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ACCIDENTAL RELEASES OF RADIOACTIVE LIQUID EFFLUENTS IN GROUND AND SURFACE WATERS
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2.4.13 ACCIDENTAL RELEASES OF RADIOACTIVE LIQUID EFFLUENTS IN GROUND AND SURFACE WATERS

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 Units 6 & 7. The source of the liquid effluent would be a postulated tank rupture in the liquid waste management system. The likelihood of an environmental release of liquid waste is remote due to multiple levels of protection in the liquid waste management system.

2.4.13.1 Groundwater

This subsection provides a conservative analysis of a postulated accidental liquid release of effluents to the groundwater at Units 6 & 7. The accident scenario is described in this subsection along with the conceptual model used to evaluate the radionuclide transport with potential pathways of contamination to water users. The radionuclide concentrations to which a water user might be exposed are compared against the regulatory limits.

The analysis as outlined in NUREG 0800 Standard Review Plan (SRP) 2.4.13 and Branch Technical Position (BTP) 11-6 considers the impact of the release on the nearest potable water supply and the use of water for direct human consumption or indirectly through animals (livestock watering), crops (agricultural irrigation), and food processing (water as an ingredient). For direct consumption, results are considered acceptable if an accidental release will not result in radionuclide concentrations in excess of the effluent concentration limits (ECLs) included in Appendix B (Table 2, Column 2, under the unity rule) to 10 CFR Part 20 in the nearest source of potable water, located in an unrestricted area. For indirect consumption, bioaccumulation in the consumed animal or plant organisms is the pathway for exposure. For Units 6 & 7, the potential for biological uptake, concentration, and human consumption of fish, crustaceans, and mollusks was considered for the groundwater pathway. For indirect consumption, results are considered acceptable if the dose associated with an accidental release does not exceed the annual dose limit given in 10 CFR 20.1301.

2.4.13.1.1 Source Term

The source term has been selected based on information provided by Westinghouse to assist in evaluating the accidental liquid release of effluents and guidance provided in NUREG-0800 BTP 11-6. Based on the expected types of

liquid waste streams processed by the liquid waste management systems, the effluent holdup tanks have the highest potential radioactive inventory based on radionuclide concentrations and volume. The effluent holdup tanks also have the highest potential exposure consequences to users of water resources as their inventory includes long-lived fission and activation products and environmentally mobile radionuclides. Therefore, they have been selected by Westinghouse as the limiting tanks for evaluating an accidental release of liquid effluents that could lead to the most adverse contamination of groundwater or surface water via the groundwater pathway.

There are two effluent holdup tanks, each with a capacity of 28,000 gallons for each unit. These tanks are located in the lowest level of the auxiliary building. The accidental release evaluation postulates a release from a single effluent holdup tank, based on guidance provided in NUREG 0800 SRP 2.4.13, and assumes that the radionuclide inventory for the tank is based on 80 percent of the tank capacity (22,400 gallons), using guidance provided in NUREG-0800 BTP 11-6.

Westinghouse estimated the radionuclide activity of the effluent holdup tanks to be 101 percent of the reactor coolant activity. Westinghouse determined the radionuclide concentrations in reactor coolant itself to be as follows:

- For tritium (H-3), a coolant concentration of 1.0 µCi/g is used. This was taken directly from the DCD, Table 11.1-8.

- Corrosion product (Cr-51, Mn-54, Mn-56, Fe-55, Fe-59, Co-58, and Co-60) concentrations are taken directly from the DCD, Table 11.1-2, *Design Basis Reactor Coolant Activity*.

- Other radionuclide concentrations are based on the DCD, Table 11.1-2, multiplied by 0.12/0.25 to adjust the failed fuel rate from the design basis to a conservatively bounding value for this analysis.

The expected radionuclide concentrations in the effluent holdup tanks have been calculated, and the results are summarized in Table 2.4.13-201.

2.4.13.1.2 Conceptual Models

This subsection describes the conceptual models 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 groundwater system is based on the hydrogeological information presented in Subsection 2.4.12. Figure 2.4.13-201 illustrates the post-construction conceptual exposure pathways considered to evaluate an accidental liquid release of effluent to groundwater or to surface water via the groundwater pathway. The post-construction plant grade is raised to approximately elevation 25.5 feet NAVD 88 by constructing a mechanically stabilized earth (MSE) wall around the plant area as described in Subsection 2.5.4.5.1. The top of the MSE wall ranges from elevation 20 to 21 feet NAVD 88 and the bottom of the wall is at elevation 0 feet NAVD 88.

For the purpose of bounding the hydrogeological conditions that define the transport of radioactive liquid effluent in ground and surface water environments, two conceptual transport and exposure models were quantitatively evaluated: (1) a primary scenario (Figure 2.4.13-202) and (2) a less plausible alternate scenario (Figure 2.4.13-203).

As indicated in Subsection 2.4.13.1.1, a single effluent holdup tank is assumed to be the source of the release, with the tank having a volume of 28,000 gallons and the radionuclide concentrations as summarized in Table 2.4.13-201. The tank is located at the lowest level of the auxiliary building, which has a floor elevation of approximately –10 feet NAVD88 and is approximately 10 feet below the preconstruction potentiometric surface at Units 6 & 7, based on the water table contour plots presented on Figures 2.4.12-221 through 2.4.12-228.

The tank rupture is postulated to release 80 percent of the liquid volume (22,400 gallons). Flow from a tank rupture would initially flood the tank room and begin to flow to the auxiliary building's radiologically controlled area sump via floor drains as described in DCD Subsection 3.4.1.2.2.2. It is assumed that the sump pumps are inoperable. According to the DCD, this would result in a 22,400-gallon release flooding the balance of level 1 of the auxiliary building via the interconnecting floor drains. Once level 1 is flooded, it is assumed that a pathway is created that would instantaneously allow the entire 22,400 gallons to enter the aquifer system below the basemat. This assumption ignores the floor drain system, and the barriers presented by the 6-foot-thick basemat and the sealed, 3-foot-thick exterior walls of the auxiliary building.

With the postulated instantaneous release of the contents of an effluent holdup tank to groundwater, radionuclides would then have to pass downward through the underlying approximately 19-foot concrete fill layer that abuts along its periphery into a cutoff wall installed as part of construction dewatering operations (Figures 2.4.13-202 and 2.4.13-203). Once the radionuclides pass through the

concrete fill layer, they would enter the Biscayne aquifer, consisting of the Miami and Key Largo (interpreted as the upper Fort Thompson Formation elsewhere) Formations (upper monitoring interval) or the Fort Thompson Formation (lower monitoring interval) and migrate with the groundwater in the direction of decreasing hydraulic head.

Potentiometric surface maps for the upper and lower monitoring intervals of the Biscayne aquifer for preconstruction conditions are presented in Figures 2.4.12-221 through 2.4.12-228. The potentiometric surface maps show a general flow direction adjacent to Unit 7 toward the west-southwest and adjacent to Unit 6, toward the east or south.

2.4.13.1.2.1 Primary Conceptual Model

The primary groundwater release scenario is to the adjacent cooling canals. In this scenario, the release to the Biscayne aquifer would occur in the vicinity of either Unit 6 or Unit 7 auxiliary building. The groundwater flow direction and proximity to the adjacent cooling canals indicate that a release from the Unit 7 auxiliary building would represent the worst case. Groundwater potentiometric surface maps indicate that the preconstruction groundwater pathway from a point of release in the Unit 7 auxiliary building flows to the southwest towards the cooling water return canal, which is part of the industrial wastewater facility for the existing generating stations. The horizontal flow of groundwater would be slowed by the emplacement of a reinforced concrete diaphragm cutoff wall installed as part of the construction process.

As noted above, plant construction alterations included the addition of backfill material to +25.5 feet NAVD 88 and the installation of a reinforced concrete diaphragm cutoff wall around the reactor building footprint. Preconstruction evaluation of groundwater flow patterns concluded that the shallow groundwater pathway in the upper monitoring zone is to the southwest. It is not expected that the local shallow groundwater flow system will change after the construction of these units as the cooling canals elevation is lower than the surrounding area. However, groundwater flow within the cutoff wall is likely to be affected, resulting in stagnant horizontal flow conditions in the upper monitoring zone. For post-construction conditions, the groundwater level at the two units is estimated to be +2 feet NAVD 88 as shown in Figures 2.4.13-202 and 2.4.13-203.

