2.4S.13 Accidental Releases of Radioactive Liquid Effluents in Ground and Surface Waters

The following site-specific supplement addresses COL License Information Item 2.21.

The information presented in this subsection describes the ability of groundwater and surface water systems to delay, disperse, dilute, or concentrate liquid effluent released from the STP site. The source of the liquid effluent would be a postulated tank rupture in the liquid radwaste system. The likelihood of an environmental release of liquid radwaste is remote due to multiple levels of protection in the liquid radwaste system. Subsection 15.7.3.3 describing the design basis accident indicates that “the liquid pathway is not considered due to the mitigative capabilities of the Radwaste Building.” Subsection 15.7.3.1 indicates “the probability of a complete tank release is considered low enough to warrant this event as a limiting fault.” In addition, Subsection 12.2.1.2.12 states that in the event of an accident involving radioactive sources in the Primary Containment or Reactor Building, such sources would be contained and isolated for further treatment and decontamination.

2.4S.13.1 Direct Release to Groundwater

Although not considered to be a credible event, this section provides a conservative analysis of a postulated, accidental liquid release of effluents to the groundwater at the STP site. The groundwater pathway includes the components of advection, retardation, and decay. For conservatism, the effects of dispersion are not considered. The advective component is discussed in Subsection 2.4S.12.3. A chemical undergoing advective transport travels at the same velocity as groundwater and is termed a conservative contaminant because it does not react with the aquifer matrix. Chemicals that react with the aquifer matrix can reduce in concentration along the flow, relative to their initial groundwater concentration. Reactions with the aquifer matrix include cation/anion exchange, complexation, oxidation-reduction reactions, and surface sorption. Radionuclide concentrations in the groundwater pathway can be significantly influenced by radioactive decay, depending on the half-life of the radionuclide.

2.4S.13.1.1 Accident Scenario

It is postulated that a liquid radwaste tank ruptures and its contents are released to groundwater. The volume of the liquid to be released and the associated radionuclide concentrations were selected to produce an accident scenario that could lead to contamination of groundwater or surface water via the groundwater pathway. Release points are discussed in Subsection 11.2.3.

An inventory of radioactive sources in the liquid radwaste system tanks is discussed in Section 12.2. A review of the radioactive sources suggests that the Low Conductivity Waste (LCW) collector tank has the greatest concentrations of radioisotopes. Each LCW collector tank has a volume of 140 m^3 (36,984 gallons) (Section 11.2, Table 11.2.4), and its radionuclide concentrations are shown on Table 2.4S.13-1. These radionuclide concentration values were compared with the reactor coolant radionuclide concentrations from Section 11.1, as shown on Table 2.4S.13-1. For conservatism, the highest concentration from either the LCW collector tank or the reactor coolant was used as a source term concentration for each radionuclide.

Several of the radionuclides are part of a decay chain sequence. Figure 2.4S.13-1 presents the decay chain sequences for chains important for dosimetric purposes. Table 2.4S.13-1 includes the half-lives of the radionuclides of concern based on information from References 2.4S.13-1 and 2.4S.13-2. The accident scenario assumes that the LCW collector tank ruptures and that its contents are released to the groundwater.

2.4S.13.1.2 Conceptual Model

This subsection describes the conceptual model used to evaluate an accidental release of liquid effluent to groundwater or surface water via the groundwater pathway. The key elements and assumptions embodied in the conceptual model are provided below.

The conceptual model of the site groundwater system is based on the hydrogeological information presented in Subsection 2.4S.12. The site groundwater system consists of two aquifers; the Shallow Aquifer and the Deep Aquifer. The Shallow Aquifer extends from near ground surface and is approximately 100 ft to 150 ft thick. The Shallow Aquifer is separated from the Deep Aquifer by a 100 ft to 150 ft thick sequence of clay and silt. Potentiometric surface maps created from onsite groundwater level measurements indicate that flow in the Deep Aquifer is towards the onsite groundwater production wells located on the east and west sides of the STP site. The Deep Aquifer is greater than 500 ft thick and is the principal groundwater production interval in the site area.

The Shallow Aquifer is divided into the Upper Shallow Aquifer and Lower Shallow Aquifer that are separated by a clay and silt layer. Both zones are considered to be semi-confined to confined with a downward hydraulic gradient between the zones. The Upper Shallow aquifer is comprised of interbedded sand layers to depths of approximately 50 ft below ground surface. The Lower Shallow Aquifer consists of interbedded sand layers approximately 50 ft to 150 ft below ground surface. Site investigations indicate that this separation is not continuous and leakage between the two units is occurring. The groundwater flow direction in both the Upper and Lower zones of the Shallow Aquifer is to the east-southeast, toward the Colorado River, with a minor flow component toward the southwest in the western portion of the site. The Shallow Aquifer has limited production capability and is used for livestock watering and occasional domestic supply within Matagorda County.

As discussed in the previous subsection, the LCW collector tank inside the Radwaste Building is assumed to be the source of the release. The Radwaste Building basement floor is at a depth of approximately 45 ft below plant grade and the Radwaste Building foundation is at a depth of approximately 53 ft below plant grade (Section 3.8). The excavation for the adjacent Reactor Building extends to a depth of approximately 90 ft below plant grade, which would involve placement of structural fill beneath the Radwaste Building as part of backfilling around the Reactor Building. The Radwaste Building includes several levels of protection such as an alarmed tank level monitoring system and steel-lined compartments surrounding the radwaste tanks. Furthermore, all radwaste tanks are located inside the Radwaste Building, which has a Seismic Category I basemat and walls to a height necessary to retain spilled liquids (Section 11.2) and is equipped with a sump collection system designed to collect any leakage from the steel compartments around the tanks.

The LCW collector tank is postulated to rupture, and 80% of the liquid volume (29,587 gallons) is assumed to be released in accordance with Branch Technical Position 11-6 in NUREG-0800 (Reference 2.4S.13-3). Flow from the tank rupture is postulated to flood the Radwaste Building. Fluids are theorized to migrate past the tank's steel lined compartment and sump collection system, and that a pathway is created that would allow the entire 29,587 gallons to enter the groundwater system instantaneously. This assumption is very conservative because it requires failure of the steel lined compartment and the sump collection system. The LCW collector tank rupture is postulated to occur in the STP 3 Radwaste Building, which would represent the shortest pathway to off site receptors based on the current understanding of groundwater flow conditions.

With the postulated instantaneous release of the contents of the LCW collector tank to groundwater, radionuclides would enter the Shallow Aquifer. Potential offsite effluent release pathways resulting from a theoretical accidental release of liquid effluent to groundwater were described in Subsection 2.4S.12.3. Two release pathways were selected as the most likely complete exposure pathways:

- Pathway 1: Lower Shallow Aquifer – Flow from the STP 3 area that discharges to a Shallow aquifer livestock watering well (well number 2004120846) located offsite, to the southeast of STP 1 & 2. This pathway assumes that the well captures the effluent release and the well discharges to livestock watering troughs.

- Pathway 2: Lower Shallow Aquifer – Flow from the STP 3 area discharges to the Colorado River.

Figure 2.4S.13-2 shows these pathways in relation to the STP site. The excavation required for the construction of STP 3 & 4 penetrates into both the Upper and Lower Shallow Aquifer zones, but is above the thick sequence of clay and silt that separates the Shallow Aquifer from the more productive Deep Aquifer. Because there is a downward, vertical hydraulic gradient between the Upper and Lower Shallow Aquifer zones, and the backfilled excavation encounters both aquifer zones, the most likely groundwater pathway for an accidental release is the Lower Shallow Aquifer.

- Pathway 1 terminates as discharge from a pumping well in the Shallow Aquifer. The well is reported to pump 200,000 gallons per year, or 0.4 gpm (Reference 2.4S.13-4). This well would be an indirect exposure pathway through animals (livestock).

- Pathway 2 represents the continuation of the contaminant release from the Lower Shallow Aquifer to the incised Colorado River channel, which is a valid alternative assumption. The incised channel is conservatively assumed to be in contact with the Lower Shallow Aquifer. This would also be an indirect exposure pathway through animals (livestock watering) and crops (irrigation). Note that the Colorado River is not used as a source of potable water downstream of the site area (Subsection 2.4S.1).

Pathway 2 represents a combined groundwater/surface water pathway, and the influent groundwater concentrations would be reduced by dilution from unimpacted surface water mixing in the Colorado River. The most conservative case would be a release during low flow conditions. The minimum 7-day low flow rate over the period from 1948 and 2006 is approximately 0.5 cfs (Subsection 2.4S.11.1).

Other pathways that were considered and then rejected include (1) flow through the Upper Shallow Aquifer, (2) flow to the relief wells surrounding the MCR dike, (3) flow in the Deep Aquifer, and (4) the southwestward groundwater flow component on the western side of the STP site.

(1) A release of liquid effluent from a ruptured LCW collector tank would flow to the lowest point in the Radwaste Building. The lowest point in the Radwaste Building (basement) is at the bottom of the Upper Shallow Aquifer. This consideration coupled with the presence of structural fill beneath the building from the Reactor Building excavation and the downward vertical hydraulic gradient between the Upper and Lower Shallow Aquifer indicates that there is no mechanism to lift the liquid effluent up into the Upper Shallow Aquifer.

