.1 addresses the environmental impacts from the uranium fuel cycle. Subsection 5.7.2.1 addresses the conditions in subparagraphs 10 CFR 51.52(a)(1) through (5) regarding use of Table S-4 to characterize the impacts of radioactive materials transportation in this environmental report. Because the light water reactor (LWR) technologies being considered do not meet all of the conditions set forth in 10 CFR 51.52(a), a further analysis of the transportation effects was required. Subsection 5.7.2.2 addresses the incident-free transportation of radioactive materials to and from the proposed nuclear units at the VCS. Transportation accidents are described in Section 7.4.

5.7.1 Uranium Fuel Cycle Impacts

This section describes the environmental impacts from the uranium fuel cycle. The uranium fuel cycle is defined as the total of those operations and processes associated with provision, utilization, and ultimate disposal of fuel for nuclear power reactors.

Table S-3 of 10 CFR 51.51(b) is used to assess environmental impacts resulting from the uranium fuel cycle. Its values are normalized for a reference 1000 MWe LWR at 80 percent capacity factor. The 10 CFR 51.51(b) Table S-3 values are reproduced as the "Reference Reactor" column in Table 5.7-1. The LWR technologies being considered to demonstrate VCS site suitability include the ABWR, the ESBWR, the AP1000, the APWR, and the mPower. The standard configuration for each of these reactor technologies is as follows. The ABWR is a single-unit, 1371 MWe reactor. The ESBWR is a single-unit, 1594 MWe reactor. The AP1000 is a single-unit, 1117 MWe reactor. The APWR is a single-unit, 1600–1700 MWe reactor. The mPower is a 6-module configuration, 125 MWe per module, for a total of 750 MWe. The APWR represents the bounding case for gross electrical output. The APWR was analyzed with an estimated gross electrical output of 1700 MWe[1] operating at 96.3 percent capacity factor. The results of this analysis for a two-unit plant are also included in Table 5.7-1.

Specific categories of natural resource use are included in Table S-3 (and duplicated in Table 5.7-1). These categories relate to land use, water, and fossil fuel consumption, chemical and thermal effluents, radiological releases, disposal of transuranic, high-level, and low-level wastes, and radiation doses from transportation and occupational exposure. In developing Table S-3, the NRC considered two fuel cycle options, which differed in the treatment of spent fuel removed from a reactor. "No recycle" treats all spent fuel as waste to be stored at a federal waste repository; "uranium only recycle" involves reprocessing spent fuel to recover unused uranium and return it to the system. Neither cycle involves the recovery of plutonium. The contributions in Table S-3 resulting from

1. Gross electrical output for the APWR was used to provide conservatism in the estimates of potential fuel cycle impacts, which are obtained by scaling the values for the reference reactor to reflect the increased electrical output of the APWR.

reprocessing, waste management, and transportation of wastes are maximized for both of the two fuel cycles (uranium only and no recycle). That is, the identified environmental impacts are based on the cycle that results in the greater impact.

The following assessment of the environmental impacts of the fuel cycle for two APWRs at VCS is based on the values in Table S-3 and the NRC's analysis of the radiological impacts from Rn-222 and Tc-99 in NUREG-1437. NUREG-1437 and Addendum 1 to the Generic Environmental Impact Statement (GEIS) for License Renewal (U.S. NRC Aug 1999) provide a detailed analysis of the environmental impacts from the uranium fuel cycle. Although NUREG-1437 is specific to impacts related to license renewal, the information is relevant to this review because the LWR designs considered here use the same type of fuel.

The fuel cycle impacts in Table S-3 are based on a reference 1000 MWe LWR operating at an annual capacity factor of 80 percent for an average electrical output of 800 MWe. The evaluation of the environmental impacts of the fuel cycle for the APWR, assumed a 1700 MWe (gross) reactor with a capacity factor of 96.3 percent for an average electrical output of 1637 MWe per unit. Two APWR units are proposed for VCS for a total of 3274 MWe. The proposed VCS output is approximately 4.1 times greater than the output used to estimate impact values in Table S-3 (reproduced here as the first column of Table 5.7-1) for the reference reactor. Analyses presented here are scaled from the reference reactor impacts to reflect the output of two APWRs at VCS.

Recent changes in the fuel cycle may have some bearing on environmental impacts; however, as described below, the contemporary fuel cycle impacts are bounded by values in Table S-3. The NRC calculated the values in Table S-3 from industry averages for the performance of each type of facility or operation associated with the fuel cycle. They chose assumptions so that the calculated values will not be underestimated. This approach was intended to ensure that the actual values will be less than the quantities shown in Table S-3 for all LWR nuclear power plants within the widest range of operating conditions. Changes in the fuel cycle and reactor operations have occurred since Table S-3 was promulgated. For example, the estimated quantity of fuel required for a year's operation of a nuclear power plant can now reasonably be calculated assuming a 60-year lifetime (40 years of initial operation plus a 20-year license renewal term). This was done in NUREG-1437 for both BWRs and PWRs, and the highest annual requirement (35 metric tons of uranium [MTU] made into fuel for a BWR) was used in NUREG-1437 as the basis for the reference reactor year. A number of fuel management improvements have been adopted by nuclear power plants to achieve higher performance and to reduce fuel and enrichment requirements, reducing annual fuel requirements. An APWR requires approximately 35 MTUs per year, approximately the same as the BWR refueling requirement evaluated in NUREG-1437, but its electrical output is more than 100 percent greater than the reference reactor. Therefore, Table S-3 remains a conservative estimate of the environmental impacts of the fuel cycle fueling nuclear power reactors operating today.

Another change is the elimination of the U.S. restrictions on the importation of foreign uranium. Until recently, the economic conditions of the uranium market favored utilization of foreign uranium at the expense of the domestic uranium industry. These market conditions forced the closing of most U.S. uranium mines and mills, substantially reducing the environmental impacts in the United States from these activities. However, more recently the spot price of uranium has increased dramatically from $24 per pound in April 2005 to a peak of $135 per pound in July 2007 (UXC 2007). As a result, there is a renewed interest in uranium mining and milling in the United States. The NRC recently received the first license application for a uranium recovery facility since 1988 (U.S. NRC Oct 2007). The NRC anticipates receiving at least 17 applications for new facilities, including in-situ operations and conventional uranium mills, over the next 3 years. The majority of these applications are expected to be for in-situ leach solution mining that does not produce tailings (U.S. NRC Feb 2008). Factoring in changes to the fuel cycle suggests that the environmental impacts of mining and milling could drop to levels below those in Table S-3. However, Table S-3 estimates have not been reduced for this analysis. Section 6.2.3 of NUREG-1437 describes the sensitivity of these changes in the fuel cycle on the environmental impacts.

5.7.1.1 Land Use

The total annual land requirements for the fuel cycle supporting a two-APWR plant will be approximately 462 acres. Approximately 53 acres will be permanently committed land, and 409 acres will be temporarily committed. A “temporary” land commitment is a commitment for the life of the specific fuel cycle plant (e.g., a mill, enrichment plant, or succeeding plants). Following decommissioning, the land could be released for unrestricted use. “Permanent” commitments represent land that may not be released for use after decommissioning because decommissioning does not result in the removal of sufficient radioactive material to meet the limits of 10 CFR 20, Subpart E for release of an area for unrestricted use.

In comparison, a coal-fired plant with the same MWe output as two APWRs using strip-mined coal requires the disturbance of approximately 820 acres per year for fuel alone. Considering common classes of land use in the United States, the fuel cycle impacts on land use will be SMALL and not warrant mitigation.

5.7.1.2 Water Use

Principal water use for the fuel cycle supporting the two APWRs would be that required to remove waste heat from the power stations supplying electricity to the enrichment process. Scaling the values from Table S-3, of the total annual water use of 4.66 x 10^{10} gallons for the fuel cycle, approximately 4.54 x 10^{10} gallons are required for the removal of waste heat. Evaporative losses from fuel cycle process cooling are approximately 6.55 x 10^{8} gallons per year and mine drainage accounts for 5.20 x 10^8 gallons per year. Impacts on water use will be SMALL and not warrant mitigation.

5.7.1.3 Fossil Fuel Impacts

Electric energy and process heat are required during various phases of the fuel cycle process. The electric energy is usually produced by the combustion of fossil fuel at conventional power plants. Electric energy associated with the fuel cycle represents approximately 5 percent of the annual electric power production of the reference reactor. Process heat is primarily generated by the combustion of natural gas. This gas consumption, if used to generate electricity, represents less that 0.4 percent of the electrical output of the reference reactor. The direct and indirect consumption of electric energy for fuel cycle operations would be small relative to the power production of the two APWR units. Therefore, impacts from fossil fuels will be SMALL and not warrant mitigation.

Note that these estimates are based on uranium enrichment using the gaseous diffusion technology evaluated in WASH-1248. NRC has issued licenses for two facilities that will use centrifuge enrichment and a third application for centrifuge enrichment is under NRC review (U.S. NRC 2009). These new uranium enrichment facilities are expected to require less electric energy with a corresponding decrease in fossil fuel impacts relative to gaseous diffusion.

5.7.1.4 Chemical Effluents

The quantities of liquid, gaseous, and particulate discharges associated with the fuel cycle processes are given in Table S-3 (Table 5.7-1) for the reference 1000 MWe LWR. The quantities of effluents for a two-APWR plant would be approximately 4.1 times greater than those in Table S-3 (Table 5.7-1). The principal effluents are SO_x, NO_x, and particulates. Based on the U.S. Environmental Protection Agency's National Air Pollutant Emissions Estimates (USEPA 2006), these emissions constitute less than 0.14 percent of all SO_2 emissions in 2005, and less than 0.029 percent of all NO_X emissions in 2005.

Uranium fuel cycle processes would also result in greenhouse gas emissions such as carbon dioxide due to the consumption of fossil fuels to generate electricity used in fuel cycle operations. In the analysis of fuel cycle impacts in WASH-1248, nearly all of the electricity consumption was associated with enrichment of the uranium using gaseous diffusion technology. The electricity to operate the gaseous diffusion plant was assumed to come from coal-fired power plants. Table S-3 indicates that the electrical energy requirements for the uranium fuel cycle for the reference 1000 MWe LWR would be approximately 5 percent of the net output of the reactor. The U.S. DOE estimated that the annual carbon emissions that would be displaced by replacing coal-fired power plants with nuclear plants would be approximately 2.1 million metric tons carbon equivalent per 1000 MWe nuclear plant operating at 90 percent capacity (Hagen et al. Nov 2001). Using the 5 percent electrical energy requirement from Table S-3 and the DOE carbon estimate, approximately 105,000 metric tons carbon equivalent would be produced from fuel cycle operations per 1000 MWe nuclear plant operating at 90 percent capacity. For a two-APWR plant, the annual emissions associated with fuel cycle processes would be approximately 382,000 metric tons carbon equivalent. The centrifuge enrichment process uses 90 percent less electricity and would have far lower impacts attributable to the use of coal-fired power plants.

Liquid chemical effluents produced in the fuel cycle processes are related to fuel enrichment and fabrication and may be released to receiving waters. As stated in NUREG-1555, Section 5.7.1, all liquid discharges into the navigable waters of the United States from plants associated with the fuel cycle operations will be subject to requirements and limitations by an appropriate federal, state, regional, local or affected Native American tribal regulatory agency. Tailing solutions and solids are generated during the milling process and are not released in quantities sufficient to have a significant impact on the environment. Impacts from chemical effluents will be SMALL and not warrant mitigation.

5.7.1.5 Radioactive Effluents

Radioactive gaseous effluents estimated to be released to the environment from waste management activities and certain other phases of the fuel cycle are set forth in Table S-3 (Table 5.7-1). Using Table S-3 data, Section 6.2.2.1 of NUREG-1437 estimates the 100-year environmental dose commitment to the U.S. population from the fuel cycle (excluding reactor releases and dose commitments due to Rn-222 and Tc-99) to be approximately 400 person-rem per reference reactor year. The estimated dose commitment to the U.S. population is approximately 1600 person-rem per year of operation for the two proposed APWRs.

Section 6.2.2.1 of NUREG-1437 estimates the additional 100-year whole body dose commitment to the U.S. population from radioactive liquid wastes effluents due to all fuel cycle operations (other than reactor operation) to be approximately 200 person-rem per reference reactor year. The estimated dose commitment to the U.S. population is approximately 820 person-rem per year of operation for the two proposed APWRs. Thus, the estimated 100-year environmental dose commitment to the U.S. population from radioactive gaseous and liquid releases from fuel cycle operations is approximately 2500 person-rem to the whole body per reactor-year for the two proposed APWRs.

The radiological impacts of Rn-222 and Tc-99 releases are not included in Table S-3. Principal radon releases occur during mining and milling operations and as emissions from mill tailings. Principal Tc-99 releases occur as releases from the gaseous diffusion enrichment process. The NRC provided an evaluation of these Rn-222 and Tc-99 releases in NUREG-1437. The NUREG-1437 evaluation was reviewed, it was considered applicable, and has been included as part the evaluation in this ESP application.

Section 6.2 of NUREG-1437 estimates Rn-222 releases from mining and milling operations, and from mill tailings for a year of operation of the reference 1000 MWe LWR. The estimated release of Rn-222 for the two-APWR plant is approximately 21,200 curies per year. Of this total, approximately 78 percent will be from mining, 15 percent from milling, and 7 percent from inactive tailings before stabilization. Radon releases from stabilized tailings were estimated to be 3.2 curies per year for the two proposed APWRs; that is, approximately 4.1 times greater than the NUREG-1437 estimate for the reference reactor year. The major risks from Rn-222 are from exposure to the bone and lung, although there is a small risk from exposure to the whole body. The organ-specific dose weighting factors from 10 CFR 20 were applied to the bone and lung doses to estimate the 100-year dose commitment from Rn-222 to the whole body. The 100-year estimated dose commitment from mining, milling, and tailings before stabilization for the two unit plant is approximately 3800 person-rem to the whole body. From stabilized tailing piles, the estimated 100-year environmental dose commitment is approximately 72 person-rem to the whole body.

NUREG-1437 considered the potential health effects associated with the releases of Tc-99 for the reference reactor. The estimated Tc-99 releases for the two proposed APWRs are 0.029 curie from chemical processing of recycled uranium hexafluoride before it enters the isotope enrichment cascade and 0.020 curie into the groundwater from a high-level waste repository. The major risks from Tc-99 are from exposure of the gastrointestinal tract and kidneys and a small risk from whole-body exposure. Applying the organ-specific dose-weighting factors from 10 CFR 20 to the gastrointestinal tract and kidney doses, the total body 100-year dose commitment from Tc-99 is estimated to be approximately 410 person-rem for the two proposed APWRs.

To be conservative, radiation protection experts assume that any amount of radiation may pose some risk of cancer, or a severe hereditary effect, and that higher radiation exposures create higher risks. Therefore, a linear, no-threshold dose response relationship is used to describe the relationship between radiation dose and detrimental effects. Based on this model, risk to the public from radiation exposure can be estimated using the nominal probability coefficient (730 fatal cancers, nonfatal cancers, or severe hereditary effects per 1×10^6 person-rem) from the International Commission on Radiological Protection Publication 60 (ICRP 1991). This coefficient was multiplied by the sum of the estimated whole-body population doses (from gaseous effluents, liquid effluents, Rn-222, and Tc-99) described above for the two-APWR plant to estimate that the U.S. population of approximately 300 million could incur a total of 4.9 fatal cancers, nonfatal cancers, or severe hereditary effects from the annual fuel cycle for the two proposed APWRs. This risk is small compared to the number of fatal cancers, nonfatal cancers and severe hereditary effects that are estimated to occur in the U.S. population annually from exposure to natural sources of radiation using the same risk estimation methods.

Based on these analyses, the environmental impacts of radioactive effluents from the fuel cycle will be SMALL and not warrant mitigation.

5.7.1.6 Radioactive Waste

The quantities of radioactive waste (low-level, high-level, and transuranic wastes) associated with fuel cycle processes are presented in Table S-3 (Table 5.7-1). For low-level waste disposal, the NRC notes in 10 CFR 51.51(b) that there will be no significant radioactive releases to the environment. For high-level and transuranic wastes, the NRC notes that these wastes are to be disposed at a repository, such as the candidate repository at Yucca Mountain, Nevada. No release to the environment is expected to be associated with such disposal because it was assumed that all of the gaseous and volatile radionuclides contained in the spent fuel are released to the atmosphere before disposal of the waste.

There is some uncertainty associated with the high-level waste and spent fuel disposal component of the fuel cycle. The regulatory limits for offsite releases of radionuclides for the current candidate repository site were recently finalized by EPA (73 FR 61256, October 15, 2008) and adopted by the NRC (U.S. NRC Feb 2009). In accordance with the Commission's Waste Confidence Decision (10 CFR 51.23), the NRC has assumed a repository can and likely will be developed at some site that will comply with such limits, with peak doses to virtually all individuals of 100 millirem per year or less (U.S. NRC May 1996). It is reasonable to conclude that the offsite radiological impacts of spent fuel and high-level waste disposal would not be sufficiently great to preclude construction of new units at VCS.

For the reasons stated above, the environmental impacts of radioactive waste disposal will be SMALL and not warrant mitigation.

5.7.1.7 Occupational Dose

The estimated occupational dose attributable to all phases of the fuel cycle is approximately 2500 person-rem per year for the two-APWR plant. This is based on a 600 person-rem per year occupational dose estimate attributable to all phases of the fuel cycle for the reference reactor (U.S. NRC May 1996). The dose to any individual worker is restricted to the dose limit of 10 CFR Part 20. The environmental impacts from this occupational dose will be SMALL.

5.7.1.8 Transportation

The transportation dose to workers and the public is estimated in Table S-3 (Table 5.7-1) to be 2.5 person-rem per year for the reference reactor. This corresponds to a dose of 10 person-rem per year for the two proposed APWRs. For comparative purposes, the estimated collective dose from natural background radiation to the population within 50 miles of VCS is 75,000 person-rem per year. On the basis of this comparison, the environmental impacts of transportation from the fuel cycle will be SMALL and not warrant mitigation.

5.7.1.9 Summary

The environmental impacts of the uranium fuel cycle as given in Table S-3 were evaluated along with the effects of Rn-222 and Tc-99 releases based on the information presented in NUREG-1437. Based on this evaluation, the impacts will be SMALL, and mitigation will not be warranted.

5.7.2 Transportation of Radioactive Materials

Transport of radioactive materials is an important activity associated with operating new reactors at VCS. The analysis in this section is based on the LWR technologies described in Section 3.2 and radioactive waste management systems described in Section 3.5. Information regarding preparation and packaging of the radioactive materials for transport offsite can be found in Section 3.8. The data currently available for the mPower reactor will not support an evaluation of radioactive materials transportation. Should Exelon select the mPower technology for the VCS, an evaluation of radioactive materials transportation will be provided as part of the COL application.

5.7.2.1 Transportation Assessment

The NRC evaluated the environmental effects of transportation of fuel and waste for LWRs in *Environmental Survey of Transportation of Radioactive Materials to and From Nuclear Power Plants* (WASH-1238, AEC Dec 1972) and Supplement 1 (NUREG-75/038, NRC Apr 1975) and found the impacts to be SMALL. These NRC analyses provided the basis for Table S-4 in 10 CFR 51.52 (see Table 5.7-2), which summarizes the environmental impacts of transportation of fuel and radioactive wastes to and from a reference reactor. The table addresses two categories of environmental considerations: (1) normal conditions of transport, and (2) accidents in transport.

To analyze the impacts of transporting LWR fuel and radioactive waste for comparison to Table S-4, the characteristics for the LWRs were normalized to a reference reactor-year. The reference reactor is an 1100 MWe reactor that has an 80 percent capacity factor, for an electrical output of 880 MWe per year. The advanced LWR technology being considered to demonstrate the VCS site suitability include the ABWR, the ESBWR, the AP1000, the APWR, and the mPower. The ABWR is assumed to be a 1300 MWe (net) reactor[2] with a 95 percent capacity factor. The ESBWR is assumed to be a 1535 MWe (net) reactor with a 96 percent capacity factor. The AP1000 is assumed to be a 1117 MWe (net) reactor with a 93 percent capacity factor. The APWR is assumed to be a 1600 MWe (net)

2. Net electrical output for all of the reactors evaluated was used to provide conservatism in the estimates of normalized transportation impacts for comparison with the reference reactor and Table S-4.

reactor with a 96.3 percent factor. The standard configuration (a single unit) for each of the LWR technologies will be used to evaluate transportation impacts relative to the reference reactor.

Subparagraph 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 a 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 sections describe the characteristics of the LWR technologies relative to the conditions of 10 CFR 51.52 for use of Table S-4.

Reactor core thermal power

Subparagraph 10 CFR 51.52(a)(1) requires that the reactor have a core thermal power level not exceeding 3800 MWt. The ABWR has a rated thermal power level of 3926 MWt that exceeds this condition. The ESBWR has a rated thermal power of 4500 MWt that exceeds this condition. The AP1000 has a rated thermal power of 3415 MWt that meets this condition. The APWR has a rated thermal power of 4451 MWt that exceeds this condition.

The core power level was established as a condition because, for the LWRs being licensed when Table S-4 was promulgated, higher power levels indicated the need for more fuel and therefore more fuel shipments. This is not the case for the new LWR designs due to the higher unit capacity factor and higher burnup for these reactors. The annual fuel reloading for the reference reactor analyzed in WASH-1238 was 30 MTU. The annual fuel loading for the ABWR is approximately 30 MTU. When normalized to equivalent electric output, the annual fuel requirement for the ABWR is approximately 21 MTU or 72 percent that of the reference LWR.

The annual fuel loading for the ESBWR is approximately 38.5 MTU. When normalized to equivalent electric output, the annual fuel requirement for the ESBWR is approximately 23 MTU or 77 percent that of the reference LWR.

The annual fuel loading for the AP1000 is approximately 23 MTU. When normalized to equivalent electric output, the annual fuel requirement for the AP1000 is approximately 19.5 MTU or 65 percent that of the reference LWR.

The annual fuel loading for the APWR is approximately 34.8 MTU. When normalized to equivalent electric output, the annual fuel requirement for the APWR is approximately 19.9 MTU or 66 percent that of the reference LWR.

WASH-1238 states:

> The analysis is based on shipments of fresh fuel to and irradiated fuel and solid waste from a boiling water reactor or a pressurized water reactor with design ratings of 3000 MWt to 5000 MWt or 1000 MWe to 1500 MWe.

The ABWR and AP1000 fall within these bounds for thermal and electrical rating. The ESBWR and APWR deviate slightly from the maximum listed electrical output due to a slightly higher thermal efficiency. The higher thermal efficiency has no impact on the analysis.

Fuel form

Subparagraph 10 CFR 51.52(a)(2) requires that the reactor fuel be in the form of sintered uranium dioxide (UO2) pellets. All of the LWR technologies use a sintered UO2 pellet fuel form.

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. For the ABWR, the enrichment of the initial core averages approximately 2.22 percent and the average for the reloads is approximately 3.2 percent. The ABWR fuel meets the 4 percent U-235 enrichment condition.

For the ESBWR, the enrichment of the initial core averages approximately 2.08 percent and the average for the reloads ranges from 4.02 to 4.12 percent. The ESBWR fuel exceeds the 4 percent U-235 enrichment condition.

For the AP1000, the enrichment of the initial core varies by region from 2.35 to 4.45 percent. The AP1000 fuel exceeds the 4 percent U-235 condition.

For the APWR, the maximum fuel enrichment is less than 5 percent and the initial core varies by region from 2.05 to 4.15 percent. The APWR fuel exceeds the 4 percent U-235 condition.

Fuel encapsulation

Subparagraph 10 CFR 51.52(a)(2) requires that the reactor fuel pellets be encapsulated in Zircaloy rods. The ABWR and ESBWR fuels use Zircaloy cladding and meet this condition. The AP1000 and

APWR fuels use ZIRLO™ cladding, which is a special zircaloy material alloyed with niobium, tin and iron and is a successor of Zircaloy-4 and meet this condition.

Average fuel irradiation

Subparagraph 10 CFR 51.52(a)(3) requires that the average burnup not exceed 33,000 megawatt-days per MTU. For the ABWR, the average burnup is 32,300 megawatt-days per MTU, which meets this condition. For the ESBWR, the average burnup after achieving an equilibrium core is 42,000 to 46,000 megawatt-days per MTU, which exceeds this condition. For the AP1000, the average burnup after achieving an equilibrium core is 50,553 megawatt-days per MTU, which exceeds this condition. For the APWR, the average burnup is approximately 46,000 megawatt-days per MTU, which exceeds this condition.

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 WASH-1238 analysis for Table S-4 assumes 150 days of decay time before shipment of any irradiated fuel assemblies. NUREG/CR-6703 (Ramsdell et al. Jan 2001), which updated this analysis to extend Table S-4 to burnups of up to 62,000 megawatt-days per MTU, assumes a minimum of 5 years between removal from the reactor and shipment. Five years is the minimum decay time expected before shipment of irradiated fuel assemblies. The U.S. DOE’s contract for acceptance of spent fuel, as set forth in 10 CFR 961, Appendix E, requires a 5-year minimum cooling time. In addition, the NRC specifies 5 years as the minimum cooling period when it issues certificates of compliance for casks used for shipment of power reactor fuel (U.S. NRC Aug 1999). As described in Section 3.8 each of the LWR technologies would have storage capacity exceeding that needed to accommodate 5-year cooling of irradiated fuel before transport offsite.

Transportation of unirradiated fuel

Subparagraph 10 CFR 51.52(a)(5) requires that unirradiated fuel be shipped to the reactor site by truck. Typical shipment of fuel from the General Electric fuel fabrication facility in Wilmington, North Carolina is by truck. It is expected that fuel will be received via truck shipments for each of the LWR technologies. Typical shipment of fuel from the Westinghouse fuel fabrication facility in Columbia, South Carolina is by truck. Mitsubishi fuel would be fabricated in Japan and transported to a port on the west coast of the United States. Shipment of the fuel from the port to VCS would be by truck.

Table S-4 includes a condition that the truck shipments will not exceed 73,000 pounds. The fuel shipments to the site would comply with federal or state weight restrictions.

Transportation of irradiated fuel

Subparagraph 10 CFR 51.52(a)(5) allows for truck, rail, or barge transport of irradiated fuel. This condition will be met for each of the LWR technologies at VCS. For the impacts analysis described in Subsection 5.7.2.2, all spent fuel shipments were assumed to be made using legal weight trucks. U.S. DOE is responsible for spent fuel transportation from reactor sites to the repository and will make the decision on transport mode (10 CFR 961.1).

Radioactive waste form and packaging

Subparagraph 10 CFR 51.52(a)(4) requires that, with the exception of spent fuel, radioactive waste shipped from the reactor be packaged and in a solid form. Low-level radioactive waste generated at VCS would be solidified and packaged. Additionally, these shipments would comply with the NRC (10 CFR 71) and U.S. DOT (49 CFR 173 and 178) packaging and transportation regulations for the shipment of radioactive material.

Transportation of radioactive waste

Subparagraph 10 CFR 51.52(a)(5) requires that the mode of transport of low-level radioactive waste be either truck or rail. Radioactive waste is planned to be shipped from the VCS site by truck. Radioactive waste shipments are subject to a weight limitation of 73,000 pounds per truck and 100 tons per cask per rail car (Table S-4). Radioactive waste would be shipped in compliance with federal or state weight restrictions.

Number of truck shipments

Table S-4 limits traffic density to less than one truck shipment per day or three rail cars per month. The number of truck shipments that would be required was estimated assuming that all radioactive materials (fuel and waste) are received at the site or transported offsite via truck.

Table 5.7-3 summarizes the number of truck shipments of unirradiated fuel. The table also normalizes the number of shipments to the electrical output for the reference reactor analyzed in WASH-1238. When normalized for electrical output, the number of truck shipments of unirradiated fuel for each of the LWR technologies is less than the number of truck shipments estimated for the reference LWR.

For the ABWR, the initial core load is estimated at 152 MTU per unit and the reload requirements are estimated at 30 MTU per year per unit. This equates to approximately 872 fuel assemblies in the initial core assuming 0.174 MTU per fuel assembly) and 173 fuel assemblies per year for refueling. General Electric Nuclear Energy estimates that a transportation container could accommodate up to 28 fuel assemblies.

For the ESBWR, the initial core load is estimated at 185 MTU per unit and the reload requirements are estimated at 38.5 MTU per year per unit. This equates to approximately 1132 fuel assemblies in the initial core assuming 0.163 MTU per fuel assembly and 236 fuel assemblies per year for refueling. General Electric-Hitachi Nuclear Energy estimates that a transportation container could accommodate up to 28 fuel assemblies.

For the AP1000, the initial core load is estimated at 84.5 MTU per unit and the reload requirements are estimated at 23 MTU per year per unit. This equates to approximately 157 fuel assemblies in the initial core (assuming 0.5383 MTU per fuel assembly) and 43 fuel assemblies per year for refueling. Westinghouse estimates that a transportation container could accommodate up to 7 fuel assemblies for the initial core load and 9 fuel assemblies for core reloads.

For the APWR, the initial core load is estimated at 139 MTU per unit and the reload requirements are estimated at 34.8 MTU per year per unit. This equates to approximately 257 fuel assemblies in the initial core (assuming 0.5398 MTU per fuel assembly) and 65 fuel assemblies per year for refueling. Mitsubishi Heavy Industries estimates that a transportation container could accommodate up to 12 fuel assemblies.

The numbers of spent fuel shipments were estimated as follows. For the reference LWR analyzed in WASH-1238, the NRC assumed that 60 shipments per year will be made, each carrying 0.5 MTU of spent fuel. This amount is equivalent to the annual refueling requirement of 30 MTU per year for the reference LWR. For this transportation analysis, shipments of spent fuel from the VCS site were assumed to occur at a rate equal to the annual refueling requirement. The shipping cask capacities used to calculate annual spent fuel shipments were assumed to be the same as those for the reference LWR (0.5 MTU per legal weight truck shipment). This results in 61 shipments per year for one ABWR, 78 shipments per year for one ESBWR, 46 shipments per year for one AP1000, and 70 shipments per year per one APWR. After normalizing for electrical output, the number of spent fuel shipments is 43 per year for the ABWR, 47 per year for the ESBWR, 39 per year for the AP1000, and 40 per year for the APWR. The normalized spent fuel shipments for each of the LWR technologies would be less than the reference reactor that was the basis for Table S-4.

Table 5.7-4 presents estimates of annual waste volumes and numbers of truck shipments. The values are normalized to the reference LWR analyzed in WASH-1238. Based on the expected shipped waste volumes provided in the AP1000 DCD, the normalized annual waste volumes and waste shipments for the AP1000 will be less than the reference reactor that was the basis for Table S-4. However, the AP1000 waste estimates include onsite processing that would reduce the waste volume by a factor of three. For this analysis, it is conservatively assumed that Exelon would not perform onsite volume reduction. The dry active waste would be packaged and shipped to offsite processors. When this is factored into the waste estimates for the LWR technologies, the waste volumes and numbers of waste shipments are higher relative to the reference LWR.

The normalized total numbers of truck shipments of fuel and radioactive waste are estimated to be 193 per year for the ABWR, 168 per year for the ESBWR, 64 per year for the AP1000, and 150 per year for the APWR. Thus, these radioactive material shipment estimates are well below the one truck shipment per day condition given in 10 CFR 51.52, Table S-4.

Summary

Table 5.7-5 compares the values for the reference conditions in paragraph (a) of 10 CFR 51.52 used in Table S-4 and the values for the LWR technologies. The ABWR does not meet the condition for rated thermal power. The ESBWR and APWR do not meet the conditions for rated thermal power, fuel enrichment, or average fuel irradiation. The AP1000 does not meet the conditions for fuel enrichment or average fuel irradiation. Therefore, Subsection 5.7.2.2 and Section 7.4 will present additional analyses of fuel transportation effects for normal conditions and accidents, respectively.

5.7.2.2 Incident-Free Transportation Impacts Analysis

The environmental impacts of radioactive materials transportation were estimated using the most recent version of the RADTRAN 5 computer code (Weiner et al. Apr 2008). 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. For accident risks, RADTRAN was used to evaluate the range of possible accident scenarios from high probability and low consequence to low probability and high consequence. Environmental impacts of incident-free transportation of fuel are described in this section. Transportation accidents are described 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, 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.

One of the key assumptions in WASH-1238 for the reference LWR unirradiated fuel shipments is that the radiation dose rate at 1 meter from the transport vehicle is approximately 0.1 millirem per hour.

This assumption was also used by the NRC to analyze advanced LWR unirradiated fuel shipments for proposed ESP sites. This assumption is reasonable for all of the advanced LWR types because the fuel materials will all be low dose rate uranium radionuclides and will be packaged similarly (inside a metal container that provides little radiation shielding). The per-shipment dose estimates are “generic” (i.e., independent of reactor technology) because they were calculated based on an assumed external radiation dose rate rather than the specific characteristics of the fuel or packaging. Thus, the results can be used to evaluate the impacts for any of the advanced LWR designs. Other input parameters used in the radiation dose analysis for advanced LWR unirradiated fuel shipments are summarized in Table 5.7-7. The RADTRAN results for this “generic” fresh fuel shipment are as follows:

Population Component	Dose
Transport workers	0.00171 person-rem per shipment
General public (Onlookers – persons at stops and sharing the highway)	0.00292 person-rem per shipment
General public (Along Route – persons living near a highway)	2.99×10^{-5} person-rem per shipment

Based on the parameters used in the analysis, these per shipment doses are expected to conservatively estimate the impacts for fuel shipments to the Victoria County site or an alternate site in the region of interest. For example, the average shipping distance of 2000 miles used in the NRC analysis will exceed the shipping distance for fuel deliveries to VCS. The fuel shipments could originate at the General Electric fuel fabrication facility located in Wilmington, North Carolina and travel approximately 1460 miles to VCS. Fuel shipments could originate at the Westinghouse fuel fabrication facility in Columbia, South Carolina and travel approximately 1170 miles to VCS. Mitsubishi fuel would be fabricated in Japan and transported to a port on the west coast of the United States, such as San Francisco, Los Angeles, or San Diego. Shipments of the fuel from the port of San Francisco would travel approximately 1900 miles to VCS.

The unit dose values were combined with the average annual shipments of unirradiated fuel to calculate annual doses to the public and workers that can be compared to Table S-4 conditions. The numbers of unirradiated fuel shipments were normalized to the reference reactor analyzed in WASH-1238. The numbers of shipments per year were obtained from Table 5.7-3. The results are presented in Table 5.7-7. As shown, the calculated radiation doses for transporting unirradiated fuel to VCS are within the Table S-4 conditions.

Although radiation may cause cancers at high doses and high dose rates, currently there are no data that unequivocally establish the occurrence of cancer following exposures to low doses, below approximately 10 rem. However, radiation protection experts conservatively assume that any amount of radiation may pose some risk of causing cancer or a severe hereditary effect and that the risk is higher for higher radiation exposures (NAS 2006). Therefore, a linear, no-threshold dose response model is used to describe the relationship between radiation dose and detriments such as cancer induction. Based on this model, the risk to the public from radiation exposure is estimated using the nominal probability coefficient for total detriment (730 fatal cancers, nonfatal cancers, and severe hereditary effects per million person-rem) from International Commission on Radiation Protection Publication 60 (ICRP 1991). All the public collective doses presented in Table 5.7-7 are less than 0.1 person-rem per year. Therefore, the total detriment estimates associated with these doses will all be less than 1 x 10^{-4} fatal cancers, nonfatal cancers, and severe hereditary effects per year. These risks are very small compared to the fatal cancers, nonfatal cancers, and severe hereditary effects that the same population will incur annually from exposure to natural sources of radiation.

5.7.2.2.2 Transportation of Spent Fuel

This section provides the environmental impacts of transporting spent fuel from VCS to a spent fuel disposal facility, using Yucca Mountain, Nevada as a possible location for a geologic repository. The impacts of the transportation of spent fuel to a potential repository in Nevada provide a reasonable bounding estimate 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 would be from the low levels of radiation that penetrate the heavily shielded spent fuel shipping cask. Radiation doses would occur to (1) persons residing along the transportation corridors between VCS and the proposed repository; (2) persons in vehicles passing a spent-fuel shipment; (3) persons at vehicle stops for refueling, rest, and vehicle inspections; and (4) 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 the environmental impacts of spent fuel transportation in Addendum 1 to NUREG-1437 (U.S. NRC Aug 1999). As described in NUREG-1437, these assumptions are conservative because the alternative assumptions involve rail transportation or heavy-haul trucks, which would reduce the overall number of spent fuel shipments.

The environmental impacts of spent fuel transportation were estimated using the most recent version of the RADTRAN 5 computer code (Weiner et al. Apr 2008). This analysis assumed the spent fuel would be transported by legal weight trucks to the potential Yucca Mountain repository over designated highway route-controlled quantity (HRCQ) routes. A transportation route was evaluated that was consistent with HRCQ requirements and traveled a total of approximately 1800 miles.

Although shipping casks have not been designed for the advanced LWR fuels, the advanced LWR fuel designs would be similar to the existing LWR designs. Thus, current shipping cask designs were used for analysis.

Radiation doses are a function of many parameters, including vehicle speed, traffic count, dose rate at 1 meter from the vehicle, packaging dimensions, number in the truck crew, stop time, and population density along the route and at stops. The values of the key variables used in this analysis are presented in Table 5.7-8. Most of the variables are extracted from literature and are considered to be standard values used in many RADTRAN applications, including environmental impact statements and regulatory analyses.

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.

Representative shipment routes for the proposed Victoria County site and alternative sites were identified using the TRAGIS (Version 1.5.4) routing model (Johnson and Michelbaugh Apr 2000). The Highway data network in TRAGIS is a computerized road atlas that includes a complete description of the interstate highway system and of all U.S. highways. The TRAGIS database version used was Highway Data Network 4.0. The population densities along a route are derived from 2000 census data from the U.S. Bureau of the Census. This transportation route information is summarized in Table 5.7-9.

Based on the transportation route information shown in Table 5.7-9, the impacts of spent fuel shipments originating at VCS are expected to be similar to the impacts for the alternative sites (Matagorda County, Buckeye, Alpha, and Bravo). The radiation dose estimates to the transport workers and the public for spent fuel shipments from VCS and alternative sites are as follows:

	Population Dose (person-rem per shipment)		
Site	**Transport workers**	**General public (Onlookers)**	**General public (Along Route)**
VCS	0.133	0.237	0.00551
Matagorda County	0.135	0.269	0.00545
Buckeye	0.135	0.269	0.00545
Alpha	0.132	0.237	0.00536
Bravo	0.129	0.236	0.00443

These per-shipment dose estimates are independent of reactor technology because they were calculated based on an assumed external radiation dose rate emitted from the cask, which was fixed at the regulatory maximum of 10 millirem per hour at two meters. For the purpose of this analysis, the transportation crew consists of two drivers. The numbers of spent fuel shipments for the transportation impacts analysis were derived as described in Subsection 5.7.2.1. The normalized annual shipment values and corresponding population dose estimates per reactor-year are presented in Table 5.7-10. The population doses were calculated by multiplying the number of spent fuel shipments per year by the per-shipment doses. For comparison to Table S-4, the population doses were normalized to the reference LWR analyzed in WASH-1238.

As shown in Table 5.7-10, population doses to the crew and onlookers for both the advanced LWR technologies and the reference LWR exceed Table S-4 values. Two key reasons for these higher population doses relative to Table S-4 are the number of spent fuel shipments and the shipping distances assumed for these analyses relative to the assumptions used in WASH-1238.

- The analyses in WASH-1238 used a “typical” distance for a spent fuel shipment of 1000 miles. The shipping distance used in this assessment is approximately 1800 miles.
- The numbers of spent fuel shipments are based on shipping casks designed to transport shorter-cooled fuel (i.e., 150 days out of the reactor). This analysis assumed that the shipping cask capacities are 0.5 MTU per legal-weight truck shipment. Newer cask designs are based on longer-cooled spent fuel (i.e., 5 years out of reactor) and have larger capacities. For example, spent fuel shipping cask capacities used in the Yucca Mountain EIS (USDOE Feb 2002, Table J-2) were approximately 1.8 MTU per legal-weight truck shipment. Use of the newer shipping cask designs will reduce the number of spent fuel shipments and decrease the associated environmental impacts because the dose rates used in the impacts analysis are fixed at the regulatory limit rather than based on the cask design and contents.

If the population doses in Table S-4 are adjusted for the longer shipping distance and larger shipping cask capacity, the population doses from incident-free spent fuel transportation from the site will fall within Table S-4 requirements.

Other conservative assumptions in the spent fuel transportation impacts calculation include:

- Use of the regulatory maximum dose rate (10 millirem per hour at two meters) in the RADTRAN 5 calculations. The shipping casks assumed in the Yucca Mountain EIS (U.S. DOE Feb 2002) transportation analyses were designed for spent fuel that has cooled for five years. In reality, most spent fuel will have cooled for much longer than five years before it is shipped to a possible geologic repository. The NRC developed a probabilistic distribution of dose rates based on fuel cooling times that indicates that approximately three-fourths of the spent fuel to be transported to a possible geologic repository will have dose rates less than half of the regulatory limit (Sprung et al. Mar 2000). Consequently, the estimated population doses in Table 5.7-10 could be divided in half if more realistic dose rate projections are used for spent fuel shipments from VCS.

- Use of 30 minutes as the average time at a truck stop in the calculations. Many stops made for actual spent fuel shipments are short duration stops (i.e., 10 minutes) for brief visual inspections of the cargo (checking the cask tie-downs). These stops typically occur in minimally populated areas, such as an overpass or freeway ramp in an unpopulated area. Based on data for actual truck stops, recent NRC transportation analyses concluded that the assumption of a 30-minute stop for every four hours of driving time used to evaluate potential ESP sites will overestimate public doses at stops by at least a factor of two. Consequently, the doses to onlookers given in Table 5.7-10 could be reduced by a factor of two to reflect more realistic truck shipping conditions.

5.7.2.2.3 Transportation of Radioactive Waste

Transportation of radioactive waste met the applicable conditions in 10 CFR 51.52(a) and no further analysis is required.

5.7.2.2.4 Maximally Exposed Individual

The incident-free radiation doses to maximally exposed individuals for fuel and waste shipments were also considered. A maximally exposed individual is a person who may receive the highest radiation dose from a shipment to and/or from the site. The radiological doses to the workers who would load casks, drive trucks, and inspect vehicles in transit would be higher than doses to individuals in the general public. Radiological protection programs would manage and limit doses to workers whose jobs would cause them to receive the greatest exposures.

Truck crew members would receive the highest radiation doses because of their proximity to the loaded shipping container for an extended period of time. DOE will take title to the spent fuel at the reactor site. Consequently, the DOE administrative control level of two rem per year (DOE Mar 2005) is expected to apply to spent fuel shipments from the site to a disposal facility. Spent fuel represents the majority of the radioactive materials shipments to and from reactor sites, and comprises those shipments with the highest radiation dose rates. Crew doses from unirradiated fuel and radioactive waste shipments will be lower than the spent fuel shipments.

5.7.2.3 Conclusion

Incident free transportation of unirradiated and spent fuel to and from VCS was evaluated. The impacts of accident free transportation will be SMALL and do not warrant additional mitigation.

5.7.2.4 References

AEC Apr 1974. U.S. Atomic Energy Commission, *Environmental Survey of the Uranium Fuel Cycle*, WASH-1248, April 1974.

AEC Dec 1972. U.S. Atomic Energy Commission, *Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants*, WASH-1238, December 1972.

GE Mar 1997. G E Nuclear Energy, A*BWR Design Control Document*, Revision 4, March 1997.

GEH Aug 2009. General Electric-hitachi Nuclear Energy, *ESBWR Design Control Document*, Revision 6, August 2009.

Hagen et al. Nov 2001, Hagen, R.E., J.R. Moens, and Z.D. Nikodem, presentation to International Atomic Energy Agency, Impact of U,S, Nuclear Generation on Greenhouse Gas Emissions, Energy Information Administration, U.S. Department of Energy, November 6-9, 2001.

ICRP 1991. International Commission of Radiological Protection,*1990 Recommendations of the International Commission of Radiological Protection*, ICRP Publication 60, Annals of the ICRP 21(1-3), 1991, Pergamon Press.

Johnson and Michelbaugh Apr 2000. Johnson, P. E. and R. D. Michelbaugh, *Transportation Routing Analysis Geographic Information System (WebTRAGIS) User's Manual*, ORNL/TM-2000/86, April 2000, Oak Ridge National Laboratory.

MHI Aug 2008, Mitsubishi Heavy Industries, Ltd., *Design Control Document for the US-APWR*, Revision 1, August 2008.

NAS 1995. National Academy of Sciences, *Technical Bases for Yucca Mountain Standards*, ISBN 0-309-05289-0, 2005, National Academy Press.

NAS 2006. National Academy of Sciences, *Health Risks from Exposure to Low Levels of Ionizing Radiation: BEIR VII – Phase 2,* ISBN 0-309-09156-X, 2006, National Academy Press.

Ramsdell et al. Jan 2001. Ramsdell, J. V., C. E. Beyer, D. D. Lanning, U. P. Jenquin, R. A. Schwarz, D. L. Strenge, P.M. Daling, and R. T. Dahowski, *Environmental Effects of Extending Fuel Burnup Above 60 GWd/MTU*, NUREG/CR-6703, January 2001, U.S. Nuclear Regulatory Commission.

Sprung et al. Mar 2000. Sprung, J. L., D. J. Ammerman, N. L. Breivik, R. J. Dukart, F. L. Kanipe, J. A. Koski, G. S. Mills, K. S. Neuhauser, H. D. Radloff, R. F. Weiner, and H. R. Yoshimura, *Reexamination of Spent Fuel Shipment Risk Estimates*, NUREG/CR-6672, Volume 1, March 2000, U.S. Nuclear Regulatory Commission.

USDOE Feb 2002. U.S. Department of Energy, *Final Environmental Impact Statement for a Geologic Repository for the Disposal of Spent Nuclear Fuel and High-Level Radioactive Waste at Yucca Mountain, Nye County, Nevada,* DOE/EIS-0250, February 2002.

USDOE Jul 2002. U.S. Department of Energy, *A Resource Handbook on DOE Transportation Risk Assessment,* DOE/EM/NTP/HB-01, July 2002.

USDOE Mar 2005. U.S. Department of Energy, *DOE Standard, Radiological Control,* DOE-STD-1098-99, March 2005.

USEPA 2006. U.S. Environmental Protection Agency, *Air Emissions Summary Through 2005*, available online at http://www.epa.gov/air/airtrends/2006/emissions_summary_2005.html, accessed October 9, 2007.

U.S. NRC Apr 1975. U.S. Nuclear Regulatory Commission, *Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants,* Supplement 1, NUREG-75/038, April 1975.

U.S. NRC Aug 1999. U.S. Nuclear Regulatory Commission, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants,* NUREG-1437, Volume 1, Addendum 1, Section 6.3, “Transportation” and Table 9-1, “Summary of findings on NEPA issues for license renewal of nuclear power plants,” August 1999.

U.S. NRC Feb 2008. U.S. Nuclear Regulatory Commission, *Expected New Uranium Recovery Facility Applications/Restarts/Expansions*, February 22, 2008.

U.S. NRC May 1996. U.S. Nuclear Regulatory Commission, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, NUREG-1437 Volume 1, Section 6.2, “Impacts of the Uranium Fuel Cycle,” May 1996.

U.S. NRC Oct 2007. U.S. Nuclear Regulatory Commission, *NRC Receives First Application in Nearly Two Decades for New Uranium Recovery Operation*, News Release No. 07-129, October 4, 2007.

U.S. NRC 2009. New Fuel Cycle Facility Licensing, available at http://www.nrc.gov/materials/fuel-cycle-fac/new-fac-licensing.html

U.S. NRC Feb 2009, NRC Approves Rule Incorporating EPA Standards for Yucca Mountain Repository, Fact Sheet No. 09-031, February 17, 2009.

UXC 2007. The Ux Consulting Company, LLC, *Ux* U_3O_8 *Prices and Historical Ux Month-end Spot Prices*, available online at www.uxc.com, accessed on October 13, 2007.

Weiner et al. Apr 2008. Weiner R.F., Osborn, D.M., Hinojosa, D., Heames, T.J., Penisten, J., and Orcutt, D., *RadCat 2.3 User Guide.* SAND2006-6315, April 2008, Sandia National Laboratories.

Westinghouse Sep 2008. Westinghouse Electric Company, LLC, *AP1000 Design Control Document*, Revision 17, September 2008.

Table 5.7-1 (Sheet 1 of 2)
Uranium Fuel Cycle Environmental Data[a]

Environmental Considerations	Reference Reactor	2 APWR Units
Natural Resource Use		
Land (acres)		
Temporarily committed[b]	100	410
Undisturbed area	79	320
Disturbed area	22	90
Permanently committed	13	53
Overburden moved (millions of MT)	2.8	11
Water (millions of gallons)		
Discharged to air	160	650
Discharged to water bodies	11,090	45,400
Discharged to ground	127	520
Total[c]	11,377	46,600
Fossil fuel		
Electrical energy (thousands of MW-hour)	323	
Equivalent coal (thousands of MT)	118	
Natural gas (millions of scf)	135	
Effluents – Chemical (MT)		
Gases (including entrainment)[d]		
SO_x	4400	18,000
NO_x[e]	1190	4,900
hydrocarbons	14	57
CO	29.6	120
particulates	1154	4,700
Other gases		
F	0.67	2.7
HCl	0.014	0.057
Liquids		
SO_4^-	9.9	41
NO_3^-	25.8	110
fluoride	12.9	53
Ca^{++}	5.4	22
Cl^-	8.5	35
Na^+	12.1	50
NH_3	10	41
Fe	0.4	1.6
Tailings solutions (thousands of MT)	240	980
Solids	91,000	372,000
Effluents – Radiological (curies)		
Gases (including entrainment)		
^{222}Rn	[f]	21,200
^{226}Ra	0.02	0.082
^{230}Th	0.02	0.082

Table 5.7-1 (Sheet 2 of 2) Uranium Fuel Cycle Environmental Data[(a)]

Environmental Considerations	Reference Reactor	2 APWR Units
Gases (including entrainment) (cont.)		
U	0.034	0.14
^{3}H (thousands)	18.1	74
^{14}C	24	98
^{85}Kr (thousands)	400	1,600
^{106}Ru	0.14	0.57
^{129}I	1.3	5.3
^{131}I	0.83	3.4
^{99}Tc	(f)	0.029
Fission products and TRU	0.203	0.83
Liquids		
U and daughters	2.1	8.6
^{226}Ra	0.0034	0.014
^{230}Th	0.0015	0.0061
^{234}Th	0.01	0.041
fission and activation	5.90×10^{-6}	2.4×10^{-5}
Solids buried		
not HLW (shallow)	11,300	46,000
TRU and HLW (deep)	1.10×10^{7}	4.5×10^{7}
Effluents – Thermal (billions of Btu)	4063	16,600
Transportation (person rem)		
exposure of workers and the general public	2.5	10
occupational exposure	22.6	92

MT = metric tons

TRU = transuranic

HLW = high level waste

(a) In some cases where no entry appears in Table S-3 it is clear from the background documents that the matter was addressed and that, in effect, the table should be read as if a specific zero entry had been made. However, there are other areas that are not addressed at all in the table. Table S-3 does not include health effects from the effluents described in the table, or estimates of releases of Rn-222 from the uranium fuel cycle or estimates of Tc-99 released from waste management or reprocessing activities. Radiological impacts of these two radionuclides are addressed in NUREG-1437, “Generic Environmental Impact Statement for License Renewal of Nuclear Plants,” (U.S. NRC May 1996) and it was concluded that the health effects from these two radionuclides posed a small significance. Data supporting Table S-3 are given in the “Environmental Survey of the Uranium Fuel Cycle,” WASH-1248 (AEC Apr 1974); the “Environmental Survey of Reprocessing and Waste Management Portion of the LWR Fuel Cycle,” NUREG-0116 (Supplement 1 to WASH-1248); the “Public Comments and Task Force Responses Regarding the Environmental Survey of the Reprocessing and Waste Management Portions of the LWR Fuel Cycle,” NUREG-0216 (Supplement 2 to WASH-1248); and in the record of final rule making pertaining to “Uranium Fuel Cycle Impacts from Spent Fuel Reprocessing and Radioactive Waste Management, Docket RM-50-3.” The contributions from reprocessing, waste management and transportation of wastes are maximized for either of the two fuel cycles (uranium only and fuel recycle). The contribution from transportation excluded transportation of cold fuel to a reactor and of irradiated fuel and radioactive wastes from a reactor which are considered in Table S-4 of § 51.20(g). The contributions from the other steps of the fuel cycle are given in columns A-E of Table S-3A of WASH-1248.

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

(c) Individual values may not sum to total due to rounding.

(d) Estimated effluents based on combustion of coal for equivalent power generation.

(e) 1.2% percent from natural gas use and processes.

(f) Radiological impacts of Rn-222 and Tc-99 are addressed in NUREG-1437, “Generic Environmental Impact Statement for License Renewal of Nuclear Plants,” (U.S. NRC May 1996). The GEIS concluded that the health effects from these two radionuclides pose a small risk.

Table 5.7-2
Summary of Environmental Impacts of Transportation of Fuel and Waste to and from One LWR, Taken from 10 CFR 51.52 Table S-4[(a)]

Normal Conditions of Transport	
	Environmental Impacts
Heat (per irradiated fuel cask in transit)	250,000 Btu per hr.
Weight (governed by federal or state restrictions)	73,000 lbs. per truck; 100 tons per cask per rail car.
Traffic density:	
Truck	Less than 1 per day
Rail	Less than 3 per month

Exposed Population	Estimated Number of Persons Exposed	Range of Doses to Exposed Individuals[(b)] (per reactor year)	Cumulative Dose to Exposed Population (per reactor year)[(c)]
Transportation workers	200	0.01 to 300 millirem	4 man-rem.
General pubic:			
Onlookers	1100	0.003 to 1.3 millirem	3 man-rem.
Along Route	600,000	0.0001 to 0.06 millirem	

Accidents in Transport	
Types of Effects	Environmental Risk
Radiological effects	Small[(d)]
Common (nonradiological) causes	1 fatal injury in 100 reactor years; 1 nonfatal injury in 10 reactor years; $475 property damage per reactor year.

(a) Data supporting this table are given in the Commission's “Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants,” WASH-1238, December 1972, and Supp. 1 NUREG-75/038, April 1975.

(b) The Federal Radiation Council has recommended that the radiation doses from all sources of radiation other than natural background and medical exposures should be limited to 5000 millirem per year for individuals as a result of occupational exposure and should be limited to 500 millirem per year for individuals in the general population. The dose to individuals due to average natural background radiation is approximately 130 millirem per year.

(c) Man-rem is an expression for the summation of whole body doses to individuals in a group. Thus, if each member of a population group of 1000 people were to receive a dose of 0.001 rem (1 millirem), or if 2 people were to receive a dose of 0.5 rem (500 millirem) each, the total man-rem dose in each case will be 1 man-rem.

(d) Although the environmental risk of radiological effects stemming from transportation accidents is currently incapable of being numerically quantified, the risk remains small regardless of whether it is being applied to a single reactor or a multi-reactor site.

Table 5.7-3
Number of Truck Shipments of Unirradiated Fuel

Reactor Type	Number of Shipments per Unit			Unit Electric Generation, MW(e)[c]	Capacity Factor	Normalized Shipments Total[d]	Normalized Shipments Annual[e]
	Initial Core[a]	Annual Reload	Total[b]				
Reference LWR	18[f]	6.0	252	1100	0.8	252	6.3
ABWR	32	6.2	273	1300	0.95	195	4.9
ESBWR	41	8.4	370	1535	0.96	221	5.5
AP1000	23	4.7	203	1117	0.93	172	4.3
APWR	22	5.4	231	1600	0.963	132	3.3

(a) Shipments of the initial core have been rounded up to the next highest whole number.
(b) Total shipments of fresh fuel over 40-year plant lifetime (i.e., initial core load plus 39 years of average annual reload quantities).
(c) ABWR unit net generating capacity from GE (Mar 1997), ESBWR unit generating capacity from GEH (Aug 2007), AP1000 unit generating capacity from WEC (Sep 2008), and APWR generating capacity from MHI (Aug 2008).
(d) Normalized to electric output for WASH-1238 reference plant (i.e., 1100 MWe plant at 80 percent or an electrical output of 880 MWe).
(e) Annual average for 40-year plant lifetime.
(f) The initial core load for the reference BWR in WASH-1238 was 150 MTU. The initial core load for the reference PWR was 100 MTU. Both types result in 18 truck shipments of fresh fuel per reactor.

Table 5.7-4
Number of Radioactive Waste Shipments

Reactor Type	Waste Generation, ft^3 per yr, per unit	Electrical Output, MWe, per unit	Capacity Factor	Normalized Waste Generation Rate, ft^3 per reactor-year[(a)]	Normalized Shipments per reactor-year[(b)]
Reference LWR	3,800	1,100	0.80	3,800	46
ABWR	16,708	1,300	0.95	11,905	145
ESBWR	15,859	1,535	0.96	9,471	115
AP1000	1,947	1,117	0.93	1,649	20
APWR	15,278	1,600	0.963	8,726	106

(a) Annual waste generation rates normalized to equivalent electrical output of 880 MWe for reference LWR analyzed in WASH-1238.

(b) The number of shipments was calculated assuming the average waste shipment capacity of 82.6 ft^3 per shipment (3800 ft^3 per yr divided by 46 shipments per yr) used in WASH-1238.

Table 5.7-5 (Sheet 1 of 2)
Reactor Design Comparisons to Table S-4 Reference Conditions

Characteristic	Table S-4 Condition	ABWR	ESBWR	AP1000	APWR
Thermal Power Rating (MWt)	not exceeding 3800 per reactor	3926	4500	3415	4451
Fuel Form	sintered UO_2 pellets	sintered UO_2 pellets	sintered UO_2 pellets	sintered UO_2 pellets	sintered UO_2 pellets
U-235 Enrichment (percent)	Not exceeding 4	Initial Core Average 2.22; Reload Average 3.2	Initial Core Average 2.08; Reload Average 4.02 to 4.12	Initial Core: Region 1 — 2.35 Region 2 — 3.40 Region 3 — 4.45	Initial Core: Region 1 — 2.05 Region 2 — 3.55 Region 3 — 4.15
Fuel Rod Cladding	Zircaloy rods; NRC has also accepted ZIRLO™ per 10 CFR 50.46	Zircaloy	Zircaloy	ZIRLO™	ZIRLO™
Average fuel irradiation (MWd per MTU)	Not exceeding 33,000	32,300	42,000 to 46,000	50,533	46,000
Unirradiated Fuel					
Transport Mode	truck	truck	truck	truck	truck
No. of shipments for initial core loading		32	41	23	22
(normalized number)		(23)[(a)]	(25)[a]	(19)[a]	(13)[a]
No. of reload shipments per year		6.2	8.4	4.7	5.4
(normalized number)		(4.4)[a]	(5.0)[a]	(4.0)[a]	(3.1)[a]
Irradiated Fuel					
Transport mode	truck, rail or barge	truck, rail	truck, rail	truck, rail	truck, rail
Decay time before shipment	minimum of 5 years	minimum of 5 years	minimum of 5 years	minimum of 5 years	minimum of 5 years
No. of spent fuel shipments by truck		61 per year	78 per year	46 per year	70 per year
(normalized number)		(43 per year)	(47 per year)	(39 per year)	(40 per year)
No. of spent fuel shipments by rail		not analyzed	not analyzed	not analyzed	not analyzed
Radioactive Waste					
Transport mode	truck or rail	truck	truck	truck	truck

Table 5.7-5 (Sheet 2 of 2)
Reactor Design Comparisons to Table S-4 Reference Conditions

Characteristic	Table S-4 Condition	ABWR	ESBWR	AP1000	APWR
Waste form	solid	solid	solid	solid	solid
Packaged	yes	yes	yes	yes	yes
No. of waste shipments by truck		203 per year	192 per year	24 per year	185 per year
(normalized number)		(145 per year)	(115 per year)	(20 per year)	(106 per year)
Traffic Density					
Trucks per day	Less than 1	<1	<1	<1	<1
(normalized total)		(193 per year)	(168 per year)	(64 per year)	(165 per year)
Rail cars per month	Less than 3	not analyzed	not analyzed	not analyzed	not analyzed

(a) Total shipments of unirradiated fuel averaged over 40-year plant lifetime (Table 5.7-3) were used to calculate the total traffic density.

