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OF

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DOE OVERSIGHT OFFICE

ENVIRONMENTAL MONITORING REPORT

JANUARY through DECEMBER 2013

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EXECUTIVE SUMMARY

The Tennessee Department of Environment and Conservation, Division of Remediation, Department of Energy Oversight Office (the Office) is providing a report of the office's independent environmental monitoring for the 2013 calendar year. Individual reports completed by office personnel make up the report. General areas of interest determine the substance of the reports: Air Quality, Biological, Drinking Water, Groundwater, Radiological, and Surface Water. An abstract is provided in each report. The office's files, containing all supporting information and data used in the completion of these reports, are available for review.

AIR QUALITY MONITORING

Monitoring of Hazardous Air Pollutants on the Oak Ridge Reservation

The Tennessee Department of Environment and Conservation (TDEC), Department of Energy Oversight Office (DOE-O) Hazardous Air Pollutants (HAPs) monitoring program was initially developed to provide independent monitoring of hazardous metals in air at the East Tennessee Technology Park (ETTP) and to verify the Department of Energy's (DOE) reported monitoring results. Monitoring at Oak Ridge National Laboratory (ORNL or X-10) and at the Y-12 National Security Complex was added as an extension of the HAPs monitoring at East Tennessee Technology Park (ETTP). Although permitted emissions have declined at DOE facilities, a number of DOE operations on the Oak Ridge Reservation (ORR), primarily the demolition of contaminated buildings, continue to have the potential to emit hazardous metals. The HAPs monitoring program continued through 2013 as an independent monitoring effort performed by TDEC's Division of Remediation (DOR), DOE-O Office to provide data on hazardous metals in ambient air on the ORR and as independent verification of DOE's monitoring at ETTP. Monitoring with high-volume air samplers was conducted for arsenic, beryllium, cadmium, total chromium, lead, nickel, and uranium. Across the ORR, levels of most metals in 2013 were slightly elevated compared with values in 2011 and 2012. With the possible exception of chromium, analytical results for all metals were below regulatory standards and risk-specific dose levels. All total chromium analyses, with the exception of those from ETTP site during the fourth quarter, were slightly above a risk-specific dose for hexavalent chromium, but below the risk-specific dose for trivalent chromium and the current laboratory quantification value for the analytical method used.

RadNet Air Monitoring on the Oak Ridge Reservation

The RadNet Air Monitoring Program on the Oak Ridge Reservation began in August of 1996 and provides radiochemical analysis of air samples taken from five air monitoring stations located near potential sources of radiological air emissions on the Oak Ridge Reservation. RadNet samples are collected by staff of the Tennessee Department of Environment and Conservation and analysis is performed at the Environmental Protection Agency's National Air and Radiation Environmental Laboratory in Montgomery, Alabama. In 2013, as in past years, the data for each of the five RadNet air monitors largely exhibited similar trends and concentrations, with a few exceptions. The results for 2013 do not indicate a significant impact on the environment or public health from Oak Ridge Reservation emissions.

Fugitive Radioactive Air Emission on the Oak Ridge Reservation

As a part of its obligation under by the Tennessee Oversight Agreement, the Tennessee Department of Environment and Conservation monitors fugitive emissions of radioactive contaminants on the Department of Energy's Oak Ridge Reservation. The results are compared to background measurements to determine if releases have occurred and standards provided by the Clean Air Act to assess compliance with associated emission standards. In 2013 eight high-volume air samplers were deployed in the program. One of the samplers was stationed to collect background information. The remaining units were positioned to monitor remedial and waste management activities on the ORR. Monitored activities included: the decommissioning and demolition of facilities constructed during the World War II Manhattan Era to produce enriched uranium, plutonium, and other radioisotopes used to manufacture the first atomic weapons; remediation of associated waste disposal facilities; and disposal of radioactive waste at the Environmental Management Waste Management Facility. Findings indicate that fugitive releases occurred during 2013, but the concentrations measured were below federal standards.

RadNet Precipitation Monitoring on the Oak Ridge Reservation

The RadNet Precipitation Monitoring Program on the Oak Ridge Reservation (ORR) provides radiochemical analysis of precipitation samples taken from monitoring stations at three locations on the Department of Energy's Oak Ridge Reservation. Samples are collected by the Tennessee Department of Environment and Conservation and analysis is performed at the Environmental Protection Agency's National Air and Radiation Environmental Laboratory. Gross beta analysis for the RadNet precipitation program was discontinued in 2010 and tritium analysis was discontinued in 2012. Analysis for gamma radionuclides is performed on each composite monthly sample in 2013 and will continue to be monitored. Since there is not a regulatory limit for radioisotopes in precipitation, the results from ORR sampling locations are compared to EPA's drinking water limits and can also be compared to data from other sites nationwide. While the stations located on the Oak Ridge Reservation stations are in areas near nuclear sources, most of the other stations in the RadNet precipitation program are located near major population centers, with no major sources of radiological contaminants nearby. Regardless, the radiological results seen in the precipitation samples collected at the RadNet sites on the ORR were all well below the EPA drinking water limits. It should be noted that the EPA drinking water limits pertain to drinking water, not precipitation, and are only used here as a conservative reference value.

BIOLOGICAL MONITORING

Benthic Macroinvertebrate Monitoring

The biotic integrity of streams originating on the Oak Ridge Reservation (ORR) was determined during 2013 by collecting semi-quantitative benthic macroinvertebrate kick samples (i.e., "SQKICK") from thirteen stream stations in four watersheds impacted by Department of Energy (DOE) operations. In addition, seven reference stream stations were sampled. Benthic samples were collected and processed following the State of Tennessee standard operating procedures for macroinvertebrate surveys. Generated data was analyzed using applicable metrics. An assessment score was calculated from the metrics and a site rating was assigned for all stream stations. Results indicate the biotic integrity at a number of the impacted sites in all four stream systems is less than optimal compared to reference conditions. Continued benthic

macroinvertebrate monitoring is necessary to provide a more thorough and accurate assessment of stream conditions. The effectiveness of DOE remedial activities can be assessed with long term monitoring efforts.

Periphyton Monitoring
Diatom communities colonizing artificial substrates were sampled to assess the water quality and ecological condition of Bear Creek impacted by Department of Energy (DOE) activities on the Oak Ridge Reservation, especially the tributaries around the Environmental Management Waste Management Facility (EMWMF). Periphyton samples were collected from artificial substrates between April and November 2013 at four impacted Bear Creek sites. The goal was to use diatoms as biomonitoring tools for the ecological assessment and scoring of the water quality and to examine the recovery of Bear Creek as compared to historical periphyton data extracted from a reference stream. Water quality parameters (i.e., conductivity, pH, etc.) were also collected during each sampling event. Laboratory work was not completed on this project by publication time.

Canada Geese Monitoring
In June 2013, the Tennessee Department of Environment and Conservation (TDEC), Department of Energy Oversight Office (DOE-O) assisted in the annual Canada geese (*Branta canadensis*) Oak Ridge Reservation (ORR) Surveillance Program. The continuing objective of this DOE/TWRA study is to determine if geese are contaminated from habitat on the ORR. Captured geese are transported to the Tennessee Wildlife Resources Agency (TWRA) game check station on Bethel Valley Road to undergo live screenings for radioactive contamination. None of the geese captured this year showed elevated gamma counts exceeding the 5 pCi/g game release level. Since no contaminated geese were captured, the DOE-Oversight Office did not conduct additional offsite sampling of Canada Geese. Relocation efforts have reduced the local population of resident geese and thus the potential for offsite transfer of contaminants.

Aquatic Vegetation Monitoring on the Oak Ridge Reservation
As a part of its obligations under the Tennessee Oversight Agreement, the DOE Oversight Office of the Tennessee Department of Environment and Conservation's Division of Remediation conducts monitoring of aquatic vegetation on and near the Department of Energy's Oak Ridge Reservation. In this program, DOE Oversight staff members collect vegetation at locations near or in water, with the potential for radiological contamination. If surface water bodies have been impacted by radioactivity, aquatic organisms in the immediate vicinity may uptake radionuclides, bioaccumulating radiological contaminants. The vegetation is analyzed for gross alpha, gross beta, and for gamma radionuclides and is compared to the radiological analysis of vegetation taken from background locations. The sampling conducted during 2013 suggests limited areas of elevated radionuclide concentrations in the vegetation associated with surface water on the ORR. In 2013, metals analysis was also completed for up to three metals at most locations. Elevated metals results were seen at some locations.

Threatened and Endangered Species Monitoring
Protection of threatened, endangered and rare species in their natural habitat is a major priority to enable their long-term survival and provide effective stewardship of natural resources on the US Department of Energy's (DOE) Oak Ridge Reservation (ORR). In support of this mission, the

Tennessee Department of Environment and Conservation, DOE-Oversight Office, Division of Remediation (TDEC DOE-O) provided monitoring, mapping, inventory and oversight of natural resources (flora and fauna), review of DOE environmental documents, and conducted field assessments of threatened, endangered and rare plant and animal species. Another goal is documentation and mapping of pest-plant invasion areas on the ORR for future eradication efforts. Staff of TDEC DOE-O lends field biology assistance to the Resource Management Division (Natural Areas Program, Bureau of Parks and Conservation) and the Tennessee Wildlife Resources Agency (TWRA) for T&E/Rare Species mapping and inventory at ORR natural areas and TWRA-managed sites [i.e., Black Oak Ridge Conservation Easement (BORCE) and the Three Bends Area]. The Tennessee Oversight Agreement mandates a comprehensive and integrated monitoring and surveillance program for all media (i.e., air, surface water, soil sediments, groundwater, drinking water, food crops, fish and wildlife, and biological systems) and the emissions of any materials (hazardous, toxic, chemical, radiological) on the ORR and environs. Accordingly, during 2013, TDEC DOE-O staff mapped plant species diversity on trails and off-trail areas of the BORCE and sections of the ORR. An important highlight of 2013 was the capture of a male Indiana Bat (*Myotis sodalis*) by an ORNL/UT team during mist-netting activities at Freels Bend. This is the first confirmed documentation of the federally endangered *M. sodalis* on the ORR since 1950.

White-tailed Deer Monitoring Program on the Oak Ridge Reservation

The DOE-Oversight Office of the TDEC Division of Remediation (TDEC DOEO) continued deer capture activities on the Oak Ridge Reservation (ORR) during 2013. The goal was to chemically immobilize deer and install global positioning system (GPS) collars on them to determine their home range and potential movements outside their home range. The scientific literature provides considerable evidence that wildlife (i.e., carnivores, herbivores, omnivores, piscivores), subsisting in habitats impacted by industrial pollution, are ingesting environmental contaminants from their respective food chains. Humans could potentially be at risk due to unwittingly consuming contaminated game meat and fish which have bioaccumulated metals and other contaminants from the environment. White-tailed deer (*Odocoileus virginianus*) mainly consume vegetation, forbs, nuts, fruits and grasses for nourishment, and ingest soils (i.e., licks) to replenish vitamins and minerals. Oak Ridge Reservation deer, grazing and foraging in contaminated areas such as the Melton Valley solid waste storage areas (SWSAs) at Oak Ridge National Laboratory (ORNL), represent a potentially significant vector for contaminant exposures to the public. This project is part of a multiyear investigation. Our previous 2011-12 GPS collar investigations and results suggest a young buck swam across the Clinch River from ORNL into Knox County. White-tailed deer may temporarily leave their home range during the rut season, or to avoid hunting pressure and other anthropogenic disturbances, and may wander into urban areas to forage. During 2013, division staff captured and successfully collared three deer, all in Melton Valley. Global positioning system (GPS) data was downloaded and home ranges (and excursions from core area) were determined from four recovered collars deployed the year before and presented herein. Two of these deer swam the Clinch River near Jones Island. One doe (Kathy) crossed the river and spent significant time on private property traveling from the Melton Valley Burial Grounds to the southwest about 2.2 miles to Pawpaw Creek areas just north of I40 (Roane County). Hair samples were collected from each captured animal to test for heavy metals. The metals and radionuclide data from available bone samples were not received from the laboratory in time for inclusion in this report.

Acoustic Survey to Assess the ORR Bat Community

Following emergence from winter hibernation, bats were monitored by conducting surveys to record echolocation calls using ultra-high frequency Anabat detectors. Bat call files obtained from the detectors were then analyzed with specialized bat identification software (i.e., BCID-East, Kaleidoscope PRO) to enable acoustic identification of species. A combination of active and passive ultrasonic field surveys were used beginning April 15, 2014, and continuing through October 31, 2014. During 2013, TDEC processed 6,231 bat call files (out of >12,000 total files) collected from ≥75 nights of Anabat surveys at forty-seven (47) ORR sites. The Anabat files were analyzed using the automated software program: BCID-East (plus Kaleidoscope PRO for verification). Our analysis of identified calls suggests thirteen (13) bat species are present on the reservation including two federally endangered species (i.e., Gray Bat, Indiana Bat). Previous ORR bat studies were limited to 3-4 night mist-net and acoustic surveys. This study, along with a concurrent ORNL Environmental Science Division bat project, was the first comprehensive, large-scale (multi-nights) acoustic bat community investigation on the ORR.

DRINKING WATER MONITORING

Sampling of Oak Ridge Reservation Potable Water Distribution Systems

As the three Department of Energy (DOE) Oak Ridge Reservation (ORR) plants become more accessible to the public, the Tennessee Department of Environment and Conservation (TDEC), Department of Energy Oversight Office (the office) is expanding its oversight of DOE facilities' safe drinking water programs. The scope of the office's independent sampling includes oversight of potable water quality potentially impacted by DOE's legacy contamination on the ORR. In 2013, TDEC conducted oversight of the potable water distribution systems and the water quality at ORR facilities. The 2013 results of this oversight revealed that the three reservation systems provide water that meets state regulatory levels.

RadNet Drinking Water on the Oak Ridge Reservation

The RadNet program was developed by the U.S. Environmental Protection Agency to ensure public health and environmental quality as well as to monitor potential pathways for significant population exposures from routine and accidental releases of radioactivity (U.S. EPA, 1988). The RadNet program focuses on nuclear sources and population centers. The RadNet Drinking Water Program in the Oak Ridge area provides for radiochemical analysis of finished water at five public water supplies located near and on the Oak Ridge Reservation. In this effort, quarterly samples are taken by staff from the Tennessee Department of Environment and Conservation and analysis for radiological contaminants is performed at the Environmental Protection Agency's National Air and Radiation Environmental Laboratory in Montgomery, Alabama. Analyses include tritium, iodine-131, gross alpha, gross beta, strontium-90, and a gamma spectrometry, with further analysis performed when warranted. While results for tritium, gross beta, and strontium-90 have tended to be slightly higher at the ETTP Water Treatment Plant, all results generated by the program have remained below regulatory criteria, since its inception in 1996.

GROUNDWATER MONITORING

Groundwater Monitoring for the Oak Ridge Reservation and Its Environs

In 2013, Tennessee Department of Environment and Conservation (TDEC), Division of Remediation's DOE Oversight Office (DOE-O) groundwater program concentrated its efforts on

the area located southwest, along strike and downgradient of legacy waste sites in Bethel Valley, on the Oak Ridge Reservation (ORR). The area of investigation consisted of the Hood Ridge Area and the TVA Clinch River Breeder Reactor (CRBR) site (Figure 1). The Hood Ridge Area is residential and agricultural and located directly southwest and across the Clinch River from Bethel Valley on the ORR. The TVA site is southwest of the Hood Ridge Area also adjacent and across the Clinch River. Three separate but interrelated investigations were carried out in 2013. The center of one investigation is an open borehole, planned as a residential well, but abandoned, 188 m (610 ft.) deep located in the Hood Ridge Area. The borehole is designated RWA-104 (or HD2) and is known from previous TDEC monitoring activities to be contaminated with BTEX, chlorinated solvents, disinfection byproducts, metals, and fluoride. With the assistance of the USGS the open hole was logged and recorded and was sampled at discrete intervals by both TDEC and DOE. DOE-O groundwater staff also sampled discrete intervals with passive diffusive sampling technology, obtained a sample by more conventional methodology, and installed a continuous water level monitor in RWA-104 (HD2).

During the early fall of 2013 TVA as part of preliminary site work for the installation of planned modular reactors on the CRBR site encountered free product (refined petroleum) in an observation well designated OW422L, radiochemical analysis of the free product reported a beta activity at 162 pico-Curies/Liter (PCi/L). TVA allowed DOE-O staff to sample groundwater and product from OW422L, the well is treated as a separate investigation in this report.

Seven residential wells in the Hood ridge Area were sampled on nine differing occasions in 2013. This sampling was conducted to obtain a "background" before TVA carried out an aquifer pumping test on the CRBR site that would have extracted an originally planned volume of 250,000 gallons of groundwater during a three day period. This raised concerns that the pump test of the aquifer might mobilize or further mobilize DOE legacy contaminants downgradient and along geologic strike toward residential wells in the area.

2013 analytic results from all three projects report a broad range of contaminants in groundwater from the area southwest of Bethel Valley (ORNL) on the ORR. Other than tritium which is common in wells on and offsite of the ORR three man-made radionuclides, strontium-90 (^{90}Sr), Technetium-99 (^{99}Tc), and Americium-241 (^{241}Am) were reported at low levels in groundwater analysis. As noted above the TVA well encountered free product which analysis reported as diesel fuel. Analysis of groundwater sampled beneath the free product in the TVA well reported elevated concentrations of metals, BTEX, pH, sodium, fluoride, ammonia and the presence of ^{241}Am. Chlorinated solvents, disinfection byproducts, elevated metals, sodium and fluoride were reported from unused residential well RWA-104(HD2). Low levels of ^{90}Sr and ^{99}Tc were reported from three residential wells, and increases in reported gross beta concentrations from previous sampling were observed in three residential wells in the area.

RADIOLOGICAL MONITORING

Facility Survey Program and Infrastructure Reduction Work Plan

The survey program examines each facility's physical condition, process history, inventory of hazardous chemical and radioactive materials, relative level of contamination, past contaminant release history and, present-day potential for release of contaminants to the environment under varying conditions ranging from catastrophic (i.e. earthquake) to normal everyday working situations. This broad-based assessment supports the objectives of Section 1.2.3 of the Tennessee Oversight Agreement, which was designed to inform local citizens and governments of the historic and present-day character of all operations on the reservation. This information is also essential for local emergency planning purposes. Since 1994, the office's survey team has characterized 206 facilities and found that forty-two percent have either historically released contaminants, or pose a relatively high potential for release of contaminants to the environment today. In many cases, this high potential-for-release is related to legacy contamination that escaped facilities through degraded infrastructures over decades of continuous industrial use (e.g. leaking underground waste lines, substandard sumps and tanks, or unfiltered ventilation ductwork). Since the inception of the program, DOE corrective actions, including demolitions, have removed thirty-nine facilities from the office's list of high Potential Environmental Release (PER) facilities. In 2013 no facilities were removed due to the expiration of American Recovery and Reinvestment Act funds. During 2013, staff conducted four full facility surveys, all at Y-12, none of which were evaluated to have a potential for significant potential environmental release.

