Phase II Assessment

Potential Impacts of Uranium Mining in Virginia on Drinking Water Sources

EXECUTIVE SUMMARY

February 2012

Baker

Executive Summary

There is interest in mining and milling a large uranium reserve at the Coles Hill site in Pittsylvania County, Virginia. This reserve, estimated to comprise over 100 million pounds, is located upstream of the John H. Kerr Reservoir (Kerr Reservoir) and Lake Gaston in southern Virginia, as shown in Figure ES-1. Uranium milling and extraction produces vast quantities of waste materials, known as tailings, which can be stored in above-ground impoundments (also known as tailings containment cells). Tailings retain about 85 percent of their original radioactivity for hundreds of thousands of years because certain radioactive materials, such as radium (radium-226) and thorium (thorium-230), are not extracted during the uranium milling process.

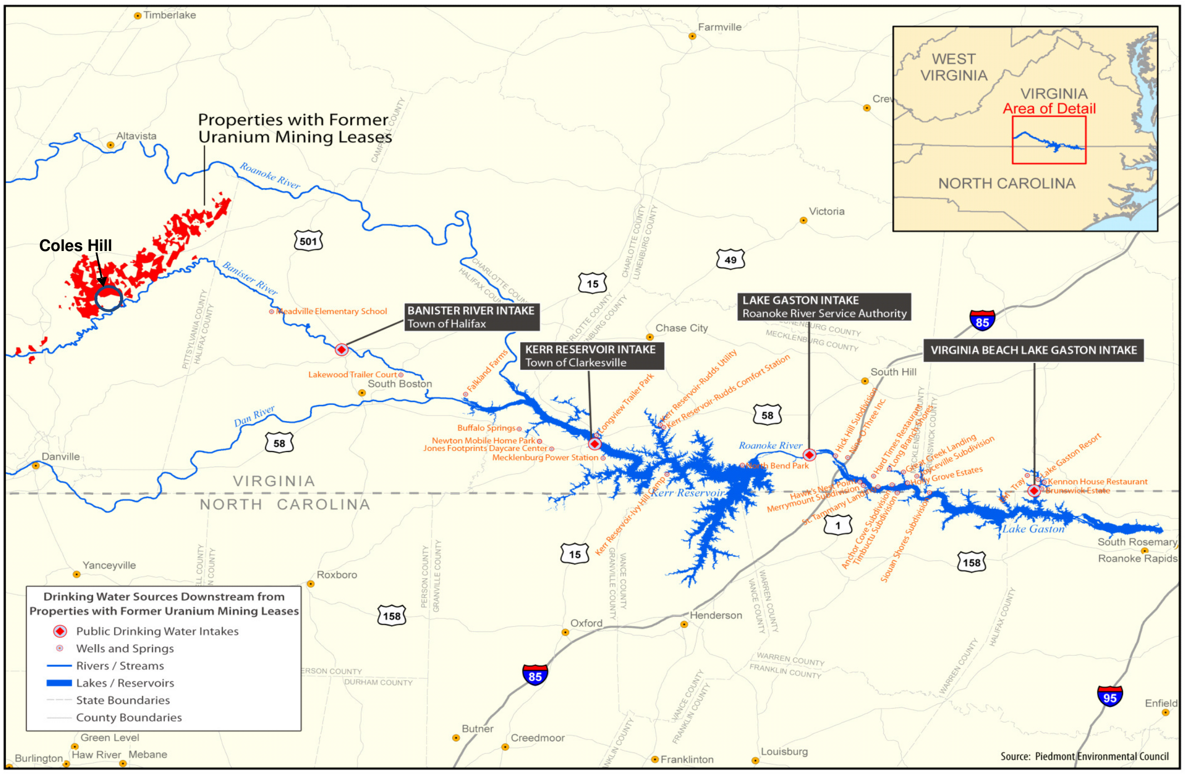

Figure ES-1 Location of Coles Hill Uranium Reserve in Virginia and Downstream Drinking Water Sources