(2) Groundwater potentiometric surface maps (Figures 2.4S.12-17, 2.4S.12-19, and 2.4S.12-21) indicate that Shallow Aquifer groundwater flow is from, rather than toward, the MCR, thus precluding a transport pathway to the MCR.

(3) As discussed above, the Deep Aquifer is separated from the Shallow Aquifer by greater than 100 ft of low hydraulic conductivity silt and clay, and groundwater flow in the Deep aquifer within the site boundary appears to be controlled by pumping from onsite groundwater production wells. These factors suggest that it is unlikely that the Deep Aquifer would be a pathway for offsite release.

(4) The westward flow component in the Shallow Aquifer may represent a pathway from the Unit 4 Radwaste Building, however the site potentiometric maps (Figure 2.4S.12-17) indicate that flow is southward along the west side of the MCR and then turns back toward the southeast, on the south side of the MCR. This results in a similar flow pattern as Pathway 2, but with a much longer flow path distance to reach the Colorado River. Little Robbins Slough is not considered to be a discharge point for the Shallow Aquifer based on the potentiometric surface maps. Therefore, considering radioactive decay and adsorption, Pathway 2 results in a more conservative estimate of concentration at the river.

2.4S.13.1.3 Analysis of Accidental Releases to Groundwater

A radionuclide transport analysis has been conducted to estimate the radionuclide concentrations that might expose existing and future water users based on an instantaneous release of the radioactive liquid of a LCW collector tank. The locations and users of surface water are discussed in Subsection 2.4S.1.2.

Analysis of liquid effluent release commences with the simplest of screening models, using demonstratively conservative assumptions and coefficients. Radionuclide concentrations resulting from the preliminary analysis are then compared against the maximum permissible concentrations, stated as the effluent concentration limits (ECLs) identified in 10 CFR 20, Appendix B, Table 2, Column 2, to determine acceptability. Further analysis, using progressively more realistic and less conservative assumptions and modeling techniques, is conducted when preliminary results using conservative assumptions and coefficients exceed an ECL.

This analysis accounts for the parent radionuclides expected to be present in the radwaste tank plus progeny radionuclides that would be generated subsequently during transport. The analysis considered all progeny radionuclides in the decay chain sequences that are important for dosimetric purposes. International Commission on Radiation Protection (ICRP) Publication 38 (Reference 2.4S.13-1) was used to identify the member for which the decay chain sequence can be truncated. For some of the radionuclides expected to be present in the tanks, consideration of up to three members of the decay chain sequence was required. The derivation of the equations governing the transport of the parent and progeny radionuclides follows.

Transport of the parent radionuclide along a groundwater pathline is governed by the advection-dispersion-reaction equation (Reference 2.4S.13-5), which is given as

$$R\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2} - v\frac{\partial C}{\partial x} - \lambda RC$$ Equation 2.4S.13-1

where: *C* = radionuclide concentration; *R* = retardation factor; *D* = coefficient of longitudinal hydrodynamic dispersion; *v* = average linear velocity; *t* = groundwater travel time, *x* = travel distance, and = radioactive decay constant. The retardation factor is defined from the relationship

$$R = 1 + \frac{\rho_b K_d}{n_e}$$ Equation 2.4S.13-2

where: $_b$ = bulk density; K_d = distribution coefficient; and n_e = effective porosity. The average linear velocity is determined using Darcy's law, which is

$$v = -\frac{K}{n_e}\frac{dh}{dx}$$ Equation 2.4S.13-3

where: *K* = hydraulic conductivity; and *dh/dx* = hydraulic gradient. The radioactive decay constant can be written as

$$\lambda = \frac{\ln 2}{t_{1/2}}$$ Equation 2.4S.13-4

where $t_{1/2}$ = radionuclide half-life.

Using the method of characteristics approach described in Reference 2.4S.13-6, the material derivative of concentration can be written as

$$\frac{dC}{dt} = \frac{\partial C}{\partial t} + \frac{dx}{dt}\frac{\partial C}{\partial x}$$ Equation 2.4S.13-5

Conservatively neglecting hydrodynamic dispersion, the characteristic equations for Equation 2.4S.13-1 can be expressed as follows:

$$\frac{dC}{dt} = -\lambda C$$ Equation 2.4S.13-6

$$\frac{dx}{dt} = \frac{v}{R}$$ Equation 2.4S.13-7

The solutions of the system of equations comprising Equations 2.4S.13-6 and 2.4S.13-7 can be obtained by integration to yield the characteristic curves of Equation 2.4S.13-1. For the parent radionuclide, the equations representing the characteristic curves can be obtained as

$$C_1 = C_{10}\exp(-\lambda_1 t)$$ Equation 2.4S.13-8

$$t = R_1 L / v$$ Equation 2.4S.13-9

where: C_1 = concentration of the parent radionuclide; C_{10} = initial concentration of the parent radionuclide; = radioactive decay constant for the parent radionuclide; R_1 = retardation factor for the parent radionuclide; and *L* = groundwater pathline length.

Similar relationships exist for progeny radionuclides. For the first progeny in the decay chain, the advection-dispersion-reaction equation is

$$R_2\frac{\partial C_2}{\partial t} = D\frac{\partial^2 C_2}{\partial x^2} - v\frac{\partial C_2}{\partial x} + d_{12}\lambda_1 R_1 C_1 - \lambda_2 R_2 C_2$$ Equation 2.4S.13-10

where: subscript 2 denotes the properties/concentration of the first progeny radionuclide; and d_{12} = fraction of parent radionuclide transitions that result in production of progeny radionuclide. The characteristic equations for Equation 2.4S.13-10, again conservatively neglecting hydrodynamic dispersion, can be derived as

$$\frac{dC_2}{dt} = d_{12}\lambda_1' C_1 - \lambda_2 C_2$$ Equation 2.4S.13-11

$$\frac{dx}{dt} = \frac{v}{R_2}$$ Equation 2.4S.13-12

where: $\lambda_1' = \lambda_1 R_1 / R_2$. Recognizing that Equation 2.4S.13-11 is formally similar to Equation B.43 of Reference 2.4S.13-2, these equations can be integrated to yield

$$C_2 = K_1 \exp(-\lambda_1' t) + K_2 \exp(-\lambda_2 t)$$ Equation 2.4S.13-13

$$t = R_2 L / v$$ Equation 2.4S.13-14

for which

$$K_1 = \frac{d_{12}\lambda_2 C_{10}}{\lambda_2 - \lambda_1'}$$

$$K_2 = C_{20} - \frac{d_{12}\lambda_2 C_{10}}{\lambda_2 - \lambda_1'}$$

The advection-dispersion-reaction equation for the second progeny in the decay chain is

$$R_3 \frac{\partial C_3}{\partial t} = D \frac{\partial^2 C_3}{\partial x^2} - v \frac{\partial C_3}{\partial x} + d_{13}\lambda_1 R_1 C_1 + d_{23}\lambda_2 R_2 C_2 - \lambda_3 R_3 C_3$$ Equation 2.4S.13-15

where: subscript 3 denotes the properties/concentration of the second progeny radionuclide; d_{13} = fraction of parent radionuclide transitions that result in production of second progeny radionuclide; and d_{23} = fraction of first progeny radionuclide transitions that result in production of second progeny radionuclide. The characteristic equations for Equation 2.4S.13-15, again conservatively neglecting hydrodynamic dispersion, can be derived as

$$\frac{dC_3}{dt} = d_{13}\lambda_1' C_1 + d_{23}\lambda_2' C_2 - \lambda_3 C_3$$ Equation 2.4S.13-16

$$\frac{dx}{dt} = \frac{v}{R_3}$$ Equation 2.4S.13-17

where: $\lambda_1' = \lambda_1 R_1 / R_3$; and $\lambda_2' = \lambda_2 R_2 / R_3$. Considering the formal similarity of Equation 2.4S.13-16 to Equation B.54 of Reference 2.4S.13-2, Equations 2.4S.13-16 and 2.4S.13-17 can be integrated to yield

$$C_3 = K_1 \exp(-\lambda_1' t) + K_2 \exp(-\lambda_2' t) + K_3 \exp(-\lambda_3 t)$$ Equation 2.4S.13-18

$$t = R_3 L / v$$ Equation 2.4S.13-19

for which

$$K_1 = \frac{d_{13}\lambda_3 C_{10}}{\lambda_3 - \lambda_1'} + \frac{d_{23}\lambda_2' d_{12}\lambda_3 C_{10}}{(\lambda_3 - \lambda_1')(\lambda_2' - \lambda_1')}$$

$$K_2 = \frac{d_{23}\lambda_3 C_{20}}{\lambda_3 - \lambda_2'} - \frac{d_{23}\lambda_2' d_{12}\lambda_3 C_{10}}{(\lambda_3 - \lambda_2')(\lambda_2' - \lambda_1')}$$

$$K_3 = C_{30} - \frac{d_{13}\lambda_3 C_{10}}{\lambda_3 - \lambda_1'} - \frac{d_{23}\lambda_3 C_{20}}{\lambda_3 - \lambda_2'} + \frac{d_{23}\lambda_2' d_{12}\lambda_3 C_{10}}{(\lambda_3 - \lambda_1')(\lambda_3 - \lambda_2')}$$

2.4S.13.1.3.1 Transport Considering Advection and Radioactive Decay

The screening model analysis was performed on Pathway 1, with a terminus at the offsite stock watering well in the Lower Shallow Aquifer, which would be the closest potential exposure point to the STP site. The screening analysis was performed considering advection and radioactive decay only. The pathway was screened using the representative linear groundwater velocity and the maximum linear groundwater velocity (shortest estimated travel time of 45,000 days) for the Lower Shallow Aquifer (Table 2.4S.12-17). The computed concentrations were compared with the 10 CFR 20, Appendix B, Table 2, ECLs. The ratio of the groundwater concentration to the ECL was used as the screening indicator. Ratios that were greater than or equal to 0.01, which means that the groundwater concentration is predicted to be greater than or equal to one percent of the ECL, were selected for further evaluation using retardation.