Table 5.7-6
RADTRAN 5 Input Parameters for Analysis of Unirradiated Fuel Shipments

Parameter	RADTRAN 5 Input Value
Shipping distance, miles[(a)]	2000
Travel Fraction – Rural	0.90
Travel Fraction – Suburban	0.05
Travel Fraction – Urban	0.05
Population Density – Rural, persons per sq. mi	25.9
Population Density – Suburban, persons per sq. mi	904
Population Density – Urban, persons per sq. mi	5850
Vehicle speed, miles per hr.	55
Traffic count – Rural, vehicles per hr.	530
Traffic count – Suburban, vehicles per hr.	760
Traffic count – Urban, vehicles per hr.	2400
Dose rate at 1 meter from vehicle, mrem per hr.	0.1
Packaging length, ft	24
Number of truck crew	2
Stop time, hr. per trip	4.0
Population density at stops, persons per sq. mi	77,700
Population density surrounding truck stops, persons per sq. mi	881

(a) WASH-1238 had a range of shipping distances between 25 and 3000 miles for unirradiated fuel shipments. A 2000-mile "average" shipping distance was used for this analysis consistent with the assumptions in NRC analyses of ESP sites.

Table 5.7-7
Radiological Impacts of Transporting Unirradiated Fuel to the Site by Truck

Reactor Type	Normalized Average Annual Shipments	Cumulative Annual Dose, person-rem per reference reactor year		
		Transport Workers	General Public - onlookers	General Public - along route
Reference LWR	6.3	0.011	0.018	1.9×10^{-4}
ABWR	4.9	0.0083	0.014	1.5×10^{-4}
ESBWR	5.5	0.0094	0.016	1.7×10^{-4}
AP1000	4.3	0.0073	0.013	1.3×10^{-4}
APWR	3.3	0.0056	0.0096	9.9×10^{-5}
10 CFR 51.52	365	4	3	3
Table S-4 condition[(a)]	(<1 per day)			

(a) Table S-4 conditions apply to all types of radioactive material transportation. The impacts of unirradiated fuel shipments constitute a small fraction of the overall cumulative annual dose limit.

Table 5.7-8
RADTRAN 5 Incident-free Exposure Parameters for Spent Fuel Shipments

Parameter	RADTRAN 5 input value	Source
Vehicle speed – Rural (miles per hr.)	55	Based on average speed in rural areas given in U.S. DOE (Jul 2002). Because most travel is on interstate highways, the same vehicle speed is assumed in rural, suburban, and urban areas. No speed reductions were assumed for travel at rush hour.
Vehicle speed – Suburban (miles per hr.)	55	
Vehicle speed – Urban (miles per hr.)	55	
Traffic count – Rural (vehicles per hr.)	530	USDOE Jul 2002
Traffic count – Suburban (vehicles per hr.)	760	
Traffic count – Urban (vehicles per hr.)	2400	
Dose rate at 1 m from vehicle (mrem per hr.)	14	Approximate rate at 1 m that is equivalent to maximum dose rate allowed by federal regulations (i.e., 10 mrem per hr. at 2 m from the side of a transport vehicle)
Packaging dimensions, m	Length = 5.2 Diameter = 1.0	USDOE Feb 2002
Number of truck crew	2	USDOE Jul 2002
Stop time (hr. per trip)	3.5 to 4	Route specific
Population density at Stops (person per square mile)	77,700	Sprung et al. Mar 2000
Min/Max Radii of Annular Area Surrounding Vehicle at Stops (m)	1 to 10	Sprung et al. Mar 2000
Shielding Factor Applied to Annular Area Surrounding Vehicle at Stops	1 (no shielding)	Sprung et al. Mar 2000
Population Density Surrounding Truck Stops (persons per square mile)	880	Sprung et al. Mar 2000
Min/Max Radii of Annular Area Surrounding Truck Stop (m)	10 to 800	Sprung et al. Mar 2000
Shielding Factor Applied to Annular Area Surrounding Truck Stop	0.2	Sprung et al. Mar 2000

Table 5.7-9
Transportation Route Information for Spent Fuel Shipments to the Potential Yucca Mountain Disposal Facility[a]

	One-way Shipping Distance, miles				Population Density, persons per square mile			
Reactor Site	**Total**	**Rural**	**Suburban**	**Urban**	**Rural**	**Suburban**	**Urban**	**Stop Time per trip, hr.[b]**
Victoria County	1807	1475	277	55	20.6	929	6268	3.5
Matagorda County	1837	1508	277	53	20.8	915	6300	4
Buckeye	1838	1509	277	53	20.8	915	6300	4
Alpha	1793	1466	275	53	20.8	906	6294	3.5
Bravo	1753	1494	214	46	19.8	940	6332	3.5

(a) Transportation route information obtained from TRAGIS.
(b) Stop time is based on one 30 minute stop per each 4 hours of driving time.

Table 5.7-10
Population Doses from Spent Fuel Transportation, Normalized to Reference LWR

Exposed Population	Cumulative dose limit specified in Table S-4, person-rem per reactor year	Reactor Type				
		Reference LWR	ABWR	ESBWR	AP1000	APWR
		Normalized Number of Spent Fuel Shipments per year				
		60	43	47	39	40
		Environmental Effects, person-rem per reactor year				
Crew	4	8.0	5.7	6.3	5.2	5.3
Onlookers	3	14	10	11	9.2	9.5
Along route	3	0.33	0.24	0.26	0.21	0.22

5.8 Socioeconomic Impacts

This section addresses the socioeconomic impacts of the operation of nuclear power units at the proposed VCS site. Subsection 5.8.1 presents an assessment of the physical impacts of operation. Subsection 5.8.2 describes the impacts to the community in the areas of demography, economy, taxes, land use, transportation, recreational resources and aesthetics, housing, and public services. Subsection 5.8.3, assesses the operation of VCS with regard to disproportionate adverse impacts to minority and low income groups.

5.8.1 Physical Impacts of Station Operation

This subsection assesses the potential physical impacts due to operation of VCS on the nearby communities or residences. Potential impacts include noise, odors, exhausts, traffic, occupational health, thermal emissions, and visual effects.

5.8.1.1 Noise

As described in Section 2.2, the region within a 50-mile radius of the site is predominantly rangeland, forest land, and agricultural land. Noise would be attenuated, through distance, over large areas of rangeland. Wooded areas provide natural noise abatement control to reduce noise propagation. Areas that are subject to farming are prone to seasonal noise-related events such as planting and harvesting. As presented in Subsection 2.7.7, Exelon conducted background noise measurements at select locations around the site. The noise levels ranged from 30 decibels A-weighted (dBA) to 55 dBA, except at the location near U.S. Highway 77 where noise levels were approximately 60 dBA.

The new units would produce noise from the operation of pumps, mechanical draft cooling towers, transformers, turbines, generators, switchyard equipment, and loudspeakers. Most equipment would be located inside structures, thereby reducing the outdoor noise level. Noise would be further attenuated by distance to the VCS site boundary. The exclusion area boundary (EAB) would be greater than 1000 feet in all directions from the plant footprint. The highest levels of noise from VCS would be associated with the operation of the cooling towers. The noise level generated by these cooling towers would be approximately 52 dBA at 400 feet from the towers and would be even lower at the EAB. This noise level would be consistent with the existing background noise levels at the site. As reported in NUREG-1437 and referenced in NUREG-1555, noise levels below 65 dBA are considered of small significance.

No public roads, public buildings, or residences are located within the EAB. U.S. Highway 77 is west of the site just outside of the EAB. The nearest residence is approximately 1.6 miles from the power block area.

Impacts from the noise of operations activities would be SMALL and would not require mitigation.

5.8.1.2 Air Quality

Section 5.4 describes the impacts to members of the public from radioactive air emissions from VCS. This subsection is focused on impacts to members of the public from non-radiological air emissions.

The National Ambient Air Quality Standards (NAAQS) define ambient concentration criteria for sulfur dioxide (SO_2), particulate matter with aerodynamic diameters of 10 microns or less (PM_{10}), particulate matter with aerodynamic diameters of 2.5 microns or less ($PM_{2.5}$), carbon monoxide (CO), nitrogen dioxide (NO_2), ozone (O_3), and lead (Pb). These pollutants are generally referred to as "criteria pollutants." Areas of the United States having air quality as good as or better than the NAAQS are designated by the EPA as attainment areas. Areas with air quality that is worse than the NAAQS criteria are designated by the EPA as non-attainment areas.

Victoria County is part of the Corpus Christi-Victoria Intrastate Air Quality Control Region, along with Calhoun, DeWitt, Jackson, and Refugio Counties (40 CFR 81.136). All areas in this region are classified as attainment areas or not designated under the NAAQS except for PM_{10}, which was unclassifiable (40 CFR 81.344). A discussion of current and projected regional air quality conditions is contained in Subsection 2.7.2.

VCS could have standby diesel generators, auxiliary boilers, combustion turbine generators, diesel-driven fire pumps, or other auxiliary diesel-driven equipment. Emissions from those sources are described in Subsection 3.6.3.1. The diesel generators would be operated under air permits issued by the state of Texas, if applicable. The auxiliary boiler would run only during startup/shutdown of the units. The diesel generators, combustion turbine generators, diesel-driven fire pumps, and other auxiliary diesel-driven equipment would operate periodically for testing or during an event that requires their designed use. The related emissions will be intermittent. Subsection 3.6.3.1 discusses the operation of these systems. Tables 3.6-2 through 3.6-4 describe estimated annual emissions from these sources, including equipment use estimates. Given the periodic and short-term operation of these pollution sources, the impact of operation of VCS on air quality would be SMALL and would not warrant mitigation.

The EPA defines greenhouse gases (GHG) to be gases that trap heat in the atmosphere. The primary GHG include carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and fluorinated gases. The process of generating electricity is the single largest source of carbon dioxide emissions in the United States, representing 41 percent of all such emissions (U.S. EPA 2009). Accordingly, the NRC has determined that its staff should examine the impact of greenhouse gas emissions in environmental reviews for all major licensing actions (U.S. NRC Nov 2009).

Nuclear power plants do not emit large quantities of carbon dioxide during plant operations. Testing of emergency diesel generators and combustion turbine generators and operation of auxiliary boilers are typical, intermittent operations that could emit carbon dioxide. The Generic Environmental Impact Statement (GEIS) for License Renewal of Nuclear Plants, both the current (U.S. NRC May 1996) and the more recent draft (U.S. NRC Jul 2009), address greenhouse gas emissions from operation of plants using alternative energy sources (coal, gas, etc.). These values are considerably larger than those from a nuclear plant.

NRC issued two supplemental environmental impact statements (SEISs) that address greenhouse gas emissions of nuclear plants, including the uranium fuel cycle. The Indian Point SEIS (U.S. NRC 2008) for license renewal of Units 2 and 3 provides a good summary of quantitative data on greenhouse gas emissions of the uranium fuel cycle. From these data, NRC concluded that there is a consensus that nuclear power currently releases less carbon dioxide over the life cycle than fossil-fuel-based generation. Additionally, the NRC concluded that life-cycle emissions from nuclear power plants are of the same order of magnitude as those from renewable sources.

The North Anna SEIS (U.S. NRC Dec 2009) for a COL, while less quantitative, also concluded that impacts from life-cycle greenhouse gas emissions from the proposed North Anna Unit 3 would be small and beneficial by comparison to fossil fuel alternatives.

Exelon has compiled 2008 data on greenhouse gas emissions (in CO_2 equivalents) for its 11 operating nuclear power plants. During 2008, these plants emitted approximately 64,000 metric tons (MT) of CO_2 equivalents, while generating 139 million megawatt-hours (MWh) of electricity. Using these data, Exelon concludes that its greenhouse gas emission rate is approximately 0.00046 MT/MWh. Therefore, a 1,000 MW plant operating at 90 percent capacity factor would emit 3,663 MT of CO_2 equivalent in a year. This value can be compared to values the U.S. Department of Energy prepared for the same sized fossil-fueled plants (Hagen et al. Nov 2001):

Alternative Fuel	Annual Carbon Dioxide Equivalents (metric tons)
Coal	2,098,580
Petroleum	1,640,995
Natural Gas	1,041,401

Exelon agrees with NRC's assessments on greenhouse gases and concludes that the assessment is applicable to VCS. Furthermore, Exelon data demonstrate that operational greenhouse gas emissions are nearly 3 orders of magnitude below that of equivalent fossil fuel plants. Therefore, effects of greenhouse gas emissions from VCS operations are determined to be SMALL.

5.8.1.3 Aesthetics

VCS would be visible from nearby residences, public roadways, recreation areas, and from other locations several miles from the site. There are few residences near the site. In 2000, only 403 people lived within 5 miles and only 6628 people lived within 10 miles. The major land use in the region is rangeland, and few people would be present on the rangeland to observe the site. From area roadways, VCS would be similar in appearance to the many other industrial sites that are present in the area, including Invista-DuPont. Therefore, the visual aesthetic impacts from the site would be SMALL and would not warrant mitigation.

The operation of the mechanical draft cooling towers would result in the presence of visible plumes. Specifics for modeling of the plume are contained in Subsection 5.3.3. Specifics for the length and frequency of elevated plumes are contained in Subsection 5.3.3.1.1. The plumes from the cooling towers would occur in each direction of the compass and would be spread over a wide area, reducing the time that the plume would be visible from a particular location. The average plume length and height would be relatively short, and the average plume length would not reach the site boundary except during the winter season. Plumes would extend beyond the site boundary at any one location for a maximum of only 69 hours during the winter season, and this duration would be less during each of the other three seasons. Because of the varying directions and short average plume length, aesthetic impacts from elevated plumes would be SMALL and would not warrant mitigation.

The raw water makeup (RWMU) system intake structure and pump station and the plant blowdown pipeline for VCS would be on the Guadalupe River and would be located in the vicinity of other industrial areas. Transmission corridors would be expected to follow existing corridors to the extent practicable. The transmission corridors would be similar in appearance to any other major transmission line in the area. Therefore, visual aesthetic impacts of offsite facilities would be SMALL and would not warrant mitigation.

5.8.1.4 Traffic

Operations and outage workers commuting to and from the VCS site would take U.S. Highway 77 to gain access to the site. U.S. Highway 77 and other roads in the vicinity would experience a temporary increase in traffic during shift changes. The impact of the operations and outage workers' vehicles on traffic is described in Subsection 5.8.2.2.4.

The miles driven for commuting would increase the risk of vehicle accidents involving injuries and fatalities. The number of accidents, injuries, and fatalities were estimated based on the number of miles driven by the workers to and from the site and the Texas accident data available from the National Highway Traffic Safety Administration (NHTSA Jul 2002, NHTSA 2006). An average incident rate was calculated from the most recent 5 years for which data was available, which were

1995 to 1999 for accidents and injuries and 2001 to 2005 for fatalities. Operations workers were assumed to travel to and from the site 250 days per year and outage workers were assumed to travel to and from the site 25 days per outage. All workers were assumed to commute 31 miles (the approximate round-trip distance between the site and Victoria, Texas, the closest population center). Consistent with the traffic impact analysis in Subsection 5.8.2.2.4, no carpooling was assumed. The estimated total annual miles driven by commuting operations and outage workers are 6.2 million and 1.4 million, respectively. By comparison, the miles driven in the region of influence (ROI) (as defined in Subsection 2.5.2) on a daily basis is 5.16 million miles (TXDOT 2007). Table 5.8-1 presents the estimated number of accidents, injuries, and fatalities estimated due to commuting to and from the VCS site based on miles driven and the calculated average incident rate. The estimated increase in traffic fatalities experienced in Victoria County, which averaged 17 fatalities per year from 2003 through 2007 (NHTSA 2007), would be less than 1 percent. The accidents, injuries, and fatality estimates are based on miles driven, so carpooling and other “share-the-ride” approaches would potentially reduce the transportation impacts.

Based on the estimated minimal increase in traffic fatalities associated with the operation of VCS, the overall impact is SMALL and would not warrant mitigation.

5.8.1.5 Occupational Health

Workers at a nuclear plant could be susceptible to industrial accidents such as falls, electric shock, and burns; or occupational illnesses because of noise exposure, exposure to toxic or oxygen replacing gases, caustic agents, or other industrial hazards. Exelon implements a nuclear industrial safety program at its facilities and employs industrial safety professionals at each facility to oversee the program.

In accordance with Occupational Safety and Health Administration (OSHA) requirements, Exelon would maintain records of a statistic known as “total recordable cases.” Total recordable cases include work-related injuries or illnesses that include death, days away from work, restricted work activity, medical treatment beyond first aid, and other criteria. An average incidence rate of recordable cases at Exelon nuclear sites was developed from OSHA records for the years 2002 through 2006. This rate of 0.34 percent compares favorably to both the nationwide rate for electrical power generation workers of 3.1 percent (BLS 2007a) and the 2.5 percent rate for Texas electrical power generation, transmission, and distribution workers (BLS 2007b). Exelon estimates that the routine operations workforce would include 800 on site personnel (Subsection 3.10.3). The average number of outage workers is estimated at 1750 per outage and outages are estimated to last 25 days Due to the nature of the work performed by outage workers, occupational injuries and illnesses were estimated for that portion of the workforce using construction industry incident rates. These rates are described in Subsection 4.4.1.5.

The number of occupational injuries and illnesses for the new units can be estimated as the number of workers multiplied by the applicable rate. The estimates are presented in Table 5.8-2. The estimated number of occupational injuries or illnesses based on the rate experienced at other Exelon facilities is 2.7 annually, well under estimates based on national and state annual rates, which are 22 and 25 injuries or illnesses, respectively. Accordingly, the overall impact is SMALL and would not warrant mitigation.

5.8.1.6 Other Impacts

The operation of the mechanical draft cooling towers will produce visible plumes, fogging, and salt deposition. The visible plumes may prevent sunlight from reaching the ground and this shadowing may be important for agricultural areas. Shadowing in all areas offsite was predicted to occur for less than 53 hours per season and 138 hours annually in any direction. Fogging from the operation of the cooling towers is predicted to occur for only 6 minutes per year offsite. Salt deposition due to water droplets drifting from the cooling towers would be below levels expected to cause impacts to vegetation. Elevated plumes, shadowing, fogging, and salt deposition are not expected from the operation of the cooling basin. Impacts from the operation of the cooling system would be SMALL and would not warrant mitigation.

5.8.1.7 Conclusion

Physical impacts to the surrounding population as a result of operation of the proposed VCS units would be SMALL, and would not warrant mitigation.

5.8.2 Social and Economic Impacts

The socioeconomic analysis of VCS in Victoria County, Texas is described below. The evaluation assesses impacts of operation and of demands placed on the region by the workforce. Operation of the proposed new nuclear power generating units would continue at least 40 years, with the possibility of a 20-year extension, for an operational life of up to 60 years. Exelon estimates that the operation of the facility would require 800 onsite employees (Subsection 3.10.3) and assumes that refueling outages for each unit would occur every 24 months, last approximately 20 to 25 days, and require 1750 additional temporary workers.

Major factors in determining socioeconomic impacts are the number of workers and family members that relocate to an area and where they settle. Assumptions regarding workforce characteristics, migration, and family characteristics for VCS are presented in Table 5.8-3. Assumptions regarding families, children, and the indirect workforce are described in more detail in Subsection 5.8.2.1. As stated in Subsection 3.10.3, Exelon assumes that 100 percent of the operations workforce would migrate into the region. In reality, Exelon estimates that a small percentage of this workforce would already reside within the 50-mile region and the remainder would migrate into the region. However, to be conservative, Exelon assumes that all 800 operations employees would migrate into the ROI.

As described in Subsection 2.5.2, the socioeconomic ROI for this project includes the following six counties: Calhoun, DeWitt, Goliad, Jackson, Refugio, and Victoria. Although the in-migrating operations workers could elect to reside in any of the 16 counties that lie wholly or partially within the 50-mile region, Exelon conservatively assumes that 100 percent of the 800 in-migrating operations workers would reside in the ROI. Exelon has no basis for determining what percentage of those workers would settle in any specific county within the ROI. Therefore, the socioeconomic impact analyses are presented on a regional level. Capacity information that is presented by county in Section 2.5 is also summed to indicate available capacity for the ROI as a whole. Incremental increases in resource use caused by the in-migrating workforce for VCS are compared to the available capacity of those resources within the ROI. However, such a high-level analysis might dilute project impacts that could be experienced on a more local level. Therefore, some specific resource areas (i.e., where capacity is limited) are examined more closely.

Exelon has identified the significance of the impacts as small, moderate, or large, in accordance with the criteria that the NRC established in 10 CFR 51, Appendix B, Table B-1, Footnote 3, as follows:

SMALL — Environmental effects are not detectable or are so minor that they will neither destabilize nor noticeably alter any important attribute of the resource.

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

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

These impact significance terms (small, moderate, large) are assigned to both the ROI-level and county- or resource-level analyses. However, the terms are shown in all capitals for the ROI-level analyses only. This is because the ROI level is the only level that can be analyzed with relative certainty. County-level impact significance terms are included for informational purposes only, and they are shown in lower case letters. The only exception to this is Subsection 5.8.2.2.2, *Taxes*, where determination of impacts can be made on a sub-ROI level with relative certainty. In that subsection, sub-ROI-level significance terms are shown in all capitals.

5.8.2.1 Demography

The 2000 population within the 50-mile radius of VCS was approximately 239,411 and is projected to grow to approximately 414,902 by 2080 (Table 2.5.1-1). The 2000 population in the ROI was approximately 153,895 and is projected to grow to approximately 202,297 by 2040 (Table 2.5.1-4).

As stated in Subsection 5.8.2, Exelon anticipates that 800 workers would migrate into the ROI to support the operations of the proposed new units.

The in-migration of 800 workers would create additional indirect jobs in the area because of the “multiplier” effect. Under the multiplier effect, each dollar spent on goods and services by an in-migrant becomes income to the recipient who saves a portion but re-spends the rest. In turn, this re-spending becomes income to someone else, who in turn saves part and re-spends the rest. The number of times the final increase in consumption exceeds the initial dollar spent is called the multiplier. The U.S. Department of Commerce’s Bureau of Economic Analysis (BEA), Economics and Statistics Division, provides multipliers for industry jobs and earnings (BEA Mar 2008). Their economic model, RIMS II, incorporates buying and selling linkages among regional industries, and provides multipliers by industry sector to estimate the impacts of changes in that sector to a regional economy. This analysis uses the detailed multipliers for the power generation and supply industry to estimate the number of indirect jobs and the impact of VCS-related expenditures in the ROI. Table 5.8-4 provides direct and indirect employment data for the ROI.

As stated in Subsection 4.4.2.1, for every in-migrating operations worker, an estimated additional 1.7786 jobs would be created in the ROI (BEA Mar 2008). During the operations period, VCS staffing would peak at 800 jobs. Spending by the 800 directly employed operations workers during this period would support 1423 indirect jobs in the ROI, for a total of 2223 jobs (both direct and indirect) (Table 5.8-4). The VCS operations positions (197) that would have been created during the peak construction period would continue to exist in the operations period and are part of the 800 positions. There would be no VCS-related construction jobs created during the operations period. Therefore, the indirect jobs created by the spending of the 197 operations workers employed during the peak construction period would continue to be supported by those same 197 operations workers’ spending during the operations period. These 197 positions were added to the 603 operational positions that were not staffed during the peak period of construction, but are expected to be filled during the operations period, for a total of 800 VCS jobs.

Exelon expects that the indirect jobs would be filled by two primary sources: workers vacating construction-related indirect jobs[3] at construction completion and working-age members of in-migrating VCS worker families. Table 5.8-4 presents these assumptions and calculations. Approximately 3760 workers would vacate construction-related indirect jobs at construction completion (Table 5.8-4) and be available to work on operations-related indirect jobs. Assuming that 52 percent of the 800 in-migrating worker families would have a second working spouse, an additional 416 people would be available to fill indirect jobs. (In Texas, in 2006, 52 percent of married

3. In reality, many of the construction-induced indirect jobs would continue beyond construction completion and become operations-induced indirect jobs. Workers in those jobs would remain through the transition.

couples had both husband and wife in the labor force [USCB 2006].) Combined, these two sources could provide 4176 workers (Table 5.8-4) to fill the indirect jobs created.

To estimate the family characteristics of the operations workforce, Exelon evaluated the NRC study, *Migration and Residential Location of Workers at Nuclear Power Plant Construction Sites* (BMI Apr 1981) and U.S. Census Bureau (USCB) data. Published in 1981, the Battelle Memorial Institute (BMI) study was based on 49,000 observations from 28 surveys at 13 nuclear power plant construction sites. The study sought to improve the accuracy of socioeconomic impact assessments by providing an improved methodology for predicting the number of in-migrating workers and their residential location patterns at future nuclear power plant construction projects. Though the study was an analysis of construction workforce in general, information about nuclear plant nonconstruction workers (i.e., managers, engineers, supervisors, clerical, security, and medical personnel who were on the site during construction) was also included. Because “nonconstruction workers” have similar characteristics to operations workforce, their data is useful for this analysis.

As stated previously, Exelon assumes that 100 percent of the 800 workers would bring families. According to the BMI study, the average family size of a nuclear plant nonconstruction worker was slightly less than 3.25. According to the USCB (USCB 2000), average family sizes in the ROI in 2000 ranged from 3.02 in Goliad County to 3.23 in Victoria County, while the average family size for the state of Texas was 3.28[4]. Therefore, Exelon assumes that the average family size of 3.25, used for the construction workforce in Subsection 4.4.2.1, would also be a reasonable estimate for the operations workforce. Thus, 800 in-migrating operations workers would bring 1800 family members (800 x 2.25), for a total of 2600 people (Table 5.8-3). The BMI study reported that, while construction workers averaged 0.8 school-age children per family, nonconstruction workers had an average of 0.6 school-age children per family. However, to provide a more conservative impact estimate, Exelon estimates that, like the construction worker families, each of the 800 operations families would bring 0.8 school-age children, for a total of 640 children (800 x 0.8) (Table 5.8-3).

The VCS-related population increase in the ROI during operations[5] (800 workers plus 1800 family members) is 2600 people. This represents an increase of 1.7 percent over the 2000 population for the ROI, 1.5 percent over the ROI’s projected 2010 population, and 1.4 percent over the ROI’s projected 2020 population level (Table 2.5.1-4[6]). Because the VCS-related population increases would be 1.7 percent or less, impacts to the ROI as a whole would be SMALL. In each county, impact levels would depend on the distributions of the in-migrating worker households. Less populated ROI counties could experience small to large impacts and more populated counties, like Victoria County,

4. Year 2006 estimates of family size were not available for all of the counties in the ROI, so the 2000 Census data was used to ensure a consistent comparison within the ROI.
5. The operations phase involves a consistent staffing level of 800 workers; therefore, the term “peak” is not relevant.
6. Note that these population calculations are conservatively based on the sum of the six counties comprising the ROI, not on the population of the 50-mile radius (which also includes portions of other counties).

whose population is more than 55 percent of the ROI total, would likely experience small to moderate impacts. Goliad and Refugio counties could only accommodate 360 and 380 additional people (over their 2006 estimates), respectively, before impacts would become moderate (Subsection 2.5.1).

5.8.2.2 Impacts to the Community

5.8.2.2.1 Economy

The impacts on the local and regional economy resulting from the operation of VCS would depend on the region's current and projected economy and population. The economic impacts of a potential 60-year period of operation are described below.

The employment of the operations workforce for such an extended period of time would have economic impacts throughout the ROI. Victoria County would be the most affected county, because the County and the Victoria Independent School District (ISD) would receive property tax revenues assessed on the new units[7]. Because the residential distribution patterns of the in-migrating operations workers are not known at this time, the location of some impacts cannot be predicted. However, the influx of people spending wages, paying taxes, building new houses or occupying existing houses, and using public services and utilities could have a more noticeable impact on the smaller counties in the ROI due to their smaller populations.

In addition to the operations workforce of 800, temporary workers would periodically support refueling outages (Subsection 5.8.2). Each refueling outage is assumed to last 20–25 days and involve 1750 temporary workers. For this analysis, Exelon assumes that the proposed new units would not experience simultaneous outages; one outage per year would occur at VCS.

Income Impacts from Operations Workers

As part of the analysis of income impacts to the ROI, Exelon examined BEA wage data for all industry sectors combined and, when available, for the utilities industry (Sector 22) and the nuclear electric power generation industry (Sector 2211133). However, much of the sector information for the ROI counties and nearby metropolitan areas was not disclosed, or the industry sector was not relevant to a specific county so no information was available. Therefore, as a surrogate, Exelon examined wages in these industries in four states for which the information was available (Illinois, New Jersey, Pennsylvania, and South Carolina). As Table 5.8-5 shows, wages for the utilities sector tend to be substantially higher than wages for all sectors combined, and wages in the nuclear electric power generation industry are higher yet. Figure 5.8-1 illustrates these variations. The relatively higher

7. As described in Subsection 2.5.2.3, the Refugio ISD would also receive property tax revenues from a portion of the VCS site, but because of the projected land use on that property, that property would likely be assessed at a lower valuation than the portion subject to Victoria ISD property taxes. See Subsection 5.8.2.2.2 for a discussion of tax impacts related to the operation of VCS.

wages earned by the in-migrating operations workers would affect their choices of housing and other services.

Exelon also obtained national data from the Bureau of Labor Statistics for annual average wages for two occupations, nuclear power reactor operators ($70,800), and nuclear technicians ($64,760) (BLS 2008d). Technicians, administrative, and support personnel would comprise the majority of the operations workforce, so the lower wage was used to provide a more conservative estimate of wage impacts. Based on the annual average nuclear technician's wage of $64,760, Exelon estimated the total annual payroll for the operations workers at $51.8 million (Table 5.8-6).

The operations workforce would purchase goods and services, creating a multiplier effect that would result in an increase in business activity, particularly in the retail and service industries. (Multipliers are described more fully in Subsection 4.4.2.2.1.) As noted earlier, Exelon assumes that 100 percent of the operations workforce would migrate into the ROI, and would spend some portion of their wages within the ROI. To estimate these economic impacts, a regional earnings multiplier for the power generation and supply industry sector 1.6355 (BEA Mar 2008), was applied to the estimated total wages earned per year. According to these calculations, the total impact of worker wages on the ROI could range from $8,473,198 to $84,731,984 per year, depending on the proportion of worker wages spent within the ROI. Table 5.8-6 presents a sensitivity analysis of impacts from workers spending between 10 percent and 100 percent of their wages within the ROI[8]. The total estimated impact (wages with the multiplier applied) represents an increase of 0.19 percent to 1.94 percent to the ROI's 2005 total personal income, which would be a SMALL and positive impact. However, as described in Subsection 4.4.2.2.1, these impacts could be overstated, as total personal income in the ROI is likely to grow independently of VCS. In that case, operations wages would represent a smaller proportion of total personal income, but impacts would remain positive and SMALL. As noted previously, the influx of people spending wages could have a more noticeable beneficial impact on the individual counties in the ROI.

Employment Impacts from Operations Workers

As stated in Subsection 5.8.2.1, for every VCS operations job, an estimated additional 1.7786 (BEA Mar 2008) indirect jobs would be created, which means that the 800 direct jobs would provide an additional 1423 jobs, for a total of 2223 jobs. This additional job estimate is based on the assumption that 100 percent of the operations workforce would migrate into the ROI. If less than 100 percent of the workers relocated into the ROI, then proportionally fewer indirect jobs would result.

8. Note that even though Exelon assumes that 100 percent of the operations workforce would reside in the ROI, it is unlikely that 100 percent of worker income would be spent within the ROI, given the proximity of the nearby large metropolitan areas of Houston, San Antonio, and Corpus Christi.

In 2006, the ROI had 74,776 employed people. Therefore, 2223 additional workers would represent a 3.0 percent increase over 2006 employment levels (Table 5.8-7). However, by the time VCS begins operations, it is likely that total ROI employment would be greater and that the additional jobs would represent a smaller percentage of the total employment. Regardless, this increase would be a positive and SMALL impact to the ROI's economy.

Most of the 1423 indirect jobs would likely be service-related, not highly specialized, and filled by the existing labor force within the ROI, or spouses of in-migrating VCS staff. The operations workforce would reach full staffing near the last year of VCS construction. In 2006, the unemployment rate in the ROI was 4.3 percent, representing 3391 people, a decline from 5.2 percent during the previous decade (Table 2.5.2-1). Even if the unemployment rate were to decline further prior to VCS operation, it is likely that there would be a more than adequate labor force to fill the indirect jobs created by the in-migrating operations workers. Also, Exelon assumes that some workers filling indirect jobs during construction could elect to remain in the area and be available to fill indirect jobs created by operations workers.

The indirect jobs would have a positive impact on the local economy and, to the extent that jobs were filled by unemployed local workers, would reduce unemployment, an additional beneficial impact. Because the residence distribution and shopping patterns of the in-migrating workers are not known at this time, Exelon cannot predict where the beneficial impacts might occur within the ROI counties. However, each county would experience small to moderate beneficial impacts.

Impacts from Outage Workers

For any given outage, Exelon assumes the number of temporary workers would be 1750, and the duration of the outage would be between 20 and 25 days. For this analysis, Exelon assumes that all temporary workers would come from outside the ROI. To estimate the economic impacts of each outage, the national annual average nuclear technician's wage of $64,760 was divided by 360 to obtain a daily average wage of approximately $180. Because of the possible variation in the outage duration, Exelon estimated a "low" and "high" level of impact. These calculations are provided in Table 5.8-8, which shows that the total annual payroll for outage workers would range from $6,296,111 to $7,870,139. When the earnings multiplier (1.6355) is applied, impacts to the ROI could range from $1,029,729 to $12,871,612, representing an increase of 0.02 percent to 0.30 percent in the ROI's 2005 total personal income. The sensitivity analysis reflects the uncertainty surrounding the proportion of wages that would be spent within the ROI (from 10 percent to 100 percent).

Because of the short duration of outages, it is unlikely that noticeable employment impacts would occur in the ROI as a result of the temporary worker influx. However, there could be temporary and short-term job opportunities for lodging and restaurant workers to serve the outage workforce, along with SMALL and positive impacts to motels, restaurants, retailers, and other businesses patronized by the outage workers.

5.8.2.2.2 Taxes

Several types of taxes would be generated by the operations of VCS. For this analysis, a dual unit plant was assumed. Exelon would pay franchise, sales, and property taxes based on the value of and power generated by the new units and on operating expenditures. Operations workers and their families would also contribute sales and property tax revenues to the area.

Subsection 4.4.2.2.2 provides a detailed description of the significance categories applicable to tax impacts, which are derived from the analysis in the GEIS for License Renewal of Nuclear Plants (U.S. NRC May 1996). Exelon has reviewed this methodology and determined that the significance levels are appropriate to apply to an assessment of tax impacts as a result of VCS operations. In summary, significance levels are considered small if new tax payments are less than 10 percent of the taxing jurisdiction's revenue, moderate if payments are 10 percent to 20 percent, and large if payments represent more than 20 percent of total revenue.

Personal Income and Corporate Franchise Taxes

As noted in Subsection 2.5.2.3, Texas has no personal income tax. The state's primary business tax is the franchise tax, which the Texas legislature extended to cover most corporations. Those changes took effect January 1, 2008.

The franchise tax is a gross margin tax (i.e., it is calculated on revenues less allowable operating costs). Therefore, Exelon would become liable for these taxes when the first unit goes into operation and begins producing revenue. Under the Texas energy industry's currently unregulated environment, neither revenues nor operating costs are fully predictable several years in the future. Therefore, in order to estimate the magnitude of impacts on the local economy, Exelon has estimated a range for annual franchise tax payment for a scenario of two VCS units, with payments based on a hypothetical estimated gross margin for each unit of $350 to $550 million per year. When both units become operational, the hypothetical estimated gross margin would total $700 to $1100 million per year (these hypothetical scenarios are based on assumptions that VCS would be 100 percent privately owned by Exelon and fully subject to the franchise tax).

Under these hypothetical scenarios, Exelon would pay an estimated $3.5 to $5.5 million in franchise taxes in the first year of operation for the first unit. When the second unit comes on line, Exelon would pay an estimated $7.0 to $11.0 million in franchise taxes annually (Table 5.8-9).

Texas franchise tax revenues in 2007 were approximately $3.1 billion (TCPA 2008a). Because the tax applicability changed substantially at the beginning of 2008, it is not possible to project the state's franchise revenues to the years when the units could begin commercial operation. However, the projected payments for VCS represent well under 1.0 percent of the state's 2007 franchise tax revenues, and it is reasonable to assume that the state's franchise tax revenues will increase over the coming years. Thus, Exelon's payments for VCS would likely represent an even smaller percentage of the state's total in future years. The franchise tax payments for VCS beginning in 2017, for example, would represent a SMALL and positive impact to the state of Texas for franchise tax collections. As described in Subsection 2.5.2.3.2, Texas uses franchise tax and other revenues to fund various programs and activities around the state. As shown in Table 2.5.2-13, the ROI received approximately 0.7 percent of the state's total county expenditures in 2006. Therefore, based on the hypothetical scenarios described above, the ROI counties would receive an estimated $49,000 to $77,000 in state expenditures, representing an increase of 0.010 percent to 0.016 percent over the 2006 state expenditures in the ROI. Impacts to the ROI from the increased state franchise tax revenues would be SMALL and positive.

In addition to direct taxes paid for VCS, local operating expenditures, and purchases by the operations workforce would affect the local economy, where money would be spent and re-spent within the region (Subsections 4.4.2.2.1 and 5.8.2.2.1). Consequently, ROI businesses, particularly retail and service sector firms, would experience revenue increases, and there could be prospects for new startup firms and additional job opportunities for local workers. Existing and new firms could generate additional profits, which would further contribute to increased franchise taxes, although the exact amount is unknown. Impacts would be positive and SMALL relative to overall state franchise tax revenues.

Sales and Use Taxes

The state of Texas and the local governments in the ROI and nearby metropolitan areas would experience an increase in the amount of sales and use taxes collected. Additional sales and use taxes would be generated from operating expenditures by VCS and by retail purchases by the operations workforce.

At the present time, the amount of local operational expenditures is not known. However, in order to estimate the magnitude of the impact to local entities from increased sales tax revenues, Exelon estimated future sales taxes for Victoria County and the city of Victoria, as shown in Table 5.8-10. Three hypothetical scenarios were then analyzed, with taxable purchases ranging from $500,000 to $1.5 million, and sales taxes were computed for both jurisdictions. Table 5.8-11 presents the results of these calculations. Under these scenarios, the tax revenues would represent an increase of 0.02 percent to 0.06 percent over the projected revenues for the first year both units are in operation. This would be a positive and SMALL impact. Projected state sales taxes on the hypothetical expenditures were compared to 2007 state sales tax revenues. State sales tax revenues would increase by 0.0002 percent to 0.0005 percent, a SMALL but positive impact.

Currently, it is difficult to assess the extent of impact on sales and use tax collections from the operations workforce, because spending would depend on residence patterns. Victoria and Victoria County are the retail center for the ROI; the other ROI counties are predominantly rural. Some shopping would undoubtedly also occur in the nearby metropolitan centers of Houston, San Antonio, and Corpus Christi. Within the ROI, it is likely that Victoria and Victoria County would realize the greatest increase in, and derive the greatest benefit from, sales tax collections, although this would be a SMALL positive impact relative to their overall sales tax revenues. However, it is also likely that the smaller ROI towns could experience small to moderate positive impacts from increased sales tax collections.

Operations workers would pay Texas sales or use tax on all items purchased within the state (or purchased elsewhere but subject to state use tax), regardless of whether the purchase was made within the ROI. In absolute terms, the amount of state sales and use taxes collected from the operations workers over a potential 60-year operating period could be substantial, but would represent only a small increase in the total amount of taxes collected by Texas. Therefore, the impacts would be SMALL and positive to the state as a whole.

As noted in Subsection 4.4.2.2.2, the cities of Victoria, Edna, and Goliad collect sales tax on telecommunications, which new residents would pay, and accommodations taxes, which VCS visitors would pay. While the actual amounts collected by each jurisdiction as a result of VCS operations are not known at this time, impacts are expected to be SMALL and positive.

Other Sales- and Use-Related Taxes

Visitors to VCS during plant operations as well as temporary workers employed for outage activities over the life of the new units, would use local motels and pay the hotel occupancy tax that is imposed by the state of Texas (currently 6 percent) and the cities within the ROI (currently 7 percent) (Subsection 2.5.2.3.3). Victoria would realize small benefits from these tax collections, and benefits to other cities in the ROI could be SMALL to MODERATE, depending on visitor choices for hotel accommodations. Impacts to hotel tax collections by the state of Texas would be SMALL and positive.

Property Taxes

Victoria County and Special Districts

During VCS operations, Exelon would pay property taxes to Victoria County, three special taxing districts, and two ISDs. Exelon estimates its total payment to all taxing entities would be approximately $24 million annually.

During the operation of VCS, the assessed valuation of the plant would be based on some combination of cost, income from the sale of electric power, and the units' market value. Some inputs to the formulas could be negotiated between Exelon and the appraisal district.

One of the main sources of economic impact related to the 60-year operation of VCS would be property taxes assessed on the facility. Based on each year's appraised valuation, Exelon would pay property taxes to Victoria County (General Fund and Road and Bridge Fund), Victoria County Junior College District, Victoria County Navigation District, and Victoria County Groundwater District (Table 2.5.2-20).

In 2006, the current landowners of the Exelon site paid these taxing jurisdictions a total of $5238, which represented 0.03 percent of the total tax levies for those jurisdictions. The taxable value of the 11 parcels making up the VCS site was $897,420 or 0.02 percent of the total Victoria County taxable value for the five entities (Table 5.8-12).

Property taxes to be paid by Exelon for VCS during operation would depend on many factors, including millage rates and taxable value. However, after VCS begins operation, the appraised value of the property would be substantially higher than it is currently. Therefore, it is likely that the tax payments to Victoria County and the special taxing districts would provide a MODERATE to LARGE positive impact to those taxing jurisdictions and to the local economy.

To gain a better understanding of the possible magnitude of its property tax impacts, Exelon estimated future property tax revenues for Victoria County, using the average annual growth rates in property tax revenues from 1991 to 2006. Because the rate of growth increased noticeably between 2000 and 2006, the analysis used both a "low" rate (based on growth from 1991–2006) and a "high" rate (based on 2000–2006 growth) for the projections, which are shown in Table 5.8-13.

Exelon estimated a property tax valuation for the plant at $2 billion, computed the tax, and then compared the tax to the projected property tax revenues for Victoria County. The results are presented in Table 5.8-14 and show that the potential tax payment would provide an increase of 15.5 percent to 16.8 percent over projected values, resulting in a positive and MODERATE to LARGE impact to the county, its residents, and the local economy.

New residents associated with the operation of VCS would also pay property taxes in the ROI counties where they choose to reside, although it is not possible at this time to estimate the amount of these impacts and know which entities would be affected. These increases would have a positive and SMALL impact on tax revenues in more heavily populated jurisdictions such as Victoria County, but in the more rural ROI counties with smaller populations, the relative impacts would be positive and SMALL to MODERATE.

Independent School Districts

As described in Subsection 2.5.2.3.5, the current landowners of the VCS site pay taxes to the Victoria and Refugio ISDs. As described in Subsection 4.4.2.2.2, Exelon has determined that the VCS site would be located on a parcel within the Victoria ISD boundaries. Therefore, increases in the valuation and tax payments for that parcel would be substantial, although it is possible that payments to the Refugio ISD would also increase to an unknown extent.

As a result of current Texas school funding guidelines for wealth equalization, it is not possible at this time to estimate the impacts of additional revenues to the Victoria ISD, which is currently designated a property-poor district (see Subsections 2.5.2.3.5 and 4.4.2.2.2 for a more detailed discussion of wealth equalization). According to the ISD business manager (VISD Apr 2008a), a substantial increase in property tax revenues could change the district's status to property-wealthy. In this case, "excess" revenues would flow to the state of Texas for redistribution to property-poor districts, after adjusting for the probable increase in enrollment that would accompany the influx of operations workers. Although the amount of the increased tax payments is unknown at this time, the larger payments would provide a relatively SMALL positive impact to the state of Texas as a whole. If Texas were to change its school funding mechanism, impacts to school districts would be different in a way that is not possible to predict at this time.

The Refugio ISD is a property-wealthy district (Subsection 2.5.2.3.5), so increased tax revenues would have only a small and positive impact. Again, any increased enrollments would alter the funding received from the state, which depends on weighted average daily attendance as well as the ISD's tax base.

The in-migrating workers required to operate VCS could result in larger enrollments in ROI schools that would receive no property tax revenues from VCS. Because the Texas school funding formula is based on weighted average daily attendance, increases in the number of students would lead to increased revenues for the affected ISDs, but would also result in the additional expenses related to a larger student body. Fiscal impacts to these ISDs from increased enrollment would be small to moderate, depending on their existing capacity, funding status, and fiscal condition. Subsection 5.8.2.2.8 discusses capacity and enrollment issues in detail.

Recently passed legislation could decrease Exelon's property tax obligations to the Victoria ISD without reducing the ISD's overall revenues (Subsection 4.4.2.2.2). The new law allows school districts to reduce the taxable value of newly constructed or expanded nuclear plants, and allows the plants to defer the effective date of an abatement agreement for up to 7 years after the date of the agreement.

Summary of Tax Impacts

The overall potential beneficial impacts of taxes collected during the operation of VCS would be positive and SMALL to LARGE in the counties and other taxing jurisdictions within the ROI, and positive and small in surrounding areas and in the state of Texas.

5.8.2.2.3 Offsite Land Use

Impacts to offsite land use from operations activities would be driven by the number of in-migrating workers and the places those workers would choose to live. Section 2.2 and Subsection 2.5.2.4 discuss the current land use in the ROI in detail. Section 4.1 and Subsection 4.4.2.2.3 discuss likely changes in land use induced by VCS-related construction activities. Land use during the initial phase of operations would mirror land use at the conclusion of construction because most land use conversions during construction would be in place before operations begin.

Assumptions regarding operations workforce characteristics, workforce migration, and family characteristics of the workforce for VCS are presented in Table 5.8-3. Assumptions regarding families, children, and the indirect workforce are described in more detail in Subsection 5.8.2.1. As shown in Table 5.8-3, the total number of people assumed to migrate into the ROI during operations phase would be 2600.

NRC Guidance

In the GEIS for License Renewal (U.S. NRC May 1996), the NRC presents its method for defining impacts to offsite land use during refurbishment (i.e., large construction activities). Exelon reviewed this methodology and determined that the significance levels were appropriate to apply to an assessment of offsite land use impacts as a result of construction activities for two proposed new reactors.

The ROI counties are the focus of this land use analysis because VCS would be built in Victoria County and most of the workforce employed during construction would migrate into one of the ROI counties (Subsection 2.5.2). In NUREG-1437, the NRC concluded that impacts to offsite land use during refurbishment at nuclear plants would be:

SMALL — If plant-related population growth results in very little new residential or commercial development compared with existing conditions and if the limited development results only in minimal changes in the area's basic land use pattern.

MODERATE — If plant-related population growth results in considerable new residential and commercial development and the development results in some changes to an area's basic land use pattern.

LARGE — If plant-related population growth results in large-scale new residential or commercial development and the development results in major changes in an area's basic land-use pattern.

Further, the NRC defined the magnitude of population-induced land use changes as follows:

SMALL — If plant-related population growth is less than 5 percent of the study area's total population, especially if the study area has established patterns of residential and commercial development, a population density of at least 60 people per square mile, and at least one urban area with a population of 100,000 or more within 50 miles.

MODERATE — If plant-related population growth is between 5 percent and 20 percent of the study area's total population, especially if the study area has established patterns of residential and commercial development, a population density of 30 to 60 people per square mile, and one urban area within 50 miles.

LARGE — If plant-related population growth is greater than 20 percent of the area's total population and density is less than 30 people per square mile.

Operations-Related Population Growth

During operation, 800 operations workers are estimated to migrate into the ROI. It is assumed that no indirect workers would migrate into the ROI because the indirect jobs created by VCS operations-related activities could be filled by working spouses of in-migrating operation workers, unemployed workers within the ROI, or workers who filled the indirect jobs during the construction period and chose to remain in the area. Some of those workers would likely continue to reside and work in the ROI during the operations period. As described in Subsection 5.8.2.1, in-migrating direct operations workers and their families would represent a population increase of less than 1.7 percent of the 2000 population in the ROI and approximately 1.5 percent of the projected 2010 population (Table 2.5.1-4). The very small increase in VCS-related population compared to the 2000 ROI population or to the ROI VCS-related population increase during construction (when the ROI population could increase by almost 20,000 people), would not result in a marked upswing in residential and commercial construction activity. The large out-migrating construction workforce would vacate more resident property than in-migrating operating workers could use. At the start of operations, commercial construction activities would also be minimal because the in-migrating operations workforce would require fewer commercial enterprises. Therefore, little additional land conversion would be expected as a result of operations.

ROI Impacts

The vacant housing stock available in the ROI at the conclusion of construction would likely be sufficient to accommodate all of the in-migrating operations worker households if the type, price, condition and other characteristics met the workers' needs. However, the higher wages of the operation workers could result in a demand for more higher-priced housing than the available inventory created by the lower-wage earning out-migrating construction workers. Also, because the average wage of an operations worker is expected to be significantly higher than the mean salary in the ROI, there may be some additional land conversion to satisfy the desire for new, higher-priced housing. However, the availability of existing vacant housing in the ROI suggests that widespread conversion of undeveloped land to residential use would still be unlikely. Because the operations period is far in the future and housing preferences are fluid, it is difficult to predict the match of the likely available housing to the desired housing characteristics of the operations workers. However, Exelon concludes that there would be sufficient housing available in the ROI to meet operations-related demand.

As the ROI would experience changes in population with the out-migration of the construction workforce, some commercial property would also likely be vacated. Because the operations workforce is considerably smaller than the construction workforce, less commercial space would be required to support the goods and service demands of the operations households.

The VCS-induced population growth in the ROI would likely result in little new residential or commercial development when compared with existing conditions or conditions that would be expected at the completion of construction. The limited development would result in minimal changes in the area's basic land use pattern described in Subsection 2.5.2.4. Impacts in the ROI would be SMALL and not warrant mitigation.

County-level Impacts

If large portions of the in-migrating operations workforce choose to live in DeWitt, Goliad, Jackson, or Refugio County and construction-related workers had not chosen to live in those counties, impacts would be more noticeable. In both Calhoun and Victoria County, the impacts would be smaller and more readily absorbed because of the non-VCS-related land conversion activities already taking place there. Calhoun and Victoria Counties have been, and will likely continue to be, experiencing land use conversion activities because of non-VCS-related population increases. Impacts to individual counties would range from small to moderate.

Summary

According to NRC guidelines, impacts from operations-related population changes are considered SMALL if the plant-related population growth is less than 5 percent of the total population of the ROI. Impacts from the VCS-related population growth would be SMALL; VCS-related population growth is estimated to be less than 2 percent of the 2000 population and less than 2 percent of the projected 2010 population.

VCS-related population growth would result in little new residential development, given the inventory of vacant housing that would result from the departing construction job force, and would result only in minimal changes, of any type, in the area's basic land use pattern. Offsite land use changes would be SMALL in the ROI.

At the county level, offsite land use impacts would range from small to moderate. Impacts to counties would be small if operations workers elected to reside in the counties in which the construction workers resided, because land conversion would have occurred during construction and the land would remain in the converted use. The existing and converted-during-construction land could accommodate all the operations worker households and commercial needs. However, if a large portion of operations workers elected to reside in the less populated counties (DeWitt, Goliad, Jackson, and Refugio) and most of the construction workers had elected to live in Calhoun and Victoria counties, then land use impacts from operations could be moderate in the less populated counties. These impacts would be due to conversion of some land in those counties from undeveloped parcels to residential, commercial, industrial, or public use. At this time, Exelon has no basis for predicting the residential distribution of the operation workers. Exelon notes that the operations worker households' residential distribution could reflect or be markedly different from residential distribution of construction workers. The impacts to land use during operations would be based on current land use, land use conversions occurring during construction, and non-VCS related changes in the ROI population.

To mitigate impacts, Exelon would communicate with local and regional governmental and nongovernmental organizations including the Golden Crescent Planning Commission, local chambers of commerce, real estate developers and agencies, and economic development organizations. Exelon would share information such as project activity scheduling, housing concerns, business development opportunities, and regional economic growth and stabilization topics thus giving these organizations the opportunity to make informed decisions in light of the proposed operation of VCS.

5.8.2.2.4 Transportation

The impacts to transportation and traffic from operation of VCS would be greatest on the roads in Victoria County, particularly U.S. Highway 77, the four-lane highway which provides the only access to the site. Impacts to traffic are determined by four elements: (1) the number of operations workers and their vehicles on the roads, (2) the number of shift changes for the operations workforce, (3) the projected population growth rate in Victoria County, and (4) the capacity of the roads.

Exelon estimates it would employ an operations workforce of 800 workers at the VCS site. Exelon evaluated up to an additional 2000 workers commuting to and from the site during outages. This bounds the expected outage requirement for 1750 additional temporary workers. The workforce (and outage workforce) would access VCS via U.S. Highway 77. This transportation analysis conservatively assumes one worker per vehicle.

For this analysis, Exelon has assumed that the entire 800-person operations workforce would be split among three shifts and a 2000-person outage workforce would be split between two shifts. Because these assumptions overestimate the actual numbers of workers and vehicles per shift, they also overestimate the traffic impacts.

For the purpose of this analysis, Exelon has assumed that the operations workforce day shift would run from 7:30 a.m. to 4 p.m., the back shift would run from 4 p.m. to 11 p.m., and the night shift would run from 11 p.m. to 7:30 a.m. Forty percent of the operations workforce would comprise the day shift, 30 percent would comprise the back shift, and 30 percent would comprise the night shift. Exelon assumes the two outage shifts would run from 7:30 a.m. to 7:30 p.m. and from 7:30 p.m. to 7:30 a.m. and that each shift would comprise 50 percent of the outage workforce.

Roadway traffic is classified by the ability of drivers to maneuver and the maintenance of the traffic flow. There are no Transportation Research Board “Level of Service” determinations for Texas roadways. Texas DOT uses a “Functional Class” system that rates roadways from 0 to 9 and A to C. This rating system was used to develop Table 2.5.2-7. Exelon assumes that the maximum vehicle capacity on a divided four-lane “other rural principal arterial” roadway, such as U.S. Highway 77 in Victoria County, would be 11,800 passenger cars per hour. The maximum vehicle capacity on a two-lane “rural major connector,” such as SR 239 would be 2300 passenger cars per hour (Table 2.5.2-7). Because the residential distribution of the operations and outage workforce cannot be determined, Exelon has analyzed traffic impacts to U.S. Highway 77 and SR 239 as surrogates for all roads that would be affected by the VCS operations. U.S. Highway 77 is the only access road to the VCS site so it would experience the greatest traffic impacts; however, Exelon acknowledges that feeder roads to U.S. Highway 77 and other roads in the region would experience impacts, though the impacts would be smaller. Feeder roads that likely would have increased traffic, as a result of VCS operations, include U.S. Highways 183, 87, 77A, and 59, and SRs 239 and 202. The Victoria County population is estimated to have an average annual growth rate from 2000 through 2020 of 1.1 percent (Table 2.5.1-4). Any increase in traffic due to growth would be small and is not further considered in this analysis. Exelon conservatively estimates that 20 truck deliveries would be made daily to the site. Exelon would schedule truck deliveries so that they would not coincide with shift changes, and consequently, this increase in vehicle traffic is not analyzed further.

Shift changes during an outage would have the largest impact on traffic, with 560 operations vehicles (70 percent of the workforce, regardless of shift change) and 2000 outage vehicles, for a total of 2560 vehicles entering or exiting the site. Exelon assumes that all vehicles would use a single access road. Exelon plans to ease traffic congestion of the access point by constructing turn lanes at the intersection of U.S. Highway 77 and the access road to minimize impediments to a constant traffic flow.

Traffic on U.S. Highway 77 north of the proposed site, as measured by the 2007 Average Annual Daily Traffic (AADT), was 16,300 vehicles per day (Table 2.5.2-7 and Figure 2.5.2-5; location 17). Based on the AADT, and assuming that the maximum number of vehicles on U.S. Highway 77 in a single hour would be 10 percent of the daily average, Exelon estimated the maximum number of cars on U.S. Highway 77 in a single hour as 1630. In this analysis, Exelon conservatively assumes that all VCS worker traffic (2560 vehicles) would use U.S. Highway 77 from the north to access the site.

During shift change during an outage, with a maximum estimated traffic count of 1630 vehicles per hour and 2560 additional cars on the road because of VCS operations, the total estimated maximum number of cars per hour would be 4190. U.S. Highway 77 would not exceed its carrying capacity of 11,800 passenger cars per hour.

SR 239 intersects U.S. Highway 77 south of the VCS. Traffic on SR 239, southwest of the proposed site, as measured by the 2007 AADT, was 720 vehicles per day (see Table 2.5.2-7 and Figure 2.5.2-5; location 19). Based on the AADT, and assuming that the maximum number of vehicles on SR 239 in a single hour would be 10 percent of the daily average, Exelon estimated the maximum number of cars on SR 239 in a single hour as 72. In this analysis, Exelon conservatively assumes that 25 percent of all VCS operations and outage worker traffic (640 vehicles) would use SR 239 from the southwest to access the site.

During night/day shift change during an outage, with a maximum estimated traffic count of 72 vehicles per hour and 640 additional cars on the road because of the VCS workforce, the total estimated maximum number of cars per hour would be 712. SR 239 would not exceed its carrying capacity of 2300 passenger cars per hour.

Increased traffic as a result of operations would have a SMALL impact on the roads in the vicinity of the site and mitigation other than that already described would not be necessary.

5.8.2.2.5 Recreation

This subsection describes the aesthetics and use impacts of the proposed VCS and its associated facilities on recreation opportunities in the 50-mile region. Subsection 2.5.2.5 presents basic information on recreation in the VCS vicinity and 50-mile region. Section 3.1 details the plant layout and external appearance. Subsection 5.8.1.3 analyzes the aesthetic impacts of VCS and associated facilities.

As stated in Subsection 4.4.1.4, the major land uses within a 6-mile radius of the VCS site are rangeland, forest land, and agricultural land. The topography of the region and the site is relatively flat and sparsely populated with trees. Currently, it is planned that the temporary construction facilities identified in Subsection 4.4.1.4 would be decommissioned after the construction phase.

In addition to the physical structures and infrastructure of the station, operational activities would produce visual and physical impacts. Operation of VCS would result in the presence of visible plumes from the mechanical draft cooling towers (Subsection 5.3.3.1.1). The plumes from the mechanical draft cooling towers would occur in each direction of the compass but be geographically scattered thus reducing the time that the plume would be visible from a particular location. The average plume lengths and heights would be relatively short and would only reach the site boundary during the winter. The visible plumes may prevent sunlight from reaching the ground, causing shadowing. Shadowing in all areas offsite in any direction is predicted to occur for less than 53 hours per season and 138 hours annually. The operation of the cooling towers would produce limited fogging and salt deposition. Fogging from the operation of the cooling tower is predicted to occur for only 6 minutes per year offsite. Salt deposition due to water droplets drifting from the cooling towers would be below levels shown to cause impacts to vegetation (Subsections 5.3.3 and 5.8.1.6).

Aesthetic Impacts to Recreation

Potential aesthetic impacts could result from operation and maintenance activities associated with the raw water makeup (RWMU) system intake pipeline, the cooling basin blowdown pipeline, and the RWMU system pumphouse. Impacts from such maintenance activities would be local to those areas, periodic, and temporary in nature; thus, the impacts would be SMALL. Although the transmission corridor routes have not been identified, the transmission service provider would be expected to use existing corridors and avoid recreational areas and population centers, to the extent practicable, during transmission corridor routing. Accordingly, aesthetic impacts associated with transmission line operation are also expected to be SMALL.

The visual impacts experienced at a given location due to the operation of VCS would be influenced by factors such as the distance to the site, local and line-of-sight topography, and the presence of existing structures and vegetation. In order to identify potentially affected recreational resources for further evaluation, it was conservatively assumed that structures on the VCS site and plumes from the cooling towers would be visible from distances of up to 10 miles. Since auditory, olfactory, and tactile impacts would be experienced at distances significantly less than the 10-mile radius used for the assessment of visual impacts, Exelon evaluated potential aesthetic impacts to recreational areas within 10 miles of the VCS site.

The private and public recreational areas identified within 10 miles of the VCS site are the Texas Independence Trail, a private hunting area, Linn Lake, and the Guadalupe River. These recreational areas were analyzed for aesthetic impacts.

As stated in Subsection 2.5.2.5, the Texas Independence Trail passes within 9 miles of the site, following SR 185 and passing through the town of Bloomington. Because of the distance from the Texas Independence Trail to VCS, as well as the presence of vegetation and modern facilities/ infrastructure along SR 185 and in the separating area, the visibility of VCS would be minimal and the visibility of cooling tower plumes would be minimal and intermittent. Trail users would also be too far away from the proposed activities associated with operations to experience auditory, olfactory, or tactile impacts. Therefore, aesthetic impacts to this resource would be SMALL.