Haul Road Surveys

The Haul Road was constructed for, and is dedicated to, trucks transporting CERCLA radioactive and hazardous waste from remedial activities on the Oak Ridge Reservation to the Environmental Management Waste Management Facility in Bear Creek Valley for disposal. To account for wastes that may have blown or dropped from the trucks in transit, personnel from the Tennessee Department of Environment and Conservation perform walk over inspections of the different segments of the nine mile road Haul Road and associated access roads weekly. Anomalous items noted are surveyed for radiological contamination, documented, and their description and location submitted to DOE for disposition. During 2013, fifty-four items that had potentially fallen from trucks transporting waste to the EMWMF were documented. None of the items exhibited radioactivity in excess of free release limits and all were removed expeditiously after being reported to the Department of Energy.

Ambient Gamma Radiation Monitoring of the Oak Ridge Reservation Using Environmental Dosimetry

The Tennessee Department of Environment and Conservation began monitoring ambient radiation levels on the Oak Ridge Reservation in 1995. The program provides conservative estimates of the dose to members of the public from exposure to gamma and neutron radiation attributable to Department of Energy activities on the reservation and baseline values for measuring the need and effectiveness of remedial activities. In this effort, environmental dosimeters have been placed at selected locations on and near the reservation. Results from the dosimeters are compared to background values and the state dose limit for members of the public. While all the doses reported in 2013 at off-site locations were below the dose limit for members of the public, several locations on the reservation that are considered to be potentially accessible to the public had results in excess

of the limit. As in the past, doses above 100 mrem were associated with various sites located in access-restricted areas of the reservation.

Real Time Monitoring of Gamma Radiation on the Oak Ridge Reservation
In 2013, the Tennessee Department of Environment and Conservation placed gamma radiation exposure rate monitors at six locations on the Department of Energy's Oak Ridge Reservation. These units measure and record gamma radiation levels at predetermined intervals over extended time periods, providing an exposure rate profile that can be correlated with activities and/or changing conditions. Monitoring with the units focuses on the measurement of exposure rates under conditions where gamma emissions can be expected to fluctuate substantially over relatively short periods and/or where there is a potential for an unplanned release of gamma emitting radionuclides to the environment. In 2013, five locations were monitored in the program: the ORNL Central Campus Remediation; the exhaust stack at the Spallation Neutron Source Facility; the Molten Salt Reactor at the Oak Ridge National Laboratory; the Environmental Management Waste Management Facility; and a background station located at Fort Loudoun Dam in Loudon County. All results were below limits specified by state and Nuclear Regulatory Commission regulations, which require their licensees to conduct operations in such a manner that the external dose in any unrestricted area does not exceed 2.0 millirem (2,000 μrem) in any one-hour period.

Surplus Material Verification
The Department of Energy (DOE) offers a wide range of surplus items for auction/sale to the general public on the Oak Ridge Reservation (ORR). The Tennessee Department of Environment and Conservation, Department of Energy Oversight Office's Radiological Monitoring and Oversight Program conducted independent radiological monitoring of these surplus materials prior to each auction/sale. During 2013, a total of seven inspection visits were conducted at the ORR facilities. Four visits were made for ORNL sales and three visits were made for Y-12 sales. No sales were conducted at the East Tennessee Technology Park (ETTP) facility. A total of three items, two at ORNL and, one at Y-12 were observed that required further evaluation. All three of these items exhibited elevated alpha and beta radioactivity, and were withdrawn from the sales until further evaluations were conducted.

Monitoring of Waste at the Environmental Management Waste Monitoring Facility Using a Radiation Portal Monitor
The EMWMF was constructed for the disposal of low level radioactive waste and hazardous waste generated by remedial activities on the DOE's Oak Ridge Reservation. The facility is operated under the authority of CERCLA and required to comply with regulations contained in the Record of Decision authorizing the facility. Only radioactive waste with concentrations below limits imposed by waste acceptance criteria (WAC) agreed to by FFA parties are authorized for disposal in the facility. To help ensure compliance with the WAC, the DOE Oversight Office of the Tennessee Department of Environment and Conservation's Division of Remediation has placed a Radiation Portal Monitor (RPM) at the check-in station for trucks transporting waste into the facility. As the waste passes through the portal, radiation levels are measured and monitored by DOE Oversight staff. When anomalies are noted, DOE and EMWMF personnel are notified and basic information on the nature and source of the waste passing through the portal at the time of the anomaly is reviewed. If the preliminary review fails

to identify a cause for the anomalous results, associated information is provided to DOE Oversight's Audit Team for review and disposition. In 2013, the only anomalies observed in the results were due to a nuclear density gauge which contains sealed cesium-137 and americium-241 sources. The density gauge is not a waste, but a tool transported into the EMWMF disposal cells as needed and otherwise stored outside the facility.

SURFACE WATER MONITORING

Environmental Monitoring at the Environmental Management Waste Management Facility

The Tennessee Oversight Agreement requires the State of Tennessee to provide monitoring to verify Department of Energy (DOE) data and to assess the effectiveness of DOE contaminant control systems on the Oak Ridge Reservation. During 2013, the Tennessee Department of Environment and Conservation's (TDEC) DOE Oversight Office monitored groundwater elevations, effluents, surface water runoff, and sediments at DOE's Environmental Management Waste Management Facility (EMWMF). The monitoring has shown the potential for groundwater levels to be above the geologic buffer along the north and northeast portion of the disposal cells. The incursion near PP-02 was identified from the 2011 water level data. This addition has progressed throughout the year. Additional monitoring is warranted to determine if the incursion near PP-02 is due to issues with the underdrain, the northern trench drain, or a function of the additional waste cells. Results from radiological water samples suggest that radionuclides are being discharged from operations conducted at EMWMF. However, those discharges are in compliance under TDEC Rule 1200-2-11-.16. Results from radiological sediment samples suggest that radiological discharges are not impacting the sediments of NT-5 and Bear Creek.

Ambient Sediment Monitoring

Sediment samples from six Clinch River sites and one Poplar Creek site were analyzed for metals and radiological parameters. The mercury levels in the Clinch River sediment samples upstream of the mouth of Poplar Creek were less than the Consensus-based Sediment Quality Guidelines (CBSQGs) Probable Effects Concentration (PEC) of 1.06 mg/kg (MacDonald et al. 2000). The mercury values at these upstream sites range from 0.028 to .056 mg/kg. The two Clinch River sites downstream of the mouth of Poplar Creek were Clinch River Mile (CRM) 9.3 and CRM 11.2; these sites had mercury values of 0.98 mg/kg and 1.7 mg/kg, respectively. The CRM 11.2 mercury value, as well as that of Poplar Creek Mile (PCM) 1.2 (1.6 mg/kg) both exceed the mercury PEC of 1.06 mg/kg. Mercury was the only metal to exceed the PECs. Although Cesium-137 was detected in Clinch River sediment samples taken downstream of the mouth of White Oak Creek, the levels are low and do not pose a threat to human health.

Ambient Surface Water Monitoring

The division conducts semi-annual surface water sampling to detect possible contamination from Department of Energy (DOE) sites. Sampling is conducted at six sites on the Clinch River and four sites on tributaries of the Clinch River (McCoy Branch, Raccoon Creek, Grassy Creek, and Poplar Creek). Samples were analyzed for alpha, beta, and gamma emissions, ammonia, dissolved residue, NO^3 & NO^2 nitrogen, suspended residue, total hardness, total Kjeldahl nitrogen, total phosphate, arsenic, cadmium, copper, iron, lead, manganese, mercury, chromium,

and zinc. Other than dissolved oxygen at Clinch River Mile (CRM) 78.7, the data were either non-detects or the values were within bounds of Tennessee Water Quality Criteria (TNWQC). Dissolved oxygen was measured at 4.82 mg/L on 10/08/2013 at Clinch River Mile (CRM) 78.7; this value is below the TNWQC of 6.0 mg/L (fish and aquatic life, trout stream). Factors that may have affected the low D.O. value were that the sampling location is upstream of the aerating weir dam and a short distance from Norris Dam where the discharge water comes from a great depth from Norris Lake. Strontium-90 specific analysis from the samples collected at Raccoon Creek showed 2.41 pCi/L in the second quarter and 1.42 pCi/L in the fourth quarter. These values are below the EPA strontium-90 MCL for drinking water of 8 pCi/L. Raccoon Creek is believed to be impacted by contaminated groundwater from SWSA 3; the primary radiological contaminant is strontium-90. Radiological data, other than the strontium-90 detection mentioned previously, show nothing of concern. Gross alpha and gross beta values were typical of background conditions.

Surface Water (Physical Parameters) Environmental Monitoring

Due to the presence of areas of extensive anthropogenic point and non-point source contamination on the Oak Ridge Reservation (ORR), there exists the potential for this pollution to impact surface waters on the ORR as well as offsite aquatic systems. The local karst topography and related structural geology influences the fate and transport of contaminants that may further degrade the groundwater and surface water quality of aquatic systems adjacent to the ORR. Therefore, during 2013, the Tennessee Department of Environment and Conservation, Department of Energy Oversight Office (TDEC DOE-O, or office), collected ambient water quality data at six ORR stream locations and one offsite reference stream location. In addition, Upper East Fork Poplar Creek (UEFPC) was instrumented with continuous water quality data logger to observe water quality data and to determine if water quality parameters are impacted during fish kills. One fish kill was reported along UEFPC, but the source of the fish kill discharged just downgradient from the continuous monitoring location.

Ambient Trapped Sediment Monitoring

In order to monitor for changes in contaminant flow through sediment transport, passive sediment samplers (traps) were deployed at three locations: Mitchell Branch km 0.1 (MIK 0.1), Bear Creek Tributary NT5, and East Fork Poplar Creek km 6.3 (EFK 6.3). The sample from EFK 6.3 (21 mg/kg) exceeded the consensus-based sediment quality guidelines (CBSQGs) Probable Effects Concentration (PEC) (1.06 mg/kg) for mercury. The PECs are CBSQGs that were established as concentrations of individual chemicals above which adverse effects in sediments are expected to frequently occur (Ingersoll et al. 2000). The CBSQGs are considered to be protective of human health and wildlife except where bioaccumulative or carcinogenic organic chemicals, such as PCBs or methylmercury, are involved. In these cases other tools such as human health and ecological risk assessments, bioaccumulation-based guidelines, bioaccumulation studies, and tissue residue guidelines should be used in addition to the CBSQGs to assess direct toxicity and food chain effects (WDNR 2003). The threshold effects concentrations (TECs) are concentrations below which adverse effects are not expected to occur (Ingersoll *et al.* 2000). Lead and Iron from the sample at EFK 6.3 exceeded the Threshold Effects Concentration (TEC). The sediment traps at Mitchell Branch km 0.1 and Bear Creek Tributary NT5 did not yield enough sediment for analysis. Radiological results indicated

background conditions, with traces of only two naturally occurring gamma radionuclides, Bi-214 (1.60 ± 0.64 pCi/g) and Pb-212 (1.26 ± 0.31 pCi/g).

2013 Benthic Macroinvertebrate Surface Water Monitoring Program

In May 2013, the division conducted surface water monitoring to complement the benthic macroinvertebrate monitoring program at the following Oak Ridge Reservation (ORR) watersheds: Bear Creek (BCK), East Fork Poplar Creek (EFK), Mitchell Branch (MIK), and White Oak Creek (WCK) / Melton Branch (MEK). In all, surface water samples were collected from eleven impacted stream sites and associated reference sites. In addition, monitoring was also conducted at Clear Creek (CCK) near Norris Dam which serves as a reference site for all the ORR watersheds. Samples were delivered to the State of Tennessee Department of Health (TDH) Laboratory for nutrients, metals, and radiological analyses. Conductivity, pH, conductivity, dissolved oxygen, and temperature were measured at each monitoring site using YSI Professional Plus multi-parameter water quality instruments. The surface water data indicate that the surface water quality in the four watersheds was less than optimal when compared to reference streams. The comprehensive stream assessment scores calculated from the benthic macroinvertebrate monitoring program indicated the same conclusion.

Overall Considerations

DOE's and the Office's monitoring of groundwater and whitetail deer movements indicate possible ORR contaminant exposure to receptors onsite and offsite. Pathways remain under evaluated, especially for a reasonably, maximally exposed individual. Historical disposal areas are contaminated such that groundwater, soils, vegetation, wildlife and fisheries are affected beyond the containment and controls utilized on the ORR. Measures to date to reduce the flux of releases and pathways to receptors are responsible for incremental improvements to the environment, but fall short of eliminating the measurable spread of contamination.

LIST OF COMMON ACRONYMS AND ABBREVIATIONS

ALARA	As Low As Reasonably Achievable
ASER	Annual Site Environmental Report (written by DOE)
ASTM	American Society for Testing and Materials
BCID	Bat Call Identification
BCK	Bear Creek Kilometer (station location)
BFK	Brushy Fork Creek Kilometer (station location)
BJC	Bechtel Jacobs Company (past DOE contractor)
BMAP	Biological Monitoring and Abatement Program
BNFL	British Nuclear Fuels Limited
BOD	Biological Oxygen Demand
BWXT	Y-12 Prime Contractor (current)
CAA	Clean Air Act
CAAA	Clean Air Act Amendments
CAP	Citizens Advisory Panel (of LOC)
CCR	Consumer Confidence Report
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
CFR	Code of Federal Regulations
COC	Contaminants of Concern
COD	Chemical Oxygen Demand
CPM (cpm)	counts per minute
CRM	Clinch River Mile
CROET	Community Reuse Organization of East Tennessee
CWA	Clean Water Act
CYRTF	Coal Yard Runoff Treatment Facility (at ORNL)
D&D	Decontamination and Decommissioning
DCG	Derived Concentration Guide
DIL	Derived Intervention Levels
DO	dissolved oxygen
DOE	Department of Energy
DOE-O	Department of Energy Oversight Office (TDEC)
DOR	Division of Remediation
DWS	Division of Water Supply (TDEC)
E. coli	*Escherichia coli*
EAC	Environmental Assistance Center (TDEC)
ED1, ED2, ED3	Economic Development Parcel 1, Parcel 2, and Parcel 3
EFPC	East Fork Poplar Creek
EMC	Environmental Monitoring and Compliance (DOE-O Program)
EMWMF	Environmental Management Waste Management Facility
EPA	Environmental Protection Agency
EPT	*Ephemeroptera, Plecoptera, Trichoptera* (may flies, stone flies, caddis flies)
ET&I	Equipment Test and Inspection
ETTP	East Tennessee Technology Park
FDA	U. S. Food and Drug Administration

FFA	Federal Facilities Agreement
FRMAC	Federal Radiation Monitoring and Assessment Center
g	gram
GHK	Gum Hollow Branch Kilometer (station location)
GIS	Geographic Information Systems
GPS	Global Positioning System
GW	Ground Water
GWQC	Ground Water Quality Criteria
ha	hectare
HAP	Hazardous Air Pollutant
HCK	Hinds Creek Kilometer (station location)
IBI	Index of Biotic Integrity
IC	In Compliance
"ISCO" Sampler	Automatic Water Sampler
IWQP	Integrated Water Quality Program
K-####	Facility at K-25 (ETTP)
K-25	Oak Ridge Gaseous Diffusion Plant (now called ETTP)
KBL	Knoxville Branch Laboratory
KFO	Knoxville Field Office
l	liter
LC_{50}	Lethal Concentration at which 50 % of Test Organisms Die
LMES	Lockheed Martin Energy Systems (past DOE Contractor)
LWBR	Lower Watts Bar Reservoir
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MACT	Maximum Achievable Control Technologies
MBK	Mill Branch Kilometer (station location)
MCL	Maximum Contaminant Level (for drinking water)
MDC	Minimum Detectable Concentration
MEK	Melton Branch Kilometer (station location)
µg	microgram
mg	milligram
MIK	Mitchell Branch Kilometer (station location)
ml	milliliter
MMES	Martin Marietta Energy Systems (past DOE Contractor)
m	meter
µmho	micro mho (mho=1/ohm)
MOU	Memorandum of Understanding
µR	microroentgen
Mrem	1/1000 of a rem – millirem
N, S, E, W	North, South, East, West
NAAQS	National Ambient Air Quality Standards
NAREL	National Air and Radiation Environmental Laboratory
NAT	No Acute Toxicity
NEPA	National Environmental Policy Act
ng	nanogram
NIC	Not In Compliance

NESHAPs	National Emissions Standards for HAPs
NNSS	Nevada National Security Site (formerly the Nevada Test Site, NTS)
NOAEC	No Observable Adverse Effect Concentration (to Tested Organisms)
NOV	Notice of Violation
NPDES	National Pollution Discharge Elimination System
NRWTF	Non-Radiological Waste Treatment Facility (at ORNL)
NT	Northern Tributary of Bear Creek in Bear Creek Valley
NTS	Nevada Test Site (now the Nevada National Security Site, NNSS)
OMI	Operations Management International (runs utilities at ETTP under CROET)
ORAU	Oak Ridge Associated Universities
OREIS	Oak Ridge Environmental Information System http://w ww-oreis.bechteljacobs.org/oreis/help/oreishome.html
ORISE	Oak Ridge Institute for Science and Education
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
ORRCA	Oak Ridge Reservation Communities Alliance
OSHA	Occupational Safety and Health Association
OSL	Optically Stimulated Luminescent (Dosimeter)
OU	Operable Unit
PACE	Paper, Allied-Industrial, Chemical, and Energy Workers Union
PAM	Perimeter Air Monitor
PER	Potential for Environmental Release
PCB	Polychlorinated Biphenol
pCi	$1x10^{-12}$ Curie (Picocurie)
PCM	Poplar Creek Mile (station location)
pH	Proportion of Hydrogen Ions (acid vs. base)
PWSID	Potable Water Supply Identification "number"
ppb	parts per billion
ppm	parts per million
ppt	parts per trillion
PPE	Personal Protective Equipment
PRG	Preliminary Remediation Goals
QA	Quality Assurance
QC	Quality Control
R	Roentgen
RBP	Rapid Bioassessment Program
RCRA	Resource Conservation and Recovery Act
REM (rem)	Roentgen Equivalent Man (unit)
RER	Remediation Effectiveness Report
RMD	Resource Management Division
ROD	Record of Decision
RSE	Remedial Site Evaluation
SLF	Sanitary Landfill
SNS	Spallation Neutron Source
SOP	Standard Operating Procedure

SPOT	Sample Planning and Oversight Team (TDEC)
SS	Surface Spring
STP	Sewage Treatment Plant or Site Treatment Plan
SW	Surface Water
TDEC	Tennessee Department of Environment and Conservation
TDS	Total Dissolved Solids
TIE	Toxicity Identification Evaluation
TLD	Thermoluminescent Dosimeter
TMI	Tennessee Macroinvertebrate Index
TOA	Tennessee Oversight Agreement
TRE	Toxicity Reduction Evaluation
TRM	Tennessee River Mile
TRU	Transuranic
TSCA	Toxic Substance Control Act
TSCAI	Toxic Substance Control Act Incinerator
TSS	Total Suspended Solids
TTHM's	Total Trihalomethanes
TVA	Tennessee Valley Authority
TWQC	Tennessee Water Quality Criteria
TWRA	Tennessee Wildlife Resources Agency
UCOR	URS/CH2M Oak Ridge LLC (Current EM Prime Contractor)
U.S.	United States
UT-Battelle	University of Tennessee-Battelle (ORNL Prime Contractor)
VOA	Volatile Organic Analytes
VOC	Volatile Organic Compound
WCK	White Oak Creek Kilometer (station location)
WM	Waste Management
WOL	White Oak Lake
X-####	Facility at X-10 (ORNL)
X-10	Oak Ridge National Laboratory
Y-####	Facility at Y-12
Y-12	Y-12 Plant Area Office

INTRODUCTION

In accordance with the Tennessee Oversight Agreement, Attachment A.7.2.2, the Tennessee Department of Environment and Conservation, DOE Oversight Office (the office), is providing this annual environmental monitoring report of the results of its monitoring and analysis activities during the calendar year of 2013 for public distribution. In 1991 the office was established to administer the Tennessee Oversight Agreement (TOA) and the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA)-required Federal Facility Agreement. These agreements are designed to assure the citizens of Tennessee that the Department of Energy (DOE) is protecting their health, safety, and environment through existing programs and substantial new commitments.