The results of the screening analysis are summarized on Table 2.4S.13-2. The results for Pathway 1 indicate that the radionuclides Ni-63, Sr-90, Y-90, Cs-137, and Pu-239 are of concern. Results were the same regardless of which travel time (representative or maximum) was used.

2.4S.13.1.3.2 Transport Considering Advection, Radioactive Decay, and Retardation

The radionuclides of concern identified by the screening analysis were further evaluated in the next step, considering retardation and using the representative travel times from Table 2.4S.12-17 (100,000 days for Pathway 1 and 197,800 days for Pathway 2) and the bulk densities presented in Table 2.4S.12-14. Distribution coefficients for these radionuclides were assigned using either literature based or site-specific laboratory measured values.

Site-specific distribution coefficients were used for Ni-63, Sr-90, Cs-137, and Pu-239. These values were based on the laboratory K_d analysis of 10 soil samples obtained from the Lower Shallow Aquifer at the STP 3 & 4 site (Reference 2.4S.13-7) as shown on Table 2.4S.13-3. ASTM method 4646-03 (Reference 2.4S.13-8) was used to determine laboratory K_d values using site groundwater. For individual K_d test results reported as greater than the given value, the given value is used for the K_d. For each of these radionuclides, the geometric mean of the reported values was used in the transport analysis to best represent the subsurface material in the Lower Shallow Aquifer zone beneath the site (Table 2.4S.13-4).

The distribution coefficients for Y-90 and Np-239 were taken from published values summarized in Reference 2.4S.13-9. The K_d values from the reference are assumed to be lognormally distributed, and, for conservatism, the selected K_d values were taken as the lowest 10 percentile probability in the data distribution. The lowest 10 percentile probability was used since the data set represents values from a wide range of soil types, but the STP site soils in the transport pathways are primarily sandy, which would have K_d values in the lower range of the data set. In the case of Y-90, no data were available to assign a K_d value. Instead, adsorption characteristics for yttrium were assumed to be similar to that of scandium, as these two elements lie adjacent in the periodic table. The K_d value for Y-90 was then estimated from the distribution for scandium.

The predicted concentrations of the radionuclides are summarized on Table 2.4S.13-4. Results are summarized as follows:

- Pathway 1: Lower Shallow Aquifer: No radionuclides are predicted to exceed the ECL
- Pathway 2: Lower Shallow Aquifer: No radionuclides are predicted to exceed the ECL

2.4S.13.1.4 Compliance with 10 CFR 20

As previously stated, the Lower Shallow Aquifer is considered the most likely groundwater pathway to be impacted by an accidental release (LCW collector tank rupture). The radionuclide transport analysis presented for the Lower Shallow Aquifer indicates that the accidental release of radionuclides to groundwater is individually below each of their ECLs at the exposure point (livestock watering well or surface water in the Colorado River). 10 CFR 20, Appendix B, Table 2 imposes additional requirements when the identity and concentration of each radionuclide in a mixture are known. In this case, the ratio present in the mixture and the concentration otherwise established in 10 CFR 20 for the specified radionuclides not in a mixture may not exceed “1” (i.e., “unity”). The sum of fractions approach has been applied to the radionuclide concentrations estimated above. Results are summarized in Table 2.4S.13-5. The sum of fractions for the mixtures is 0.01 for both pathways. This analysis conservatively assumes the advection/radioactive decay screening concentrations for pathway 2 are the same as for pathway 1. The longer travel time for pathway 2 would allow additional radioactive decay along this pathway and would result in lower predicted concentrations. Ignoring this additional decay time would result in higher predicted radionuclide concentrations at the pathway 2 receptor, and thus a more conservative prediction of exposure. The analysis results indicate that an accidental liquid release of effluents in groundwater would not exceed 10 CFR 20 limits at the Lower Shallow Aquifer exposure points, which are the most likely groundwater exposure routes to be impacted by an accidental release.

A sensitivity analysis was performed using the range of average linear velocities/travel times from Table 2.4S.12-17 and the range of distribution coefficients (K_d) from Table 2.4S.13-3. For example, the maximum average linear velocity (shortest travel time) incorporated the minimum laboratory K_d values (or 10 percent of the literature value for those isotopes without site specific laboratory tests) and the minimum average linear velocity (longest travel time) incorporated the maximum laboratory K_d values (or 10 percent of the literature value for those isotopes without site specific laboratory tests).

The result of the sensitivity analysis indicates that only one radionuclide (Pu-239) would slightly exceed its ECL when using the maximum average linear velocity (minimum travel time) and minimum K_d laboratory values for Transport Pathway 1. The geologic depositional environment at the STP site suggests that the use of the maximum average linear velocity would be extreme and that the representative average linear velocities used in the analyses best represents the hydrogeologic conditions beneath the STP site. The representative average linear velocities utilizing averages and geometric means of the material properties would best represent the discontinuous, fine-grained mixtures of the sand, silt, and clay subsurface materials described in Subsection 2.4S.12. Using the representative average linear velocities, no radionuclides are predicted to exceed the ECL.

The analysis presented in this section is considered to be conservative because:

- The analysis does not consider dispersion or dilution; both of these mechanisms would act to reduce the concentrations of the radionuclides.
- The analysis assumes that no mitigative measures are implemented to reduce offsite exposure. Because the travel times to the receptors are on the order of hundreds of years, it would be possible to implement measures to further reduce off site exposure.
- No credit is taken for the radwaste system components designed to prevent environmental releases, such as a stainless steel lined compartment to contain tank spillage and specially constructed building components surrounding the tanks to capture and prevent releases from the Radwaste Building. In accordance with Branch Technical Position 11-6 in NUREG-0800 (Reference 2.4S.13-3), these design components would mitigate potential release from the building tanks to the subsurface environment.
- The radwaste building foundation level is below the groundwater potentiometric surface of both the Upper and Lower Shallow Aquifer zones. In the unlikely event the basement exterior walls leaked and associated steel liners and sump pumps were to fail simultaneously, groundwater would flow into the Radwaste Building, precluding the release of liquid effluents out of the building unless the water level in the building is higher in elevation than that of the surrounding groundwater potentiometric head.

2.4S.13.2 Direct Releases to Surface Waters

The design of the Liquid Radioactive Waste System (LWMS) for STP 3 & 4 as described in Section 11.2 specifies that all liquid radwaste tanks are to be contained indoors and the Radwaste Building will have Seismic Category I walls and basemat of sufficient dimensions to contain all liquid radwaste. Because there are no outdoor tanks in the LWMS that could release radioactive effluent, no accident scenario could result in the release of effluent directly to the surface water.

The Radwaste Building is a reinforced concrete structure consisting of Seismic Category I substructure. As described in Section 3.4, the building does not contain safety-related equipment and is not contiguous with other plant structures except through the radwaste piping and tunnel. In case of flooding, the building structure serves as a large sump which can collect and hold any leakage within the building. The medium and large radwaste tanks are housed in sealed compartments which are designed to contain any spillage or leakage from tanks that may rupture.

Subsection 2.4S.1, Figure 2.4S.1-9 shows the flood inundated areas delineated by the Federal Emergency Management Agency in the vicinity of the STP site. STP 3 & 4 is located in Zone C, identified as areas of minimal flooding. The figure suggests STP 3 & 4 is beyond the areas moderately impacted by 100-year and 500-year flood event.

A flood, such as that caused by an MCR dike breach, could flood the Radwaste Building and potentially release radioactive materials into the environment. A flood of this magnitude would disperse and dilute the radionuclide concentration of a surface water spill. As stated in Subsection 2.4S.1, there are no known Colorado River or Little Robbins Slough water users downstream of the STP site and therefore, no surface water user would be affected by a diluted surface water release due to an unlikely event of a flood of this magnitude.

2.4S.13.3 References

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2.4S.13-3 "Postulated Radioactive Releases Due to Liquid-Containing Tank Failures," Branch Technical Position 11-6, NUREG-0800, U.S. Nuclear Regulatory Commission, March 2007.