The City of Virginia Beach commissioned a preliminary assessment to determine whether a catastrophic failure of a tailings containment cell in the vicinity of the potential uranium mining location at Coles Hill could cause the contamination of the City's drinking water source at Lake Gaston (consisting of an intake and pumping system on the Pea Hill Creek tributary). This preliminary assessment (the Phase I Assessment) relied on the best available data from various sources because detailed site-specific data, such as the design of the tailings containment structure and likely characteristics of the tailings, were not available. The Phase I Assessment used published data associated with uranium mining in the United States, flood hydrographs with various occurrence probabilities derived from recorded streamflow data, and a number of failure scenarios to develop an understanding of the range of potential impacts of a tailings containment cell failure. The results of the Phase I Assessment were published in February 2011.

The Phase I Assessment used one-dimensional numerical modeling and simulations of hydrodynamics, sediment transport, and contaminant transport and fate for the Banister and Roanoke Rivers and Kerr Reservoir. The one-dimensional simulations assumed the uniform transport of water and sediments through Kerr Reservoir. Potential lateral or non-uniform transport of water and sediments, especially in and around tributaries to the reservoir, was not modeled. Additionally, the Phase I Assessment did not extend to areas beyond Kerr Reservoir.

Objective of Phase II Assessment

The objective of the Phase II Assessment was to estimate the concentrations and residence times of the contaminants radium, thorium, and uranium in Kerr Reservoir and Lake Gaston that could result if a catastrophic mill tailings containment structure failure occurred in the vicinity of the Coles Hill site during periods of wet or dry weather, using site-specific data to the extent available under actual hydrologic conditions. This evaluation specifically emphasized results at the drinking water intake locations in these reservoirs, including the City of Virginia Beach's intake in Lake Gaston.

Phase II Assessment Approach

To achieve the Phase II objective, two-dimensional models were developed for Kerr Reservoir and Lake Gaston. Two-dimensional models allowed the simulation of possible interaction of the flow in the main channel with tributaries, and residence time of the contaminants in the reservoirs, by taking into account lateral mixing processes.

The following modeling approach was used for the Phase II Assessment:

- Banister River: One-dimensional modeling was used for the Banister River to generate flow, sediment, and contaminant input (boundary conditions) from the river to Kerr Reservoir. This model began upstream of Coles Hill and continued to Kerr Reservoir, utilizing the same cross section data as the Phase I Assessment but with additional detail for Banister Lake. Dan River was incorporated in the Banister River model as a side discharge.

- Roanoke River: One-dimensional modeling was used for the Roanoke River to generate flow and sediment input (boundary conditions) from the river to Kerr Reservoir. This model began at the USGS gage location at Randolph and continued to Kerr Reservoir, utilizing the same cross section data as the Phase I Assessment. The Phase II Assessment did not include a scenario of tailings discharge to the Roanoke River. This assessment only evaluated a catastrophic tailings containment structure failure in the vicinity of the Banister River.

- Kerr Reservoir: Two-dimensional modeling was used to simulate hydrodynamics and contaminant transport within the reservoir and to generate input data for the Lake Gaston model.

- Lake Gaston: Two-dimensional modeling was used to simulate hydrodynamics and contaminant transport within the reservoir. In the simulations, it was assumed that following a catastrophic failure of a tailings containment structure, the City of Virginia Beach would stop the operation of the pump station on Pea Hill Creek to prevent contamination.

Simulation scenarios for this study were established using the following variables:

- Hydrology: Actual flow data for the wettest and driest 2-year periods recorded for the rivers.

- Partition Coefficients: Low and high partition coefficients for each contaminant (radium, thorium and uranium).