The Guadalupe River is approximately 4 miles east of the proposed VCS power block area. A private hunting area is located between the river and the site. As described in Subsection 5.8.1, the highest levels of noise associated with VCS would result from the operation of the mechanical draft cooling towers. The noise levels generated by the mechanical draft cooling towers would be approximately 52 dBA at 400 feet from the towers, which is comparable to existing background noise levels at the site and is lower than the NUREG-1555 significance level of 65 dBA, below which impacts are deemed small. Thus, there would be minimal impact to users of the private hunting area or Guadalupe River from noise associated with the operation of VCS. As addressed in Subsection 5.3.3, the predominant directions predicted for the cooling tower plumes to travel are north and south. Given the relatively abrupt change in elevation from the Guadalupe River floodplain (approximately 10–20 feet MSL) to the VCS site (approximately 70–80 feet MSL), the distance to the site, and the presence of shoreline and floodplain vegetation, the visibility of VCS and the mechanical draft cooling tower plumes from the river would be limited. While there is a potential that VCS structures and mechanical draft cooling tower plumes could be visible from portions of the private hunting area, it is likely that the distance to the VCS site and the presence of vegetation would limit visibility. Additionally, the visibility of the site structures or plumes alone would not affect hunting success. Vehicle emissions and odors from the onsite wastewater treatment plant would be expected to disperse within short distances of their sources. Accordingly, impacts to recreational users of the Guadalupe River and the private hunting area from the operation of VCS would be SMALL.

In addition to the small direct impacts experienced at the private hunting area, wildlife could be startled by traffic noise and vibration and other plant-related noise. As described above, noise and vibration impacts are expected to be local to the generating activities and small; similarly, any wildlife displacement would likely have a small impact on the overall game population on the property. Additionally, other hunting opportunities (e.g., wildlife management areas) exist within 50 miles of the site. The impacts to the Guadalupe River and the private hunting area from plant operations are expected to be SMALL.

In summary, for the reasons described above, the aesthetic impacts to recreational opportunities resulting from the operation of VCS and the associated offsite infrastructure would be SMALL and would not warrant mitigation.

Use Impacts to Recreation

While aesthetic impacts to recreation are driven by the recreation user's proximity to VCS, use impacts to recreation are driven by recreational facilities' and events' proximity to the user's residence. Operations workers and their families would be expected to use recreational facilities nearer their residences, rather than near their place of work (i.e., the VCS site). Some recreational opportunities would be sought out because of their uniqueness, a particular national wildlife refuge area for example, independently of recreation area's proximity to the workers residence.

The influx of workers during operations could affect the use of recreational areas and participation in recreational events in the 50-mile region. Use impacts to recreation would be the result of VCS-related population growth, including indirect worker migration in the ROI, and hence, increased usage of recreational facilities and events. Although there are recreational facilities and areas outside the ROI counties that fall within the 50-mile radius of the VCS site that may be used by in-migrating workers and their families, this analysis focuses on recreational facilities and areas in the ROI counties and on fishing and boating opportunities within a short commute from those counties. Residential distribution of the in-migrating workers in the ROI is the most important determinant of recreational facility use. Because of the inherent difficulty in predicting the residential distribution of in-migrating workers, Exelon has analyzed impacts to recreation on a regional basis.

The in-migrating workforce during operations would result in a 1.7 percent increase over the 2000 ROI population. Use of recreational facilities and areas would be expected to increase by a similar percentage. For the purposes of this analysis, the recreational facilities are broadly classified into five groups; (1) national and state facilities which include state parks, Wildlife Management Areas (WMAs), National Wildlife Refuge Areas (NWRs), and nature (birding) trails in the ROI; (2) local facilities which include county, municipal, and special districts parks in the ROI; (3) bodies of water in the ROI and waters located outside the ROI but used by residents of the ROI; (4) privately owned recreational facilities expected to be impacted by operations; and (5) special recreational events in the ROI. Subsection 2.5.2.5 presents information about these facilities and events and, where available, information about the current usage rates and capacities of those facilities and events. In addition to these public recreation facilities and events, residents of the ROI could pursue recreational opportunities on the Guadalupe and San Antonio Rivers and in the Matagorda and San Antonio Bays. Private recreation facilities and non-profit organizations' recreational areas that could be impacted are also noted in Subsection 2.5.2.5.

The state park system could be impacted by the VCS-related population increase. As stated in Subsection 4.4.2.2.5, the Texas Parks and Wildlife Department (TPWD) study, *Texas Parks and Wildlife for the 21st Century,* recommends that the state provide 55 acres of state park land (state parks, state natural areas, and state historic sites) per 1000 residents. The three state parks in the region (Goliad State Park, Goose Island State Park, and Lake Texana State Park) and the three WMAs (Matagorda, Guadalupe, and Welder Flats) total approximately 66,663 acres (Table 2.5.2-32), or about 430 acres per 1000 residents. Because the state park acreage available to ROI residents exceeds the recommended minimum, and would continue to exceed that threshold after the operations population influx, impacts to the state park system in the ROI would be SMALL. Because the state park system has open and wooded lands appropriate for multiple uses (birding, nature walks, picnics, camping, fishing), the state park system can accommodate additional usage more readily than local park systems which often specialize in dedicated use opportunities (tennis, swimming pools, baseball fields). Other state-sponsored recreational opportunities in the ROI include the Coastal Birding Trail and the Texas Independence Trail. Both of these trails cater to bird watching, a popular form of recreation in the ROI. However, it is unlikely that the increased use of either of the trails would cause adverse impacts to birding.

There could be use impacts to the local municipal and county parks in the ROI. The TPWD has determined that, in general, state and local parks are in short supply, given the size and population of Texas (TPWD Nov 2001). The small, VCS-induced population increase of 1.7 percent in the ROI could slightly exacerbate the shortage of local parks because the in-migrating population would also use these recreational facilities and areas. The increase in usage of local parks would likely reflect the operation-related population increase of 1.7 percent. Based on the findings of the TPWD, Exelon has assumed that the local parks in the ROI are functioning at or near capacity. Local park systems generally provide facilities (boat docks, picnic tables, and swimming pools) and specialty land uses (ball fields, tennis courts, nature trails) that cannot readily accommodate increased usage; however, at the time of the peak operations workforce, the ROI would have experienced a recent decrease in population due to the departure of the construction workforce. Therefore, it is probable that many municipal and county park systems would have adjusted to meet the needs of the larger construction workforce at the time the ROI would experience the influx of operations workers.

There could be use impacts to water-based recreational activities both inside and outside the ROI. The boating, fishing, and passive use of the Guadalupe and San Antonio Rivers would likely increase with the influx of workers and their families. Boating, fishing, and passive use of the waters of the Matagorda and San Antonio Bays would also increase. The increased usage of water bodies could result in a small impact, but increased usage would not compromise current users' access to or enjoyment of the waters. Linn Lake is privately owned, inaccessible, and not used for recreation.

The area outside of the ROI, but within 50 miles of the VCS site, includes the privately owned and managed Audubon Sanctuary and the public Aransas National Wildlife Refuge. Both facilities could experience additional minor visitation.

Of note are two annual, recreational sporting events: the Texas Water Safari, which is held on a section of the Guadalupe River in the ROI, and the Texas River Marathon, hosted in DeWitt County. These events could see increased participation because of VCS-related population increases. Increased participation is considered a positive impact because it means more people could enjoy the recreational opportunity.

In summary, impacts to the use of recreation facilities and opportunities outside the ROI but within 50 miles of the VCS site would be SMALL and would not warrant mitigation. Usage of recreation areas outside the ROI by VCS-related populations would likely be because the recreational areas are water-based or part of the state park system. The state park system in southeastern coastal Texas has adequate acreage to accommodate growth, and adequate water-based recreational opportunities, such as fishing and boating, in part because the use of the waters by one person fishing or boating is not diminished if another fisher or boater also uses the resource. In addition, residents of the ROI would not be expected to make regular use of local parks outside of the county in which they reside. Privately owned and managed recreational facilities outside of the ROI would likely experience minimal additional usage from VCS-related populations.

In general, impacts to the use of recreation systems and opportunities within the ROI would be from SMALL to MODERATE. Impacts to the state park system would be SMALL because of the adequate acreage available in the ROI. Impacts to local parks would be SMALL, reflecting increased usage based on the small rate of induced population growth due to operation of VCS. However, possible impacts could be mitigated by the increase in property tax revenues, resulting from the VCS-generated increase in property values. Recreational impacts to fishing and boating would be SMALL because of the expanse of available waters. Impacts to one private hunting area and to other privately owned and managed recreational facilities, including the non-profit Audubon Sanctuary, would be SMALL. Property owners who hunt could experience small impacts. The impacts would be mitigated, in part, by the availability of other hunting areas within the 50-mile radius. The impacts to notable, annual recreational sporting events would be SMALL and positive because of the expansive nature of these events.

5.8.2.2.6 Housing

Impacts on housing from VCS operations depend on the number of operations workers that would relocate from outside the 50-mile region and the type and location of housing those workers would desire. The housing impact from VCS operations should also depend, to some extent, on housing options exercised by construction workers. As described previously, at the full staffing of VCS operations there would be 800 direct operations jobs and 1423 indirect jobs. Although all 800 operations jobs would be expected to be filled by in-migrating workers, as described previously, indirect workers are expected to already reside in the area, or to be a spouse of an in-migrating direct worker, so no indirect workers would require additional housing. Also, in reality, the in-migration would be less than 800 workers because some workers, having completed a construction assignment, would transfer to an operations position and, therefore, would already reside in the ROI as the operations period would begin. Therefore, Exelon conservatively assumes that a maximum of 800 workers would migrate into the ROI for operations and require housing.

Forecasting residential distribution patterns in a large geographical area is inherently problematic because workers' preferred housing is driven by many individual variables. Housing options are varied: owner versus rental occupancy; detached versus attached units; single unit versus multiple unit complexes; permanent units versus mobile units (mobile homes and the need for short-term (motel/hotel) accommodations versus more permanent solutions. To present a more realistic analysis, Exelon has analyzed the impacts to housing during operations on an ROI basis only.

Subsection 2.5.2.6 discusses and presents data about the existing housing conditions in the ROI. Subsection 4.4.2.2.6 discusses housing conditions during the construction period. The sources for all data presented in this section are Subsections 2.5.2.6 and 4.4.2.2.6, except where cited.

ROI

The housing required by the operations workforce would be different than the housing required by the construction workforce for the following reasons: the operations workforce is much smaller than the construction workforce; the operations workers would be permanent residents of the ROI and therefore require permanent housing (as opposed to temporary housing as required by the construction workers); the wages of operations workers are estimated to be higher than construction workers and wages are a proxy for type and location of housing sought; and the operations period is further in the future and it follows the construction period.

The amount of housing required by the in-migrating operations workforce (all of whom are direct workers) is much smaller than the amount of housing required by the peak in-migrating workforce (including the construction, operations, and indirect workforce) during construction. The amount of housing required by the operations workforce, 800 units (one unit for each in-migrating worker), is approximately 11 percent of the 7163 units of housing required by the in-migrating workforce during construction (one unit for each in-migrating direct or indirect worker; Subsection 4.4.2.2.6). Although there is currently ample vacant housing in the ROI to accommodate all workers during construction, newly built housing would likely be added to that inventory during the VCS construction period, thus leaving the area with a housing inventory in excess of the inventory needed by the operations workers. Although there is likely to be excess vacant housing after construction workers leave the area, a percentage of that housing may not have the characteristics desired by the operations workers. Thus, additional housing could be added to the inventory during the operations period.

Because the operations period is of a permanent nature, and the construction period is temporary, operations workers are more likely to seek permanent housing whereas construction workers would be expected to select a more temporary housing arrangement. Permanent housing is generally comprised of single-family units that are frequently owner-occupied, while temporary housing is often renter-occupied, multi-family, and/or mobile. In addition, operations workers may prefer housing in a different location than construction workers prefer. Permanent housing represents a long and large financial commitment; hence, operations workers may select housing based on its proximity to family-friendly amenities and on lifestyle choices, while construction workers, without the financial commitment of a mortgage, may focus more on commuting distance to the job site and the ready availability of housing. In a project such as this, the development of infrastructure and amenities (i.e., roads, water and sewer systems, schools, shopping, etc) to support the construction workforce could influence the residential settlements of the operations workforce. Operations workers could choose to purchase existing housing or build housing where infrastructure is already available.

Housing choices are determined, in part, by occupant wages. The average annual wage of the VCS operations workforce is expected to be higher than the current mean or average wage in the ROI and higher than the construction workers' wages. As described in Subsection 4.4.2, the average annual wage of a worker in the utilities industry in the region, the type of worker expected to be employed at the proposed facility, is $64,760 (BEA 2007). The average annual wage for all industries in the ROI ranges from $26,506 in DeWitt County to $49,933 in Calhoun County (Subsection 2.5.2.1). Because wages are a proxy for the type, price, and location of housing sought, operations workers could exhaust the available inventory of higher-priced housing in the ROI. Table 2.5.2-34 displays data about the median housing price of owner-occupied units in the ROI.

Given the likely increased demand for higher-priced housing, prices of existing higher-priced single-family and multi-family housing could rise. County and local governments in the ROI would benefit from the increased taxable value of existing housing. In addition, they would benefit from new housing construction because newly developed property would generate more tax revenue than undeveloped property. Conversely, the VCS-induced upward price pressure on owner-occupied units and higher-priced rental units could change the patterns of residency options for families with lower incomes. However, because of the surplus of housing created by the departing construction workforce, rental housing rates and modestly-priced, owner-occupied units would likely experience little upward pressure on prices.

Individual Counties

Subsection 4.4.2.2.6 indicates how much housing was available within each ROI county in 2000. Housing impacts in individual counties could be determined primarily by settlement patterns, much of which would have been established by the construction workforce since those decisions would drive where the available housing inventory would be and the location of infrastructure and amenities. The infrastructure would remain in place at construction completion and provide a basis for the additional housing the operations workers could build. Although operations workers could choose different housing units than construction workers would choose, housing options for operations workers are likely to be in geographical proximity to the residential units of construction workers because of the availability of infrastructure.

Conclusion

The characteristics of preferred housing for the construction and operations workforce would likely be different. Construction workers would require more temporary housing that would be closer to the VCS site. Operations workers would prefer more permanent housing located near family-oriented amenities. Operations workers' wages would be higher than those of the construction workers, enabling operations workers to purchase higher-priced housing than the construction workers.

Initially, the demand for lower-priced, temporary housing by the construction workforce could increase prices and rents for that type of housing and, to a lesser extent, all housing in the ROI. However, with time, market forces would begin to match the quantity supplied with the quantity demanded and housing prices and rental rates would stabilize. VCS-related operations employment, beginning with the initial arrival of operations workers during the construction period, would increase gradually, allowing market forces to accommodate the new arrivals. The in-migrating operations workforce is much smaller than the departing construction workforce, and the type of housing demanded by the operations workers would be different than that of the construction workers. Hence, it would be unlikely that the operations workforce would be able to use the entire housing inventory vacated by the construction workforce. The excess lower-cost, temporary housing would flood the market, driving prices and rents down again. The reduction in prices and rents could enable low-income residents displaced by the construction workforce to afford a higher standard of housing.

Also, during both construction and operations, county and local governments in the ROI would benefit from the increased taxable value of existing housing and new housing. Exelon concludes that the ROI could accommodate the entire in-migrating operations workforce and local governments would benefit from positive tax impacts. Therefore, the impact to the ROI's housing market would be SMALL and mitigation would not be warranted.

To minimize any potential impacts to housing availability, Exelon could initiate early communications with local and regional governmental organizations, including the Golden Crescent Regional Planning Commission, to disseminate VCS related information such as the schedule of expected worker influx in a timely manner. County and regional planning organizations and, ultimately, developers and real estate agencies, could factor the details of the emerging housing market into their decision-making and plan accordingly.

5.8.2.2.7 Public Services

5.8.2.2.7.1 Water Supply Facilities

Exelon considered both VCS facilities demand and VCS-worker related population growth demand on local water resources. Subsection 2.5.2.7.1.1 describes the public water supply systems in the ROI, their permitted capacities, and current demands. For VCS operations, Exelon would not use water from an offsite public water supply system. Onsite wells would provide potable water, and in conjunction with surface water from the Guadalupe River, would provide the water for operation of VCS. Therefore, water usage by the workforce while onsite would not impact municipal water supplies.

ROI

As indicated in Table 5.8-3, operations could bring as many as 2600 new workers and family members to the ROI. As described in Subsection 2.5.2.7.1.1, municipal water suppliers in the ROI have excess capacity. The impact to the local water supply systems from operations-related population growth can be estimated by calculating the amount of water that would be required by the in-migrating operations-related population and comparing it to the publicly available resources. The average person in the United States uses 90 gpd for personal use (U.S. EPA Oct 2003). The increase of 2600 people could increase consumption by 234,000 gpd (0.234 million gallons per day) in the ROI. Currently, public water use within the ROI is at 23 percent of capacity (56.6 mgd) (Table 2.5.2-38). VCS-related demand would reduce ROI public water supply system capacity by 0.4 percent. The increased use would not stress public water supplies or infrastructure.

Collectively, the counties in Water Planning Region L (Calhoun, DeWitt, Goliad, Refugio, and Victoria) are operating at 24 percent of their capacity. If the entire 2600 operations-related population located in Region L, the population of the Region L ROI counties would increase above the 2000 population (Table 2.5.1-4) by 1.9 percent. The additional demand of approximately 0.234 mgd would reduce the total available public water supply capacity in the Region L counties by approximately 0.3 percent. Impacts to the Region counties would be small and would not warrant mitigation.

Jackson County is the only county in the ROI located in Water Planning Region P. Water suppliers in the county are currently operating at 13 percent of their capacity. If all of the in-migrating operations-related population were to live in Jackson County, the public water demand could increase by approximately 4 percent, for a total of approximately 17 percent of capacity.

Calhoun, DeWitt, Goliad, Refugio, and Victoria Counties

The impact to the individual counties within the ROI from operations-worker-related population growth can be estimated by adding the entire operations-related population increase of 2600 people to each county. This increased demand could decrease the excess public water supply capacity for Calhoun, DeWitt, Goliad, Refugio and Victoria counties by 4 percent, 2 percent, 14 percent, 6 percent, and 1 percent, respectively. Each of the individual counties could accept all of the new operations-related worker households and maintain excess capacity of at least 63 percent. Therefore, the estimated increase in population due to the operations-related workforce would not exceed the available capacity of the municipal water supplies within the ROI or within the individual counties.

The impact of the in-migrating operational workforce on municipal water supplies for the ROI would decrease the available capacity by only 0.4 percent, resulting in SMALL impacts and would not require mitigation. In addition, if all of the in-migrating workforce population settled in any one of the individual counties, the impacts to that county would also be small and would not require additional mitigation.

Exelon would communicate with local and regional governmental planning organizations such as the Golden Crescent Planning Commission. Exelon would share information such as project activity scheduling, and projected workforce in-migration, thus giving these organizations ample time to prepare for demands on services due to the increased population as a result of VCS operations.

5.8.2.2.7.2 Wastewater Treatment Facilities

VCS would have an onsite wastewater treatment facility to meet all of its operational needs. Therefore, onsite operations for VCS would have no impact on public wastewater services.

Subsection 2.5.2.7.1.2 describes the public wastewater treatment systems in the ROI, their plant-designed average flows, and monthly average wastewater processed. Wastewater treatment facilities in the ROI have at least 31 percent available capacity with the exception of the city of Port

Lavaca facility (17 percent), Victoria County Water Control and Improvement District (WCID) No. 1 (4 percent), and Jackson County WCID No. 2 (0 percent) (Table 2.5.2-39). No data was available for the town of Bayside facility or the Victoria County WCID No. 1.

Impacts to local wastewater treatment systems would occur as the population would increase due to the in-migration of the operations-related workers and their families. The magnitude of the impact can be conservatively estimated by assuming 100 percent of the water used by this population would go to a wastewater treatment facility. As previously described, the operations-related population increase could require 0.234 mgd of drinking water and, by extension, 0.234 mgd additional wastewater treatment capacity. As described in the following paragraphs, the in-migration of the maximum operations-related workforce and their families would increase the current wastewater treatment system use for the ROI from approximately 60 percent to 61 percent.

ROI

Monthly average wastewater processed in the ROI is 12.9 mgd, with a systems capacity of 21.4 mgd (Table 2.5.2-39). If an additional 0.234 mgd were added in the ROI, the average wastewater processed would rise to 13.1 mgd, a 1 percent increase, (60 percent to 61 percent) in the ROI's total capacity. Impacts to wastewater treatment capacity within the ROI would be SMALL and would not require mitigation.

Calhoun, DeWitt, Goliad, Jackson, Refugio and Victoria Counties

Collectively, Calhoun County wastewater treatment facilities are currently operating at approximately 59 percent of capacity. The city of Port Lavaca is currently operating at approximately 83 percent of capacity and is therefore over the 75 percent criteria threshold for operation expansion planning. Individually, the remaining facilities within the county are operating at 18 percent to 50 percent of capacity. For Calhoun County as a whole, there is enough excess capacity (1.118 mgd) to accommodate approximately 478 percent of the estimated in-migrating operations-related workforce population. Therefore, impacts on wastewater treatment facilities due to VCS-induced population increases for Calhoun County could be small to large. Any increase to any one facility at or near zero planning threshold capacity, such as the city of Port Lavaca, would be large.

Collectively, DeWitt County wastewater treatment facilities are currently operating at approximately 63 percent of capacity. The three public wastewater facilities in DeWitt County are currently operating between 59 percent (city of Yorktown) and 68 percent (city of Yoakum) of capacity. These cities are all close to the 75 percent criteria threshold for operation expansion planning. Because there are only three facilities in the county, any significant increase in population within the county could cause one or all of the facilities to exceed the 75 percent criteria threshold for operation expansion planning. For DeWitt County as a whole, there is enough excess capacity (1.011 mgd) to accommodate approximately 432 percent of the estimated in-migrating operations-related workforce population. Therefore, impacts to the county would be small to large. Any increase to any one facility at or near zero planning threshold capacity would be large.

The only public wastewater treatment facility in Goliad County serves the city of Goliad. The system is currently operating at approximately 69 percent of capacity. Because there is only one facility in the county, a VCS-induced population increase of 250 or more people would cause the facility to exceed the 75 percent criteria threshold for operation expansion planning. The county has enough overall excess capacity (0.11 mgd) to accommodate approximately 47 percent of the total estimated in-migrating operations-related workforce population. Therefore, impacts to the county could be small to large depending on actual VCS-related in-migration population increases.

Collectively, Jackson County wastewater treatment facilities are currently operating at approximately 44 percent of capacity. Jackson County WCID No. 2 is currently operating at maximum capacity. Individually, the remaining systems within the county are operating between 14 percent and 68 percent of capacity. For Jackson County as a whole, there is enough excess capacity (1.267 mgd) to accommodate approximately 542 percent of the estimated in-migrating operations-related workforce population. Therefore, impacts to the County would be small to large, depending on the actual VCS-related in-migration population increase. Any increase to any one facility at near zero planning threshold capacity would be large.

Collectively, Refugio County wastewater treatment facilities, excluding the city of Bayside because capacity information is not available, are currently operating at approximately 46 percent of capacity. Individually, systems in the county are currently operating between 17 percent and 61 percent capacity. For Refugio County, as a whole, there is enough excess capacity (0.521 mgd) to accommodate approximately 223 percent of the estimated in-migrating operations-related workforce population. Impacts to the county would be small to large, depending on the actual VCS-related in-migration population increase. Any increase to any one facility at or near the systems planning threshold capacity would be large.

Collectively, Victoria County wastewater treatment facilities, excluding Victoria County WCID No. 2 because capacity information is not available, are currently operating at approximately 64 percent of capacity. Individually, systems in the county are currently operating between 39 percent and 96 percent capacity. For Victoria County as a whole, there is enough excess capacity (6.742 mgd) to accommodate approximately 2881 percent of the estimated in-migrating operations-related workforce population. Therefore, impacts to the county would be small to large, depending on actual VCS-related in-migrating population increase. Any increase to any one facility, particularly the Victoria County WCID No. 1, at or near the systems' planning threshold capacity would be large.

To mitigate potential impacts, Exelon would initiate early communication with local and regional governmental organizations, including planning commissions and local and regional economic development agencies, such as the Golden Crescent Regional Planning Commission, to disseminate VCS-related information in a timely manner. Local governments and planning groups would have time to plan for the influx. Infrastructure upgrades and expansions could be funded, at least in part, by VCS-related property and sales and use tax payments.

5.8.2.2.7.3 Law Enforcement, Fire Protection Services, and Medical Services

Law Enforcement

Residents-per-officer ratios for the counties in the ROI and the ROI, as a whole, are presented in Table 2.5.2-46. In the ROI, in 2005, the ratio of residents per officer was 482:1. As stated in Subsection 2.5.2.7.2, the national average was 2.4 officers per 1000 inhabitants, or 417 residents per officer. There is no national standard for residents-per-officer ratios, as there is a great deal of variance between populations of similar sizes. Urban areas tend to employ more law enforcement services per resident than rural areas. With the exception of Refugio County, the ROI counties' ratios are above the national average; the ROI, as a whole, is above the national average. However, most of the ROI counties and the ROI, as a whole, are considered primarily rural. Therefore, their ratios would be expected to be higher than the national average.

With respect to onsite law enforcement, Exelon would employ its own security force. Onsite security services and emergency response would be addressed in the VCS Physical Security Plan and Radiological Emergency Response Plan, respectively, at the time of COL. With respect to the influx of workers and their families during peak operations, 2600 people would move into the ROI (Table 5.8-3). If the number of officers in the ROI remained at 2005 levels, the additional population would increase the 2005 residents-per-officer ratio in the ROI by 1.9 percent (Table 5.8-15), creating a SMALL impact.

During peak construction period, in order to maintain pre-VCS operations ratios, 41 additional law enforcement officers are estimated to be required in the ROI. The operations workforce would reach full staff well after the construction peak (Figure 4.4-1). During the operations period, a maximum of six additional officers and associated equipment would be required in the ROI (Table 5.8-15) to maintain current ratios. Therefore, assuming that 41 additional police officers were hired in the ROI during the peak construction period, only six of those officers would be required by the end of construction (when the number of workers on the site would drop to 800) to serve the operations-related population increase (Figure 3.10-1). This could cause an overstaffing of 35 officers (41 minus 6) and an overstock of equipment. In order to reduce ratios to pre-VCS operations levels, officers could be dismissed from their duties. Alternatively, officers could be retained to supplement the general provision of law enforcement services in the ROI, thereby reducing the ratios to achieve national averages. VCS-related tax payments, including both property taxes and sales and use taxes made by VCS and its employees, could continue to assist in funding these services.

Fire Protection Services

Residents-per-active-firefighter ratios for the counties in the ROI and the ROI as a whole are presented in Table 2.5.2-46. In the ROI, the 2007 ratio was 245:1. As stated in Subsection 2.5.2.7.2, the national average was 262:1. The Public Protection Classification (PPC) ratings for the ROI indicate that the more populated areas are the most equipped to handle fire emergencies than are the less populated areas (Table 2.5.2-47[9]). The PPC ratings of the largest population centers in each county are between 4 and 7. The cities of Victoria and Port Lavaca have ratings of 4. Outside of those centers, the rating numbers are generally higher because there are relatively fewer fire protection facilities and personnel. Onsite fire protection capability and emergency response would be addressed in the proposed plant's emergency plan at the time of COL. With respect to the influx of workers and their families during operations period, 2600 people would move into the ROI (Table 5.8-3). If the number of active firefighters in the ROI remained at 2007 levels, the additional population would increase the 2007 residents-per-active firefighter ratios in the ROI by 1.6 percent (Table 5.8-16), creating a SMALL impact.

During the peak construction period, in order to maintain pre-VCS operations ratios, 81 additional active firefighters are estimated to be required in the ROI. The operations workforce would reach 800 people, or full staff, well after the peak construction period (Figure 4.4-1). During the operations period, a maximum of 11 additional active firefighters and associated equipment are estimated to be required in the ROI (Table 5.8-16). Therefore, assuming that within the ROI, 81 additional active firefighters were hired during the peak construction period, only 11 of those firefighters would be required by the end of construction (when the number of workers on site would drop to 800) to serve the operations-related population increase (Figure 3.10-1). This could cause an overstaffing of 70 firefighters (81 minus 11) and an overstock of equipment. In order to reduce ratios to pre-VCS operations levels, firefighters could be dismissed from their duties. Alternatively, firefighters could be retained to supplement the general provision of fire protection services in the ROI, thereby reducing the ratios from their pre-VCS operations levels. VCS-related tax payments, including both property taxes and sales and use taxes made by VCS and its employees, could continue to assist in funding these services.

9. Lower PPC ratings are more desirable.

Medical Services

Detailed information concerning medical services in the ROI is provided in Subsection 2.5.2.7.3.

Onsite medical capabilities and emergency response would be addressed in the proposed plant's emergency plan at the time of COL. Minor injuries to operations workers would be assessed and treated by onsite medical personnel. Other injuries would be treated at hospitals in the ROI, depending on the severity of the injury. Agreements are in place with some local medical providers to support emergencies. Therefore, operations activities should not burden existing medical services.

As indicated in Table 2.5.2-48, Victoria County provides the most opportunities for medical care in the ROI. As indicated in Table 2.5.1-4, the 2000 population of the ROI was 153,895. Adding 2600 residents to the ROI population would increase the 2000 population by 1.7 percent (Subsection 5.8.2.1). A 1.7 percent increase in the average daily census, annual admissions, and annual outpatient visits would not be noticeable or burden existing medical service capacity. Therefore, the potential impacts of VCS operations on medical services would be SMALL and not warrant mitigation.

5.8.2.2.8 Education

Exelon estimates that approximately 640 school-age children would be part of the operations-related in-migration (Table 5.8-3). For this analysis, Exelon evaluated impacts that conservatively assume that all school-age children would reside in one of the six counties in the ROI. The discussion focuses on the ROI as a whole, and follows with discussion of each of the six counties. For the counties in the ROI, Table 5.8-17 presents the 2007–2008 school year enrollment, student capacity, excess student capacity, and number of operations worker families the ISDs could accommodate without exceeding capacity. This subsection discusses the public school systems and post-secondary institutions in the ROI. The sources for the data presented are Subsection 2.5.2.8 and 4.4.2.2.8, except where cited.

ROI

As described in Subsection 4.4.2.2.8, the ROI has the capacity to accommodate 14,728 (or 32 percent) more students than attended in the 2007–2008 school year (Table 2.5.2-50). Six ISDs have proposed to construct or are constructing one or more new schools or have announced expansion plans of existing facilities, for a total of 12 new or expanded schools (Table 2.5.2-49). As stated in Subsection 4.4.2.2.8, the new and expanded facilities will provide capacity for an additional 6683 students, for a total student enrollment capacity of approximately 46,299. Based on the excess capacity, the education systems within the ROI could accommodate all 640 school-age children of the VCS operations workers because the excess capacity is greater than the anticipated influx of school-age children (Table 5.8-17). The ROI as a whole would experience an enrollment increase of

2.0 percent over the 2007–2008 year enrollment. Because the residential distribution of the operations workers could mimic the settlement patterns of the construction workforce, the children of operations workers could attend the same schools that the 3352 children of the in-migrating workers during the construction period would have attended. Thus, staffing and facilities would be in place to serve the smaller number of new students from operations worker families. Impacts to the ROI would likely be SMALL and not warrant mitigation.

Although the impacts to the ROI would be SMALL, the impacts to the individual counties could range from small to large. The magnitude of the impact depends on where the workforce would reside, the number of the workforce's school-age children in each grade level, and the county's facilities to accommodate those specific students. Property taxes, paid in part to individual ISDs, could mitigate impacts; however, ISDs in the ROI other than the Victoria and Refugio ISDs would not directly benefit from property taxes paid by VCS (Subsection 5.8.2.2.2 discusses property tax impacts from VCS operations and Subsection 2.5.2.3.5 discusses the Texas school wealth equalization process).

Individual Counties

Calhoun County

Calhoun County, which has only one ISD, has excess capacity to seat an additional 1342 students (Table 5.8-17). Since the excess capacity is greater than the estimated number of in-migrating students, the education system within the county could accommodate all students that would accompany the operations workers. If all 640 VCS-related children were to live in the county, the county would experience an increase in total enrollment of 15 percent. However, because there is currently excess capacity in the county and the staffing and facilities that would remain in place after the children of the construction workforce leave the area, impacts to the county would again be small and not warrant mitigation.

DeWitt County

DeWitt County has excess capacity to seat 1240 additional students (Table 5.8-17). Since the excess capacity is greater than the estimated number of in-migrating students, the education system within the county could accommodate all students that would accompany the operations workers. If all 640 VCS-related children were to live in the county, the county would experience an increase in total enrollment of 15 percent. However, because there is currently excess capacity in the county and the staffing and facilities that would remain in place after the children of the construction workforce leave the area; impacts to the county would be small and not warrant mitigation.

As stated in Subsection 2.5.2.8, the Yoakum ISD, one of the six ISDs in the county, is operating at capacity and could not accommodate any additional students without exceeding capacity. The ISD has no plans for expansion. The ISD is located in the outer extremes of the ROI (Figure 2.5.2-16). Possible mitigation to address overcrowding, should there be additional enrollment, could include transporting some students to another ISD in the county.

Goliad County

Goliad County, which has one ISD, is operating at capacity and has no plans for expansion. Since the county does not have any excess capacity, the education system within the county could not accommodate any additional enrollment without exceeding capacity. If all 640 VCS-related children were to live in Goliad County, the county would experience an increase in total enrollment of 49 percent. However, because the county could not accommodate any new students, impacts to the county could be small to large, depending on the number of operations-related students that enroll in the ISD.

Jackson County

Jackson County has excess capacity to seat an additional 940 students (Table 5.8-17). Since the excess capacity is greater than the estimated number of in-migrating students, the education system within the county could accommodate all students that would accompany the operations workers. If all 640 VCS-related children were to live in the county, the county would experience an increase in total enrollment of 12 percent. However, because there is currently excess capacity in the county and the staffing and facilities that would remain in place after the children of the construction workforce leave the area, impacts to the county would be small and not warrant mitigation.

Refugio County

Refugio County has excess capacity to seat an additional 1164 students (Table 5.8-17). Since the excess capacity is greater than the estimated number of in-migrating students, the education system within the county could accommodate all students that would accompany the operations workers. If all 640 VCS-related children were to live in the county, the county would experience an increase in total enrollment of 45 percent. However, because there is currently excess capacity in the county and the staffing and facilities that would remain in place after the children of the construction workforce leave the area, impacts to the county would be small and not warrant mitigation.

Victoria County

Victoria County has excess capacity to seat an additional 10,042 students (Table 5.8-17). Since the excess capacity is greater than the estimated number of in-migrating students, the education system within the county could accommodate all students that would accompany the operations workers. If all 640 VCS-related children were to live in the county, the county would experience an increase in total enrollment of 4 percent. Because there is currently excess capacity in the county and the staffing and facilities that would remain in place after the children of the construction workforce leave the area, impacts to the county would be small and not warrant mitigation.

In conclusion, the public education systems in the ROI, as a whole, have the capacity to accommodate all of the school-age children of the operations workers. Calhoun, DeWitt, Jackson, Refugio, and Victoria counties' systems could each individually seat all the in-migrating operations-related school-age children with current capacity. However, Goliad County is operating at capacity and could not seat any additional children without exceeding capacity.

Colleges, Universities, Vocational Schools

Subsection 2.5.2.8.2 discusses postsecondary institutions, colleges and universities, vocational schools, and the Texas technical college system in the ROI. The peak operations workforce would not be reached until approximately 4 to 5 years after construction began. Exelon could provide the local education institutions, including post-secondary institutions, with timely information regarding the proposed activities at VCS, giving the institutions several years to make accommodations for the influx of operations workers or worker family members that may seek additional post-secondary education or training. The institutions could also modify curriculum offerings and/or contract with Exelon to provide onsite and offsite academic courses and job-specific training.

5.8.3 Environmental Justice

Environmental justice refers to a federal policy under which each federal agency identifies and addresses, as appropriate, disproportionately high and adverse human health, environmental, or socioeconomic effects of its programs, policies, and activities on minority or low-income populations. The NRC has a policy on the treatment of environmental justice matters in licensing actions (69 FR 52040). Exelon relied on the U.S. Census Bureau 2000 data at the block group level to identify concentrations of minority and of low-income populations. Figures 2.5.4-1 through 2.5.4-6 locate minority and low-income populations within 50 miles of the VCS site. There are 216 census block groups that are at least partially within the 50-mile radius of the VCS site, 123 of which are wholly in the region of influence (ROI). The six-county ROI geographically dominates the 50-mile radius. In addition, Exelon conservatively assumes that 100 percent of the in-migrating operations workforce would settle in the ROI; therefore, the health and environmental impacts and socioeconomic impacts evaluated in this environmental justice analysis are focused on the ROI. Victoria County, the host county of the proposed VCS site, has 62 block groups. Thirty-four of these block groups have significant minority populations, but there are no block groups containing a significant percentage of low-income households in Victoria County. The closest low-income block groups to the VCS site are in the city of Refugio in Refugio County (approximately 26 miles south-southwest of the site), and in the city of Cuero in DeWitt County (approximately 36 miles north-

northwest of the site). There are several block groups that lie approximately 8 miles east of the VCS site as well as several block groups 12 miles north of the site in the city of Victoria that have concentrations of minority populations.

For the environmental justice analysis, Exelon evaluated two types of impacts: health and environmental impacts and socioeconomic impacts. The following paragraphs summarize the magnitude of each type of impact to the general population and then discuss whether low-income or minority populations would experience disproportionately high and adverse impacts. Exelon identified the most likely pathways by which adverse environmental impacts associated with operations could affect human populations, determined the level of significance of the impact, and assessed whether characteristics of the minority or low-income populations would result in disproportionately high and adverse impacts to those populations. Exelon also evaluated several socioeconomic resources to determine if operations-related activities could disproportionately, in a high and adverse manner, impact minority or low-income populations. If the impacts to the general population were found to be SMALL, and there were no resource dependencies, preexisting health conditions, or location-dependent reasons that would affect the level of significance of the impact to minority or low-income populations, Exelon concluded there would be no disproportionately high and adverse impact on low-income or minority populations.

5.8.3.1 Health and Environmental Impacts

There are three primary pathways for health and environmental impacts: soil, water, and air.

Operations activities would have minimal impacts to soils at VCS and in the vicinity. Doses to nearby residents from the ground or through ingestion of vegetables would be below 10 CFR 50, Appendix I criteria (Section 5.4). Therefore, impacts to the general population, as well as any minority or low-income populations would be SMALL. Low-level radioactive waste, as well as non-radioactive waste, would be generated onsite, but these would be disposed in permitted facilities. Impacts to soils from VCS would be SMALL and would not require mitigation.

As presented in Subsection 5.2.1, the proposed units at VCS would use both surface water and groundwater. Projected surface water demands, supplies, and needs for Victoria and Calhoun Counties were assessed to determine the impact of VCS surface water withdrawals from the Guadalupe River. Subsection 5.2.1.1 concludes the impacts to present and future surface water users would be SMALL. Blowdown discharge to the Guadalupe River would meet all requirements established in the VCS Texas Pollutant Discharge Elimination System (TPDES) permit and impacts to water quality would also be SMALL (Subsection 5.2.3.1). There would be no disproportionately high and adverse impacts to minority or low-income populations.

VCS would use groundwater for potable water, demineralized water, and fire protection (Section 3.3). Groundwater would be withdrawn from the Evangeline Aquifer, which is not in communication with local surface water bodies (Subsection 5.2.2.2). Victoria County is predicted to have adequate unallocated groundwater supplies through 2060. Hydrological alteration from the VCS groundwater withdrawal as related to present and future groundwater users would be SMALL (Subsection 5.2.1.2). It is unlikely that the proposed VCS productions wells would impact offsite well users given that the closest wells are well outside the site boundary and the fact that wells in the site vicinity are screened in the shallow aquifer and have low pumping rates (Subsection 5.2.2.2). Because impacts to all well users in the 6-mile vicinity would be SMALL, and the closest minority or low-income population is outside the 6-mile radius, impacts would not disproportionately affect minority or low-income populations in a high and adverse manner. Likewise, impacts to groundwater quality would be SMALL, since a Spill Prevention, Control, and Countermeasures Plan would be in place to prevent spilled oil from penetrating the groundwater. The potential for saltwater intrusion is unlikely, given the distance to the nearest saltwater source and the pumping rates proposed for VCS (Subsection 5.2.3.2).

Given the SMALL impact on water quantity and quality in the Guadalupe River and groundwater, there would be no operations-related environmental effects that need to be mitigated and, therefore, there are no disproportionately high and adverse impacts to minority and low-income populations.

The total liquid and gaseous effluent doses from VCS would be well within the regulatory limits of 40 CFR 190. Radiological impacts to members of the public would be SMALL (Subsection 5.4.3). As described in Subsection 2.4.1.3.4, the annual prevailing wind direction is from 170 degrees (i.e., south-southeasterly). There are no minority or low-income block groups located north-northwest of the proposed VCS site and, therefore, there would be no disproportionately high and adverse impacts to minority or low-income populations. VCS would produce noise from the operation of pumps, mechanical draft cooling towers, transformers, turbines, generators, switchyard equipment, and loudspeakers, with the highest level of noise associated with the operation of the mechanical draft cooling towers. Any noise generated would be attenuated by the distance to the VCS exclusion area boundary and would be consistent with the existing background noise levels. Impacts due to noise would be SMALL and would not warrant mitigation (Subsection 5.8.1.1). VCS would operate diesel and combustion turbine generators under air permits issued by the state of Texas. The impact of these emissions on air quality would be SMALL and would not warrant mitigation (Subsection 5.8.1.2). Because all impacts would be SMALL, and the closest minority or low-income population is located approximately 8 miles from the site, there would be no disproportionately high and adverse impacts to minority or low-income populations.

Health and Environmental impacts to the general population from operations via the three pathways would be small; therefore, Exelon concludes that there would be no disproportionately high and adverse impacts to minority or low-income populations within a 50-mile radius of the proposed site via soil, water, or air pathways that would affect the health and environment of populations studied in this environmental justice analysis.

5.8.3.2 Socioeconomic Impacts

There is ample housing within the ROI, (Subsection 5.8.2.2.6) to accommodate the in-migrating operations workforce. Therefore, the impact to the region's housing market would be SMALL. Because the in-migrating operations workforce would be much smaller than that of the construction workforce, it would be unlikely that the operations workforce would be able to use the entire housing inventory vacated by the construction workforce. The excess housing would likely result in a downward pressure on housing prices, resulting in a supply of more affordable housing, a benefit to low-income populations.

As presented in Subsection 5.8.2.2.8, Exelon assumes that 640 school-aged children would accompany the in-migrating workforce. The education systems within the ROI have capacity to seat 27 percent more students than are currently enrolled. It is estimated that the number of school aged children accompanying workers during operations could increase school enrollment by 2.0 percent over the 2007–2008 school year. Since schools in the ROI have capacity to accommodate the increase in school enrollment, impacts would be SMALL and there would be no disproportionately high and adverse impacts to minority or low-income populations (Subsection 5.8.2.2.8).

As described in Subsection 5.8.2.2.3, offsite land use impacts would be concentrated in the ROI. Impacts would be considered SMALL within the ROI because the operations-related population growth would result in little new residential development, given the existing, large inventory of vacant housing that would result from departing construction workers. Because the VCS-related change in population is relatively small, and the operations workforce is small, impacts to land use would likely be SMALL. The small impact to offsite land use would not result in disproportionately high and adverse impacts to minority or low-income populations.

U.S. Highway 77 is the only access road to the proposed VCS site, so it would experience the greatest traffic impacts. The additional passenger vehicles would have a small impact on U.S. Highway 77 and SR 239, but would not exceed the roads' capacities (Subsection 5.8.2.2.4). Increased traffic as a result of operations would have a SMALL impact on the roads in the vicinity of the site. U.S. Highway 77 borders Hispanic ethnicity block groups in Refugio County and in the city of Victoria, but does not run through these areas. There would be no disproportionate transportation impacts to minority or low-income populations.

As presented in Subsection 5.8.2.2.1, VCS operations would result in 800 direct jobs and the creation of 1423 indirect jobs, for a total of 2223 jobs. The new workers would represent a 2.8

percent increase over 2006 employment levels. The percentage increase would probably be smaller because the total ROI employment would be greater after construction. Regardless, this increase in employment opportunities would be a positive and SMALL impact to the ROI's economy and would be a beneficial impact to minority or low-income populations because of the creation of jobs.

Exelon also assessed potential impacts from operations on public services in the ROI (Subsection 5.8.2.2.7). Impacts to water supply and wastewater treatment facilities in the overall ROI would be SMALL. Impacts to law enforcement, fire protection services, and medical facilities would also be SMALL in the ROI (Subsection 5.8.2.2.7.3). There would be no disproportionately high and adverse impacts to minority or low-income populations.

Exelon contacted local government officials and the staff of social welfare agencies in the ROI including the Calhoun County Health Department, the U.S. Department of Agriculture in Calhoun County, the DeWitt County Commerce and Health Department, Family Promise of Victoria, the Health Department of Victoria County, the Neighborhood Services Program (Victoria County), and the United Way of Victoria County concerning unusual resource dependencies or practices that could result in potentially disproportionately adverse impacts to minority or low-income populations. No agency reported dependencies or practices, such as subsistence agriculture, hunting, or fishing, through which the populations could be disproportionately adversely affected by operations of VCS. Exelon did not identify any location-dependent disproportionately high and adverse impacts affecting minority and low-income populations.

In summary, there were no operations-related impacts identified that would have disproportionately high and adverse effects on the human health, environment, or socioeconomic resources of minority or low-income populations.

5.8.3.3 References

BEA 2007. U.S. Department of Commerce, Economic and Statistics Administration, Bureau of Economic Analysis, *Regional Economic Accounts, Local Area Personal Income: Table CA25N — Total full-time and part-time employment by NAICS industry.* Available at http://www.bea.gov/bea/regional/reis/, accessed February 1, 2008.

BEA Mar 2008. U.S. Department of Commerce, Economic and Statistics Administration, Bureau of Economic Analysis, *RIMS II Multipliers 1997/2005, Table 1.5, Total Multipliers for Output, Earnings, Employment, and Value Added by Detailed Industry, Victoria Region—Endogenous*, March 2008.

BLS (Bureau of Labor Statistics) 2007a. Table 1. *Incidence rates of nonfatal occupational injuries and illnesses by industry and case types, 2005*. Available at http://www.bls.gov/iif/oshwc/osh/os/ostb1619.pdf, accessed September 19, 2007.

BLS (Bureau of Labor Statistics) 2007b. Table 6. *Incidence rates of nonfatal occupational injuries and illnesses by industry and case types, 2005, Texas*. Available at http://www.bls.gov/iif/oshwc/osh/os/pr056tx.pdf, accessed September 19, 2007.

BLS 2008a. U.S. Department of Labor, *Bureau of Labor Statistics, Quarterly Census of Employment and Wages, Average Annual Wages (2001–2006) for ROI: Calhoun, DeWitt, Goliad, Jackson, Refugio, and Victoria Counties, TX for all sectors combined, Sector 22, Utilities, and Sector 221113, Nuclear Electric Power Generation*. Available at http://www.bls.gov/cew/, accessed May 26, 2008.

BLS 2008b. U.S. Department of Labor, *Bureau of Labor Statistics, Quarterly Census of Employment and Wages, Average Annual Wages (2001–2006) for Corpus Christi, Houston, and San Antonio MSAs, TX for all sectors combined, Sector 22, Utilities, and Sector 221113, Nuclear Electric Power Generation*. Available at http://www.bls.gov/cew/, accessed May 26, 2008.

BLS 2008c. U.S. Department of Labor, *Bureau of Labor Statistics, Quarterly Census of Employment and Wages, Average Annual Wages (2001–2006) for U.S., IL, NJ, PA, SC, and TX for all sectors combined, Sector 22, Utilities, and Sector 221113, Nuclear Electric Power Generation*. Available at http://www.bls.gov/cew/, accessed May 26, 2008.

BLS 2008d. U.S. Department of Labor, *Bureau of Labor Statistics, Occupational Employment Statistics: Occupational Employment and Wages, May 2006, 51-8011 Nuclear Power Reactor Operators, and 19-4051 Nuclear Technicians, National Wage Estimates*. Available at http://www.bls.gov/oes/current/oes194051.htm, accessed April 11, 2008.

BMI Apr 1981. Battelle Memorial Institute, Malhotra, S. and Manninen, D., *Migration and Residential Location of Workers at Nuclear Power Plant Construction Sites; Forecasting Methodology (Volume 1) and Profile Analysis of Worker Surveys (Volume 2)*, NUREG/CR-2002, PNL-3757, U.S. NRC Accession Numbers 8105180373 (Volume 1) and 8105180378 (Volume 2), April 1981.

CBC Jan 2008. Coastal Bend College, *Enrollment and Capacity*, Phone call from R. Henderson–Tetra Tech to A. Ulloa–Coastal Bend College on January 16, 2008.

CCISD Apr 2008. Calhoun County Independent School District, *Enrollment and Capacity*, Phone call
EISD Apr 2008. Edna Independent School District, Enrollment and Capacity, Phone call from R. Henderson–Tetra Tech to B. Wells–Edna ISD on April 11, 2008.

Hagen et al. Nov 2001. International Atomic Energy Agency, Hagen, R.E., J.R. Moens, and Z.D. Nikoder. “Impact of U.S. Nuclear Generation on Greenhouse Gas Emissions,” Vienna, Austria, November 2001.

IISD Apr 2008. Industrial Independent School District, *Enrollment and Capacity*, Phone call from R. Henderson–Tetra Tech to T. Williams–Industrial ISD on April 4, 2008.

NCES May 2008. U.S. Department of Education National Center for Educational Statistics, *Search for Schools, Colleges, and Libraries*. Available at http://nces.ed.gov/globallocator/, accessed May 8, 2008.

NHTSA (National Highway Traffic Safety Administration) 2002. *State Data System Crash Data Report: 1990–1999. July*. Available at http://www.nhtsa.dot.gov/staticfiles/DOT/NHTSA/NCSA/Content/PDF/809_301.pdf, accessed September 23, 2007.

NHTSA (National Highway Traffic Safety Administration) 2006. *Texas, Toll of Motor Vehicle Crashes, 2006*. Available at http://www-nrd.nhtsa.dot.gov/departments/nrd-30/ncsa/STSI/48_TX/2005/48_TX_2005.htm, accessed September 20, 2007.

NHTSA (National Highway Traffic Safety Administration) 2007. *Texas — Victoria County, Toll of Motor Vehicle Crashes, 2006*. Available at http://www-nrd.nhtsa.dot.gov/departments/nrd-30/ncsa/STSI/48_TX/2006/Counties/Texas_Victoria%20County_2006.HTM, accessed October 31, 2007.

NUISD Apr 2008. Nursery Independent School District, *Enrollment and Capacity*, Phone call from R. Henderson–Tetra Tech to S. Bell–Nursery ISD on April 4, 2008.

OMB Nov 2007. Office of Management and Budget, *OMB BULLETIN NO. 08-01: Update of Statistical Area Definitions and Guidance on Their Uses*, November 20, 2007. Available at http://www.whitehouse.gov/omb/bulletins/fy2008/b08-01.pdf, accessed April 13, 2008.

RISD Apr 2008. Refugio Independent School District, *Enrollment and Capacity*, Phone call from R. Henderson–Tetra Tech to B. Azam–Refugio ISD on April 14, 2008.

TAOC 2007. Texas Association of Counties, *County Information Project County Data Clearinghouse, Victoria County Property Tax Information*. Available at http://www.txcip.org/tac/census/taxes.php?FIPS=48469, accessed November 2007.

TCPA 2008a. Texas Comptroller of Public Accounts, *Texas Net Revenue by Source—Fiscal 2007*. Available at http://www.window.state.tx.us/taxbud/revenue.html, accessed January 2008.

TCPA 2008b. Texas Comptroller of Public Accounts, *Texas Sales and Use Tax Rates*, January 2008. Available at http://www.window.state.tx.us/taxinfo/local/jan08rates.pdf, accessed February 2008.

TPWD Nov 2001. Texas Parks and Wildlife Department, *Texas Parks and Wildlife for the 21st Century, An Overview of the Texas Tech University Studies in Conservation and Recreation for the Coming Decades*, November 2001.

TXDOT (Texas Department of Transportation) 2007. District/County Statistics: Statistical Comparison of Texas Counties (9/1/2006 thr 8/31/2007). Available at http://www.dot.state.tx.us/apps/discos/default.htm, accessed July 16, 2008.

UHV Oct 2007. University of Houston Victoria, *Enrollment and Accreditation*, Phone call from R. Henderson–Tetra Tech to T. Wortham–University of Houston Victoria on October 12, 2007.

USCB 2000. U.S. Census Bureau, *Texas—County. GCT-P7. Households and Families: 2000, Data Set: Census 2000 Summary File 1 (SF1)*. Available at http://factfinder.census.gov/, accessed May 22, 2008.

USCB 2006. U.S. Census Bureau, *United States and States R2304 Percent of Married-Couple Families with Both Husband and Wife in the Labor Force: 2006*. Available at http://factfinder.census.gov, accessed May 22, 2008.

USEPA Oct 2003. U.S. Environmental Protection Agency, *Water on Tap What You Need to Know*, October 2003.

USEPA 2009. United States Environmental Protection Agency. Human-Related Sources and Sinks of Carbon Dioxide. Available at: http://www.epa.gov/climatechange/emissions/co2_human.html. Accessed on December 10, 2009.

U.S. NRC May 1996. U.S. Nuclear Regulatory Commission, *Generic Environmental Impact Statement for License Renewal for Nuclear Plants (GEIS)*, Volumes 1 and 2, NUREG-1437, May 1996.

U.S. NRC 2008. U.S. Nuclear Regulatory Commission. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants: Regarding Indian Point Nuclear Generating Unit Nos. 2 and 3* (NUREG-1437, Supplement 38) Office of Nuclear Reactor Regulation, Washington, D.C., December 2008.

U.S. NRC Jul 2009. U.S. Nuclear Regulatory Commission. *Generic Environmental Impact Statement for License Renewal of Nuclear Plants*, Volumes 1 and 2, Draft Report for Comment. NUREG-1437, Revision 1. Office of Nuclear Reactor Regulation, Washington, D.C., July 2009.

U.S. NRC Nov 2009. U.S. Nuclear Regulatory Commission. Commission Order CLI-09-21, In the Matter of Duke Energy Carolinas, LLC and Tennessee Valley Authority. November 3, 2009.

U.S. NRC Dec 2009. U.S. Nuclear Regulatory Commission. *Supplemental Environmental Impact Statement for the Combined License (COL) for North Anna Power Station Unit 3* Draft Report for Comment. NUREG-1917. Office of New Reactors, Washington, D.C., December 2009.

VC Oct 2007. Victoria College, *Enrollment and Accreditation*, Phone call from R. Henderson–Tetra Tech to B. Willemin–Victoria College on October 12, 2007.

VCTA 2007. Victoria County Tax Assessor, *Victoria County Tax Information Online, Victoria County Tax Information—Public Access*. Available at http://www.victoriacountytx.org/departments/tax/property.htm, accessed December 2007.

VISD Apr 2008a. Victoria Independent School District, *Wealth equalization status*. E-mail to K. Sutherlin–Tetra Tech from F. Hoch–VISC Business Manager, April 3, 2008.

VISD Apr 2008b. Victoria Independent School District, *Enrollment and Capacity*, Phone call from R. Henderson–Tetra Tech to R. Leach–Victoria ISD on April 11, 2008.

Table 5.8-1
Estimated Transportation Impacts from Workers Commuting to the Site

	Accidents per year	Injuries per year	Fatalities per year
Operations	10	11	0.10
Outage[(a)]	2.2	2.4	0.021

(a) Outage estimates are for a single 25-day outage. Values would be doubled if more than one outage occurs per year.

Table 5.8-2
Estimated Occupational Injuries and Illnesses per Year

Number of Workers	TRC Incidence at US Rate	TRC Incidence at TX Rate[(a)]	TRC Incidence at Exelon Rate[(b)]
Operations: 800	22	25	2.7
Outage: 1750	8.2	6.0[(c)]	Not applicable

(a) Based on nonfatal incidence rates developed by U.S. Bureau of Labor Statistics.
(b) Based on records of Total Recordable Cases (TRC) at existing Exelon facilities from 2002 through 2006.
(c) Outage estimates are for a single 25-day outage. Values would be doubled if more than one outage occurs per year.
Note: TRC = total recordable cases.

Table 5.8-3
Assumptions for Work Force Migration and Family Composition During VCS Operations

Workforce Characterization	Operations
Number of operations workers onsite	800
Workforce migration	
Percent of workforce migrating into ROI	100
Total number of workers migrating into ROI during operations	800
Families	
Percent of workers who bring families	100
Number of workers who bring families into ROI	800
Average worker family size (worker, spouse, children)[a]	3.25
Total in-migrating workers plus family members (= population increase)	2600
School-age children	
Number of school-age children per family[b]	0.8
Total number of school-age children (0.8 times 800 families)	640

(a) According to USCB table GCT-P7 the average family size in 2000 for the ROI counties ranged from 3.02 in Goliad County to 3.23 in Victoria County. The average family size for the state of Texas was 3.28. Therefore, Exelon assumes that an average family size of 3.25 for the construction workforce would also be a reasonable estimate for the operations workforce. (Year 2006 estimates of family size were not available for all of the counties in the ROI, so they were not used.)

(b) BMI Apr 1981

Sources: USCB 2000, BMI Apr 1981.

Table 5.8-4
Direct and Indirect Employment during VCS Operations

Employment/Demographic Characteristic	Both Units
Direct jobs—operations workforce (100% migrating into ROI)	800
Employment multiplier for Power Generation and Supply Sector workers in the ROI	1.7786
Indirect jobs—resulting from in-migration of operations workers (800 x 1.7786)	1423
Total number of jobs (800 Direct plus 1423 Indirect)	2223
Number of workers vacating construction-related indirect jobs at construction completion	3760
Number of working-age adults accompanying in-migrating operations workers, assuming each operations worker household includes one additional working-age adult	800
Percent of married couple families with both husband and wife in the labor force, 2006: Texas[a]	52.0
Percentage of working-age adults, accompanying in-migrating workforce, available to work (52% of 800)	416
Total number of adults available to fill indirect jobs	4176
Additional indirect jobs that need to be filled by adults currently residing outside of 50-mile radius	0

(a) USCB 2000

Table 5.8-5
Average Annual Wages for All Industry Sectors, Sector 22, Utilities, and Sector 221113, Nuclear Electric Power Generation, in ROI and Comparison Areas, 2006

	Total, All Industry Sectors[(a)]	Sector 22, Utilities	Sector 221113, Nuclear Electric Power Generation[(b)]	Utilities — Percentage Increase over Total	Nuclear Sector — Percentage Increase over Utilities
United States	$42,414	$78,341	$95,927	85%	22%
Texas[(c)]	$43,276	$82,032	ND	90%	–
Calhoun[(c)]	$49,933	ND	N/A	–	–
DeWitt	$26,506	$45,774	N/A	73%	–
Goliad[(c)]	$29,836	$70,386	N/A	136%	–
Jackson[(c)]	$31,200	ND	N/A	–	–
Refugio[(c)]	$28,754	ND	N/A	–	–
Victoria	$34,704	$62,337	N/A	80%	–
Corpus Christi, TX MSA[(c),(d)]	$34,741	ND	N/A	–	–
Houston-Sugar Land-Baytown, TX MSA[(c),(e)]	$51,470	ND	N/A	–	–
San Antonio, TX MSA[(c),(f)]	$36,071	ND	N/A	–	–
Comparison States for Sector 221113, Utilities & Nuclear Electric Power Generation					
Illinois	$45,872	$92,647	$100,867	102%	9%
New Jersey	$51,375	$86,969	$91,873	69%	6%
Pennsylvania	$41,019	$88,442	$110,611	116%	25%
South Carolina	$33,741	$67,816	$85,572	101%	26%

(a) Information is for private firms, all establishment sizes.
(b) n/a = data not available (industry sector does not exist in county or MSA).
(c) ND = information was not provided due to BLS or state agency disclosure standards.
(d) Corpus Christi, TX MSA includes Aransas, Nueces, and San Patricio Counties (OMB Nov 2007).
(e) Houston-Sugar Land-Baytown, TX MSA includes Austin, Brazoria, Chambers, Fort Bend, Galveston, Harris, Liberty, Montgomery, San Jacinto, and Waller Counties (OMB Nov 2007).
(f) San Antonio, TX MSA includes Atascosa, Bandera, Bexar, Comal, Guadalupe, Kendall, Medina, Wilson Counties (OMB Nov 2007).