2.4S.13-4 Coastal Plain/Coastal Bend Groundwater Conservation Districts Database. available at http://www.gis.aecom/cbcpgcd, accessed 3/20/07.

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2.4S.13-7 Savannah River National Laboratory, STP Site Specific Kd Results, Submitted by Correspondence in Letter dated August 31, 2007 from MACTEC to Bechtel Power Corporation.

2.4S.13-8 "Standard Test Method for 24-h Batch-Type Measurements of Contaminant Sorption by Soils and Sediments," ASTM (American Society for Testing and Materials), 2003.

2.4S.13-9 "Development of Probabilistic RESRAD 6.0 and RESRAD-BUILD 3.0 Computer Codes," NUREG/CR-6697, Yu, C., LePoire, D., Gnanapragasam, E., Arnish, J., Kamboj, S., Biwer, B.M., Cheng, J-J, Zilen, A., and Chen, S.Y., Argonne National Laboratory, 2000.

Table 2.4S.13-1 Low Conductivity Waste Collection Tank and Reactor Coolant Radionuclide Inventory

Radioisotope	Half-life [1] $t^{1/2}$ (days)	Low Conductivity Waste Tank [2]		Reactor Coolant [3]	
		Activity (MBq)	Concentration (µCi/mL)	Concentration (MBq/g)	Concentration (µCi/mL)
H-3	4,510	NA	NA	3.7E-04	1.0E-02
Na-24	0.625	1.3E+04	2.5E-03	1.3E-03	3.5E-02
P-32	14.3	2.7E+03	5.1E-04	2.4E-05	6.5E-04
Cr-51	27.7	1.0E+05	2.0E-02	7.4E-04	2.0E-02
Mn-54	313	2.2E+03	4.3E-04	8.5E-06	2.3E-04
Mn-56	0.107	1.2E+04	2.3E-03	6.7E-03	1.8E-01
Fe-55	986	1.1E+04	2.1E-03	1.2E-04	3.2E-03
Fe-59	44.5	6.0E+02	1.2E-04	3.7E-06	1.0E-04
Co-58	70.8	4.4E+03	8.6E-04	2.4E-05	6.5E-04
Co-60	1,930	1.5E+04	2.8E-03	4.8E-05	1.3E-03
Ni-63	35,100	3.8E+04	7.3E-03	1.2E-04	3.2E-03
Cu-64	0.529	3.2E+04	6.1E-03	3.7E-03	1.0E-01
Zn-65	244	6.0E+03	1.2E-03	2.4E-05	6.5E-04
Rb-89	0.0106	9.4E+01	1.8E-05	7.8E-04	2.1E-02
Sr-89 [4]	50.5	2.1E+03	4.1E-04	1.2E-05	3.2E-04
Sr-90	10,600	2.7E+02	5.2E-05	8.5E-07	2.3E-05
Sr-91	0.396	3.3E+03	6.4E-04	5.2E-04	1.4E-02
Sr-92	0.113	2.6E+03	5.0E-04	1.4E-03	3.8E-02
Y-90 [4]	2.67	2.7E+02	5.2E-05	8.5E-07	2.3E-05
Y-91 [4]	58.5	3.0E+04	5.7E-03	4.8E-06	1.3E-04
Y-92 [4]	0.148	2.3E+03	4.5E-04	8.1E-04	2.2E-02
Y-93	0.421	2.7E+04	5.3E-03	5.2E-04	1.4E-02
Zr-95	64	6.0E+03	1.2E-03	9.6E-07	2.6E-05
Nb-95 [4]	35.2	6.0E+03	1.2E-03	9.6E-07	2.6E-05
Mo-99	2.75	8.9E+03	1.7E-03	2.4E-04	6.5E-03
Tc-99m [4]	0.251	8.9E+03	1.7E-03	2.4E-04	6.5E-03
Ru-103	39.3	1.4E+04	2.7E-03	2.4E-06	6.5E-05
Ru-106	368	2.7E+03	5.2E-04	3.7E-07	1.0E-05
Rh-103m [4]	0.0392	1.4E+04	2.7E-03	2.4E-06	6.5E-05
Rh-106 [4]	0.000345	2.7E+03	5.2E-04	3.7E-07	1.0E-05
Ag-110m	250	3.0E+01	5.8E-06	1.2E-07	3.2E-06
Te-129m	33.6	7.1E+02	1.4E-04	4.8E-06	1.3E-04

Table 2.4S.13-1 Low Conductivity Waste Collection Tank and Reactor Coolant Radionuclide Inventory (Continued)

Radioisotope	Half-life [1] $t^{1/2}$ (days)	Low Conductivity Waste Tank [2] Activity (MBq)	Low Conductivity Waste Tank [2] Concentration (µCi/mL)	Reactor Coolant [3] Concentration (MBq/g)	Reactor Coolant [3] Concentration (µCi/mL)
Te-131m	1.25	2.3E+02	4.3E-05	1.2E-05	3.2E-04
Te-132	3.26	5.1E+02	9.8E-05	1.2E-06	3.2E-05
I-131 [4]	8.04	2.0E+04	3.9E-03	5.9E-04	1.6E-02
I-132 [4]	0.0958	8.1E+03	1.6E-03	5.2E-03	1.4E-01
I-133	0.867	5.5E+04	1.1E-02	4.1E-03	1.1E-01
I-134	0.0365	5.3E+03	1.0E-03	8.9E-03	2.4E-01
I-135	0.275	2.5E+04	4.8E-03	5.6E-03	1.5E-01
Cs-134	753	4.0E+02	7.7E-05	3.3E-06	8.9E-05
Cs-136	13.1	1.4E+02	2.6E-05	2.2E-06	5.9E-05
Cs-137	11,000	1.2E+03	2.4E-04	8.9E-06	2.4E-04
Cs-138	0.0224	5.5E+02	1.1E-04	1.5E-03	4.1E-02
Ba-140	12.7	5.0E+03	9.7E-04	4.8E-05	1.3E-03
La-140 [4]	1.68	1.9E+05	3.6E-02	4.8E-05	1.3E-03
Ce-141	32.5	2.0E+04	3.9E-03	3.7E-06	1.0E-04
Ce-144	284	2.7E+03	5.1E-04	3.7E-06	1.0E-04
Pr-143	13.6	2.7E+03	5.1E-04	NA	NA
Pr-144 [4]	0.012	NA	NA	3.7E-07	1.0E-05
W-187	0.996	5.7E+02	1.1E-04	3.7E-05	1.0E-03
Np-239 [4]	2.36	3.2E+04	6.2E-03	1.0E-03	2.7E-02
Total		7.4E+05	1.4E-01	4.5E-02	1.2E+00

Bounding concentration used for source term

[1] Values from references 2.4S.13-1 and 2.4S.13-2

[2] Concentrations obtained by dividing the activities by the tank volume of 140,000,000 mL. Activity concentrations from Section 12.2 (Low Conductivity Waste Tank)

[3] Concentrations obtained from Section 11.1 (Reactor Coolant Water)