The primary flow path in the Biscayne aquifer system is considered to be between the Unit 7 auxiliary building and the cooling canals. During transport, radionuclide concentrations are reduced by the processes of adsorption, hydrodynamic

dispersion, and radioactive decay. There are no water-supply wells between the postulated release point and the cooling canals that withdraw water from the Biscayne aquifer. The Biscayne aquifer also contains saline to saltwater groundwater in the site vicinity and the freshwater/saltwater boundary is located over 6 miles to the west of Units 6 & 7 (Subsection 2.4.12.1.3.1 and Figure 2.4.12-207).

The radial collector wells installed for Units 6 & 7 receive minor (<8 percent) groundwater contribution from the northern portion and downgradient area of the cooling canals. This results from the effects of the withdrawal of water by the radial collector wells on the groundwater flow paths in this area. Subsection 2.4.12.1.6 indicates that process and cooling water-supply wells for the existing Units 1, 2, and 5 withdraw their water from the deeper, confined Upper Floridan aquifer. No potable water-supply wells in the Floridan aquifer system are located within or downgradient of the Units 6 & 7 area.

Figures 2.4.13-201 and 2.4.13-202 illustrate the conceptual models for evaluating radionuclide transport in the Biscayne aquifer. The cooling canals serve as a groundwater discharge area in the plant area. The cooling canal water level is kept below the level of the Biscayne Bay to the east and the freshwater portions of the Biscayne aquifer to the west (Reference 201). The radionuclides associated with a liquid release in the primary release pathway would enter the surface water system via the cooling canals, which is in contact with the Biscayne aquifer. Radionuclide concentrations would then be rapidly diluted in the cooling canals. Groundwater flow into the system is continuous, and the water level is controlled through use of cooling water by Units 1–4 and tidal fluctuations. The cooling canals have an average total volume of approximately 4 billion gallons (Reference 202), over 175,000 times the total volume of the release scenario effluents. The cooling canals have a level of tritium associated with the operation of Units 3 & 4. For the period of 2000 to 2007, the average tritium concentration in the canals was 5250 picocuries per liter (5.25E-06 microcuries per cubic centimeter).

After release to the cooling canals and dilution, the overall regional groundwater flow is east toward Biscayne Bay; locally the site modeling results (Subsection 2.4.12.3.1) and cooling canal water balance studies (Reference 202) show that the cooling canals act as a groundwater sink, and thus there is no net flow toward the Biscayne Bay. However, for the purposes of exposure assessment, it is assumed that the cooling canal concentration is transferred to Biscayne Bay for uptake and accumulation by marine organisms.

2.4.13.1.2.2 Alternate Conceptual Model

A less plausible alternate release scenario was also considered based on the postulated presence of a post-construction downward hydraulic gradient between the upper and lower monitoring intervals in the Biscayne aquifer. Subsection 2.4.12.2.2.1 indicates that preconstruction vertical hydraulic gradients between the two zones are generally upward. However, once the plant buildings are constructed, the potential exists for mounding caused by the concrete fill layer and cutoff wall, which may locally reverse the vertical hydraulic gradient. In this scenario, the pathway is through the 19-foot concrete fill layer and into the lower monitoring interval; the lower monitoring interval consists of the Fort Thompson Formation approximately 50 to 60 feet below preconstruction ground surface. The base of the cutoff wall for construction is keyed into a thin unit of freshwater limestone within the Fort Thompson Formation that separates the two monitoring intervals in the Biscayne aquifer. Once in the Fort Thompson Formation, groundwater moves horizontally to the east, below the cooling canal and discharges into Biscayne Bay or is captured by the radial collector wells (Figure 2.4.13-203).

The alternate model considers the potential biological uptake by fish, crustaceans, and mollusks directly from groundwater released at the groundwater/sediment interface. Human consumption of fish, crustaceans, and mollusks was then considered as a potential exposure pathway.

2.4.13.1.3 Radionuclide Transport Analysis

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 an effluent holdup tank. Analysis of liquid effluent release commenced with the simplest of models, using conservative assumptions and coefficients. Radionuclide concentrations resulting from the preliminary analysis were then compared against the ECLs identified in 10 CFR Part 20, Appendix B, Table 2, Column 2, to determine acceptability.

Radionuclide transport along a groundwater path line is governed by the advection-dispersion-reaction equation (Reference 203);

$$R\frac{\partial C}{\partial t} = D\frac{\partial^2 C}{\partial x^2} - v\frac{\partial C}{\partial x} - \lambda RC \qquad \text{Equation 2.4.13-1}$$

Where,

C = radionuclide atom density
R = retardation factor

D = coefficient of longitudinal hydrodynamic dispersion
v = average linear velocity
λ = radioactive decay constant

The retardation factor is defined from the relationship;

$$R = 1 + \frac{\rho_b K_d}{n_e}$$ Equation 2.4.13-2

Where,

ρ_b = bulk density
K_d = distribution coefficient
n_e = effective porosity

The average linear velocity is determined using Darcy's law, which is;

$$v = -\frac{K}{n_e}\frac{dh}{dl}$$ Equation 2.4.13-3

Where,

K = hydraulic conductivity
dh/dl = hydraulic gradient

The radioactive decay constant can be written as;

$$\lambda = \frac{\ln 2}{t_{1/2}}$$ Equation 2.4.13-4

Where,

$t_{1/2}$ = radionuclide half-life (References 204, 205, and 209)

Conservatively neglecting hydrodynamic dispersion, Equation 2.4.13-1 can be integrated to yield;

$$A = A_0 \exp(-\lambda t)$$ Equation 2.4.13-5

Where,

A = radionuclide activity concentration
A_0 = initial radionuclide activity concentration
t = LR/v = radionuclide travel time
L = groundwater path line 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 2.4.13-6

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 2.4.13-6, again conservatively neglecting hydrodynamic dispersion, can be derived as

$$\frac{dC_2}{dt} = d_{12}\lambda_1' C_1 - \lambda_2 C_2 \qquad \text{Equation 2.4.13-7}$$

$$\frac{dx}{dt} = \frac{v}{R_2} \qquad \text{Equation 2.4.13-8}$$

Where,

$$\lambda_1' = \lambda_1 R_1 / R_2$$

Assuming $R_1 \approx R_2$ and recognizing that Equation 2.4.13-7 is formally similar to Equation B.43 of Reference 204, these equations can be integrated to yield

$$A_2 = K_1 \exp(-\lambda_1 t) + K_2 \exp(-\lambda_2 t) \qquad \text{Equation 2.4.13-9}$$

$$t = R_2 L / v \qquad \text{Equation 2.4.13-10}$$

For which,

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

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

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

$$R_3 \frac{\partial C_3}{\partial t} = D\frac{\partial^2 C_3}{\partial x^2} - v\frac{\partial C_3}{\partial x} + d_{13}\lambda_1 R_1 C_1 + d_{23}\lambda_2 R_2 C_2 - \lambda_3 R_3 C_3 \qquad \text{Equation 2.4.13-11}$$

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 2.4.13-11, again conservatively neglecting hydrodynamic dispersion, can be derived as

$$\frac{dC_3}{dt} = d_{13}\lambda_1' C_1 + d_{23}\lambda_2' C_2 - \lambda_3 C_3 \qquad \text{Equation 2.4.13-12}$$

$$\frac{dx}{dt} = \frac{v}{R_3} \qquad \text{Equation 2.4.13-13}$$

Where, $\lambda_1' = \lambda_1 R_1 / R_3$ and $\lambda_2' = \lambda_2 R_2 / R_3$. Assuming $R_1 \approx R_2 \approx R_3$ and considering the formal similarity of Equation 2.4.13-13 to Equation B.54 of Reference 204, Equations 2.4.13-12 and 2.4.13-13 can be integrated to yield

$$A_3 = K_1 \exp(-\lambda_1 t) + K_2 \exp(-\lambda_2 t) + K_3 \exp(-\lambda_3 t) \qquad \text{Equation 2.4.13-14}$$

$$t = R_3 L / v \qquad \text{Equation 2.4.13-15}$$

For which,

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

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

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

Equations 2.4.13-5, 2.4.13-9, and 2.4.13-14 were used to estimate the radionuclide concentrations in the Biscayne aquifer groundwater that discharges to the cooling canals or to Biscayne Bay. Equations 2.4.13-5, 2.4.13-9, and 2.4.13-14 were applied to the pathway traversing the 19-foot concrete fill layer. These analyses were performed as described below.