Sources: BLS 2008a; BEA 2008b; BEA 2008c; OMB Nov 2007.

Table 5.8-6
Sensitivity Analysis — Estimated Wage Impacts of Operations Workers

National Annual Average Operations Worker Wages, May 2006[(a)]			$64,760
Number of Operations Workers[(b)]			800
Estimated Total Annual Payroll			$51,808,000
Earnings Multiplier[(c)]			1.6355
Total Personal Income in ROI, 2005[(d)]			$4,358,157,000
Percent of Total Operations Workforce Wages that could be Spent in Region	**Wage Dollars**	**Total Dollar Impact to Region (Earnings Multiplier Applied)**	**Multiplied Wages as Percent of 2005 Total Personal Income in ROI**
10%	$5,180,800	$8,473,198	0.19%
20%	$10,361,600	$16,946,397	0.39%
30%	$15,542,400	$25,419,595	0.58%
40%	$20,723,200	$33,892,794	0.78%
50%	$25,904,000	$42,365,992	0.97%
60%	$31,084,800	$50,839,190	1.17%
70%	$36,265,600	$59,312,389	1.36%
80%	$41,446,400	$67,785,587	1.56%
90%	$46,627,200	$76,258,786	1.75%
100%	$51,808,000	$84,731,984	1.94%

(a) This is the national average annual wage for BLS occupational category 19-4051, Nuclear Technicians, as of May 2006 (BLS 2008d).
(b) The operations workforce is projected to achieve full staffing as of Month 56 (near the end of Year 6) of the Construction phase. See ER Section 3.10.
(c) Source: BEA Mar 2008.
(d) Source: BEA 2007.
Sources: BEA 2007; BEA Mar 2008; BLS 2008d.

Table 5.8-7
VCS Workforce and Indirect Workers as Percentage of ROI Total Employment

Workforce Characterization, 60-year Operations Period	Operations Workforce	Indirect Workers	Total
Operations workers[(a)]	800		
Employment multiplier for ROI, Power Generation and Supply Sector Workers[(b)]	1.7786		
Indirect workers		1423	
TOTAL Workers			2223
ROI Total Employment, 2006[(c)]			74,776
VCS workers and Indirect Workers as Percent of Total in ROI			3.0%

(a) See Table 5.8-3
(b) BEA Mar 2008
(c) BEA 2007

Sources: BEA 2007; BEA Mar 2008

Table 5.8-8
Sensitivity Analysis — Estimated Wage Impacts of Outage Workers

Annual Operations Worker Wages, May 2006[(a)]						$64,760
Estimated Daily Wages (Annual ÷ 360)						$179.89
Earnings Multiplier[(b)]						1.6355
Total Personal Income in ROI, 2005						$4,358,157,000
			Low Estimate			**High Estimate**
Length of Outage in Days[(c)]			20			25
Number of Outage Workers Per Unit[(c)]			1750			1750
Estimated Total Annual Payroll			$6,296,111			$7,870,139
Percent of Total Operations Workforce Wages Assumed to be Spent in Region	**Wage Dollars Spent in ROI**	**Total Dollar Impact to Region (Earnings Multiplier Applied)**	**Total Dollar Impact as a Percent of 2005 Total Personal Income in ROI[(d)]**	**Wage Dollars Spent in ROI**	**Total Dollar Impact to Region (Earnings Multiplier Applied)**	**Total Dollar Impact as a Percent of 2005 Total Personal Income in ROI[(d)]**
10%	$629,611	$1,029,729	0.02%	$787,014	$1,287,161	0.03%
20%	$1,259,222	$2,059,458	0.05%	$1,574,028	$2,574,322	0.06%
30%	$1,888,833	$3,089,187	0.07%	$2,361,042	$3,861,484	0.09%
40%	$2,518,444	$4,118,916	0.09%	$3,148,056	$5,148,645	0.12%
50%	$3,148,056	$5,148,645	0.12%	$3,935,069	$6,435,806	0.15%
60%	$3,777,667	$6,178,374	0.14%	$4,722,083	$7,722,967	0.18%
70%	$4,407,278	$7,208,103	0.17%	$5,509,097	$9,010,129	0.21%
80%	$5,036,889	$8,237,832	0.19%	$6,296,111	$10,297,290	0.24%
90%	$5,666,500	$9,267,561	0.21%	$7,083,125	$11,584,451	0.27%
100%	$6,296,111	$10,297,290	0.24%	$7,870,139	$12,871,612	0.30%

(a) This is the national average annual wage for BLS occupational category 19-4051, Nuclear Technicians, as of May 2006 (BLS 2008d).
(b) BEA Mar 2008.
(c) The outage workforce is estimated at 1750 workers per unit for each outage (midpoint of the 1500–2000 estimate), which is assumed to occur approximately every 18 to 24 months and last 20–25 days. For years in which two outages occur, impacts will be doubled.
(d) Income is Total Personal Income for the six counties of the ROI (BEA 2007).

Sources: BEA 2007; BEA Mar 2008; BLS 2008d.

Table 5.8-9
Sensitivity Analysis — Estimated Franchise Taxes on VCS: Hypothetical Scenarios

	VCS Unit 1 (begins 2017)		VCS Unit 2 (begins 2018)		Total	
Year[a]	**Low**	**High**	**Low**	**High**	**Low**	**High**
Hypothetical Scenarios: Gross Margin						
2017	$350,000,000	$550,000,000	$0	$0	$350,000,000	$550,000,000
2018	$350,000,000	$550,000,000	$350,000,000	$550,000,000	700,000,000	1,100,000,000
Estimated Franchise Tax (1% of Gross Margin)						
2017	$3,500,000	$5,500,000	$0	$0	$3,500,000	$5,500,000
2018	$3,500,000	$5,500,000	$3,500,000	$5,500,000	$7,000,000	$11,000,000
Total Texas Franchise Tax Revenues in 2007:						$3,144,059,392
VCS estimated payments for 2017 as percent of Texas 2007 total:					0.11%	0.17%
VCS estimated payments for 2018 and subsequent years as percent of Texas 2007 total:					0.22%	0.35%

(a) For this analysis, Exelon assumes a two-unit plant. VCS Unit 1 begins operations in 2017; Unit 2 begins in 2018.
Source: TCPA 2008a

Table 5.8-10
Estimated Projected Sales Taxes, Victoria County and the City of Victoria, 2007–2020[(a)]

Year	Victoria County	City of Victoria
2007	$7,179,370	$19,615,179
2008	7,597,809	20,684,252
2009	8,040,636	21,811,593
2010	8,509,273	23,000,375
2011	9,005,223	24,253,950
2012	9,530,079	25,575,847
2013	10,085,526	26,969,790
2014	10,673,346	28,439,707
2015	11,295,426	29,989,738
2016	11,953,763	31,624,248
2017	12,650,471	33,347,844
2018[(b)]	13,387,785	35,165,380
2019	14,168,072	37,081,975
2020	14,993,837	39,103,029

(a) Projections are based on growth rates between 1997 and 2007.
See Subsection 2.5.2.3.

(b) 2018 = First year of operation, assumed for this representative analysis.

Table 5.8-11
Hypothetical Sales Tax Scenarios — Annual Operational Expenditures Subject to Sales & Use Tax in Victoria County/City of Victoria

Scenario	Taxable Purchases				
Scenario 1	$500,000				
Scenario 2	$1,000,000				
Scenario 3	$1,500,000				
	Victoria County	**City of Victoria**	**Local Total**	**Texas**	**Total**
Sales tax rate[a]	0.5%	1.5%	2.0%	6.25%	8.25%
Estimated VCS Taxes by Scenario					
Scenario 1	$2,500	$7,500	$10,000	$31,250	$41,250
Scenario 2	$5,000	$15,000	$20,000	$62,500	$82,500
Scenario 3	$7,500	$22,500	$30,000	$93,750	$123,750
Estimated VCS Tax Payments as Percent of Projected 2018 Total, Local Entities:					
Projected Local Taxes, 2018:	$13,387,785	$35,165,380	$48,553,165		
Scenario 1	0.02%	0.02%	0.02%		
Scenario 2	0.04%	0.04%	0.04%		
Scenario 3	0.06%	0.06%	0.06%		
Estimated VCS Tax Payments as Percent of 2007 Total, Texas					
Texas Total Sales Tax Revenue in 2007[b],[c]				$20,300,000,000	
Scenario 1				0.0002%	
Scenario 2				0.0003%	
Scenario 3				0.0005%	

(a) Source: TCPA 2008b.
(b) For this analysis, sales taxes were not projected for the State due to the small contribution (less than 0.005%) expected from the new units.
(c) Source for Texas 2007 sales tax revenues: TCPA 2008a.

Table 5.8-12
Current Owner's Taxable Property Value and Tax Payments for VCS Site, 2006

	Total Taxable Property Value	Total County Levy
Victoria County Totals[(a)]	$4,237,939,605	$16,892,428
Payments by Current Owner of Exelon Site (11 parcels)[(b)]		
County Of Victoria General Fund	$897,420	$3084
Road & Bridge Fund	$897,420	$494
Victoria County Junior College District	$897,420	$1271
Victoria County Navigation District	$897,420	$301
Victoria County Groundwater District	$897,420	$90
Total Tax Payments – County and Special Districts		$5238
Site as a Percent of Victoria County Totals	0.02%	0.03%

(a) Source: TAOC 2007 (see Subsection 2.5.2.3, Table 2.5.2-16)
(b) Source: VCTA 2007 (see Subsection 2.5.2.3, Table 2.5.2-20)

Table 5.8-13
Projected Taxable Property Value and Tax Payments, Victoria County, 2007–2020

	Total Taxable Value, General Fund		Total County Levy	
2006 – Actual(a)	**$4,237,939,605**		**$16,892,428**	
Projections(b)	**Low**	**High**	**Low**	**High**
2007	$4,377,469,913	$4,412,944,900	$17,911,053	$18,053,566
2008	$4,521,594,130	$4,595,177,021	$18,991,102	$19,294,516
2009	$4,670,463,506	$4,784,934,399	$20,136,279	$20,620,767
2010	$4,824,234,271	$4,982,527,789	$21,350,511	$22,038,179
2011	$4,983,067,798	$5,188,280,779	$22,637,961	$23,553,021
2012	$5,147,130,775	$5,402,530,318	$24,003,046	$25,171,989
2013	$5,316,595,376	$5,625,627,270	$25,450,447	$26,902,240
2014	$5,491,639,445	$5,857,936,989	$26,985,126	$28,751,424
2015	$5,672,446,681	$6,099,839,914	$28,612,348	$30,727,715
2016	$5,859,206,830	$6,351,732,197	$30,337,693	$32,839,851
2017	$6,052,115,888	$6,614,026,347	$32,167,077	$35,097,169
2018	$6,251,376,301	$6,887,151,907	$34,106,774	$37,509,648
2019	$6,457,197,182	$7,171,556,160	$36,163,436	$40,087,955
2020	$6,669,794,529	$7,467,704,859	$38,344,117	$42,843,487

(a) See Subsection 4.4.2.2.2, Table 4.4.2-19.
(b) "Low" is projected at average annual growth rate from 1991 to 2006; "High" is projected at average annual growth rate from 2000 to 2006 (see Subsection 2.5.2.3 and Table 2.5.2-16). Dollars are not adjusted for inflation.

Table 5.8-14
Estimated Impact of VCS Property Taxes on Victoria County

Victoria County general tax rate per $100 of appraised value, 2007[a]	0.3436
Total Victoria County levy, projected for 2018 – Low[b]	$34,106,774
Total Victoria County levy, projected for 2018 – High[b]	$37,509,648
VCS Taxable Estimate for 2018	
Taxable Value	$2,000,000,000
Amount of Tax	$6,872,000
Total Projected Levy (Victoria County Levy plus VCS Tax Payment) — Low	$40,978,774
Total Projected Levy (Victoria County Levy plus VCS Tax Payment) — High	$44,381,648
VCS as% of Total Projected Levy (Low)	16.8%
VCS as% of Total Projected Levy (High)	15.5%

(a) Source: TCPA 2008b (County Tax Rates).
(b) “Low” is projected at average annual growth rate from 1991 to 2006; “High” is projected at average annual growth rate from 2000 to 2006 (Table 5.8-13).

Table 5.8-15
Law Enforcement in the ROI, Adjusted for the Operations Workforce and Associated Population Increase

Location	Total Population in 2000	Additional Population due to Plant Operations	Population Adjusted for Operations Workforce	Sworn Officers (2005)	Operations Labor Force-Adjusted People-per-Officer Ratio	Pre-VCS Operations People-per-Officer Ratio	Percent Increase from Pre-VCS Operations People-per-Officer Ratio	Additional Officers Required during Operations to Maintain Pre-VCS Ratios
ROI	153,895	2600	156,495	319	491:1	482:1	1.9	6

Source: Table 2.5.2-46.

Table 5.8-16
Fire Protection in the ROI, Adjusted for the Operations Workforce and Associated Population Increase

Location	Total Population in 2000	Additional Population due to Plant Operations	Population Adjusted for Operations Workforce	Active Firefighters (career, volunteer, and paid per call) (2007)	Operations Labor Force-Adjusted People-per-Firefighter Ratio	Pre-VCS Operations People-per-Firefighter Ratio	Percent Increase from Pre-VCS Operations People-per-Firefighter Ratio	Additional Firefighters Required during Operations to Maintain Pre-VCS Ratios
ROI	153,895	2600	156,495	628	249:1	245:1	1.6	11

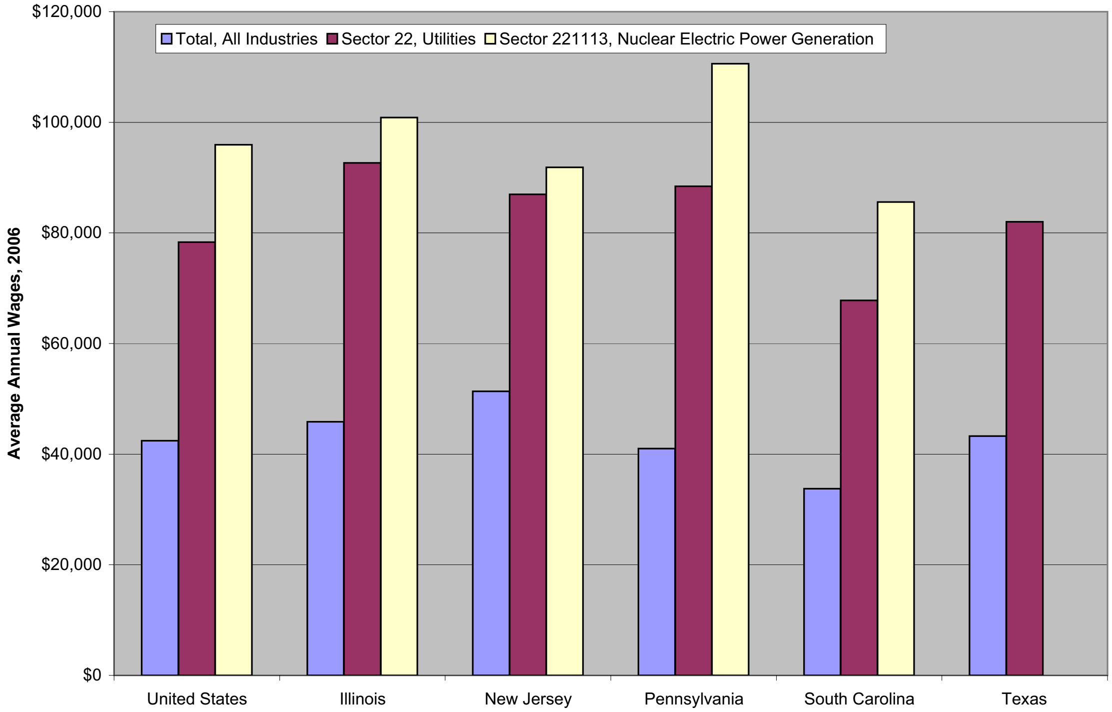
Source: Table 2.5.2-46.

Table 5.8-17
Educational Enrollment Capacity of Counties

ISD	Current Enrollment	Enrollment Capacity[(a)]	Excess Student Capacity[(b)]	Number of Operations-Worker Families the County can Support without Exceeding Capacity[(c)]
Calhoun County				
Calhoun County ISD	4290	5632	1342	
County-wide Total	4290	5632	1342	1678
DeWitt County				
Cuero ISD	1950	2700	750	
Meyersville ISD	125	160	35	
Nordheim ISD	82	175	93	
Westhoff ISD	48	160	112	
Yoakum ISD	1550	1550	0	
Yorktown ISD	650	900	250	
County-wide Total	4405	5645	1240	1550
Goliad County				
Goliad ISD	1312	1312	0	
County-wide Total	1312	1312	0	0
Jackson County				
Edna ISD	1450	1800	350	
Ganado ISD	640	700	60	
Hallettsville ISD	887	1050	163	
Industrial ISD	1060	1150	90	
Palacios ISD	1523	1800	277	
County-wide Total	5560	6500	940	1175
Refugio County				
Austwell-Tivoli ISD	155	500	345	
Refugio ISD	735	1500	765	
Woodsboro ISD	546	600	54	
County-wide Total	1436	2600	1164	1455
Victoria County				
Bloomington ISD	908	1050	142	
Nursery ISD	110	210	100	
Victoria ISD	13,550	23,350	9800	
County-wide Total	14,568	24,610	10,042	12,553
ROI TOTAL	31,571	46,299	14,728	18,410

(a) Sums the capacity of existing schools and the capacity of proposed or expanded schools
(b) Enrollment Capacity (including proposed and expansion school capacity) minus 2007-2008 year student enrollment
(c) Sums may not total due to rounding

Sources: Table 2.5.2-50



(Note: Sector 221113 information for Texas was undisclosed. See Table 5.8-5.)

Figure 5.8-1 Comparison of Average Annual Wages for All Industry Sectors, Sector 22, Utilities, and Sector 221113, Nuclear Electric Power Generation, 2006

5.9 Decommissioning

The NRC defines decommissioning as the safe removal of a nuclear facility from service and the reduction of residual radioactivity to a level that permits release of the property for unrestricted use or under restricted conditions and termination of the license. NRC regulation 10 CFR 50.82 specifies the regulatory actions that NRC and a licensee must take to decommission a nuclear power facility. The radiological criteria to be met for license termination are specified in 10 CFR 20, Subpart E. These requirements apply to the existing fleet of power reactors and to advanced reactors.

Decommissioning must occur because NRC regulations do not permit a license holder to abandon a facility after ending operations. The NRC prohibits licensees from performing decommissioning activities that result in significant environmental impacts not previously reviewed under 10 CFR 50.82. The NRC has indicated that licensees for existing reactors can rely on the information in the Generic Environmental Impact Statement (GEIS) on decommissioning of nuclear facilities to determine the environmental impacts of decommissioning for the existing fleet of domestic nuclear power reactors as documented in Supplement 1 to NUREG-0586 (U.S. NRC Nov 2002).

Further, NRC regulation 10 CFR 50.75 establishes the financial requirements for providing reasonable assurance that adequate funds for performing decommissioning are available at the end of the plant operations. The DOE funded a study that compares activities and costs required to decommission existing reactors to those required for advanced reactors (U.S. DOE May 2004).

Exelon has concluded that Supplement 1 to NUREG-0586 is appropriate to provide a basis for concluding that the generic environmental impacts identified in the GEIS bound the impacts that can be reasonably expected from decommissioning the new reactors (U.S. NRC Nov 2002).

5.9.1 NRC GEIS Regarding Decommissioning

NUREG-0586, Supplement 1 describes decommissioning regulatory requirements, the decommissioning process, and environmental impacts of decommissioning (U.S. NRC Nov 2002). Before presenting impacts, the GEIS describes the NRC process for evaluating impacts. Activities and impacts that NRC considered to be within the scope of the GEIS include:

- Activities performed to remove the facility from service once the licensee certifies that the facility has permanently ceased operations.
- Activities performed in support of radiological decommissioning, including decontamination and dismantlement of radioactive structures, systems, and components (SSCs) and any activities required to support the decontamination and dismantlement process.

- Activities performed in support of dismantlement of nonradiological SSCs, such as diesel generator buildings and cooling towers.
- Activities performed up to license termination and their resulting impacts as provided by the definition of decommissioning.
- Human health impacts from radiological and nonradiological decommissioning activities.

According to Section 5.9 of NUREG-1555 (U.S. NRC Oct 1999), studies of social and environmental effects of decommissioning large commercial power generating units have not identified any significant impacts beyond those considered in the GEIS on decommissioning. The GEIS evaluates the environmental impact of the following three decommissioning methods:

- DECON — The equipment, structures, and portions of the facility and site that contain radioactive contaminants are removed or decontaminated to a level that permits termination of the license shortly after cessation of operations.
- SAFSTOR — The facility is placed in a safe stable condition and maintained in that state (safe storage) until it is subsequently decontaminated and dismantled to levels that permit license termination. During SAFSTOR, a facility is left intact, but the fuel is removed from the reactor vessel and radioactive liquids are drained from systems and components and then processed. Radioactive decay occurs during the SAFSTOR period, thus reducing the quantity of contaminated and radioactive material that must be disposed of during the decontamination and dismantlement of the facility at the end of the storage period.
- ENTOMB — This alternative involves encasing radioactive SSCs in a structurally long-lived substance, such as concrete. The entombed structure is appropriately maintained, and continued surveillance is carried out until the radioactivity decays to a level that permits termination of the license.

NRC regulations do not require an ESP applicant to select one of the decommissioning methods or to prepare definite plans for decommissioning. These plans are required by the NRC after a decision has been made to cease operations. Therefore, detailed analyses of decommissioning alternatives are not prepared until cessation of operations, and only general environmental impacts are addressed in this section.

As stated in NUREG-0586 (U.S. NRC Nov 2002), decommissioning a nuclear facility that has reached the end of its useful life generally has a positive environmental impact. The air quality, water quality, and ecological impacts of decommissioning are expected to be substantially smaller than those of power plant construction or operation because the level of activity and the releases to the environment are expected to be smaller during decommissioning than during construction and operation. The major environmental impact, regardless of the specific decommissioning option selected, is the commitment of small amounts of land for waste burial in exchange for the potential reuse of the land where the facility is located. Socioeconomic impacts of decommissioning will result from the demands on, and contributions to, the community by the workers employed to decommission a power plant (U.S. NRC Oct 1999).

Experience with decommissioned power plants has shown that the occupational exposures during the decommissioning period are comparable to those associated with refueling and plant maintenance when a plant is operational. Each potential decommissioning alternative will have radiological impacts from the transport of materials to their disposal sites. The expected impact from this transportation activity will not be significantly different from normal operations (U.S. NRC Oct 1999).

5.9.2 DOE-Funded Study on Decommissioning Costs

The total cost of decommissioning depends on many factors, including the sequence and timing of the various stages of the program, location of the facility, current radioactive waste burial costs, and plans for spent fuel storage. To ensure that a lack of funds does not result in delays in or improper conduct of decommissioning that may adversely affect public health and safety, 10 CFR 50.75 requires that operating license applicants and licensees provide reasonable assurance that adequate funds for performing decommissioning will be available at the end of operation. To provide this assurance, the regulation requires that two factors be considered: (1) the amount of funds needed for decommissioning, and (2) the method used to provide financial assurance. At its discretion, an applicant may submit a certification based either on the formulas provided in 10 CFR 50.75 or, when a higher funding level is desired, on a facility-specific cost estimate that is equal to or greater than that calculated using the formula in 10 CFR 50.75, consistent with guidance provided by RG 1.159 (U.S. NRC Oct 2003).

To support development of advanced reactors for production of electric power and to establish the requirements for providing reasonable assurance that adequate funds for performing decommissioning will be available at the end of plant operations, a study was commissioned by DOE (U.S. DOE May 2004). The study presented estimates of the costs to decommission the advanced reactor designs following a scheduled cessation of plant operations. Four reactor types were evaluated in this report: the GEH ESBWR, the GE ABWR, the Westinghouse advanced passive pressurized water reactor (AP1000), and the Atomic Energy of Canada, Limited advanced CANDU reactor (ACR-700). The cost analysis described in the study was based on the prompt decommissioning alternative, or DECON, as defined in the GEIS (U.S. NRC Nov 2002). The DECON alternative is also the basis for the NRC funding regulations in 10 CFR 50.75 and use of the DECON alternative for the advanced reactor designs facilitates the comparison with NRC estimates and financial provisions.

DECON comprises four distinct periods of effort:

1. Pre-shutdown planning/engineering.
2. Plant deactivation and transition (no activities are conducted during this period that will affect the safe operation of the spent fuel pool).
3. Decontamination and dismantlement with concurrent operations in the spent-fuel pool until the pool inventory is zero.
4. License termination.

Each of the decommissioning activities evaluated in the GEIS is performed during one or more of the periods identified above. Because of the delays in developing the federal waste management system, it may be necessary to continue operation of a dry fuel storage facility on the reactor site after the reactor systems have been dismantled and the reactor nuclear license terminated. However, these latter storage costs are considered operational costs and are not considered part of decommissioning (U.S. NRC Nov 2002).

The cost estimates described in the DOE study were developed using the same cost estimating methodology used by NRC and consider the typical features of a generic site located in the southeast, including the nuclear steam supply systems, power generation systems, support services, site buildings, and ancillary facilities. Although no decommissioning cost estimates for the VCS units are prepared as part of this application, Exelon considers the DOE approach to be valid for the VCS units. The estimates are based on numerous fundamental assumptions, including labor costs, low-level radioactive waste disposal costs and practices, regulatory requirements, and project contingencies. Individual cost contributors for the VCS units may be slightly higher or slightly lower than for the DOE study's generic southeastern site; however, the overall conclusion from the study remains applicable. The primary cost contributors identified in the study are either labor-related or associated with the management and disposition of the radioactive waste. Overall, the DOE study concluded that with consistent operating and management assumptions, the total decommissioning costs projected for the advanced reactor designs are comparable to those projected by NRC for operating reactors with appropriate reductions in costs due to reduced physical plant inventories (U.S. DOE May 2004).

5.9.3 Plant Design Features for Decommissioning

The features of the selected reactor design that ensure the VCS units can be operated and maintained with ALARA exposures also serve to assist in achieving ALARA exposures during the decommissioning process. Examples of features which will assist in maintaining low occupational exposures during decommissioning include the following:

- Provisions for draining, flushing, and decontaminating equipment and piping.
- Design of equipment to minimize the buildup of radioactive material and to facilitate flushing of crud traps.
- Shielding which provides protection during maintenance or repairs and during decommissioning operations.
- Provision of means and adequate space for utilization of movable shielding.
- Separation of more highly radioactive equipment from less radioactive equipment and provision of separate shielded compartments for adjacent items of radioactive equipment.
- Provision for access hatches for the installation or removal of plant components.
- Provision of design features such as the Reactor Water Cleanup System and the condensate demineralizer to minimize crud buildup.

5.9.4 Conclusions

Exelon compared the activities analyzed in the GEIS of the environmental impacts associated with decommissioning the existing fleet of domestic nuclear power reactors with the activities that form the basis for decommissioning cost estimates prepared by DOE for advanced reactor designs and determined that the scope of activities is the same. Projected physical plant inventories associated with advanced reactor designs will generally be less than those for currently operating power reactors due to advances in technology that simplify maintenance and benefit decommissioning. Based on this comparison, Exelon has concluded that the environmental impacts identified in the GEIS are representative of impacts that can be reasonably expected from decommissioning the new VCS units.

5.9.5 References

U.S. DOE May 2004, *U.S. Department of Energy, Study of Construction Technologies and Schedules, O&M Staffing and Cost, and Decommissioning Costs and Funding Requirements for Advanced Reactor Designs*, prepared by Dominion Energy Inc., Bechtel Power Corporation, TLG, Inc., and MPR Associates for United States Department of Energy Cooperative Agreement DE-FC07-03ID14492, Contract DE-AT01-020NE23476, May 27, 2004.

U.S. NRC Oct 1999, *Environmental Standard Review Plan*, Section 5.9, NUREG-1555, October 1999.

U.S. NRC Nov 2002, *Generic Environmental Impact Statement on Decommissioning of Nuclear Facilities*, NUREG-0586, Supplement 1, Volume 1, November 2002.

U.S. NRC Oct 2003, *Assuring the Availability of Funds for Decommissioning Nuclear Reactors*, Regulatory Guide 1.159, Revision 1, October 2003.

5.10 Measures and Controls to Limit Adverse Impacts During Operations

Sections 5.1 through 5.9 describe potential environmental impacts that could result from the operation of a nuclear power plant at the VCS site. Adverse environmental impacts would be reduced or eliminated through implementation of measures and controls. The following operations-related measures and controls (OMC) would be used in limiting adverse environmental impacts:

OMC1. For mineral rights and leases outside the exclusion area boundary, Exelon would evaluate the impact on operations of allowing the current land use to continue.

OMC2. Cultural resource surveys and mitigation, if necessary, will be performed in coordination with the Texas Historical Commission (THC). Appropriate actions (e.g., stopping work and contacting appropriate regulatory agencies) would be taken following an unexpected discovery of potential historic or archeological resources.

OMC3. The depth of the proposed site groundwater production zone in the Evangeline Aquifer would minimize potential localized subsidence from groundwater pumping.

OMC4. During low Guadalupe River flow periods, the plant could limit water withdrawals. The cooling basin would be designed to contain enough makeup water to support the operation of the plant for several months during potential low river flow periods. Withdrawals consistent with water allocation laws and regulations and the South Texas Regional Water Planning Group (Region L) water plan to minimize impacts on the availability of water resources in the region.

OMC5. Mitigation of potential water quality impacts to the Guadalupe River from cooling basin blowdown discharges will be accomplished through: (1) appropriate design and operation of the discharge system, (2) ensuring compliance with the requirements of the facility's Texas Pollutant Discharge Elimination System (TPDES) permit, which will consider the generic and segment-specific chemical and thermal water quality standards developed by the TCEQ to preserve the water quality of surface waters in the state, and (3) monitoring and reporting, conducted in accordance with the TPDES permit requirements to demonstrate continued compliance with the permit and protection of the environment.

OMC6. Minor spills of diesel fuel, hydraulic fluid, or lubricants during operations would be cleaned up quickly in accordance with Exelon’s Spill Prevention, Control, and Countermeasures Plan and Facility Response Plan.

OMC7. Impacts to vegetation and wildlife habitat from transmission system operation, which include corridor maintenance and transmission line use, would be expected to be mitigated by the transmission service provider through the use of best management practices for the application and storage of chemicals used in transmission corridor maintenance; only EPA-approved chemicals would be used.

OMC8. To mitigate impingement and entrainment impacts, the raw water makeup (RWMU) system pumphouse is designed to mitigate impacts on aquatic ecosystems. Control measures include limiting the through-screen intake velocity, the use of Ristroph traveling screens, and the inclusion of a fish return system.

OMC9. Personnel and public access to the cooling basin would be controlled by administrative controls and security patrols. The cooling basin would be located within the site boundary, precluding access by members of the public to heated water potentially containing thermophylic organisms.

OMC10. A Stormwater Pollution Prevention Plan (SWPPP) will be developed to prevent or minimize the discharge of pollutants with stormwater. The SWPPP will include the use of best management practices, such as limiting the storage of petroleum materials to designated areas. Retention ponds would be constructed to reduce the rate and volume of stormwater flow from the impervious areas of the site, as well as to allow for the passive removal of settelable solids and entrained debris.

OMC11. Industry accepted chemical handling techniques, pre-job planning, and compliance with a facility waste minimization plan will ensure that only small quantities of mixed wastes will be generated.

OMC12. Provisions or devices for preventing avian collisions implemented by the transmission service provider would be expected to be similar on new transmission lines to those in existing lines and/or as determined in coordination with regulatory agencies.

OMC13. In order to mitigate potential impacts to aquatic populations from operation and maintenance of transmission lines, practices and procedures would be expected to be adopted by the transmission service provider to prevent impacts to surface waters and wetlands.

OMC14. Should complaints of noise or radio and television interference occur, the cause of complaints would be expected to be investigated by the transmission service provider and, if necessary, problems would be corrected.

OMC15. Radiological protection programs would manage and limit doses to workers who are exposed to radiation emitted during incident-free transportation of radiological materials.

OMC16. Exelon would maintain communication with local government, planning officials, and media so that adequate time is given to plan for significant workforce changes.

OMC17. The separation of operations and outage workforces into shifts would result in not all workers arriving at and departing from VCS at the same time. Additionally, carpooling and other “share-the-ride” approaches could potentially reduce the transportation impacts.

OMC18. Physical structures and infrastructure of VCS onsite and offsite (e.g., intake structure), as well as operational activities, would produce visual and physical impacts for recreational facilities in the vicinity. The color of the plant will be selected to be aesthetically compatible with the surrounding environment. The landscaping design for the site areas adjacent to the structures, including parking areas, will be compatible with the natural surroundings at the plant location.

OMC19. An industrial safety program would be implemented and safety professionals would be employed to oversee the program.

In Table 5.10-1, the environmental impacts and corresponding measures and controls discussed in previous sections of Chapter 5 are summarized.

Table 5.10-1 (Sheet 1 of 5)
Summary of Potentially Adverse Impacts of Operation

Impact	Adverse Impact Description or Activity	Specific Measures and Controls
5.1 Land-Use Impacts		
5.1.1 The Site and Vicinity	Approximately 6354 acres of land would be permanently dedicated to the plant use.	None[a]
	Not allowing some mineral rights and associated oil and gas leases to continue.	OMC1
	Impacts of salt deposition and shadowing from the cooling tower operation.	None[a]
	Maintenance of the heavy haul road as access to Victoria Barge Canal via VCND transportation corridor.	None[a]
5.1.2 Transmission Corridors and Offsite Area	Portions of approximately 2809 acres of land would be permanently dedicated to the new transmission line corridor.	None[a]
	Operation and maintenance of transmission lines and corridors. Operation would be potentially compatible with cultivation, grazing, and hunting, but preclude residential and industrial use. Maintenance practices would include mowing and application of herbicides and growth-regulating chemicals.	OMC7
	Maintenance of the rail spur.	None[a]
	Operation and maintenance of RWMU system intake and conveyance piping/structures.	None[a]
	Impacts to offsite land from disposal of radioactive (low-level radioactive waste and spent nuclear fuel) and nonradioactive wastes that would be generated at VCS. The wastes would be disposed of in offsite disposal facilities.	None[a]
5.1.3 Historic Properties and Cultural Resources	Potential impacts to historic resources due to operation of VCS and the transmission lines. Visual impacts to offsite historic facilities from the ability to see the structures and mechanical draft cooling tower plumes of VCS.	OMC2
5.2 Water-Related Impacts		
5.2.1 Hydrologic Alternations and Plant Water Supply	Potential localized hydrologic impacts from the withdrawal of groundwater from the Evangeline Aquifer.	OMC3
	Seepage from the operation of the cooling basin would increase infiltration to the underlying Chicot Aquifer, which would most likely alter the natural shallow groundwater flow direction and gradient near the cooling basin.	None[a]
5.2.2 Water-Use Impacts	Water withdrawal from the Guadalupe River in order to replace water lost to evaporation, drift, seepage, and blowdown.	OMC4
	Groundwater would be withdrawn from the Evangeline Aquifer through onsite wells to meet an estimated operations demand of 1200 gpm (peak).	None[a]
5.2.3 Water Quality Impacts	Potential water quality impacts to the Guadalupe River from discharges from the cooling basin.	OMC5
	Potential water quality impacts to surface water and groundwater from spills of chemicals or petroleum products.	OMC6
	Potential water quality impacts to streams or rivers in or near the transmission corridors due to the use of EPA-approved herbicides.	OMC13

Table 5.10-1 (Sheet 2 of 5)
Summary of Potentially Adverse Impacts of Operation

Impact	Adverse Impact Description or Activity	Specific Measures and Controls
5.3 Cooling System Impacts		
5.3.1 Intake System	Impingement of a small number of juvenile and adult fish at the RWMU system intake.	OMC8
	Fish eggs and larvae entrainment at the RWMU system intake.	OMC8
5.3.2 Discharge System	Impacts (thermal, chemical, and physical) to the Guadalupe River and its aquatic life due to blowdown from the VCS cooling basin.	OMC5
5.3.3 Heat-Discharge System	Potential visual impacts from mechanical draft cooling tower plumes. Operation of the mechanical draft cooling towers would result in plumes that would occur in each direction of the compass and would be spread over a wide area, reducing the time that the plume would be visible from any particular location.	None[a]
	Potential impacts to vegetation and terrestrial wildlife in the area due to atmospheric effects from operations of the mechanical draft cooling towers. Operation of the cooling towers could lead to minor shadowing, very small increase in precipitation, no noticeable increases in ground-level humidity in the immediate vicinity, and salt deposition that is a fraction of the level needed to have visible effects on vegetation.	None[a]
	Potential impacts to wildlife from noise from the mechanical draft cooling towers. Noise from the cooling towers would be less than the level the NRC considers of small significance.	None[a]
5.3.4 Impacts to Members of the Public	Potential health impact to members of the public from contact with human disease-causing thermophilic microorganisms in the cooling basin and at the Guadalupe River from the blowdown.	OMC5, OMC9
	Potential impact to members of the public from noise emitted by the mechanical draft cooling towers. Noise levels 400 feet from the cooling towers are estimated to be less than 65 dBA.	None[a]
5.4 Radiological Impacts of Normal Operation		
5.4.3 Impacts to Members of the Public	Potential health impacts to members of the public from exposure to radiological releases. Modeling using the design and operational parameters of VCS results in estimated doses to the public that are within the design objectives of 10 CFR 50 Appendix I and within regulatory limits of 40 CFR 190.	None[a]; monitor radiological releases as required by radiological monitoring program.
5.4.4 Impacts to Biota Other than Members of the Public	Potential impacts to terrestrial and aquatic ecosystems from chronic radiation exposure (less than 100 mrad/day) caused by the small discharges of radioactive liquids and gases from the operation of VCS.	None[a]; monitor radiological releases as required by radiological monitoring program.
5.4.5 Occupational Radiation Doses	Potential health impacts to workers from radiation exposure will be in accordance with applicable 10 CFR 20 and 10 CFR 50 Appendix I criteria.	None[a]; monitor radiological releases as required by radiological monitoring program.
5.5 Environmental Impacts of Waste		
5.5.1 Nonradioactive Waste System Impacts	Potential impacts to water quality of Guadalupe River from discharges from the VCS cooling basin.	OMC5

Table 5.10-1 (Sheet 3 of 5)
Summary of Potentially Adverse Impacts of Operation

Impact	Adverse Impact Description or Activity	Specific Measures and Controls
5.5.1 Nonradioactive Waste System Impacts (continued)	Potential impacts to water quality of surface water due to increased volume of stormwater resulting from new impervious surfaces.	OMC10
	Potential impacts from land disposal of nonradioactive solid wastes.	None[(a)]
	Potential impacts to air quality from emissions of auxiliary systems operated on an intermittent basis.	None[(a)]
5.5.2 Mixed Waste Impacts	Operation of the units will result in generation of mixed waste, which is regulated as both radioactive waste and hazardous waste.	OMC11
5.6 Transmission System Impacts		
5.6.1 Terrestrial Ecosystems	Potential impacts to vegetation and wildlife habitat from transmission system operation, which include corridor maintenance and transmission line use, relative to terrestrial ecosystems.	OMC7
	Avian mortality resulting from collision with transmission lines.	OMC12
5.6.2 Aquatic Ecosystems	Potential water quality impacts and subsequent impacts to aquatic populations from maintenance of transmission lines that lie at or near water bodies and wetlands.	OMC13
5.6.3 Impacts of Members of the Public	Impacts to members of the public resulting from the operation and maintenance of the transmission system may occur as visual impacts, electric shock hazards, electromagnetic field exposure, noise impacts, or radio and television interference.	OMC14
5.7 Uranium Fuel Cycle and Transportation Impacts		
5.7.1 Uranium Fuel Cycle	Potential impacts to land use from fuel cycle. Total annual land requirements for fuel cycle support would be about 462 acres, 53 acres of which would be permanently committed.	None[(a)]
	Potential impacts to water resources from fuel cycle. Total annual water use for the fuel cycle would be 4.66×10^{10} gallons.	None[(a)]
	Potential impacts to fossil fuel resources from fuel cycle. Electric energy needs for fuel cycle would be about 5% of the output of one of the proposed units. Natural gas consumption for fuel cycle support if used instead to generate electricity would yield less than 0.4% of the energy output of one of the proposed units.	None[(a)]
	Potential impacts to air and water quality from fuel cycle. Gaseous effluents would be less than 0.14% of all 2005 US SO_2 emissions and less than 0.029% of all 2005 US NO_x emissions. Milling process chemical effluents are not released in quantities sufficient to have significant impacts on the environment. Greenhouse gases are released as part of the fuel cycle.	None[(a)]
	Potential health impacts to members of the public from radioactive effluents from the fuel cycle. The estimated whole-body population dose commitment to the U.S. population would be approximately 820 person-rem per year.	None[(a)]
	Potential environmental impacts from disposal of radioactive wastes generated as a result of the fuel cycle.	None[(a)]

Table 5.10-1 (Sheet 4 of 5)
Summary of Potentially Adverse Impacts of Operation

Impact	Adverse Impact Description or Activity	Specific Measures and Controls
5.7.1 Uranium Fuel Cycle (continued)	Potential health impacts to fuel cycle workers caused by radiation exposure. The estimated occupational dose (to all fuel cycle workers cumulatively) is approximately 2500 person-rem per year.	None[(a)]
	Potential health impacts to transportation workers and members of the public caused by radiation exposure resulting from the loading, unloading, and transport of radioactive materials associated with the fuel cycle. The estimated collective dose to workers and the public from transportation associated with the fuel cycle is 10 person-rem per year. For comparative purposes, the estimated collective dose from natural background radiation to the population within 50 miles of VCS is 75,000 person-rem per year.	None[(a)]
5.7.2 Transportation of Radioactive Materials	Potential health impacts to the public and workers caused by exposure to radiation emitted during incident-free transportation of radiological material. Shipments would be less than the one-per-day condition of 10 CFR 51.52.	OMC15
5.8 Socioeconomic Impacts		
5.8.1 Physical Impacts of Station Operation	Noise impacts due to the operation of plant systems including the cooling towers. Noise levels would be below 65 dBA.	None[(a)]
	Potential impacts to air quality from limited, short-term operation of auxiliary systems.	None[(a)]
	Visual impacts to landscape from reactor buildings, mechanical draft cooling towers and associated plumes, and offsite facilities.	OMC2, OMC18
	The increased traffic resulting from these commuters would increase the risk of vehicle accidents involving injuries and fatalities. Additional injuries were estimated to be less than 14 annually.	OMC17
	Impact to worker health due to occupational injuries and illnesses. Total recordable cases of occupational injuries and illnesses estimated per year for the onsite worker population of VCS is less than three cases based on historical incident rates at Exelon facilities.	OMC19
5.8.2 Social and Economic Impacts of Station Operation	Operations-related population increase of the 6-County Region of Influence of less than 2%.	OMC16
	Limited development would result in minimal changes in the area's basic land use pattern due to the operations-related population.	None[(a)]
	Potential impact to housing market affecting prices and rents.	OMC16
	Increased traffic on area roadways due to operations and outage workers commuting to VCS.	OMC17
	Physical structures and infrastructure of VCS on site and offsite (e.g., intake structure) as well as operational activities would produce visual and physical impacts for recreational facilities in the vicinity.	OMC18
	Additional water demand due to operations-related population would slightly reduce the excess capacity in public water supply of the two water planning regions in the ROI.	OMC16
	Impacts to local wastewater treatment systems could occur as the population would increase due to the in-migration of the operations-related workers and their families.	OMC16

Table 5.10-1 (Sheet 5 of 5)
Summary of Potentially Adverse Impacts of Operation

Impact	Adverse Impact Description or Activity	Specific Measures and Controls
5.8.2 Social and Economic Impacts of Station Operation (continued)	Potential impact to police and fire department services in the ROI due to small increases in the ratio of persons to police and firefighters over preconstruction levels. The ratio would be less than that during the construction period, which could lead to the dismissal of officers and firefighters hired to provide services at that higher population time.	OMC16
	Potential impact to housing market affecting prices and rents.	None[a]
	Impact to schools due to operations workforce increasing the student population.	OMC16
5.8.3 Environmental Justice Impacts of Station Operation	No disproportionately high and adverse impacts to low-income and minority populations.	None[a]
5.9 Decommissioning		
	Commitment of small amounts of land for waste burial.	None[a]
	Potential impact to worker health due to occupational exposures. Experience with decommissioned power plants has shown that the occupational exposures during the decommissioning period are comparable to those associated with refueling and plant maintenance when a plant is operational.	None[a]; comply with applicable radiological control and monitoring program and regulatory requirements.
	Radiological impacts from the transport of materials removed during decommissioning to their disposal sites. The expected impact from this transportation activity would not be significantly different from normal operations.	None[a]; comply with applicable radiological control and monitoring program and regulatory requirements.

(a) No practical mitigation measures were identified or required.

5.11 Cumulative Impacts

This section discusses cumulative adverse impacts to the region's environment that could result from the operation of nuclear reactors at VCS. A cumulative impact is defined in the Council of Environmental Quality regulations (40 CFR 1508.7) as an "impact on the environment which results from the incremental impact of the action when added to other past, present, and reasonably foreseeable future actions regardless of what agency (Federal or non-Federal) or person undertakes such other actions."

The impacts of operations of VCS, as described in previous Chapter 5 sections, are combined with other past, present, and reasonably foreseeable future actions in the vicinity of VCS that would affect the same resources, regardless of what agency (federal or nonfederal) or person undertakes such other actions. The cumulative impacts described in this section are those expected to overlap with the impacts of VCS operations because of timing and proximity. The timing for impacts that could be cumulative with operation of VCS is 2020 and beyond. The geographic area or region of influence that was used when considering cumulative impacts for the various resource areas is found in Table 5.11-1. Not all the impacts of VCS operations would be cumulative with other past, present, and reasonably foreseeable actions. In addition, the impacts of VCS operations are based on existing environmental conditions, so the impact analyses have already accounted for present actions. For example, potential water resource impacts from operations of VCS already have factored in existing users and dischargers such as Invista-DuPont and Dow Chemical Company (formerly Union Carbide Corporation [UCC]).

Projects in the geographic area considered for cumulative impacts (see Table 5.11-1) include Coleto Creek Power Station; the South Texas Project; Guadalupe-Blanco River Authority (GBRA) development of water withdrawal, storage, and delivery infrastructure to meet the existing and projected water supply demands of their 10-county district; a clean coal plant in Matagorda County, the White Stallion Energy Center (WSEC); and a uranium mining project, the Uranium Energy Corporation (UEC) Goliad Project, in Goliad County. The locations of these planned projects are shown in Figure 4.7-1

Other projects described for cumulative impacts during construction in Section 4.7 are the VCND transportation corridor, the upgrade of U.S. Highway 77 to an interstate highway, and the inclusion of additional pumping capacity at the VCS raw water makeup (RWMU) intake structure. The roadways would be operational, but not have impacts that would overlap with VCS operation impacts. The additional pumping capacity of the RWMU intake structure is considered as a potential cumulative ecological impact. There are no plans for the use of the additional pumping capacity at this time. Because the use of this additional pumping capacity could be offset by decreases in other proposed water withdrawals, the water use impacts would not be cumulative and are not considered in the evaluation of cumulative water use impacts.

Coleto Creek Power Station is located at the Coleto Creek Reservoir, approximately 11 miles northwest of the VCS site (see Figure 4.7-1). Coleto Creek Reservoir serves as the cooling pond for Coleto Creek Power Station (GBRA 2008) and is part of the lower Guadalupe River basin. Coleto Creek Unit 2, a coal-fired unit with 650 MW generating power, is to be operational in fall/winter 2015 (IP and STEC 2009). A back-up supply needed to firm up run-of-river surface water rights stored in the Coleto Creek Reservoir would be supplied by GBRA.

South Texas Project Units 1 and 2 are operating nuclear generating plants located in Matagorda County approximately 60 miles from the VCS site. Two additional units, Units 3 and 4, are proposed and expected to be operational by 2020. The source of water supply for South Texas Project is the Lower Colorado River. The workforce would be expected to reside in the host county, Matagorda County, as well as the more populous adjacent county, Brazoria County. (STP Sep 2009)

GBRA has two projects involving the withdrawal of water from the Guadalupe River Basin for distribution to various upstream delivery points. The Lower Guadalupe Water Supply Project (LGWSP) for Upstream GBRA Needs at Reduced Capacity, with a firm yield of 35,000 acre-feet per year, would divert under existing GBRA water rights by installing a diversion pump station at the GBRA Relift #1 Pump Station on the Calhoun Canal System, an estimated 3-mile long diversion pipeline to a new 16,500 acre-feet reservoir in Calhoun County, and a 160-mile long transmission pipeline from the reservoir to delivery points in the middle and upper Guadalupe River basin (Luling-Lockhart, Lake Dunlap, New Braunfels, and Western Canyon Water Treatment Plant) crossing Calhoun, Victoria, De Witt, Gonzales, Caldwell, Guadalupe, and Comal Counties. (TWDB Feb 2010) The origin and delivery points for the LGWSP are presented in Figure 5.11-1.

A second project to provide water to upstream users requires approval of a new water right. GBRA has applied to the Texas Commission on Environmental Quality (TCEQ) for a new state water right to divert up to 189,484 acre feet per yr from the Guadalupe River at a rate of diversion not to exceed 500 cfs. The water would be diverted from the Guadalupe River just upstream of the saltwater barrier using existing gravity-flow diversion facilities that are part of GBRA's Calhoun Canal System. The project includes the development of one or more new off-channel storage reservoirs in Calhoun and Victoria counties for a combined storage capacity not to exceed 200,000 acre-feet. GBRA may construct storage capacity and other facilities, and develop firm water supplies, in stages, with the fully developed configuration to include one or more pipelines to convey water from the Calhoun Canal System to the GBRA Western Canyon Water Treatment Plant in Comal County as well as other points of need. Figure 5.11-1 illustrates the scope of this project. (GBRA Aug 2009) Conceptual design of these water supply projects is being developed for inclusion in the 2011 Regional Water Plan.

WSEC is a planned 1320-megawatt, solid fueled electric power generating station using clean-coal technology. The plant is to be located near the Port of Bay City in Matagorda County and would use the Lower Colorado River as its water source. (WSEC 2008 and Bay City Tribune Oct 2008)

The Goliad Project is a planned in situ uranium recovery operation for northeast Goliad County under development by the UEC. The total acreage for the 13 current in situ uranium mining leases is 1421 acres and the area would be accessed by U.S. Highway 77A/183 at a location approximately 14 miles north of the town of Goliad. (Carothers Mar 2008) The workers for operation of the project are expected to be hired locally and are estimated at 80 to 100. (My Victoria Jun 2009) In situ uranium mining involves injecting a solution of water and chemicals into a well to mix with and dissolve (leach) the uranium from the ore body and pumping the leachate to the surface for recovery of uranium. The wastewater is then later re-injected into a wastewater well. This process generates no tailings. The proposed mining area is 424 acres and overlies the Goliad formation of the Gulf Coast aquifer. (E&E May 2009)

5.11.1 Land Use

Approximately 6354 acres of land would be dedicated for VCS operations. The land use impact for the operation of VCS is described as small in Section 5.1. Operation of the planned projects described above located within 50 miles of VCS was reviewed for cumulative land use impacts. Operation of Coleto Creek Unit 2 would not impact land use within 50 miles of VCS, and both STP and the WSEC sites are more than 50 miles away. The Goliad project would continue to dedicate 1421 acres to mining. Furthermore, operation and maintenance of transmission lines and the GBRA LGWSP water delivery line would have small impacts to land use. The transmission corridors and the pipeline right-of-way are compatible with many land use categories including agricultural. Operation of the GBRA diversion canal and reservoirs would not impact land use. The cumulative land use impact of the operation of these other projects along with the operation of VCS would be SMALL.

5.11.2 Hydrology and Water Use

The impacts to the lower Guadalupe River basin's hydrology and water use from existing users and dischargers were factored into the analysis of the impacts of VCS operation. As discussed in Section 5.2, the operation of VCS would require an annual maximum withdrawal of 75,000 acre-feet of water from the Guadalupe River for makeup water to the cooling basin, and the consumptive use of surface water by VCS would range from approximately 46,000 gpm under normal use conditions to approximately 68,300 gpm for maximum use conditions (Subsection 5.2.1.1). Considered for cumulative impact is the up to 60,000 acre-feet per year of water that would be withdrawn by GBRA for the LGWSP (TWDB Feb 2010). Expansion of the GBRA water delivery system would support the demand from future GBRA customers including the Coleto Creek Power Station. Both the LGWSP and the GBRA projects seeking a new water right would use the existing Calhoun Canal System and require construction of a pump station, pipeline, and off-channel reservoirs. The South Texas Project's and WSEC's water source is the lower Colorado River, so these facilities would not contribute to cumulative hydrology or water use impacts in the lower Guadalupe River basin. The impacts of constructing the GBRA system upgrades are discussed in Section 4.7. No additional hydrology impacts to the lower Guadalupe River basin are expected from the operation of these water conveyance projects.

The 2011 draft Initially Prepared Plan includes two recommended projects considered for cumulative water use impacts. The "GBRA-Exelon Project" would supply up to 75,000 acre-feet per year to the VCS from the existing GBRA/UCC water rights. The LGWSP would divert up to 60,000 acre-feet per year of available surface water rights from the GBRA Calhoun Canal System. The LGWSP would supply a firm yield of 35,000 acre-feet per year. The junior portions of the GBRA water rights committed to the LGWSP may not be firm during each month of a repeat of the most severe drought on record. Hence, this strategy includes off-channel storage facilities that serve to firm-up run-of-river diversions.

The GBRA lower basin water rights total 175,501 acre-fee per year and represent about 30 percent of all surface water rights in the Guadalupe-San Antonio River Basin authorized for consumptive use. A majority of these rights are jointly held with UCC. These GBRA/UCC water rights are quite reliable, as the upstream watershed encompasses approximately 10,128 square miles and includes the two largest springs in Texas. In addition, substantial volumes of treated effluent are discharged upstream of the proposed diversion point. Maximum reported water use under these lower basin water rights did not exceed 63,000 acre-feet per year during the 1991 through 2006 historical period. GBRA estimated that up to 75,000 acre-feet per year under one or more of these rights is available for periods of time into the future leaving 100,000 acre-feet per year available for lower basin uses. In all years, there is unappropriated streamflow passing the GBRA saltwater barrier and entering the Guadalupe River Estuary. (TWDB Feb 2010)

Preparation of the 2011 draft Initially Prepared Plan included use of hydrologic models to quantify the cumulative effects of implementation of the South Central Texas Regional Water Plan through the year 2060. Cumulative effects were quantified through long-term simulation of natural hydrologic processes including precipitation, streamflow, aquifer recharge, springflow, and evaporation as they are affected by human influences such as aquifer pumpage, reservoirs, diversions, and the discharge of treated effluent. The cumulative impact assessment for the 2011 draft Initially Prepared Plan includes implementation of the VCS project and LGWSP as well as other recommended water management strategies. That analysis indicates freshwater inflows to the Guadalupe Estuary during drought are expected to increase when all regional projects considered in the plan are implemented. (TWDB Feb 2010)

The new water right for withdrawal of up to 189,484 acre-feet per year from the Guadalupe River that GBRA is seeking would be junior to all existing water rights, and therefore, withdrawals under this junior right would occur during periods of average to relatively high flow. The new water right may include conditions to protect the San Antonio Bay and estuary system. Under this new water right, GBRA would be able to supply water from off-channel storage to areas of need during times of drought. TCEQ would consider freshwater inflow requirements prior to issuance of the water right. The execution of this proposed water right would be beneficial in producing firm supply to satisfy projected demands in the region. Its junior status as well as any conditions stipulated to ensure adequate freshwater inflows for the Guadalupe Estuary would prevent adverse water use impacts. Therefore, cumulative impacts related to the proposed withdrawals for the VCS cooling basin and LGWSP and the execution of the proposed GBRA water right of up to 189,484 acre-feet per year from the Guadalupe River, are expected to be SMALL.

5.11.2.1 Groundwater

As discussed in Section 5.2, it is unlikely that the proposed VCS production wells would impact the offsite well users because of the estimated groundwater demand of 1200 gpm (maximum), depth of withdrawal, and distance to offsite wells. Of the projects considered in this cumulative analysis, only Coleto Creek Unit 2 would potentially use groundwater with withdrawals being from the Evangeline Aquifer. However, because of the distance (approximately 11 miles) separating the two facilities, their zones of influence would not overlap, and any Coleto Creek Unit 2 impacts would not be considered cumulative with VCS groundwater use impacts. The Goliad project overlies the Gulf Coast aquifer but is at an even greater distance from VCS, and their zones of influence would not overlap. Neither the operation of Coleto Creek Unit 2 nor VCS is expected to adversely affect groundwater quality. Therefore, cumulative impacts to groundwater are expected to be SMALL.

5.11.3 Ecology (Terrestrial and Aquatic)

5.11.3.1 Ecological Impacts of Land Use (Terrestrial and Aquatic)

Approximately 6354 acres of the VCS site would be permanently disturbed and unavailable as habitat for terrestrial wildlife. However, this acreage includes the cooling basin that would provide large, open water habitat of benefit to multiple species of water birds. There are no other projects within close enough proximity to the VCS site to be considered cumulative. With regard to impacts to resident waterfowl and migratory birds, the cumulative impacts analysis considers projects in the lower Guadalupe River basin.

5.11.3.2 Ecological Impacts of Water Use (Terrestrial and Aquatic)

Water Use Evaluation

As stated in Subsection 5.11.2, the net result of the LGWSP and VCS cooling basin makeup water withdrawals and the VCS blowdown discharge would be a small reduction in the Guadalupe River flow compared to current conditions. Despite the small reduction in flow, the combination of the GBRA and VCS consumptive use of water from the lower Guadalupe River basin would result in reduced freshwater inflows into the Guadalupe estuary and San Antonio Bay, which support aquatic species and migratory birds. The potential of reduced freshwater inflows into the Guadalupe River estuary and San Antonio Bay is a possible concern for the whooping crane (*Grus americana*). The whooping crane is an endangered species that overwinters and forages in habitats on the periphery of the Guadalupe River estuary and San Antonio Bay (see Subsection 2.4.1). There are differing professional and scientific opinions regarding the impacts of freshwater inflows on the whooping cranes and their habitat.

For example, the U.S. Fish and Wildlife Service (USFWS) Whooping Crane Coordinator has observed the whooping crane population at the Aransas National Wildlife Refuge (ANWR) for approximately 30 years. Based upon his observations, he has expressed the opinion that there is a relationship between marsh salinities, blue crab populations, and whooping crane mortality rates. He has stated that with reduced freshwater inflows and high marsh and bay salinities, blue crabs do poorly and whooping crane mortality rises (comments dated June 5, 2009, included in Slack et al. Aug 2009),

In contrast, as discussed in Section 2.4, Texas A&M University recently conducted a multi-year study evaluating the relationships among freshwater inflows, whooping cranes and their prey, *Linking Freshwater Inflows and Marsh Community Dynamics in San Antonio Bay to Whooping Cranes* (Slack et al. Aug 2009). Among the many results of this project, field and laboratory studies documented that the diet of wintering cranes can vary annually (including wolfberry fruit, blue crabs, clams, snails and other items); blue crabs are not always the dominant food item; blue crab abundance and distribution are influenced by a combination of environmental factors (water levels, wind speed, temperature and salinity); salinity levels alone do not determine crab abundance and distribution; and wolfberry production is strongly influenced by salinity levels during summer leaf production. Many of these findings were incorporated into computer models examining impacts of freshwater inflows on whooping cranes and their food over an 11-year period (1997–2007). These models suggested that food supply within the bay area does not appear to be limiting, even during the lower inflow years, but also that the relationship between salinity and whooping crane energetics and/or survival remains unclear.

As discussed in Subsection 2.4.1.5, the Whooping Crane Eastern Partnership (WCEP) reported high mortality rates for the Aransas-Wood Buffalo population of whooping cranes during 2008–2009. According to WCEP, the majority of losses appear to have occurred during migration. Several possible factors for this mortality level have been identified such as extreme drought which affected food sources and fresh drinking water available in the wintering grounds and disease (e.g., infectious bursal disease (IBD)). Further, chick mortality at Wood Buffalo National Park in Canada was also high, potentially due to higher than average rainfall while the chicks were young. Data from specific analyses (e.g., necropsies, water quality and food source abundance data correlation) was not included in the WCEP assessment. (WCEP Nov 2009)

Due to the fact that only four crane carcasses were recovered, the reports of mortality during the 2008–2009 overwintering period were based primarily on the apparent absence of birds during USFWS aerial census events. These missing birds, which were documented as arriving at ANWR during earlier aerial censuses, accounted for up to 19 of the 23 suspected mortalities (USFWS 2009a and USFWS 2009b).