[4] Decay chain progeny

Table 2.4S.13-2 Bounding concentration used for source term

Pathway 1 Lower Shallow Aquifer

Parent	Progeny	Half-life (days)	d_{12}	d_{13}	d_{23}	Decay Rate ($days^{-1}$)[1]	Bounding Concentration (±Ci/cm^3)[2]	K_1 [3]	K_2 [4]	K_3 [5]	Travel Time (days)[6]	Groundwater (±Ci/cm^3)[7]	ECL (±Ci/cm^3)[8]	Groundwater/ ECL Ratio
H-3[	-	4.51E+03	-	-	-	1.54E-04	1.00E-02	-	-	-	4.50E+04	9.9E-06	1.00E-03	9.92E-03
Na-24	-	6.25E-01	-	-	-	1.11E+00	3.50E-02	-	-	-	4.50E+04	0.0E+00	5.00E-05	0.00E+00
P-32	-	1.43E+01	-	-	-	4.85E-02	6.50E-04	-	-	-	4.50E+04	0.0E+00	9.00E-06	0.00E+00
Cr-51	-	2.77E+01	-	-	-	2.50E-02	2.00E-02	-	-	-	4.50E+04	0.0E+00	5.00E-04	0.00E+00
Mn-54	-	3.13E+02	-	-	-	2.21E-03	4.30E-04	-	-	-	4.50E+04	2.3E-47	3.00E-05	7.54E-43
Mn-56	-	1.07E-01	-	-	-	6.48E+00	1.80E-01	-	-	-	4.50E+04	0.0E+00	7.00E-05	0.00E+00
Fe-55	-	9.86E+02	-	-	-	7.03E-04	3.20E-03	-	-	-	4.50E+04	5.8E-17	1.00E-04	5.84E-13
Fe-59	-	4.45E+01	-	-	-	1.56E-02	1.20E-04	-	-	-	4.50E+04	0.0E+00	1.00E-05	0.00E+00
Co-58	-	7.08E+01	-	-	-	9.79E-03	8.60E-04	-	-	-	4.50E+04	4.0E-195	2.00E-05	2.00E-190
Co-60	-	1.93E+03	-	-	-	3.59E-04	2.80E-03	-	-	-	4.50E+04	2.7E-10	3.00E-06	8.94E-05
Ni-63	-	3.51E+04	-	-	-	1.97E-05	7.30E-03	-	-	-	4.50E+04	3.0E-03	1.00E-04	3.00E+01
Cu-64	-	5.29E-01	-	-	-	1.31E+00	1.00E-01	-	-	-	4.50E+04	0.0E+00	2.00E-04	0.00E+00
Zn-65	-	2.44E+02	-	-	-	2.84E-03	1.20E-03	-	-	-	4.50E+04	3.6E-59	5.00E-06	7.28E-54
Rb-89	-	1.06E-02	-	-	-	6.54E+01	2.10E-02	-	-	-	4.50E+04	0.0E+00	9.00E-04	0.00E+00
-	Sr-89	5.05E+01	1	-	-	1.37E-02	4.10E-04	-8.61E-08	4.14E-04	-	4.50E+04	2.4E-272	8.00E-06	2.95E-267
Sr-90	-	1.06E+04	-	-	-	6.54E-05	5.20E-05	-	-	-	4.50E+04	2.7E-06	5.00E-07	5.48E+00
-	Y-90	2.67E+00	1	-	-	2.60E-01	5.20E-05	5.20E-05	-1.31E-08		4.50E+04	2.7E-06	7.00E-06	3.92E-01
Sr-91	-	3.96E-01	-	-	-	1.75E+00	1.40E-02	-	-	-	4.50E+04	0.0E+00	2.00E-05	0.00E+00
-	Y-91m	3.45E-02	0.578	-	-	2.01E+01	0.00E+00	8.86E-03	-8.86E-03	-	4.50E+04	0.0E+00	2.00E-03	0.00E+00
-	Y-91	5.58E+01	-	0.422	1	1.24E-02	5.70E-03	-4.45E-05	5.48E-06	5.76E-03	4.50E+04	9.9E-246	8.00E-06	1.23E-240
Sr-92	-	1.13E-01	-	-	-	6.13E+00	3.80E-02	-	-	-	4.50E+04	0.0E+00	4.00E-05	0.00E+00
-	Y-92	1.48E-01	1	-	-	4.68E+00	2.20E-02	-7.10E-02	1.45E-01		4.50E+04	0.0E+00	4.00E-05	0.00E+00
Y-93	-	4.21E-01	-	-	-	1.65E+00	1.40E-02	-	-	-	4.50E+04	0.0E+00	2.00E-05	0.00E+00
Zr-95	-	6.40E+01	-	-	-	1.08E-02	1.20E-03	-	-	-	4.50E+04	2.6E-215	2.00E-05	1.31E-210
-	Nb-95m	3.61E+00	0.007	-	-	1.92E-01	0.00E+00	8.90E-06	-8.90E-06	-	4.50E+04	1.9E-217	3.00E-05	6.47E-213

Table 2.4S.13-2 Bounding concentration used for source term (Continued)

Pathway 1 Lower Shallow Aquifer

Parent	Progeny	Half-life (days)	d_{12}	d_{13}	d_{23}	Decay Rate (days^{-1})[1]	Bounding Concentration (±Ci/cm^3)[2]	K_1 [3]	K_2 [4]	K_3 [5]	Travel Time (days)[6]	Groundwater (±Ci/cm^3)[7]	ECL (±Ci/cm^3)[8]	Groundwater/ ECL Ratio
-	Nb-95	3.52E+01	-	0.993	1	1.97E-02	1.20E-03	2.65E-03	1.02E-06	1.32E-03	4.50E+04	5.8E-215	3.00E-05	1.92E-210
Mo-99	-	2.75E+00	-	-	-	2.52E-01	6.50E-03	-	-	-	4.50E+04	0.0E+00	2.00E-05	0.00E+00
-	Tc-99m	2.51E-01	0.876	-	-	2.76E+00	6.50E-03	6.27E-03	2.34E-04	-	4.50E+04	0.0E+00	1.00E+03	0.00E+00
Ru-103	-	3.93E+01	-	-	-	1.76E-02	2.70E-03	-	-	-	4.50E+04	0.0E+00	3.00E-05	0.00E+00
-	Rh-103m	3.90E-02	0.997	-	-	1.78E+01	2.70E-03	2.69E-03	5.43E-06	-	4.50E+04	0.0E+00	6.00E-03	0.00E+00
Ru-106	-	3.68E+02	-	-	-	1.88E-03	5.20E-04	-	-	-	4.50E+04	8.0E-41	3.00E-06	2.68E-35
-	Rh-106	3.45E-04	1	-	-	2.01E+03	5.20E-04	5.20E-04	-4.88E-10	-	4.50E+04	8.0E-41	NA	NA
Ag-110m	-	2.50E+02	-	-	-	2.77E-03	5.80E-06	-	-	-	4.50E+04	3.8E-60	6.00E-06	6.31E-55
-	Ag-110	2.85E-04	0.0133	-	-	2.43E+03	0.00E+00	7.71E-08	-7.71E-08	-	4.50E+04	5.0E-62	NA	NA
Te-129m	-	3.36E+01	-	-	-	2.06E-02	1.40E-04	-	-	-	4.50E+04	0.0E+00	7.00E-06	0.00E+00
-	Te-129	4.83E-02	0.65	-	-	1.44E+01	0.00E+00	9.11E-05	-9.11E-05	-	4.50E+04	0.0E+00	4.00E-04	0.00E+00
Te-131m	-	1.25E+00	-	-	-	5.55E-01	3.20E-04	-	-	-	4.50E+04	0.0E+00	8.00E-06	0.00E+00
-	Te-131	1.74E-02	0.222	-	-	3.98E+01	0.00E+00	7.20E-05	-7.20E-05	-	4.50E+04	0.0E+00	8.00E-05	0.00E+00
-	I-131	8.04E+00	-	0.778	1	8.62E-02	1.60E-02	-5.36E-05	1.56E-07	1.60E-02	4.50E+04	0.0E+00	1.00E-06	0.00E+00
Te-132	-	3.26E+00	-	-	-	2.13E-01	9.80E-05	-	-	-	4.50E+04	0.0E+00	9.00E-06	0.00E+00
-	I-132	9.58E-02	1	-	-	7.24E+00	1.40E-01	1.01E-04	1.40E-01	-	4.50E+04	0.0E+00	1.00E-04	0.00E+00
I-133	-	8.67E-01	-	-	-	7.99E-01	1.10E-01	-	-	-	4.50E+04	0.0E+00	NA	NA
-	Xe-133m	2.19E+00	0.029	-	-	3.17E-01	0.00E+00	-2.09E-03	2.09E-03	-	4.50E+04	0.0E+00	NA	NA
-	Xe-133	5.25E+00	-	0.971	1	1.32E-01	0.00E+00	-2.11E-02	-1.50E-03	7.75E-02	4.50E+04	0.0E+00	NA	NA
I-134	-	3.65E-02	-	-	-	1.90E+01	2.40E-01	-	-	-	4.50E+04	0.0E+00	4.00E-04	0.00E+00
I-135	-	2.75E-01	-	-	-	2.52E+00	1.50E-01	-	-	-	4.50E+04	0.0E+00	3.00E-05	0.00E+00
-	Xe-135m	1.06E-02	0.154	-	-	6.54E+01	0.00E+00	2.40E-02	-2.40E-02	-	4.50E+04	0.0E+00	NA	NA
-	Xe-135	3.79E-01	-	0.846	1	1.83E+00	0.00E+00	-3.36E-01	6.91E-04	6.65E-02	4.50E+04	0.0E+00	NA	NA
Cs-134	-	7.53E+02	-	-	-	9.21E-04	8.90E-05	-	-	-	4.50E+04	9.1E-23	9.00E-07	1.01E-16
Cs-136	-	1.31E+01	-	-	-	5.29E-02	5.90E-05	-	-	-	4.50E+04	0.0E+00	6.00E-06	0.00E+00

Table 2.4S.13-2 Bounding concentration used for source term (Continued)