2.4.13.1.3.1 Transport Considering Radioactive Decay Only

An initial screening analysis was performed considering radioactive decay only. This analysis assumes that all radionuclides migrate at the same rate as groundwater and considers no adsorption and retardation, which would otherwise result in a longer travel time and more radioactive decay. The concentrations of the radionuclides in Table 2.4.13-201 were first decayed for a period equal to the groundwater travel time from the point of release to the building subsurface below the basemat and through the underlying 19-foot concrete fill layer, using Equations 2.4.13-5, 2.4.13-9, and 2.4.13-14 with $R_1 = R_2 = R_3 = 1$.

The groundwater travel time for both the primary and alternate conceptual models first considered the pathway through the concrete fill layer, which was estimated in the following manner. Travel time in years (t), ignoring retardation (R), is a function of travel distance (L in feet), hydraulic conductivity (K in feet per day), hydraulic gradient (*dh/dl*), and effective porosity (n_e) as shown in the following formula:

$$t = \frac{L}{\frac{K}{n_e}\frac{dh}{dl}} \div 365\, days / year \qquad \text{Equation 2.4.13-16}$$

The travel time through the concrete fill layer was calculated to be a minimum of 1480 years using Equation 2.4.13-16, with a travel distance (L) of 19 feet, a vertical hydraulic conductivity of 8.25E-09 centimeters per second (0.023 feet per day) (this is an order of magnitude higher hydraulic conductivity than that of intact concrete [Reference 206]), a porosity of 0.07 (Reference 208), and an average vertical hydraulic gradient of 0.105 (using the post-construction head difference relative to the cooling canals [2 feet uncorrected for density] and the thickness of the concrete fill). Based on this travel time and using Equations 2.4.13-5, 2.4.13-9, and 2.4.13-14, the initial concentrations given in Table 2.4.13-201 were decayed for a period of 1480 years.

Once in the Key Largo Formation, the additional travel time for migration to the cooling canals were evaluated in the same manner using Equation 2.4.13-16, with a travel distance of 810 feet, a hydraulic conductivity of 12,000 feet per day, an average hydraulic gradient of 4E-04 and an effective porosity of 0.20. Equation 2.4.13-16 was used to determine a lateral groundwater travel time of approximately 0.09 years.

For the alternate release scenario, the additional travel time from the Unit 6 reactor through the Fort Thompson Formation and to the Biscayne Bay was evaluated in the same manner. Using Equation 2.4.13-16, the travel time was calculated to be 2 years based on a distance of 1800 feet, a hydraulic conductivity of 490 feet per day, an average hydraulic gradient of 1E-03, and an effective porosity of 0.20. Due to the very short lateral groundwater travel times for the primary and alternate release pathways, a travel time of 1480 years is assumed.

The porosity and hydraulic conductivity values presented are described in Subsection 2.4.12.2.4.

Table 2.4.13-202 summarizes the results considering only radioactive decay.

2.4.13.1.3.2 Transport Considering Radioactive Decay and Dilution

In addition to the transport and decay of radionuclides scenario described above, the groundwater plume will reach the cooling canals and then be diluted therein. The entire volume of the release (22,400 gallons) would mix with its 4 billion-gallon capacity, with a dilution factor of 5.6E-06 (approximately 1:180,000). Table 2.4.13-203 provides the results after dilution.

The tritium concentration shown on the table includes the existing tritium concentration in the cooling canals. The average concentration in the canals is 5.25E-06 microcuries per cubic centimeter and the groundwater concentration

resulting from the release is 7.0E-37 microcuries per cubic centimeter, thus the concentration contributed to the cooling canals is negligible compared to the existing concentration.

2.4.13.1.3.3 Transport Considering Radioactive Decay and Adsorption

An initial evaluation of isotopes likely to exceed their ECL was performed prior to conducting the field investigation based on a limited understanding of site conditions. Samples were collected for distribution coefficient analysis for the following elements: Mn, Fe, Co, Sr, Ag, Te, Ce, and Cs. The evaluation of the adsorption effects was limited to these elements, which were expected to exceed 10 percent or more of their ECL.

Eight aquifer matrix samples were taken from the Biscayne aquifer system in the Units 6 & 7 power block area that are representative of materials in the top 100 feet beneath the site. Representative samples of site groundwater were provided to the laboratory for use as the contact liquid. The tests were performed using elemental surrogates of the radionuclides identified for testing.

Laboratory testing of these samples yielded distribution coefficients with the following range and mean values (summarized from Table 2.4.13-204):

Element	Range	Geometric Mean (cm^3/g)
Mn	6.3 to 29.4	19
Fe	0.06 to 16.4	0.74
Co	0.6 to 4.1	1.8
Sr	0.03 to 1	0.25
Ag	0.32 to 7.5	2.0
Te	7.7 to 816	64
Cs	0.04 to 0.68	0.17
Ce	323 to 684	549

The 2-sigma uncertainties are 14 percent for the analyses. The uncertainties for the distribution coefficients, K_d, were calculated by propagation of uncertainty from the Inductively Coupled Plasma Mass Spectrometer data.

Due to the short travel times in the Key Largo Limestone and the Fort Thompson Formation determined in the preceding flow path analyses and the inability to directly apply these retardation rates to flow through the concrete fill layer, these distribution coefficients were not used. It is likely, however, that the retardation processes are active in either the primary or alternate release pathway and would

add to overall travel time and reduce radionuclide concentrations due to adsorption processes and additional radioactive decay. Retardation processes are conservatively ignored for this analysis.

2.4.13.1.3.4 Biological Uptake and Potential Consumption of Fish, Crustaceans, and Mollusks

The potential for biological uptake and human consumption of fish, crustaceans, and mollusks in Biscayne Bay was evaluated for both exposure pathways using exposure parameters and dose conversion factors from the residual radioactive (RESRAD) materials model code Version 6 (Reference 207).

The potential for biological uptake, accumulation, and human exposure was evaluated for the four radionuclides with the highest potential for exposure (H-3, Sr-90, I-129, and Cs-137). The groundwater concentration for each contaminant (Tables 2.4.13-202 or 2.4.13-203) was considered directly available for biological uptake and a fish-water and mollusk-crustacean uptake ratio was applied from Table D-5 of Reference 207. It is conservatively assumed that the exposure concentrations in the surface water of Biscayne Bay are equal to the groundwater concentrations discharging to the bay.

The dose via each consumption pathway (crustaceans, mollusks, and fish) was determined using default assumptions for fraction of food contaminated mollusks and crustaceans (50 percent), a non-default value of 25 percent for fish, and default assumptions for yearly consumption (5.4 kilograms [11.9 pounds] fish and 0.9 kilograms [2 pounds] mollusks per year) to determine the dose. The rationale for using a non-default value for percent contaminated fish is based on the likelihood that a fisherman would fish outside of the area of contamination for at least half of the time and that fish, themselves are wide-ranging and would spend time both in and outside of the area of potential discharge. The resultant dose for each radionuclide by each intake exposure pathway was summed and a total dose was determined. Table 2.4.13-205 shows the summary of the calculations.

2.4.13.1.4 Compliance with 10 CFR Part 20

The calculated dose of 6E-04 millirem per year for the primary pathway and 0.113 millirem per year for the alternate pathway is well below the exposure level of 100 millirem per year given in 10 CFR 20.1301.

The travel time (1480 years) for the release through the concrete fill allows time to implement remedial measures to further mitigate the impact of the release.

2.4.13.2 Surface Water

No outdoor tanks contain licensed radioactive material in the Units 6 & 7 design. In particular, Units 6 & 7 do not require boron changes for load follow and do not recycle boric acid or reactor coolant water, so the boric acid tank is not radioactive. Because no outdoor tanks contain radioactivity, no accident scenario will result in the release of liquid effluent directly to the surface water.

