Virginia Beach Uranium Mining Study – Summary of Results
Virginia Beach Department of Public Utilities
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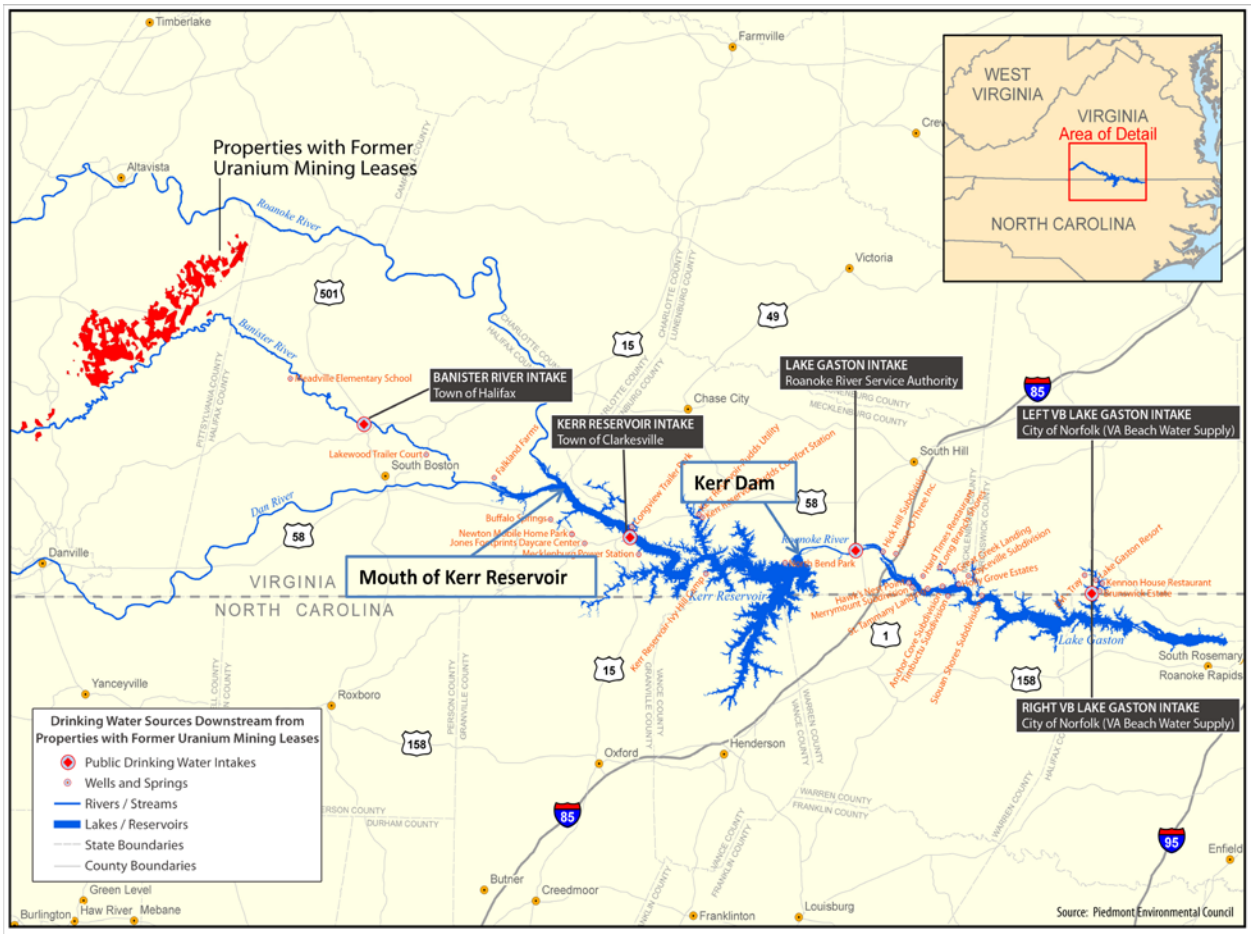
Task and Purpose of the Study

- Model an assumed storm-based catastrophe at a uranium mine/mill located in the Roanoke River Basin, which results in a significant release of mill tailings downstream
- Estimate the amount of tailings and radiological contaminants that would be transported downstream
- Estimate the downstream water quality impacts with respect to radiological substances in the water

Map of Study Area



Study Limitations

The model does not address the issue of whether there will be a catastrophe – it only simulates the outcome if one did occur.