This report consists of a compilation of individual reports that involve independent environmental monitoring projects conducted by the office. The individual reports are organized by general areas of interest: Air Quality, Biological, Drinking Water, Groundwater, Radiological and Surface Water. Abstracts and conclusions are available in each report to provide a quick overview of the content and outcome of each monitoring effort. All supporting information and data used in the completion of these reports are available for review in the office's program files. Overall, this report characterizes and evaluates the chemical and radiological emissions in the air, water, and sediments both on and off the Oak Ridge Reservation (ORR).

The office considers location, environmental setting, history, and on-going DOE operations in each of its environmental monitoring programs. The information gathered provides information for a better understanding of the fate and transport of contaminants released from the ORR into the environment. This understanding has led to the development of an ambient monitoring system and increased the probability of detecting releases in the event that institutional controls on the Oak Ridge Reservation fail.

Currently, the office's monitoring activities have not detected imminent threats to public health or the environment outside of the Oak Ridge Reservation. Unacceptable releases of contaminants from past DOE operational and disposal activities continue to pose risk to the environment and it is imperative to note that, if current institutional controls fail or if the present contaminant source controls can no longer be maintained, the public would be at risk from environmental contamination.

Site Description

The ORR, as shown in Figure 1, encompasses approximately 35,000 acres and three major operational DOE facilities: the Oak Ridge National Laboratory (ORNL), the Oak Ridge Y-12 Plant (Y-12), and the East Tennessee Technology Park (ETTP, formerly the K-25 Gaseous Diffusion Plant). The initial objectives of the ORR operations were the production of plutonium and the enrichment of uranium for nuclear weapons components. In the 70 years since the ORR was established, a variety of production and research activities have generated numerous radioactive, hazardous, and mixed wastes. These wastes, along with wastes from other locations, were disposed on the ORR. Early waste disposal methods on the ORR were rudimentary compared to today's standards.

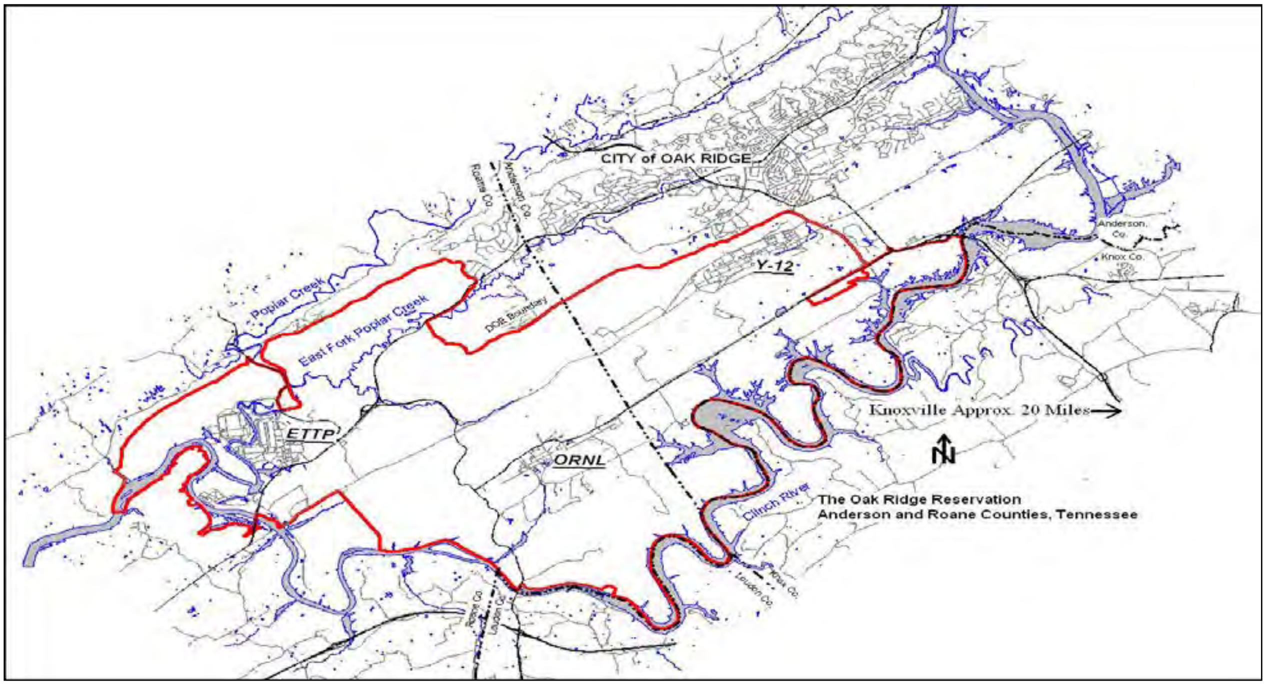

Figure 1: The Oak Ridge Reservation

The ORR is located in the counties of Anderson and Roane within the corporate boundaries of the City of Oak Ridge, Tennessee. The reservation is bound on the north and east by residential areas of the City of Oak Ridge and on the south and west by the Clinch River. Counties adjacent to the reservation include Knox to the east, Loudon to the southeast and Morgan to the northwest. Meigs and Rhea counties are immediately downstream on the Tennessee River from the ORR. The nearest cities are Oak Ridge, Oliver Springs, Kingston, Lenoir City, Harriman, Farragut, and Clinton. The nearest metropolitan area, Knoxville, lies approximately 20 miles to the east. Figure 2 depicts the general location of the Oak Ridge Reservation in relation to nearby cities and surrounding counties.

The ORR lies in the Valley and Ridge Physiographic Province of East Tennessee. The Valley and Ridge Province is a zone of complex geologic structures dominated by a series of thrust faults and characterized by a succession of elongated southwest-northeast trending valleys and ridges. In general, sandstones, limestones, and/or dolomites underlie the ridges that are relatively resistant to erosion. Weaker shales and more soluble carbonate rock units underlie the valleys.

The hydrogeology of the ORR is very complex with a number of variables influencing the direction, quantity, and velocity of groundwater flow that may or may not be evident from surface topography. In many areas of the ORR, groundwater appears to travel primarily along short flow paths in the storm flow zone to nearby streams. In other areas, evidence indicates substantial groundwater flow paths, possibly causing preferential contaminant transport in fractures and solution cavities in the bedrock for relatively long distances and at considerable depths increasing the probability for off-site migration of those contaminants to the public.

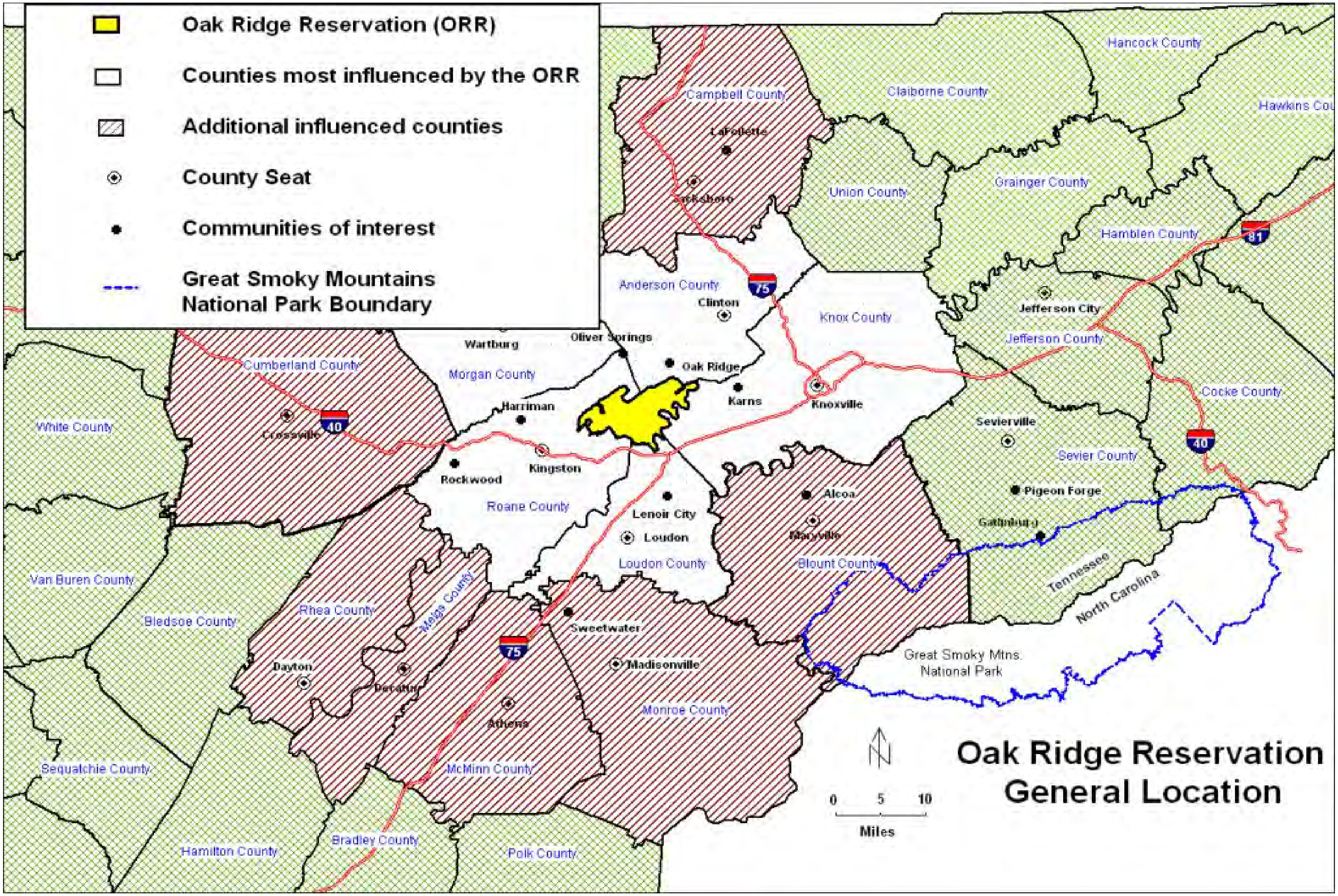

Figure 2: Location of the Oak Ridge Reservation in relation to surrounding counties

As seen in Figure 3, streams on the ORR drain to the Clinch River and then to the Tennessee River. Melton Hill Dam impounded the Clinch River in 1963. Contaminants released on the Oak Ridge Reservation, and that do not remain permanently in the groundwater, enter area streams (e.g., White Oak Creek, Bear Creek, East Fork Poplar Creek, and Poplar Creek) and are transported into the Clinch River and Watts Bar Reservoir on the Tennessee River. Groundwater travels through fractures and solution channels to offsite locations, including underneath the Clinch River. Traveling fish and wildlife also pose pathways to offsite locations.

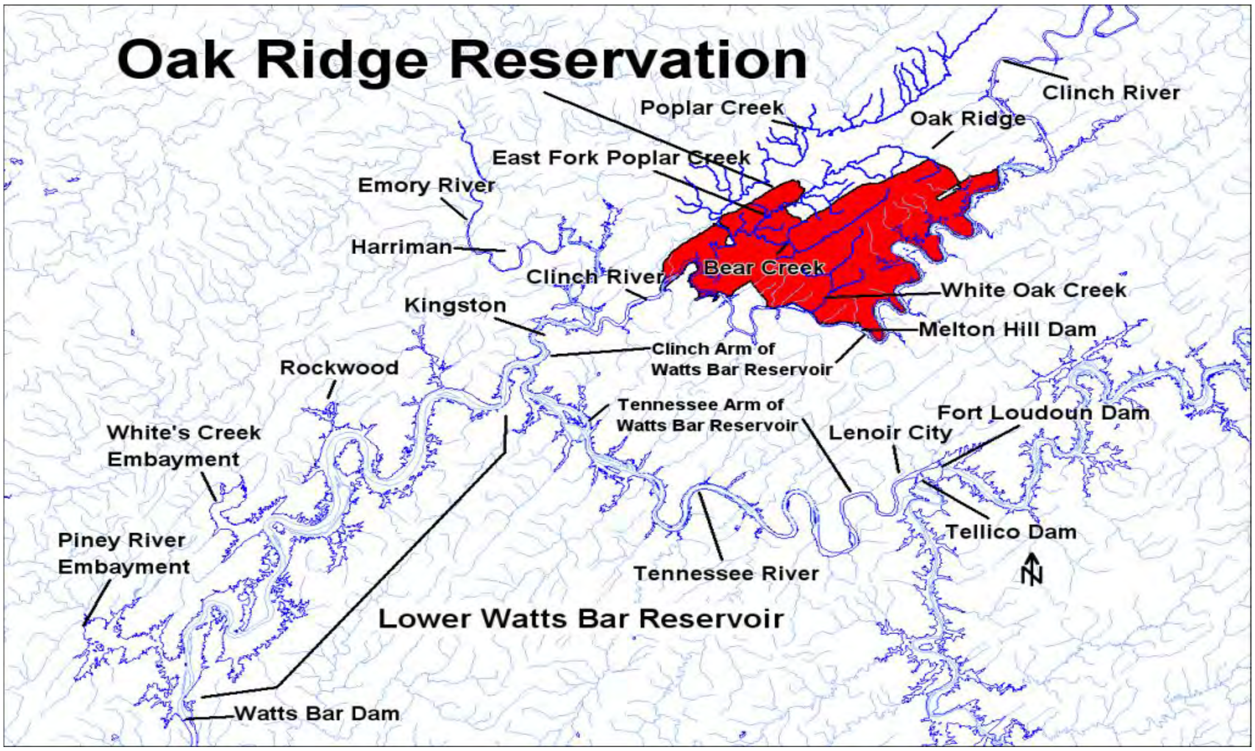

Figure 3: Watts Bar Reservoir

The climate of the region is moderately humid and the annual average precipitation is around 55 inches. Winds on the reservation are controlled, in large part, by the valley and ridge topography with prevailing winds moving up the valleys (northeasterly) during the daytime and down the valleys (southwesterly) at night.

AIR QUALITY MONITORING

Monitoring of Hazardous Air Pollutants on the Oak Ridge Reservation

Principal Author: Sid Jones

Abstract

The Tennessee Department of Environment and Conservation (TDEC), Department of Energy Oversight Office (DOE-O) Hazardous Air Pollutants (HAPs) monitoring program was initially developed to provide independent monitoring of hazardous metals in air at the East Tennessee Technology Park (ETTP) and to verify the Department of Energy's (DOE) reported monitoring results. Monitoring at Oak Ridge National Laboratory (ORNL or X-10) and at the Y-12 National Security Complex was added as an extension of the HAPs monitoring at East Tennessee Technology Park (ETTP). Although permitted emissions have declined at DOE facilities, a number of DOE operations on the Oak Ridge Reservation (ORR), primarily the demolition of contaminated buildings, continue to have the potential to emit hazardous metals. The HAPs monitoring program continued through 2013 as an independent monitoring effort performed by TDEC's Division of Remediation (DOR), DOE-O Office to provide data on hazardous metals in ambient air on the ORR and as independent verification of DOE's monitoring at ETTP. Monitoring with high-volume air samplers was conducted for arsenic, beryllium, cadmium, total chromium, lead, nickel, and uranium. Across the ORR, levels of most metals in 2013 were slightly elevated compared with values in 2011 and 2012. With the possible exception of chromium, analytical results for all metals were below regulatory standards and risk-specific dose levels. All total chromium analyses, with the exception of those from ETTP site during the fourth quarter, were slightly above a risk-specific dose for hexavalent chromium, but below the risk-specific dose for trivalent chromium and the current laboratory quantification value for the analytical method used. Due to the continuing reduction in permitted sources on the ORR and the completion of the demolition of the K-25 building at ETTP, this project will be discontinued until other major demolition projects on the ORR are initiated or other potential sources of hazardous air pollutants are identified.

Introduction

Title III of the Clean Air Act Amendments (CAAAs) identified 189 toxic chemicals. These chemicals, called hazardous air pollutants (HAPs), are associated with adverse health effects and are used widely in a variety of industries. Major stationary sources of HAPs are subject to the National Emissions Standards for Hazardous Air Pollutants (NESHAPs) found in Title III of the CAAAs of 1990. Rather than set NESHAPs limits for each pollutant, the 1990 CAAAs directed the Environmental Protection Agency (EPA) to set technology-based standards using maximum achievable control technologies (MACT) for 175 source categories to achieve reductions of routine emissions of toxic air pollutants.