Numerical simulations for the Phase II Assessment were carried out for two hydrologic conditions – wet year and dry year – using recorded data from USGS gages on the Banister, Dan and Roanoke Rivers. The wet year figures were based on a 2-year period during which recorded discharges were the highest. The dry year was based on the lowest recorded discharges for a 2-year period. The specific properties of the uranium mill tailings that could potentially be generated from the Coles Hill reserves are not yet known. To effectively model the downstream impacts of uranium tailings discharged into the Banister River as a result of the failure of a tailings containment cell, two important parameters – the radioactivity of radium and thorium, and a solid/liquid partition coefficient (K_d) for both contaminants – were estimated using information reported in a preliminary economic assessment report (the Lyntek report). This report was prepared specifically for the Coles Hill uranium property in 2010 by Lyntek, Inc., for Virginia Uranium, Inc. and Virginia Energy Resources, Inc.

Table ES-1 summarizes the estimated mill tailings concentration values for radium, thorium, and uranium that were used in the Phase II Assessment. These values are based on the assumption that an alkaline leaching process is used to extract uranium from the ore. The partition coefficients have a large range of variability. It was therefore decided to define two scenarios with different values of partition coefficients for the three contaminants, based on the range of values reported in the literature. Both scenarios, however, use the same contaminant concentrations in liquids, slimes, and sands.

Table ES-1 Properties of Tailings Used in Phase II Assessment and the Partition Coefficients Assumed for Two Scenarios

Contaminant				Scenario 1	Scenario 2
Contaminant	Concentration in Tailings			Partition Coefficient (mL/g)	Partition Coefficient (mL/g)
	Medium	Amount	Unit	Value	Value
Radium-226	Liquids	125	pCi/L	10	3,000
	Slimes	580	pCi/g		
	Sands	145	pCi/g		
Thorium-230	Liquids	0	pCi/L	2,500	10,000
	Slimes	580	pCi/g		
	Sands	145	pCi/g		
Uranium-238	Liquids	3.02	mg/L	50	1,000
	Slimes	114.4	mg/L		
	Sands	46.72	mg/L		

Although the mining method evaluated in the Lyntek report suggests that a portion of the tailings would be returned to the underground mine shafts as structural backfill, a substantial portion will have to be stored permanently in surface tailings impoundments. The volume of the uranium tailings to be stored in a containment cell was estimated to be 1.6×10^6 m^3, a value close to the tailings impoundment size projected in the Lyntek report, as well as in data reported in other literature[1]. For the purpose of this study, it was assumed that the surface impoundments will be above grade. Even though partial or full

[1] Rico, M., G. Benito, and A. Díez-Herrero. "Floods from Tailings Dam Failures." Journal of Hazardous Materials (2008): 154, 79-87.

below-grade disposal is the prime option under current Nuclear Regulatory Commission regulations, the shallow groundwater table at Coles Hill might preclude this option. [2]

Phase II Assessment Results

For each reservoir, four simulations were performed for the two hydrographs (wet year and dry year) with the two sets of partition coefficients (Scenario 1 and Scenario 2). Results from three key locations are presented in Figures ES-2, ES-3 and ES-4 as composite time series graphs for each contaminant. In these graphs, the results for each hydrological condition (dry and wet year) are represented as colored bands, where the width of the band represents the potential range of contaminant levels caused by the two selected partition coefficients. The top of the band represents Scenario 1, the low partition coefficient, and the lower limit of the band represents Scenario 2, the high partition coefficient. The graphs represent the sum concentrations of dissolved and suspended radium, total radioactivity (due to radium and thorium), and uranium. The dashed red lines represent the maximum contaminant levels (MCL) under the Safe Drinking Water Act.