In order to deliver a credible product in the time frame provided and within the resources allotted, certain assumptions and concessions were made:

- The model is a one-dimensional model
- Kerr Reservoir is modeled as a large, one-dimensional channel from its headwaters to the dam. This is a common practice at this level of modeling; however, it has implications with respect to long-term results
- Lake Gaston is not modeled, but on average, outflow from Kerr is 93% of Gaston's inflow. Water quality impacts at Kerr Dam are extremely indicative of impacts in Lake Gaston. Not modeling Lake Gaston also has implications with respect to long-term results
- Only thorium, radium and uranium were modeled. These are the most significant radiological contaminants in mill tailings

The model used is a one-dimensional, transient, river model, with sediment transport and water quality modeling functions developed by the Center for Computational Hydroscience and Engineering at the University of Mississippi. A widely-accepted, one-dimensional model developed by the U.S. Army Corps of Engineers was used to confirm that the University of Mississippi model was producing acceptable results with respect to stream flow simulation and sediment transport.

Model Scenarios

- The Roanoke River Basin, Dan River Basin and Banister River Basin from their headwaters, through Kerr Reservoir, to Kerr Dam were modeled
- Flows: 10-yr, 100-yr, and 500-yr floods were modeled. After each flood scenario, a "normal" year was modeled to simulate long-term effects. Sunny-day failures followed by years with normal and extreme flows were also modeled
- Confinement cell dam heights 5 m, 15 m, 30 m, and 50 m were modeled
- Two levels of radioactivity in the tailings were modeled – RAD1 (lower) and RAD2 (higher)
- High and low partition coefficients for uranium were modeled[1]

[1] The partition coefficient is the ratio of the concentration of a substance in the particulate phase, to the dissolved phase. The solubility of uranium depends upon a number of water chemistry and geochemical parameters.

The Aftermath of a Tailings Release

The model indicates that the tailings separate into particulate and dissolved phases. In general, the particulates contain more thorium, while the dissolved components contain more radium. The distribution of uranium between particulate and dissolved phases varies, depending upon the partition coefficient assumed.

Most particulates settle out of the water column and tend to remain above Kerr Dam – distributed in the reservoir, the river bed and the flood plain. Subsequent periods of high runoff and river flows re-suspend portions of the settled particulates from the river bed and flood plain and move them incrementally downstream, to Kerr Reservoir.

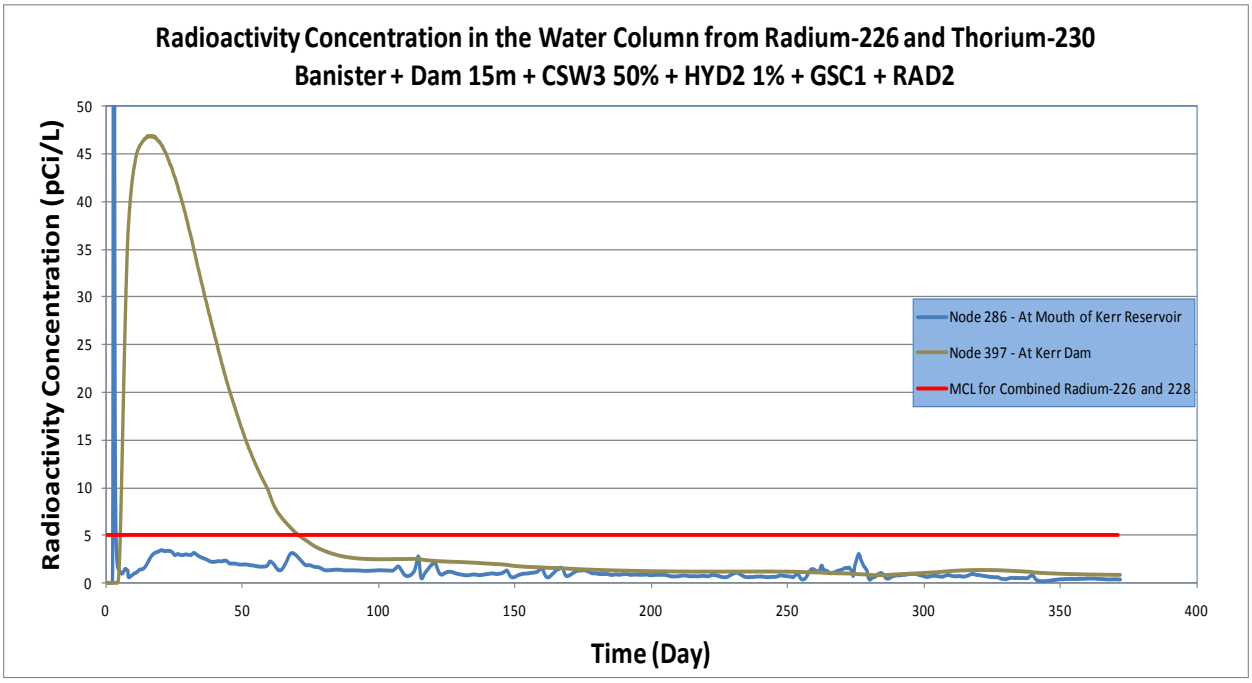
The dissolved contaminants along with some suspended particulates move downstream with the water and flow into Kerr Reservoir where they accumulate for some time, then eventually flow into Lake Gaston. Although not modeled at this time, dissolved and suspended contaminants released from Kerr Dam would similarly accumulate in Lake Gaston. Some of the suspended particulates may settle in Gaston, but dissolved contaminants and most suspended particulates would eventually flow out of Lake Gaston, through the Roanoke Rapids Reservoir, and ultimately downstream to Albemarle-Pamlico Sound via the lower Roanoke River.