In 1997, concerns were raised by members of the public regarding potential health effects due to possible concentrations of HAPs in the ambient air on and around the ORR, specifically near the Toxic Substances Control Act Incinerator (TSCAI) at the East Tennessee Technology Park (ETTP). In response to these concerns, the Tennessee Department of Environment and Conservation (TDEC), Department of Energy Oversight Office's (DOE-O) Hazardous Air Pollutants (HAPs) monitoring program was developed to provide monitoring of hazardous

metals in air at ETTP and to verify the Department of Energy's (DOE) HAPs monitoring program, which was restricted to monitoring for metals at the ETTP site. In 1998 and 1999 the division's Waste Management (WM) program developed a more comprehensive monitoring program for the ORR to determine what effects, if any, DOE operations were having on levels of hazardous metals in the ambient air on and around the reservation. This program was designed to extend the range of monitoring beyond the East Tennessee Technology Park area to other sites on the reservation. Background data were collected at a site located near Norris Lake in 1997. These data were used to establish a baseline for the area surrounding the ORR. A change in analytical methods initiated in 2006 by the Tennessee Department of Health (TDH) Environmental Laboratories resulted in lower limits for detection and quantification of all metals. Over the past six years, samples have been composited for quarterly analysis rather than analyzed weekly, consistent with the procedure used by the DOE program for monitoring of metals at the ETTP site. The program continued until 2013 as a part of the independent monitoring around the ORR carried out by TDEC's Division of Remediation (DOR), DOE-O Office under authority of the Tennessee Oversight Agreement between TDEC and DOE. Air monitoring data generated by this program and by DOE were reviewed annually to refine or change sampling techniques, analytical methods, or location of samplers.

ETTP

The ambient air-sampling at this site has been primarily conducted at stations co-located with DOE monitors K-2 (Blair Rd opposite the TSCA Incinerator), Perimeter Air Monitor K-42 (next to Poplar Creek) and Perimeter Air Monitor K-35 (Gallaher Road Bridge area). The locations of these monitoring stations are shown in Figure 1. Sampling was at Blair Road exclusively from 2005 until the third quarter of 2012, primarily to facilitate comparison with a co-located DOE sampler. Additional factors in selecting locations were the availability of a power source and monitoring data reported by the DOE in the Annual Site Environmental Report (ASER). These data indicated that both lead and uranium average values were typically highest at the K-2 (as opposed to the K-35 or K-42) site. In 2012, the sampler was moved to the K-11 site shown in Figure 1. This site is in closer proximity to the demolition activities that potentially constitute the primary source of HAPs emissions following closure of the TSCA incinerator in 2009. Results reported for four sites at ETTP in the 2012 ASER indicate that the K-11 monitoring station typically records the highest values for both metals and radionuclides throughout 2011 and 2012.

X-10 (ORNL)

Monitoring at ORNL was resumed in 2008 after being temporarily discontinued in 2007 due to relocation of the power supply. The location of the sampler has remained on the main ORNL campus facility near the Tank W1A (Core Hole 8) removal action (where it was moved in 2006) to monitor airborne radionuclides. Remedial work at the Tank W1A site continued into 2012, and the sampler was left at the site throughout 2013 as it was located near demolition projects that had the potential to create fugitive emissions of HAPs metals and radionuclides. The sampler location (X-10 CH-8) and the historical monitoring sites at the east end and west end of the plant are shown in Figure 2.

Y-12

For the past five years, air monitoring at Y-12 was conducted at the station located at the east end of this facility. The old sampling station located south of the Lake Reality area was

abandoned when the Y-12 plant needed to expand parking in this area. The air monitor was relocated about 1000 feet to the north near Station 17 on East Fork Poplar Creek, as shown in Figure 3, during the summer of 2012. The monitoring site at the west end of Y-12, also shown, is west of the main plant area north of Bear Creek Valley Road.

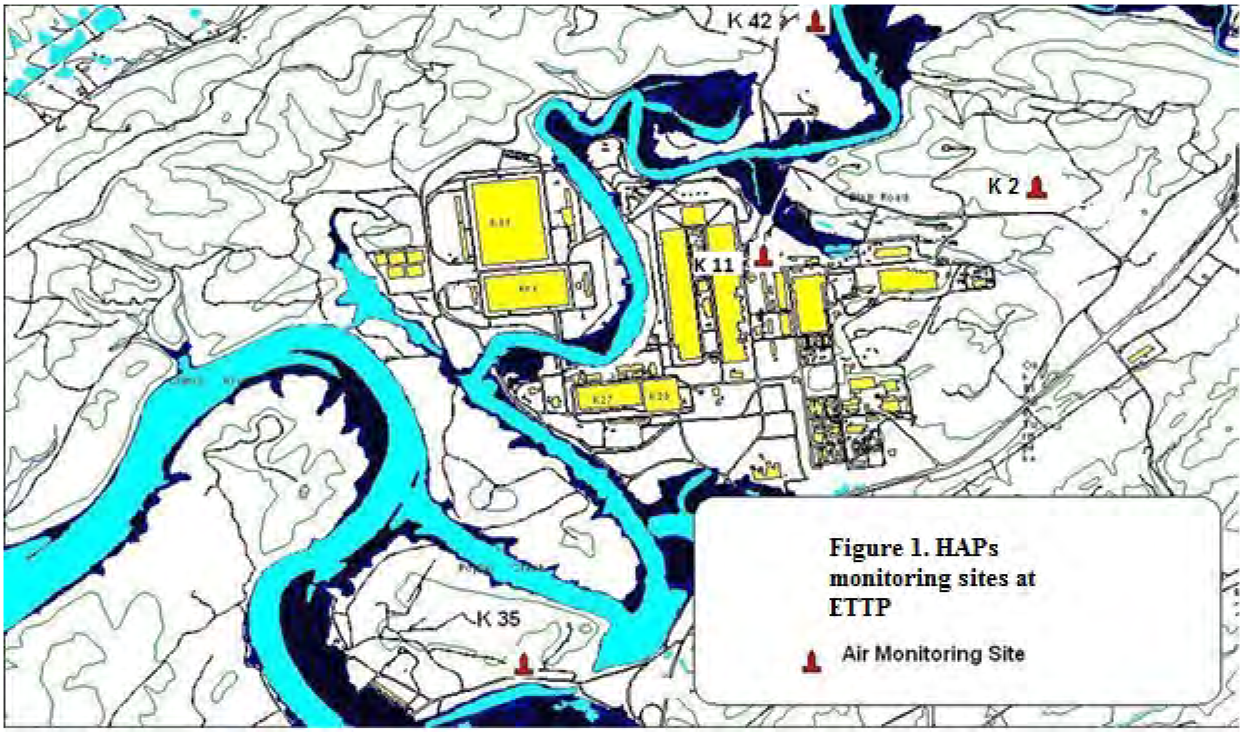

Figure 1: ETTP HAPs Sampling Locations

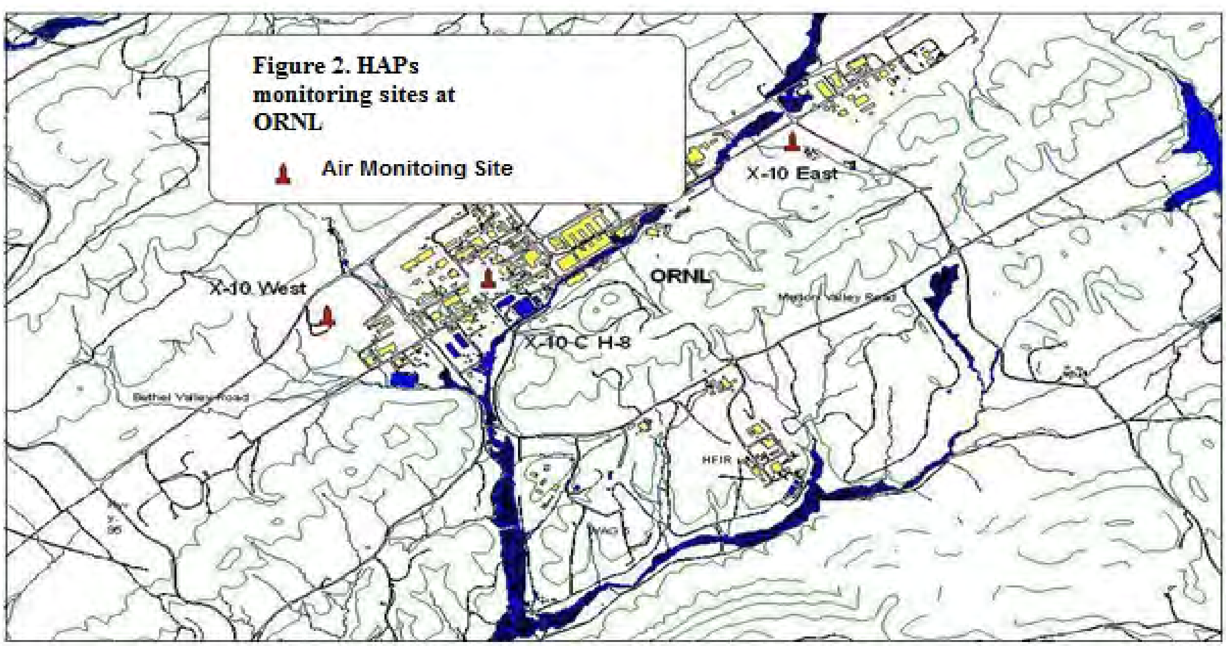

Figure 2: ORNL HAPs Sampling Stations

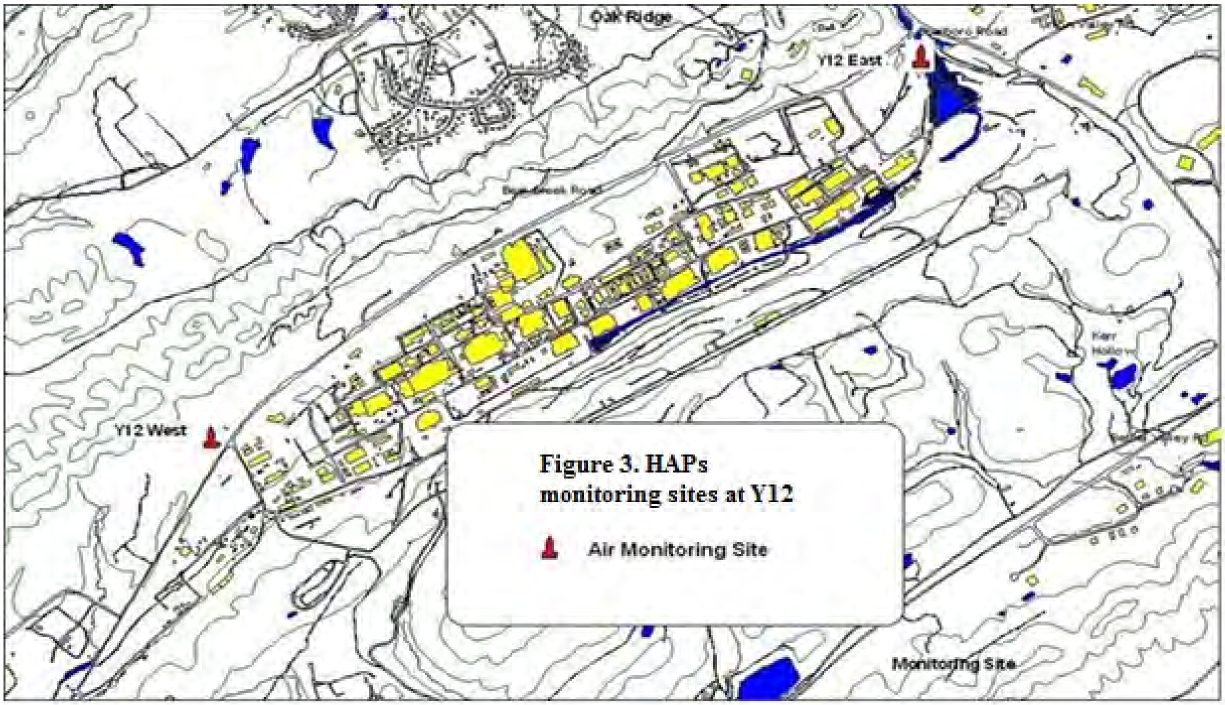

Figure 3: Y-12 HAPs Sampling Locations

Methods and Materials

Wind rose data indicating that the selected sites were in the prevailing wind flow patterns downwind of potential sources on the ORR were considered when establishing the monitoring stations. The wind flow during the day is generally a southwest to northeast pattern. During the night the flow pattern is reversed. The placement of TDEC's monitoring sites allowed for sampling that would be representative of a 24-hour wind flow pattern at the ORR. Until 2006, monitors were moved quarterly in an attempt to sample downwind of sources during both night and day. In 2007, the Y-12 and ETTP monitors were permanently located at the K-2 and Y-12 East sites, where 2005 and 2006 data indicated the highest concentrations of HAPs metals in ambient air. As stated above, the ORNL monitor was later moved to the interior of the plant in 2006 to facilitate monitoring of radionuclides and hazardous metals near the site of the Tank W1A removal action and the ETTP monitor was moved to the K-11 site in 2012 because of proximity to active demolition projects. An additional factor in selecting monitoring locations was the availability of a power source.

When the program was initiated, sampling for arsenic, beryllium, cadmium, chromium, and lead was performed. In 1999 nickel and uranium were added to the list of analytes. Samples were collected on glass fiber filters on a weekly basis and mailed to the Tennessee Department of Health (TDH) laboratory in Nashville for analysis through 2006. Since 2007, laboratory analysis has primarily been performed quarterly on composited samples. In addition, the analytical method was changed in 2007 from inductively coupled plasma (ICP) analysis of metals to analysis by ICP – mass spectroscopy (ICP-MS), lowering detection and quantification limits for all metals. Table 1 lists the frequency of sample collection and analysis during 2013. In 2013, quarterly composites made from weekly samples from the three sites were sent to the TDH

laboratory for analysis. The office retained a portion of each filter and, hence, the ability to analyze archived weekly samples. Since 2012, the HAPs program has split filters taken for radiological analysis by the Radiological Monitoring program at the X-10 site. Beginning at the start of the third quarter of 2012, the HAPs program and Radiological Monitoring program have split samples at the ETTP and Y-12 sites.

Table 1: HAPs Metals Ambient Air Sampling Schedule at ETTP, ORNL and Y-12 for 2013

Monitoring period	Sampling Locations	Sampling period	Collection frequency	Analysis frequency
12/31/11-12/29/12	K2	Continuous	Weekly	Quarterly
12/31/11-12/29/12	X-10 CH8	Continuous	Weekly	Quarterly
12/31/11-12/29/12	Y-12 E	Continuous	Weekly	Quarterly

Results and Discussion

Quarterly lead results were determined from composite analyses of continuous weekly samples from the K-11 station at the ETTP site, the Y-12 East station at the Y-12 site, and from the Core Hole 8 station at ORNL. Lead analytical results are summarized in Table 2 and are compared with the national quarterly ambient air quality standard, revised in 2008 to 0.15 μg/m^3. The 2013 results were slightly elevated when compared to the 2012 results, but were generally comparable to results from the last few years, with a maximum of 12% of the quarterly standard.

At the time of this report, the ORR Annual Site Environmental Report (ASER) for 2013 was not available. Analytical results for lead generated from the HAPs monitoring program over the past five years at all three ORR sites were generally comparable with the concentrations reported by DOE in the ASER for the ETTP site. The 2012 ASER reported lead around ETTP at levels between 0.005 and 0.015 μg/m3. The change in analytical technique from inductively coupled plasma (ICP) to inductively coupled plasma - mass spectrometry (ICP-MS) by the Tennessee Department of Health (TDH) Environmental Laboratory in Nashville may have resulted in better resolution at low values. Reported concentrations of lead for 2007, the first year ICP-MS was used, were typically one half to one third those reported for most of the previous years. In 2013, average lead values increased at all sites from 2012.

Table 2: Lead Concentration in Ambient Air in 2013 at ETTP, Y-12 and ORNL

Site	Quarterly composite sample results (μg/m3)				Max quarterly result (μg/m3)	Max percent of quarterly standard (μg/m3)*
	1	2	3	4		
ETTP	0.0068	0.0023	0.0068	0.018	0.018	12%
Y-12	0.0039	**0.0039**	0.0049	0.0051	0.0051	3% 0.0051
ORNL	0.004	0.004	0.0044	0.0027	0.0044	3%

*National air quality standard for lead is 0.15 μg/m3 quarterly arithmetic average.

Analytical results for 2013 of all hazardous metals except lead are summarized in Tables 3 through 5. Averages are calculated using the laboratory minimum detection limit (MDL) when

the sample concentration is less than this value. The quarterly results for 2013 are given in Tables 6-8. As there are no current Tennessee or national ambient air quality standards for these hazardous air pollutants, concentrations were compared to risk-specific doses and reference air concentrations as listed in Appendix V of Part 266, Title 40 of the U.S. Code of Federal Regulations (40 CFR 266). Estimated quarterly results for total chromium at all locations except ETTP during the fourth quarter of 2013 were above the annual concentration guide for chromium in the +6 oxidation state (Cr VI), but at levels well below the guide for chromium in the +3 state (Cr III). Tables 6 through 8 show the maximum quarterly percentage of the reference dose based on the most restrictive value.

Table 3: Summary Table of Hazardous Air Pollutant Carcinogenic Metals Concentration in Ambient Air at the Y-12 East Site for 2013

Analyte	Ambient air concentration (µg/m3)			Minimum quantitation limit (µg/m3)	Minimum detection limit (µg/m3)
	Annual average concentration	Quarterly Maximum	Annual concentration guideline		
Arsenic	0.0016J	0.0019J	0.0023[a]	0.0037	0.00032
Beryllium	4.4E-05J	0.00014	0.004[a]	0.00005	0.00001
Cadmium	0.00023	0.0003	0.0056[a]	0.00005	0.00002
Chromium	0.00165J	0.0019J	0.00083[a] Cr-VI 1000.0[a] Cr-III	0.0037	0.00081
Nickel	0.00071	0.00073	0.042[a]	0.00005	0.00001
Uranium	0.0001	0.00015	0.15[b]	0.00004	0.000001

[a] Risk-specific doses for As, Be, Cd, Cr-VI, and Ni and the reference air concentration for Cr-III as listed in 40 CFR 266.

[b] DOE Order 5400.5 Derived Concentration Guide (DCG) for naturally occurring uranium is an annual concentration of 1E-01 pCi/m3, which is equivalent to 100 mrem annual inhalation dose. This is equivalent to 0.15 µg/m3 assuming mass-to-curie concentration conversion for natural uranium assay of 0.717% 235U.

J concentration is less than quantitation limit

Table 4: Summary Table of Hazardous Air Pollutant Carcinogenic Metals Concentration in Ambient Air at the X-10 Core Hole 8 Site for 2013

Analyte	Ambient air concentration (µg/m3)			Minimum quantitation limit (µg/m3)	Minimum detection limit (µg/m3)
	Annual average concentration	Quarterly Maximum	Annual concentration guideline		
Arsenic	0.0016J	0.0019J	0.0023[a]	0.0037	0.00032
Beryllium	0.000013J	0.000013J	0.004[a]	0.00005	0.00001
Cadmium	0.00023	0.00027	0.0056[a]	0.00005	0.00002
Chromium	0.0014J	0.0016J	0.00083[a] Cr-VI 1000.0[a] Cr-III	0.0037	0.00081
Nickel	0.00065	0.00073	0.042[a]	0.00005	0.00001
Uranium	0.000104	0.0003	0.15[b]	0.00004	0.000001

[a] Risk-specific doses for As, Be, Cd, Cr-VI, and Ni and the reference air concentration for Cr-III as listed in 40 CFR 266.