During the 2008-2009 overwintering season at ANWR, above-normal upland and water hole use was noted, scattering the cranes over a geographical area beyond their typical territory (USFWS 2009a). As described in the January 2009 USFWS aerial census report, "This makes it very difficult to determine the identity of pairs and family groups and leads to much uncertainty during the census count" (USFWS 2009a). Limited visibility due to weather conditions and smoke from prescribed burns, as well as flight time limitations, were noted on multiple census flights, adding to the difficulty in spotting the widely dispersed cranes (USFWS 2009a). Considering these and other factors, it is possible that the extent of whooping crane mortality during the 2008–2009 overwintering period could be lower than reported.

Given the few carcasses recovered, questions also remain regarding the causes of the reported whooping crane deaths. USFWS reports from the first half of 2009 postulated that the birds absent during the later aerial census counts succumbed to injury, predation, and/or disease resulting primarily from food-related stress (particularly related to small amounts of wolfberries and blue crabs) believed to be brought on by the regional drought conditions (USFWS 2009b). Additionally, the need for the cranes to fly to upland areas to find fresh water to drink was cited as an energy burden that could have further weakened the birds (USFWS 2009b). However, as discussed previously, empirical research indicates that the crane diet is rich and varied, and even when blue crab and wolfberry numbers are low, cranes can meet their daily energy and protein requirements by efficiently foraging on foods such as insects, snails, and razor clams (Slack et al. Aug 2009). As an example, cranes were noted eating fiddler crabs immediately prior to their early departure from ANWR in spring 2009 (USFWS 2009b). Furthermore, the flock departed ANWR relatively early in 2009 (USFWS 2009b).

Previous research has indicated that birds will generally migrate earlier than usual when food availability allows for rapid fattening and good physical condition (Studds and Marra 2007).

Additionally, other factors could have contributed to crane mortality. As noted in the USFWS report Whooping Crane Recovery Activities, October 2008–October 2009, the National Wildlife Health Center in Madison, Wisconsin was able to isolate a virus very similar to IBD in a recovered juvenile carcass. One of the symptoms of IBD is emaciation, even when a bird is receiving adequate food. If it turns out the virus is a form of IBD, this would be the first case ever documented in a crane from the Central Flyway (USFWS 2009b). Taking into account the available information, there is uncertainty regarding the specific cause or causes of death for the whooping crane mortalities reported over the 2008-2009 overwintering period at ANWR.

Additional studies have been proposed to further clarify the relationship among freshwater inflows, salinity, and whooping cranes. Freshwater inflows provide nutrient and sediment loading to the estuary, and they are one factor affecting salinity gradients in the bay system.

Regional Water Plan Cumulative Effects Analysis

The 2011 South Central Texas (Region L) Regional Water Plan was approved by Region L on August 5, 2010, and submitted to the TWDB for review and inclusion in the 2012 State Water Plan in September 2010 (SCTRWPG 2010). As discussed in Subsection 5.11.2, preparation of the 2011 Initially Prepared Plan included use of hydrologic models to quantify the cumulative effects of implementation of the South Central Texas Regional Water Plan through the year 2060. The TCEQ water availability model, modified for regional water planning purposes, was used to simulate freshwater inflows to the Guadalupe Estuary given full implementation of the recommended water management strategies (the Regional Water Plan case). Three additional simulations were performed for comparison with the Regional Water Plan case:

- The first comparison scenario, the Baseline (Full Permits) case, included the assumptions used elsewhere in the 2011 Initially Prepared Plan to determine surface water supply reliability and perform technical evaluations of surface water management strategies. These assumptions included full utilization of existing surface water rights and treated effluent discharges representative of current conditions.
- The second comparison simulation, the Present Conditions case, was intended to be a realistic, but somewhat conservative, portrayal of current basin conditions with respect to springflows, surface water rights use, and effluent discharges.

- The third comparison scenario, the Natural Conditions case, is an historical set of theoretical streamflows and estuarine inflows, in which the effects of mankind on water resources have been removed.

Two ecologically based assessments, based on spring / early summer freshwater pulse criteria and low-flow inflow criteria, were used to compare simulated inflows to the Guadalupe Estuary under the four estuarine inflow scenarios described above (i.e., the Regional Water Plan, Baseline (Full Permits), Present Conditions, and Natural Conditions cases). The freshwater pulse evaluation was used to compare Guadalupe Estuary inflow conditions based on occurrences below a target inflow of 526,000 acre-feet over the critical four month period from April–July. The low-flow inflow evaluation was focused on whether enough freshwater would be available to maintain salinity conditions within reasonable tolerance ranges and enable sufficient populations of organisms such as oysters, shrimp, and crabs to survive drought periods. This analysis identified periods where inflows were simulated to be below a drought tolerance level for key estuarine species for six or more consecutive months during the March–October period. Six months was selected because it represents a significant portion of the life-cycle of several principal estuarine species. Both of the ecologically based assessments relied, in part, upon the freshwater inflow recommendations of the Texas Parks & Wildlife Department (TPWD) and the Texas Water Development Board (TWDB) discussed in Section 2.3.

For the spring/early summer freshwater pulse criteria, the 49-year simulations indicated that the numbers of years with April–July freshwater pulses below the target value (derived, in part, from TWDB and TPWD recommendations) were:

Natural	Present Conditions	Baseline (Full Permits)	Regional Water Plan
19	20	23	24

The numbers of occurrences with simulated estuary inflows below the drought tolerance level (based, in part, on TWDB and TPWD recommendations) for six consecutive months or longer were:

Natural	Present Conditions	Baseline (Full Permits)	Regional Water Plan
3	5	8	8

From the results, it can be seen that the simulated natural conditions were responsible for most of the years when the simulated estuary inflows did not meet the target freshwater spring/early summer pulse criterion. Relative to the present conditions, the differences from the Present Conditions simulation to the Baseline (Full Permits) and the Regional Water Plan case simulations resulted in 3 to 4 additional occurrences over the 49-year simulation period. For the low-flow inflow condition, the difference for the Baseline (Full Permits) and Regional Water Plan case simulations relative to the Present Conditions case simulation is 3 additional occurrences. It should be noted that 3 of the 8 predicted occurrences when inflows did not meet the drought tolerance criterion resulted from the 1950s drought of record. The other 5 occurrences are isolated events.

The results also indicate that the decrease in modeled inflows to the Guadalupe Estuary would primarily be realized as a result of the increase in water use from the Present Conditions to the Baseline (Full Permits) case. Considering the full utilization of permitted rights is very conservative for evaluating the cumulative impacts of the considered projects. As discussed in Sections 2.3 and 5.2, many permit holders do not currently withdraw the full volume of water authorized by their rights. During normal and high inflow periods, additional inflow reductions beyond the Baseline (Full Permits) case as a result of fully implementing the 2011 Region L Water Plan were predicted to be relatively small. Additionally, as discussed in Subsection 5.11.2, implementation of the 2011 Region L Water Plan is expected to slightly increase inflows to the Guadalupe Estuary relative to the Baseline (Full Permits) case during dry or drought periods.

VCS Bio-statistical Study

As discussed in Subsection 5.2.2.1, a bio-statistical study was conducted to evaluate the potential effects of VCS water withdrawals on the ecological health of the San Antonio Bay system, using the average annual abundance of four key estuarine species (brown shrimp, white shrimp, blue crab, and eastern oyster) as a representation of bay health. The TPWD Coastal Fisheries database provided approximately 787,000 records for the selected species for the period 1977–2008. Freshwater inflow data was obtained from the TWDB and the USGS and aggregated to estimate daily inflows to the bay system over the same period, from which seasonal (i.e., “freshet”) and annual representations of freshwater inflow were characterized. Roughly 60,000 multivariate linear regression analyses were performed and evaluated for their ability to relate freshwater inflows to the average annual abundance of the selected species, ultimately yielding a relationship for white shrimp and relatively weaker relationships for blue crab and eastern oyster. No relationship was identified for brown shrimp.

To use the identified linear regressions to evaluate the potential effects on San Antonio Bay health resulting from the proposed VCS water withdrawals, the South Central Texas Regional Water Planning Group (Region L) Guadalupe-San Antonio (GSA) Water Availability Model (WAM) and the TCEQ WAM (see Subsection 2.3.2.3.3) were chosen as available and accepted means of modeling present “without-VCS” and “with VCS” demand scenarios, as well as several potential future hydrological scenarios, as follows:

Present Conditions Without VCS Scenario (Present Conditions) — The Present Conditions Scenario uses results from a Region L WAM simulation that represents current demand conditions with respect to water availability for individual water rights. Comparisons to the present demand conditions are consistent with the TCEQ's procedure for evaluating surface water permit applications, wherein the current demand scenario is modeled using a WAM. The Region L Present Conditions WAM used to represent current conditions in the VCS bio-statistical study includes the following assumptions:

- The maximum diversion amount being sought by each individual water right is established as the actual maximum annual use in the 10 years prior to when the WAM was originally developed (1990–1999) as reported by the individual water rights owners. Additionally, the Region L Present Conditions WAM has been updated to reflect changes in water use patterns for seven major water rights and reservoirs in the GSA basin since 1999.

- The maximum storage capacity of all reservoirs specified as the actual year-2000 storage capacity (rather than the authorized maximum storage amount).

- Return flows associated with individual water rights and within the basin are set to 2006 reported levels, adjusted for San Antonio Water System (SAWS) direct recycled consumptive water use of about 24,900 acre-feet per year (based on contracts for consumptive use). The Region L Present Conditions WAM contains approximately 157,000 acre-feet per year of discharges, including 70,306 acre-feet per year of SAWS discharges (accounting for the aforementioned direct recycled water use).

- The model assumes a total use of 73,900 acre-feet per year of the Guadalupe-Blanco River Authority (GBRA) Lower Basin rights, including a diversion of 4,199 acre-feet per year under the most junior GBRA right, Certificate of Adjudication (COA) #18-5178. The total amount of 73,900 acre-feet per year is greater than the historical average cumulative use of approximately 50,000 acre-feet per year, as derived from GBRA's reported historical usage of its lower basin rights.

Present Conditions with VCS Scenario — This project-specific scenario simulates basin conditions with the VCS project in operation and no other changes from the Present Conditions Scenario. The use of the Present Conditions with VCS Scenario in evaluating the potential direct effects on the ecological health of San Antonio Bay associated specifically with the proposed VCS water withdrawals is discussed in Subsection 5.2.2.1.

TCEQ WAM Run 3 Scenario — This scenario assumes that all currently authorized water rights are used up to their full authorization with no return flows to the GSA basin. The TCEQ WAM Run 3 Scenario is a conservative representation of water rights utilization and discharges in a possible future condition. The model run is used by the TCEQ to assess water availability and possible impacts of new water rights applications and assess incremental effects of new diversion. This WAM simulation incorporates several assumptions, including:

- All existing surface water rights in the Guadalupe-San Antonio basin model are fully exercised (that is, used 100 percent) at their authorized annual diversion and impoundment amounts.
- No return flows or effluent discharges throughout the basin.
- Springflow discharges from the Edwards Aquifer consistent with aquifer management rules in effect at the time the WAM was developed (1999).

Region L Baseline Scenario - The Region L Baseline Scenario (as named by Region L) is based on the previously described TCEQ WAM Run 3, modified to include return flows and upper basin operational assumptions. This model assumes full use of permitted water rights, includes Edwards Aquifer permitted pumping (minimum supply of 320,000 acre-feet per year during drought), and adds return flows equal to 2006 reported effluent returns adjusted for SAWS consumptive use of direct recycled water. Hydrologic assumptions for the Region L Baseline model are discussed in Sections 7.1.3.1.3 and 3.2.3.1 of the Region L 2011 Regional Water Plan. This model is used in the TWDB approved Region L planning process as the future baseline condition for evaluating implementation of water management strategies recommended in the 2011 Region L Regional Water Plan. (SCTRWPG 2010)

Region L Cumulative Effects Scenario - The Region L Cumulative Effects Scenario (also known as the “Regional Water Plan” scenario) is based on the Region L Baseline model described above. In addition to the previously described Region L Baseline model assumptions, the Cumulative Effects scenario includes implementation of the Region L 2011 Regional Water Plan Recommended Water Management Strategies (see Appendix D, Table 1 of SCTRWPG 2010). Thus, the Cumulative Effects scenario portrays the potential cumulative effects of all recommended water management strategies and full utilization of permitted water on streamflow and estuarine inflow. Consistent with the Present Conditions without VCS and Region L Baseline scenarios, the Region L Cumulative Effects model was developed and approved through the Region L regional water planning process. This scenario is conservative in its assumption that all of the recommended water strategies will be implemented.

The Region L Baseline, Region L Cumulative Effects, and TCEQ WAM Run 3 model scenarios represent alternative characterizations of potential future conditions in the GSA basin. Unlike the Present Conditions without VCS and Present Conditions with VCS scenarios, all three of these models depict full utilization of existing GSA water rights, including Certificate of Adjudication (COA) 18-5178. As previously described, COA 18-5178 is the preferred water right under which makeup cooling water would be supplied from the Guadalupe River to the VCS cooling basin. Thus, these scenarios (i.e., Region L Baseline, Region L Cumulative Effects, and WAM Run 3) characterize a range of potential future freshwater inflow conditions to the San Antonio Bay system, regardless of whether VCS is constructed and operated. It should be noted that none of these full utilization models has been modified to reflect the VCS-specific withdrawal and blowdown patterns included in the Present Conditions with VCS model. Rather, they reflect full use of COA 18-5178 (up to approximately 106,000 acre-feet per year) assuming a standard use pattern.

In the event that VCS were to obtain a portion of its makeup water under the new water rights totaling 189,484 acre-feet per year applied for by GBRA (Subsection 5.11.2), the use of the applicable portion of the makeup water would be junior to all existing water rights and likely include environmental flow restrictions being developed by TCEQ in the Senate Bill 3 process (Subsection 2.3.2.1.1). Additionally, because GBRA's pending water right is a recommended water management strategy in the 2011 Region L Regional Water Plan (SCTRWPG 2010), makeup water withdrawals under the new right are included in the Region L Cumulative Effects model. As described above, the Region L Cumulative Effects model is conservative in its assumption that all of the recommended water strategies will be implemented.

Figure 5.11-2 provides a comparison of the historical frequency distribution of monthly freshwater inflows to San Antonio Bay with similar distributions generated using the five modeled hydrological scenarios (Present Conditions without and with VCS, Region L Baseline, Region L Cumulative Effects, and TCEQ WAM Run 3) used in the bio-statistical evaluation. The relatively tight pairing of the lines depicting the Present Conditions without VCS and Present Conditions with VCS scenarios demonstrates the relatively small impact that operation of VCS would have on monthly inflows to the bay (see Subsection 5.2.2.1) compared to the modeled present demand. The comparatively larger gap between the lines representing the Present Conditions without VCS scenario and the three full utilization scenarios indicates that the bulk of reductions of inflows to the San Antonio Bay system results from full utilization of existing water rights. This observation is consistent with the findings of the cumulative effects analysis conducted in the Region L 2011 Regional Water Plan, as summarized earlier in Subsection 5.11.3.2.

The selected hydrologic scenarios were used in conjunction with the previously described linear regressions (Subsection 5.2.2.1) relating average annual organism abundance to freshwater inflow parameters to evaluate the potential effects on the health of the San Antonio Bay system (i.e., compared to the current health of the bay through the use of key organism abundance as a surrogate for bay “health”) associated with the Region L Baseline, Region L Cumulative Effects, and TCEQ WAM Run 3 hydrological scenarios. The results of these analyses are summarized in Tables 5.11-4, 5.11-5, and 5.11-6, respectively.

Inspection of Tables 5.11-4, 5.11-5, and 5.11-6 indicates that the estimated potential changes (relative to abundance predictions made using the Present Conditions without VCS model) in white shrimp abundance range from approximately 12 percent to 50 percent, with the larger potential changes predicted at lower abundances (i.e., occurrence frequencies exceeded 90 percent the time). For blue crab, the estimated potential changes in abundance relative to the modeled present conditions abundance range from approximately 12 percent to 15 percent, all estimated to occur at higher abundances (i.e., occurrence frequencies exceeded 10 percent of the time). Lower blue crab abundances are driven by the constant in the regression and therefore yield no apparent change between the various hydrologic scenarios. No negative impacts are identified for eastern oyster as all modeled scenarios result in increases in oyster abundance.

Given the wide range of variability in the historically (1977-2008) observed organism abundances of white shrimp, blue crab, and eastern oyster, the identified regressions relating average annual abundances for these organisms to freshwater inflow are relatively weak, with particularly low explained variance for blue crab and eastern oyster. Accordingly, a sensitivity analysis was performed to determine at what level of statistical confidence in the predictions potential impacts are determined. Statistical confidence (starting at $\alpha = 0.05$, or 95 percent confidence) was iteratively adjusted until a negative impact was discernible from the Present Conditions without VCS scenario. As one lowers the level of statistical confidence, the associated confidence bounds in the prediction constrict. Thus, the statistical confidence of a discernible potential impact has been characterized at the first identification of a negative impact exceeding the corresponding confidence level. Tables 5.11-4, 5.11-5, and 5.11-6 present the statistical confidences in the predicted abundance changes for each species and hydrological scenario. The greatest level of confidence in the prediction of an impact occurs for each organism via the Region L Cumulative Effects scenario, with confidences ranging from 6 percent to 66 percent. These predicted negative impacts (at the aforementioned confidences) are first exhibited in the higher abundances of white shrimp and blue crab.

It is standard to employ a 95 percent confidence level in statistical assessments of biology (McDonald 2009). At this level of confidence, none of the potential impacts of the various future hydrologic scenarios analyzed are statistically discernible. If the confidence level is reduced to that approximate to one standard deviation (approximately 68 percent), these potential impacts are still not-statistically discernible (with the possible exception of the potential impacts from the Region L Cumulative Effects scenario on blue crab abundances at a 66 percent confidence level). While the low confidences in the predictions are not surprising considering the relatively weak regressions, they underscore the fact that other external factors unrelated to freshwater inflow (as characterized in the bio-statistical evaluation) contribute to variations in organism abundances in San Antonio Bay (see Subsection 5.2.2.1 for additional discussion).

As previously described in the Region L Plan cumulative effects analysis discussion, the assumption that all existing water rights are fully utilized is conservative for the purpose of evaluating cumulative effects in the GSA basin. Thus, although the VCS bio-statistical study report identified the potential for changes in modeled white shrimp and blue crab abundances (relative to abundances predicted using the Present Conditions without VCS hydrological models) using the Region L Baseline, Region L Cumulative Effects, and TCEQ WAM Run 3 models, the hydrological inputs are conservative. Furthermore, the predicted changes are discernible at confidence levels ranging from less than 3 percent to 66 percent, well below the 95 percent confidence level typically employed in biological assessments. Accordingly, the VCS bio-statistical study results are consistent with the conclusion that the cumulative impacts of VCS water use on the ecological health of San Antonio Bay would be small.

Summary

Based on the information provided in the cumulative effects assessment prepared as part of the Region L 2011 Regional Water Plan, the discussion of cumulative hydrologic impacts presented in Hydrology and Water Use, and the results of the VCS bio-statistical study, it is concluded that the cumulative impacts on freshwater inflows to the Guadalupe Estuary would be small. Accordingly, although the relationship of freshwater inflows, salinity, and other factors to whooping crane health and energetics remains unclear, the cumulative impacts on aquatic and terrestrial wildlife relying on the Guadalupe Estuary and San Antonio Bay system, including whooping cranes and their habitat, would be SMALL.

5.11.3.3 Impingement and Entrainment

Additional pumping capacity of 50 cfs would be available at the RWMU intake structure beyond the maximum of 217 cfs needed to provide makeup water to the VCS cooling basin. This additional pumping capacity would not be used by VCS but would be held in reserve to support increasing demand for other non-VCS water users. Should another water user(s) take advantage of the full capacity of the RWMU intake structure, the increase in the pumping rate would increase the number of fish impinged and entrained. Even if the full 267 cfs pump capacity is used, Exelon is committed to limiting the through-screen velocity to 0.5 feet per second or less in accordance with “technology-based performance standards” for cooling water intake structures established in EPA’s Track 1 requirements for compliance with Section 316(b) of the Clean Water Act.

As described in Subsection 5.3.1.2.2, Exelon surveyed fish, including ichthyoplankton (eggs and larvae), in the Guadalupe River immediately upstream of the salt water barrier, in Goff Bayou, and in the GBRA main canal in 2008. Ichthyoplankton collections from the lower Guadalupe River were dominated by three species (common carp (*Cyprinus carpio*, 60 percent of total), inland silverside (*Minidia beryllina*, 15.6 percent) and red shiner (*Cyprinella lutrensis*, 14.6 percent). Exelon’s analysis of entrainment assumed 100 percent mortality of eggs and larvae entrained in pumping systems. Table 5.11-2 shows the estimated number of larvae that would have been entrained at the RWMU system intake at a maximum pumping rate of 267 cfs (217 cfs + 50 cfs) based on the larval densities observed in the Guadalupe River in 2008.

Most larvae collected were common carp, a nonnative nuisance species. Carp were only collected in one month, March 2008, but spawning almost certainly continued, at a lower intensity, into early summer. Based on larval densities in the river in 2008, an estimated 301,305 carp larvae would have been entrained (see Table 5.11-2) at a pumping rate of 267 cfs. A single large female carp can produce several million eggs per season, but the more typical range is 100,000 to 500,000 eggs. These eggs would develop into 10,000–50,000 larvae, according to the species- and age-specific mortality table in the case study analysis for the Phase II Cooling Water Intake Structures [Section 316(b)] rule (U.S. EPA Feb 2002). Thus, the number of larvae that would have been entrained represents the production of approximately 6–30 female carp. Losing the production of 6–30 fish could have a small impact on carp in the immediate vicinity of the intake canal, but would have negligible impact on the lower Guadalupe River carp population.

This evaluation assumes that carp have some intrinsic value, and their losses would adversely affect the fish community of the Guadalupe River. Many fisheries managers regard the common carp, a nonnative species introduced to the United States in the middle of the 19th century, as a nuisance. The common carp is considered a pest in the Gulf states and much of the United States because it roots along the bottom searching for food and stirs up bottom sediments. These suspended sediments increase turbidity, reduce photosynthetic growth in submerged vascular plants, and may settle out in the spawning beds of more valuable fish species, smothering their eggs. Carp also eat the eggs and larvae of other fish including those of native fish and more highly esteemed sport fish.

Smaller numbers of inland silverside larvae were collected at the lower Guadalupe River sampling station. Based on larval densities in the river in 2008, an estimated 78,388 inland silverside larvae would have been entrained (see Table 5.11-2) at a pumping rate of 267 cfs. Females can produce 20,000 to 170,000 eggs during their reproductive lifetime (Weinstein 1986), which equates to 10,000 to 85,000 eggs per individual as fish normally line for 1 to 2 years. Assuming 10 percent of inland silverside eggs hatch into larvae (U.S. EPA Feb 2002), the 78,388 larvae represent the production of 9 to 78 inland silverside. The total number of inland silverside larvae lost, 78,388, would develop into 10,089 reproducing adults, according to the mortality table in the U.S. EPA (Feb 2002) case study. A single school of inland silversides may contain tens of thousands of fish. These projected losses would be insignificant for the inland silverside, a species with a very high reproductive potential.

Smaller numbers of red shiner larvae were also collected at the lower Guadalupe River sampling station. A hardy species that thrives in unstable environments (waterbodies subject to extreme temperature and dissolved oxygen fluctuations and high turbidity), the red shiner is found across the Great Plains and is locally abundant in low-gradient streams and rivers in Texas. This species spawns over the April-October period, with peak spawning activity in summer months. However, all red shiner larvae were collected late in the spawning season, in August and October 2008. Based on observed densities of larval red shiners in 2008, an estimated 73,489 larvae would have been entrained at the RWMU system intake (see Table 5.11-2) at a pumping rate of 267 cfs. A mature female red shiner produces 2,925-11,115 eggs per spawning season (Hassan-Williams 2009), which translates into 293-1112 larvae per spawning season, based on a typical eggs-to-larvae survival rate of 10 percent for shiners and minnows (U.S. EPA Feb 2002). Thus, the estimated number of larvae that would have been entrained represents the annual production of 66-251 mature female red shiners. Based on the life-stage-specific survival rates for a surrogate species, the emerald shiner (no data are provided in U.S. EPA Feb 2002 for the red shiner), the 73,489 larvae that would have been entrained would develop into approximately 1,837 reproducing adults. Losses of this magnitude would have a negligible impact on the lower Guadalupe River population.

Very small numbers of sunfish and shad larvae also appeared in lower Guadalupe River ichthyoplankton collections. Based on larval densities in 2008, an estimated 34,295 sunfish (*Lepomis* species) larvae would have been entrained at the RWMU system intake (see Table 5.11-2) at a pumping rate of 267 cfs. Four *Lepomis* species were collected from Station GR-05 during monthly surveys of adult and juvenile fish, but the overwhelming majority were three species: bluegill (*Lepomis macrochirus),* warmouth (*Lepomis gulosus*), and longear sunfish (*Lepomis megalotis*). The reproductive behavior of these three sunfish is quite similar. All three are nest builders and nest guarders. All three spawn over the spring and summer, with the bluegill spawning period extending into September. Lepomids normally reach sexual maturity in their second or third year of life, as one and two year old fish. Fecundity is determined by body size and ranges from 4500 (small warmouth) to 80,000 (large bluegill) eggs per female (Hassan-Williams and Bonner 2009). Based on known fecundity rates and mortality rates (U.S. EPA Feb 2002), the estimated entrainment loss (34,295 larvae) represents the production of 2 to 42 female sunfish. Losses of this magnitude would have virtually no effect on lower Guadalupe River sunfish populations.

Based on the observed densities of shad (mostly gizzard shad) in the lower Guadalupe River in 2008, an estimated 14,698 larvae would have been entrained at the RMWU intake (see Table 5.11-2) at a pumping rate of 267 cfs. Gizzard shad make use of a range of spawning habitats, including large rivers, backwaters of rivers, ponds, lakes, and reservoirs (Jenkins and Burkhead Feb 1994). Females broadcast eggs near the surface; eggs sink to the bottom or adhere to vegetation. A single female may produce from 22,000 to 540,000 eggs per spawning season, depending on its age and size (Carlander 1969). Given that approximately 10 percent of gizzard shad eggs survive and hatch into larvae (U.S. EPA Feb 2002), the estimated entrainment over the February–October spawning period at the RWMU system intake represents the production of less than seven mature female shad. Losses of this magnitude would have virtually no effect on lower Guadalupe River shad populations.

In summary, small numbers of fish larvae were collected by biologists from sampling station GR-05 on the lower Guadalupe River over the February–October 2008 spawning period. Densities of larvae in the river were used to estimate the total number of larvae that would have been entrained over the same period if Guadalupe River water were being withdrawn at a rate of 267 cfs. Only five ichthyoplankton taxa were collected, and the bulk of these specimens were common carp, a nonnative nuisance species. An estimated 301,305 carp larvae would have been entrained, an ecologically insignificant number. Smaller and ecologically insignificant numbers of inland silverside, red shiner, sunfish (*Lepomis* species), and shad (*Dorosoma* species) larvae were also collected. These data suggest that densities of larval fish in this reach of the Guadalupe River are very low, and entrainment losses would be correspondingly small. Entrainment losses of this magnitude would have no detectable impact on fish populations. The species most likely to be affected are common to ubiquitous in the river, are of no value as food or sport fish, and have high reproductive potential, thus can easily replace any losses. Therefore, the cumulative impact of the VCS makeup water withdrawal (maximum of 217 cfs) and the additional pumping capacity of the RWMU system intake (50 cfs) would be SMALL.

5.11.4 Socioeconomic Resources

The operation of VCS, Coleto Creek Unit 2, and the Goliad Project would have cumulative socioeconomic impacts on the region of influence (ROI) stemming from the operations workforce needing housing and public services and also spending their salaries and paying taxes within the ROI. As discussed in Subsection 5.8.2.1, the operation of VCS would result in less than a 2 percent increase in population of the ROI. STP and the WSEC sites are located outside of the VCS ROI, and current STP workers and workers for the proposed projects are expected to reside outside of the VCS ROI. Therefore, STP and WSEC would not contribute to cumulative impacts. The operation of GBRA water supply infrastructure would have socioeconomic impacts on the ROI. Their operation would require a few workers and taxes and fees would be paid by GBRA and their customers; however, the greater socioeconomic impact would be the positive impact provided by a firm water supply to meet current and future water supply demand, assuring that the region could grow economically. This positive socioeconomic impact is not captured in this analysis, which focuses on Coleto Creek 2 and the Goliad Project.

South Texas Electric Cooperative, a co-owner of Coleto Creek Unit 2, estimated that the new unit would create 72 new permanent direct and indirect jobs with salaries totaling $46 million during 10 years of operation (IP and STEC 2009). The Goliad Project is expected to provide 80 to 100 jobs (My Victoria Jun 2009) and an estimated 142 indirect jobs using the same multiplier used in the VCS analysis (1.7786 x 80 = 142). As stated in Subsection 5.8.2.1, 2223 jobs would be attributable to VCS operations. The approximately 300 additional new jobs created by Coleto Creek Unit 2 and the Goliad Project would lead to a slight increase in socioeconomic impacts in the ROI. The cumulative impacts to the ROI's economy would be SMALL. The property taxes paid on Coleto Creek Unit 2 and the Goliad Project would not be cumulative with VCS because they are located in different counties and within different independent school districts. The cumulative impacts to community services would also be SMALL.

5.11.5 Atmospheric and Meteorological

Impacts to air quality would not be from the reactors themselves, but from backup emergency equipment (e.g., diesel generators and firefighting equipment) and the mechanical draft cooling towers. Emissions of criteria pollutants from VCS would be from fossil-fired equipment, as discussed in Section 5.5. Because such equipment is operated only intermittently, it would only have a very small impact to air quality. Operation of the mechanical draft cooling towers would result in (1) noise and salt deposition that do not impact the area beyond the VCS site, and (2) plumes that would impact areas beyond the VCS site boundary with minor shadowing and a very small increase in precipitation. The maximum amount of time that a plume would extend beyond the site boundary at any location is estimated to 159 hours annually, with shadowing predicted to occur no more than 138 hours annually and a maximum of less than 1 inch of additional precipitation annually (see Subsection 5.3.3.1). VCS would have a small contribution to the cumulative air quality to the Corpus Christi-Victoria Intrastate Air Quality Control Region. Outside of the Corpus Christi-Victoria Intrastate Air Quality Control Region, but located in an adjacent county approximately 11 miles from the VCS site, is the fossil-fueled Coleto Creek Power Station, which would have a greater effect on the air quality of the geographic vicinity. Because permit limits would be imposed on the individual sources, the cumulative impacts to regional air quality would be SMALL.

5.11.6 Radiological

VCS would release small quantities of radioactivity to the environment through both permissible liquid and gaseous releases. STP in Matagorda County, approximately 60 miles from the VCS site, would also release small quantities of radioactivity to the environment through both permissible liquid and gaseous releases. The liquid releases from STP would be outside of the Lower Guadalupe River Basin and STP is not located in the same air quality control region as VCS. Therefore, radiological cumulative impacts are not expected.

The fuel cycle specific to VCS would contribute to the cumulative impacts of fuel production, storage, and disposal of all nuclear units in the United States, but the impacts of the fuel cycle for VCS are SMALL and the addition of the impacts of VCS would be a small contribution to the cumulative impacts from the nation's nuclear units. Fuel and waste transportation impacts from VCS also would be SMALL, and would be a minor increase to the cumulative impacts of transportation of all nuclear reactor fuel.

5.11.7 Summary

Cumulative impacts are expected in the categories of land use, water use, ecology, socioeconomics, air quality, and radiological health. The adverse cumulative impacts are summarized in Table 5.11-3.

5.11.8 References

Bay City Tribune Oct 2008. The Bay City Tribune, *Clean-coal plant looks at site near Wadsworth*, article by M. Reddell, October 6, 2008. Available at http://baycitytribune.com/story.lasso?ewcd=84db803c0fd7d2ae, accessed June 24, 2009.

Carlander 1969. Carlander, K.D., *Handbook of Freshwater Fishery Biology,* 1969, Iowa State University Press.

Carothers Mar 2008. Uranium Energy Corporation, T. A. Carothers, P.G., *Technical Report for Uranium Energy Corp's Goliad Project In-Situ Recovery Uranium Property Goliad County, Texas,* March 7, 2008. Available at http://www.uraniumenergy.com/projects/texas/goliad/, accessed June 24, 2009.

E&E May 2009. Energy & Environment, Land Letter Article by A. Reese, *MINING: Uranium proposal draws challenge from Texas county*, May 14, 2009. Available at http://www.eenews.net/public/Landletter/print/2009/05/14/3, accessed June 29, 2009

GBRA 2008. Guadalupe-Blanco River Authority, Coleto Creek Park and Reservoir Newsletter, Volume 8 Issue 1, Spring 2008. Available at http://www.gbra.org/Documents/Recreation/Coleto/ColetoNewsletter.pdf, accessed May 24, 2008.

GBRA Aug 2009. Guadalupe-Blanco River Authority, *Application of the GBRA for a Permit to Appropriate State Water, Application No. 12482*, dated August 5, 2009.

Hassan-Williams and Bonner 2009. Texas State University San Marcos Department of Biology, Hassan-Williams, C., and T.H. Bonner, *Texas Freshwater Fishes,* 2009. Available at http://www.bio.txstate.edu/~tbonner/txfishes/, accessed June 3, 2009.

IP and STEC 2009. International Power and South Texas Electric Coop, *Coleto Creek 2.* Available at http://www.coletocreek2.com, accessed June 22, 2009.

Jenkins and Burkhead Feb 1994. Jenkins, R.E. and N.M. Burkhead, *Freshwater Fishes of Virginia,*1993, February 1994, American Fisheries Society.

McDonald 2009. McDonald, J.H., Handbook of Biological Statistics (2nd ed.). Sparky House Publishing, Baltimore, Maryland. pp. 1–3. 2009.

My Victoria Jun 2009. *Uranium Mining Controversy Continues*. Available at http://www.myvictoriaonline.com/index.php?id=1588:pkg-only-from-10-or-tape-17-09-tc-2310506&option=com_content&cati

SCTRWPG 2010. South Central Texas Regional Water Planning Group, 2011 South Central Texas Regional Water Plan, September 2010. Available at http://www.regionltexas.org/2011_rwp2.php, accessed September 29, 2011.

Slack et. al. Aug 2009. Slack, R. D., W. E. Grant, S. E. Davis III, T. M. Swannack, J. Wozniak, D. Greer, and A. Snelgrove, *Linking Freshwater Inflows and Marsh Community Dynamics in San Antonio Bay to Whooping Cranes,* San Antonio Guadalupe Estuarine System (SAGES), Final Report, Texas A&M University, August 2009.

STP Sep 2009. STP Nuclear Operating Company South Texas Project Units 3 & 4 COLA (Environmental Report), Rev. 3, September 16, 2009. Available at http://www.nrc.gov/reactors/new-reactors/col/south-texas-project/documents. html#appDocuments.

Studds and Marra 2007. Studds, C. E., and P.P. Marra. Linking fluctuations in rainfall to nonbreeding season performance in a long-distance migratory bird, *Setophaga ruticilla*. Climate Research 35:115-122, December 31, 2007. Available at http://www.int-res.com/articles/cr_oa/c035p115.pdf., accessed June 6, 2010.

TPWD Dec 1998. Texas Parks and Wildlife Department, *Freshwater Inflow Recommendation for the Guadalupe Estuary of Texas,* Coastal Studies Technical Report No. 98-1, December 1998.

TPWD 2007. Texas Parks and Wildlife Department, Freshwater Inflow Recommendations for the Guadalupe River Estuary of Texas, 2007, Available at http://www.tpwd.state.tx.us/landwater/water/conservation/freshwater_inflow/guadalupe/index.phtml.

TWDB Feb 2010. Texas Water Development Board, *2011 South Central Texas Regional Water Plan.* DRAFT Initially Prepared Plan, February 2010.

UEC Jun 2009. Uranium Energy Corp, *Uranium Energy Corp Receives Final Draft Permit for First Production Area at Goliad ISR Project*, June 11, 2009. Available at http://www.uraniumenergy.com/investor_info/news_releases/2009, accessed June 24, 2009.

U.S. EPA Feb 2002. U.S. Environmental Protection Agency, *Phase II — Large Existing Electric Generating Plants: Case Study Analysis,* February 2002. Available at http://www.epa.gov/waterscience/316b/phase2/casestudy/, accessed May 30, 2008.

USFWS 2009a. January 2009 to April 2009 ANWR Migration-Population Status Reports. U. S. Fish and Wildlife Service, Aransas National Wildlife Refuge, Austwell, Texas, USA. Available at http://www.ccbirding.com/twc/, accessed June 6, 2010.

USFWS 2009b. Whooping crane recovery activities, October 2008-October 2009. Prepared by Tom Stehn. U. S. Fish and Wildlife Service, Aransas National Wildlife Refuge, Austwell, Texas, USA. Available at http://www.ccbirding.com/twc/ 2009/09_10-2008_to_10-2009_WCRA.pdf, accessed June 6, 2010.

WCEP Nov 2009. Whooping Crane Eastern Partnership, *Whooping Crane Recovery Activities October 2008-October 2009*, available at http://www.bringbackthecranes.org/recovery/recv2009.html, last updated November 17, 2009.

Weinstein 1986. Weinstein, M. P., Habitat Suitability Models: Inland Silverside, 1986.

WSEC 2008. White Stallion Energy Center, LLC, *Project Description*. Available at http://white stallionenergycenter.com, accessed March 4, 2009.

Table 5.11-1
Geographic Areas Used in Cumulative Analysis

Resource	Geographic Area
Land Use	50-mile radius
Hydrology & Water Use	Lower Guadalupe River basin
Ecology	Terrestrial: immediate surrounding area for resident wildlife, lower Guadalupe River basin and San Antonio Bay for resident waterfowl and migratory birds
	Aquatic: Lower Guadalupe River basin and San Antonio Bay
Socioeconomics	Economics and Social Services: Region of Influence (Calhoun, DeWitt, Goliad, Jackson, Refugio, and Victoria Counties)
Atmospheric and Meteorological	Corpus Christi-Victoria Intrastate Air Quality Control Region
Radiological	Liquid radiological releases: lower Guadalupe River basin
	Gaseous radiological releases: Corpus Christi-Victoria Intrastate Air Quality Control Region
	Fuel cycle: United States

Table 5.11-2
Estimated Cumulative Number of Larvae Entrained Monthly (2008) at the RWMU Intake Structure with Withdrawal Rate of 267 cfs

Species	February	March	April	May	June	July	August	September	October	Annual Total
Shad spp										
Day	0	14,698	0	0	0	0	0	0	0	
Night	0	0	0	0	0	0	0	0	0	
Monthly Total	0	14,698	0	0	0	0	0	0	0	14,698
Inland silverside										
Day	0	0	0	44,093	0	0	0	0	0	
Night	0	0	34,295	0	0	0	0	0	0	
Monthly Total	0	0	34,295	44,093	0	0	0	0	0	78,388
Common carp										
Day	0	68,590	0	0	0	0	0	0	0	
Night	0	232,715	0	0	0	0	0	0	0	
Monthly Total	0	301,305	0	0	0	0	0	0	0	301,305
Red shiner										
Day	0	0	0	0	0	0	0	0	39,194	
Night	0	0	0	0	0	0	34,295	0	0	
Monthly Total	0	0	0	0	0	0	34,295	0	39,194	73,489
Sunfish spp.										
Day	0	0	0	0	0	0	0	0	0	
Night	0	0	0	0	0	0	34,295	0	0	
Monthly Total	0	0	0	0	0	0	34,295	0	0	34,295

Table 5.11-3 (Sheet 1 of 2)
Summary of Adverse Cumulative Impacts

Category	Description of Cumulative Impact	Potential Cumulative Impacts Significance
Land Use	• VCS: Permanent use of 6354 acres land. • GBRA Water Supply Projects: Operation and maintenance of the water supply infrastructure would have small impacts to land use. • Operation and maintenance of transmission lines would have small impacts to land use.	Small
Hydrology & Water Use	• VCS: Withdraw up to 75,000 acre-feet per year. Permitted discharge of water and water return to lower Guadalupe River basin through reservoir seepage. The consumptive use of surface water by VCS would range from approximately 46,000 gpm under normal use conditions to approximately 68,300 gpm for maximum use conditions. Withdrawal of groundwater for consumption with minimal impact to offsite users. • GBRA Water Supply Projects: GBRA would withdraw up to 60,000 acre-feet per year water under existing water rights and up to 189,484 acre-feet per year under a new junior water right for storage and use by its customers including Coleto Creek Power Station. • Coleto Creek Unit 2: Potential groundwater use and makeup water received as a portion of the GBRA withdrawals. Consumptive Guadalupe River water use by Coleto Creek Power Station of up to 12,500 acre-feet per year.	Small
Ecology Terrestrial and Aquatic	• VCS: VCS operation on approximately 6354 acres including basins that provide large, open water habitat of benefit to multiple species of water birds. Water withdrawals and returns to the lower Guadalupe River basin resulting in reduced freshwater inflows into the Guadalupe estuary and San Antonio Bay, which support aquatic species and migratory birds. • GBRA Water Supply Projects: Water withdrawals would result in some water loss resulting in reduced freshwater inflows into the Guadalupe estuary and San Antonio Bay, which support aquatic species and migratory birds. • VCS and GBRA Water Withdrawals: Proportional increase in amounts of fish, larvae, and eggs impinged or entrained in the RWMU Intake Structure. The species most likely to be affected are common to ubiquitous in the river, are of no value as food or sport fish, and have high reproductive potential, thus, can easily replace any losses.	Small
Socioeconomics	• VCS: Less than 2 percent increase in population of the ROI, increased demand for social services. • Coleto Creek Unit 2: 72 direct and indirect jobs added to the ROI, slightly increased demand for social services. • Goliad Project: 80-100 operations jobs and estimated 142 indirect jobs.	Small
Air Quality	• VCS: Emissions of criteria pollutants from VCS would be from fossil-fired equipment operated only intermittently. Operation of cooling towers would result in noise and salt deposition that do not impact the area beyond the VCS site and plumes that would impact areas beyond the VCS site boundary with minor shadowing and a very small increase in precipitation. • Coleto Creek Power Station is located outside of the air quality control region.	Small

Table 5.11-3 (Sheet 2 of 2)
Summary of Adverse Cumulative Impacts

Radiological Health	• VCS: Release small quantities of radioactivity to the environment through both permissible liquid and gaseous releases. • STP: Radiological releases outside of the cumulative impacts area. • Fuel Cycle: The fuel cycle specific to VCS would require resources, emit pollutants, and generate wastes, but the impacts of the fuel cycle for VCS are SMALL.	Small

Table 5.11-4
Organism Abundances Estimated using the Region L Baseline Hydrological Model, Including Potential Changes Relative to Abundances Estimated using the Present Conditions without VCS Hydrological Model

Organism	Occurrence	Present Conditions without VCS Project—abundance (number/acre-foot)	Region L Baseline—abundance (number/acre-foot)	Potential Region L Baseline Impact on Present Conditions (number/acre-foot)	Percent change from Present Condition by Region L Baseline	Statistical Confidence in the Predicted Change
White Shrimp	90% Exceedance	1.18	0.58	-0.59	-50.45%	at most 27%
	10% Exceedance	8.69	7.66	-1.04	-11.92%	
	Average	4.43	3.57	-0.86	-19.45%	
Eastern Oyster	90% Exceedance	1,380.16	1,410.93	30.77	2.23%	at most 3%
	10% Exceedance	2,181.07	2,209.54	28.47	1.31%	
	Average	1,868.01	1,897.48	29.47	1.58%	
Blue Crab	90% Exceedance	3.84	3.84	0.00	0.00%	at most 19%
	10% Exceedance	10.31	9.05	-1.26	-12.25%	
	Average	6.82	6.12	-0.70	-10.26%	

Table 5.11-5
Organism Abundances Estimated using the Region L Cumulative Effects Hydrological Model, Including Potential Changes Relative to Abundances Estimated using the Present Conditions without VCS Hydrological Model

Organism	Occurrence	Present Conditions without VCS Project—abundance (number/acre-foot)	Region L Cumulative Effects—abundance (number/acre-foot)	Potential Cumulative Effects Impact on Present Conditions (number/acre-foot)	Percent change from Present Condition by Cumulative Effects	Statistical Confidence in the Predicted Change
White Shrimp	90% Exceedance	1.18	0.76	-0.42	-35.72%	at most 45%
	10% Exceedance	8.69	6.74	-1.95	-22.43%	
	Average	4.43	3.54	-0.89	-20.04%	
Eastern Oyster	90% Exceedance	1,380.16	1,448.96	68.80	4.98%	at most 6%
	10% Exceedance	2,181.07	2,203.81	22.74	1.04%	
	Average	1,868.01	1,910.59	42.58	2.28%	
Blue Crab	90% Exceedance	3.84	3.84	0.00	0.00%	at most 66%
	10% Exceedance	10.31	8.91	-1.40	-13.57%	
	Average	6.82	6.00	-0.82	-12.06%	

Table 5.11-6
Organism Abundances Estimated using the TCEQ WAM Run 3 Hydrological Model, Including Potential Changes Relative to Abundances Estimated using the Present Conditions without VCS Hydrological Model

Organism	Occurrence	Present Conditions without VCS Project—abundance (number/acre-foot)	TCEQ Run 3—abundance (number/acre-foot)	Potential TCEQ Run 3 Impact on Present Conditions (number/acre-foot)	Percent change from Present Condition by Region L Baseline	Statistical Confidence in the Predicted Change
White Shrimp	90% Exceedance	1.18	0.63	-0.55	-46.47%	at most 39%
	10% Exceedance	8.69	7.39	-1.30	-15.01%	
	Average	4.43	3.27	-1.16	-26.28%	
Eastern Oyster	90% Exceedance	1,380.16	1,438.18	58.02	4.20%	at most 5%
	10% Exceedance	2,181.07	2,215.36	34.29	1.57%	
	Average	1,868.01	1,914.35	46.34	2.48%	
Blue Crab	90% Exceedance	3.84	3.84	0.00	0.00%	at most 32%
	10% Exceedance	10.31	8.60	-1.72	-16.64%	
	Average	6.82	5.90	-0.92	-13.51%	

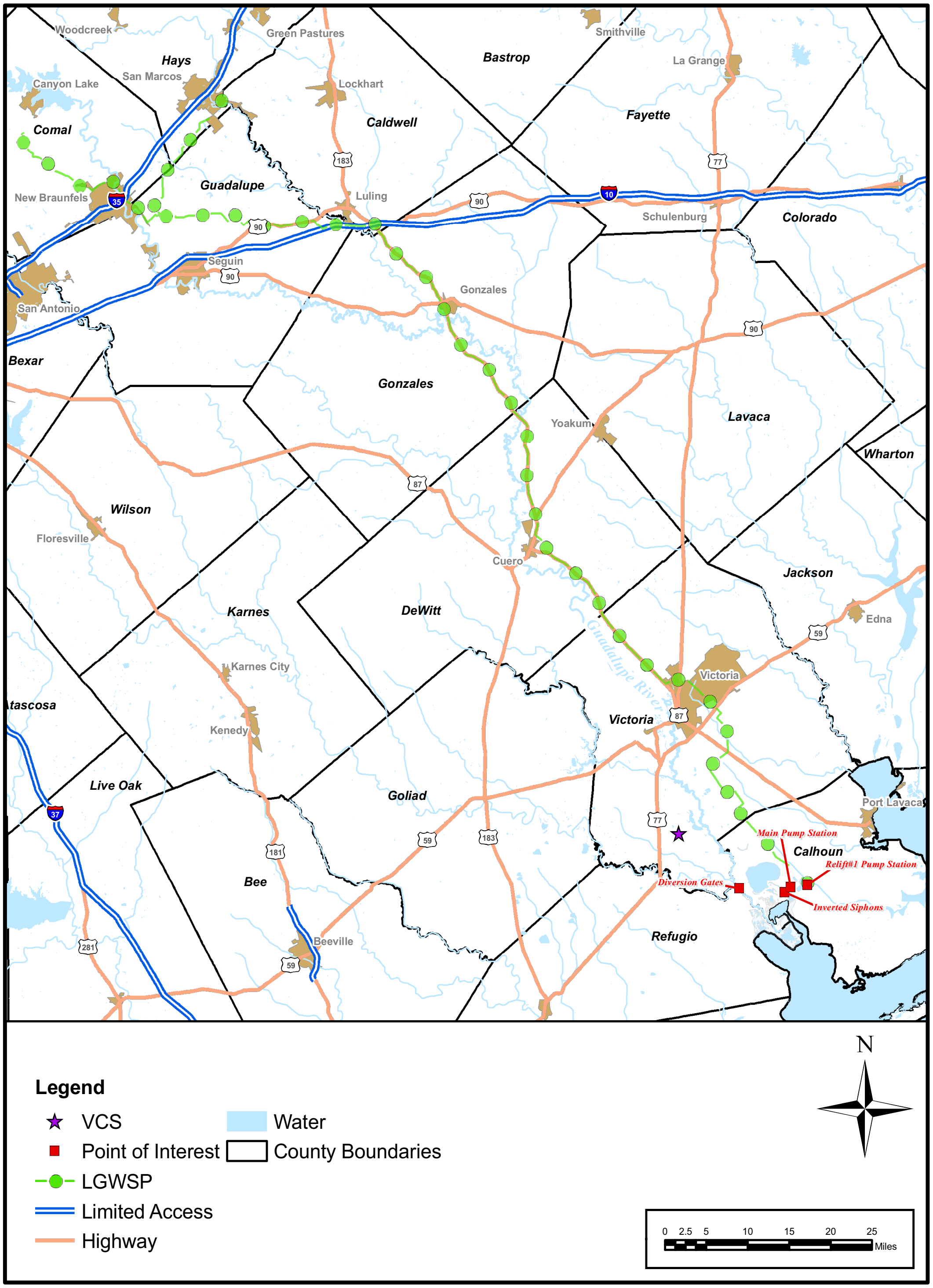


Figure 5.11-1 GBRA Water Supply Infrastructure Project

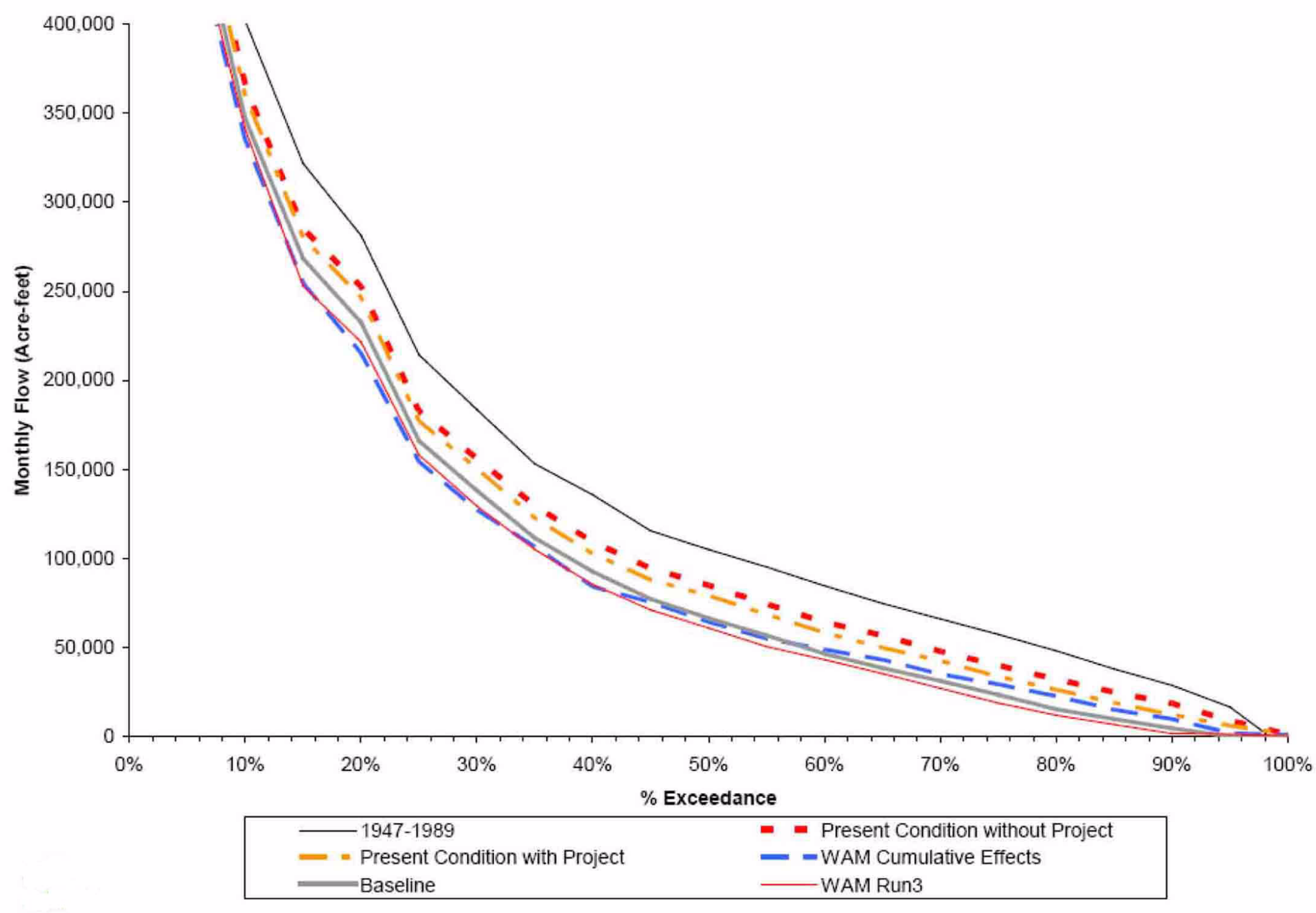


Figure 5.11-2 Comparison of the 1947–1989 Monthly Historical Freshwater Inflow Frequency Distribution to Similar Monthly Distributions for the Five Modeled Hydrological Scenarios used in the Bio-statistical Evaluation

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Chapter 7 Environmental Impacts of Postulated Accidents Involving Radioactive Materials

The purpose of this section is to assess the environmental impacts of postulated accidents involving radioactive materials. Section 7.1 evaluates DBAs, Section 7.2 considers the impact of severe accidents, Section 7.3 addresses severe accident mitigation alternatives (SAMA), and Section 7.4 pertains to transportation accidents.

7.1 Design Basis Accidents

7.1.1 Selection of Accidents

The radiological consequences of accidents are assessed to demonstrate that new units could be constructed and operated at the ESP site without undue risk to the health and safety of the public. To analyze the suitability of the ESP site, site-specific accident meteorology is used to evaluate the radiological consequences of DBAs associated with selected reactor designs. The DBAs include a spectrum of events, including those of relatively greater probability of occurrence as well as those that are less probable but have greater severity.

The set of accidents selected focuses on four light water reactor (LWR) designs: AP1000, APWR, ABWR, and ESBWR. Two versions of the ABWR (GE and Toshiba) are being considered for the VCS site, but the evaluation of this section is based upon the source term associated with the ABWR certified design. These four designs have been chosen because these are standard designs that have recognized bases for postulated accident analyses. The mPower technology is still in the early stages of design, thus the accidents are not as well defined as those for the other LWRs. The mPower design is standard LWR technology, and given its relatively small thermal output, the accident consequences associated with the mPower reactor are considered to be bounded by those for the other four reactor types. If the mPower (or another reactor technology not previously evaluated) is selected for the ESP site, the COL application would verify that the accident doses are bounded by those provided in the ESP or would provide a complete evaluation of accident radiological consequences compared with regulatory limits.

The following LWR accidents are identified in NUREG-1555 (U.S. NRC Oct 1999), Section 7.1, Appendix A, as those that should be considered for radiological consequences, based on the SRP, NUREG-0800 (U.S. NRC Mar 2007):

- SRP Section 15.1.5A, Radiological Consequences of Main Steam Line Failure Outside Containment of a PWR
- SRP Section 15.2.8, Feedwater System Pipe Break

- SRP Section 15.3.3, Reactor Coolant Pump Rotor Seizure (Locked Rotor Accident)
- SRP Section 15.3.4, Reactor Coolant Pump Shaft Break
- SRP Section 15.4.9, Spectrum of Rod Drop Accidents
- SRP Section 15.6.2, Radiological Consequences of the Failure of Small Lines Carrying Primary Coolant Outside Containment
- SRP Section 15.6.3, Radiological Consequences of Steam Generator Tube Failure
- SRP Section 15.6.5, Loss of Coolant Accidents Resulting from Spectrum of Postulated Piping Breaks within the Reactor Coolant Pressure Boundary
- SRP Section 15.7.4, Radiological Consequences of Fuel Handling Accidents

RG 1.183 (U.S. NRC Jul 2000) includes the following additional accidents:

- PWR Rod Ejection Accident (corresponding to SRP Section 15.4.8)
- BWR Main Steam Line Break (corresponding to SRP Section 15.6.4)

In addition, a cleanup water line break is evaluated for the ABWR and the ESBWR.

This set of accidents provides a reasonable basis for evaluating the suitability of the ESP site, and the associated radiological consequences from the above DBAs are analyzed as follows.

7.1.2 Evaluation Methodology

Doses for the representative DBAs are evaluated at the EAB and the LPZ. These doses must meet the site acceptance criteria in 10 CFR 52.17 (a)(1). Although the emergency safety features are expected to prevent core damage and mitigate releases of radioactivity, the loss-of-coolant accidents (LOCAs) analyzed presume substantial core melt with the release of significant amounts of fission products. The postulated LOCAs are expected to more closely approach 10 CFR 52.17 limits than the other DBAs of greater probability of occurrence but lesser magnitude of activity releases. The calculated accident doses are compared to the acceptance criteria in RG 1.183 and NUREG-0800 to demonstrate that the consequences of the postulated accidents are acceptable.

The evaluations use short-term accident atmospheric dispersion factors (X/Qs). The X/Qs are calculated using the methodology of RG 1.145 (U.S. NRC Nov 1982) and site-specific meteorological data. As indicated in Subsection 2.7.5, the RG 1.145 methodology is implemented in the NRC-sponsored PAVAN computer program. This program computes X/Qs at the EAB and the LPZ for each combination of wind speed and atmospheric stability for each of the 16 downwind direction sectors.

Releases are assumed to be at ground level, and the shortest distances between the power block area and the offsite locations are selected to conservatively maximize the X/Q values. The following site-specific 50th percentile X/Q values from Subsection 2.7.5 are used in these evaluations, in accordance with NUREG-1555:

- EAB, 0 to 2 hours: 8.85×10^{-5} sec/m^3
- LPZ, 0 to 8 hours: 5.30×10^{-6} sec/m^3
  8 to 24 hours: 3.92×10^{-6} sec/m^3
  24 to 96 hours: 2.05×10^{-6} sec/m^3
  96 to 720 hours: 8.05×10^{-7} sec/m^3

The accident dose calculations are performed using the activity releases for the following time intervals:

- EAB: 2–hour period yielding the maximum dose
- LPZ: 0 to 8 hours, 8 to 24 hours, 24 to 96 hours, and 96 to 720 hours

The accident doses are expressed as total effective dose equivalent (TEDE), consistent with 10 CFR 52.17. The TEDE consists of the sum of the committed effective dose equivalent (CEDE) from inhalation and either the deep dose equivalent (DDE) or the effective dose equivalent (EDE) from external exposure. The CEDE is determined using the dose conversion factors in Federal Guidance Report 11 (U.S. EPA 1988), while the DDE and the EDE are based on dose conversion factors in Federal Guidance Report 12 (U.S. EPA 1993).

7.1.3 Source Terms

Doses are calculated based on the time-dependent activities released to the environment during each DBA. The activities are based on the analyses used to support the reactor standard safety analysis reports. Different reactor technologies use different source terms and approaches in defining the activity releases. The ABWR source terms, methodologies, and assumptions are based on the guidance in NUREG-0800 and Regulatory Guides 1.3 (U.S. NRC Jun 1974) and 1.25 (U.S. NRC Mar 1972). The AP1000, APWR, and ESBWR source terms, methodologies, and assumptions are based on the alternative source term guidance in RG 1.183.

7.1.4 Radiological Consequences

For the accidents identified in Subsection 7.1.1, site-specific doses are calculated by multiplying the design certification doses by the ratio of site X/Qs to design certification X/Qs. Using the EAB and LPZ site-specific X/Qs provided in Subsection 2.7.5, with the design certification X/Qs

(Westinghouse Sep 2008, MHI Aug 2008, GENE Mar 1997, GEH Aug 2009), the ratios presented in Tables 7.1-1 through 7.1-4 are obtained.