2.4.13.3 References

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Table 2.4.13-201 (Sheet 1 of 2)
Radionuclide Concentrations in the Effluent Holdup Tanks

Radionuclide	Design Basis Reactor Coolant Activity[a] (μCi/g)	Reactor Coolant Concentration[b] (μCi/cm^3)	Effluent Holdup Tank Concentration[c] (μCi/cm^3)
H-3	1.00E+00	1.00E+00	1.01E+00
Cr-51	1.30E-03	1.30E-03	1.31E-03
Mn-54	6.70E-04	6.70E-04	6.77E-04
Mn-56	1.70E-01	1.70E-01	1.72E-01
Fe-55	5.00E-04	5.00E-04	5.05E-04
Fe-59	1.30E-04	1.30E-04	1.31E-04
Co-58	1.90E-03	1.90E-03	1.92E-03
Co-60	2.20E-04	2.20E-04	2.22E-04
Br-83	3.20E-02	1.54E-02	1.55E-02
Br-84	1.70E-02	8.16E-03	8.24E-03
Br-85	2.00E-03	9.60E-04	9.70E-04
Rb-88	1.50E+00	7.20E-01	7.27E-01
Rb-89	6.90E-02	3.31E-02	3.35E-02
Sr-89	1.10E-03	5.28E-04	5.33E-04
Sr-90	4.90E-05	2.35E-05	2.38E-05
Sr-91	1.70E-03	8.16E-04	8.24E-04
Sr-92	4.10E-04	1.97E-04	1.99E-04
Y-90	1.30E-05	6.24E-06	6.30E-06
Y-91m	9.20E-04	4.42E-04	4.46E-04
Y-91	1.40E-04	6.72E-05	6.79E-05
Y-92	3.40E-04	1.63E-04	1.65E-04
Y-93	1.10E-04	5.28E-05	5.33E-05
Nb-95	1.60E-04	7.68E-05	7.76E-05
Zr-95	1.60E-04	7.68E-05	7.76E-05
Mo-99	2.10E-01	1.01E-01	1.02E-01
Tc-99m	2.00E-01	9.60E-02	9.70E-02
Ru-103	1.40E-04	6.72E-05	6.79E-05
Rh-103m	1.40E-04	6.72E-05	6.79E-05
Rh-106	4.50E-05	2.16E-05	2.18E-05
Ag-110m	4.00E-04	1.92E-04	1.94E-04
Te-127m	7.60E-04	3.65E-04	3.68E-04
Te-129m	2.60E-03	1.25E-03	1.26E-03
Te-129	3.80E-03	1.82E-03	1.84E-03
Te-131m	6.70E-03	3.22E-03	3.25E-03
Te-131	4.30E-03	2.06E-03	2.08E-03
Te-132	7.90E-02	3.79E-02	3.83E-02
Te-134	1.10E-02	5.28E-03	5.33E-03
I-129	1.50E-08	7.20E-09	7.27E-09
I-130	1.10E-02	5.28E-03	5.33E-03

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Table 2.4.13-201 (Sheet 2 of 2)
Radionuclide Concentrations in the Effluent Holdup Tanks

Radionuclide	Design Basis Reactor Coolant Activity[a] (μCi/g)	Reactor Coolant Concentration[b] (μCi/cm^3)	Effluent Holdup Tank Concentration[c] (μCi/cm^3)
I-131	7.10E-01	3.41E-01	3.44E-01
I-132	9.40E-01	4.51E-01	4.56E-01
I-133	1.30E+00	6.24E-01	6.30E-01
I-134	2.20E-01	1.06E-01	1.07E-01
I-135	7.80E-01	3.74E-01	3.78E-01
Cs-134	6.90E-01	3.31E-01	3.35E-01
Cs-136	1.00E+00	4.80E-01	4.85E-01
Cs-137	5.00E-01	2.40E-01	2.42E-01
Cs-138	3.70E-01	1.78E-01	1.79E-01
Ba-137m	4.70E-01	2.26E-01	2.28E-01
Ba-140	1.00E-03	4.80E-04	4.85E-04
La-140	3.10E-04	1.49E-04	1.50E-04
Ce-141	1.60E-04	7.68E-05	7.76E-05
Ce-143	1.40E-04	6.72E-05	6.79E-05
Pr-143	1.50E-04	7.20E-05	7.27E-05
Ce-144	1.20E-04	5.76E-05	5.82E-05
Pr-144	1.20E-04	5.76E-05	5.82E-05

(a) Values from DCD Table 11.1-2.
(b) For tritium (H-3), a coolant concentration of 1.0 μCi/g is used; corrosion products (Cr-51, Mn-54, Mn-56, Fe-55, Fe-59, Co-58 and Co-60) are taken directly from the DCD Table 11.1-2, and other radionuclides are based on the DCD, Table 11.1-2 multiplied by 0.12/0.25. The density of all liquids is assumed to be 1 g/cm^3.
(c) Values are 101 percent of the reactor coolant concentrations.

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Table 2.4.13-202 (Sheet 1 of 3)
Results of Transport Analysis Considering Radioactive Decay in Concrete Fill Layer