[b] DOE Order 5400.5 Derived Concentration Guide (DCG) for naturally occurring uranium is an annual concentration of 1E-01 pCi/m3, which is equivalent to 100 mrem annual inhalation dose. This is equivalent to 0.15 µg/m3 assuming mass-to-curie concentration conversion for natural uranium assay of 0.717% 235U.

J concentration in sample is less than quantitation limit

Other metals were detected at levels less than concentration guidelines (guidelines based on risk-specific doses are listed in Tables 3 through 5). With the possible exception of chromium VI, arsenic continues to be the primary contributor to risk from hazardous metals in ambient air around the ORR. DOE results for metals monitoring at ETTP reported in the ASER also consistently showed arsenic to be the lead contributor to risk. Current minimum quantitation limits remain higher than risk-specific values for both arsenic and chromium VI. Arsenic, cadmium chromium, nickel, and lead were detected on blank filters in 2013. Results for metals detected on blanks included in Tables 6 -8 were computed using the results blank filters divided by the mean volume of air passing through filters at each site in 2013.

Table 5: Summary Table of Hazardous Air Pollutant Carcinogenic Metals Concentration in Ambient Air at the ETTP (K-2 and K-11 sites) for 2013

Analyte	Ambient air concentration (µg/m3)			Minimum quantitation limit (µg/m3)	Minimum detection limit (µg/m3)
	Annual average concentration	Quarterly Maximum	Annual concentration guideline		
Arsenic	0.0018J	0.0023J	0.0023[a]	0.0037	0.00032
Beryllium	1.25E-05J	0.000013J	0.004[a]	0.00005	0.00001
Cadmium	0.00032	0.00055	0.0056[a]	0.00005	0.00002
Chromium	0.0013J	0.0013J	0.00083[a] Cr-VI 1000.0[a] Cr-III	0.0037	0.00081
Nickel	0.00095	0.0011	0.042[a]	0.00005	0.00001
Uranium	0.00097	0.0014	0.15[b]	0.00004	0.000001

[a] Risk-specific doses for As, Be, Cd, Cr-VI, and Ni and the reference air concentration for Cr-III as listed in 40 CFR 266.

[b] DOE Order 5400.5 Derived Concentration Guide (DCG) for naturally occurring uranium is an annual concentration of 1E-01 pCi/m3, which is equivalent to 100 mrem annual inhalation dose. This is equivalent to 0.15 µg/m3 assuming mass-to-curie concentration conversion for natural uranium assay of 0.717% 235U.

J concentration in sample is less than quantitation limit

Table 6: Hazardous Air Pollutant Metals Concentrations in Ambient Air at Y-12 in 2013

Analyte	Quarterly composite sample results (µg/m3)				Results for blanks based on mean volume (µg/m3)	Maximum percent of guideline (µg/m3)*
	Quarter 1	Quarter 2	Quarter 3	Quarter 4		
Arsenic	0.0014J	0.0014J	0.0018J	0.0019J	6.4E-05	83
Beryllium	0.00014J	0.000014J	0.000011J	0.00001J	U	4
Cadmium	0.00017	0.00017	0.00027	0.0003	4.6E-06	5
Chromium	0.0017J	0.0017J	0.0013J	0.0019J	0.00011	229
Nickel	0.00071	0.00071	0.00069	0.00073	1.0E-05	2
Uranium	0.00015	0.00015	0.000038J	0.000062	U	0

U - Not detected in sample

J - concentration in sample is less than quantitation limit.

* Concentration guidelines, detection and quantitation limits are listed in Tables 3 through 5 above

Table 7: Hazardous Air Pollutant Metals Concentrations in Ambient Air at X-10 in 2013

Analyte	Quarterly composite sample results (µg/m3)				Results for blanks based on mean volume (µg/m3)	Maximum percent of guideline (µg/m3)*
	Quarter 1	Quarter 2	Quarter 3	Quarter 4		
Arsenic	0.0013J	0.0013J	0.0017J	0.0019	6.3E-05	83
Beryllium	0.000013J	0.000013J	0.000013J	U	U	0
Cadmium	0.00023	0.00023	0.0002	0.00027	4.5E-06	5
Chromium	0.0013J	0.0013J	0.0016J	0.0014J	0.00011	193
Nickel	0.00064	0.00064	0.00073	0.00059	1E-05	2
Uranium	0.0003	0.00003J	0.000052	0.000034J	U	0

U - Not detected in sample
J - concentration in sample is less than quantitation limit.
* Concentration guidelines, detection and quantitation limits are listed in Tables 3 through 5 above

Table 8: Hazardous Air Pollutant Metals Concentrations in Ambient Air at ETTP in 2013
U - Not detected in sample

Analyte	Quarterly composite sample results (µg/m3)				Results for blanks based on mean volume (µg/m3)	Maximum percent of guideline (µg/m3)*
	Quarter 1	Quarter 2	Quarter 3	Quarter 4		
Arsenic	0.0015J	0.0015J	0.002J	0.0023J	6.9E-05	100
Beryllium	0.000013J	0.000013J	0.000012J	0.000012J	U	0
Cadmium	0.00024	0.00024	0.00023	0.00055	4.9E-06	10
Chromium	0.0013J	0.0013J	0.0013J	U	0.00012	157
Nickel	0.0009	0.0009	0.00088	0.0011	1.1E-05	3
Uranium	0.0014	0.0014	0.00011	0.00098	U	1

J - concentration in sample is less than quantitation limit.
* Concentration guidelines, detection and quantitation limits are listed in Tables 3 through 5 above

As stated previously, results from the ORR Annual Site Environmental Report (ASER) for 2013 are not available at this time. However, analytical results generated by the HAPs monitoring program over the past five years were compared with results for past years reported in the 2012 ASER. The ASER data indicated sporadic detection of hazardous air pollutant metals at ETTP, with no quarterly concentrations exceeding the risk-specific doses except possibly that for hexavalent chromium at K-11 during the fourth quarter of 2012. ASER data show a general increase in metals concentration in 2007, lower values through 2010, and an increase in 2011 through 2012. TDEC data prior to 2006 include some weekly concentrations that significantly exceed both the more recent TDEC results and the averages reported by DOE for total chromium. Some of these TDEC results were higher than the risk-specific dose level for chromium VI, although significantly below standards for chromium III. Laboratory analyses for the air data reported in the DOE ASER were done using inductively coupled plasma mass spectrometry (ICP-MS), perhaps with better detection or quantification limits than those done by the TDH laboratory prior to 2007.

Conclusions

All HAPs metals with the possible exception of chromium were measured at annual average concentrations below ambient air standards or the annual risk specific guidelines as prescribed in 40 CFR 266 and DOE Order 5400.5. The results of the 2013 HAPs monitoring conducted by TDEC at ETTP, ORNL and Y-12 sites do indicate possible elevated levels of chromium VI at all locations throughout much of the year, but exact levels are uncertain. Current minimum quantitation limits for total chromium are higher than risk-specific values for chromium VI. Results are well below the risk specific guidelines for chromium III, and the chromium analysis does not distinguish between the two common oxidation states of chromium (III and VI). Analyses on blank filters show trace amounts of chromium, as well as arsenic, cadmium, lead and nickel, but at values too low to greatly influence results. Due to the continuing reduction in permitted sources on the ORR and the completion of the demolition of the K-25 building at ETTP, this project will be discontinued until other major demolition projects on the ORR are initiated or other potential sources of hazardous air pollutants are identified.

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RadNet Air Monitoring on the Oak Ridge Reservation

Principal Author: Natalie Pheasant

Abstract

The RadNet Air Monitoring Program on the Oak Ridge Reservation began in August of 1996 and provides radiochemical analysis of air samples taken from five air monitoring stations located near potential sources of radiological air emissions on the Oak Ridge Reservation. RadNet samples are collected by staff of the Tennessee Department of Environment and Conservation and analysis is performed at the Environmental Protection Agency's National Air and Radiation Environmental Laboratory in Montgomery, Alabama. In 2013, as in past years, the data for each of the five RadNet air monitors largely exhibited similar trends and concentrations, with a few exceptions. The results for 2013 do not indicate a significant impact on the environment or public health from Oak Ridge Reservation emissions.

Introduction

In the past, air emissions from Department of Energy (DOE) activities on the Oak Ridge Reservation (ORR) were believed to have been a potential cause of illnesses affecting area residents. While these emissions have substantially decreased over the years, concerns have remained that air pollutants from current activities (e.g., production of radioisotopes and demolition of radioactively contaminated facilities) could pose a threat to public health, the surrounding environment, or both. As a consequence, the Tennessee Department of Environment and Conservation (TDEC) has implemented three air monitoring programs to assess the impact of ORR air emissions on the surrounding environment and the effectiveness of DOE controls and monitoring systems. TDEC's fugitive air monitoring program (described in an associated report) focuses on monitoring non-point sources of emissions. TDEC's participation in the Environmental Protection Agency's (EPA) RadNet air and precipitation monitoring programs supplements information generated by TDEC's fugitive air monitoring program, targets specific operations such as the High Flux Isotope Reactor (HFIR) and provides independent verification of both state and DOE monitoring data.

Methods and Materials

The approximate locations of the five RadNet air samplers are provided in Figure 1 and EPA's analytical parameters and frequencies are listed in Table 1. The RadNet air samplers run continuously, collecting suspended particulates on synthetic fiber filters (10 centimeters in diameter) as air is drawn through the units by a pump at approximately 35 cubic feet per minute. TDEC staff collect the filters from each sampler twice weekly and estimate the radioactivity on each filter using the supplied alpha-beta scintillation detector. Following EPA protocol (U.S. EPA 1988, U.S. EPA 2006), the filters are then shipped to EPA's National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama, for analysis.

NAREL performs gross beta analysis on each sample collected. If the gross beta result for a sample exceeds one picocurie per cubic meter (pCi/m^3), gamma spectrometry is performed on the sample. A composite of the air filters collected from each monitoring station during the year is analyzed for uranium and plutonium isotopes annually.

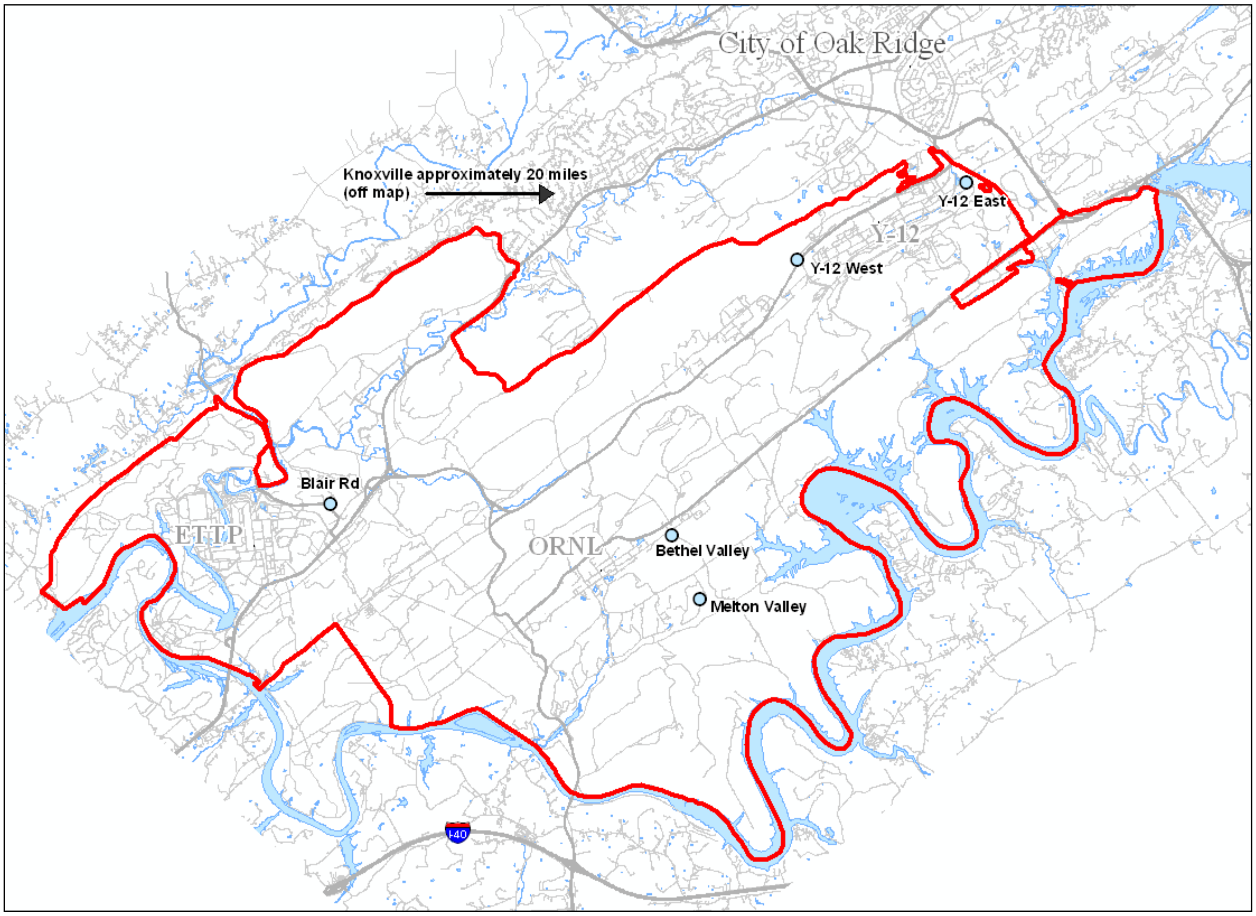

Figure 1: Approximate locations of air stations monitored by TDEC on the Oak Ridge Reservation in association with EPA's RadNet air monitoring program

The results of NAREL's analyses are provided to TDEC annually. Nationwide data is available at NAREL's website in the Envirofacts RadNet Searchable Database, via either a simple or customized search (websites listed in references).

Table 1: EPA Analysis of Air Samples Taken in Association with EPA's RadNet Program

ANALYSIS	FREQUENCY
Gross Beta	Each sample, twice weekly
Gamma Scan	As needed on samples showing greater than 1 pCi/m^3 of gross beta
Plutonium-238, Plutonium-239, Plutonium-240,Uranium-234, Uranium-235, Uranium-238	Annually on a composite of the filters from each station

Gross beta from the RadNet air monitoring program is compared to background data from the fugitive monitoring program and to the Clean Air Act (CAA) environmental limit for strontium-90, as it is a pure beta emitter with a conservative limit. The background sampler for the fugitive

program is located at Fort Loudoun Dam in Loudon County and samples are collected on a weekly basis.

Results and Discussion

As seen in Figure 2, the results for the gross beta analysis in 2013 were generally similar for each of the five ORR RadNet monitoring stations and most were lower than, but similar to the results reported for the Fugitive Air Monitoring Program background station. There were a few exceptions to this in 2013, which can easily be seen in Figure 2. While each of these results is much higher than those seen at the other stations during the same time period, the highest of these is 0.0975 pCi/ m^3, and is well below the 1.0 pCi/m^3 screening level that requires further analysis. The exact cause of these elevated results is not known. The fluctuations that can be seen in the results in Figure 2 are largely attributable to natural phenomena (e.g., wind and rain) that influence the amount of particulates suspended in the air and, thus, what is ultimately deposited on the filters. The 2013 results are also all well below 1.0 pCi/m^3, which is the screening level requiring further analysis.

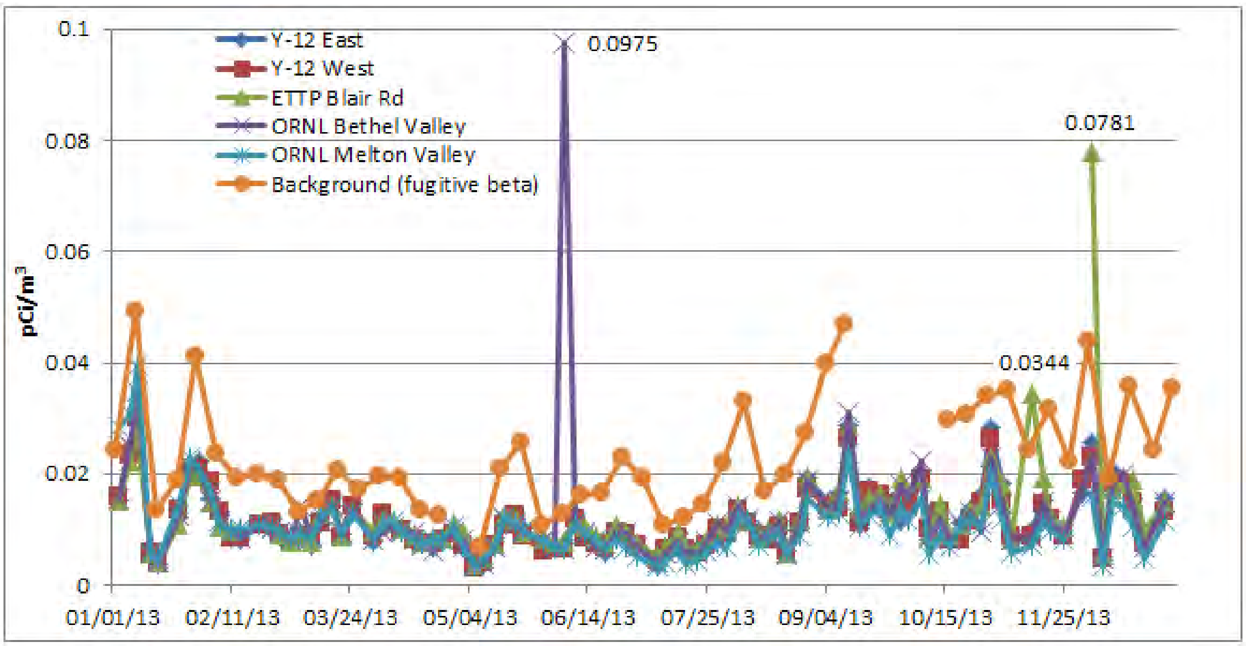

Figure 2: 2013 Gross beta results from air samples taken on the ORR in association with EPA's RadNet air monitoring program and background measurements from the DOE-Oversight Office's fugitive air monitoring program

Note: This figure is intended to convey the correlation of the results for the various monitoring stations, not to depict individual results. Individual measurements are available at the DOE-O office.