Details about the methodology and assumptions pertaining to each of the accidents, such as activity release paths and the credited mitigation features, may be found in the design certification documents for each of the reactor technologies.

As the ABWR design certification document presents whole body and thyroid doses, an equivalent TEDE value is estimated by multiplying the thyroid dose by 0.03 and adding the product to the whole body dose, in accordance with RG 1.183.

A summary of the resulting accident doses is presented in Table 7.1-5. This table also compares the environmental doses to the recommended limits in RG 1.183 and NUREG-0800 and shows that the evaluated dose consequences are within the recommended limits.

The TEDE dose limits in Table 7.1-5 are taken from RG 1.183, Table 6, for all accidents except PWR Reactor Coolant Pump Shaft Break (SRP Section 15.3.4) and Failure of Small Lines Carrying Primary Coolant Outside Containment (SRP Section 15.6.2). For these two accidents, NUREG-0800 indicates that the dose limit is a “small fraction” or 10 percent of the 10 CFR 100 guideline of 25 rem, meaning a limit of 2.5 rem. No guidance is provided in RG 1.183 or NUREG-0800 for Feedwater Line Break and Cleanup Water Line Break; the regulatory limits shown are based on similar accidents.

The doses summarized in Table 7.1-5 are based on the time-dependent doses for each of the accidents, as shown in Tables 7.1-6 through 7.1-70. In addition to doses, the latter tables also show the activities released to the environment. In these tables, the EAB dose for each accident is shown for the 2-hour period yielding the maximum dose. The LPZ dose is shown for the duration of the accident.

7.1.5 References

GEH Aug 2009. Document 26A6642, *ESBWR Design Control Document*, Tier 2, GE-Hitachi Nuclear Energy, Revision 6, August 2009.

GENE Mar 1997. *ABWR Design Control Document*, Tier 2, GE Nuclear Energy, Revision 4, March 1997.

MHI Oct 2009. Document MUAP-DC001, *APWR Design Control Document for the US-APWR,* Tier 2, Mitsubishi Heavy Industries, Ltd., Revision 2, October 2009.

U.S. EPA 1988. Federal Guidance Report 11, *Limiting Values of Radionuclide Intake and Air Concentration and Dose Conversion Factors for Inhalation, Submersion, and Ingestion*, U. S. Environmental Protection Agency, EPA-520/1-88-020, 1988.

U.S. EPA 1993. Federal Guidance Report 12, *External Exposure to Radionuclides in Air, Water, and Soil*, U. S. Environmental Protection Agency, EPA-402-R-93-081, 1993.

U.S. NRC Mar 1972. Regulatory Guide 1.25 (Safety Guide 25), *Assumptions Used for Evaluating the Potential Radiological Consequences of a Fuel Handling Accident in the Fuel Handling and Storage Facility for Boiling and Pressurized Water Reactors*, NRC, March 1972.

U.S. NRC Jun 1974. Regulatory Guide 1.3, *Assumptions Used for Evaluating the Potential Radiological Consequences of a Loss of Coolant Accident for Boiling Water Reactors*, Revision 2, NRC, June 1974.

U.S. NRC Nov 1982. Regulatory Guide 1.145, *Atmospheric Dispersion Models for Potential Accident Consequence Assessments at Nuclear Power Plants*, Revision 1, NRC, November 1982.

U.S. NRC Oct 1999. NUREG-1555, *Standard Review Plans for Environmental Reviews for Nuclear Power Plants*, Section 7.1, Design Basis Accidents, U.S. NRC, October 1999,

U.S. NRC Jul 2000. Regulatory Guide 1.183, *Alternative Radiological Source Terms for Evaluating Design Basis Accidents at Nuclear Power Reactors*, NRC, July 2000.

U.S. NRC Mar 2007. NUREG-0800, *Standard Review Plan for the Review of Safety Analysis Reports for Nuclear Power Plants*, U.S. NRC, March 2007.

Westinghouse Sep 2008. AP1000 Document No. APP-GW-GL-700, *AP1000 Design Control Document*, Tier 2, Westinghouse, Revision 17, September 2008.

Table 7.1-1
Design Certification X/Q Values and Ratios to Site X/Q Value for AP1000

Accident	Location	Release Time (hr)	X/Q (sec/m^3) DCD	X/Q (sec/m^3) Site	X/Q Ratio (Site/DCD)
LOCA	EAB	0–2	5.1×10^{-4}	8.85×10^{-5}	1.74×10^{-1}
	LPZ	0–8	2.2×10^{-4}	5.30×10^{-6}	2.41×10^{-2}
		8–24	1.6×10^{-4}	3.92×10^{-6}	2.45×10^{-2}
		24–96	1.0×10^{-4}	2.05×10^{-6}	2.05×10^{-2}
		96–720	8.0×10^{-5}	8.05×10^{-7}	1.01×10^{-2}
Other	EAB	0–2	1.0×10^{-3}	8.85×10^{-5}	8.85×10^{-2}
	LPZ	0–8	5.0×10^{-4}	5.30×10^{-6}	1.06×10^{-2}
		8–24	3.0×10^{-4}	3.92×10^{-6}	1.31×10^{-2}
		24–96	1.5×10^{-4}	2.05×10^{-6}	1.37×10^{-2}
		96–720	8.0×10^{-5}	8.05×10^{-7}	1.01×10^{-2}

Reference: AP1000 DCD Rev. 17 (Westinghouse Sep 2008)

Table 7.1-2
Design Certification X/Q Values and Ratios to Site X/Q Values for APWR

Location	Release Time (hr)	X/Q (sec/m^3)		X/Q Ratio (Site/DCD)
		DCD	Site	
EAB	0–2	5.0×10^{-4}	8.85×10^{-5}	1.77×10^{-1}
LPZ	0–8	2.1×10^{-4}	5.30×10^{-6}	2.52×10^{-2}
	8–24	1.3×10^{-4}	3.92×10^{-6}	3.02×10^{-2}
	24–96	6.9×10^{-5}	2.05×10^{-6}	2.97×10^{-2}
	96–720	2.8×10^{-5}	8.05×10^{-7}	2.88×10^{-2}

Reference: APWR DCD Rev. 2 (MHI Oct 2009)

Table 7.1-3
Design Certification X/Q Values and Ratios to Site X/Q Values for ABWR

Accident	Location	Release Time (hr)	X/Q (sec/m^3)		X/Q Ratio (Site/DCD)
			DCD	Site	
Cleanup Water Line Break	EAB	0–2	2.29×10^{-2}	8.85×10^{-5}	3.86×10^{-3}
	LPZ	0–8	2.29×10^{-2}	5.30×10^{-6}	2.31×10^{-4}
LOCA	EAB	0–2	1.37×10^{-3}	8.85×10^{-5}	6.46×10^{-2}
	LPZ	0–8	1.56×10^{-4}	5.30×10^{-6}	3.40×10^{-2}
		8–24	9.61×10^{-5}	3.92×10^{-6}	4.08×10^{-2}
		24–96	3.36×10^{-5}	2.05×10^{-6}	6.10×10^{-2}
		96–720	7.42×10^{-6}	8.05×10^{-7}	1.08×10^{-1}
Other	EAB	0–2	1.37×10^{-3}	8.85×10^{-5}	6.46×10^{-2}
	LPZ	0–8	1.37×10^{-3}	5.30×10^{-6}	3.87×10^{-3}

Reference: ABWR DCD Rev. 4 (GENE Mar 1997)

Table 7.1-4
Design Certification X/Q Values and Ratios to Site X/Q Values for ESBWR

Accident	Location	Release Time (hr)	X/Q (sec/m^3) DCD	X/Q (sec/m^3) Site	X/Q Ratio (Site/DCD)
LOCA	EAB	0–2	2.00×10^{-3}	8.85×10^{-5}	4.43×10^{-2}
	LPZ	0–8	1.90×10^{-4}	5.30×10^{-6}	2.79×10^{-2}
		8–24	1.40×10^{-4}	3.92×10^{-6}	2.80×10^{-2}
		24–96	7.50×10^{-5}	2.05×10^{-6}	2.73×10^{-2}
		96–720	3.00×10^{-5}	8.05×10^{-7}	2.68×10^{-2}
Small Break Outside Containment	EAB	0–2	2.00×10^{-3}	8.85×10^{-5}	4.43×10^{-2}
	LPZ	0–8	1.90×10^{-4}	5.30×10^{-6}	2.79×10^{-2}
		8–24	1.40×10^{-4}	3.92×10^{-6}	2.80×10^{-2}
		24–96	7.50×10^{-5}	2.05×10^{-6}	2.73×10^{-2}
		96–720	3.00×10^{-5}	8.05×10^{-7}	2.68×10^{-2}
Other	EAB	0–2	2.00×10^{-3}	8.85×10^{-5}	4.43×10^{-2}
	LPZ	0–8	1.90×10^{-4}	5.30×10^{-6}	2.79×10^{-2}

Reference: ESBWR DCD Rev. 6 (GEH Aug 2009)

Table 7.1-5 (Sheet 1 of 2)
Summary of Design Basis Accident Site Doses

SRP Section	Accident		Design	DCD Section	Site Dose (rem TEDE)		
					EAB	LPZ	Limit
15.1.5A	Steam System Piping Failure	Pre-Incident Iodine Spike	AP1000	15.1.5	8.9×10^{-2}	8.6×10^{-3}	25
			APWR	15.1.5	3.4×10^{-2}	2.8×10^{-3}	
		Accident-Initiated Iodine Spike	AP1000	15.1.5	9.7×10^{-2}	2.3×10^{-2}	2.5
			APWR	15.1.5	5.7×10^{-2}	7.3×10^{-3}	
15.3.3	Locked Rotor Accident	No Feedwater	AP1000	15.3.3	7.1×10^{-2}	4.1×10^{-3}	2.5
		Feedwater Available	AP1000	15.3.3	5.3×10^{-2}	8.0×10^{-3}	
	Locked Rotor Accident		APWR	15.3.3	8.7×10^{-2}	1.9×10^{-2}	
15.4.8	Rod Ejection Accident		AP1000	15.4.8	3.2×10^{-1}	5.8×10^{-2}	6.3
			APWR	15.4.8	9.0×10^{-1}	1.2×10^{-1}	
15.6.2	Small Break Outside Containment		AP1000	15.6.2	1.9×10^{-1}	1.1×10^{-2}	2.5
			APWR	15.6.2	2.7×10^{-1}	1.5×10^{-2}	
			ABWR	15.6.2	1.5×10^{-2}	9.2×10^{-4}	
	Small Break Outside Ctmt	Pre-Incident Iodine Spike	ESBWR	15.4.8	1.5×10^{-2}	2.8×10^{-3}	25
		Equilibrium Iodine Activity	ESBWR	15.4.8	4.4×10^{-3}	2.8×10^{-3}	2.5
15.6.3	Steam Generator Tube Rupture	Pre-Incident Iodine Spike	AP1000	15.6.3	1.9×10^{-1}	1.3×10^{-2}	25
			APWR	15.6.3	6.4×10^{-1}	3.8×10^{-2}	
		Accident-Initiated Iodine Spike	AP1000	15.6.3	9.7×10^{-2}	8.7×10^{-3}	2.5
			APWR	15.6.3	1.7×10^{-1}	1.1×10^{-2}	
15.6.4	Main Steam Line Break	Pre-Incident Iodine Spike	ABWR	15.6.4	1.8×10^{-1}	1.1×10^{-2}	25
			ESBWR	15.4.5	1.2×10^{-1}	5.6×10^{-3}	
		Equilibrium Iodine Activity	ABWR	15.6.4	9.0×10^{-3}	5.4×10^{-4}	2.5
			ESBWR	15.4.5	8.9×10^{-3}	2.8×10^{-3}	
15.6.5	Loss-of-Coolant Accident		AP1000	15.6.5	4.3	5.5×10^{-1}	25
			APWR	15.6.5	2.3	3.4×10^{-1}	
			ABWR	15.6.5	6.3×10^{-1}	7.9×10^{-1}	
			ESBWR	15.4.4	9.9×10^{-1}	5.7×10^{-1}	
15.7.4	Fuel Handling Accident		AP1000	15.7.4	4.6×10^{-1}	2.7×10^{-2}	6.3
			APWR	15.7.4	5.8×10^{-1}	3.5×10^{-2}	
			ABWR	15.7.4	2.2×10^{-1}	1.3×10^{-2}	
			ESBWR	15.4.1	1.8×10^{-1}	1.1×10^{-2}	

Table 7.1-5 (Sheet 2 of 2)
Summary of Design Basis Accident Site Doses

SRP Section	Accident		Design	DCD Section	Site Dose (rem TEDE)		
					EAB	LPZ	Limit
None	Feedwater Line Break	Pre-Incident Iodine Spike	ESBWR	15.4.7	8.0×10^{-1}	4.7×10^{-2}	25
		Equilibrium Iodine Activity	ESBWR	15.4.7	4.9×10^{-2}	2.8×10^{-3}	2.5
None	Cleanup Water Line Break		ABWR	15.6.6	4.6×10^{-3}	2.7×10^{-4}	25
	Cleanup Water Line Break	Pre-Incident Iodine Spike	ESBWR	15.4.9	3.1×10^{-1}	2.0×10^{-2}	25
		Equilibrium Iodine Activity	ESBWR	15.4.9	1.8×10^{-2}	2.8×10^{-3}	2.5

Note: This table summarizes the doses from the tables that follow. For the ABWR, the whole body and thyroid doses within Tables 7.1-44 to 7.1-53 are converted into TEDE values using weighting factors as indicated in Subsection 7.1.4. For the designs being considered, there are no radiological consequences for the accidents described in SRP Sections 15.2.8, 15.3.4, and 15.4.9.

References: AP1000 DCD Rev. 17 (Westinghouse Sep 2008)
APWR DCD Rev. 2 (MHI Oct 2009)
ABWR DCD Rev. 4 (GENE Mar 1997)
ESBWR DCD Rev. 6 (GEH Aug 2009)

Table 7.1-6
Activity Releases for AP1000 Main Steam System Piping Failure with Pre-Incident Iodine Spike

Isotope	Activity Release (Ci)				
	0–2 hr	2–8 hr	8–24 hr	24–72 hr	Total
Kr-85m	6.86×10^{-2}	1.14×10^{-1}	6.80×10^{-2}	6.20×10^{-3}	2.57×10^{-1}
Kr-85	2.82×10^{-1}	8.47×10^{-1}	2.25	6.68	1.01×10^{1}
Kr-87	2.76×10^{-2}	1.34×10^{-2}	5.20×10^{-4}	0.00	4.15×10^{-2}
Kr-88	1.12×10^{-1}	1.37×10^{-1}	4.04×10^{-2}	8.00×10^{-4}	2.90×10^{-1}
Xe-131m	1.28×10^{-1}	3.79×10^{-1}	9.81×10^{-1}	2.70	4.19
Xe-133m	1.59×10^{-1}	4.51×10^{-1}	1.04	2.05	3.70
Xe-133	1.18×10^{1}	3.45×10^{1}	8.65×10^{1}	2.16×10^{2}	3.49×10^{2}
Xe-135m	3.04×10^{-3}	1.30×10^{-5}	0.00	0.00	3.05×10^{-3}
Xe-135	3.10×10^{-1}	6.90×10^{-1}	8.35×10^{-1}	3.39×10^{-1}	2.17
Xe-138	3.99×10^{-3}	1.10×10^{-5}	0.00	0.00	4.00×10^{-3}
I-130	3.59×10^{-1}	1.42×10^{-1}	2.09×10^{-1}	1.33×10^{-1}	8.43×10^{-1}
I-131	2.40×10^{1}	1.21×10^{1}	3.10×10^{1}	8.21×10^{1}	1.49×10^{2}
I-132	3.05×10^{1}	4.14	8.07×10^{-1}	6.00×10^{-3}	3.55×10^{1}
I-133	4.34×10^{1}	1.90×10^{1}	3.53×10^{1}	3.98×10^{1}	1.38×10^{2}
I-134	6.74	1.63×10^{-1}	1.40×10^{-3}	0.00	6.90
I-135	2.60×10^{1}	8.16	7.54	1.71	4.34×10^{1}
Cs-134	1.90×10^{1}	1.95×10^{-1}	5.19×10^{-1}	1.54	2.13×10^{1}
Cs-136	2.82×10^{1}	2.86×10^{-1}	7.42×10^{-1}	2.06	3.13×10^{1}
Cs-137	1.37×10^{1}	1.41×10^{-1}	3.74×10^{-1}	1.11	1.53×10^{1}
Cs-138	1.01×10^{1}	1.02×10^{-3}	0.00	0.00	1.01×10^{1}
Total	$\mathbf{2.15 \times 10^{2}}$	$\mathbf{8.15 \times 10^{1}}$	$\mathbf{1.68 \times 10^{2}}$	$\mathbf{3.56 \times 10^{2}}$	$\mathbf{8.21 \times 10^{2}}$

Note: Source terms are for the radiation dose values recorded in DCD Rev. 17 (Westinghouse Sep 2008)

Table 7.1-7
Doses for AP1000 Steam System Piping Failure with Pre-Incident Iodine Spike

Time (hr)	DCD Dose (rem TEDE)		X/Q Ratio	Site Dose (rem TEDE)	
	EAB	LPZ	Site to DCD	EAB	LPZ
0–2	1.00	—	8.85×10^{-2}	8.85×10^{-2}	—
0–8	—	5.81×10^{-1}	1.06×10^{-2}	—	6.16×10^{-3}
8–24	—	7.18×10^{-2}	1.31×10^{-2}	—	9.38×10^{-4}
24–96	—	1.08×10^{-1}	1.37×10^{-2}	—	1.48×10^{-3}
Total	1.00	7.61×10^{-1}	—	8.85×10^{-2}	8.57×10^{-3}
Limit	—	—	—	25	25

Note: Time-dependent LPZ doses and total LPZ and EAB doses correspond to the radiation doses in DCD Rev. 17 (Westinghouse Sep 2008)

Table 7.1-8
Activity Releases for AP1000 Main Steam System Piping Failure with Accident-Initiated Iodine Spike

Isotope	Activity Release (Ci)				
	0–2 hr	2–8 hr	8–24 hr	24–72 hr	Total
Kr-85m	6.86×10^{-2}	1.14×10^{-1}	6.80×10^{-2}	6.20×10^{-3}	2.57×10^{-1}
Kr-85	2.82×10^{-1}	8.47×10^{-1}	2.25	6.68	1.01×10^{1}
Kr-87	2.76×10^{-2}	1.34×10^{-2}	5.20×10^{-4}	0.00	4.15×10^{-2}
Kr-88	1.12×10^{-1}	1.37×10^{-1}	4.04×10^{-2}	8.00×10^{-4}	2.90×10^{-1}
Xe-131m	1.28×10^{-1}	3.79×10^{-1}	9.81×10^{-1}	2.70	4.19
Xe-133m	1.59×10^{-1}	4.51×10^{-1}	1.04	2.05	3.70
Xe-133	1.18×10^{1}	3.45×10^{1}	8.65×10^{1}	2.16×10^{2}	3.49×10^{2}
Xe-135m	3.04×10^{-3}	1.30×10^{-5}	0.00	0.00	3.05×10^{-3}
Xe-135	3.10×10^{-1}	6.90×10^{-1}	8.35×10^{-1}	3.39×10^{-1}	2.17
Xe-138	3.99×10^{-3}	1.10×10^{-5}	0.00	0.00	4.00×10^{-3}
I-130	4.15×10^{-1}	9.95×10^{-1}	1.58	1.01	4.00
I-131	2.57×10^{1}	5.73×10^{1}	1.56×10^{2}	4.13×10^{2}	6.52×10^{2}
I-132	4.57×10^{1}	9.74×10^{1}	2.23×10^{1}	2.00×10^{-1}	1.66×10^{2}
I-133	4.85×10^{1}	1.14×10^{2}	2.27×10^{2}	2.55×10^{2}	6.45×10^{2}
I-134	1.33×10^{1}	1.86×10^{1}	2.60×10^{-1}	0.00	3.22×10^{1}
I-135	3.20×10^{1}	7.74×10^{1}	7.83×10^{1}	1.77×10^{1}	2.05×10^{2}
Cs-134	1.90×10^{1}	1.95×10^{-1}	5.19×10^{-1}	1.54	2.13×10^{1}
Cs-136	2.82×10^{1}	2.86×10^{-1}	7.42×10^{-1}	2.06	3.13×10^{1}
Cs-137	1.37×10^{1}	1.41×10^{-1}	3.74×10^{-1}	1.11	1.53×10^{1}
Cs-138	1.01×10^{1}	1.02×10^{-3}	0.00	0.00	1.01×10^{1}
Total	$\mathbf{2.50 \times 10^{2}}$	$\mathbf{4.03 \times 10^{2}}$	$\mathbf{5.79 \times 10^{2}}$	$\mathbf{9.19 \times 10^{2}}$	$\mathbf{2.15 \times 10^{3}}$

Note: Source terms are for the radiation dose values recorded in DCD Rev. 17 (Westinghouse Sep 2008)

Table 7.1-9
Doses for AP1000 Steam System Piping Failure with Accident-Initiated Iodine Spike

Time (hr)	DCD Dose (rem TEDE)		X/Q Ratio	Site Dose (rem TEDE)	
	EAB	LPZ	Site to DCD	EAB	LPZ
0–2	1.10	—	8.85×10^{-2}	9.74×10^{-2}	—
0–8	—	1.02	1.06×10^{-2}	—	1.08×10^{-2}
8–24	—	3.77×10^{-1}	1.31×10^{-2}	—	4.93×10^{-3}
24–96	—	5.36×10^{-1}	1.37×10^{-2}	—	7.33×10^{-3}
Total	1.10	1.93	—	9.74×10^{-2}	2.31×10^{-2}
Limit	—	—	—	2.5	2.5

Note: Time-dependent LPZ doses and total LPZ and EAB doses correspond to the radiation doses in DCD Rev. 17 (Westinghouse Sep 2008)

Table 7.1-10
Activity Releases for AP1000 Locked Rotor Accident

Isotope	Activity Release (Ci)			
	No Feedwater	With Feedwater		
	0–2 hr	0–6 hr	6–8 hr	Total
Kr-85m	8.16×10^{1}	2.38×10^{2}	4.12×10^{1}	2.79×10^{2}
Kr-85	7.58	3.03×10^{1}	1.01×10^{1}	4.04×10^{1}
Kr-87	1.20×10^{2}	2.07×10^{2}	5.40	2.12×10^{2}
Kr-88	2.08×10^{2}	5.21×10^{2}	6.04×10^{1}	5.81×10^{2}
Xe-131m	3.77	1.50×10^{1}	4.94	1.99×10^{1}
Xe-133m	2.02×10^{1}	7.85×10^{1}	2.48×10^{1}	1.03×10^{2}
Xe-133	6.66×10^{2}	2.63×10^{3}	8.57×10^{2}	3.49×10^{3}
Xe-135m	3.24×10^{1}	3.30×10^{1}	0.00	3.30×10^{1}
Xe-135	1.59×10^{2}	5.40×10^{2}	1.32×10^{2}	6.72×10^{2}
Xe-138	1.29×10^{2}	1.30×10^{2}	0.00	1.30×10^{2}
I-130	8.45×10^{-1}	8.81×10^{-1}	5.65×10^{-1}	1.45
I-131	3.77×10^{1}	4.60×10^{1}	3.46×10^{1}	8.06×10^{1}
I-132	2.79×10^{1}	1.43×10^{1}	3.95	1.83×10^{1}
I-133	4.86×10^{1}	5.33×10^{1}	3.64×10^{1}	8.97×10^{1}
I-134	2.88×10^{1}	5.53	2.09×10^{-1}	5.74
I-135	4.19×10^{1}	3.74×10^{1}	2.05×10^{1}	5.79×10^{1}
Cs-134	1.29	1.48	1.11	2.59
Cs-136	5.63×10^{-1}	5.17×10^{-1}	3.47×10^{-1}	8.64×10^{-1}
Cs-137	7.74×10^{-1}	8.71×10^{-1}	6.50×10^{-1}	1.52
Cs-138	6.08	2.95	1.13	4.08
Rb-86	1.33×10^{-2}	1.64×10^{-2}	1.27×10^{-2}	2.91×10^{-2}
Total	$\mathbf{1.62 \times 10^{3}}$	$\mathbf{4.59 \times 10^{3}}$	$\mathbf{1.24 \times 10^{3}}$	$\mathbf{5.82 \times 10^{3}}$

Note: Source terms are for the radiation dose values recorded in DCD Rev. 17 (Westinghouse Sep 2008)

Table 7.1-11
Doses for AP1000 Locked Rotor Accident with No Feedwater

Time (hr)	DCD Dose (rem TEDE)		X/Q Ratio	Site Dose (rem TEDE)	
	EAB	LPZ	Site to DCD	EAB	LPZ
0–2	8.00×10^{-1}	—	8.85×10^{-2}	7.08×10^{-2}	—
0–8	—	3.89×10^{-1}	1.06×10^{-2}	—	4.12×10^{-3}
Total	8.00×10^{-1}	3.89×10^{-1}	—	7.08×10^{-2}	4.12×10^{-3}
Limit	—	—	—	2.5	2.5

Note: Time-dependent LPZ doses and total LPZ and EAB doses correspond to the radiation doses in DCD Rev. 17 (Westinghouse Sep 2008)

Table 7.1-12
Doses for AP1000 Locked Rotor Accident with Feedwater Available

Time (hr)	DCD Dose (rem TEDE)		X/Q Ratio	Site Dose (rem TEDE)	
	EAB	LPZ	Site to DCD	EAB	LPZ
6–8[(a)]	6.00×10^{-1}	—	8.85×10^{-2}	5.31×10^{-2}	—
0–8	—	7.52×10^{-1}	1.06×10^{-2}	—	7.97×10^{-3}
Total	6.00×10^{-1}	7.52×10^{-1}	—	5.31×10^{-2}	7.97×10^{-3}
Limit	—	—	—	2.5	2.5

(a) Worst case 2-hour period is 6–8 hours.

Note: Time-dependent LPZ doses and total LPZ and EAB doses correspond to the radiation doses in DCD Rev. 17 (Westinghouse Sep 2008)

Table 7.1-13
Activity Release for AP1000 Rod Ejection Accident

Isotope	Activity Release (Ci)					
	0–2 hr	2–8 hr	8–24 hr	24–96 hr	96–720 hr	Total
Kr-85m	1.12×10^{2}	6.48×10^{1}	3.87×10^{1}	1.80	0.00	2.17×10^{2}
Kr-85	5.01	5.60	1.49×10^{1}	3.35×10^{1}	2.88×10^{2}	3.47×10^{2}
Kr-87	1.82×10^{2}	2.60×10^{1}	1.03	0.00	0.00	2.09×10^{2}
Kr-88	2.91×10^{2}	1.18×10^{2}	3.49×10^{1}	3.00×10^{-1}	0.00	4.44×10^{2}
Xe-131m	4.94	5.46	1.42×10^{1}	2.86×10^{1}	1.16×10^{2}	1.69×10^{2}
Xe-133m	2.67×10^{1}	2.81×10^{1}	6.49×10^{1}	8.45×10^{1}	5.31×10^{1}	2.57×10^{2}
Xe-133	8.79×10^{2}	9.59×10^{2}	2.40×10^{3}	4.27×10^{3}	8.44×10^{3}	1.69×10^{4}
Xe-135m	7.34×10^{1}	5.00×10^{-2}	0.00	0.00	0.00	7.35×10^{1}
Xe-135	2.15×10^{2}	1.72×10^{2}	2.09×10^{2}	4.34×10^{1}	2.00×10^{-1}	6.40×10^{2}
Xe-138	2.99×10^{2}	1.40×10^{-1}	0.00	0.00	0.00	2.99×10^{2}
I-130	4.90	7.28	4.32	2.00×10^{-1}	0.00	1.67×10^{1}
I-131	1.36×10^{2}	2.45×10^{2}	2.31×10^{2}	3.10×10^{1}	1.68×10^{1}	6.60×10^{2}
I-132	1.53×10^{2}	9.94×10^{1}	9.80	0.00	0.00	2.62×10^{2}
I-133	2.72×10^{2}	4.40×10^{2}	3.18×10^{2}	2.30×10^{1}	0.00	1.05×10^{3}
I-134	1.66×10^{2}	2.85×10^{1}	1.00×10^{-1}	0.00	0.00	1.95×10^{2}
I-135	2.39×10^{2}	2.97×10^{2}	1.19×10^{2}	2.40	0.00	6.57×10^{2}
Cs-134	3.08×10^{1}	6.22×10^{1}	6.03×10^{1}	7.70	5.20	1.66×10^{2}
Cs-136	8.79	1.75×10^{1}	1.67×10^{1}	2.05	6.50×10^{-1}	4.57×10^{1}
Cs-137	1.79×10^{1}	3.62×10^{1}	3.51×10^{1}	4.52	3.05	9.68×10^{1}
Cs-138	1.09×10^{2}	7.00	0.00	0.00	0.00	1.16×10^{2}
Rb-86	3.62×10^{-1}	7.27×10^{-1}	6.96×10^{-1}	8.40×10^{-2}	3.70×10^{-2}	1.91
Total	**3.23×10^{3}**	**2.62×10^{3}**	**3.57×10^{3}**	**4.53×10^{3}**	**8.92×10^{3}**	**2.29×10^{4}**

Note: Source terms are for the radiation dose values recorded in DCD Rev. 17 (Westinghouse Sep 2008)

Table 7.1-14
Doses for AP1000 Rod Ejection Accident

Time (hr)	DCD Dose (rem TEDE)		X/Q Ratio	Site Dose (rem TEDE)	
	EAB	LPZ	Site to DCD	EAB	LPZ
0–2	3.60	—	8.85×10^{-2}	3.19×10^{-1}	—
0–8	—	4.38	1.06×10^{-2}	—	4.64×10^{-2}
8–24	—	7.85×10^{-1}	1.31×10^{-2}	—	1.03×10^{-2}
24–96	—	6.34×10^{-2}	1.37×10^{-2}	—	8.66×10^{-4}
96–720	—	2.02×10^{-2}	1.01×10^{-2}	—	2.03×10^{-4}
Total	3.60	5.25	—	3.19×10^{-1}	5.78×10^{-2}
Limit	—	—	—	6.3	6.3

Note: Time-dependent LPZ doses and total LPZ and EAB doses correspond to the radiation doses in DCD Rev. 17 (Westinghouse Sep 2008)

Table 7.1-15
Activity Releases for AP1000 Small Break Outside Containment

Isotope	Activity Release (Ci) 0–0.5 hr
Kr-85m	1.24×10^{1}
Kr-85	4.40×10^{1}
Kr-87	7.05
Kr-88	2.21×10^{1}
Xe-131m	1.99×10^{1}
Xe-133m	2.50×10^{1}
Xe-133	1.84×10^{3}
Xe-135m	2.59
Xe-135	5.20×10^{1}
Xe-138	3.65
I-130	1.89
I-131	9.26×10^{1}
I-132	3.49×10^{2}
I-133	2.01×10^{2}
I-134	1.58×10^{2}
I-135	1.68×10^{2}
Cs-134	4.16
Cs-136	6.16
Cs-137	3.00
Cs-138	2.21
Rb-86	0.00
Total	**3.01×10^{3}**

Note: Source terms are for the radiation dose values recorded in DCD Rev. 17 (Westinghouse Sep 2008)

Table 7.1-16
Doses for AP1000 Small Break Outside Containment

Time (hr)	DCD Dose (rem TEDE)		X/Q Ratio	Site Dose (rem TEDE)	
	EAB	LPZ	Site to DCD	EAB	LPZ
0–2	2.10	—	8.85×10^{-2}	1.86×10^{-1}	—
0–8	—	1.03	1.06×10^{-2}	—	1.09×10^{-2}
Total	2.10	1.03	—	1.86×10^{-1}	1.09×10^{-2}
Limit	—	—	—	2.5	2.5

Note: Time-dependent LPZ doses and total LPZ and EAB doses correspond to the radiation doses in DCD Rev. 17 (Westinghouse Sep 2008)

Table 7.1-17
Activity Releases for AP1000 Steam Generator Tube Rupture with Pre-Incident Iodine Spike

Isotope	Activity Release (Ci)			
	0–2 hr	2–8 hr	8–14 hr	Total
Kr-85m	5.53×10^{1}	1.93×10^{1}	0.00	7.46×10^{1}
Kr-85	2.20×10^{2}	1.08×10^{2}	2.00×10^{-1}	3.28×10^{2}
Kr-87	2.39×10^{1}	3.61	0.00	2.75×10^{1}
Kr-88	9.22×10^{1}	2.65×10^{1}	0.00	1.19×10^{2}
Xe-131m	9.96×10^{1}	4.88×10^{1}	0.00	1.48×10^{2}
Xe-133m	1.24×10^{2}	5.91×10^{1}	1.00×10^{-1}	1.83×10^{2}
Xe-133	9.19×10^{3}	4.47×10^{3}	1.00×10^{1}	1.37×10^{4}
Xe-135m	3.44	6.00×10^{-3}	0.00	3.45
Xe-135	2.46×10^{2}	1.02×10^{2}	1.00×10^{-1}	3.48×10^{2}
Xe-138	4.56	5.00×10^{-3}	0.00	4.57
I-130	1.79	5.39×10^{-2}	2.67×10^{-1}	2.11
I-131	1.21×10^{2}	5.27	3.05×10^{1}	1.57×10^{2}
I-132	1.42×10^{2}	7.86×10^{-1}	1.91	1.45×10^{2}
I-133	2.16×10^{2}	7.63	4.06×10^{1}	2.64×10^{2}
I-134	2.74×10^{1}	1.06×10^{-2}	2.00×10^{-4}	2.74×10^{1}
I-135	1.27×10^{2}	2.70	1.17×10^{1}	1.41×10^{2}
Cs-134	1.63	6.10×10^{-2}	2.16×10^{-1}	1.91
Cs-136	2.42	8.80×10^{-2}	3.15×10^{-1}	2.82
Cs-137	1.17	4.40×10^{-2}	1.56×10^{-1}	1.37
Cs-138	5.64×10^{-1}	0.00	0.00	5.64×10^{-1}
Total	**1.07×10^{4}**	**4.85×10^{3}**	**9.61×10^{1}**	**1.57×10^{4}**

Note: Source terms are for the radiation dose values recorded in DCD Rev. 17 (Westinghouse Sep 2008)

Table 7.1-18
Doses for AP1000 Steam Generator Tube Rupture with Pre-Incident Iodine Spike

Time (hr)	DCD Dose (rem TEDE)		X/Q Ratio	Site Dose (rem TEDE)	
	EAB	LPZ	Site to DCD	EAB	LPZ
0–2	2.20	—	8.85×10^{-2}	1.95×10^{-1}	—
0–8	—	1.16	1.06×10^{-2}	—	1.23×10^{-2}
8–24	—	7.20×10^{-2}	1.31×10^{-2}	—	9.41×10^{-4}
Total	2.20	1.23	—	1.95×10^{-1}	1.32×10^{-2}
Limit	—	—	—	25	25

Note: Time-dependent LPZ doses and total LPZ and EAB doses correspond to the radiation doses in DCD Rev. 17 (Westinghouse Sep 2008)

Table 7.1-19
Activity Releases for AP1000 Steam Generator Tube Rupture with Accident Initiated Iodine Spike

Isotope	Activity Release (Ci)			
	0–2 hr	2–8 hr	8–14 hr	Total
Kr-85m	5.53×10^{1}	1.93×10^{1}	0.00	7.46×10^{1}
Kr-85	2.20×10^{2}	1.08×10^{2}	2.00×10^{-1}	3.28×10^{2}
Kr-87	2.39×10^{1}	3.61	0.00	2.75×10^{1}
Kr-88	9.22×10^{1}	2.65×10^{1}	0.00	1.19×10^{2}
Xe-131m	9.96×10^{1}	4.88×10^{1}	0.00	1.48×10^{2}
Xe-133m	1.24×10^{2}	5.91×10^{1}	1.00×10^{-1}	1.83×10^{2}
Xe-133	9.19×10^{3}	4.47×10^{3}	1.00×10^{1}	1.37×10^{4}
Xe-135m	3.44	6.00×10^{-3}	0.00	3.45
Xe-135	2.46×10^{2}	1.02×10^{2}	1.00×10^{-1}	3.48×10^{2}
Xe-138	4.56	5.00×10^{-3}	0.00	4.57
I-130	8.87×10^{-1}	1.62×10^{-1}	8.23×10^{-1}	1.87
I-131	4.36×10^{1}	1.14×10^{1}	6.76×10^{1}	1.23×10^{2}
I-132	1.47×10^{2}	4.89	1.29×10^{1}	1.65×10^{2}
I-133	9.33×10^{1}	1.99×10^{1}	1.08×10^{2}	2.21×10^{2}
I-134	5.59×10^{1}	6.06×10^{-2}	6.02×10^{-2}	5.60×10^{1}
I-135	7.61×10^{1}	9.89	4.38×10^{1}	1.30×10^{2}
Cs-134	1.63	6.10×10^{-2}	2.16×10^{-1}	1.91
Cs-136	2.42	8.80×10^{-2}	3.15×10^{-1}	2.82
Cs-137	1.17	4.40×10^{-2}	1.56×10^{-1}	1.37
Cs-138	5.64×10^{-1}	0.00	0.00	5.64×10^{-1}
Total	**1.05×10^{4}**	**4.88×10^{3}**	**2.44×10^{2}**	**1.56×10^{4}**

Note: Source terms are for the radiation dose values recorded in DCD Rev. 17 (Westinghouse Sep 2008)

Table 7.1-20
Doses for AP1000 Steam Generator Tube Rupture with Accident-Initiated Iodine Spike

Time (hr)	DCD Dose (rem TEDE)		X/Q Ratio	Site Dose (rem TEDE)	
	EAB	LPZ	Site to DCD	EAB	LPZ
0–2	1.10	—	8.85×10^{-2}	9.74×10^{-2}	—
0–8	—	6.10×10^{-1}	1.06×10^{-2}	—	6.47×10^{-3}
8–24	—	1.68×10^{-1}	1.31×10^{-2}	—	2.20×10^{-3}
Total	1.10	7.78×10^{-1}	—	9.74×10^{-2}	8.66×10^{-3}
Limit	—	—	—	2.5	2.5

Note: Time-dependent LPZ doses and total LPZ and EAB doses correspond to the radiation doses in DCD Rev. 17 (Westinghouse Sep 2008)

Table 7.1-21 (Sheet 1 of 2)
Activity Releases for AP1000 Loss-of-Coolant Accident

Isotope	Activity Release (Ci)							
	1.4–3.4 hr	0–2 hr	2–8 hr	8–24 hr	24–72 hr	72–96 hr	96–720 hr	Total
I-130	5.64×10^{1}	3.24×10^{1}	7.85×10^{1}	6.21	5.11×10^{-1}	1.17×10^{-1}	6.00×10^{-3}	1.18×10^{2}
I-131	1.68×10^{3}	9.19×10^{2}	2.57×10^{3}	2.56×10^{2}	1.33×10^{2}	5.84×10^{1}	5.79×10^{2}	4.52×10^{3}
I-132	1.23×10^{3}	8.79×10^{2}	1.26×10^{3}	1.62×10^{1}	6.00×10^{-3}	0	0	2.16×10^{3}
I-133	3.23×10^{3}	1.82×10^{3}	4.72×10^{3}	3.71×10^{2}	7.41×10^{1}	9.90	7.80	7.00×10^{3}
I-134	6.60×10^{2}	7.09×10^{2}	4.29×10^{2}	3.07×10^{-2}	0	0	0	1.14×10^{3}
I-135	2.56×10^{3}	1.54×10^{3}	3.36×10^{3}	1.56×10^{2}	4.79	1.00×10^{-2}	0	5.06×10^{3}
Kr-85m	1.42×10^{3}	6.32×10^{2}	3.14×10^{3}	1.87×10^{3}	8.60×10^{1}	0	0	5.73×10^{3}
Kr-85	8.31×10^{1}	3.22×10^{1}	2.65×10^{2}	7.06×10^{2}	1.06×10^{3}	5.28×10^{2}	1.36×10^{4}	1.62×10^{4}
Kr-87	1.10×10^{3}	6.88×10^{2}	1.26×10^{3}	5.00×10^{1}	0	0	0	2.00×10^{3}
Kr-88	3.11×10^{3}	1.50×10^{3}	5.76×10^{3}	1.70×10^{3}	1.70×10^{1}	0	0	8.98×10^{3}
Xe-131m	8.26×10^{1}	3.21×10^{1}	2.62×10^{2}	6.79×10^{2}	9.42×10^{2}	4.31×10^{2}	5.57×10^{3}	7.92×10^{3}
Xe-133m	4.43×10^{2}	1.74×10^{2}	1.37×10^{3}	3.15×10^{3}	3.14×10^{3}	9.65×10^{2}	2.58×10^{3}	1.14×10^{4}
Xe-133	1.47×10^{4}	5.71×10^{3}	4.62×10^{4}	1.16×10^{5}	1.46×10^{5}	5.97×10^{4}	4.07×10^{5}	7.81×10^{5}
Xe-135m	1.06×10^{1}	3.33×10^{1}	2.62	0	0	0	0	3.59×10^{1}
Xe-135	3.15×10^{3}	1.31×10^{3}	8.33×10^{3}	1.01×10^{4}	2.06×10^{3}	4.00×10^{1}	1.00×10^{1}	2.19×10^{4}
Xe-138	3.11×10^{1}	1.14×10^{2}	6.90	0	0	0	0	1.21×10^{2}
Rb-86	3.04	1.72	4.60	2.80×10^{-1}	1.00×10^{-3}	0	8.00×10^{-3}	6.61
Cs-134	2.58×10^{2}	1.46×10^{2}	3.92×10^{2}	2.40×10^{1}	1.00×10^{-1}	0	1.20	5.63×10^{2}
Cs-136	7.33×10^{1}	4.14×10^{1}	1.11×10^{2}	6.70	0	0	2.00×10^{-1}	1.59×10^{2}
Cs-137	1.51×10^{2}	8.49×10^{1}	2.28×10^{2}	1.41×10^{1}	0	0	7.00×10^{-1}	3.28×10^{2}
Cs-138	1.50×10^{2}	2.60×10^{2}	6.96×10^{1}	0	0	0	0	3.30×10^{2}
Sb-127	2.42×10^{1}	1.14×10^{1}	3.67×10^{1}	2.14	1.00×10^{-2}	0	1.00×10^{-2}	5.03×10^{1}
Sb-129	5.10×10^{1}	2.71×10^{1}	6.23×10^{1}	1.48	0	0	0	9.09×10^{1}
Te-127m	3.15	1.47	4.83	2.95×10^{-1}	2.00×10^{-3}	0	1.30×10^{-2}	6.61
Te-127	2.05×10^{1}	1.02×10^{1}	2.81×10^{1}	1.11	0	0	0	3.94×10^{1}
Te-129m	1.07×10^{1}	5.01	1.64×10^{1}	1.00	1.00×10^{-2}	0	3.00×10^{-2}	2.25×10^{1}
Te-129	1.88×10^{1}	1.39×10^{1}	1.45×10^{1}	3.00×10^{-2}	0	0	0	2.84×10^{1}
Te-131	3.17×10^{1}	1.51×10^{1}	4.69×10^{1}	2.51	0	0	1.00×10^{-2}	6.45×10^{1}
Te-132	3.23×10^{2}	1.52×10^{2}	4.89×10^{2}	2.84×10^{1}	1.00×10^{-1}	0	1.00×10^{-1}	6.70×10^{2}
Sr-89	9.23×10^{1}	4.31×10^{1}	1.45×10^{2}	5.40	1.00×10^{-1}	0	3.00×10^{-1}	1.94×10^{2}
Sr-90	7.95	3.71	1.22×10^{1}	7.50×10^{-1}	0	0	4.00×10^{-2}	1.67×10^{1}
Sr-91	9.68×10^{1}	4.79×10^{1}	1.33×10^{2}	5.30	0	0	0	1.86×10^{2}
Sr-92	6.83×10^{1}	3.91×10^{1}	7.40×10^{1}	1.00	0	0	0	1.14×10^{2}

Table 7.1-21 (Sheet 2 of 2)
Activity Releases for AP1000 Loss-of-Coolant Accident

Isotope	Activity Release (Ci)							
	1.4–3.4 hr	0–2 hr	2–8 hr	8–24 hr	24–72 hr	72–96 hr	96–720 hr	Total
Ba-139	5.44×10^{1}	3.74×10^{1}	4.56×10^{1}	1.50×10^{-1}	0	0	0	8.32×10^{1}
Ba-140	1.63×10^{2}	7.61×10^{1}	2.49×10^{2}	1.51×10^{1}	0	0	4.00×10^{-1}	3.41×10^{2}
Mo-99	2.15×10^{1}	1.01×10^{1}	3.24×10^{1}	1.86	1.00×10^{-2}	0	0	4.44×10^{1}
Tc-99m	1.47×10^{1}	7.54	1.91×10^{1}	5.90×10^{-1}	0	0	0	2.72×10^{1}
Ru-103	1.73×10^{1}	8.08	2.65×10^{1}	1.62	0	1.00×10^{-2}	6.00×10^{-2}	3.63×10^{1}
Ru-105	8.18	4.33	1.00×10^{1}	2.40×10^{-1}	0	0	0	1.46×10^{1}
Ru-106	5.70	2.66	8.75	5.40×10^{-1}	0	0	3.00×10^{-2}	1.20×10^{1}
Rh-105	1.03×10^{1}	4.88	1.53×10^{1}	8.30×10^{-1}	0	0	0	2.10×10^{1}
Ce-141	3.89	1.82	5.96	3.64×10^{-1}	1.00×10^{-3}	1.00×10^{-3}	1.20×10^{-2}	8.16
Ce-143	3.46	1.64	5.14	2.78×10^{-1}	1.00×10^{-3}	0	0	7.06
Ce-144	2.94	1.37	4.51	2.76×10^{-1}	1.00×10^{-3}	1.00×10^{-3}	1.30×10^{-2}	6.17
Pu-238	9.16×10^{-3}	4.28×10^{-3}	1.41×10^{-2}	8.60×10^{-4}	0	0	4.00×10^{-5}	1.93×10^{-2}
Pu-239	8.06×10^{-4}	3.76×10^{-4}	1.24×10^{-3}	7.60×10^{-5}	0	1.00×10^{-6}	3.00×10^{-6}	1.70×10^{-3}
Pu-240	1.18×10^{-3}	5.52×10^{-4}	1.81×10^{-3}	1.11×10^{-4}	1.00×10^{-6}	0	5.00×10^{-6}	2.48×10^{-3}
Pu-241	2.65×10^{-1}	1.24×10^{-1}	4.08×10^{-1}	2.50×10^{-2}	1.00×10^{-4}	0	1.20×10^{-3}	5.58×10^{-1}
Np-239	4.48×10^{1}	2.12×10^{1}	6.75×10^{1}	3.84	1.00×10^{-2}	1.00×10^{-2}	1.00×10^{-2}	9.26×10^{1}
Y-90	8.08×10^{-2}	3.81×10^{-2}	1.22×10^{-1}	7.00×10^{-3}	0	0	0	1.67×10^{-1}
Y-91	1.19	5.54×10^{-1}	1.82	1.11×10^{-1}	1.00×10^{-3}	0	4.00×10^{-3}	2.49
Y-92	7.89×10^{-1}	4.32×10^{-1}	9.19×10^{-1}	1.80×10^{-2}	0	0	0	1.37
Y-93	1.21	6.00×10^{-1}	1.68	6.80×10^{-2}	0	0	0	2.35
Nb-95	1.59	7.46×10^{-1}	2.44	1.49×10^{-1}	1.00×10^{-3}	0	5.00×10^{-3}	3.34
Zr-95	1.59	7.41×10^{-1}	2.43	1.49×10^{-1}	0	0	6.00×10^{-3}	3.33
Zr-97	1.43	6.89×10^{-1}	2.05	9.80×10^{-2}	0	0	0	2.84
La-140	1.67	7.92×10^{-1}	2.50	1.39×10^{-1}	0	0	0	3.43
La-141	1.03	5.54×10^{-1}	1.23	2.70×10^{-2}	0	0	0	1.81
La-142	5.38×10^{-1}	3.57×10^{-1}	4.74×10^{-1}	2.00×10^{-3}	0	0	0	8.33×10^{-1}
Nd-147	6.16×10^{-1}	2.89×10^{-1}	9.42×10^{-1}	5.70×10^{-2}	0	0	1.00×10^{-3}	1.29
Pr-143	1.39	6.50×10^{-1}	2.13	1.28×10^{-1}	1.00×10^{-3}	0	3.00×10^{-3}	2.91
Am-241	1.20×10^{-4}	5.59×10^{-5}	1.84×10^{-4}	1.13×10^{-5}	0	0	6.00×10^{-7}	2.52×10^{-4}
Cm-242	2.82×10^{-2}	1.32×10^{-2}	4.33×10^{-2}	2.65×10^{-3}	1.00×10^{-5}	1.00×10^{-5}	1.20×10^{-4}	5.93×10^{-2}
Cm-244	3.46×10^{-3}	1.62×10^{-3}	5.32×10^{-3}	3.26×10^{-4}	1.00×10^{-6}	0	1.60×10^{-5}	7.28×10^{-3}
Total	**3.53×10^{4}**	**1.72×10^{4}**	**8.14×10^{4}**	**1.35×10^{5}**	**1.54×10^{5}**	**6.17×10^{4}**	**4.29×10^{5}**	**8.78×10^{5}**

Note: Source terms are for the radiation dose values recorded in DCD Rev. 17 (Westinghouse Sep 2008)

Table 7.1-22
Doses for AP1000 Loss-of-Coolant Accident

Time (hr)	DCD Dose (rem TEDE)		X/Q Ratio	Site Dose (rem TEDE)	
	EAB	LPZ	Site to DCD	EAB	LPZ
1.4–3.4[a]	2.46×10^{1}	—	1.74×10^{-1}	4.27	—
0–8	—	2.17×10^{1}	2.41×10^{-2}	—	5.23×10^{-1}
8–24	—	7.50×10^{-1}	2.45×10^{-2}	—	1.84×10^{-2}
24–96	—	2.93×10^{-1}	2.05×10^{-2}	—	6.01×10^{-3}
96–720	—	5.49×10^{-1}	1.01×10^{-2}	—	5.52×10^{-3}
Total	2.46×10^{1}	2.33×10^{1}	—	4.27	5.53×10^{-1}
Limit	—	—	—	25	25

(a) Worst case 2-hour period is 1.4–3.4 hours.

Note: Time-dependent LPZ doses and total LPZ and EAB doses correspond to the radiation doses in DCD Rev. 17 (Westinghouse Sep 2008)

Table 7.1-23
Activity Releases for AP1000 Fuel Handling Accident

Isotope	Activity Release (Ci)
	0–2 hr
Kr-85m	8.40
Kr-85	1.10×10^{3}
Kr-88	3.00×10^{-1}
Xe-131m	5.52×10^{2}
Xe-133m	2.30×10^{3}
Xe-133	8.88×10^{4}
Xe-135m	1.02×10^{2}
Xe-135	5.68×10^{3}
I-130	7.00×10^{-1}
I-131	3.47×10^{2}
I-132	2.44×10^{2}
I-133	1.08×10^{2}
I-135	3.20
Total	**9.92×10^{4}**

Note: Source terms are for the radiation dose values recorded in DCD Rev. 17 (Westinghouse Sep 2008)

Table 7.1-24
Doses for AP1000 Fuel Handling Accident

Time (hr)	DCD Dose (rem TEDE)		X/Q Ratio	Site Dose (rem TEDE)	
	EAB	LPZ	Site to DCD	EAB	LPZ
0–2	5.20	—	8.85×10^{-2}	4.60×10^{-1}	—
0–8	—	2.59	1.06×10^{-2}	—	2.75×10^{-2}
Total	5.20	2.59	—	4.60×10^{-1}	2.75×10^{-2}
Limit	—	—	—	6.3	6.3

Note: Time-dependent LPZ doses and total LPZ and EAB doses correspond to the radiation doses in DCD Rev. 17 (Westinghouse Sep 2008)

Table 7.1-25
Activity Releases for APWR Steam System Piping Failure with Pre-Incident Iodine Spike

Isotope	Activity Release (Ci)		
	0–8 hr	8–24 hr	Total
Kr-85	3.21×10^{1}	2.40×10^{1}	5.61×10^{1}
Kr-85m	3.56×10^{-1}	8.77×10^{-2}	4.43×10^{-1}
Kr-87	9.12×10^{-2}	1.13×10^{-3}	9.23×10^{-2}
Kr-88	5.10×10^{-1}	6.46×10^{-2}	5.74×10^{-1}
Xe-133	1.07×10^{2}	7.75×10^{1}	1.85×10^{2}
Xe-135	4.38	3.39	7.78
I-131	1.72×10^{1}	7.25	2.44×10^{1}
I-132	6.18	1.66×10^{-1}	6.35
I-133	2.79×10^{1}	9.03	3.69×10^{1}
I-134	3.49	1.01×10^{-3}	3.49
I-135	1.62×10^{1}	2.73	1.89×10^{1}
Rb-86	8.64×10^{-2}	1.62×10^{-3}	8.80×10^{-2}
Cs-134	8.80	1.68×10^{-1}	8.97
Cs-136	2.32	4.33×10^{-2}	2.37
Cs-137	5.01	9.56×10^{-2}	5.11
Total	2.32×10^{2}	1.25×10^{2}	3.56×10^{2}

Reference: APWR DCD Rev. 2 (MHI Oct 2009)

Table 7.1-26
Doses for APWR Steam System Piping Failure with Pre-Incident Iodine Spike

Time (hr)	DCD Dose (rem TEDE)		X/Q Ratio	Site Dose (rem TEDE)	
	EAB	LPZ	Site to DCD	EAB	LPZ
0–2	1.9×10^{-1}	—	1.77×10^{-1}	3.4×10^{-2}	—
0–8	—	1.0×10^{-1}	2.52×10^{-2}	—	2.5×10^{-3}
8–24	—	7.6×10^{-3}	3.02×10^{-2}	—	2.3×10^{-4}
Total	1.9×10^{-1}	1.1×10^{-1}	—	3.4×10^{-2}	2.8×10^{-3}
Limit	—	—	—	25	25

Note: Time-dependent LPZ doses and total LPZ and EAB doses correspond to the radiation doses in DCD Rev. 2 (MHI Oct 2009)

Table 7.1-27
Activity Releases for APWR Steam System Piping Failure with Accident-Initiated Iodine Spike

Isotope	Activity Release (Ci)		
	0–8 hr	8–24 hr	Total
Kr-85	3.21×10^{1}	2.40×10^{1}	5.61×10^{1}
Kr-85m	3.56×10^{-1}	8.77×10^{-2}	4.43×10^{-1}
Kr-87	9.12×10^{-2}	1.13×10^{-3}	9.23×10^{-2}
Kr-88	5.10×10^{-1}	6.46×10^{-2}	5.74×10^{-1}
Xe-133	1.08×10^{2}	8.03×10^{1}	1.88×10^{2}
Xe-135	7.61	1.33×10^{1}	2.09×10^{1}
I-131	5.05×10^{1}	6.50×10^{1}	1.16×10^{2}
I-132	9.89	1.49	1.14×10^{1}
I-133	7.65×10^{1}	8.09×10^{1}	1.57×10^{2}
I-134	3.77	9.11×10^{-3}	3.78
I-135	3.77×10^{1}	2.45×10^{1}	6.21×10^{1}
Rb-86	8.64×10^{-2}	1.62×10^{-3}	8.80×10^{-2}
Cs-134	8.80	1.68×10^{-1}	8.97
Cs-136	2.32	4.33×10^{-2}	2.37
Cs-137	5.01	9.56×10^{-2}	5.11
Total	3.43×10^{2}	2.90×10^{2}	6.33×10^{2}

Reference: APWR DCD Rev. 2 (MHI Oct 2009) |

Table 7.1-28
Doses for APWR Steam System Piping Failure with Accident-Initiated Iodine Spike

Time (hr)	DCD Dose (rem TEDE)		X/Q Ratio	Site Dose (rem TEDE)	
	EAB	LPZ	Site to DCD	EAB	LPZ
0–2	3.2×10^{-1}	—	1.77×10^{-1}	5.7×10^{-2}	—
0–8	—	2.1×10^{-1}	2.52×10^{-2}	—	5.3×10^{-3}
8–24	—	6.5×10^{-2}	3.02×10^{-2}	—	2.0×10^{-3}
Total	3.2×10^{-1}	2.8×10^{-1}	—	5.7×10^{-2}	7.3×10^{-3}
Limit	—	—	—	2.5	2.5

Note: Time-dependent LPZ doses and total LPZ and EAB doses correspond to the radiation doses in DCD Rev. 2 (MHI Oct 2009) |

Table 7.1-29
Activity Releases for APWR Locked Rotor Accident

Isotope	Activity Release (Ci)		
	0–8 hr	8–24 hr	Total
Kr-85	1.12×10^{2}	8.40×10^{1}	1.96×10^{2}
Kr-85m	6.40×10^{2}	1.58×10^{2}	7.98×10^{2}
Kr-87	5.02×10^{2}	6.21	5.08×10^{2}
Kr-88	1.37×10^{3}	1.74×10^{2}	1.55×10^{3}
Xe-133	6.87×10^{3}	4.96×10^{3}	1.18×10^{4}
Xe-135	1.61×10^{3}	7.67×10^{2}	2.37×10^{3}
I-131	8.81×10^{1}	2.32×10^{2}	3.20×10^{2}
I-132	1.94×10^{1}	8.35	2.77×10^{1}
I-133	9.85×10^{1}	2.17×10^{2}	3.15×10^{2}
I-134	6.46	1.10×10^{-1}	6.57
I-135	6.38×10^{1}	9.16×10^{1}	1.55×10^{2}
Rb-86	3.23×10^{-2}	8.66×10^{-2}	1.19×10^{-1}
Cs-134	3.24	8.78	1.20×10^{1}
Cs-136	8.72×10^{-1}	2.33	3.21
Cs-137	1.84	5.00	6.84
Total	1.14×10^{4}	6.71×10^{3}	1.81×10^{4}

Reference: APWR DCD Rev. 2 (MHI Oct 2009)

Table 7.1-30
Doses for APWR Locked Rotor Accident

Time (hr)	DCD Dose (rem TEDE)		X/Q Ratio	Site Dose (rem TEDE)	
	EAB	LPZ	Site to DCD	EAB	LPZ
10–12[(a)]	4.9×10^{-1}	—	1.77×10^{-1}	8.7×10^{-2}	—
0–8	—	4.4×10^{-1}	2.52×10^{-2}	—	1.1×10^{-2}
8–24	—	2.5×10^{-1}	3.02×10^{-2}	—	7.5×10^{-3}
Total	4.9×10^{-1}	6.9×10^{-1}	—	8.7×10^{-2}	1.9×10^{-2}
Limit	—	—	—	2.5	2.5

(a) Worst case 2-hour period is 10–12 hours.