The following general observations were made from the results of the simulations for both Kerr Reservoir and Lake Gaston:

- The hydrologic condition exerts a much larger effect on the contaminant concentrations than the partition coefficients. Whereas the uncertainty due to the contaminant chemistry is generally less than one order of magnitude, the hydrology (dry versus wet year) generally affects contaminant peak timing by months and the peak value by more than one order of magnitude.
- The contaminant concentrations along the main channel drop more rapidly in wet-year scenarios than in dry-year scenarios.
- Typically, the impact of the tailings radioactivity is more severe in the main channel of the reservoirs than in the tributaries.
- For the same hydrologic time series, the contaminant concentrations along the main channel drop more rapidly in simulations with high partition coefficients (i.e., low solubility) than in scenarios with low partition coefficients (i.e., high solubility).
- Radium concentrations and total radioactivity (combined radioactivity from radium and thorium) remain above the U.S. Environmental Protection Agency's MCL for the longest time in the dry year/low partition coefficient simulation. The radium radioactivity can remain at or above the MCL value of 5 pCi/L for more than 500 days after the tailings release, and the total radioactivity remains at or above the MCL value of 15 pCi/L (for gross alpha activity) at the same locations approximately 300 days.
- During wet years, the contaminants in the main channel may exceed their maximum regulatory levels for up to 90 days following the tailings release.

---

[2] During the recently completed licensing process for the Energy Fuels Piñon Ridge uranium mill, the Colorado Department of Public Health and Environment did not require full below-ground disposal despite favorable groundwater conditions.

The following results were observed for Kerr Reservoir:

- The time for peak concentrations to arrive in the main channel varies from within a few days (during wet years) to several weeks (dry years), and there is substantial attenuation (i.e., decrease in concentrations and broadening of the peak) along the main channel of the reservoir. This is indicative of longitudinal mixing, which would be expected from a reservoir operated for flood control with large water-level fluctuations.

- During wet years, the peak contaminant concentrations may considerably exceed the MCLs in the main channel of the reservoir, but they subside within weeks to levels below the MCL. In the branches, high concentrations can last for a few months.

- During dry years, elevated concentrations of radium and thorium persist in the main channel throughout the entire period of simulations (2 years). The branches furthest downstream also experience elevated concentrations after a considerable delay.

The following results were observed for Lake Gaston:

- Because Lake Gaston is operated at a nearly constant water level, there is little attenuation of the contaminant levels along the main channel of the lake and little or no migration of the tailings residues into its tributaries. Under all scenarios, assuming the City of Virginia Beach intake on Pea Hill Creek is not withdrawing water, the contaminant concentrations remain below their MCLs in Pea Hill Creek.

- Uranium concentrations do not exceed the MCL anywhere in Lake Gaston.

- Following a tailings release during dry years, radium concentrations can remain above the MCL in the main channel for nearly 1.5 years. Total radioactivity concentration can remain above the MCL in the main channel for approximately 1 year.

The study findings regarding the water quality impacts on the Banister River as well as the fate of contaminated sediments are provided in the main body of the report.

Conclusions

Based on the findings of this study, the impact of a tailings release into the Banister River on downstream water supplies is highly dependent on the stream flows in the watershed. However, under any scenario, the partial release of the contents of only one containment cell at the proposed mining site at Coles Hill is likely to result in contaminant concentrations above allowable Safe Drinking Water Act levels in both Kerr Reservoir and Lake Gaston. The simulations reveal that the City of Virginia Beach's drinking water intake, located on the Pea Hill Creek tributary, probably will not experience a significant increase in levels of radium, thorium, or uranium as long as the intake is not withdrawing water. Based on the model projections, in order to prevent the migration of contaminants into the Pea Hill Creek tributary and the City of Virginia Beach water intake and pumping system, the City of Virginia Beach may have to cease pumping water from Lake Gaston for up to 1.5 years. This inability to withdraw water from Lake Gaston could result in severe water shortages for the cities of Virginia Beach, Chesapeake, and Norfolk.