Figure 3 depicts the 2013 average gross beta results for each of the five stations in the ORR RadNet Program, the average background concentration measured at Fort Loudoun Dam by the DOE-O Office's Fugitive Air Monitoring Program, and the Clean Air Act (CAA) environmental limit for strontium-90.

The CAA specifies that exposures to the public from radioactive materials released to the air from DOE facilities shall not cause members of the public to receive an effective dose equivalent greater than 10 mrem above background measurements in a year. For point source emissions,

compliance with this standard is generally determined with air dispersion models that predict the dose at offsite locations. The CAA also provides environmental concentrations for radionuclides equivalent to a dose of 10 mrem in a year. Staff use these concentrations to assess the compliance of the emissions measured with the CAA dose limit.

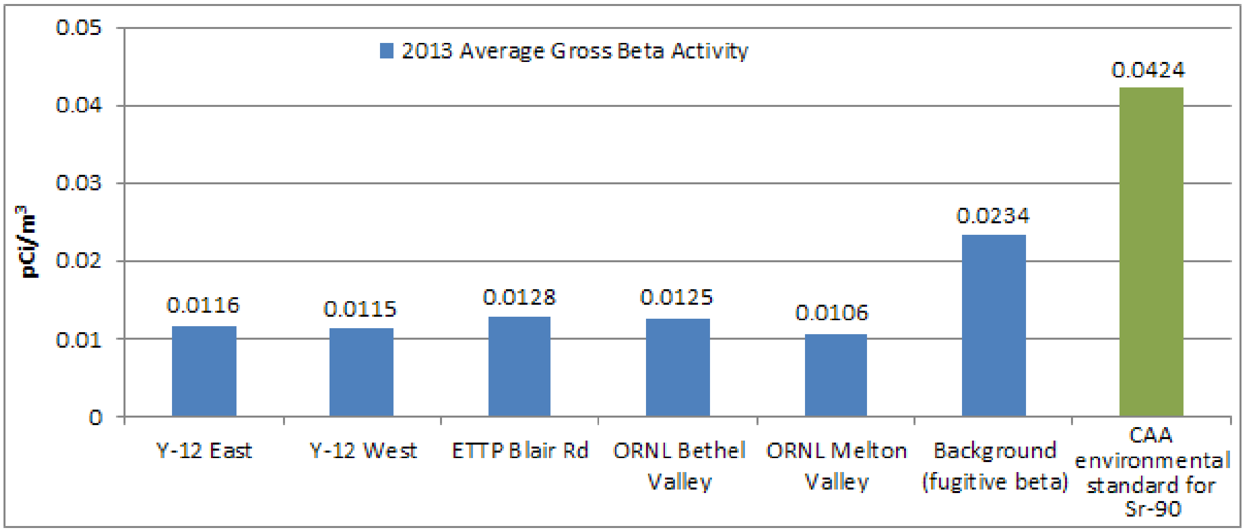

Figure 3: 2013 Average gross beta results for air samples taken on the ORR in association with EPA's RadNet air monitoring program

Note: Typical background values for gross beta range from 0.005- 0.1 pCi/m^3 (ORISE, 1993). The standards provided by the Clean Air Act apply to the dose above background; therefore, the standard provided for reference in this figure has been adjusted to include the background measurements taken from the DOE-Oversight Office's Fugitive Air Monitoring Program for 2013 (CAA value for Sr-90 [0.019 pCi/ m^3] + annual average gross beta = CAA environmental standard for Sr-90).The CAA's Environmental Limit for strontium-90 is used as a screening mechanism and is provided here for comparison. It is unlikely that this isotope contributes a major proportion of the gross beta activity reported for the samples.

To evaluate the RadNet data, staff compare the average gross beta results reported for the program to the CAA limit for strontium-90, which has one of the most stringent standards of the beta emitting radionuclides. The standards apply to the dose above background, so the limit represented in Figure 3 has been adjusted to include the average gross beta measurement taken at the background station for the Fugitive Air Monitoring Program, which operates at a similar flow rate to the RadNet air program. It is important to note that strontium-90 is unlikely to be a large contributor to the total beta measurements reported here and is used only as a reference point to determine if further analysis is warranted.

While the results at all the RadNet air stations in 2013 are largely comparable (results showed that all sites responded in a similar pattern during each sampling period), the average gross beta results for the RadNet program in 2013 were slightly lower overall at the ORNL Melton Valley station and slightly higher at the ORNL Bethel Valley and ETTP Blair Road locations. The average results from each of the ORR RadNet monitoring stations fall well below the strontium-90 limit (Figure 3).

In 2013, none of the gross beta results reported for the program exceeded the screening level (1.0 pCi/m^3) that would have required analysis by gamma spectrometry. The 2013 results for the uranium and plutonium analysis performed on annual composites of the air filters were not available at the time of this report: however, the 2012 results can be seen in Table 2.

Table 2: 2012 Composite Results for Uranium and Plutonium in RadNet Air (pCi/m³)

	Y-12 East	Y-12 West	ETTP Blair Road	ORNL Bethel Valley	ORNL Melton Valley	Background (fugitive air program)	CAA standard (amount above background)
Pu-238	1.70E-07	4.20E-07	3.50E-07	-2.10E-07	1.50E-07	-	2.10E-03
Pu-239/240	0.00E+00	1.10E-07	1.30E-07	-1.60E-07	3.10E-07	-	2.00E-03
U-234	2.55E-05	4.81E-05	2.25E-05	1.22E-05	6.80E-06	8.57E-05	7.70E-03
U-235	5.00E-07	4.30E-06	2.04E-06	-1.10E-07	6.20E-07	7.28E-06	7.10E-03
U-238	5.90E-06	9.80E-06	5.10E-06	6.80E-06	4.81E-06	8.36E-05	8.30E-03

Note: The colored bars can be used as a quick comparison of results of the same isotope (same color). Negative values are not compared for simplicity's sake.

While the annual composite uranium and plutonium values would generally be compared to similar analyses at a background location, this data was only available for uranium analyses. The averaged uranium analyses for each of the three isotopes for 2012 from the background location was much higher than the results seen from the annual composite samples from the RadNet program, however the sampling for the fugitive monitoring program takes place on a different schedule, the filter media is different, and the compositing schedule is also different. Even assuming a background of zero and disregarding the background results from the fugitive air program, the values seen were well below CAA limits.

Conclusion

As in the past, the gross beta results for each of the five RadNet air monitoring stations generally exhibited similar trends and concentrations. The available RadNet data for 2013 do not indicate a significant impact on the environment or public health from ORR emissions.

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Fugitive Radiological Air Emissions Monitoring

Principal Authors: Gary Riner, Howard Crabtree

Abstract

As a part of its obligation under by the Tennessee Oversight Agreement, the Tennessee Department of Environment and Conservation monitors fugitive emissions of radioactive contaminants on the Department of Energy's Oak Ridge Reservation. The results are compared to background measurements to determine if releases have occurred and standards provided by the Clean Air Act to assess compliance with associated emission standards. In 2013 eight high-volume air samplers were deployed in the program. One of the samplers was stationed to collect background information. The remaining units were positioned to monitor remedial and waste management activities on the ORR. Monitored activities included: the decommissioning and demolition of facilities constructed during the World War II Manhattan Era to produce enriched uranium, plutonium, and other radioisotopes used to manufacture the first atomic weapons; remediation of associated waste disposal facilities; and disposal of radioactive waste at the Environmental Management Waste Management Facility. Findings indicate that fugitive releases occurred during 2013, but the concentrations measured were below federal standards.

Introduction

As part of the State's obligation under the Tennessee Oversight Agreement, the DOE Oversight Office of the Tennessee Department of Environment and Conservation's Division of Remediation performs routine monitoring of fugitive air emissions on the Department of Energy's (DOE) Oak Ridge Reservation (ORR). Monitoring in the program focuses on locations where there is a potential for airborne releases of radioactive contaminants from diffuse (non-point sources) sources. In 2013, monitored activities included: the decommissioning and demolition of uranium enrichment facilities at the East Tennessee Technology Park (ETTP); the Central Campus Removal Action at the Oak Ridge National Laboratory (ORNL); footprint reduction activities at the Y-12 Nation Security Complex (Y-12); and the disposal of radioactive waste at the Environmental Management Waste Management Facility (EMWMF) in Bear Creek Valley. Data from the program, along with information derived from the division's RadNet Air Monitoring Programs, are used to:

- identify and characterize unplanned releases;
- evaluated DOE controls to prevent releases to the environment;
- verify data reported by DOE and its contractors; and
- assess the potential impact of DOE activities on the public health and environment.

Eight high-volume air samplers are used in the program. Seven of the units are mounted on trailers or elevated platforms positioned near the location and / or activities of interest. The eighth sampler has been stationed at Fort Loudoun Dam in Loudon County to collect background information. Results from the ORR samplers are compared to the results from the background location to determine if releases have occurred and to standards provided in the Clean Air Act (CAA) to assess compliance with federal regulations. Title 40 of the Code of Federal Regulations Part 61 (40CFR61), *National Emission Standards for Hazardous Air Pollutants* (NESHAPS), Subpart H (*National Emission Standards for Emissions of Radionuclides other than Radon from Department of Energy Facilities*) limits DOE radiological emissions to

quantities that would not cause a member of the public to receive an effective dose equivalent[1] greater than 10 millirem (mrem) in a year. Appendix E, Table 2 of the rule provides environmental concentration for individual radionuclides that would be equivalent to the 10 mrem/year dose limit, if inhaled continuously over the course of a year. To account for the synergistic effect of multiple radionuclides, the rule calls for a sum of fractions[2] to determine compliance when more than one radionuclide is present. DOE is also required to meet provisions of the law that require all radioactive emissions to be as low as reasonably achievable (ALARA).

It should be noted, that the Fugitive Air Monitoring Program was designed to identify air releases from non-point sources (e.g., remedial activities) to the environment and evaluate DOE control measures and ALARA consideration. Consequently, the monitors are located as near to the activity of interest as feasible. The actual compliance point for the 40CFR61 Subpart H standard is the nearest off-site residence, school, business, or office occupied by members of the public.

Methods and Materials

The eight high-volume air samplers used in the program run continuously, except during sampling, maintenance, or power outages. Seven of the samplers are used to monitor activities on the ORR: the eighth to collect background information. Each sampler uses an 8x10 inch, glass-fiber filter to collect particulates from air, as it is drawn through the unit at a rate of approximately 35 cubic feet per minute. Airflow through each sampler is calibrated quarterly and routine maintenance is performed as described in DOE Oversight Standard Operational Procedure 203, *High Volume Total Suspended Particulate System Maintenance.* Samples are collected weekly and shipped to the State of Tennessee's Environmental Laboratory in Nashville, Tennessee, for analysis.[3] Analyses are based on the radionuclides of concern for the location being monitored, and thus vary for different locations.

When the results are received from the laboratory, the data from the reservation samplers are compared to the background results to assess if releases have occurred and limits provided in 40CFR61 Appendix E Table 2 (*Concentration Levels for Environmental Compliance)* to assess compliance. Since the regulations do not provide standards for gross analysis, gross alpha and beta results when used are compared to the standards for uranium-235 and strontium-90 respectively. These radionuclides are found routinely on the reservation and have some of the more restrictive limits provided in the rule. If the results exceed the screening levels, additional analysis is performed to identify the specific radionuclide(s) contributing to elevated results and the data is reevaluated based on the isotopic analysis.

The locations of the 2013 monitoring stations are depicted in Figure 1 and current analysis for each station is provided in Table 1, along with the activities being monitored.

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[1] Effective dose equivalent means the sum of the products of absorbed dose and appropriate factors to account for differences in biological effectiveness due to the quality of radiation and its distribution in the body of reference man. The unit of the effective dose equivalent is the rem. (40CFR61.91(a)

[2] To calculate a sum of fractions, the annual average concentration for each radionuclide is divided by its limit and the results summed. If the sum of the fractions is equal to, or greater than, one the facility would be considered out of compliance. The compliance point is the nearest off-site residence, school, business or office.

[3] Analysis maybe performed by the state radiochemistry laboratory or a contract laboratory of their choosing.

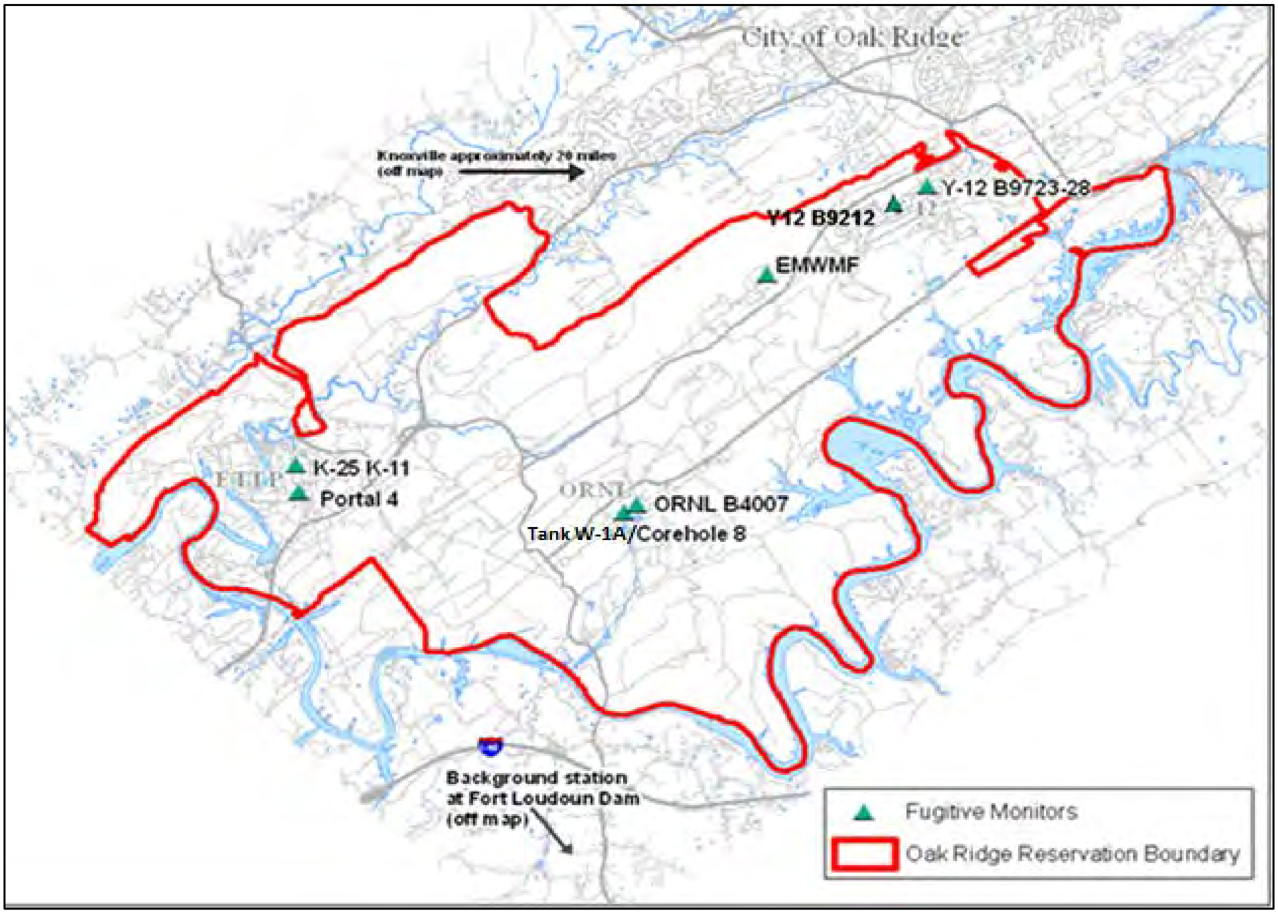


Figure 1: Approximate locations of sites monitored for fugitive air emissions in 2013

Table 1: 2013 fugitive air emission monitoring stations & associated radiochemical analysis

Monitoring Station	Activity Monitored	Frequency		Analysis			
		Sampling	Analysis	Gross Alpha & Beta	Uranium Isotopes	Gamma Spectrometry	Technetium-99
Y-12: Building 9723	Y-12 facility reduction activities	weekly	biweekly composite		X		
Y-12 Building 9212	Y-12 facility reduction activities	weekly	biweekly composite		X		
ETTP: K-25/K-11	K-25 D&D, K-1070B Burial Ground remediation	weekly	biweekly composite		X		X
ETTP: Portal 4	K-25 & K-27 D&D	weekly	biweekly composite		X		X
ORNL: TankW1A / Core Hole 8	ORNL central campus remediation	weekly	weekly	X		X	
ORNL: B4007	ORNL central campus remediation	weekly	weekly	X		X	
EMWMF	Disposal of radioactive waste	weekly	weekly	X		X	
Fort Loudoun Dam (Loudon County)	Background	weekly	weekly	X		X	X
			biweekly composite				

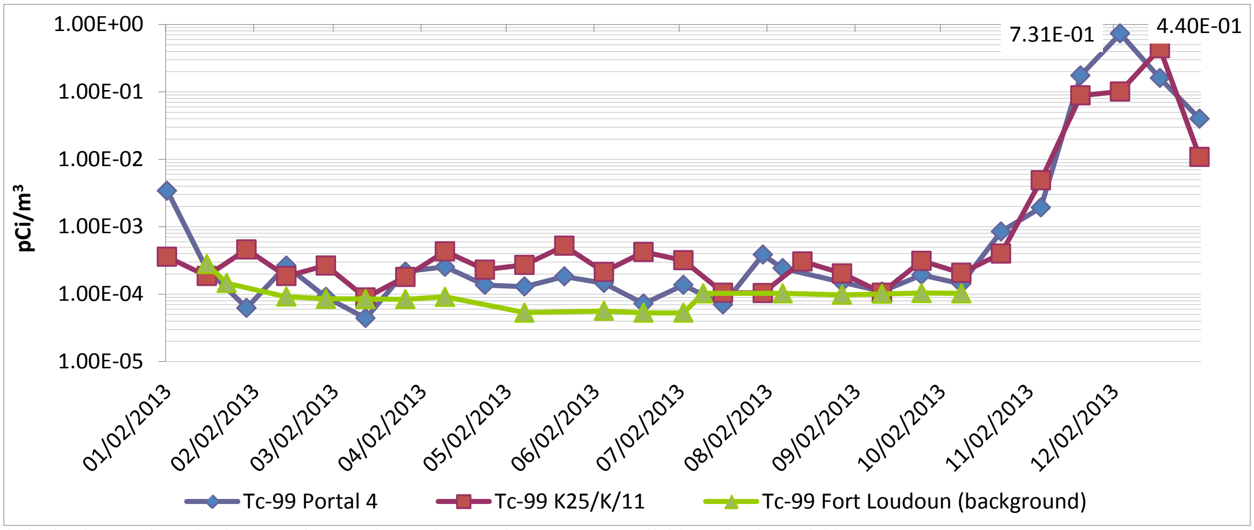
Results and Discussion

East Tennessee Technology Park (ETTP

The K-25 Gaseous Diffusion Plant, now known as the East Tennessee Technology Park, began operations in World War II as part of the Manhattan Project. Its original mission was to produce uranium enriched in the uranium-235 isotope (U-235) for use in the first atomic weapons and later to fuel commercial and government owned reactors. The plant was permanently shut down in 1987. As a consequence of operational practices and accidental releases, many of the facilities scheduled for decontamination and decommissioning (D&D) at ETTP are contaminated to some degree. Uranium isotopes are the primary contaminants, but technetium-99 (Tc-99) and other fission and activation products are also present, due to the processing of recycled uranium obtained from spent nuclear fuel originating from reactors. Two samplers (K-25/K-11 & Portal 4) are stationed at ETTP to monitor D&D of the contaminated buildings and associated remedial activities. Samples are collected weekly from the two units and composited biweekly for radiochemical analysis. Current analysis includes Uranium (U) -234, U-235, U-238, and Tc-99.