Pathway 1 Lower Shallow Aquifer

Parent	Progeny	Half-life (days)	d_{12}	d_{13}	d_{23}	Decay Rate (days^{-1})[1]	Bounding Concentration (±Ci/cm^3)[2]	K_1 [3]	K_2 [4]	K_3 [5]	Travel Time (days)[6]	Groundwater (±Ci/cm^3)[7]	ECL (±Ci/cm^3)[8]	Groundwater/ ECL Ratio
Cs-137	-	1.10E+04	-	-	-	6.30E-05	2.40E-04	-	-	-	4.50E+04	1.4E-05	1.00E-06	1.41E+01
-	Ba-137m	1.77E-03	0.946	-	-	3.92E+02	0.00E+00	2.27E-04	-2.27E-04	-	4.50E+04	1.3E-05	NA	NA
Cs-138	-	2.24E-02	-	-	-	3.09E+01	4.10E-02	-	-	-	4.50E+04	0.0E+00	4.00E-04	0.00E+00
Ba-140	-	1.27E+01	-	-	-	5.46E-02	1.30E-03	-	-	-	4.50E+04	0.0E+00	8.00E-06	0.00E+00
-	La-140	1.68E+00	1	-	-	4.13E-01	3.60E-02	1.50E-03	3.45E-02	-	4.50E+04	0.0E+00	9.00E-06	0.00E+00
Ce-141	-	3.25E+01	-	-	-	2.13E-02	3.90E-03	-	-	-	4.50E+04	0.0E+00	3.00E-05	0.00E+00
Ce-144	-	2.84E+02	-	-	-	2.44E-03	5.10E-04	-	-	-	4.50E+04	1.0E-51	3.00E-06	3.40E-46
-	Pr-144m	5.07E-03	0.0178	-	-	1.37E+02	0.00E+00	9.08E-06	-9.08E-06	-	4.50E+04	1.8E-53	NA	NA
-	Pr-144	1.20E-02	-	0.9822	0.999	5.78E+01	1.00E-05	5.01E-04	6.63E-06	3.61E-04	4.50E+04	1.0E-51	6.00E-04	1.67E-48
Pr-143	-	1.36E+01	-	-	-	5.10E-02	5.10E-04	-	-	-	4.50E+04	0.0E+00	2.00E-05	0.00E+00
W-187	-	9.96E-01	-	-	-	6.96E-01	1.00E-03	-	-	-	4.50E+04	0.0E+00	3.00E-05	0.00E+00
Np-239	-	2.36E+00	-	-	-	2.94E-01	2.70E-02	-	-	-	4.50E+04	0.0E+00	2.00E-05	0.00E+00
-	Pu-239	8.79E+06	1	-	-	7.89E-08	0.00E+00	-7.25E-09	7.25E-09	-	4.50E+04	7.2E-09	2.00E-08	3.61E-01

Exceeds Effluent Screening Concentration Level of 1% of ECL. Values greater than or equal to 1% of the ECL are conservatively selected for further analysis

[1] Equation 2.4S.13-4
[2] Table 2.4S.13-1
[3] Equation 2.4S.13-13 or Equation 2.4S.13-18
[4] Equation 2.4S.13-13 or Equation 2.4S.13-18
[5] Equation 2.4S.13-18
[6] Table 2.4S.12-17
[7] Equation 2.4S.13-8, Equation 2.4S.13-13, or Equation 2.4S.13-18
[8] 10 CFR 20 Appendix B Table 2 Column 2
NA – Not Available

Table 2.4S.13-3 Laboratory Distribution Coefficient Measurements in mL/g for the Lower Shallow Aquifer

Boring ID	Sample ID	Corresponding Well	Replicate Analysis	Fe K_d			Ni K_d			Pu K_d			Co K_d			Sr K_d			Cs K_d		
				Value	Ave.	St Dev	Value	Ave.	St Dev	Value	Ave.	St. Dev.	Value	Ave.	St. Dev.	Value	Ave.	St. Dev.	Value	Ave.	St. Dev.
B-308	SS25	OW-308 L	-	-	>1820.0	1971.0	-	35.1	7.3	-	>1037.7	510.0	-	17.1	5.3	-	2.3	0.7	-	531.7	287.9
			1	>426.3	-	-	40.3	-	-	1398.3	-	-	13.4	-	-	1.8	-	-	328.2	-	-
			2	>3213.7	-	-	29.9	-	-	>677.1	-	-	20.8	-	-	2.8	-	-	735.3	-	-
B-332	SS23	OW-332 L [R]	-	-	847.5	896.2	-	50.2	2.1	-	>1577.2	399.4	-	8.3	0.1	-	1.6	0.1		160.1	0.1
			1	1481.2	-	-	48.7	-	-	>1294.7	-	-	8.2	-	-	1.6	-	-	160.2	-	-
			2	213.8	-	-	51.7	-	-	1859.6	-	-	8.4	-	-	1.5	-	-	160.1	-	-
B-348	SS17	OW-348 L	-	-	164.0	195.7	-	113.3	97.6	-	>962.2	284.6	-	9.6	0.8	-	2.0	1.0	-	242.6	65.4
			1	302.4	-	-	44.3	-	-	>1163.4	-	-	9.0	-	-	1.3	-	-	288.9	-	-
			2	25.6	-	-	182.3	-	-	761.0	-	-	10.2	-	-	2.6	-	-	196.4	-	-
B-349	SS23	OW-349 L	-	-	>1513.5	570.3	-	39.2	8.2	-	>2434.2	3.9	-	13.1	2.7	-	2.9	0.3	-	409.5	203.5
			1	>1916.8	-	-	44.9	-	-	2437.0	-	-	15.0	-	-	3.1	-	-	553.5	-	-
			2	>1110.2	-	-	33.4	-	-	>2431.4	-	-	11.2	-	-	2.7	-	-	265.6	-	-
B-408	SS22	OW-408 L	-	-	>1880.5	1856.2	-	31.6	10.7	-	>979.9	417.8	-	11.2	2.6	-	2.2	0.5	-	520.0	124.0
			1	>3193.0	-	-	39.1	-	-	>684.4	-	-	13.1	-	-	2.6	-	-	607.7	-	-
			2	>567.9	-	-	24.0	-	-	>1275.3	-	-	9.4	-	-	1.8	-	-	432.3	-	-
B-438	SS24	OW-438 L	-	-	>2447.5	920.2	-	30.3	5.1	-	877.6	353.8	-	5.5	1.2	-	1.0	0.9	-	104.0	27.3
			1	>3098.2	-	-	33.9	-	-	627.4	-	-	6.3	-	-	1.6	-	-	123.3	-	-
			2	>1796.8	-	-	26.7	-	-	1127.8	-	-	4.7	-	-	0.3	-	-	84.7	-	-
B-910	SS24	OW-910 L	-	-	>2032.5	1332.7	-	>567.9	744.6	-	>1063.4	550.2	-	24.1	1.2	-	6.5	0.8	-	2994.3	32.6
			1	>1090.2	-	-	>1094.4	-	-	>1452.4	-	-	24.9	-	-	7.1	-	-	3017.4	-	-
			2	>2974.9	-	-	41.3	-	-	>674.4	-	-	23.2	-	-	5.9	-	-	2971.3	-	-
B-930	SS27	OW-930 L	-	-	21.7	16.0	-	177.6	106.2	-	>627.3	822.4	-	5.9	0.6	-	1.3	0.4	-	83.3	9.3
			1	33.0	-	-	102.4	-	-	>1208.8	-	-	6.3	-	-	1.6	-	-	89.9	-	-
			2	10.4	-	-	252.7	-	-	45.8	-	-	5.4	-	-	1.1	-	-	76.8	-	-
B-933	SS24	OW-933 L	-		40.9	0.7	-	74.3	25.4	-	311.7	260.3	-	5.8	0.1	-	1.2	0.1	-	78.5	0.1
			1	41.3	-	-	56.3	-	-	495.7	-	-	5.9	-	-	1.3	-	-	78.6	-	-
			2	40.4	-	-	92.3	-	-	127.6	-	-	5.8	-	-	1.1	-	-	78.5	-	-
B-934	SS26	OW-934 L	-		15.5	8.1	-	237.5	46.3	-	141.8	134.9	-	6.6	0.9	-	1.9	0.8	-	56.5	4.1
			1	9.8	-	-	270.2	-	-	237.2	-	-	6.0	-	-	1.3	-	-	53.6	-	-
			2	21.2	-	-	204.7	-	-	46.4	-	-	7.3	-	-	2.4	-	-	59.4	-	-

Summary Statistics	Fe K_d	Ni K_d	Pu K_d	Co K_d	Sr K_d	Cs K_d
Number of samples	10.0	10.0	10.0	10.0	10.0	10.0
Minimum	15.5	30.3	141.8	5.5	1.0	56.5
Maximum	>2447.5	>567.9	>2434.2	24.1	6.5	2994.3
Arithmetic Mean	>1078.4	>135.7	>1001.3	10.7	2.3	518.1
Geometric Mean	>370.9	>81.8	>792.1	9.5	2.0	234.6
Standard Deviation	964.9	167.3	646.5	6.0	1.6	889.1
Skewness	0.0	2.3	1.1	1.4	2.4	2.9

Table 2.4S.13-4 Transport Analysis Considering Advection, Radioactive Decay, and Retardation

Pathway 1 | Bulk Density = 1.63 g/cm³ | Effective Porosity = 0.31 | Lower Shallow Aquifer