Note: Time-dependent LPZ doses and total LPZ and EAB doses correspond to the radiation doses in DCD Rev. 2 (MHI Oct 2009)

Table 7.1-31
Activity Releases for APWR Rod Ejection Accident

Isotope	Activity Release (Ci)				
	0–8 hr	8–24 hr	24–96 hr	96–720 hr	Total
Kr-85	2.63×10^{2}	2.50×10^{2}	1.90×10^{2}	1.63×10^{3}	2.33×10^{3}
Kr-85m	3.59×10^{3}	9.58×10^{2}	9.86	0	4.56×10^{3}
Kr-87	2.81×10^{3}	3.50×10^{1}	0	0	2.85×10^{3}
Kr-88	7.70×10^{3}	1.02×10^{3}	2.05	0	8.72×10^{3}
Xe-133	3.81×10^{4}	3.46×10^{4}	2.11×10^{4}	4.22×10^{4}	1.36×10^{5}
Xe-135	9.31×10^{3}	5.32×10^{3}	5.40×10^{2}	2.81	1.52×10^{4}
I-131	5.82×10^{2}	7.17×10^{2}	2.58×10^{2}	7.79×10^{2}	2.34×10^{3}
I-132	4.62×10^{2}	3.93×10^{1}	1.40×10^{-2}	0	5.01×10^{2}
I-133	1.12×10^{3}	1.06×10^{3}	1.13×10^{2}	1.13×10^{1}	2.30×10^{3}
I-134	4.95×10^{2}	5.15×10^{-1}	0	0	4.95×10^{2}
I-135	8.75×10^{2}	4.39×10^{2}	6.60	4.00×10^{-3}	1.32×10^{3}
Rb-86	4.16×10^{-1}	9.65×10^{-2}	0	0	5.13×10^{-1}
Cs-134	4.15×10^{1}	9.79	1.01×10^{-3}	0	5.13×10^{1}
Cs-136	1.13×10^{1}	2.60	1.00×10^{-6}	0	1.39×10^{1}
Cs-137	2.36×10^{1}	5.57	0	0	2.92×10^{1}
Total	6.53×10^{4}	4.45×10^{4}	2.22×10^{4}	4.46×10^{4}	1.77×10^{5}

Reference: APWR DCD Rev. 2 (MHI Oct 2009)

Table 7.1-32
Doses for APWR Rod Ejection Accident

Time (hr)	DCD Dose (rem TEDE)		X/Q Ratio	Site Dose (rem TEDE)	
	EAB	LPZ	Site to DCD	EAB	LPZ
0–2	5.1	—	1.77×10^{-1}	9.0×10^{-1}	—
0–8	—	3.2	2.52×10^{-2}	—	8.1×10^{-2}
8–24	—	8.8×10^{-1}	3.02×10^{-2}	—	2.7×10^{-2}
24–96	—	1.6×10^{-1}	2.97×10^{-2}	—	4.8×10^{-3}
96–720	—	1.7×10^{-1}	2.88×10^{-2}	—	4.9×10^{-3}
Total	5.1	4.4	—	9.0×10^{-1}	1.2×10^{-1}
Limit	—	—	—	6.3	6.3

Note: Time-dependent LPZ doses and total LPZ and EAB doses correspond to the radiation doses in DCD Rev. 2 (MHI Oct 2009)

Table 7.1-33
Activity Releases for APWR Small Break Outside Containment

Isotope	Activity Release (Ci), 0-8 hr
Kr-85	6.84×10^{2}
Kr-85m	1.25×10^{1}
Kr-87	7.05
Kr-88	2.26×10^{1}
Xe-133	2.32×10^{3}
Xe-135	7.70×10^{1}
I-131	1.72×10^{2}
I-132	7.98×10^{1}
I-133	2.93×10^{2}
I-134	4.33×10^{1}
I-135	1.85×10^{2}
Total	3.90×10^{3}

Reference: APWR DCD Rev. 2 (MHI Oct 2009)

Table 7.1-34
Doses for APWR Small Break Outside Containment

Time (hr)	DCD Dose (rem TEDE)		X/Q Ratio	Site Dose (rem TEDE)	
	EAB	LPZ	Site to DCD	EAB	LPZ
0–2	1.5	—	1.77×10^{-1}	2.7×10^{-1}	—
0–8	—	6.0×10^{-1}	2.52×10^{-2}	—	1.5×10^{-2}
Total	1.5	6.0×10^{-1}	—	2.7×10^{-1}	1.5×10^{-2}
Limit	—	—	—	2.5	2.5

Note: Time-dependent LPZ doses and total LPZ and EAB doses correspond to the radiation doses in DCD Rev. 2 (MHI Oct 2009)

Table 7.1-35
Activity Releases for APWR Steam Generator Tube Rupture with Pre-Incident Iodine Spike

Isotope	Activity Release (Ci)				
	0–8 hr	8–24 hr	24–96 hr	96–720 hr	Total
Kr-85	3.43×10^{3}	4.64×10^{1}	2.06×10^{2}	1.59×10^{3}	5.27×10^{3}
Kr-85m	6.17×10^{1}	9.70×10^{-2}	8.00×10^{-3}	0	6.18×10^{1}
Kr-87	3.40×10^{1}	0	0	0	3.40×10^{1}
Kr-88	1.11×10^{2}	6.00×10^{-2}	1.00×10^{-2}	0	1.11×10^{2}
Xe-133	1.16×10^{4}	1.44×10^{2}	5.06×10^{2}	9.44×10^{2}	1.32×10^{4}
Xe-135	3.75×10^{2}	2.18	6.70×10^{-1}	0	3.78×10^{2}
I-131	4.18×10^{2}	1.81	0	0	4.20×10^{2}
I-132	2.09×10^{2}	3.92×10^{-2}	0	0	2.09×10^{2}
I-133	7.16×10^{2}	2.24	0	0	7.18×10^{2}
I-134	1.28×10^{2}	6.00×10^{-5}	0	0	1.28×10^{2}
I-135	4.61×10^{2}	6.70×10^{-1}	0	0	4.62×10^{2}
Rb-86	4.54×10^{-3}	5.44×10^{-4}	0	0	5.09×10^{-3}
Cs-134	4.63×10^{-1}	5.63×10^{-2}	0	0	5.19×10^{-1}
Cs-136	1.22×10^{-1}	1.45×10^{-2}	0	0	1.37×10^{-1}
Cs-137	2.64×10^{-1}	3.21×10^{-2}	0	0	2.96×10^{-1}
Total	1.76×10^{4}	1.98×10^{2}	7.12×10^{2}	2.53×10^{3}	2.10×10^{4}

Reference: APWR DCD Rev. 2 (MHI Oct 2009)

Table 7.1-36
Doses for APWR Steam Generator Tube Rupture with Pre-Incident Iodine Spike

Time (hr)	DCD Dose (rem TEDE)		X/Q Ratio	Site Dose (rem TEDE)	
	EAB	LPZ	Site to DCD	EAB	LPZ
0–2	3.6	—	1.77×10^{-1}	6.4×10^{-1}	—
0–8	—	1.5	2.52×10^{-2}	—	3.8×10^{-2}
8–24	—	2.0×10^{-3}	3.02×10^{-2}	—	6.0×10^{-5}
24–96	—	2.1×10^{-4}	2.97×10^{-2}	—	6.2×10^{-6}
96–720	—	1.7×10^{-4}	2.88×10^{-2}	—	4.9×10^{-6}
Total	3.6	1.5	—	6.4×10^{-1}	3.8×10^{-2}
Limit	—	—	—	25	25

Note: Time-dependent LPZ doses and total LPZ and EAB doses correspond to the radiation doses in DCD Rev. 2 (MHI Oct 2009)

Table 7.1-37
Activity Releases for APWR Steam Generator Tube Rupture with Accident-Initiated Iodine Spike

Isotope	Activity Release (Ci)				
	0–8 hr	8–24 hr	24–96 hr	96–720 hr	Total
Kr-85	3.43×10^{3}	4.64×10^{1}	2.06×10^{2}	1.59×10^{3}	5.27×10^{3}
Kr-85m	6.17×10^{1}	9.70×10^{-2}	8.00×10^{-3}	0	6.18×10^{1}
Kr-87	3.40×10^{1}	0	0	0	3.40×10^{1}
Kr-88	1.11×10^{2}	6.00×10^{-2}	1.00×10^{-2}	0	1.11×10^{2}
Xe-133	1.16×10^{4}	1.45×10^{2}	5.06×10^{2}	9.44×10^{2}	1.32×10^{4}
Xe-135	3.70×10^{2}	3.82	6.70×10^{-1}	0	3.74×10^{2}
I-131	1.10×10^{2}	1.03×10^{1}	0	0	1.20×10^{2}
I-132	5.24×10^{1}	2.12×10^{-1}	0	0	5.26×10^{1}
I-133	1.87×10^{2}	1.27×10^{1}	0	0	2.00×10^{2}
I-134	3.05×10^{1}	1.06×10^{-3}	0	0	3.05×10^{1}
I-135	1.19×10^{2}	3.74	0	0	1.23×10^{2}
Rb-86	4.54×10^{-3}	5.44×10^{-4}	0	0	5.09×10^{-3}
Cs-134	4.63×10^{-1}	5.63×10^{-2}	0	0	5.19×10^{-1}
Cs-136	1.22×10^{-1}	1.45×10^{-2}	0	0	1.37×10^{-1}
Cs-137	2.64×10^{-1}	3.21×10^{-2}	0	0	2.96×10^{-1}
Total	1.61×10^{4}	2.22×10^{2}	7.12×10^{2}	2.53×10^{3}	1.96×10^{4}

Reference: APWR DCD Rev. 2 (MHI Oct 2009)

Table 7.1-38
Doses for APWR Steam Generator Tube Rupture with Accident-Initiated Iodine Spike

Time (hr)	DCD Dose (rem TEDE)		X/Q Ratio	Site Dose (rem TEDE)	
	EAB	LPZ	Site to DCD	EAB	LPZ
0–2	9.6×10^{-1}	—	1.77×10^{-1}	1.7×10^{-1}	—
0–8	—	4.1×10^{-1}	2.52×10^{-2}	—	1.0×10^{-2}
8–24	—	1.0×10^{-2}	3.02×10^{-2}	—	3.0×10^{-4}
24–96	—	2.1×10^{-4}	2.97×10^{-2}	—	6.2×10^{-6}
96–720	—	1.7×10^{-4}	2.88×10^{-2}	—	4.9×10^{-6}
Total	9.6×10^{-1}	4.2×10^{-1}	—	1.7×10^{-1}	1.1×10^{-2}
Limit	—	—	—	2.5	2.5

Note: Time-dependent LPZ doses and total LPZ and EAB doses correspond to the radiation doses in DCD Rev. 2 (MHI Oct 2009)

Table 7.1-39 (Sheet 1 of 2)
Activity Releases for APWR Loss-of-Coolant Accident

Isotope	Activity Release (Ci)				
	0–8 hr	8–24 hr	24–96 hr	96–720 hr	Total
Kr-85	7.75×10^{2}	1.74×10^{3}	3.92×10^{3}	3.35×10^{4}	3.99×10^{4}
Kr-85m	9.16×10^{3}	4.37×10^{3}	1.99×10^{2}	0	1.37×10^{4}
Kr-87	3.54×10^{3}	7.83×10^{1}	0	0	3.62×10^{3}
Kr-88	1.68×10^{4}	3.68×10^{3}	3.70×10^{1}	0	2.05×10^{4}
Xe-133	1.26×10^{5}	2.76×10^{5}	4.93×10^{5}	9.77×10^{5}	1.87×10^{6}
Xe-135	3.79×10^{4}	4.05×10^{4}	9.60×10^{3}	4.41×10^{1}	8.80×10^{4}
I-131	1.42×10^{3}	5.61×10^{2}	1.85×10^{3}	5.60×10^{3}	9.43×10^{3}
I-132	1.50×10^{3}	1.01×10^{2}	2.22×10^{2}	2.48×10^{2}	2.07×10^{3}
I-133	2.67×10^{3}	7.37×10^{2}	8.09×10^{2}	8.07×10^{1}	4.30×10^{3}
I-134	4.22×10^{2}	1.84×10^{-1}	0	0	4.22×10^{2}
I-135	1.95×10^{3}	2.44×10^{2}	4.67×10^{1}	1.20×10^{-1}	2.24×10^{3}
Rb-86	1.44	1.60×10^{-2}	0	0	1.45
Cs-134	1.44×10^{2}	1.62	0	0	1.46×10^{2}
Cs-136	3.90×10^{1}	4.31×10^{-1}	0	0	3.94×10^{1}
Cs-137	8.19×10^{1}	9.21×10^{-1}	1.00×10^{-3}	0	8.28×10^{1}
Sb-127	1.04×10^{1}	1.26×10^{-1}	1.00×10^{-5}	0	1.05×10^{1}
Sb-129	1.99×10^{1}	6.87×10^{-2}	0	0	2.00×10^{1}
Te-127	1.04×10^{1}	1.30×10^{-1}	0	0	1.05×10^{1}
Te-127m	1.39	1.80×10^{-2}	0	0	1.40
Te-129	2.30×10^{1}	1.12×10^{-1}	0	0	2.31×10^{1}
Te-129m	4.75	6.13×10^{-2}	0	0	4.81
Te-131m	1.36×10^{1}	1.44×10^{-1}	0	0	1.37×10^{1}
Te-132	1.41×10^{2}	1.71	1.00×10^{-4}	0	1.43×10^{2}
Sr-89	4.74×10^{1}	6.12×10^{-1}	0	0	4.80×10^{1}
Sr-90	3.93	5.10×10^{-2}	0	0	3.98
Sr-91	5.01×10^{1}	3.54×10^{-1}	1.00×10^{-3}	0	5.05×10^{1}
Sr-92	3.11×10^{1}	4.95×10^{-2}	0	0	3.11×10^{1}
Ba-139	1.96×10^{1}	5.04×10^{-3}	0	0	1.96×10^{1}
Ba-140	7.49×10^{1}	9.53×10^{-1}	0	0	7.59×10^{1}
Co-58	3.36×10^{-3}	4.50×10^{-8}	0	0	3.36×10^{-3}
Co-60	1.59×10^{-2}	2.00×10^{-4}	1.01×10^{-6}	0	1.61×10^{-2}
Mo-99	9.57	1.11×10^{-1}	1.00×10^{-4}	0	9.68
Tc-99m	8.50	1.04×10^{-1}	1.00×10^{-4}	0	8.60

Table 7.1-39 (Sheet 2 of 2)
Activity Releases for APWR Loss-of-Coolant Accident

Isotope	Activity Release (Ci)				
	0–8 hr	8–24 hr	24–96 hr	96–720 hr	Total
Ru-103	7.62	9.83×10^{-2}	1.01×10^{-4}	0	7.72
Ru-105	3.14	1.12×10^{-2}	0	0	3.15
Ru-106	2.67	3.46×10^{-2}	0	0	2.70
Rh-105	4.61	5.41×10^{-2}	0	0	4.67
Y-90	7.44×10^{-2}	5.12×10^{-3}	6.06×10^{-6}	0	7.96×10^{-2}
Y-91	6.00×10^{-1}	8.54×10^{-3}	0	0	6.09×10^{-1}
Y-92	4.13	1.04×10^{-1}	0	0	4.24
Y-93	5.90×10^{-1}	4.32×10^{-3}	0	0	5.94×10^{-1}
Zr-95	7.55×10^{-1}	9.76×10^{-3}	0	0	7.65×10^{-1}
Zr-97	6.65×10^{-1}	6.12×10^{-3}	0	0	6.71×10^{-1}
Nb-95	7.60×10^{-1}	9.85×10^{-3}	1.01×10^{-5}	0	7.69×10^{-1}
La-140	1.76	1.43×10^{-1}	2.02×10^{-4}	0	1.90
La-141	4.25×10^{-1}	1.29×10^{-3}	0	0	4.27×10^{-1}
La-142	2.01×10^{-1}	7.07×10^{-5}	0	0	2.01×10^{-1}
Pr-143	6.74×10^{-1}	8.91×10^{-3}	1.00×10^{-5}	0	6.83×10^{-1}
Nd-147	2.80×10^{-1}	3.55×10^{-3}	0	0	2.83×10^{-1}
Am-241	7.51×10^{-5}	9.77×10^{-7}	0	0	7.60×10^{-5}
Cm-242	1.86×10^{-2}	2.41×10^{-4}	0	0	1.88×10^{-2}
Cm-244	2.26×10^{-3}	2.93×10^{-5}	0	0	2.29×10^{-3}
Ce-141	1.78	2.29×10^{-2}	0	0	1.80
Ce-143	1.63	1.78×10^{-2}	0	0	1.65
Ce-144	1.35	1.75×10^{-2}	0	0	1.36
Np-239	1.85×10^{1}	2.16×10^{-1}	1.00×10^{-5}	0	1.87×10^{1}
Pu-238	5.30×10^{-3}	6.88×10^{-5}	0	0	5.37×10^{-3}
Pu-239	4.00×10^{-4}	5.19×10^{-6}	0	0	4.05×10^{-4}
Pu-240	6.28×10^{-4}	8.14×10^{-6}	1.01×10^{-8}	0	6.36×10^{-4}
Pu-241	1.39×10^{-1}	1.81×10^{-3}	0	0	1.41×10^{-1}
Total	2.03×10^{5}	3.28×10^{5}	5.09×10^{5}	1.02×10^{6}	2.06×10^{6}

Reference: APWR DCD Rev. 2 (MHI Oct 2009)

Table 7.1-40
Doses for APWR Loss-of-Coolant Accident

Time (hr)	DCD Dose (rem TEDE)		X/Q Ratio	Site Dose (rem TEDE)	
	EAB	LPZ	Site to DCD	EAB	LPZ
0.5–2.5[a]	1.3×10^{1}	—	1.77×10^{-1}	2.3	—
0–8	—	9.0	2.52×10^{-2}	—	2.3×10^{-1}
8–24	—	1.2	3.02×10^{-2}	—	3.6×10^{-2}
24–96	—	1.3	2.97×10^{-2}	—	3.9×10^{-2}
96–720	—	1.4	2.88×10^{-2}	—	4.0×10^{-2}
Total	1.3×10^{1}	1.3×10^{1}	—	2.3	3.4×10^{-1}
Limit	—	—	—	25	25

(a) Worst case 2-hour period is 0.5–2.5 hours

Note: Time-dependent LPZ doses and total LPZ and EAB doses correspond to the radiation doses in DCD Rev. 2 (MHI Oct 2009)

Table 7.1-41
Activity Releases for APWR Fuel Handling Accident

Isotope	Activity Release (Ci), 0–8 hr
Kr-85	1.20×10^{3}
Kr-85m	3.90×10^{2}
Kr-87	5.98×10^{-2}
Kr-88	1.25×10^{2}
Xe-133	9.90×10^{4}
Xe-135	2.21×10^{4}
I-131	3.67×10^{2}
I-132	2.75×10^{2}
I-133	2.31×10^{2}
I-134	2.71×10^{-6}
I-135	3.80×10^{1}
Total	1.24×10^{5}

Reference: APWR DCD Rev. 2 (MHI Oct 2009)

Table 7.1-42
Doses for APWR Fuel Handling Accident

Time (hr)	DCD Dose (rem TEDE)		X/Q Ratio	Site Dose (rem TEDE)	
	EAB	LPZ	Site to DCD	EAB	LPZ
0–2	3.3	—	1.77×10^{-1}	5.8×10^{-1}	—
0–8	—	1.4	2.52×10^{-2}	—	3.5×10^{-2}
Total	3.3	1.4	—	5.8×10^{-1}	3.5×10^{-2}
Limit	—	—	—	6.3	6.3

Note: Time-dependent LPZ doses and total LPZ and EAB doses correspond to the radiation doses in DCD Rev. 2 (MHI Oct 2009)

Table 7.1-43
Activity Releases for ABWR Main Steam Line Break

Isotope	Activity Release (MBq)	
	Equilibrium Activity	Pre-Incident Spike
I-131	7.29×10^{4}	1.46×10^{6}
I-132	7.10×10^{5}	1.42×10^{7}
I-133	5.00×10^{5}	9.99×10^{6}
I-134	1.40×10^{6}	2.79×10^{7}
I-135	7.29×10^{5}	1.46×10^{7}
Kr-83m	4.07×10^{2}	2.44×10^{3}
Kr-85m	7.18×10^{2}	4.29×10^{3}
Kr-85	2.26	1.36×10^{1}
Kr-87	2.44×10^{3}	1.47×10^{4}
Kr-88	2.46×10^{3}	1.48×10^{4}
Kr-89	9.88×10^{3}	5.92×10^{4}
Kr-90	2.55×10^{3}	1.55×10^{4}
Xe-131m	1.76	1.06×10^{1}
Xe-133m	3.39×10^{1}	2.04×10^{2}
Xe-133	9.47×10^{2}	5.70×10^{3}
Xe-135m	2.89×10^{3}	1.74×10^{4}
Xe-135	2.70×10^{3}	1.62×10^{4}
Xe-137	1.23×10^{4}	7.40×10^{4}
Xe-138	9.44×10^{3}	5.66×10^{4}
Xe-139	4.33×10^{3}	2.59×10^{4}

Reference: ABWR DCD Rev. 4 (GENE Mar 1997)

Table 7.1-44
Doses for ABWR Main Steam Line Break with Pre-Incident Iodine Spike

Location	Time (hr)	DCD Dose (Sv)		X/Q Ratio	Site Dose (rem)	
		W. Body	Thyroid	Site to DCD	W. Body	Thyroid
EAB	0–2	1.3×10^{-2}	5.1×10^{-1}	6.46×10^{-2}	8.4×10^{-2}	3.3
LPZ	0–8	—	—	3.87×10^{-3}	5.0×10^{-3}	2.0×10^{-1}
Limit	—	—	—	—	25	300

Reference: ABWR DCD Rev. 4 (GENE Mar 1997)

Table 7.1-45
Doses for ABWR Main Steam Line Break with Equilibrium Iodine Activity

Location	Time (hr)	DCD Dose (Sv)		X/Q Ratio	Site Dose (rem)	
		W. Body	Thyroid	Site to DCD	W. Body	Thyroid
EAB	0–2	6.2×10^{-4}	2.6×10^{-2}	6.46×10^{-2}	4.0×10^{-3}	1.7×10^{-1}
LPZ	0–8	—	—	3.87×10^{-3}	2.4×10^{-4}	1.0×10^{-2}
Limit	—	—	—	—	2.5	30

Reference: ABWR DCD Rev. 4 (GENE Mar 1997)

Table 7.1-46
Activity Releases for ABWR Small Break Outside Containment

Isotope	Activity Release (MBq)					
	1 min	10 min	1 hr	2 hr	4 hr	8 hr
I-131	6.36×10^{-1}	5.77×10^{1}	2.77×10^{4}	6.81×10^{4}	1.27×10^{5}	1.41×10^{5}
I-132	6.18	5.51×10^{2}	2.52×10^{5}	5.96×10^{5}	1.09×10^{6}	1.19×10^{6}
I-133	4.37	3.96×10^{2}	1.87×10^{5}	4.59×10^{5}	8.51×10^{5}	9.44×10^{5}
I-134	1.21×10^{1}	1.06×10^{3}	4.44×10^{5}	9.92×10^{5}	1.76×10^{6}	1.90×10^{6}
I-135	6.36	5.74×10^{2}	2.71×10^{5}	6.59×10^{5}	1.21×10^{6}	1.34×10^{6}

Reference: ABWR DCD Rev. 4 (GENE Mar 1997)

Table 7.1-47
Doses for ABWR Small Break Outside Containment

Location	Time (hr)	DCD Dose (Sv)		X/Q Ratio	Site Dose (rem)	
		W. Body	Thyroid	Site to DCD	W. Body	Thyroid
EAB	0–2	9.4×10^{-4}	4.8×10^{-2}	6.46×10^{-2}	6.1×10^{-3}	3.1×10^{-1}
LPZ	0–8	—	—	3.87×10^{-3}	3.6×10^{-4}	1.9×10^{-2}
Limit	—	—	—	—	2.5	30

Reference: ABWR DCD Rev. 4 (GENE Mar 1997)

Table 7.1-48 (Sheet 1 of 2)
Activity Releases for ABWR Loss-of-Coolant Accident

Isotope	Activity Release from Reactor Building (MBq)									
	1 min	10 min	1 hr	2 hr	4 hr	8 hr	12 hr	24 hr	96 hr	720 hr
I-131	2.9×10^4	2.6×10^6	9.6×10^6	9.6×10^6	1.0×10^7	1.3×10^7	1.7×10^7	3.6×10^7	1.9×10^8	6.7×10^8
I-132	4.1×10^4	3.7×10^6	1.3×10^7	1.3×10^7	1.4×10^7	1.4×10^7	1.5×10^7	1.5×10^7	1.5×10^7	1.5×10^7
I-133	5.9×10^4	5.6×10^6	2.0×10^7	2.0×10^7	2.1×10^7	2.6×10^7	3.3×10^7	5.6×10^7	1.2×10^8	1.3×10^8
I-134	6.7×10^4	5.6×10^6	1.9×10^7	1.9×10^7	1.9×10^7	1.9×10^7	1.9×10^7	1.9×10^7	1.9×10^7	1.9×10^7
I-135	5.6×10^4	5.2×10^6	1.9×10^7	1.9×10^7	2.0×10^7	2.3×10^7	2.6×10^7	3.1×10^7	3.5×10^7	3.5×10^7
Kr-83m	2.7×10^4	2.3×10^6	9.3×10^6	1.2×10^7	1.9×10^7	2.8×10^7	3.2×10^7	3.3×10^7	3.3×10^7	3.3×10^7
Kr-85	2.6×10^3	2.3×10^5	1.0×10^6	1.5×10^6	3.6×10^6	1.2×10^7	2.4×10^7	8.1×10^7	6.7×10^8	5.6×10^9
Kr-85m	5.6×10^4	5.2×10^6	2.1×10^7	3.1×10^7	5.9×10^7	1.3×10^8	1.9×10^8	2.7×10^8	2.9×10^8	2.9×10^8
Kr-87	1.1×10^5	9.3×10^6	3.6×10^7	4.4×10^7	6.3×10^7	7.8×10^7	8.1×10^7	8.1×10^7	8.1×10^7	8.1×10^7
Kr-88	1.6×10^5	1.4×10^7	5.6×10^7	7.8×10^7	1.4×10^8	2.5×10^8	3.1×10^8	3.6×10^8	3.7×10^8	3.7×10^8
Kr-89	1.7×10^5	4.8×10^6	6.7×10^6	6.7×10^6	6.7×10^6	6.7×10^6	6.7×10^6	6.7×10^6	6.7×10^6	6.7×10^6
Xe-131m	1.3×10^3	1.2×10^5	5.2×10^5	7.8×10^5	1.9×10^6	5.9×10^6	1.3×10^7	4.1×10^7	3.0×10^8	1.4×10^9
Xe-133	4.8×10^5	4.1×10^7	1.8×10^8	2.8×10^8	6.7×10^8	2.1×10^9	4.4×10^9	1.4×10^{10}	8.9×10^{10}	2.5×10^{11}
Xe-133m	2.0×10^4	1.8×10^6	7.4×10^6	1.1×10^7	2.7×10^7	8.5×10^7	1.7×10^8	5.2×10^8	2.6×10^9	4.1×10^9
Xe-135	5.9×10^4	5.6×10^6	2.3×10^7	3.4×10^7	7.4×10^7	1.9×10^8	3.3×10^8	6.7×10^8	1.0×10^9	1.0×10^9
Xe-135m	8.5×10^4	5.9×10^6	1.7×10^7	1.8×10^7	1.8×10^7	1.8×10^7	1.8×10^7	1.8×10^7	1.8×10^7	1.8×10^7
Xe-137	3.7×10^5	1.3×10^7	1.9×10^7	1.9×10^7	1.9×10^7	1.9×10^7	1.9×10^7	1.9×10^7	1.9×10^7	1.9×10^7
Xe-138	3.7×10^5	2.6×10^7	7.4×10^7	7.4×10^7	7.4×10^7	7.4×10^7	7.4×10^7	7.4×10^7	7.4×10^7	7.4×10^7

Table 7.1-48 (Sheet 2 of 2)
Activity Releases for ABWR Loss-of-Coolant Accident

Isotope	Activity Release from Condenser (MBq)									
	1 min	10 min	1 hr	2 hr	4 hr	8 hr	12 hr	24 hr	96 hr	720 hr
I-131	0	0	7.0×10^{2}	1.2×10^{4}	1.2×10^{5}	8.5×10^{5}	2.4×10^{6}	1.2×10^{7}	1.8×10^{8}	2.0×10^{9}
I-132	0	0	8.1×10^{2}	1.1×10^{4}	7.0×10^{4}	2.4×10^{5}	3.5×10^{5}	4.4×10^{5}	4.4×10^{5}	4.4×10^{5}
I-133	0	0	1.5×10^{3}	2.4×10^{4}	2.3×10^{5}	1.5×10^{6}	3.7×10^{6}	1.5 x 107	7.4×10^{7}	8.9×10^{7}
I-134	0	0	8.5×10^{2}	8.5×10^{3}	3.0×10^{4}	4.8×10^{4}	4.8×10^{4}	4.8×10^{4}	4.8×10^{4}	4.8×10^{4}
I-135	0	0	1.3×10^{3}	2.1×10^{4}	1.7×10^{5}	9.3×10^{5}	2.0×10^{6}	5.2×10^{6}	7.4×10^{6}	7.4×10^{6}
Kr-83m	0	0	5.9×10^{3}	7.8×10^{4}	4.4×10^{5}	1.3×10^{6}	1.7×10^{6}	1.9×10^{6}	1.9×10^{6}	1.9×10^{6}
Kr-85	0	0	7.4×10^{2}	1.3×10^{4}	1.3×10^{5}	9.3×10^{5}	2.6×10^{6}	1.3×10^{7}	2.3×10^{8}	5.9×10^{9}
Kr-85m	0	0	1.5×10^{4}	2.3×10^{5}	1.8×10^{6}	8.5×10^{6}	1.6×10^{7}	3.0×10^{7}	3.6×10^{7}	3.6×10^{7}
Kr-87	0	0	2.0×10^{4}	2.4×10^{5}	1.1×10^{6}	2.4×10^{6}	2.7×10^{6}	2.8×10^{6}	2.8×10^{6}	2.8×10^{6}
Kr-88	0	0	3.7×10^{4}	5.6×10^{5}	3.7×10^{6}	1.4×10^{7}	2.3×10^{7}	3.1×10^{7}	3.2×10^{7}	3.2×10^{7}
Kr-89	0	0	4.1	4.1	4.1	4.1	4.1	4.1	4.1	4.1
Xe-131m	0	0	4.1×10^{2}	6.7×10^{3}	6.7×10^{4}	4.8×10^{5}	1.3×10^{6}	6.7×10^{6}	1.0×10^{8}	1.3×10^{9}
Xe-133	0	0	1.4×10^{5}	2.4×10^{6}	2.3×10^{7}	1.6×10^{8}	4.4×10^{8}	2.2×10^{9}	3.0×10^{10}	1.8×10^{11}
Xe-133m	0	0	5.6×10^{3}	1.0×10^{5}	9.3×10^{5}	6.7×10^{6}	1.8×10^{7}	8.1×10^{7}	8.1×10^{8}	2.0×10^{9}
Xe-135	0	0	1.7×10^{4}	2.7×10^{5}	2.4×10^{6}	1.4×10^{7}	3.3×10^{7}	9.6×10^{7}	2.0×10^{8}	2.0 x 108
Xe-135m	0	0	2.9×10^{3}	1.0×10^{4}	1.3×10^{4}	1.3×10^{4}	1.3×10^{4}	1.3×10^{4}	1.3×10^{4}	1.3×10^{4}
Xe-137	0	0	3.4×10^{1}	3.5×10^{1}	3.5×10^{1}	3.5×10^{1}	3.5×10^{1}	3.5×10^{1}	3.5×10^{1}	3.5×10^{1}
Xe-138	0	0	1.0×10^{4}	3.2×10^{4}	3.7×10^{4}	3.7×10^{4}	3.7×10^{4}	3.7×10^{4}	3.7×10^{4}	3.7×10^{4}

Reference: ABWR DCD Rev. 4 (GENE Mar 1997)

Table 7.1-49
Doses for ABWR Loss-of-Coolant Accident

Location	Time (hr)	DCD Dose (Sv)		X/Q Ratio	Site Dose (rem)	
		W. Body	Thyroid	Site to DCD	W. Body	Thyroid
EAB	0–2	4.1×10^{-2}	1.9	6.46×10^{-2}	2.6×10^{-1}	1.2×10^{1}
	0–8	1.0×10^{-2}	3.1×10^{-1}	3.40×10^{-2}	3.4×10^{-2}	1.1
	8–24	8.0×10^{-3}	2.0×10^{-1}	4.08×10^{-2}	3.3×10^{-2}	8.2×10^{-1}
	24–96	1.1×10^{-2}	7.9×10^{-1}	6.10×10^{-2}	6.7×10^{-2}	4.8
	96–720	9.0×10^{-3}	1.1	1.08×10^{-1}	9.8×10^{-2}	1.2×10^{1}
LPZ	Total	3.8×10^{-2}	2.4	—	2.3×10^{-1}	1.9×10^{1}
Limit	—	—	—	—	25	300

Reference: ABWR DCD Rev. 4 (GENE Mar 1997)

Table 7.1-50
Activity Releases for ABWR Cleanup Water Line Break

Isotope	Activity Release (MBq)
I-131	8.1×10^{4}
I-132	1.9×10^{5}
I-133	2.3×10^{5}
I-134	3.2×10^{5}
I-135	2.5×10^{5}

Reference: ABWR DCD Rev. 4 (GENE Mar 1997)

Table 7.1-51
Doses for ABWR Cleanup Water Line Break

Location	Time (hr)	DCD Dose (Sv)		X/Q Ratio	Site Dose (rem)	
		W. Body	Thyroid	Site to DCD	W. Body	Thyroid
EAB	0–2	2.8×10^{-3}	3.0×10^{-1}	3.86×10^{-3}	1.1×10^{-3}	1.2×10^{-1}
LPZ	0–8	—	—	2.31×10^{-4}	6.5×10^{-5}	6.9×10^{-3}
Limit	—	—	—	—	25	300

Reference: ABWR DCD Rev. 4 (GENE Mar 1997)

Table 7.1-52
Activity Releases for ABWR Fuel Handling Accident

Isotope	Activity Release (MBq)			
	1 min	10 min	1 hr	2 hr
I-131	2.85×10^{5}	2.56×10^{6}	4.55×10^{6}	4.55×10^{6}
I-132	3.67×10^{5}	3.22×10^{6}	5.62×10^{6}	5.62×10^{6}
I-133	2.95×10^{5}	2.64×10^{6}	4.70×10^{6}	4.70×10^{6}
I-134	1.60×10^{-2}	1.36×10^{-1}	2.28×10^{-1}	2.28×10^{-1}
I-135	4.85×10^{4}	4.29×10^{5}	7.62×10^{5}	7.62×10^{5}
TOTAL	9.96×10^{5}	8.85×10^{6}	1.56×10^{7}	1.56×10^{7}
Kr-83m	1.52×10^{4}	1.32×10^{5}	2.33×10^{5}	2.38×10^{5}
Kr-85m	1.94×10^{5}	1.72×10^{6}	3.08×10^{6}	3.16×10^{6}
Kr-85	1.05×10^{6}	9.47×10^{6}	1.72×10^{7}	1.77×10^{7}
Kr-87	3.00×10^{1}	2.59×10^{2}	4.51×10^{2}	4.55×10^{2}
Kr-88	5.62×10^{4}	4.92×10^{5}	8.81×10^{5}	8.99×10^{5}
Kr-89	6.55×10^{-7}	2.77×10^{-6}	3.01×10^{-6}	3.01×10^{-6}
Xe-131m	1.84×10^{5}	1.65×10^{6}	3.00×10^{6}	3.09×10^{6}
Xe-133m	2.44×10^{6}	2.18×10^{7}	3.96×10^{7}	4.07×10^{7}
Xe-133	6.22×10^{7}	5.59×10^{8}	1.01×10^{9}	1.04×10^{9}
Xe-135m	7.25×10^{5}	5.44×10^{6}	8.18×10^{6}	8.18×10^{6}
Xe-135	1.42×10^{7}	1.27×10^{8}	2.29×10^{8}	2.36×10^{8}
Xe-137	1.45×10^{-6}	6.77×10^{-6}	7.66×10^{-6}	7.66×10^{-6}
Xe-138	1.46×10^{-6}	1.07×10^{-5}	1.59×10^{-5}	1.59×10^{-5}

Reference: ABWR DCD Rev. 4 (GENE Mar 1997)

Table 7.1-53
Doses for ABWR Fuel Handling Accident

Location	Time (hr)	DCD Dose (Sv)		X/Q Ratio	Site Dose (rem)	
		W. Body	Thyroid	Site to DCD	W. Body	Thyroid
EAB	0–2	1.2×10^{-2}	7.5×10^{-1}	6.46×10^{-2}	7.8×10^{-2}	4.8
LPZ	0–8	—	—	3.87×10^{-3}	4.6×10^{-3}	2.9×10^{-1}
Limit	—	—	—	—	6	75

Reference: ABWR DCD Rev. 4 (GENE Mar 1997)

Table 7.1-54
Activity Releases for ESBWR Main Steam Line Break

Isotope	Activity Release (Ci)	
	Equilibrium Iodine	Pre-Incident Iodine
Co-58	8.95×10^{-3}	8.95×10^{-3}
Co-60	1.79×10^{-2}	1.79×10^{-2}
Kr-85	9.48×10^{-4}	9.48×10^{-4}
Kr-85m	2.42×10^{-1}	2.42×10^{-1}
Kr-87	7.84×10^{-1}	7.84×10^{-1}
Kr-88	7.84×10^{-1}	7.84×10^{-1}
Sr-89	4.11×10^{-2}	4.11×10^{-2}
Sr-90	2.85×10^{-3}	2.85×10^{-3}
Sr-91	1.59	1.59
Sr-92	3.60	3.60
Y-90	2.85×10^{-3}	2.85×10^{-3}
Y-91	1.68×10^{-2}	1.68×10^{-2}
Y-92	2.18	2.18
Y-93	1.59	1.59
Zr-95	3.27×10^{-3}	3.27×10^{-3}
Nb-95	3.27×10^{-3}	3.27×10^{-3}
Mo-99	8.13×10^{-1}	8.13×10^{-1}
Tc-99m	8.13×10^{-1}	8.13×10^{-1}
Ru-103	8.21×10^{-3}	8.21×10^{-3}
Ru-106	1.26×10^{-3}	1.26×10^{-3}
Te-129m	1.68×10^{-2}	1.68×10^{-2}
Te-131m	4.02×10^{-2}	4.02×10^{-2}
Te-132	4.11×10^{-3}	4.11×10^{-3}
I-131	1.55	3.10×10^{1}
I-132	1.08×10^{1}	2.15×10^{2}
I-133	1.01×10^{1}	2.02×10^{2}
I-134	1.68×10^{1}	3.36×10^{2}
I-135	1.35×10^{1}	2.69×10^{2}
Xe-133	3.29×10^{-1}	3.29×10^{-1}
Xe-135	9.10×10^{-1}	9.10×10^{-1}
Cs-134	1.09×10^{-2}	1.09×10^{-2}
Cs-136	7.37×10^{-3}	7.37×10^{-3}
Cs-137	2.93×10^{-2}	2.93×10^{-2}
Ba-140	1.68×10^{-1}	1.68×10^{-1}
La-140	1.68×10^{-1}	1.68×10^{-1}
Ce-141	1.26×10^{-2}	1.26×10^{-2}
Ce-144	1.26×10^{-3}	1.26×10^{-3}
Np-239	3.27	3.27

Reference: ESBWR DCD Rev. 6 (GEH Aug 2009)

Table 7.1-55
Doses for ESBWR Main Steam Line Break with Pre-Incident Iodine Spike

Location	Time (hr)	DCD Dose (rem TEDE)	X/Q Ratio (Site to DCD)	Site Dose (rem TEDE)
EAB	0–2	2.6	4.43×10^{-2}	1.2×10^{-1}
LPZ	0–8	2.0×10^{-1}	2.79×10^{-2}	5.6×10^{-3}
Limit	—	—	—	25

Reference: ESBWR DCD Rev. 6 (GEH Aug 2009)

Table 7.1-56
Doses for ESBWR Main Steam Line Break with Equilibrium Iodine Activity

Location	Time (hr)	DCD Dose (rem TEDE)	X/Q Ratio (Site to DCD)	Site Dose (rem TEDE)
EAB	0–2	2.0×10^{-1}	4.43×10^{-2}	8.9×10^{-3}
LPZ	0–8	1.0×10^{-1}	2.79×10^{-2}	2.8×10^{-3}
Limit	—	—	—	2.5

Reference: ESBWR DCD Rev. 6 (GEH Aug 2009)

Table 7.1-57
Activity Releases for ESBWR Feedwater Line Break

Isotope	Activity Release (Ci)	
	Equilibrium Iodine	Pre-Incident Spike
I-131	1.08×10^{1}	2.16×10^{2}
I-132	7.50×10^{1}	1.50×10^{3}
I-133	7.03×10^{1}	1.41×10^{3}
I-134	1.17×10^{2}	2.34×10^{3}
I-135	9.37×10^{1}	1.87×10^{3}
Cs-134	7.75×10^{-2}	7.75×10^{-2}
Cs-136	5.25×10^{-2}	5.25×10^{-2}
Cs-137	2.09×10^{-1}	2.09×10^{-1}
Co-58	6.37×10^{-2}	6.37×10^{-2}
Co-60	1.27×10^{-1}	1.27×10^{-1}
Sr-89	2.92×10^{-1}	2.92×10^{-1}
Sr-90	2.03×10^{-2}	2.03×10^{-2}
Y-90	2.03×10^{-2}	2.03×10^{-2}
Sr-91	1.13×10^{1}	1.13×10^{1}
Sr-92	2.56×10^{1}	2.56×10^{1}
Y-91	1.19×10^{-1}	1.19×10^{-1}
Y-92	1.55×10^{1}	1.55×10^{1}
Y-93	1.13×10^{1}	1.13×10^{1}
Zr-95	2.33×10^{-2}	2.33×10^{-2}
Nb-95	2.33×10^{-2}	2.33×10^{-2}
Mo-99	5.78	5.78
Tc-99m	5.78	5.78
Ru-103	5.84×10^{-2}	5.84×10^{-2}
Ru-106	8.94×10^{-3}	8.94×10^{-3}
Te-129m	1.19×10^{-1}	1.19×10^{-1}
Te-131m	2.86×10^{-1}	2.86×10^{-1}
Te-132	2.92×10^{-2}	2.92×10^{-2}
Ba-140	1.19	1.19
La-140	1.19	1.19
Ce141	8.94×10^{-2}	8.94×10^{-2}
Ce-144	8.94×10^{-3}	8.94×10^{-3}
Np-239	2.33×10^{1}	2.33×10^{1}

Reference: ESBWR DCD Rev. 6 (GEH Aug 2009)

Table 7.1-58
Doses for ESBWR Feedwater Line Break with Pre-Incident Iodine Spike

Location	Time (hr)	DCD Dose (rem TEDE)	X/Q Ratio (Site to DCD)	Site Dose (rem TEDE)
EAB	0–2	1.8×10^{1}	4.43×10^{-2}	8.0×10^{-1}
LPZ	0–8	1.7	2.79×10^{-2}	4.7×10^{-2}
Limit	—	—	—	25

Reference: ESBWR DCD Rev. 6 (GEH Aug 2009)

Table 7.1-59
Doses for ESBWR Feedwater Line Break with Equilibrium Iodine Activity

Location	Time (hr)	DCD Dose (rem TEDE)	X/Q Ratio (Site to DCD)	Site Dose (rem TEDE)
EAB	0–2	1.1	4.43×10^{-2}	4.9×10^{-2}
LPZ	0–8	1.0×10^{-1}	2.79×10^{-2}	2.8×10^{-3}
Limit	—	—	—	2.5

Reference: ESBWR DCD Rev. 6 (GEH Aug 2009)

Table 7.1-60
Activity Releases for ESBWR Small Break Outside Containment with Pre-Incident Iodine Spike

Isotope	Activity Release (Ci)				
	0.5 hr	1 hr	2 hr	4 hr	6 hr
Co-58	4.32×10^{-4}	6.91×10^{-4}	1.21×10^{-3}	1.90×10^{-3}	1.96×10^{-3}
Co-60	8.64×10^{-4}	1.38×10^{-3}	2.42×10^{-3}	3.81×10^{-3}	3.93×10^{-3}
Sr-89	1.98×10^{-3}	3.17×10^{-3}	5.55×10^{-3}	8.74×10^{-3}	9.02×10^{-3}
Sr-90	1.38×10^{-4}	2.20×10^{-4}	3.85×10^{-4}	6.06×10^{-4}	6.26×10^{-4}
Sr-91	7.69×10^{-2}	1.23×10^{-1}	2.15×10^{-1}	3.39×10^{-1}	3.50×10^{-1}
Sr-92	1.74×10^{-1}	2.78×10^{-1}	4.87×10^{-1}	7.67×10^{-1}	7.91×10^{-1}
Y-90	1.38×10^{-4}	2.20×10^{-4}	3.85×10^{-4}	6.06×10^{-4}	6.26×10^{-4}
Y-91	8.09×10^{-4}	1.29×10^{-3}	2.26×10^{-3}	3.57×10^{-3}	3.68×10^{-3}
Y-92	1.05×10^{-1}	1.68×10^{-1}	2.94×10^{-1}	4.64×10^{-1}	4.78×10^{-1}
Y-93	7.69×10^{-2}	1.23×10^{-1}	2.15×10^{-1}	3.39×10^{-1}	3.50×10^{-1}
Zr-95	1.58×10^{-4}	2.52×10^{-4}	4.42×10^{-4}	6.95×10^{-4}	7.18×10^{-4}
Nb-95	1.58×10^{-4}	2.52×10^{-4}	4.42×10^{-4}	6.95×10^{-4}	7.18×10^{-4}
Mo-99	3.93×10^{-2}	6.28×10^{-2}	1.10×10^{-1}	1.73×10^{-1}	1.78×10^{-1}
Tc-99m	3.93×10^{-2}	6.28×10^{-2}	1.10×10^{-1}	1.73×10^{-1}	1.78×10^{-1}
Ru-103	3.97×10^{-4}	6.34×10^{-4}	1.11×10^{-3}	1.75×10^{-3}	1.80×10^{-3}
Ru-106	6.07×10^{-5}	9.71×10^{-5}	1.70×10^{-4}	2.67×10^{-4}	2.76×10^{-4}
Te-129m	8.09×10^{-4}	1.29×10^{-3}	2.26×10^{-3}	3.57×10^{-3}	3.68×10^{-3}
Te-131m	1.94×10^{-3}	3.11×10^{-3}	5.44×10^{-3}	8.56×10^{-3}	8.83×10^{-3}
Te-132	1.98×10^{-4}	3.17×10^{-4}	5.55×10^{-4}	8.74×10^{-4}	9.02×10^{-4}
I-131	1.46	2.34	4.09	6.44	6.65
I-132	1.02×10^{1}	1.63×10^{1}	2.85×10^{1}	4.48×10^{1}	4.63×10^{1}
I-133	9.54	1.53×10^{1}	2.67×10^{1}	4.20×10^{1}	4.34×10^{1}
I-134	1.59×10^{1}	2.54×10^{1}	4.45×10^{1}	7.01×10^{1}	7.23×10^{1}
I-135	1.27×10^{1}	2.03×10^{1}	3.56×10^{1}	5.60×10^{1}	5.78×10^{1}
Cs-134	5.26×10^{-4}	8.41×10^{-4}	1.47×10^{-3}	2.32×10^{-3}	2.39×10^{-3}
Cs-136	3.56×10^{-4}	5.70×10^{-4}	9.96×10^{-4}	1.57×10^{-3}	1.62×10^{-3}
Cs-137	1.42×10^{-3}	2.27×10^{-3}	3.96×10^{-3}	6.24×10^{-3}	6.44×10^{-3}
Ba-140	8.09×10^{-3}	1.29×10^{-2}	2.26×10^{-2}	3.57×10^{-2}	3.68×10^{-2}
La-140	8.09×10^{-3}	1.29×10^{-2}	2.26×10^{-2}	3.57×10^{-2}	3.68×10^{-2}
Ce-141	6.07×10^{-4}	9.71×10^{-4}	1.70×10^{-3}	2.67×10^{-3}	2.76×10^{-3}
Ce-144	6.07×10^{-5}	9.71×10^{-5}	1.70×10^{-4}	2.67×10^{-4}	2.76×10^{-4}
Np-239	1.58×10^{-1}	2.52×10^{-1}	4.42×10^{-1}	6.95×10^{-1}	7.18×10^{-1}

Reference: ESBWR DCD Rev. 6 (GEH Aug 2009)

Table 7.1-61
Doses for ESBWR Small Break Outside Containment with Pre-Incident Iodine Spike

Location	Time (hr)	DCD Dose (rem TEDE)	X/Q Ratio (Site to DCD)	Site Dose (rem TEDE)
EAB	0–2	3.4×10^{-1}	4.43×10^{-2}	1.5×10^{-2}
LPZ	0–720	1.0×10^{-1}	2.80×10^{-2}	2.8×10^{-3}
Limit	—	—	—	25

Reference: ESBWR DCD Rev. 6 (GEH Aug 2009)

Note: Although the DCD indicates that the LPZ dose extends to 720 hr, it does not provide the dose as a function of time. The site LPZ dose is estimated by multiplying the total DCD dose by the maximum X/Q ratio from Table 7.1-4.

Table 7.1-62
Activity Releases for ESBWR Small Break Outside Containment with Equilibrium Iodine Activity

Isotope	Activity Release (Ci)				
	0.5 hr	1 hr	2 hr	4 hr	6 hr
Co-58	4.32×10^{-4}	6.91×10^{-4}	1.21×10^{-3}	1.90×10^{-3}	1.96×10^{-3}
Co-60	8.64×10^{-4}	1.38×10^{-3}	2.42×10^{-3}	3.81×10^{-3}	3.93×10^{-3}
Sr-89	1.98×10^{-3}	3.17×10^{-3}	5.55×10^{-3}	8.74×10^{-3}	9.02×10^{-3}
Sr-90	1.38×10^{-4}	2.20×10^{-4}	3.85×10^{-4}	6.06×10^{-4}	6.26×10^{-4}
Sr-91	7.69×10^{-2}	1.23×10^{-1}	2.15×10^{-1}	3.39×10^{-1}	3.50×10^{-1}
Sr-92	1.74×10^{-1}	2.78×10^{-1}	4.87×10^{-1}	7.67×10^{-1}	7.91×10^{-1}
Y-90	1.38×10^{-4}	2.20×10^{-4}	3.85×10^{-4}	6.06×10^{-4}	6.26×10^{-4}
Y-91	8.09×10^{-4}	1.29×10^{-3}	2.26×10^{-3}	3.57×10^{-3}	3.68×10^{-3}
Y-92	1.05×10^{-1}	1.68×10^{-1}	2.94×10^{-1}	4.64×10^{-1}	4.78×10^{-1}
Y-93	7.69×10^{-2}	1.23×10^{-1}	2.15×10^{-1}	3.39×10^{-1}	3.50×10^{-1}
Zr-95	1.58×10^{-4}	2.52×10^{-4}	4.42×10^{-4}	6.95×10^{-4}	7.18×10^{-4}
Nb-95	1.58×10^{-4}	2.52×10^{-4}	4.42×10^{-4}	6.95×10^{-4}	7.18×10^{-4}
Mo-99	3.93×10^{-2}	6.28×10^{-2}	1.10×10^{-1}	1.73×10^{-1}	1.78×10^{-1}
Tc-99m	3.93×10^{-2}	6.28×10^{-2}	1.10×10^{-1}	1.73×10^{-1}	1.78×10^{-1}
Ru-103	3.97×10^{-4}	6.34×10^{-4}	1.11×10^{-3}	1.75×10^{-3}	1.80×10^{-3}
Ru-106	6.07×10^{-5}	9.71×10^{-5}	1.70×10^{-4}	2.67×10^{-4}	2.76×10^{-4}
Te-129m	8.09×10^{-4}	1.29×10^{-3}	2.26×10^{-3}	3.57×10^{-3}	3.68×10^{-3}
Te-131m	1.94×10^{-3}	3.11×10^{-3}	5.44×10^{-3}	8.56×10^{-3}	8.83×10^{-3}
Te-132	1.98×10^{-4}	3.17×10^{-4}	5.55×10^{-4}	8.74×10^{-4}	9.02×10^{-4}
I-131	7.31×10^{-2}	1.17×10^{-1}	2.05×10^{-1}	3.22×10^{-1}	3.33×10^{-1}
I-132	5.09×10^{-1}	8.14×10^{-1}	1.42	2.24	2.31
I-133	4.77×10^{-1}	7.63×10^{-1}	1.33	2.10	2.17
I-134	7.95×10^{-1}	1.27	2.22	3.50	3.61
I-135	6.36×10^{-1}	1.02	1.78	2.80	2.89
Cs-134	5.26×10^{-4}	8.41×10^{-4}	1.47×10^{-3}	2.32×10^{-3}	2.39×10^{-3}
Cs-136	3.56×10^{-4}	5.70×10^{-4}	9.96×10^{-4}	1.57×10^{-3}	1.62×10^{-3}
Cs-137	1.42×10^{-3}	2.27×10^{-3}	3.96×10^{-3}	6.24×10^{-3}	6.44×10^{-3}
Ba-140	8.09×10^{-3}	1.29×10^{-2}	2.26×10^{-2}	3.57×10^{-2}	3.68×10^{-2}
La-140	8.09×10^{-3}	1.29×10^{-2}	2.26×10^{-2}	3.57×10^{-2}	3.68×10^{-2}
Ce-141	6.07×10^{-4}	9.71×10^{-4}	1.70×10^{-3}	2.67×10^{-3}	2.76×10^{-3}
Ce-144	6.07×10^{-5}	9.71×10^{-5}	1.70×10^{-4}	2.67×10^{-4}	2.76×10^{-4}
Np-239	1.58×10^{-1}	2.52×10^{-1}	4.42×10^{-1}	6.95×10^{-1}	7.18×10^{-1}

Reference: ESBWR DCD Rev. 6 (GEH Aug 2009)

Table 7.1-63
Doses for ESBWR Small Break Outside Containment with Equilibrium Iodine Activity

Location	Time (hr)	DCD Dose (rem TEDE)	X/Q Ratio (Site to DCD)	Site Dose (rem TEDE)
EAB	0–2	1.0×10^{-1}	4.43×10^{-2}	4.4×10^{-3}
LPZ	0–720	1.0×10^{-1}	2.80×10^{-2}	2.8×10^{-3}
Limit	—	—	—	2.5

Reference: ESBWR DCD Rev. 6 (GEH Aug 2009)

Note: Although the DCD indicates that the LPZ dose extends to 720 hr, it does not provide the dose as a function of time. The site LPZ dose is estimated by multiplying the total DCD dose by the maximum X/Q ratio from Table 7.1-4.