The major remedial activity at ETTP in 2013 was the demolition of the final section of the K-25 Process Building. The K-25 Process Building housed the first production facility built to produce highly enriched uranium by the gaseous diffusion process. The largest building in the nation when it began operations in 1945, the building stood four stories high and covered approximately 40 acres. Demolition of the facility began in 2008 and has continued through subsequent years, with only a portion of the east wing, the purge cascades, remaining to be addressed in 2013. The purge cascades were used to remove light gases (e.g., air, nitrogen) and Tc-99 from the process gas (uranium hexafluoride). Tc-99 is a long lived fission product that tended to migrate up the enrichment cascades as an intermediate gas and accumulate behind the lighter gases, blocking the flow of the process gas. Associated spills and releases resulted in significant Tc-99 contamination of both the equipment and the building structure, in addition to associated uranium contamination.

Demolition of the purge cascades began in the fall of 2013 and continued through December 19. During the demolition, the high concentrations of Tc-99 associated with the purge cascades and the mobility of the radionuclide in the environment proved problematic. Elevated levels of Tc-99 have been reported in storm drains, sewer lines, and electrical ducts that previously serviced the facility that were reported to have been sealed prior to demolition. While below the NESHAPS limits, elevated results were also reported for the two ETTP fugitive air monitors. Figures 2 through 4 chart the results for Tc-99 and uranium isotopes at the two air monitoring stations in 2013. As can be noted in Figure 2, Tc-99 results increased during the period of demolition then began to decline after the demolition was completed. The results for the uranium isotopes have peaks during similar time frames as Tc-99 (Figures 3 and 4), but are lower relative to the NESHAP limits, as are the annual averages. The limits imposed by NESHAPS are based on a twelve-month average, so individual results can exceed the limiting value without violating the rule. The larger peaks for Tc-99 exceed the limit for the annual average for the isotope by factors of 3 and 5, but the twelve month averages (on which compliance is based) are well below the limit, as are the sum of fractions that include the annual averages for the uranium isotopes. The sum of fractions were 0.22 for the K25/K11 station and 0.32 for the Portal 4 monitoring station (Tables 2 and 3).



*The background results for part of November and December were not available at the time of this report.

Figure 2: 2013 Air monitoring results for technitium-99 at the ETTP air stations and the Fort Loudoun Dam background station

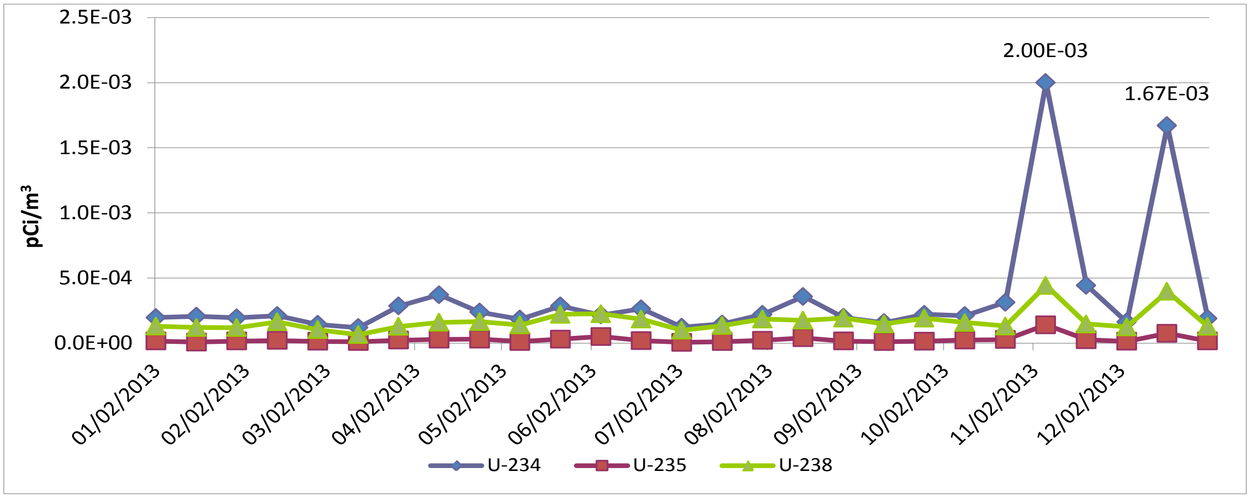


Figure 3: 2013 ETTP K25/K11 air monitor results for Uranium (U)-234, U-235. U-238

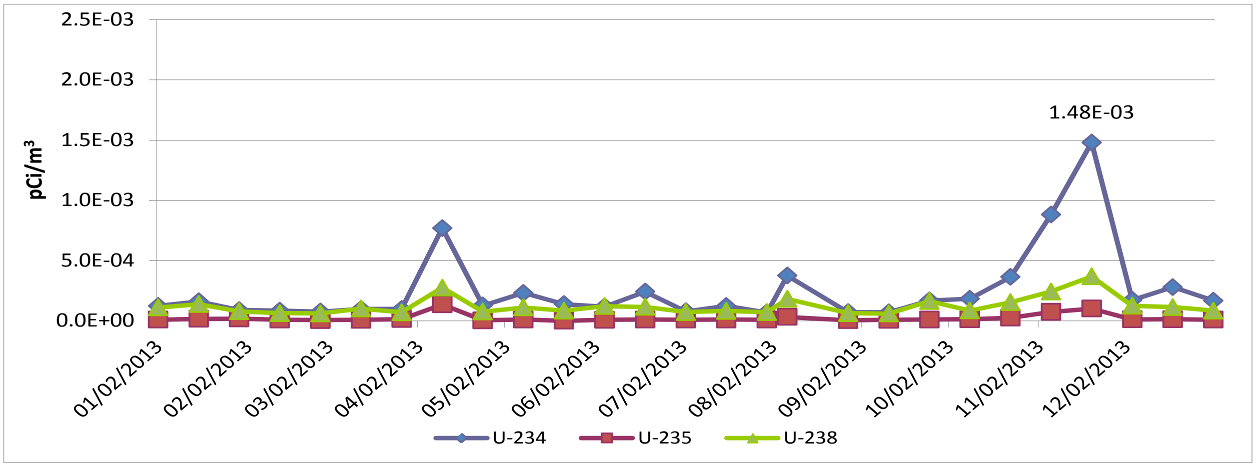


Figure 4: 2013 ETTP Portal 4 air monitoring results for Uranium (U)-234, U-235. U-238

Table 2: Average results and sum of fractions for the ETTP K25/K11 air monitor in 2013

ETTP K-25/K11 Air Monitor Average Results for 2013 (pCi/m3) & Sum of Fractions					
	U-234	U-235	U-238	Tc-99	Sum of Fractions
12 Month Average for 2013	3.46E-04	2.72E-05	1.70E-04	2.41E-02	
Average Background (Fort Loudoun Dam)*	9.34E-05	7.63E-06	9.55E-05	8.90E-05	
Net Activity (Avg. minus Background)	2.52E-04	1.95E-05	7.44E-05	2.40E-02	
40CFR61 Limit (Appendix E Table 2)	7.70E-03	7.10E-03	8.30E-03	1.40E-01	
Fraction of limit (Net Activity/limit)	**3.28E-02**	**2.75E-03**	**8.97E-03**	**1.72E-01**	**0.22**

** The background results for part of November and December were not available at the time of this report, so available data for the year were used to estimate the background concentrations. The difference would not be expected to be significant.*

Table 3: Average results and sum of fractions for the ETTP Portal 4 air monitor in 2013

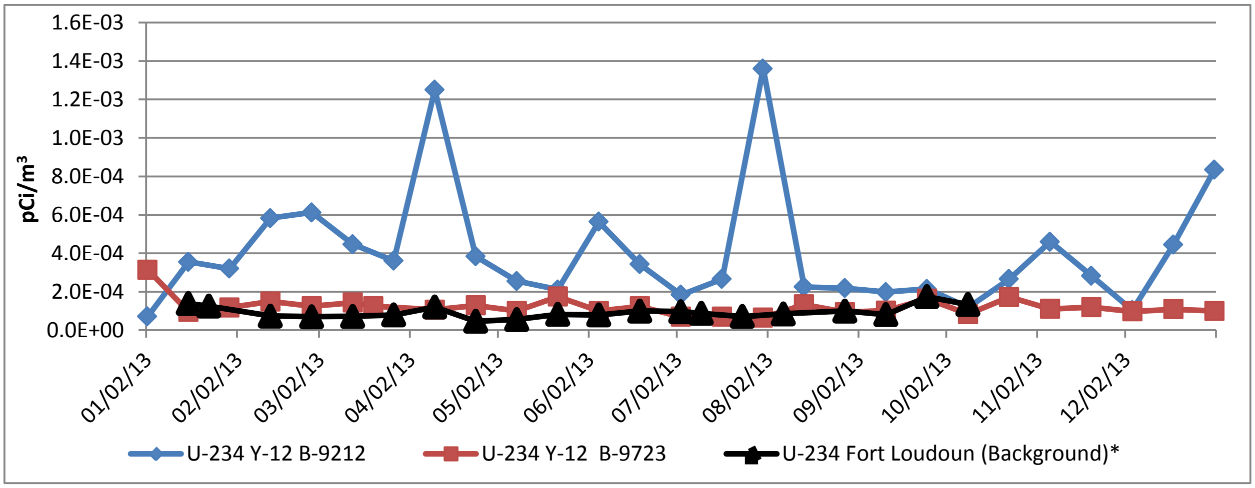
ETTP Portal 4 Air Monitor Average Results for 2013 (pCi/m^3) & Sum of Fractions					
	U-234	U-235	U-238	Tc-99	Sum of Fractions
12 Month Average for 2013	2.53E-04	2.16E-05	1.21E-04	4.13E-02	
Average Background (Fort Loudoun Dam)*	9.34E-05	7.63E-06	9.55E-05	8.90E-05	
Net Activity (Avg. minus Background)	1.60E-04	1.39E-05	2.59E-05	4.12E-02	
40CFR61 Limit (Appendix E Table 2)	7.70E-03	7.10E-03	8.30E-03	1.40E-01	
Fraction of limit (Net Activity/limit)	**2.08E-02**	**1.96E-03**	**3.12E-03**	**2.94E-01**	**0.32**

** The background results for part of November and December were not available at the time of this report, so available data for the year were used to estimate the background concentrations. The difference would not be expected to be significant.*

Y-12 National Security Complex (Y-12)

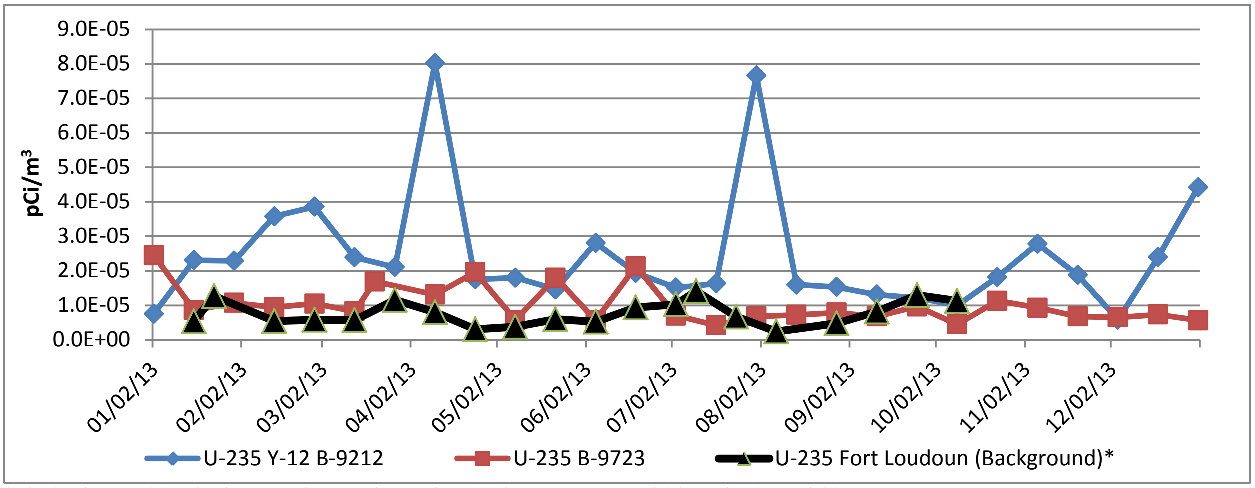
The Y-12 Plant, now known as the Y-12 National Security Complex, was also constructed during World War II to enrich uranium, in this case by the electromagnetic separation process. In ensuing years, the facility was expanded and used to produce fuel for naval reactors, conduct lithium/mercury enrichment operations, manufacture components for nuclear weapons, dismantle nuclear weapons, and store highly enriched uranium. The Y-12 B9723 air monitor was located centrally at Y-12 near building 9723 in July of 2010 to monitor the D&D of contaminated facilities associated with the Y-12 Integrated Facilities Disposition Project. A second air monitor was stationed east of Building 9212 in September of 2012 to monitor footprint reduction activities. Building 9212 was constructed in 1945 and is currently used to process highly enriched uranium. The aging facility is expected to be replaced by the proposed Uranium Processing Facility in the future. Samples were collected weekly from the two Y-12 samplers and composited biweekly for radiochemical analysis. Current analysis includes U-234, U-235, and U-238.

The results of the uranium analysis performed on samples collected at Y-12 are provided in Figures 5 through 7, along with the background measurements for each isotope. The higher U-234 activity measured relative to U-238 at station B-9212 indicates enriched uranium: although, at low levels relative to the NESHAPS standard (4.0%). The concentrations measured at the B-9723 monitor were overall similar to background results collected at Fort Loudoun Dam and a small percentage of the NESHAP Standard (0.3%). The sum of fractions were 0.040 for the B-9212 station and 0.003 for the B-9723 monitoring station (Tables 4 and 5).



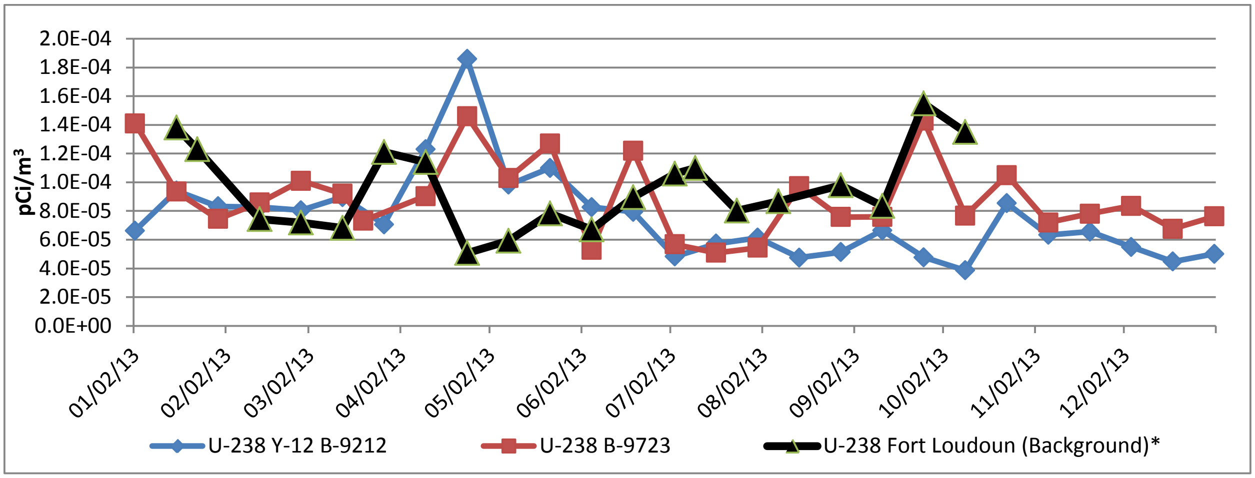
*The background results for part of November and December were not available at the time of this report.

Figure 5: 2013 Air Monitoring Results for Uranium-234 at the Y-12 National Security Complex



*The background results for part of November and December were not available at the time of this report.

Figure 6: 2013 Air Monitoring Results for Uranium-235 at the Y-12 National Security Complex



*The background results for part of November and December were not available at the time of this report.