Principal Radionuclide	Decay Chain Progeny[a]	Half-life[b] (days)	d_{12}	d_{13}	d_{23}	Decay Constant ($days^{-1}$)[c]	Effluent Holdup Tank Concentration ($\mu Ci/cm^3$)[d]	K_1[e]	K_2[f]	K_3[g]	Travel Time (days)[h]	Groundwater ($\mu Ci/cm^3$)[i]	ECL ($\mu Ci/cm^3$)[j]	Groundwater/ECL Ratio
I-129		5.73E+09	—	—	—	1.21E-10	7.27E-09	—	—	—	5.42E+05	7.3E-09	2.00E-07	3.63E-02
Cs-137		1.10E+04	—	—	—	6.30E-05	2.42E-01	—	—	—	5.42E+05	3.6E-16	1.00E-06	3.61E-10
	Ba-137m	1.77E-03	0.946	—	—	3.92E+02	2.28E-01	2.29E-01	–9.32E-04	—	5.42E+05	3.4E-16	N/A	N/A
Sr-90		1.06E+04	—	—	—	6.54E-05	2.38E-05	—	—	—	5.42E+05	9.8E-21	5.00E-07	1.96E-14
	Y-90	2.67E+00	1	—	—	2.60E-01	6.30E-06	2.38E-05	–1.75E-05	—	5.42E+05	9.8E-21	7.00E-06	1.40E-15
H-3		4.51E+03	—	—	—	1.54E-04	1.01E+00	—	—	—	5.42E+05	7.0E-37	1.00E-03	6.95E-34
Co-60		1.93E+03	—	—	—	3.59E-04	2.22E-04	—	—	—	5.42E+05	0.0E+00	3.00E-06	0.00E+00
Fe-55		9.86E+02	—	—	—	7.03E-04	5.05E-04	—	—	—	5.42E+05	0.0E+00	1.00E-04	0.00E+00
Cs-134		7.53E+02	—	—	—	9.21E-04	3.35E-01	—	—	—	5.42E+05	0.0E+00	9.00E-07	0.00E+00
Mn-54		3.13E+02	—	—	—	2.21E-03	6.77E-04	—	—	—	5.42E+05	0.0E+00	3.00E-05	0.00E+00
Ce-144		2.84E+02	—	—	—	2.44E-03	5.82E-05	—	—	—	5.42E+05	0.0E+00	3.00E-06	0.00E+00
	Pr-144m	5.00E-03	0.0178	—	—	1.39E+02	0.00E+00	1.04E-06	–1.04E-06	—	5.42E+05	0.0E+00	N/A	N/A
	Pr-144	1.20E-02	—	0.9822	0.999	5.78E+01	5.82E-05	5.82E-05	7.39E-07	–7.41E-07	5.42E+05	0.00E+00	6.00E-04	0.00E+00
Ag-110m		2.50E+02	—	—	—	2.77E-03	1.94E-04	—	—	—	5.42E+05	0.0E+00	6.00E-06	0.00E+00
	Ag-110	2.85E-04	0.0133	—	—	2.43E+03	0.00E+00	2.58E-06	–2.58E-06		5.42E+05	0.0E+00	N/A	N/A
Rh-106		3.45E-04	—	—	—	2.01E+03	2.18E-05	—	—	—	5.42E+05	0.0E+00	N/A	N/A
Cr-51		2.77E+01	—	—	—	2.50E-02	1.31E-03	—	—	—	5.42E+05	0.0E+00	5.00E-04	0.00E+00
Mn-56		1.07E-01	—	—	—	6.48E+00	1.72E-01	—	—	—	5.42E+05	0.0E+00	7.00E-05	0.00E+00
Fe-59		4.45E+01	—	—	—	1.56E-02	1.31E-04	—	—	—	5.42E+05	0.0E+00	1.00E-05	0.00E+00
Co-58		7.08E+01	—	—	—	9.79E-03	1.92E-03	—	—	—	5.42E+05	0.0E+00	2.00E-05	0.00E+00
Br-83		9.96E-02	—	—	—	6.96E+00	1.55E-02	—	—	—	5.42E+05	0.0E+00	9.00E-04	0.00E+00
Br-84		2.21E-02	—	—	—	3.14E+01	8.24E-03	—	—	—	5.42E+05	0.0E+00	4.00E-04	0.00E+00
Br-85		2.01E-03	—	—	—	3.45E+02	9.70E-04	—	—	—	5.42E+05	0.0E+00	N/A	N/A
Rb-88		1.24E-02	—	—	—	5.59E+01	7.27E-01	—	—	—	5.42E+05	0.0E+00	4.00E-04	0.00E+00
Rb-89		1.06E-02	—	—	—	6.54E+01	3.35E-02	—	—	—	5.42E+05	0.0E+00	9.00E-04	0.00E+00
	Sr-89	5.05E+01	—	—	—	1.37E-02	5.33E-04	–7.03E-06	5.40E-04	—	5.42E+05	0.0E+00	8.00E-06	0.00E+00
Sr-91		3.96E-01	—	—	—	1.75E+00	8.24E-04	—	—	—	5.42E+05	0.0E+00	2.00E-05	0.00E+00
	Y-91m	3.45E-02	0.578			2.01E+01	4.46E-04	5.22E-04	–7.57E-05	—	5.42E+05	0.0E+00	2.00E-03	0.00E+00
	Y-91	5.85E+01	—	0.422	1	1.18E-02	6.79E-05	–5.93E-06	4.47E-08	7.38E-05	5.42E+05	0.0E+00	8.00E-06	0.00E+00
Sr-92		1.13E-01	—	—	—	6.13E+00	1.99E-04	—	—	—	5.42E+05	0.0E+00	4.00E-05	0.00E+00
	Y-92	1.48E-01	1	—	—	4.68E+00	1.65E-04	–6.42E-04	8.07E-04	—	5.42E+05	0.0E+00	4.00E-05	0.00E+00
Y-93		4.21E-01	—	—	—	1.65E+00	5.33E-05	—	—	—	5.42E+05	0.0E+00	2.00E-05	0.00E+00
Zr-95		6.40E+01	—	—	—	1.08E-02	7.76E-05	—	—	—	5.42E+05	0.0E+00	2.00E-05	0.00E+00
	Nb-95m	3.61E+00	0.007	—	—	1.92E-01	0.00E+00	5.76E-07	–5.76E-07	—	5.42E+05	0.0E+00	3.00E-05	0.00E+00
	Nb-95	3.52E+01	—	0.993	1	1.97E-02	7.76E-05	1.73E-04	6.58E-08	–9.50E-05	5.42E+05	0.0E+00	3.00E-05	0.00E+00

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Table 2.4.13-202 (Sheet 2 of 3)
Results of Transport Analysis Considering Radioactive Decay in Concrete Fill Layer

Principal Radionuclide	Decay Chain Progeny[a]	Half-life[b] (days)	d_{12}	d_{13}	d_{23}	Decay Constant ($days^{-1}$)[c]	Effluent Holdup Tank Concentration ($\mu Ci/cm^3$)[d]	K_1[e]	K_2[f]	K_3[g]	Travel Time (days)[h]	Groundwater ($\mu Ci/cm^3$)[i]	ECL ($\mu Ci/cm^3$)[j]	Groundwater/ECL Ratio
Mo-99		2.75E+00	—	—	—	2.52E-01	1.02E-01	—	—	—	5.42E+05	0.0E+00	2.00E-05	0.00E+00
	Tc-99m	2.51E-01	0.876	—	—	2.76E+00	9.70E-02	9.83E-02	–1.33E-03	—	5.42E+05	0.0E+00	1.00E-03	0.00E+00
Ru-103		3.93E+01	—	—	—	1.76E-02	6.79E-05	—	—	—	5.42E+05	0.0E+00	3.00E-05	0.00E+00
	Rh-103m	3.90E-02	0.997	—	—	1.78E+01	6.79E-05	—	6.78E-05	1.36E-07	5.42E+05	0.0E+00	6.00E-03	0.00E+00
Te-127m		1.09E+02	—	—	—	6.36E-03	3.68E-04	—	—	—	5.42E+05	0.0E+00	9.00E-06	0.00E+00
	Te-127	3.90E-01	0.976	—	—	1.78E+00	0.00E+00	—	3.60E-04	-3.60E-04	5.42E+05	0.0E+00	1.00E-04	0.00E+00
Te-129m		3.36E+01	—	—	—	2.06E-02	1.26E-03	—	—	—	5.42E+05	0.0E+00	7.00E-06	0.00E+00
	Te-129	4.83E-02	0.65	—	—	1.44E+01	1.84E-03	—	8.20E-04	1.02E-03	5.42E+05	0.0E+00	4.00E-04	0.00E+00
I-130		5.15E-01	—	—	—	1.35E+00	5.33E-03	—	—	—	5.42E+05	0.0E+00	2.00E-05	0.00E+00
Te-131m		1.25E+00	—	—	—	5.55E-01	3.25E-03	—	—	—	5.42E+05	0.0E+00	8.00E-06	0.00E+00
	Te-131	1.74E-02	0.222	—	—	3.98E+01	2.08E-03	—	7.32E-04	1.35E-03	5.42E+05	0.0E+00	8.00E-05	0.00E+00
	I-131	8.04E+00	—	0.778	1	8.62E-02	3.44E-01	–6.00E-04	–2.92E-06	3.45E-01	5.42E+05	0.0E+00	1.00E-06	0.00E+00
Te-132		3.26E+00	—	—	—	2.13E-01	3.83E-02	—	—	—	5.42E+05	0.0E+00	9.00E-06	0.00E+00
	I-132	9.58E-02	1	—	—	7.24E+00	4.56E-01	3.95E-02	4.17E-01	—	5.42E+05	0.0E+00	1.00E-04	0.00E+00
Te-134		2.90E-02	—	—	—	2.39E+01	5.33E-03	—	—	—	5.42E+05	0.0E+00	3.00E-04	0.00E+00
	I-134	3.65E-02	1	—	—	1.90E+01	1.07E-01	–2.06E-02	1.28E-01		5.42E+05	0.0E+00	4.00E-04	0.00E+00
I-133		8.67E-01	—	—	—	7.99E-01	6.30E-01	—	—	—	5.42E+05	0.0E+00	7.00E-06	0.00E+00
I-135		2.75E-01	—	—	—	2.52E+00	3.78E-01	—	—	—	5.42E+05	0.0E+00	3.00E-05	0.00E+00
Cs-136		1.31E+01	—	—	—	5.29E-02	4.85E-01	—	—	—	5.42E+05	0.0E+00	6.00E-06	0.00E+00
Cs-138		2.24E-02	—	—	—	3.09E+01	1.79E-01	—	—	—	5.42E+05	0.0E+00	4.00E-04	0.00E+00
Ba-140		1.27E+01	—	—	—	5.46E-02	4.85E-04	—	—	—	5.42E+05	0.0E+00	8.00E-06	0.00E+00
	La-140	1.68E+00	1	—	—	4.13E-01	1.50E-04	5.59E-04	–4.09E-04	—	5.42E+05	0.0E+00	9.00E-06	0.00E+00
Ce-141		3.25E+01	—	—	—	2.13E-02	7.76E-05	—	—	—	5.42E+05	0.0E+00	3.00E-05	0.00E+00
Ce-143		1.38E+00	—	—	—	5.02E-01	6.79E-05	—	—	—	5.42E+05	0.0E+00	2.00E-05	0.00E+00
	Pr-143	1.36E+01	1	—	—	5.10E-02	7.27E-05	–7.67E-06	8.04E-05	—	5.42E+05	0.0E+00	2.00E-05	0.00E+00