Parent	Progeny	Decay Rate λ_1 or λ_2 (day^{-1})	Progeny Branching Fraction d_{12}	K_1 [1]	K_2 [2]	Initial Concentration (µCi/cm³) [3]	Literature K_d [4] Mean µ	Literature K_d [4] Standard Deviation s	Literature K_d [4] 10% Probability Kd (cm³/g)	Site Specific Kd [4] Laboratory Geometric Mean (mL/g)	Retardation Factor[5]	Average Linear Velocity (ft/d)	Flow Path Length (ft)	Travel Time (days) [6]	Groundwater Concentration (µCi/cm³)[7]	ECL (µCi/cm³) [8]	Groundwater/ ECL Ratio
Ni-63	-	1.97E-05	-	-	-	7.30E-03	6.05	1.46	65.30	**81.8**	431.11	0.09	9,000	43,110,968	0.00E+00	1.00E-04	0.00E+00
Sr-90	-	6.54E-05	-	-	-	5.20E-05	3.45	2.12	2.08	**2.0**	11.52	0.09	9,000	1,151,613	1.02E-37	5.00E-07	2.03E-31
-	Y-90	2.60E-01	1	5.20E-05	-1.88E-09	5.20E-05	6.84	3.22	**15.08**	-	80.29	0.09	9,000	8,029,436	1.02E-37	7.00E-06	1.45E-32
Cs-137	-	6.30E-05	-	-	-	2.40E-04	6.10	2.33	22.51	**234.6**	1234.54	0.09	9,000	123,454,194	0.00E+00	1.00E-06	0.00E+00
Np-239	-	2.94E-01	-	-	-	2.70E-02	2.84	2.25	**0.96**	-	6.03	0.09	9,000	603,429	0.00E+00	2.00E-05	0.00E+00
-	Pu-239	7.89E-08	1	-5.00E-06	5.00E-06	0.00E+00	6.86	1.89	84.59	**792.1**	4165.91	0.09	9,000	416,591,290	2.66E-20	2.00E-08	1.33E-12

Pathway 2 | Bulk Density = 1.63 g/cm³ | Effective Porosity = 0.31 | Lower Shallow Aquifer

Parent	Progeny	Decay Rate λ_1 or λ_2 (day^{-1})	Progeny Branching Fraction d_{12}	K_1 [1]	K_2 [2]	Initial Concentration (µCi/cm³) [3]	Literature K_d [4] Mean µ	Literature K_d [4] Standard Deviation s	Literature K_d [4] 10% Probability Kd (cm³/g)	Site Specific Kd [4] Laboratory Geometric Mean (mL/g)	Retardation Factor[5]	Average Linear Velocity (ft/d)	Flow Path Length (ft)	Travel Time (days) [6]	Groundwater Concentration (µCi/cm³)[7]	ECL (µCi/cm³) [8]	Groundwater/ ECL Ratio
Ni-63	-	1.97E-05	-	-	-	7.30E-03	6.05	1.46	65.30	**81.8**	431.11	0.09	17,800	85,263,914	0.00E+00	1.00E-04	0.00E+00
Sr-90	-	6.54E-05	-	-	-	5.20E-05	3.45	2.12	2.08	**2.0**	11.52	0.09	17,800	2,277,634	1.06E-69	5.00E-07	2.12E-63
-	Y-90	2.60E-01	1	5.20E-05	-1.88E-09	5.20E-05	6.84	3.22	**15.08**	-	80.29	0.09	17,800	15,880,439	1.06E-69	7.00E-06	1.51E-64
Cs-137	-	6.30E-05	-	-	-	2.40E-04	6.10	2.33	22.51	**234.6**	1234.54	0.09	17,800	244,164,961	0.00E+00	1.00E-06	0.00E+00
Np-239	-	2.94E-01	-	-	-	2.70E-02	2.84	2.25	**0.96**	-	6.03	0.09	17,800	1,193,448	0.00E+00	2.00E-05	0.00E+00
-	Pu-239	7.89E-08	1	-5.00E-06	5.00E-06	0.00E+00	6.86	1.89	84.59	**792.1**	4165.91	0.09	17,800	823,924,996	2.93E-34	2.00E-08	1.46E-26

[1] Equation 2.4S.13-13
[2] Equation 2.4S.13-13
[3] Table 2.4S.13-1
[4] Literature values from Reference 2.4S.13-9
[5] Equation 2.4S.13-2
[6] Equation 2.4S.13-9 or 2.4S.13-14
[7] Equation 2.4S.13-8 or 2.4S.13-13
[8] 10 CFR 20 Appendix B Table 2 Column 2
Site-Specific values from Reference 2.4S.13-7
-“**Bold Value**” was selected for use in the analysis
-cm³/g ~= mL/g

Table 2.4S.13-5 Compliance with 10 CFR 20, Appendix B, Table 2, Column 2

Parent	Progeny	All Pathways	Pathway 1 Lower Shallow Aquifer	Pathway 2 Lower Shallow Aquifer	Pathway 1 Lower Shallow Aquifer	Pathway 2 Lower Shallow Aquifer
		Advection/Decay	Advection/Decay/Retardation		Minimum value	
		Groundwater/ECL Ratio	Groundwater/ECL Ratio	Groundwater/ECL Ratio	Groundwater/ECL Ratio	Groundwater/ECL Ratio
H-3	-	9.92E-03	-	-	9.92E-03	9.92E-03
Na-24	-	0.00E+00	-	-	0.00E+00	0.00E+00
P-32	-	0.00E+00	-	-	0.00E+00	0.00E+00
Cr-51	-	0.00E+00	-	-	0.00E+00	0.00E+00
Mn-54	-	7.54E-43	-	-	7.54E-43	7.54E-43
Mn-56	-	0.00E+00	-	-	0.00E+00	0.00E+00
Fe-55	-	5.84E-13	-	-	5.84E-13	5.84E-13
Fe-59	-	0.00E+00	-	-	0.00E+00	0.00E+00
Co-58	-	2.00E-190	-	-	2.00E-190	2.00E-190
Co-60	-	8.94E-05	-	-	8.94E-05	8.94E-05
Ni-63	-	3.00E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
Cu-64	-	0.00E+00	-	-	0.00E+00	0.00E+00
Zn-65	-	7.28E-54	-	-	7.28E-54	7.28E-54
Rb-89	-	0.00E+00	-	-	0.00E+00	0.00E+00
-	Sr-89	2.95E-267	-	-	2.95E-267	2.95E-267
Sr-90	-	5.48E+00	2.03E-31	2.12E-63	2.03E-31	2.12E-63
-	Y-90	3.92E-01	1.45E-32	1.51E-64	1.45E-32	1.51E-64
Sr-91	-	0.00E+00	-	-	0.00E+00	0.00E+00
-	Y-91m	0.00E+00	-	-	0.00E+00	0.00E+00
-	Y-91	1.23E-240	-	-	1.23E-240	1.23E-240
Sr-92	-	0.00E+00	-	-	0.00E+00	0.00E+00
-	Y-92	0.00E+00	-	-	0.00E+00	0.00E+00
Y-93	-	0.00E+00	-	-	0.00E+00	0.00E+00
Zr-95	-	1.31E-210	-	-	1.31E-210	1.31E-210
-	Nb-95m	6.47E-213	-	-	6.47E-213	6.47E-213
-	Nb-95	1.92E-210	-	-	1.92E-210	1.92E-210
Mo-99	-	0.00E+00	-	-	0.00E+00	0.00E+00
-	Tc-99m	0.00E+00	-	-	0.00E+00	0.00E+00
Ru-103	-	0.00E+00	-	-	0.00E+00	0.00E+00
-	Rh-103m	0.00E+00	-	-	0.00E+00	0.00E+00
Ru-106	-	2.68E-35	-	-	2.68E-35	2.68E-35
-	Rh-106	NA	-	-	NA	NA
Ag-110m	-	6.31E-55			6.31E-55	6.31E-55
-	Ag-110	NA	-	-	NA	NA
Te-129m	-	0.00E+00	-	-	0.00E+00	0.00E+00
-	Te-129	0.00E+00	-	-	0.00E+00	0.00E+00
Te-131m	-	0.00E+00	-	-	0.00E+00	0.00E+00
-	Te-131	0.00E+00	-	-	0.00E+00	0.00E+00
-	I-131	0.00E+00	-	-	0.00E+00	0.00E+00
Te-132	-	0.00E+00	-	-	0.00E+00	0.00E+00
-	I-132	0.00E+00	-	-	0.00E+00	0.00E+00
I-133	-	NA	-	-	NA	NA
-	Xe-133m	NA	-	-	NA	NA
-	Xe-133	NA	-	-	NA	NA

Table 2.4S.13-5 Compliance with 10 CFR 20, Appendix B, Table 2, Column 2 (Continued)