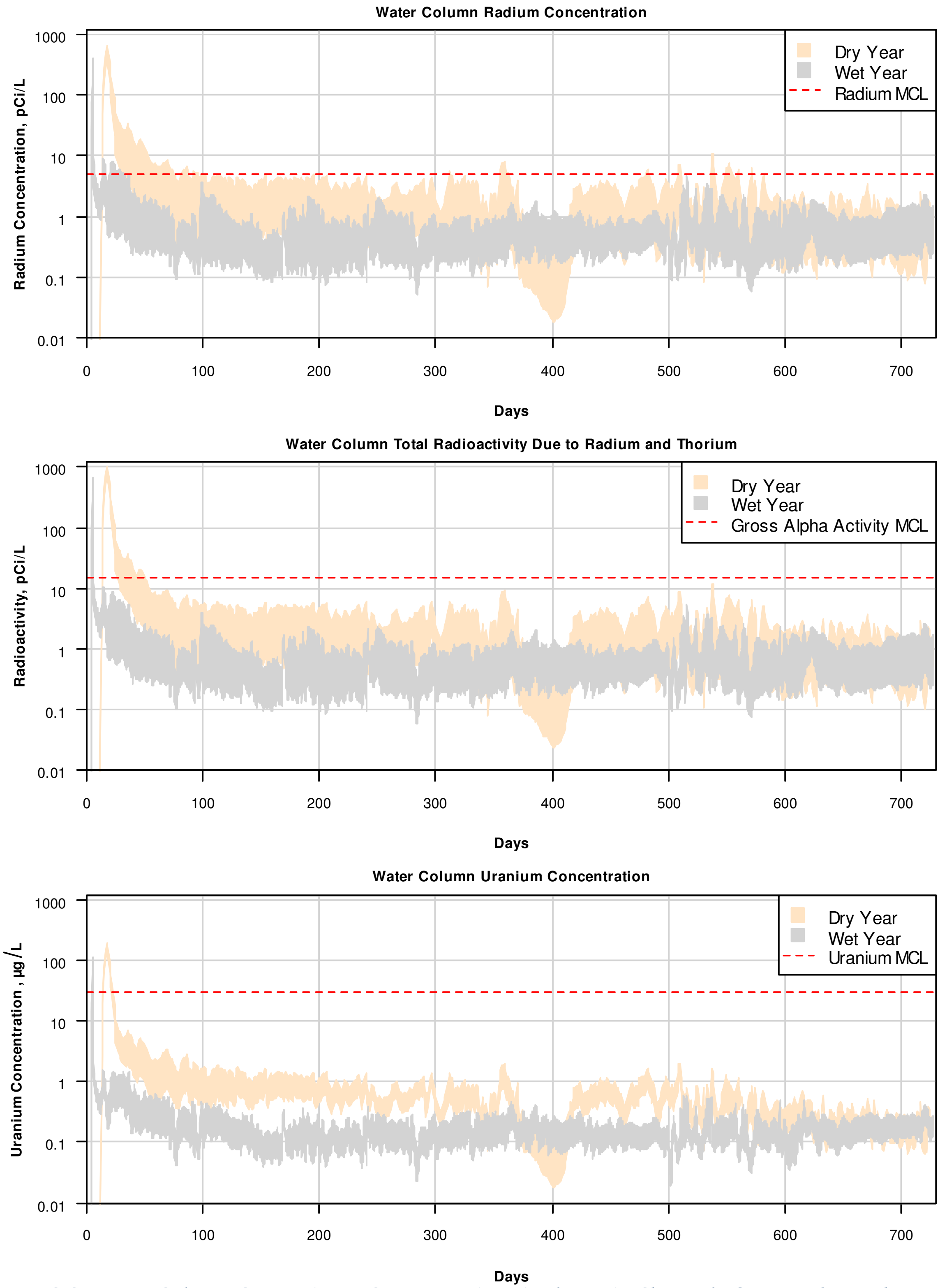

Figure ES-2 Water Column Contaminant Concentrations in the Main Channel of Kerr Lake at the Town of Clarksville Water Intake