(a) Decay chain progeny does not include any noble gases — these are assumed to off-gas upon production.
(b) Values from Table E.1 (Reference 204), Reference 205 for Sr-92, Rh-106, and Ba-137m, and Reference 209 for Pr-144m.
(c) Equation 2.4.13-4.
(d) Table 2.4.13-201.
(e) Equation 2.4.13-9 and Equation 2.4.13-14.
(f) Equation 2.4.13-9 and Equation 2.4.13-14.
(g) Equation 2.4.13-14.
(h) Travel time of 1,480 years or 542,000 days (see Table 2.4.13-202, Sheet 3 of 3).
(i) Equation 2.4.13-5, Equation 2.4.13-9, or Equation 2.4.13-14. Concentrations less than 1.00E-40 $\mu Ci/cm^3$ are reported as zero.
(j) Values from 10 CFR Part 20, Appendix B, Table 2, Column 2.
N/A = Not Applicable

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Table 2.4.13-202 (Sheet 3 of 3)
Results of Transport Analysis Considering Radioactive Decay in Concrete Fill Layer

Primary and Alternate Release Pathways — Through Lean Concrete								
	Hydraulic Conductivity (cm/sec)[a]	**Length (ft)**	**Length (cm)**	**Porosity[b]**	**Hydraulic Gradient[c]**	**Travel Time (yrs)**	**Travel Time (days)**	**Average linear velocity (cm/sec)**
Lean Concrete	8.25E-09	19	579	0.07	0.105	1,480	542,000	1.2375E-08

(a) Reference 206
(b) Reference 208
(c) 2 feet post-construction head ÷ 19 foot concrete thickness

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Table 2.4.13-203
Results of Transport Analysis from Unit 7 Considering Radioactive Decay and Dilution in the Cooling Canal

Radionuclide	Effluent Holdup Tank Concentration[a] ($\mu Ci/cm^3$)	Half-life[b] (days)	Decay Constant[c] ($days^{-1}$)	ECL[d] ($\mu Ci/cm^3$)	Groundwater Concentration[e] ($\mu Ci/cm^3$)	Concentration With Dilution Factor Applied[f] ($\mu Ci/cm^3$)	Surface Water Concentration/ ECL
I-129	7.27E-09	5.73E+09	1.21E-10	2.0E-07	7.3E-09	4.1E-14	2.0E-07
Cs-137	2.42E-01	1.10E+04	6.30E-05	1.0E-06	3.6E-16	2.0E-21	2.0E-15
Ba-137m	2.28E-01	1.77E-03	3.92E+02	N/A[g]	3.4E-16	1.9E-21	N/A[g]
Sr-90	2.38E-05	1.06E+04	6.54E-05	5.0E-07	9.8E-21	5.5E-26	1.1E-19
Y-90	6.30E-06	2.67E+00	2.60E-01	7.0E-06	9.8E-21	5.5E-26	7.8E-21
H-3[h]	1.01E+00	4.51E+03	1.54E-04	1.0E-03	7.0E-37	3.9E-42	5.3E-03

(a) Values from Table 2.4.13-201.
(b) Table 2.4.13-202.
(c) Equation 2.4.13-4.
(d) 10 CFR Part 20, Appendix B, Table 2, Column 2.
(e) Table 2.4.13-202.
(f) Dilution factor based on dilution volume of release (22,400 gallons)/volume of cooling canals (4 billion gallons).
(g) Effluent Concentration Limit (ECL) is not available.
(h) Includes 5,250 pCi/L (5.25E-06 $\mu Ci/cm^3$) background tritium concentration in cooling canals.
N/A = Not Applicable

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Table 2.4.13-204
Results of K_d Analysis

Sample Location (size)	Element							
	Mn	Fe	Co	Sr	Ag	Te	Cs	Ce
606-2 (1 mm)	15.3	<1	2.1	<1	1.5	21.8	0.22	>578
606-2 (1 mm) duplicate	18.4	0.06	1.9	<1	1.3	56.6	0.13	>528
606-2 (1 mm) triplicate	17.9	<1	1.7	<1	1.3	93.6	0.17	>521
606-2 (1 cm)	7.9	<1	1.5	0.03	1.6	30.6	0.1	>503
621-9 (1 mm)	24.7	0.46	4.1	0.27	7.2	>422	0.15	>441
621-9 (1 cm)	29.4	16.4	1.6	0.33	2.9	32.5	0.09	>445
706-1 (1 mm)	26.1	0.25	1.4	0.09	0.89	73.2	0.16	>652
706-1 (1 cm)	15.8	0.44	0.85	0.15	1	7.7	0.09	>617
721-8 (1 mm)	28	0.86	2.1	0.1	1.4	73.6	0.28	>558
721-8 (1 cm)	17.8	0.58	1.5	0.08	0.32	12.1	0.21	>578
735-9 (1 mm)	26.1	<1	0.6	0.23	6.1	169	0.68	>621
735-9 (1 cm)	18.6	<1	1.9	0.24	7.5	99.1	0.42	>668
735-9 (1 cm) duplicate	17.3	<1	2	0.18	6.2	107	0.29	>510
802-8 (1 cm)	18.3	<1	1.4	0.28	2.4	36.4	0.13	>606
805 (1 mm)	27.4	1	3	0.56	3.3	816	0.17	>437
805 (1 cm)	6.3	1.3	2.1	0.75	1.9	23.6	0.2	>323
809-1 (1 mm)	26.5	<1	3.1	0.27	3.1	124	0.17	>657
809-1 (1 mm) duplicate	26.4	<1	2.8	0.1	2.6	221	0.04	>684
809-1 (1 cm)	18	0.1	1.6	0.3	0.6	27.4	0.2	>677
Minimum	6.3	0.06	0.6	0.03	0.32	7.7	0.04	323
Maximum	29.4	16.4	4.1	1	7.5	816	0.68	684
Average	20.3	1.6	2.0	0.4	2.8	128.8	0.2	558
Geometric Mean	19	0.74	1.8	0.25	2.0	64	0.17	549

Notes:
All results in cubic centimeter per gram
(1 mm) — sample crushed to 1 millimeter passing
(1 cm) — sample crushed to 1 centimeter passing

Shaded value was less than value included in this table, less than sign was ignored for calculation purposes

Shaded value was reported as greater than value included in this table, greater than sign was ignored for calculation purposes

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Table 2.4.13-205
Evaluation of Biouptake and Human Consumption of Fish, Crustaceans, and Mollusks in Biscayne Bay

Primary Pathway

Radionuclide	Surface Water Concentration[a] (μCi/cm³)	Surface Water Concentration (pCi/L)	Fish-Water Ratio[b] (FWR) (L/Kg)	Crustacean Mollusk-Water Ratio[b] (CMWR) (L/Kg)	Fraction of Aquatic Food (Crustacean/ Mollusk) that is Contaminated[c] (FR) (unitless)	Fraction of Aquatic Food (Fish) that is Contaminated[c] (FR) (unitless)	Dietary Factor for Annual Consumption of Fish[d] (DFf) (kg/year)	Dietary Factor for Annual Consumption of Crustaceans and Mollusks[d] (DFcm) (kg/year)	Intake from Fish Ingestion[e] (pCi/year)	Intake from Crustacean/ Mollusk Ingestion[f] (pCi/year)	Dose Conversion Factor[g] (DCF) (mrem/pCi)	Dose from Fish Ingestion[h] (mrem/year)	Dose from Crustacean/ Mollusk Ingestion[i] (mrem/year)	Total Dose-Aquatic Ingestion[j] (mrem/year)
Cs-137	2.00E-21	2.00E-12	2.00E+03	1.00E+02	0.5	0.25	5.4	0.9	5.40E-09	9.00E-11	5.00E-05	2.70E-13	4.50E-15	2.75E-13
H-3	5.25E-06	5.25E+03	1	1	0.5	0.25	5.4	0.9	7.09E+03	2.36E+03	6.40E-08	4.54E-04	1.51E-04	6.05E-04
Sr-90	5.50E-26	5.50E-17	6.00E+01	1.00E+02	0.5	0.25	5.4	0.9	4.46E-15	2.48E-15	1.53E-04[k]	6.82E-19	3.79E-19	1.06E-18
I-129	4.10E-14	4.10E-05	4.00E+01	5.00E+00	0.5	0.25	5.4	0.9	2.21E-03	9.23E-05	2.76E-04	6.11E-07	2.55E-08	6.37E-07
								Totals	7.09E+03	2.36E+03	—	4.54E-04	1.51E-04	**0.0006**
												Maximum Dose		**100**

