Balancing Environmental Management Challenges with the Complexity of the Oak Ridge Reservation

Introduction

For years, many have recognized the extreme complexity of the Oak Ridge Reservation (ORR) with regard to environmental management (EM) activities and challenges. The complexity includes a diversity of waste products disposed of and treated in a myriad ways in a setting where there is abundant rainfall and nearby population centers. This situation is further complicated by the highly complex geology of the site and the resulting hydrologic conditions. This document is intended to elucidate aspects of the complexity and to demonstrate this complexity with specific examples and statements. Indeed, the ORR is the most complex of any Department of Energy (DOE) sites with regard to EM activities.

Specific Aspects of the Complexity

1) **Waste Types**. Virtually all types of radioactive and hazardous wastes have been disposed of on the ORR, starting in 1943. At Oak Ridge National Laboratory (ORNL), high-level liquid waste and low-level solid wastes have been generated, characterized by fission products (e.g., strontium-90, cesium-137), uranium, transuranium elements (e.g., plutonium), and decay daughter products (e.g., polonium). In contrast, at Y-12 National Security Complex the dominant waste types include uranium (40 million pounds), mercury (> 2 million pounds), and hazardous organics, often dense non-aqueous phase liquids (DNAPLS) (e.g., carcinogenic trichloroethylene). At East Tennessee Technology Park (formerly known as K-25), wastes include uranium, hexavalent chromium, technetium-99, and a diversity of hazardous organic materials.

   In some instances waste is in storage for later disposal. For instance, about 450 kilograms of uranium-233, now considered to be a waste product, is embedded in two metric tons of uranium and stored in Building 3019 in the central campus of ORNL. Should there be an accidental release of radiation, operations of the lab would be in jeopardy, costing millions in lost work time and decontamination.

2) **Disposal Methods.** A wide variety of disposal methods were employed throughout the ORR over the years; over 6 million curies of activity were disposed of across the ORR. These include shallow-land burial for low-level and uranium wastes (140 acres); engineered landfills for low-level waste; seepage ponds, pits and trenches for liquid wastes (radioactive and organic); direct disposal (diluted) of liquid wastes into the Clinch River; disposal of reactive metals in flooded quarries; and deep well injection (hydrofracture) for highly radioactive liquid wastes. Also, liquid radioactive wastes have been stored for decades in underground tanks for decay of shorter-lived radionuclides; tank wastes were treated in various ways (injection, seepage, etc.) for final disposal. Injected wastes were generally mixed with cement grout and forced under pressure into subsurface strata (hydrofracture), and pits and trenches were filled with liquid wastes, which were allowed to seep into groundwater and ultimately surface water.

3) **Remediation Technologies.** Many technologies have been used to remediate (clean up, immobilize) the disposed wastes. Included are excavation and shipment of wastes to engineered landfills or off site (Waste Isolation Pilot Plant, Nevada National Security Site); compaction and *in situ* immobilization using cement or polyacrylamide grouts; open-atmosphere burning of waste materials in trenches and uranium metal; groundwater diversion systems; *ex situ* bioremediation of groundwaters; land farming; surface impoundments for mercury removal; and *in situ* vitrification (experimental).

4) **ORR Geology.** The ORR is underlain by a complex assemblage of sedimentary rocks (carbonates, sandstone, shale) that have undergone an intense deformation during the formation of the Appalachians. Resulting from this deformation is a series of folded, tilted and faulted strata containing highly developed fracture systems that extend both laterally and to thousands of feet in depth. The geology of the ORR is widely known as the most complex of any DOE site.

5) **Rainfall.** The climate of the ORR area is temperate and humid, with average annual rainfall about 55 inches.

6) **Hydrology**. As a result of the fracture systems, high rainfall, noted above, and karst development, the hydrology is exceptionally complex. Most groundwater flow is controlled by the fracture systems, which are exceedingly difficult to understand and predict as pathways for groundwater and waste movement; conventional mathematical modeling of these transport mechanisms is not applicable here. In addition, carbonate units are often characterized by solution development (karst) where groundwater can rapidly flow great distances. There is close interaction between surface water and groundwater, and contaminants carried by groundwater generally end up in the surface water, principally the Clinch River, which flows to the southwest into the Tennessee River.

7) **Population Centers.** Because of the interaction of surface water and groundwater, special attention must be given to the water usage in communities downstream from the ORR. In fact, the population density in the immediate vicinity of the ORR is higher than any other DOE site in the complex. The population in the counties immediately surrounding Oak Ridge is more than 815,000 people.

   For instance, communities like Kingston, Rockwood, Dayton, Spring City, and as far as Chattanooga draw water supplied from the Clinch and Tennessee Rivers (fortunately most insoluble contaminants in the river systems are covered by “clean” sediment, but the possibility persists that this could be upset by man-induced or natural causes). The City of Oak Ridge lies adjacent to the Y-12 National Security Complex, and surface drainage from Y-12 in the Poplar Creek system that flows through Oak Ridge carries potentially dangerous amounts of mercury; the creek is posted for this reason. To the northeast of Y-12, off the ORR, groundwater is contaminated with carcinogenic organic chemicals; private drilling for groundwater in this commercial area is prohibited. Although unconfirmed at present, the possibility exists that there may be affected rural areas southwest of ORNL across the Clinch River where contaminants may have spread in the groundwater.

<u>Overview</u>

The information presented above demonstrates the extreme complexity of the ORR with respect to EM activities. Many more examples can be cited, but it is hoped that the reader will agree with the fundamental tenet of this short statement, based on the information presented. No attempt is made herein to compare the ORR to other DOE facilities, each of which has its own set of complexities and challenges. Other sites *do* demonstrate complexity of one or more of these aspects (e.g., Hanford has fracture flow in its bedrock and large amounts of liquid high-level waste, but it has sparse rainfall and is remote with respect to large population centers; the Savannah River Site has relatively close smaller population centers, but lacks the diversity of waste types and disposal methods). In no case, however, does any other DOE site display the spectrum of characteristics described here for the ORR.

Indeed, it can be stated that the complexity of the ORR from a variety of factors, related to EM interests, is the greatest of any DOE site.