Table 7.1-64
Activity Releases for ESBWR Cleanup Water Line Break

Isotope	Activity Release (Ci) Equilibrium Iodine	Activity Release (Ci) Pre-Incident Spike
I-131	4.10	8.21×10^{1}
I-132	2.85×10^{1}	5.71×10^{2}
I-133	2.68×10^{1}	5.35×10^{2}
I-134	4.46×10^{1}	8.92×10^{2}
I-135	3.57×10^{1}	7.14×10^{2}
Cs-134	2.95×10^{-2}	2.95×10^{-2}
Cs-136	2.00×10^{-2}	2.00×10^{-2}
Cs-137	7.95×10^{-2}	7.95×10^{-2}
Co-58	2.42×10^{-2}	2.42×10^{-2}
Co-60	4.85×10^{-2}	4.85×10^{-2}
Sr-89	1.11×10^{-1}	1.11×10^{-1}
Sr-90	7.72×10^{-3}	7.72×10^{-3}
Y-90	7.72×10^{-3}	7.72×10^{-3}
Sr-91	4.31	4.31
Sr-92	9.76	9.76
Y-91	4.54×10^{-2}	4.54×10^{-2}
Y-92	5.90	5.90
Y-93	4.31	4.31
Zr-95	8.86×10^{-3}	8.86×10^{-3}
Nb-95	8.86×10^{-3}	8.86×10^{-3}
Mo-99	2.20	2.20
Tc-99m	2.20	2.20
Ru-103	2.23×10^{-2}	2.23×10^{-2}
Ru-106	3.41×10^{-3}	3.41×10^{-3}
Te-129m	4.54×10^{-2}	4.54×10^{-2}
Te-131m	1.09×10^{-1}	1.09×10^{-1}
Te-132	1.11×10^{-2}	1.11×10^{-2}
Ba-140	4.54×10^{-1}	4.54×10^{-1}
La-140	4.54×10^{-1}	4.54×10^{-1}
Ce141	3.41×10^{-2}	3.41×10^{-2}
Ce-144	3.41×10^{-3}	3.41×10^{-3}
Np-239	8.86	8.86

Reference: ESBWR DCD Rev. 6 (GEH Aug 2009)

Table 7.1-65
Doses for ESBWR Cleanup Water Line Break with Pre-Incident Iodine Spike

Location	Time (hr)	DCD Dose (rem TEDE)	X/Q Ratio (Site to DCD)	Site Dose (rem TEDE)
EAB	0–2	6.9	4.43×10^{-2}	3.1×10^{-1}
LPZ	0–8	7.0×10^{-1}	2.79×10^{-2}	2.0×10^{-2}
Limit	—	—	—	25

Reference: ESBWR DCD Rev. 6 (GEH Aug 2009)

Table 7.1-66
Doses for ESBWR Cleanup Water Line Break with Equilibrium Iodine Activity

Location	Time (hr)	DCD Dose (rem TEDE)	X/Q Ratio (Site to DCD)	Site Dose (rem TEDE)
EAB	0–2	4.0×10^{-1}	4.43×10^{-2}	1.8×10^{-2}
LPZ	0–8	1.0×10^{-1}	2.79×10^{-2}	2.8×10^{-3}
Limit	—	—	—	2.5

Reference: ESBWR DCD Rev. 6 (GEH Aug 2009)

Table 7.1-67 (Sheet 1 of 2)
Activity Releases for ESBWR Loss-of-Coolant Accident

Isotope	Activity Release (Ci)								
	0.5 hr	2 hr	8 hr	12 hr	24 hr	72 hr	96 hr	168 hr	720 hr
Co-58	0	8.0×10^{-3}	6.7×10^{-2}	1.0×10^{-1}	1.8×10^{-1}	3.0×10^{-1}	3.3×10^{-1}	4.0×10^{-1}	7.6×10^{-1}
Co-60	0	1.9×10^{-2}	1.6×10^{-1}	2.4×10^{-1}	4.2×10^{-1}	7.2×10^{-1}	7.9×10^{-1}	9.5×10^{-1}	2.0
Kr-85	1.7×10^{-1}	1.5×10^{1}	3.6×10^{2}	8.0×10^{2}	2.9×10^{3}	1.8×10^{4}	2.7×10^{4}	5.9×10^{4}	3.5×10^{5}
Kr-85m	3.2	2.3×10^{2}	3.1×10^{3}	5.0×10^{3}	7.5×10^{3}	8.2×10^{3}	8.2×10^{3}	8.2×10^{3}	8.2×10^{3}
Kr-87	5.2	2.4×10^{2}	1.1×10^{3}	1.2×10^{3}	1.2×10^{3}	1.2×10^{3}	1.2×10^{3}	1.2×10^{3}	1.2×10^{3}
Kr-88	8.3	5.4×10^{2}	5.5×10^{3}	7.5×10^{3}	9.1×10^{3}	9.2×10^{3}	9.2×10^{3}	9.2×10^{3}	9.2×10^{3}
Rb-86	1.3×10^{-2}	2.8×10^{-1}	2.1	3.1	5.3	8.9	9.7	1.1×10^{1}	1.8×10^{1}
Sr-89	0	8.9	7.4×10^{1}	1.1×10^{2}	2.0×10^{2}	3.4×10^{2}	3.7×10^{2}	4.4×10^{2}	8.2×10^{2}
Sr-90	0	1.0	8.4	1.3×10^{1}	2.2×10^{1}	3.8×10^{1}	4.2×10^{1}	5.1×10^{1}	1.1×10^{2}
Sr-91	0	1.0×10^{1}	6.8×10^{1}	9.1×10^{1}	1.2×10^{2}	1.3×10^{2}	1.3×10^{2}	1.3×10^{2}	1.3×10^{2}
Sr-92	0	8.3	3.6×10^{1}	4.0×10^{1}	4.1×10^{1}	4.2×10^{1}	4.2×10^{1}	4.2×10^{1}	4.2×10^{1}
Y-90	0	1.6×10^{-2}	3.8×10^{-1}	8.0×10^{-1}	2.5	8.4	1.1×10^{1}	1.7×10^{1}	7.0×10^{1}
Y-91	0	1.2×10^{-1}	1.0	1.5	2.8	5.1	5.6	6.8	1.3×10^{1}
Y-92	0	9.7×10^{-1}	1.9×10^{1}	2.8×10^{1}	3.6×10^{1}	3.7×10^{1}	3.7×10^{1}	3.7×10^{1}	3.7×10^{1}
Y-93	0	1.3×10^{-1}	8.7×10^{-1}	1.2	1.6	1.7	1.7	1.7	1.7
Zr-95	0	1.7×10^{-1}	1.4	2.1	3.7	6.4	7.0	8.4	1.6×10^{1}
Zr-97	0	1.6×10^{-1}	1.2	1.7	2.5	3.1	3.1	3.1	3.1
Nb-95	0	1.7×10^{-1}	1.4	2.1	3.8	6.5	7.1	8.6	1.7×10^{1}
Mo-99	0	2.2	1.8×10^{1}	2.6×10^{1}	4.4×10^{1}	6.7×10^{1}	7.1×10^{1}	7.6×10^{1}	8.0×10^{1}
Tc-99m	0	2.0	1.7×10^{1}	2.5×10^{1}	4.2×10^{1}	6.6×10^{1}	7.0×10^{1}	7.5×10^{1}	7.9×10^{1}
Ru-103	0	1.8	1.5×10^{1}	2.3×10^{1}	4.0×10^{1}	6.9×10^{1}	7.5×10^{1}	8.9×10^{1}	1.6×10^{2}
Ru-105	0	1.0	5.4	6.6	7.4	7.5	7.5	7.5	7.5
Ru-106	0	6.9×10^{-1}	5.8	8.7	1.5×10^{1}	2.6×10^{1}	2.9×10^{1}	3.5×10^{1}	7.1×10^{1}
Rh-105	0	1.1	9.4	1.4×10^{1}	2.3×10^{1}	3.2×10^{1}	3.3×10^{1}	3.4×10^{1}	3.4×10^{1}
Sb-127	0	2.5	2.0×10^{1}	3.0×10^{1}	5.2×10^{1}	8.2×10^{1}	8.7×10^{1}	9.5×10^{1}	1.0×10^{2}
Sb-129	0	6.0	3.2×10^{1}	3.9×10^{1}	4.3×10^{1}	4.4×10^{1}	4.4×10^{1}	4.4×10^{1}	4.4×10^{1}
Te-127	0	2.5	2.1×10^{1}	3.1×10^{1}	5.4×10^{1}	8.7×10^{1}	9.3×10^{1}	1.0×10^{2}	1.3×10^{2}
Te-127m	0	3.4×10^{-1}	2.8	4.3	7.6	1.3×10^{1}	1.4×10^{1}	1.7×10^{1}	3.5×10^{1}
Te-129	0	6.6	4.0×10^{1}	5.0×10^{1}	6.5×10^{1}	8.1×10^{1}	8.4×10^{1}	9.1×10^{1}	1.3×10^{2}
Te-129m	0	1.1	9.3	1.4×10^{1}	2.5×10^{1}	4.2×10^{1}	4.6×10^{1}	5.5×10^{1}	9.7×10^{1}
Te-131m	0	3.3	2.6×10^{1}	3.7×10^{1}	5.9×10^{1}	8.0×10^{1}	8.2×10^{1}	8.4×10^{1}	8.4×10^{1}
Te-132	0	3.3×10^{1}	2.7×10^{2}	4.0×10^{2}	6.7×10^{2}	1.0×10^{3}	1.1×10^{3}	1.2×10^{3}	1.3×10^{3}
I-131	5.8	1.5×10^{2}	1.1×10^{3}	1.6×10^{3}	2.8×10^{3}	5.1×10^{3}	5.7×10^{3}	7.1×10^{3}	1.1×10^{4}

Table 7.1-67 (Sheet 2 of 2)
Activity Releases for ESBWR Loss-of-Coolant Accident

Isotope	Activity Release (Ci)								
	0.5 hr	2 hr	8 hr	12 hr	24 hr	72 hr	96 hr	168 hr	720 hr
I-132	8.0	1.9×10^{2}	8.5×10^{2}	1.0×10^{3}	1.4×10^{3}	1.8×10^{3}	1.9×10^{3}	2.1×10^{3}	2.2×10^{3}
I-133	1.2×10^{1}	2.8×10^{2}	1.9×10^{3}	2.7×10^{3}	4.2×10^{3}	5.5×10^{3}	5.6×10^{3}	5.7×10^{3}	5.7×10^{3}
I-134	9.9	1.1×10^{2}	2.0×10^{2}	2.1×10^{2}	2.1×10^{2}	2.1×10^{2}	2.1×10^{2}	2.1×10^{2}	2.1×10^{2}
I-135	1.1×10^{1}	2.4×10^{2}	1.3×10^{3}	1.7×10^{3}	2.1×10^{3}	2.2×10^{3}	2.2×10^{3}	2.2×10^{3}	2.2×10^{3}
Xe-133	2.6×10^{1}	2.2×10^{3}	5.2×10^{4}	1.2×10^{5}	4.0×10^{5}	2.1×10^{6}	2.9×10^{6}	5.2×10^{6}	1.1×10^{7}
Xe-135	9.4	8.2×10^{2}	1.6×10^{4}	3.0×10^{4}	6.5×10^{4}	1.0×10^{5}	1.0×10^{5}	1.0×10^{5}	1.0×10^{5}
Cs-134	1.2	2.7×10^{1}	2.0×10^{2}	2.9×10^{2}	5.1×10^{2}	8.7×10^{2}	9.6×10^{2}	1.1×10^{3}	2.3×10^{3}
Cs-136	4.1×10^{-1}	8.7	6.3×10^{1}	9.4×10^{1}	1.6×10^{2}	2.7×10^{2}	2.9×10^{2}	3.4×10^{2}	5.0×10^{2}
Cs-137	7.9×10^{-1}	1.7×10^{1}	1.2×10^{2}	1.9×10^{2}	3.3×10^{2}	5.6×10^{2}	6.1×10^{2}	7.3×10^{2}	1.5×10^{3}
Ba-139	0	8.2	2.3×10^{1}	2.3×10^{1}	2.3×10^{1}	2.3×10^{1}	2.3×10^{1}	2.3×10^{1}	2.3×10^{1}
Ba-140	0	1.6×10^{1}	1.4×10^{2}	2.1×10^{2}	3.6×10^{2}	6.0×10^{2}	6.5×10^{2}	7.6×10^{2}	1.1×10^{3}
La-140	0	3.2×10^{-1}	8.8	1.9×10^{1}	5.9×10^{1}	1.9×10^{2}	2.3×10^{2}	3.3×10^{2}	7.4×10^{2}
La-141	0	1.2×10^{-1}	6.2×10^{-1}	7.4×10^{-1}	8.1×10^{-1}	8.2×10^{-1}	8.2×10^{-1}	8.2×10^{-1}	8.2×10^{-1}
La-142	0	7.8×10^{-2}	2.3×10^{-1}	2.4×10^{-1}	2.4×10^{-1}	2.4×10^{-1}	2.4×10^{-1}	2.4×10^{-1}	2.4×10^{-1}
Ce-141	0	3.9×10^{-1}	3.3	4.9	8.6	1.5×10^{1}	1.6×10^{1}	1.9×10^{1}	3.4×10^{1}
Ce-143	0	3.5×10^{-1}	2.8	4.0	6.4	8.9	9.1	9.3	9.4
Ce-144	0	3.2×10^{-1}	2.7	4.0	7.2	1.2×10^{1}	1.4×10^{1}	1.6×10^{1}	3.3×10^{1}
Pr-143	0	1.4×10^{-1}	1.2	1.8	3.2	5.6	6.1	7.3	1.1×10^{1}
Nd-147	0	6.3×10^{-2}	5.2×10^{-1}	7.8×10^{-1}	1.4	2.3	2.4	2.8	4.0
Np-239	0	4.6	3.7×10^{1}	5.4×10^{1}	9.1×10^{1}	1.4×10^{2}	1.4×10^{2}	1.5×10^{2}	1.6×10^{2}
Pu-238	0	9.6×10^{-4}	8.0×10^{-3}	1.2×10^{-2}	2.1×10^{-2}	3.7×10^{-2}	4.0×10^{-2}	4.9×10^{-2}	1.0×10^{-1}
Pu-239	0	1.1×10^{-4}	8.9×10^{-4}	1.3×10^{-3}	2.4×10^{-3}	4.1×10^{-3}	4.5×10^{-3}	5.4×10^{-3}	1.1×10^{-2}
Pu-240	0	1.4×10^{-4}	1.2×10^{-3}	1.7×10^{-3}	3.1×10^{-3}	5.3×10^{-3}	5.8×10^{-3}	7.0×10^{-3}	1.5×10^{-2}
Pu-241	0	4.4×10^{-2}	3.7×10^{-1}	5.6×10^{-1}	9.8×10^{-1}	1.7	1.9	2.2	4.6
Am-241	0	2.1×10^{-5}	1.8×10^{-4}	2.7×10^{-4}	4.7×10^{-4}	8.2×10^{-4}	9.1×10^{-4}	1.1×10^{-3}	2.4×10^{-3}
Cm-242	0	5.0×10^{-3}	4.2×10^{-2}	6.3×10^{-2}	1.1×10^{-1}	1.9×10^{-1}	2.1×10^{-1}	2.5×10^{-1}	5.1×10^{-1}
Cm-244	0	2.6×10^{-4}	2.2×10^{-3}	3.3×10^{-3}	5.8×10^{-3}	1.0×10^{-2}	1.1×10^{-2}	1.3×10^{-2}	2.8×10^{-2}

Reference: ESBWR DCD Rev. 6 (GEH Aug 2009)

Table 7.1-68
Doses for ESBWR Loss-of-Coolant Accident

Location	Time (hr)	DCD Dose (rem TEDE)	X/Q Ratio (Site to DCD)	Site Dose (rem TEDE)
EAB	2.3–4.3[(a)]	2.24×10^{1}	4.43×10^{-2}	9.91×10^{-1}
LPZ	0–8	6.93	2.79×10^{-2}	1.93×10^{-1}
	8–24	4.54	2.80×10^{-2}	1.27×10^{-1}
	24–96	4.72	2.73×10^{-2}	1.29×10^{-1}
	96–720	4.56	2.68×10^{-2}	1.22×10^{-1}
	Total	2.08×10^{1}	—	5.72×10^{-1}
Limit	—	—	—	25

(a) Worst case 2-hour period is 2.3–4.3 hours.

Note: Time-dependent LPZ doses and total LPZ and EAB doses correspond to the radiation doses in DCD Rev. 6 (GEH Aug 2009)

Table 7.1-69
Activity Releases for ESBWR Fuel Handling Accident

Isotope	Activity Release (Ci), 0–2 hr
I-131	1.37×10^{2}
I-132	7.01×10^{-2}
I-133	8.21×10^{1}
I-134	5.24×10^{-7}
I-135	1.28×10^{1}
Kr-85m	9.96×10^{1}
Kr-85	4.98×10^{2}
Kr-87	1.07×10^{-2}
Kr-88	2.85×10^{1}
Xe-133	3.23×10^{4}
Xe-135	2.01×10^{3}

Reference: ESBWR DCD Rev. 6 (GEH Aug 2009)

Table 7.1-70
Doses for ESBWR Fuel Handling Accident

Location	Time (hr)	DCD Dose (rem TEDE)	X/Q Ratio (Site to DCD)	Site Dose (rem TEDE)
EAB	0–2	4.1	4.43×10^{-2}	1.8×10^{-1}
LPZ	0–8	4.0×10^{-1}	2.79×10^{-2}	1.1×10^{-2}
Limit	—	—	—	6.3

Reference: ESBWR DCD Rev. 6 (GEH Aug 2009)

7.2 Severe Accidents

Severe accidents are those involving multiple failures of equipment to function. The likelihood of occurrence is lower for severe accidents than for design basis accidents, but the consequences of such accidents may be higher. Although severe accidents are not part of the design basis for the plant, NRC, in its policy statement on Severe Reactor Accidents Regarding Future Designs and Existing Plants (50 FR 32138), requires the completion of a probabilistic risk assessment (PRA) for severe accidents for new reactor designs. This requirement is codified under 10 CFR 52.47.

As described in Chapter 3, Exelon's ESP analyses are based on the following reactor types: ESBWR, ABWR, AP1000, APWR, and mPower. For the severe accident analysis, Exelon selected the ESBWR and ABWR to represent the entire suite of advanced light water reactor technologies. Exelon believes this representative approach is appropriate because:

- Unlike for safety analyses, a representative analysis is acceptable under the National Environmental Policy Act.
- In its 1985 policy statement on severe accidents (50 FR 32138), NRC stated its expectation that new reactors would achieve a higher standard of severe accident safety performance than the earlier designs. This has proven to be true as severe accident risks from new reactor design certification applications and ESP/COL applications are compared to license renewal applications. The greatest risk associated with a new generation reactor design (for which data is available) is well below that of the already low risk associated with the existing fleet undergoing license renewal.

General Electric-Hitachi (GEH) completed a PRA for the ESBWR design (GEH Jun 2009) as part of the application for design certification. GE prepared a PRA as part of the Standard Safety Analysis Report (SSAR) Amendment 35 for the ABWR design. NRC reviewed the ABWR SSAR, and the review was documented in NUREG-1503 (U.S. NRC Jul 1994). NRC has certified the ABWR design, concluding that the ABWR is of a robust design, and that the design meets NRC's safety goals.

In this section, Exelon presents an update of the two generic PRA analyses described above. Exelon's analysis includes VCS site-specific characteristics. The analysis evaluates the impacts of a severe accident at VCS to demonstrate that the impacts are bounded by the generic certification analyses.

7.2.1 ESBWR and ABWR Reactor Vendor Methodology

ESBWR

The GEH PRA for the ESBWR established a containment event tree that defined the possible end states of the containment following a severe accident. Using EPRI's Modular Accident Analysis Program code, GEH determined that 10 release categories would represent the entire suite of potential severe accidents. Five of the release categories were represented by dual source term categories. An accident frequency was assigned to each of the 10 source term categories (Table 7.2-2). For the dual source term release categories, GEH assigned the entire frequency of the release category to each of the source terms. (The site specific analysis described further on in this section made the conservative assumption that the entire frequency of each of the dual source term release categories was attributed to the source term resulting in the greater population dose.)

The 10 release categories and associated source term categories are as follows:

Break Outside of Containment (BOC) — Radioactivity is released through an unisolated break outside the containment in the shutdown cooling piping allowing direct communication between the reactor pressure vessel and the environment outside the containment. This is followed by no injection of cooling water into the reactor pressure vessel. Two separate locations of a break in the piping were selected for determining source term categories in this release category, one mid-level in the reactor pressure vessel (BOC mid) and the other at the lower level (BOC low).

Containment Bypass (BYP) — Radioactivity is released directly to the atmosphere from the containment due to a failure of the containment isolation system to function. Sequences in which the reactor pressure vessel is depressurized generally result in the core being uncovered earlier than those with a failure to depressurize. Both a low pressure sequence (BYP low) and a high pressure sequence (BYP high) were selected for determining the source term categories for this release category.

Core-Concrete Interaction Dry (CCID) — This release category applies to sequences in which the containment fails due to interaction between the core and the containment concrete. The deluge function is assumed to fail, and the lower drywell debris bed is uncovered. Sequences in which the containment vessel is not depressurized may result in earlier containment vessel failure. A low pressure sequence (CCID low) and a high pressure sequence (CCID high) were selected for determining the source term categories in this release category.

Core-Concrete Interaction Wet (CCIW) — This release category applies to sequences in which the containment fails due to interaction between the core and containment concrete. The deluge function works; however, the basemat internal melt arrest and coolability device is not effective in providing debris bed cooling. Unlike the CCID category, cooling water is present and provides the potential for scrubbing of the radionuclides that evolve from the debris bed, thus reducing the magnitude of the source term. Sequences in which the reactor vessel is not depressurized may result in earlier reactor vessel failure. A low pressure sequence (CCIW low) and a high pressure sequence (CCIW high) were selected for determining the source term categories associated with this release category.

Ex-Vessel Steam Explosion (EVE) — This release category applies to sequences in which the reactor vessel fails at low pressure and a significant steam explosion occurs. Containment depressurization is assumed to occur when the vessel fails, at which time there is direct communication with the environment. Due to the uncertainties associated with equipment damage and water availability, no credit is taken for lower drywell water to reduce the source term.

Filtered Release (FR) — Radioactivity is released by manually venting the containment from the suppression chamber air space. This action may be implemented to limit the containment pressure increase if containment heat removal fails or the containment is over pressurized. Venting the suppression chamber forces the radionuclides through the suppression pool, which reduces the magnitude of the source term.

Overpressure-Vacuum Breaker (OPVB) — This release category applies to sequences in which the vacuum breaker failure has occurred (either by failing to close or by remaining open in a preexisting condition), resulting in failure of the containment pressure function, which in turn causes failure in containment heat removal. Two sequences are associated with this release category; both high (OPVB high) and low pressure (OPVB low) sequences were selected for source term categories.

Overpressure-Early Containment Heat Removal Loss (OPW1) — This release category applies to sequences in which containment heat removal fails within 24 hours after event initiation. A sequence with the reactor pressure vessel failure at high pressure was selected because it has an earlier failure and higher probability of the loss of containment heat removal. Containment heat removal is assumed to be unavailable for the duration of the sequence.

Overpressure-Late Containment Heat Removal Loss (OPW2) — This release category applies to sequences in which containment heat removal fails in the period after that addressed by OPW1, above, until 72 hours after onset of core damage. The passive containment cooling system is assumed to be unavailable 24 hours after event initiation and the availability of the fuel and auxiliary pool cooling system is determined. A sequence with the reactor pressure vessel failure at high pressure was selected because it has an earlier failure and higher probability of the loss of containment heat removal. Containment heat removal is terminated 24 hours after the event initiation.

Technical Specification Leakage (TSL) — This category applies to sequences in which the containment is intact and the only release is due to the maximum leak rate allowed by technical specifications. For additional conservatism, the area of containment leakage corresponding to the maximum allowable technical specification leak rate was doubled to produce the representative source term used for this release category.

In addition, a direct containment heating (DCH) category was evaluated. The DCH category applies to sequences in which the reactor fails at high pressure and a significant DCH event occurs. GEH subsequently determined that catastrophic containment failure due to DCH is physically unreasonable and studied local damage to the liner in the lower drywell as a sensitivity case. Thus, no DCH sequence was evaluated for the baseline case.

GEH then used the MACCS2 (MELCOR Accident Consequence Code System) to model the environmental consequences of severe accidents using generic, but conservative, meteorological and population parameters to represent a generic ESBWR site. The analysis focused on the 24-hour period following core damage as a measure of the consequences from a large release and, therefore, did not address the chronic pathways such as ingestion, inhalation of re-suspended material, or groundshine subsequent to plume passage. GEH also considered the releases for the first 72 hours after core damage. Additional details of analysis are found in the ESBWR PRA (GEH Jun 2009) and are reported in the ESBWR Design Control Document (GEH Aug 2009).

ABWR

The GE PRA for the ABWR established a containment event tree that defined the possible end states of the containment following a severe accident. These end states can logically be grouped to produce 10 source term categories that represent the entire suite of potential severe accidents. An accident frequency was assigned to each of the 10 source term categories (Table 7.2-2).

The 10 source term categories can be characterized as follows (GE Jan 1995):

NCL — Normal Containment Leakage to Reactor Building

Case 1 — Core melt arrested in vessel or in containment with actuation of containment rupture disk.

Case 2 — Low pressure core melt with suppression pool bypass and actuation of containment rupture disk.

Case 3 — High pressure core melt with drywell head failure and fire water spray initiation.

Case 4 — Suppression pool decontamination reduction.

Case 5 — Large break LOCA (loss of cooling accident) without recovery and actuation of containment rupture disk.

Case 6 — High pressure core melt with drywell head failure and no fire water spray initiation.

Case 7 — Low pressure core melt with drywell head failure and no mitigation.

Case 8 — High pressure core melt with early containment failure.

Case 9 — ATWS (anticipated transient without scram) event with drywell head failure.

GE then used the CRAC-2 code to model the environmental consequences of the severe accidents using the generic meteorology, population, and evacuation characteristics as described in Section 19E.3 of the Design Control Document (DCD). CRAC-2 is a revision of the CRAC program developed in support of NRC's Reactor Safety Study (often referred to as WASH-1400) to assess the risk from potential accidents at nuclear power plants.

GE only included severe accidents that were initiated from internal events. External events, including tornado strikes and earthquakes, were evaluated and GE concluded that the accident frequency for these external initiated events was much less than the accident frequency for the internally initiated events.

Details of the analysis are reported in Chapter 19 of the ABWR DCD (GE Mar 1997).

7.2.2 Exelon Methodology

Exelon used the MACCS2 computer code (Version 1.13.1), which was developed for the NRC as a successor to CRAC-2, to evaluate offsite risks and consequences of severe accidents, using VCS site-specific information. MACCS2 simulates the impact of severe accidents at nuclear power plants on the surrounding environment. The principal phenomena considered in MACCS2 include atmospheric transport, mitigation actions based on dose projection, dose accumulation by a number of pathways including food and water ingestion, early and latent human health effects, and economic costs. The specific pathways modeled include external exposure to the passing plume, external exposure to material deposited on the ground, inhalation of material in the passing plume or re-suspended from the ground, and ingestion of contaminated food and surface water. The MACCS2 code primarily addresses dose from the air pathway, but also calculates dose from surface runoff and deposition on surface water to determine a drinking water risk from airborne releases. The code also evaluates the extent of contamination. Exelon used site-specific meteorology and population data to model both the early exposure pathways, such as inhalation of the passing plume and direct exposure to the passing plume, and the long-term exposure pathways, such as ingestion, over the life cycle of the accident. Ingestion exposure was determined using the COMIDA2 food model option of MACCS2.

To assess human health impacts, Exelon determined the collective dose to the 50-mile population, number of latent cancer fatalities, and number of early fatalities associated with a severe accident. Economic costs were also determined, including the costs associated with short-term relocation of people, decontamination of property and equipment, interdiction of food supplies, and indirect costs resulting from loss of use of the property and incomes derived as a result of the accident.

Five files provide input to a MACCS2 analysis: EARLY, ATMOS, CHRONC, MET, and SITE.

ATMOS provides data to calculate the amount of material released to the atmosphere that is dispersed and deposited. The calculation uses a Gaussian plume model. Important inputs in this file include the core inventory, release fractions, and geometry of the reactor and associated buildings. This input data is taken from the generic PRAs.

A second file, EARLY, provides inputs to calculations regarding exposure in the time period immediately following the release, including parameters describing breathing rates and sheltering. Important site-specific information includes emergency response information such as evacuation time; in this case, the conservative assumption of no evacuation was made.

The third input file, CHRONC, provides data for calculating long-term impacts and economic costs and includes region-specific data on agriculture and economic factors. These files access a meteorological file that uses actual VCS site meteorological monitoring data and a site characteristics file which is built using SECPOP2000 (U.S. NRC Aug 2003).

MACCS2 requires a calendar year of meteorological data for the MET file. One year of VCS site meteorological data (July 2008 to June 2009) was used to create the meteorological data file. Sensitivity studies considered VCS meteorological data from July 2007 through June 2008, along with five years of National Weather Service Victoria Regional Airport data (years 2003–2007 and July 2007 through June 2008). The sensitivity studies indicate that the site data is representative of recent conditions near the site.

The SITE file requires the 50-mile population distribution as well as agricultural-economic data. SECPOP2000 incorporates 2000 census data for the 50-mile region around the VCS site. For this analysis, the census data were modified to include transient populations and projected to the year 2060 (included in the population projections in Subsection 2.5.1), using county-specific growth rates. MACCS2 also requires the spatial distribution of certain agriculture and economic data (fraction of land devoted to farming, annual farm sales, fraction of farm sales resulting from dairy production, and property value of farm and nonfarmland) in the same manner as the population. This data was prepared using the 2007 National Census of Agriculture (USDA Sep 2009).

Exelon used the resulting MACCS2 calculations and accident frequency information to determine risk. The sum of the accident frequencies is known as the core damage frequency and includes only internally initiated events during reactor operation. Risk is the product of frequency of an accident times the consequences of the accident. The consequence can be any measure of release impacts such as radiation dose and economic cost. Dose-risk is the product of the collective dose times the accident frequency. Because the severe accident analysis addressed a suite of accidents, the individual risks were summed to provide a total risk. The same process was applied to estimating cost-risk. Risk from these consequences can be reported as person-rem per reactor year or dollars per reactor year.

Exelon used the source term parameters (e.g., core inventory, release height at top of containment, release heat, nuclide release fractions and durations) applied in the generic PRAs. Similar to the vendors' analyses, only internal events were analyzed. Exelon assumed perpetual rainfall in the last spatial segment (40-50 miles) of the model domain so that a conservatively large quantity of the nuclides released in each accident scenario were deposited (via wet deposition) within the model domain.

7.2.3 Consequences to Population Groups

The pathway consequences to population groups including air pathways, surface water, and groundwater pathways are described in the following sections. The presence of threatened and endangered species and federally designated critical habitat are described in Subsections 2.4.1 and 2.4.2. The impacts on biota due to the previously calculated radiation exposure levels are described in Subsection 5.4.4. Risk values in the text of this section below are for the reactor technology resulting in the highest value.

7.2.3.1 Air Pathways

Each of the accident categories was analyzed with MACCS2 to estimate population dose, number of early and latent fatalities, cost, and farmland requiring decontamination. The analysis conservatively assumed that none of the 10-mile emergency planning zone population was evacuated following declaration of a general emergency. For each accident category, the risk for each analytical endpoint was calculated by multiplying the analytical endpoint by the accident category frequency and adding across all accident categories. The results are provided in Tables 7.2-1 and 7.2-2.

7.2.3.2 Surface Water Pathways

People can be exposed to radiation when airborne radioactivity is deposited onto the ground and runs off into surface water or is deposited directly onto surface water. The exposure pathway can be from drinking the water, submersion in the water (swimming), undertaking activities near the shoreline (fishing and boating), or ingestion of fish or shellfish. For the surface water pathway, MACCS2 only calculates the dose from drinking the water. It is conservatively assumed that all water within 50 miles of the site is drinkable (even though most of it is saltwater). The maximum MACCS2 code severe accident dose-risk to the 50-mile population from drinking the water is 1.8×10^{-4} person-rem per year of ESBWR operation. As shown in Table 7.2-1, this value is the sum of all accident category risks.

Surface water bodies within the 50-mile region of the VCS site that are accessible to the public include the Guadalupe River, San Antonio River, Matagorda Bay, Hynes Bay, Guadalupe Bay, San Antonio Bay, Lake Texana, the Gulf of Mexico, and other smaller water bodies. In NUREG-1437, the NRC evaluated doses from the aquatic food pathway (fishing) for the current nuclear fleet of reactors (U.S. NRC May 1996). For sites discharging to small rivers, the NRC evaluation estimated the un-interdicted aquatic food pathway dose risk as 0.4 person-rem per reactor year. For sites near large water bodies, values ranged from 270 person-rem per reactor year (Hope Creek on Delaware Bay) to 5500 person-rem per reactor year (Calvert Cliffs on Chesapeake Bay). The VCS site would more likely fall between the small river analysis and the least impacting large water body analysis (Hope Creek), given the VCS site's distance from nearby major water bodies (approximately 20 miles to the Gulf of Mexico). Actual dose-risk values would be expected to be much less (by a factor of 2 to 10) due to interdiction of contaminated foods (U.S. NRC May 1996). Both the ESBWR and ABWR atmospheric pathway doses are significantly lower than those of the current nuclear fleet (Subsection 7.2.5). Given the dependency of surface water doses on airborne releases, it is reasonable to conclude that the doses from surface water sources would be consistently lower than those reported above for the surface water pathway.

Doses associated with submersion in the water and undertaking activities near the shoreline are not modeled by MACCS2, and NUREG-1437 does not provide specific data on submersion and shoreline activities. However, it does indicate that these contributors to dose are much less than for drinking water and consuming aquatic foods, especially at estuary sites.

7.2.3.3 Groundwater Pathways

People can also receive dose from groundwater pathways. Radioactivity released during a severe accident can enter groundwater and may move through an aquifer and eventually be discharged to surface water. The consequences of a radioactive spill are evaluated in Subsection 2.4.13 of the Site Safety Evaluation Report, and the results show that if radioactive liquids were released directly to groundwater, the isotopic concentrations would be below 10 CFR 20 effluent limits before they reached a drinking water receptor.

NUREG-1437 evaluated the groundwater pathway dose, based on the analysis in NUREG-0440, the Liquid Pathway Generic Study (U.S. NRC Feb 1978). NUREG-0440 analyzed a core meltdown that contaminated groundwater, which subsequently contaminated surface water; NUREG-0440 did not analyze direct consumption of groundwater because it assumed a limited number of potable groundwater wells and limited accessibility.

The Liquid Pathway Generic Study results provide conservative, un-interdicted population dose estimates for six generic categories of plants. These dose estimates were one or more orders of magnitude less than those attributed to the atmospheric pathway. Therefore, although VCS was not specifically included in the Liquid Pathway Generic Study, the doses from the VCS site groundwater pathway would be expected to be much less than the doses from the atmospheric pathway, given that all categories of plant locations showed the same trend.

7.2.4 Comparison to NRC Safety Goals

Exelon evaluated performance of the ESBWR and the ABWR relative to two safety goals: (1) individual risk goal, and (2) societal risk goal. These goals are defined in the following subsections. Table 7.2-3 provides the quantitative evaluation of these safety goals and the VCS site-specific calculation of these risk values.

7.2.4.1 Individual Risk Goal

The risk to an average individual in the vicinity of a nuclear power plant of experiencing a prompt fatality resulting from a severe reactor accident should not exceed one-tenth of one percent (0.1 percent) of the sum of “prompt fatality risks” resulting from other accidents to which members of the United States population are generally exposed. As defined in the Safety Goals Policy statement (51 FR 30028), “vicinity” is the area within one mile of the plant site boundary. The population within one mile of the proposed VCS reactors is zero. Exelon conservatively assumed a uniformly distributed synthetic population surrounding the site within 1 mile of the reactor. “Prompt Fatality Risks” are defined as the sum of risks which the average individual residing in the vicinity of the plant is exposed to as a result of normal daily activities (driving, household chores, occupational activities, etc). For this evaluation, the sum of prompt fatality risks was taken as the United States accidental death risk value of 39.8 deaths per 100,000 people per year (CDC Apr 2009).

7.2.4.2 Societal Risk Goal

The risk to the population in the area near a nuclear power plant of cancer fatalities that might result from its operation should not exceed one-tenth of one percent (0.1 percent) of the sum of the cancer fatality risks resulting from all other causes. As defined in the Safety Goal Policy Statement (51 FR 30028), “near” is within 10 miles of the plant. The cancer fatality risk was taken as 180.7 deaths per 100,000 people per year based upon National Center for Health Statistics data (CDC Apr 2009).

7.2.5 Conclusions

The total calculated dose-risk to the 50-mile population from airborne releases from an ABWR reactor at the VCS site would be 0.0020 person-rem per reactor year (Table 7.2-2). This value is less than the population risk for all current reactors that have undergone license renewal, and less than that for the five reactors analyzed in NUREG-1150 (U.S. NRC Jun 1989).

Comparisons with the existing nuclear reactor fleet (Subsection 7.2.3.2) indicate that risk from the surface water pathway is small. Under the severe accident scenarios, surface water is primarily contaminated by atmospheric deposition. The atmospheric pathway doses are significantly lower than those of the current nuclear fleet. Therefore, it is reasonable to conclude that the doses from the surface water pathway at the VCS site would be consistently lower than those reported in Subsection 7.2.3.2 for the current fleet.

The risks of groundwater contamination from a severe accident (see Subsection 7.2.3.3) would be much less than the risk from currently licensed reactors. Additionally, interdiction could substantially reduce the groundwater pathway risks.

For comparison, as reported in Section 5.4, the total collective whole body dose from the VCS site normal airborne releases is expected to be 1.1 person-rem annually. As previously described, dose-risk is dose times frequency. Normal operations have a frequency of one. Therefore, the dose-risk for normal operations is 1.1 person-rem per reactor year. Comparing this value to the severe accident dose-risk of 0.0020 person-rem per reactor year indicates that the dose risk from severe accidents is approximately 0.2 percent of the dose risk from normal operations.

The probability-weighted risk of fatalities (early and latent cancer) from a severe accident for the VCS site is reported in Table 7.2-2 as 1.2×10^{-6} fatalities per reactor year. The probability of an individual dying from any cancer from any cause is approximately 0.24 over a lifetime (ACS Mar 2008). Comparing this value to the 1.2×10^{-6} fatalities per reactor year indicates that individual risk is 0.0005 percent of the background risk. As reported in Table 7.2-3, the individual and societal risks for a severe accident from both the ESBWR and the ABWR reactors at the VCS site would be less than the NRC risk goals described in Subsection 7.2.4.

7.2.6 References

ACS Mar 2008. American Cancer Society, *Lifetime Probability of Developing or Dying From Cancer,* available at http://www.cancer.org/ docroot/CRI/content/ CRI_2_6x_ Lifetime_Probability_ of_Developing _or_Dying_From _Cancer.asp?sitearea=, accessed March 15, 2008.

CDC Apr 2009. Centers for Disease Control, *Deaths: Data for 2006*, National Vital Statistics Reports Volume 57 Number 14, April 17, 2009.

GE Jan 1995. GE Nuclear Energy, *Technical Support Document for the ABWR,* 25A5680, Revision 1, January 18, 1995.

GE Mar 1997. General Electric Nuclear, *ABWR Design Control Document*, Revision 4, transmitted by letter March 28, 1997.

GEH Jun 2009. GE Hitachi, *ESBWR Design Certification Probabilistic Risk Assessment, NEDO-33201*, Revision 4. NRC Accession Number ML092030199, June 26, 2009.

GEH Aug 2009. GE Hitachi Nuclear Energy, ESBWR Design Control Document, Tier 2, Chapter 19, 26A6642BY, Revision 6, August 2009.

USDA (U.S. Department of Agriculture) Sep 2009. *2007 Census of Agriculture*, Issued February 2009; Updated September 2009. Available at http://www.agcensus.usda.gov/Publications/ 2007/Full_Report/index.asp, accessed October 9, 2009.

U.S. NRC Feb 1978. U.S. Nuclear Regulatory Commission, *Liquid Pathway Generic Study: Impacts of Accidental Radioactive Releases to the Hydrosphere from Floating and Land-Based Nuclear Power Plants*, NUREG-0440, February 1978.

U.S. NRC Jun 1989. U.S. Nuclear Regulatory Commission, *Severe Accident Risks: An Assessment for Five U.S. Nuclear Power Plants*, NUREG-1150, June 1989.

U.S.NRC July 1994. *Final Safety Evaluation Report Related to Certification of the Advanced Boiling Water Reactor Design*, NUREG-1503, July 1994.

U.S. NRC May 1996. U.S. Nuclear Regulatory Commission, *Generic Environmental Impact Statement for License Renewal of Nuclear Plants. Volumes 1 and 2,* NUREG-1437, May 1996.

U.S. NRC Aug 2003. U.S. Nuclear Regulatory Commission, *SECPOP 2000: Sector Population Land Fraction, and Economic Estimation Program*, NUREG/CR-6525, August 2003.

Table 7.2-1
Impacts to the Population and Land from Severe ESBWR Accidents Analysis

Accident Category	Accident Frequency	Population Dose-Risk (person-rem/ reactor year)	Cost in Dollars (per reactor year)	Number of Early Fatalities (per reactor year)	Number of Latent Fatalities (per reactor year)	Water Ingestion Dose (person-rem per reactor year)	Land Requiring Decontamination (acres per reactor year)
BOC	7.9×10^{-11}	1.5×10^{-4}	2.9×10^{-1}	1.6×10^{-10}	1.2×10^{-7}	2.0×10^{-5}	4.0×10^{-5}
BYP	5.7×10^{-11}	1.2×10^{-4}	1.5×10^{-1}	2.9×10^{-11}	1.2×10^{-7}	3.8×10^{-6}	2.7×10^{-5}
CCID	1.5×10^{-12}	1.5×10^{-6}	4.5×10^{-3}	8.1×10^{-14}	9.5×10^{-10}	2.1×10^{-7}	7.1×10^{-7}
CCIW	2.9×10^{-12}	1.3×10^{-6}	3.5×10^{-3}	0.0	7.7×10^{-10}	5.1×10^{-8}	7.9×10^{-7}
EVE	1.1×10^{-9}	1.2×10^{-3}	3.5	9.3×10^{-11}	7.6×10^{-7}	1.5×10^{-4}	5.5×10^{-4}
FR	9.2×10^{-11}	1.9×10^{-5}	4.0×10^{-2}	0.0	1.1×10^{-8}	2.7×10^{-7}	8.3×10^{-6}
OPVB	2.1×10^{-12}	6.4×10^{-7}	1.6×10^{-3}	0.0	3.8×10^{-10}	1.5×10^{-8}	3.8×10^{-7}
OPW1	2.0×10^{-12}	6.0×10^{-7}	1.6×10^{-3}	0.0	3.6×10^{-10}	1.6×10^{-8}	3.9×10^{-7}
OPW2	8.5×10^{-12}	8.0×10^{-7}	7.8×10^{-4}	0.0	4.8×10^{-10}	4.7×10^{-9}	6.0×10^{-8}
TSL	1.5×10^{-8}	3.0×10^{-4}	2.3×10^{-1}	0.0	1.8×10^{-7}	6.5×10^{-7}	1.1×10^{-5}
Total	1.7×10^{-8}	1.8×10^{-3}	4.2	2.8×10^{-10}	1.2×10^{-6}	1.8×10^{-4}	6.4×10^{-4}

Table 7.2-2
Impacts to the Population and Land From Severe ABWR Accident Analysis

Accident Category	Accident Frequency	Population Dose-Risk (person-rem/ reactor year)	Cost in Dollars (per reactor year)	Number of Early Fatalities (per reactor year)	Number of Latent Fatalities (per reactor year)	Water Ingestion Dose (person-rem/ reactor year)	Land Requiring Decontamination (acres per reactor year)
NCL	1.3×10^{-07}	1.0×10^{-3}	2.8×10^{-1}	0.0	6.1×10^{-7}	1.7×10^{-6}	5.4×10^{-07}
Case 1	2.1×10^{-08}	9.7×10^{-5}	2.3×10^{-2}	0.0	5.8×10^{-8}	1.5×10^{-7}	5.5×10^{-09}
Case 2	1.0×10^{-10}	2.7×10^{-7}	4.1×10^{-5}	0.0	1.6×10^{-10}	2.8×10^{-10}	$0.0 \times 10^{+00}$
Case 3	1.0×10^{-10}	1.4×10^{-5}	1.9×10^{-2}	0.0	8.6×10^{-9}	1.2×10^{-7}	2.1×10^{-06}
Case 4	1.0×10^{-10}	1.0×10^{-5}	1.3×10^{-2}	0.0	6.1×10^{-9}	8.8×10^{-8}	1.5×10^{-06}
Case 5	1.0×10^{-10}	5.1×10^{-6}	8.8×10^{-3}	0.0	3.1×10^{-9}	2.9×10^{-8}	5.1×10^{-07}
Case 6	1.0×10^{-10}	5.8×10^{-5}	1.9×10^{-1}	0.0	3.5×10^{-8}	4.2×10^{-6}	3.8×10^{-05}
Case 7	3.9×10^{-10}	2.6×10^{-4}	8.3×10^{-1}	0.0	1.6×10^{-7}	2.1×10^{-5}	1.6×10^{-04}
Case 8	4.1×10^{-10}	3.9×10^{-4}	1.3	5.1×10^{-14}	2.5×10^{-7}	5.7×10^{-5}	2.0×10^{-04}
Case 9	1.7×10^{-10}	1.8×10^{-4}	5.9×10^{-1}	1.2×10^{-13}	1.2×10^{-7}	3.3×10^{-5}	8.3×10^{-05}
Total	1.6×10^{-7}	2.0×10^{-3}	3.2	1.7×10^{-13}	1.2×10^{-6}	1.2×10^{-4}	4.8×10^{-04}

Note: $<1.0 \times 10^{-10}$ frequencies taken as 1.0×10^{-10} for analysis.

Table 7.2-3
Comparison to NRC Safety Goals

Goal	Risk Goal	Exelon ESBWR per unit	Exelon ABWR per unit
Individual Risk (0-1 mile)	4.0×10^{-7}	5.3×10^{-11}	1.4×10^{-12}
Societal Risk (0-10 miles)	1.8×10^{-6}	1.4×10^{-13}	1.5×10^{-13}

7.3 Severe Accident Mitigation Alternatives

The purpose of severe accident mitigation alternatives (SAMAs) is to review and evaluate plant design alternatives that could significantly reduce the radiological risk from a severe accident by preventing substantial core damage or by limiting releases from containment in the event that substantial core damage does occur.

SAMAs depend on design issues evaluated during the development and review of standard design certifications and COL applications. The design of the reactor and analyses of projected severe accidents are major contributing factors in the determination of SAMAs. To determine whether mitigation alternatives are cost beneficial, severe accident analyses must be included in these evaluations. SAMA would be evaluated for the new units in the COL application.

7.4 Transportation Accidents

Subsection 5.7.2.2 describes the methodology used to analyze the impacts of transportation of radioactive materials. Subsection 7.4.1 describes the radiological impacts of transportation accidents. The nonradiological impacts of transportation accidents are addressed in Subsection 7.4.2. The data currently available for the mPower reactor will not support an evaluation of radioactive materials transportation. Should Exelon select the mPower technology for VCS, an evaluation of radioactive materials transportation will be provided as part of the COL application.

7.4.1 Radiological Impacts of Transportation Accidents

7.4.1.1 Transportation of Unirradiated Fuel

Accidents involving unirradiated fuel shipments are addressed in Table S-4 of 10 CFR 51.52. Unirradiated fuel would be transported to the site via truck. Accident risks are calculated as frequency multiplied by consequence. Accident frequencies for transportation of fuel to future reactors are expected to be lower than those used in the analysis in WASH-1238 (AEC Dec 1972), which forms the basis for Table S-4 of 10 CFR 51.52, because of improvements in highway safety and security. Traffic accident, injury, and fatality rates have decreased over the past 30 years. Because fuel forms, cladding, and packages for the advanced light water reactor (LWR) technologies are similar to those of current generation LWRs, the consequences of accidents that are severe enough to result in a release of radioactivity to the environment are also similar. Accordingly, the risks of accidents during transportation of unirradiated fuel to the VCS site would be expected to be smaller than the reference LWR consequences listed in Table S-4.

7.4.1.2 Transportation of Spent Fuel

The RADTRAN 5 computer code was used to estimate impacts of transportation accidents involving spent fuel shipments. RADTRAN 5 considers a spectrum of potential transportation accidents, ranging from those with high frequencies and low consequences (i.e., “fender benders”) to those with low frequencies and high consequences (i.e., accidents in which the shipping container is exposed to severe mechanical and thermal conditions).

The radionuclide inventory of the advanced LWR spent fuel after 5 years of decay was estimated using the ORIGEN code. A screening analysis was performed to select the dominant contributors to accident risks and to simplify the RADTRAN 5 calculations. This screening identified the radionuclides that would collectively contribute more than 99.999 percent of the dose from inhalation of radionuclides released following a transportation accident (U.S. NRC Dec 2006). The spent fuel inventory used in this analysis is presented in Table 7.4-1. The spent fuel transportation accident risks for each advanced LWR were calculated assuming the entire Co-60 inventory (Table 7.4-1) is in the form of crud.

Massive shipping casks are used to transport spent fuel because of the radiation shielding and accident resistance features required by 10 CFR 71, “Packaging and Transportation of Radioactive Material.” Spent fuel shipping casks must be certified Type B packaging systems, meaning they must withstand a series of severe hypothetical accident conditions with essentially no loss of containment or shielding capability[1]. As stated in NUREG/CR-6672 (Sprung et al. Mar 2000), the probability of encountering accident conditions that would lead to shipping cask failure is less than 0.01 percent (i.e., more than 99.99 percent of all accidents would result in no release of radioactive material from the shipping cask). This analysis assumed that shipping casks for the advanced LWR spent fuel would provide equivalent mechanical and thermal protection of the spent fuel cargo, in accordance with the requirements of 10 CFR 71.

The RADTRAN 5 accident risk calculations were performed using an assumption of 0.5 metric tons of uranium (MTU) per shipment for radionuclide inventories. The resulting risk estimates were multiplied by the expected annual spent fuel shipment amounts (in MTU per year) to derive estimates of the annual accident risks associated with the advanced LWR spent fuel shipments. The amount of spent fuel shipped per year was assumed to be equivalent to the annual discharge quantity: 30 MTU per year for the ABWR, 38.5 MTU per year for the ESBWR, 23 MTU per year for the AP1000, and 34.8 MTU per year for the APWR. (This discharge quantity has not been normalized to the reference LWR. The normalized value is presented in Table 7.4-2.)

The release fractions for current generation LWR fuels were used to approximate the impacts from the advanced LWR spent fuel shipments. This assumes that the fuel materials and containment systems (i.e., cladding and fuel coatings) behave similarly to current LWR fuel under applied mechanical and thermal conditions.

Using RADTRAN 5, the population dose from the released radioactive material was calculated for five possible exposure pathways:

- External dose from exposure to the passing cloud of radioactive material.
- External dose from the radionuclides deposited on the ground by the passing plume (the radiation exposure from this pathway was included even though the area surrounding a potential accidental release would be evacuated and decontaminated, thus preventing long-term exposures from this pathway).
- Internal dose from inhalation of airborne radioactive contaminants.

1. Requirements for Type B packaging are set forth in 49 CFR § 173.413 and 10 CFR §§ 71.41 through 47 and § 71.51.

- Internal dose from resuspension of radioactive materials that were deposited on the ground (the radiation exposures from this pathway were included even though evacuation and decontamination of the area surrounding a potential accidental release would prevent long-term exposures).
- Internal dose from ingestion of contaminated food. No internal dose due to ingestion of contaminated foods was calculated because the analysis assumed interdiction of foodstuffs and evacuation of people after an accident would prevent such ingestion.

A sixth pathway, external doses from increased radiation fields surrounding a shipping cask with damaged shielding, was considered. It is possible that shielding materials incorporated into the cask structures could become damaged because of an accident; however, the loss of shielding events was not included in the analysis because their contribution to spent fuel transportation risk is much smaller than the dispersal accident risks from the pathways listed above.

Calculations were performed to assess the environmental consequences of transportation accidents when shipping spent fuel from the VCS to a spent fuel repository assumed to be at Yucca Mountain, Nevada. The shipping distances and population distribution information for the route were the same as those used for the “incident-free” transportation impacts analysis described in Subsection 5.7.2.2.

Table 7.4-2 presents accident risks associated with transportation of spent fuel from VCS to the proposed Yucca Mountain repository. The accident risks are provided in the form of a collective population dose (i.e., person-rem per year over the shipping campaign). The table also presents estimates of accident risk per reactor year normalized to the reference reactor analyzed in WASH-1238. The transportation accident impacts were also calculated for the alternative sites (Matagorda County, Buckeye, Alpha, and Bravo) in the region of interest.

The risk to the public from radiation exposure was estimated using the nominal probability coefficient for total detrimental health effects (730 fatal cancers, nonfatal cancers, and severe hereditary effects per 1×10^6 person-rem) per reference reactor year from the International Commission on Radiological Protection Publication 60 (ICRP 1991). These values are presented in Table 7.4-2. These estimated risks are small compared to the fatal cancers, nonfatal cancers, and severe hereditary effects that would be expected to occur annually in the same population from exposure to natural sources of radiation. Therefore, negligible increases in environmental risk effects are expected from accidents that may result during shipping spent fuel from the site to a spent fuel disposal repository. The risks of accidents during transportation of spent fuel from the VCS site or an alternate site would be consistent with the environmental impacts presented in Table S-4.

7.4.2 Nonradiological Impacts of Transportation Accidents

Nonradiological impacts would include the projected number of accidents, injuries, and fatalities that could result from shipments of radioactive materials to or from the VCS site and return of empty containers. Nonradiological impacts were estimated using accident, injury, and fatality rates from Table 4 of *State-Level Accident Rates for Surface Freight Transportation: A Reexamination* (Saricks and Tompkins Apr 1999). This data is representative of the traffic accident, injury, and fatality rates for heavy truck shipments similar to those that would be used to transport radioactive materials to and from the site. These rates (measured in impacts per vehicle-mile traveled) are multiplied by the annual numbers of shipments and estimated travel distances for the shipments to estimate annual impacts. These estimates include the human health impacts projected to result from traffic accidents involving shipments of radioactive materials; they do not consider the radiological or hazardous characteristics of the cargo.

7.4.2.1 Transportation of Unirradiated Fuel

The nonradiological accident impacts that could result from shipments of unirradiated fuel to the VCS site and return of empty containers from the site are presented in Table 7.4-3. The nonradiological impacts for the reference LWR analyzed in WASH-1238 are also shown for comparison. Nationwide median rates for interstate highway transportation from Saricks and Tompkins (Apr 1999) were used to estimate the annual impacts. Consistent with the incident-free transportation analysis described in Subsection 5.7.2, an average one-way shipping distance of 2000 miles was used to evaluate the unirradiated fuel shipments. The differences between the reference LWR and the advanced LWR results are due to the lower number of shipments per year (when normalized for electrical output) projected for the units at VCS. The values presented in Table 7.4-3 would be doubled for a two-unit plant.

7.4.2.2 Transportation of Spent Fuel

The general approach to calculating the nonradiological impacts for spent fuel shipments is similar to that for other radioactive materials shipments. The main difference is that the spent fuel shipping route characteristics are better defined, allowing the state-specific accident statistics in Saricks and Tompkins (Apr 1999) to be used in the analysis. State-by-state shipping distances and road types were obtained from the TRAGIS output file (see Subsection 5.7.2.2.2 for a discussion of the TRAGIS routing model). The shipping distances were doubled to allow for return shipments of empty containers to VCS. This information, the annual number of shipments, and state-specific accident statistics were used to estimate the nonradiological impacts presented in Table 7.4-4.

7.4.2.3 Transportation of Radioactive Waste

Nonradiological impacts of radioactive waste shipments were calculated using the same general approach as the unirradiated fuel shipments. A shipping distance of 500 miles was assumed consistent with the analysis in WASH-1238. Because the destination of the waste shipments is not known, the national median accident, injury, and fatality rates from Saricks and Tompkins (Apr 1999) were used to calculate the values presented in Table 7.4-5. The nonradiological impacts for the reference LWR analyzed in WASH-1238 are also shown for comparison. The differences between the reference LWR and the advanced LWR results are due to the higher number of radioactive waste shipments projected for the reactors except for the AP1000. The AP1000 design control document provides estimated shipped waste volumes assuming onsite processing to reduce the waste volume by a factor of three. Waste estimates for the other advanced LWR technologies do not reflect onsite processing. The values presented in Table 7.4-5 would be doubled for a two-unit plant.

7.4.3 Conclusion

Based on this analysis, the overall transportation accident risks associated with spent fuel shipments from the advanced LWR technologies being considered to demonstrate VCS site suitability are consistent with the risks associated with transportation of spent fuel from current generation reactors presented in WASH-1238 and Table S-4 of 10 CFR 51.52 (reproduced in Table 5.7-3) and thus will be SMALL.

7.4.4 References

AEC Dec 1972. U.S. Atomic Energy Commission, *Environmental Survey of Transportation of Radioactive Materials to and from Nuclear Power Plants*, WASH-1238, December 1972.

ICRP 1991. International Commission on Radiological Protection, *1990 Recommendations of the International Commission on Radiological Protection*, ICRP Publication 60, 1991, Pergamon Press.

Saricks and Tompkins Apr 1999. Saricks, C. L. and M. M. Tompkins, *State-Level Accident Rates for Surface Freight Transportation: A Reexamination,* ANL/ESD/TM-150, April 1999, Argonne National Laboratory.

Sprung et al. Mar 2000. Sprung, J. L., D. J. Ammerman, N. L. Breivik, R. J. Dukart, F. L. Kanipe, J. A. Koski, G. S. Mills, K. S. Neuhauser, H. D. Radloff, R. F. Weiner, and H. R. Yoshimura, *Reexamination of Spent Fuel Shipment Risk Estimates*, NUREG/CR-6672, Volume 1, March 2000, U.S. Nuclear Regulatory Commission.

U.S. NRC Dec 2006. U.S. Nuclear Regulatory Commission, *Environmental Impact Statement for an Early Site Permit (ESP) at the North Anna ESP Site*, NUREG-1811, December 2006.

Table 7.4-1
Radionuclide Inventory Used in Transportation Accident Risk Calculations

Radionuclide	ABWR Inventory (curies per MTU)	ESBWR Inventory (curies per MTU)	AP1000 Inventory (curies per MTU)	APWR Inventory (curies per MTU)
Am-241	1.44×10^3	1.30×10^3	7.27×10^2	1.81×10^3
Am-242m	3.32×10^1	2.79×10^1	1.31×10^1	2.04×10^1
Am-243	5.95×10^1	3.26×10^1	3.34×10^1	7.45×10^1
Ce-144	1.32×10^4	1.35×10^4	8.87×10^3	1.39×10^4
Cm-242	6.22×10^1	4.86×10^1	2.83×10^1	6.08×10^1
Cm-243	6.17×10^1	3.47×10^1	3.07×10^1	5.76×10^1
Cm-244	1.35×10^4	4.96×10^3	7.75×10^3	1.25×10^4
Cm-245	2.25	6.75×10^{-1}	1.21	–
Co-60	3.63×10^3	2.86×10^3	4.09	8.58×10^1
Cs-134	7.76×10^4	5.19×10^4	4.80×10^4	6.41×10^4
Cs-137	1.58×10^5	1.27×10^5	9.31×10^4	1.76×10^5
Eu-154	1.56×10^4	1.05×10^4	9.13×10^3	1.03×10^4
Eu-155	8.27×10^3	5.47×10^3	4.62×10^3	2.74×10^3
Pm-147	3.13×10^4	3.53×10^4	1.76×10^4	5.17×10^4
Pu-238	1.09×10^4	6.15×10^3	6.07×10^3	9.50×10^3
Np-239	–	–	–	7.45×10^1
Pu-239	4.27×10^2	3.86×10^2	2.55×10^2	4.08×10^2
Pu-240	8.52×10^2	6.22×10^2	5.43×10^2	6.97×10^2
Pu-241	1.35×10^5	1.22×10^5	6.96×10^4	1.68×10^5
Pu-242	3.19	2.24	1.82	–
Ru-106	2.29×10^4	1.86×10^4	1.55×10^4	2.46×10^4
Sb-125	7.17×10^3	5.80×10^3	3.83×10^3	3.39×10^3
Sr-90	1.06×10^5	9.08×10^4	6.19×10^4	1.20×10^5
Y-90	1.06×10^5	9.09×10^4	6.19×10^4	1.20×10^5

Table 7.4-2
Spent Fuel Transportation Accident Risks

Site	Victoria County	Matagorda County	Buckeye	Alpha	Bravo
ABWR					
Unit Population Dose (person-rem per MTU)[(a)]	2.78×10^{-7}	2.60×10^{-7}	2.60×10^{-7}	2.58×10^{-7}	2.92×10^{-7}
MTU per Reference Reactor Year	21.5	21.5	21.5	21.5	21.5
Population Dose (person-rem per reference reactor year)[(a)]	5.97×10^{-6}	5.59×10^{-6}	5.59×10^{-6}	5.54×10^{-6}	6.27×10^{-6}
Total Detrimental Health Effects per Reference Reactor Year	4.36×10^{-9}	4.08×10^{-9}	4.08×10^{-9}	4.05×10^{-9}	4.58×10^{-9}
ESBWR					
Unit Population Dose (person-rem per MTU)[(a)]	1.03×10^{-7}	9.70×10^{-8}	9.70×10^{-8}	9.62×10^{-8}	1.09×10^{-7}
MTU per Reference Reactor Year	23.0	23.0	23.0	23.0	23.0
Population Dose (person-rem per reference reactor year)[(a)]	2.38×10^{-6}	2.23×10^{-6}	2.23×10^{-6}	2.21×10^{-6}	2.50×10^{-6}
Total Detrimental Health Effects per Reference Reactor Year	1.73×10^{-9}	1.63×10^{-9}	1.63×10^{-9}	1.62×10^{-9}	1.82×10^{-9}
AP1000					
Unit Population Dose (person-rem per MTU)[(a)]	3.62×10^{-8}	3.40×10^{-8}	3.40×10^{-8}	3.38×10^{-8}	3.82×10^{-8}
MTU per Reference Reactor Year	19.5	19.5	19.5	19.5	19.5
Population Dose (person-rem per reference reactor year)[(a)]	7.04×10^{-7}	6.62×10^{-7}	6.62×10^{-7}	6.58×10^{-7}	7.43×10^{-7}
Total Detrimental Health Effects per Reference Reactor Year	5.14×10^{-10}	4.83×10^{-10}	4.83×10^{-10}	4.80×10^{-10}	5.43×10^{-10}
APWR					
Unit Population Dose (person-rem per MTU)[(a)]	6.34×10^{-8}	5.96×10^{-8}	5.96×10^{-8}	5.92×10^{-8}	6.68×10^{-8}
MTU per Reference Reactor Year	19.9	19.9	19.9	19.9	19.9
Population Dose (person-rem per reference reactor year)[(a)]	1.26×10^{-6}	1.19×10^{-6}	1.19×10^{-6}	1.18×10^{-6}	1.33×10^{-6}
Total Detrimental Health Effects per Reference Reactor Year	9.20×10^{-10}	8.65×10^{-10}	8.65×10^{-10}	8.59×10^{-10}	9.70×10^{-10}

(a) Value presented is the product of probability multiplied by collective dose.

Table 7.4-3
Nonradiological Impacts of Transporting Unirradiated Fuel to the Victoria County Station

				Annual Impacts		
Reactor	**Total Shipments Normalized to Reference LWR**	**One-Way Shipping Distance (miles)**	**Total Round-trip Shipping Distance (miles)**	**Fatalities per Year**	**Injuries per Year**	**Accidents per Year**
Reference LWR	252	2000	1.01×10^{6}	3.7×10^{-4}	0.0078	0.011
ABWR	195	2000	7.80×10^{5}	2.9×10^{-4}	0.0060	0.0088
ESBWR	221	2000	8.84×10^{5}	3.3×10^{-4}	0.0069	0.010
AP1000	172	2000	6.88×10^{5}	2.5×10^{-4}	0.0053	0.0078
APWR	132	2000	5.28×10^{5}	2.0×10^{-4}	0.0041	0.0060

Table 7.4-4 (Sheet 1 of 2)
Nonradiological Impacts of Transporting Spent Fuel from the Victoria County Station

State	Highway Type	One-Way Shipping Distance (miles)	Fatalities per Year	Injuries per Year	Accidents per Year
ABWR					
Arizona	Interstate	391	5.1×10^{-4}	0.0063	0.0071
California	Interstate	367	3.6×10^{-4}	0.0063	0.0081
Nevada	Interstate	66	6.0×10^{-5}	0.0013	0.0020
	Primary	79	1.8×10^{-4}	0.0028	0.0042
New Mexico	Interstate	164	2.7×10^{-4}	0.0026	0.0026
Texas	Interstate	670	0.0012	0.051	0.056
	Primary	71	2.8×10^{-4}	0.0051	0.0068
Totals	–	1,807	0.0029	0.075	0.086
ESBWR					
Arizona	Interstate	391	5.6×10^{-4}	0.0069	0.0078
California	Interstate	367	3.9×10^{-4}	0.0069	0.0089
Nevada	Interstate	66	6.5×10^{-5}	0.0015	0.0022
	Primary	79	2.0×10^{-4}	0.0030	0.0046
New Mexico	Interstate	164	2.9×10^{-4}	0.0029	0.0028
Texas	Interstate	670	0.0013	0.055	0.061
	Primary	71	3.1×10^{-4}	0.0056	0.0074
Totals	–	1,807	0.0031	0.082	0.094
AP1000					
Arizona	Interstate	391	4.6×10^{-4}	0.0057	0.0065
California	Interstate	367	3.2×10^{-4}	0.0057	0.0074
Nevada	Interstate	66	5.4×10^{-5}	0.0012	0.0019
	Primary	79	1.7×10^{-4}	0.0025	0.0038
New Mexico	Interstate	164	2.4×10^{-4}	0.0024	0.0023
Texas	Interstate	670	0.0011	0.046	0.050
	Primary	71	2.5×10^{-4}	0.0047	0.0062
Totals	–	1,807	0.0026	0.068	0.078

Table 7.4-4 (Sheet 2 of 2)
Nonradiological Impacts of Transporting Spent Fuel from the Victoria County Station

State	Highway Type	One-Way Shipping Distance (miles)	Fatalities per Year	Injuries per Year	Accidents per Year
APWR					
Arizona	Interstate	391	4.7×10^{-4}	0.0059	0.0066
California	Interstate	367	3.3×10^{-4}	0.0059	0.0076
Nevada	Interstate	66	5.6×10^{-5}	0.0013	0.0019
	Primary	79	1.7×10^{-4}	0.0026	0.0039
New Mexico	Interstate	164	2.5×10^{-4}	0.0024	0.0024
Texas	Interstate	670	0.0011	0.047	0.052
	Primary	71	2.6×10^{-4}	0.0048	0.0063
Totals	–	1,807	0.0027	0.070	0.080

Table 7.4-5
Nonradiological Impacts of Transporting Radioactive Waste from the Victoria County Station

Reactor	Shipments per Year Normalized to Reference LWR	One-Way Shipping Distance (miles)	Annual Impacts		
			Fatalities per Year	Injuries per Year	Accidents per Year
Reference LWR	46	500	6.8×10^{-4}	0.014	0.021
ABWR	144	500	2.1×10^{-3}	0.045	0.066
ESBWR	115	500	1.7×10^{-3}	0.036	0.052
AP1000	20	500	3.0×10^{-4}	0.0062	0.0091
APWR	106	500	1.6×10^{-3}	0.033	0.048