Parent	Progeny	All Pathways	Pathway 1 Lower Shallow Aquifer	Pathway 2 Lower Shallow Aquifer	Pathway 1 Lower Shallow Aquifer	Pathway 2 Lower Shallow Aquifer
		Advection/Decay	Advection/Decay/Retardation		Minimum value	
		Groundwater/ECL Ratio	Groundwater/ECL Ratio	Groundwater/ECL Ratio	Groundwater/ECL Ratio	Groundwater/ECL Ratio
I-134	-	0.00E+00	-	-	0.00E+00	0.00E+00
I-135	-	0.00E+00	-	-	0.00E+00	0.00E+00
-	Xe-135m	NA	-	-	NA	NA
-	Xe-135	NA	-	-	NA	NA
Cs-134	-	1.01E-16	-	-	1.01E-16	1.01E-16
Cs-136	-	0.00E+00	-	-	0.00E+00	0.00E+00
Cs-137	-	1.41E+01	0.00E+00	0.00E+00	0.00E+00	0.00E+00
-	Ba-137m	NA	-	-	NA	NA
Cs-138	-	0.00E+00	-	-	0.00E+00	0.00E+00
Ba-140	-	0.00E+00	-	-	0.00E+00	0.00E+00
-	La-140	0.00E+00	-	-	0.00E+00	0.00E+00
Ce-141	-	0.00E+00	-	-	0.00E+00	0.00E+00
Ce-144	-	3.40E-46	-	-	3.40E-46	3.40E-46
-	Pr-144m	NA	-	-	NA	NA
-	Pr-144	1.67E-48	-	-	1.67E-48	1.67E-48
Pr-143	-	0.00E+00	-	-	0.00E+00	0.00E+00
W-187	-	0.00E+00	-	-	0.00E+00	0.00E+00
Np-239	-	0.00E+00	0.00E+00	0.00E+00	0.00E+00	0.00E+00
-	Pu-239	3.61E-01	1.33E-12	1.46E-26	1.33E-12	1.46E-26
				Sum of Fractions	**0.010**	**0.010**

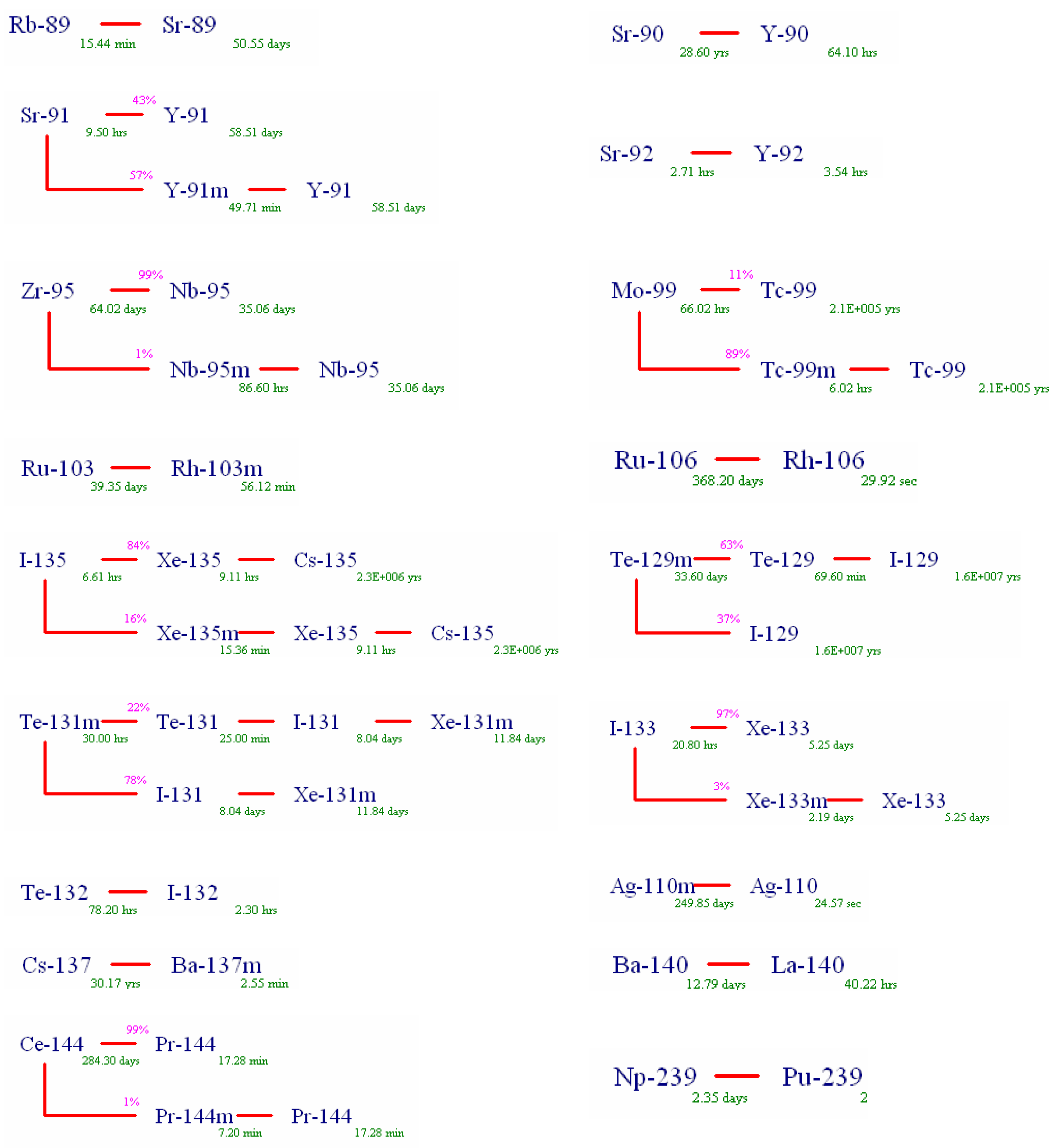

Figure 2.4S.13-1 Decay Chains Considered in Accidental Effluent Release

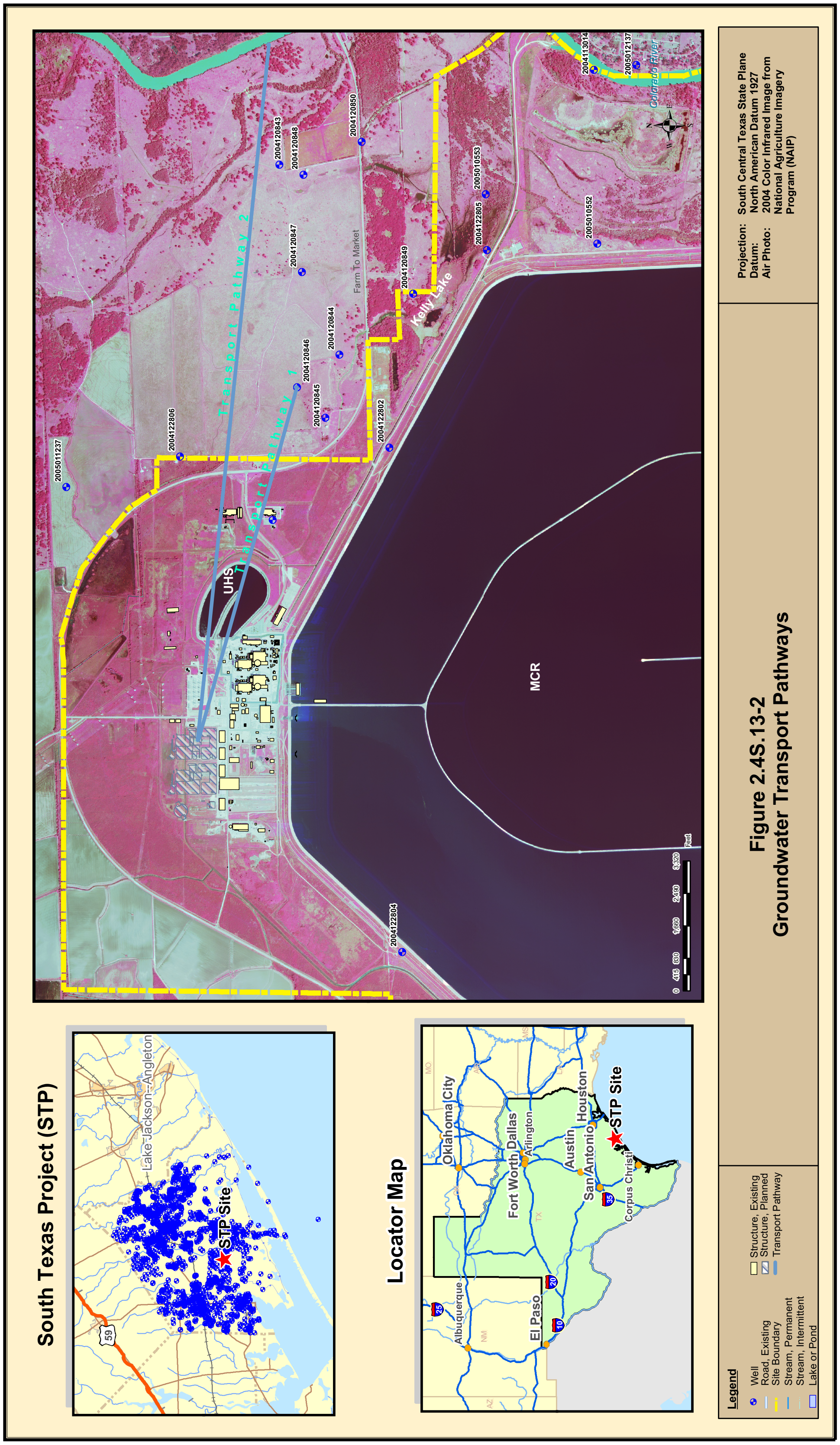

Figure 2.4S.13-2 Groundwater Transport Pathways