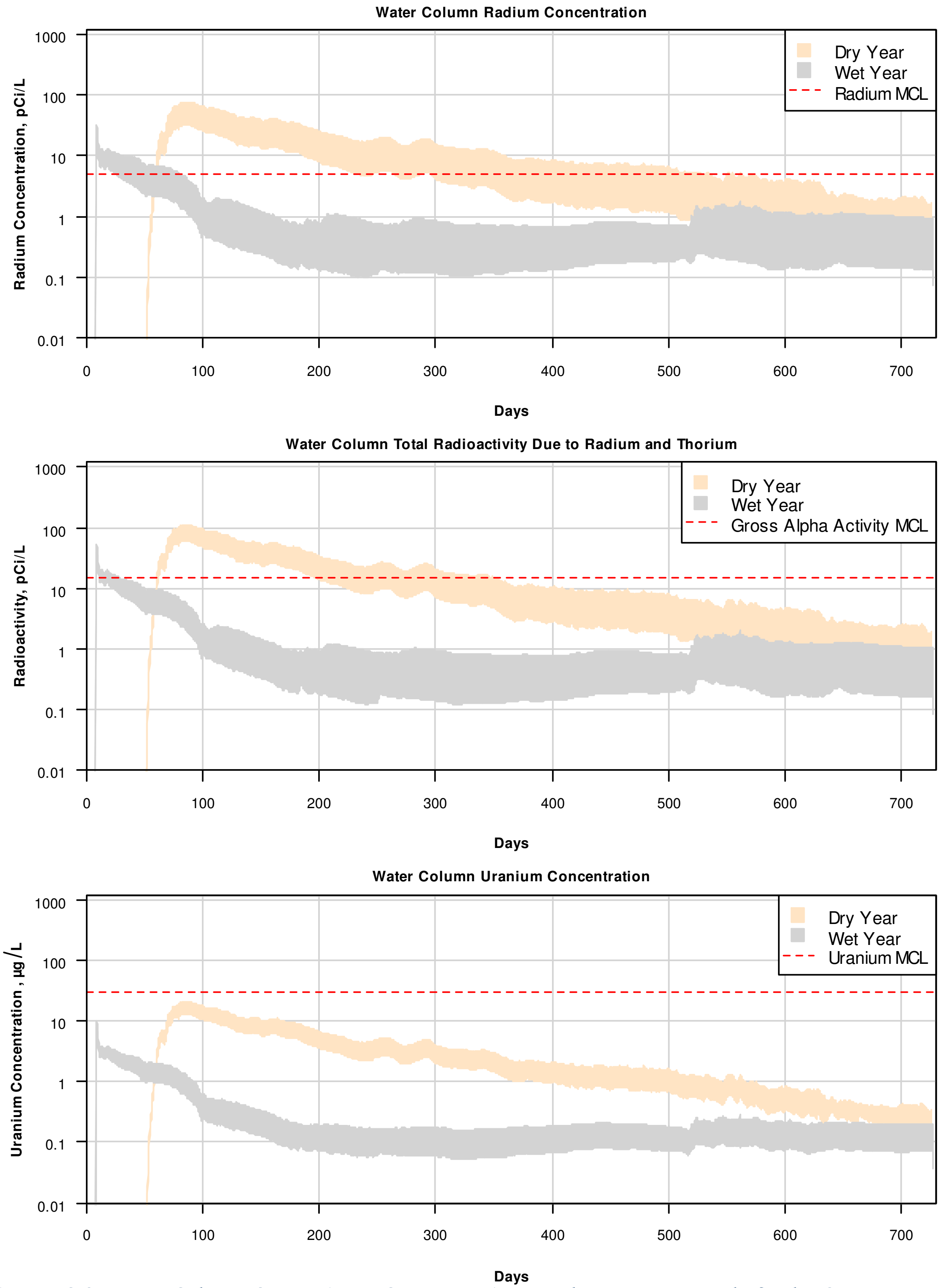

Figure ES-3 Water Column Contaminant Concentrations at the Upstream End of Lake Gaston near the Roanoke River Service Authority Water Intake