Alternate Pathway

Radionuclide	Ground-water Concentration[a] (μCi/cm³)	Surface Water Concentration (pCi/L)	Fish-Water Ratio[b] (FWR) (L/Kg)	Crustacean Mollusk-Water Ratio[b] (CMWR) (L/Kg)	Fraction of Aquatic Food (Crustacean/ Mollusk) that is Contaminated[c] (FR) (unitless)	Fraction of Aquatic Food (Fish) that is Contaminated[c] (FR) (unitless)	Dietary Factor for Annual Consumption of Fish[d] (DFf) (kg/year)	Dietary Factor for Annual Consumption of Crustaceans and Mollusks[d] (DFcm) (kg/year)	Intake from Fish Ingestion[e] (pCi/year)	Intake from Crustacean/ Mollusk Ingestion[f] (pCi/year)	Dose Conversion Factor[g] (DCF) (mrem/pCi)	Dose from Fish Ingestion[h] (mrem/year)	Dose from Crustacean/ Mollusk Ingestion[i] (mrem/year)	Total Dose-Aquatic Ingestion[j] (mrem/year)
Cs-137	3.60E-16	3.60E-07	2.00E+03	1.00E+02	0.5	0.25	5.4	0.9	9.72E-04	1.62E-05	5.00E-05	4.86E-08	8.10E-10	4.94E-08
H-3	7.00E-37	7.00E-28	1	1	0.5	0.25	5.4	0.9	9.45E-28	3.15E-28	6.40E-08	6.05E-35	2.02E-35	8.06E-35
Sr-90	9.80E-21	9.80E-12	6.00E+01	1.00E+02	0.5	0.25	5.4	0.9	7.94E-10	4.41E-10	1.53E-04[k]	1.21E-13	6.75E-14	1.89E-13
I-129	7.30E-09	7.30E+00	4.00E+01	5.00E+00	0.5	0.25	5.4	0.9	3.94E+02	1.64E+01	2.76E-04	1.09E-01	4.53E-03	1.13E-01
								Totals	3.94E+02	1.64E+01	—	1.09E-01	4.53E-03	**0.113**
												Maximum Dose		**100**

(a) Concentration at groundwater/sediment interface from Tables 2.4.13-202 or 2.4.13-203, no dilution in the bay is assumed.
(b) Table D.5 in Reference 207.
(c) Modified from Section D.2.2 in Appendix D of Reference 207.
(d) Table D.2 in Reference 207.
(e) Calculated as: [GW - pCi/L] * FWR * DFf *FR.
(f) Calculated as: [GW - pCi/L] * CMMR * DFcm *FR.
(g) Table D.1 in Reference 207. Note DCF for Cs-137 and Sr-90 includes aggregated dose conversion factors for intake of principal radionuclide together with radionuclides in the decay chain (i.e. Ba-137m and Y-90).
(h) Calculated as: Dose from Fish Ingestion (pCi/year) * DCF (mrem/pCi).
(i) Calculated as: Dose from Crustacean/Mollusk Ingestion (pCi/year) * DCF (mrem/pCi).
(j) Calculated as Dose from Fish Ingestion (mrem/year) + Dose from Crustacean/Mollusk Ingestion (mrem/year).
(k) Used higher of two values presented in Table D.1 of Reference 207 (note [g]).

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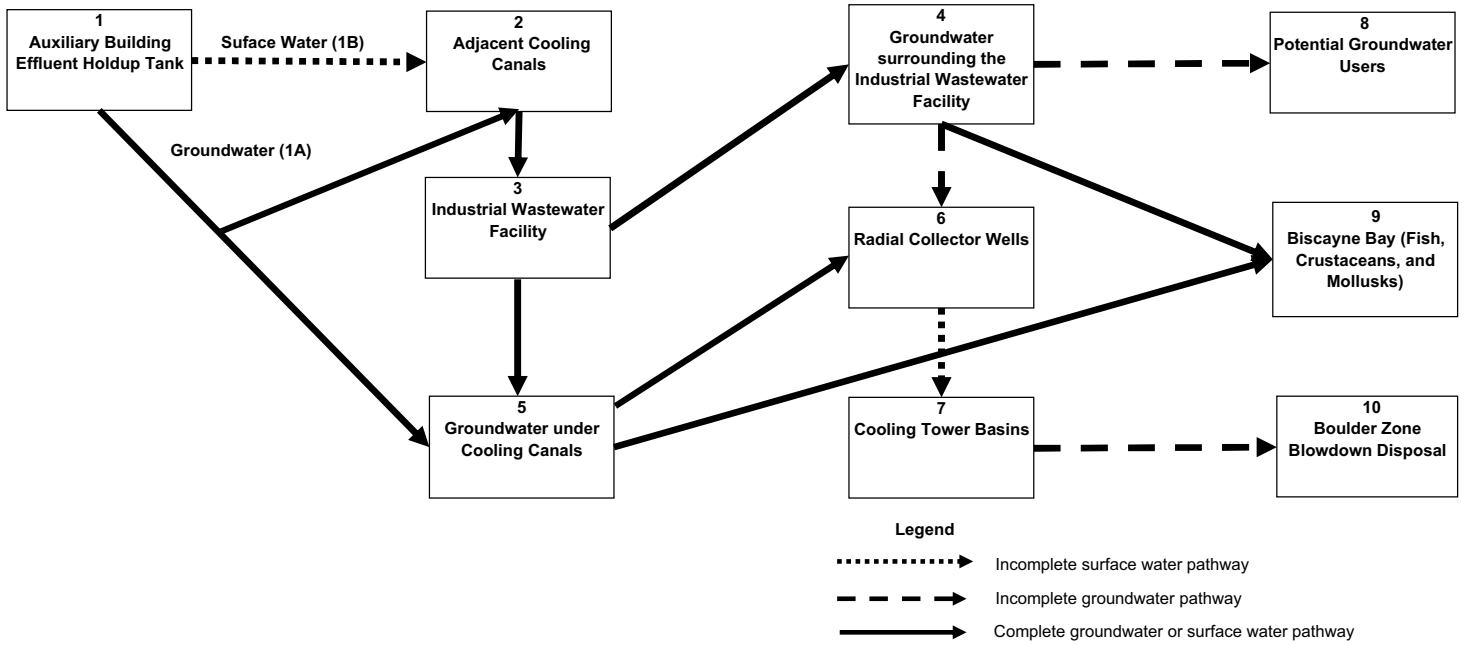
Figure 2.4.13-201 Conceptual Exposure Pathways for Evaluating Radionuclide Transport in the Biscayne Aquifer



Notes:

1 Release Point for 22,400 gallons (80 percent of 28,000 gallon effluent holdup tank).
1A Biscayne aquifer.
1B Hypothetical direct release to surface water; an incomplete pathway due to the location of the tank in the basement and the absence of any direct release mechanism to surface water.
2 Most likely pathway is groundwater discharge to cooling canals located at the perimeter of Units 6 & 7 with a depth of 20 feet (Reference 201).
3 Larger connected cooling canals to west and south with a capacity of about 4,000,000,000 gallons (Reference 202); release is diluted to below level of concern.
4 Groundwater surrounding the cooling canals discharging to Biscayne Bay.
5 Migration route below the cooling canals; this pathway is considered to be less likely due to a upward vertical hydraulic gradient in the lower Fort Thompson Formation.
6 Extraction wells using radial collector wells with a pumping rate of 90,000 gallons per minute; incomplete pathway due to dilution by groundwater from beneath Biscayne Bay.
7 Units 6 & 7 cooling tower basin.
8 Potential groundwater users—this pathway is considered incomplete due to the presence of non-potable groundwater and absence of identified downgradient water users.
9 Biscayne Bay located to east of Units 6 & 7; complete pathway with consumption of fish, crustaceans, or mollusks.
10 Boulder Zone Blowdown Disposal in Floridan aquifer—management of cooling water blowdown; this pathway is incomplete; see 6 and 7 above.