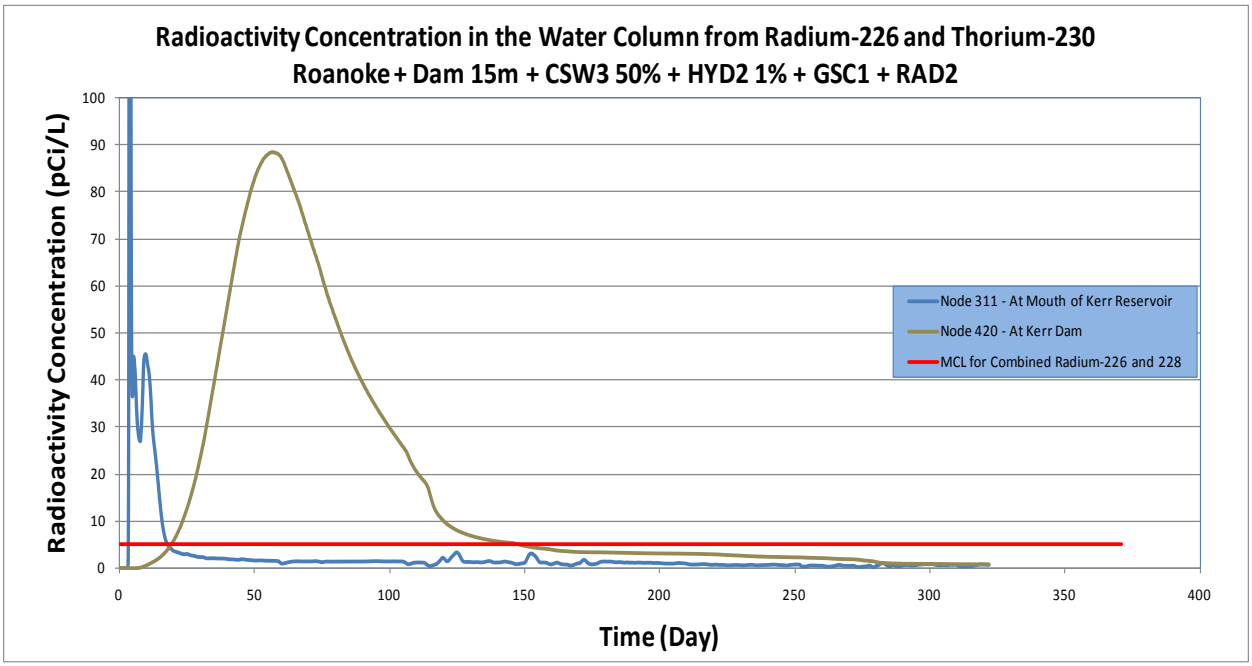
Model Results

Upstream of Kerr Reservoir: Most scenarios indicate significant accumulation of radioactive sediments in the river bed, flood plain and reservoir. Radioactive levels in the water column are initially very high, but decline as the particulates settle and the dissolved and suspended contaminants flow downstream. The radioactivity of the sediments remains very high on a long-term basis. Periods of high flow re-suspend a portion of the settled particulates and move them downstream, incrementally. Most of the particulates, representing 78 to 93 percent of the radioactively released, remain in the flood plain, river bottom, and Kerr Reservoir at the end of the one-year simulation:

	Units	Banister				Roanoke			
		DAM = 15m		DAM = 30m		DAM = 15m		DAM = 30m	
		RAD1	RAD2	RAD1	RAD2	RAD1	RAD2	RAD1	RAD2
Radioactivity Released from the Tailings Containment Failure	Ci	94	548	186	1086	91	533	183	1066
Radioactivity Out of the System at the end of Simulation	Ci	10	35	18	69	22	74	36	130
Radioactivity Remaining in the Water Column	Ci	0.3	0.8	0.5	1.5	0.3	1.9	0.5	1.7
Percent Radioactivity Remaining in the System	%	89	93	89	93	78	87	80	87

Downstream of Kerr Reservoir: Most scenarios indicate that radioactivity in the water column many times greater than what is allowed by the Safe Drinking Water Act accumulates in Kerr Reservoir over a period of months, but eventually flows out of Kerr Dam into Lake Gaston. The model indicates that given normal flows, most radioactivity in the water column is flushed from Kerr Reservoir in periods ranging from three to six months. The time required for flushing is highly dependent upon the flooding scenario assumed as well as the mixing regime in the lake:





Limitations With Respect to Long-term Results

As indicated previously, one of the model limitations was that Kerr Reservoir was modeled as a large, one-dimensional channel – or in simpler terms – a giant river. This is most accurate during flood periods. During normal and drought periods, Kerr Reservoir will act more like a lake. Dissolved contaminants could experience various levels of mixing, distribution throughout the lake volume, and stagnation. The net effect of changing from a river regime to a reservoir regime would be to increase the time required to flush dissolved and suspended contaminants from the water column. Lake Gaston has a volume equal to about 50% of Kerr Reservoir and will add to the time required to flush contaminants from the system.

The average retention time for the combined, total volume of Kerr and Gaston reservoirs (excluding flood storage) is on the order of a month during severe flooding, six months during normal inflows, and one year during major droughts.[2] In one-dimensional river flow, most dissolved contaminants would be flushed from the water column in a single retention time. In a lake scenario with good mixing, it would take approximately two retention times. Therefore, depending upon whether it is very wet or very dry following a significant contamination event upstream of Kerr Reservoirs, it could take from two months to two years for dissolved and suspended contaminants in the water column to be flushed out of both reservoirs.

Eventually, virtually all dissolved and (non-settleable) suspended radiological contaminants will be flushed downstream into Albemarle and Pamlico Sounds, where they would be subject to additional dilution, as well as additional retention time.

Model Sensitivity

Certain variables in the model demonstrated significant influence in the results:

- Dam height which influenced the amount of tailings released
- Initial radioactivity of the tailings
- Assumption of stream flow patterns after a simulated tailings release

Conclusions

- If a significant confinement cell failure were to occur, hydrology in Virginia is more than adequate to move the tailings downstream, and significantly impact water quality in Kerr Reservoir and Lake Gaston

[2]Retention time (also called detention time, residence time or flushing time) is the average time that water spends in a given body of water for a given inflow and outflow. At its simplest, retention time is the result of dividing a reservoir volume by the average flow in and out of the reservoir.

- Tailings carried downstream separate into particulate and dissolved phases. The particulates tend to settle in the flood plain, river bed, and Kerr Reservoir. Dissolved contaminants move downstream with the water flow
- Radiation levels in the water column can rise significantly above Safe Drinking Water Act levels. The model indicates that eventually, most of the contaminants either settle out above Kerr Dam, or are flushed downstream
- The time required to flush radioactive contaminants out of the water column in Kerr Reservoir and Lake Gaston could be on the order of a few months or two years, depending upon the magnitude of stream flows following a catastrophic tailings release
- Kerr Reservoir functions as a significant trap for particulate contaminants
- Environmental impacts and water quality impacts to drinking water systems in and upstream of Kerr Reservoir are more significant and more lasting than downstream

Recommended Future Investigations

Additional work that should be pursued to better understand the impacts to public water supplies in southside Hampton Roads includes the following:

- Additional investigations to better characterize mixing in Kerr and Gaston in order to determine how long it would take to completely flush dissolved and suspended contaminants from both reservoirs in normal and dry periods and whether there would be any significant accumulation of radioactive sediments in Gaston
- Various parameters, including storm intensity and timing thereof, dam height, and volume and radioactivity of released tailings should be refined and narrowed to a few representative scenarios. This will reduce the number of model runs and data that needs to be analyzed
- Better characterization of the tailings and refinement of the partition coefficients, particularly for uranium
- Investigation of the capacity and ability of water treatment plants in the region to remove uranium, thorium and radium, including sludge disposal issues

Although not directly related to water quality impacts in the Norfolk, Virginia Beach and Chesapeake water systems, Virginia Beach should cooperate with upstream interests that may want to use the model and data to better understand the environmental and water quality impacts above Kerr Dam.