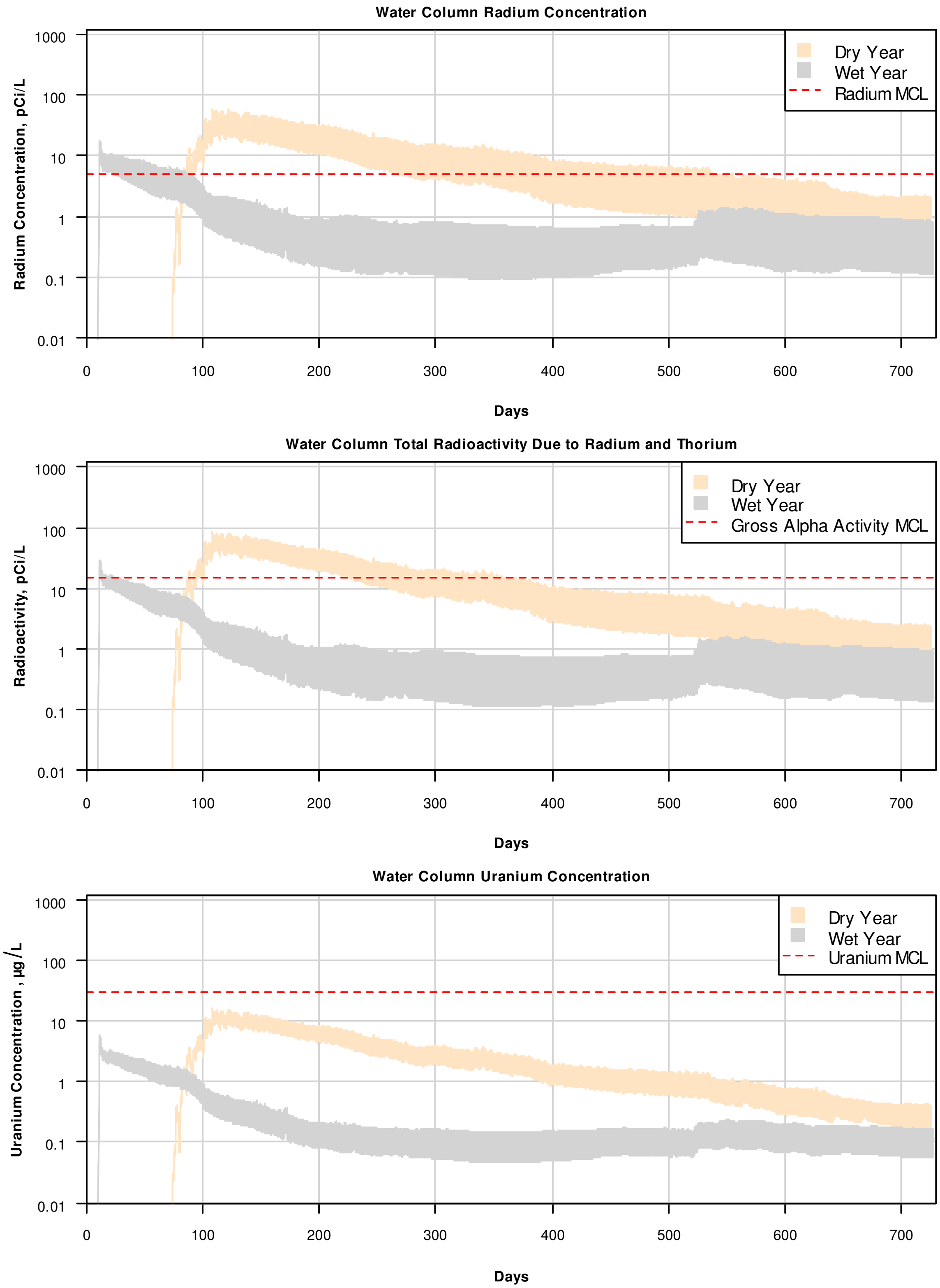

Figure ES-4 Water Column Contaminant Concentrations in the Main Channel of Lake Gaston near the Confluence With Pea Hill Creek. The City's Water Supply Intake Is Located on Pea Hill Creek