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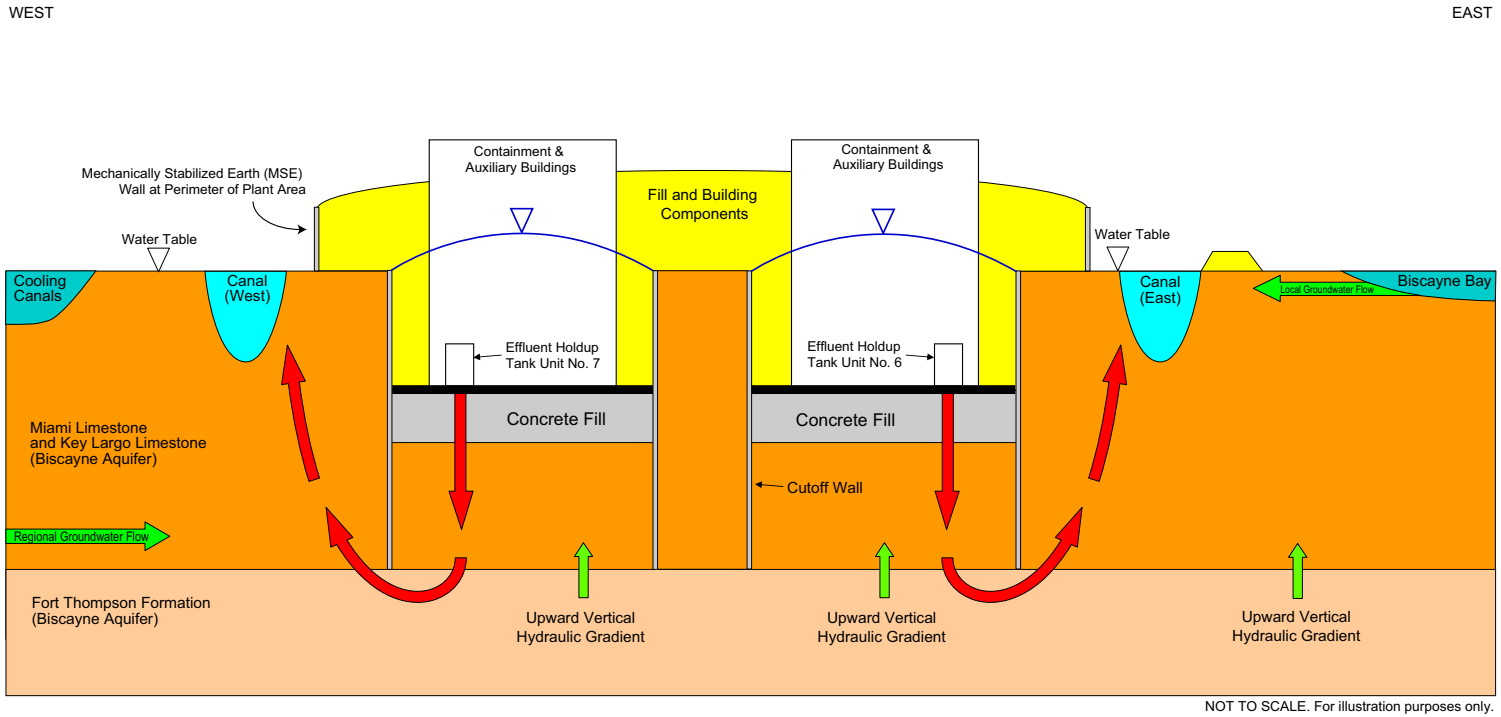
Figure 2.4.13-202 Primary Conceptual Model for Evaluating Radionuclide Transport in the Biscayne Aquifer



NOT TO SCALE. For illustration purposes only.

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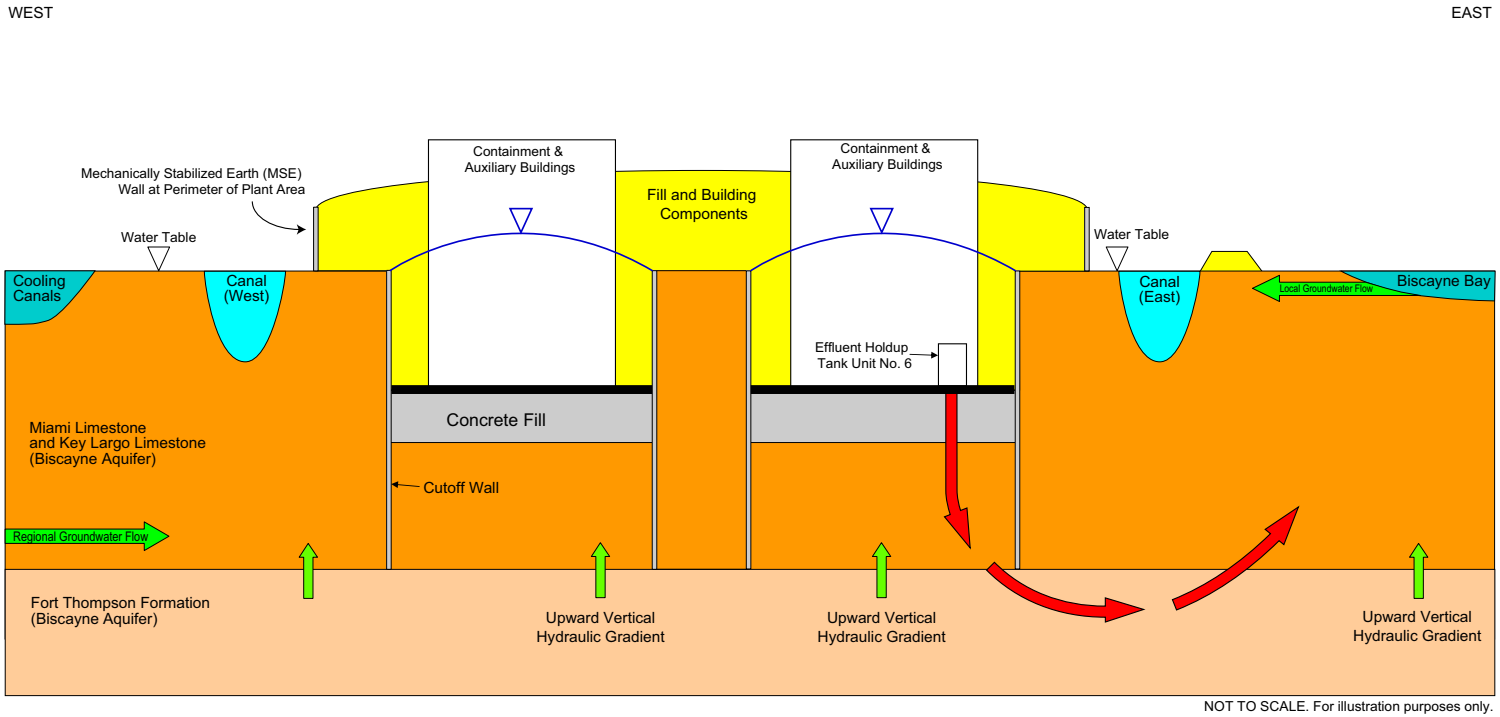
Figure 2.4.13-203 Alternate Conceptual Model for Evaluating Radionuclide Transport in the Biscayne Aquifer



NOT TO SCALE. For illustration purposes only.