Figure 7: 2013 Air Monitoring Results for Uranium-238 at the Y-12 National Security Complex

Table 4: Average results and sum of fractions for the Y-12 National Security Complex B-9212 Air Monitor in 2013

Y-12 National Security Complex B-9212 Air Monitor Average Results for 2013 (pCi/m^3) & Sum of Fractions				
	U-234	**U-235**	**U-238**	**Sum of Fractions**
12 Month Average for 2013	4.05E-04	2.46E-05	7.51E-05	
Average Background (Fort Loudoun Dam)*	9.34E-05	7.63E-06	9.55E-05	
Net Activity (Avg. minus Background)	3.11E-04	1.70E-05	-2.03E-05	
40CFR61 Limit (Appendix E Table 2)	7.7E-03	7.10E-03	8.30E-03	
Fraction of limit (Net Activity/limit)	4.04E-02	**2.39E-03**	**-2.45E-03**	**0.040**

** The background results for part November and December were not available at the time of this report, so available data for the year were used to estimate the background concentrations. The difference would not be expected to be significant.*

Table 5: Average results and sum of fractions for the Y-12 National Security Complex B-9723 Air Monitor in 2013

Y-12 National Security Complex B-9723 Air Monitor Average Results for 2013 (pCi/m^3) & Sum of Fractions				
	U-234	**U-235**	**U-238**	**Sum of Fractions**
12 Month Average for 2013	1.22E-04	1.01E-05	8.95E-05	
Average Background (Fort Loudoun Dam)*	9.34E-05	7.63E-06	9.55E-05	
Net Activity (Avg. minus Background)	2.81E-05	2.49E-06	-6.02E-06	
40CFR61 Limit (Appendix E Table 2)	7.70E-03	7.10E-03	8.30E-03	
Fraction of limit (Net Activity/limit)	**3.66E-03**	**3.50E-04**	**-7.25E-04**	**0.003**

** The background results for part November and December were not available at the time of this report, so available data for the year were used to estimate the background concentrations. The difference would not be expected to be significant.*

This Oak Ridge National Laboratory (ORNL)

Construction of the Oak Ridge National Laboratory began in 1943. While the K-25 and Y-12 Plant's initial missions were the production of enriched uranium, the ORNL site focused on reactor research and the production of plutonium and other activation and fission products, which were chemically extracted from uranium irradiated in ORNL's Graphite Reactor and later other ORNL and Hanford reactors. During early operations, leaks and spills were common in the facilities and associated radioactive materials were released from operations as gaseous, liquid, and solid effluents, with little or no treatment (ORAU, 2003). As a consequence, many of the facilities are contaminated with a long list of fission and activation products. Many of these facilities are considered the highest risk facilities at ORNL, due to their physical deterioration, the presence of loose contamination, and their proximity to privately funded facilities, active ORNL facilities, and pedestrian & vehicular traffic. Over recent years, a concerted effort has been made to D&D these facilities and to remediate associate sites. Two of the fugitive air monitors are currently positioned to monitor the remedial efforts: one to the southwest of the W1A/Core Hole 8 removal action which was completed in 2012 and the other at Building B4007, which is northeast of the D&D of the 3026 Radioisotope Development Laboratory and in the vicinity of other facilities undergoing or scheduled for remediation.

The 3026 Radioisotope Development Laboratory consisted of two facilities (3026-C & 3026-D) that shared a common wall, which were constructed in the early 1940s to house operations for the separation of barium-140 from uranium fuel slugs irradiated in the Graphite Reactor and Hanford reactors. Over the years, the facilities were modified for various uses, including the separation of radioisotopes from liquid wastes generated by processing of irradiated uranium fuel

elements for plutonium. 3026-D was modified in the 1960s to support processing of fuel from the Molten Salt Reactor Experiment and examine irradiated metallurgical reactor components. Both facilities were shut down in the late 1980s. In the interim, the wood frame structures physical deteriorated to the point of failure.

As a consequence of the hazards presented by radioactive contamination present in the 3026 C & D faculties, a time-critical removal action was initiated in 2009 to include demolition of the 3026 wooden frame structure and stabilization of the hot cells contained in each of the two 3026 facilities. The 3026 wooden superstructure was demolished in 2010 and demolition of the 3026-C hot cells was completed in 2012. Although hindered by high radiation levels, the 3026-D hot cell demolition was completed in 2013. Due to the nature of historic operations in the faculties, potential contaminants include a long list of radionuclides including Cesium-137, Strontium-90, Carbon-14, Nickel-59 & 63, Iron-55 & 59, Krypton-85, Promethium-147, Silver-110m, Tritium, Technetium-99, Zinc-65, Americium-241, and Neptunium-239, along with isotopes of Europium (153, 154, & 155), Plutonium (239, 240, & 241), and Uranium (233, 234, 235, 236, & 238). As a consequence, it was decided to increase the frequency of analysis to weekly and screen the samples using gross alpha, gross beta, and gamma spectrometry, with the intent to perform the more costly isotopic analysis, if elevated results were noted. The results, presented Figures 8 and 9, were all consistent with background level, as were those for gamma spectrometry.

The Environmental Management Waste Management Facility (EMWMF)
The EMWMF was constructed in in Bear Creek Valley near the Y-12 National Security Complex to dispose of low level radioactive waste and hazardous waste generated by remedial activities on the reservation. During disposal and prior to being covered, wastes disposed in the facility are subject to dispersion by winds that tend to blow up the valley (northeast) in the daytime and down the valley (southwest) at night. To monitor the air emissions at the EMWMF, one of the fugitive air samplers was placed at the southeast corner of the facility in December of 2004. Since many different radionuclides are contained in waste disposed in the EMWMF, gross alpha, gross beta, and gamma spectrometry are used to screen samples and isotopic analysis performed as warranted. The results, which are presented Figures 8 and 9, were all consistent with background level.

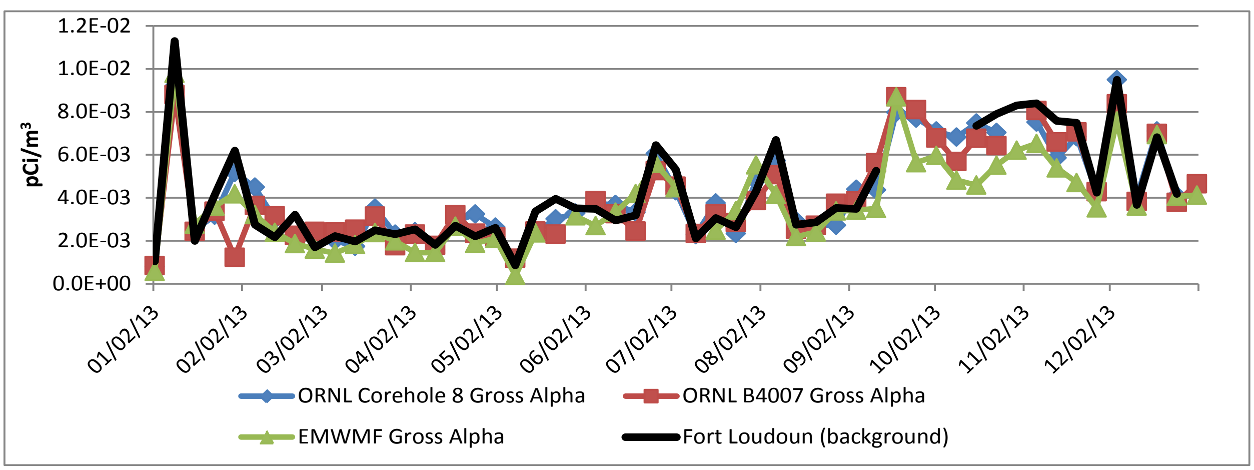


Figure 8: 2013 Gross alpha results for air monitoring at ORNL, the EMWMF, and the Fort Loudoun Dam background stations.

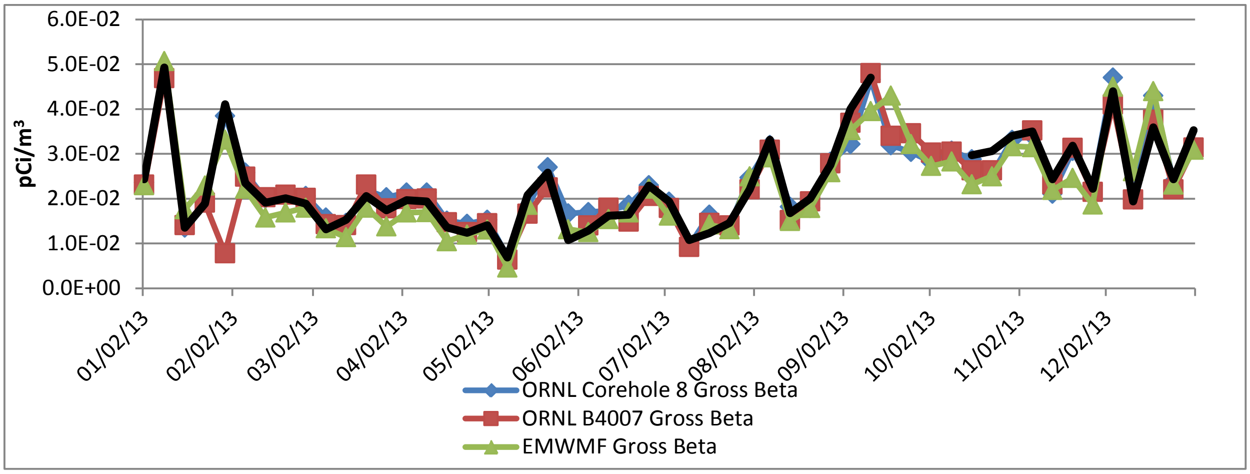


Figure 9: Gross beta results for air monitoring at ORNL, the EMWMF, and the Fort Loudoun Dam background station.

Conclusion

Results for uranium isotopes and technitium-99 were measured significantly above background levels for the two monitoring stations at ETTP during the demolition of the K-25 Process Building's purge cascades, but were well below the NESHAPS limits for the isotopes, as were the sum of fractions for each location. Elevated results for uranium isotopes were also noted at the Y-12 B-9212 station, but at much lower levels than measured at the ETTP stations. In both cases the ratio of U-234 to U-238 indicates the uranium measured was enriched. The results for the **B-**9723 station at the Y-12, both ORNL stations, and the EMWMF monitoring station were all similar to background measurements.

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RadNet Precipitation Monitoring on the Oak Ridge Reservation

Principal Author: Natalie Pheasant

Abstract

The RadNet Precipitation Monitoring Program on the Oak Ridge Reservation (ORR) provides radiochemical analysis of precipitation samples taken from monitoring stations at three locations on the Department of Energy's Oak Ridge Reservation. Samples are collected by the Tennessee Department of Environment and Conservation and analysis is performed at the Environmental Protection Agency's National Air and Radiation Environmental Laboratory. Gross beta analysis for the RadNet precipitation program was discontinued in 2010 and tritium analysis was discontinued in 2012. Analysis for gamma radionuclides is performed on each composite monthly sample in 2013 and will continue to be monitored. Since there is not a regulatory limit for radioisotopes in precipitation, the results from ORR sampling locations are compared to EPA's drinking water limits and can also be compared to data from other sites nationwide. While the stations located on the Oak Ridge Reservation stations are in areas near nuclear sources, most of the other stations in the RadNet precipitation program are located near major population centers, with no major sources of radiological contaminants nearby. Regardless, the radiological results seen in the precipitation samples collected at the RadNet sites on the ORR were all well below the EPA drinking water limits. It should be noted that the EPA drinking water limits pertain to drinking water, not precipitation, and are only used here as a conservative reference value.

Introduction

In association with the Environmental Protection Agency's (EPA) RadNet Monitoring Program, staff from the DOE Oversight Office (DOE-O) of the Tennessee Department of Conservation's (TDEC) Division of Remediation monitor precipitation on the Department of Energy Oak Ridge Reservation (ORR). The RadNet Precipitation Monitoring Program measures radioactive contaminants that are washed out of the atmosphere and carried to the earth's surface by precipitation. There are no standards that apply directly to contaminants in precipitation. However, the data provide an indication of the presence of radioactive materials that may not be evident in the particulate samples collected by DOE-O's air monitors. EPA has provided three monitors to date, which have been co-located at RadNet air stations at each of the ORR sites. One is located in Melton Valley, in the vicinity of the Oak Ridge National Laboratory (ORNL). Another is located east of the East Tennessee Technological Park (ETTP), off of Blair Road. The third is co-located with the RadNet air station east of the Y-12 National Security Complex (Y-12). Figure 1 depicts the location of the precipitation samplers.

The initial precipitation monitor provided by EPA was placed at an existing RadNet air station near ORNL's High Flux Isotope Reactor (HFIR) and the Solid Waste Storage Area 5 (SWSA5) Burial Grounds in Melton Valley, since tritium is released as water vapor in reactor effluents and from the evapotranspiration associated with buried wastes and is the major source area for tritium on the ORR. While this program no longer analyses the monthly composite samples for tritium, the station is still used to monitor that area of ORNL for gamma radionuclides. The second precipitation monitor was placed off of Blair Road, near the TSCA Incinerator east of ETTP to monitor contaminants burned in the incinerator and those from demolition activities at

ETTP. While the TSCA Incinerator closed at the beginning of December 2009, this station still monitors continuing demolition activities at ETTP. The third station is used to monitor the Y-12 facility. It also could provide an indication of any other gamma radioisotopes traveling towards the city of Oak Ridge from Melton Valley. Gross beta analysis for the RadNet precipitation program was discontinued in 2010 and tritium analysis was discontinued in 2012, however, analysis for gamma radionuclides was performed on each composite monthly sample in 2013 and will continue to be monitored.

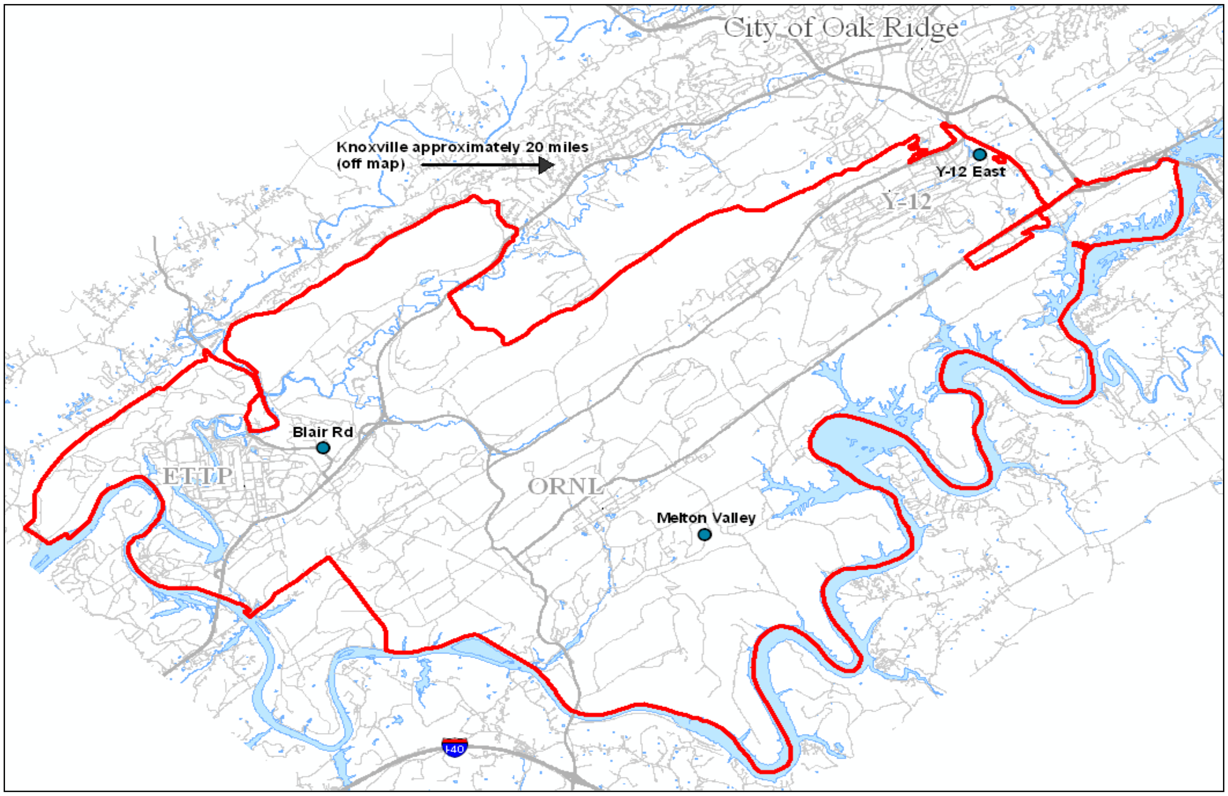

Figure 1: Locations of the RadNet Precipitation Samplers on the Oak Ridge Reservation

Since there are no regulatory limits for radiological contaminants in precipitation, the results of the gamma analyses can be compared to drinking water limits used by EPA as a conservative limit. EPA's Radionuclides Rule for drinking water allows gross alpha levels of up to 15 pCi/L, while beta and photon emitters are limited to 4 mrem per year and are radionuclide specific. The monthly composite samples are now solely analyzed for gamma radionuclides, but not all isotopes have EPA drinking water limits. A large portion of the results are non-detects, with the result less than the minimum detectable concentration. Barring nuclear accidents, the results for gamma radionuclides with drinking water limits would be expected to be below these regulatory limits. Table 1 shows for select isotopes the maximum contaminant levels (MCLs) of beta and photon emitters that EPA uses as drinking water limits.

Table 1: EPA Drinking Water Limits for Select Isotopes (MCLs)

Isotope	EPA limit (pCi/L)
Barium-140 (Ba-140)	90
Beryllium-7 (Be-7)	6,000
Cobalt-60 (Co-60)	100
Cesium-134 (Cs-134)	80
Cesium-137 (Cs-137)	200
Tritium (H-3)	20,000
Iodine-131 (I-131)	3

Methods and Materials

The precipitation samplers provided by EPA's RadNet program are used to collect samples for the RadNet precipitation program. Each sampler drains precipitation that falls on a 0.5 square meter fiberglass collector into a five-gallon plastic collection bucket. A sample is collected from the bucket (in a four-liter Cubitainer®) and sent in to EPA when a minimum of two liters of precipitation has accumulated in the Cubitainer®, or potentially less than that if it is the final sample of the month. The sample is processed as specified by EPA (U.S. EPA, 1988) and is shipped to EPA's National Air and Radiation Environmental Laboratory (NAREL) in Montgomery, Alabama, for analysis. NAREL composites samples collected during the month for each station and analyzes each composite by gamma spectrometry. Prior to 2010, the composite samples were also analyzed for gross beta, and prior to 2012, monthly samples were analyzed for tritium.

The results of NAREL's analyses are provided to TDEC annually and are available at NAREL's website in the Envirofacts RadNet Searchable Database, via either a simple or customized search (websites listed in references). The data is used to identify anomalies in radiological contaminant levels, to assess the significance of precipitation in contaminant pathways, to evaluate associated control measures, and to appraise conditions on the Oak Ridge Reservation compared to other locations in the RadNet program.

Results and Discussion

For 2013, gamma spectrometry analysis was available through November. The gamma isotopes for which there were data for the first eleven months of 2013 were barium-140, beryllium-7, cobalt-60, cesium-137, potassium-40, and radium-228. For all isotopes except beryllium-7, the reported results were less than the minimum detectable concentration (MDC) and are considered non-detects. The results for January through November of 2013 for barium-140, cobalt-60, cesium-137, potassium-40, and radium-228 were all non-detects. The average result for beryllium-7 for the three ORR samplers for the first 11 months of 2013 was 54.3 pCi/L, compared to an average minimum detectable concentration of 21.7 pCi/L. The highest beryllium-7 result for the ORR stations was 105 pCi/L. The national average for the same time period was 37.5 pCi/L. Beryllium-7, however, is a cosmogenic isotope, formed by the action of cosmic rays on the atmosphere. Also, when compared to the relatively conservative EPA drinking water limit for beryllium-7 of 6,000 pCi/L, the values seen in the monthly composite precipitation samples on the ORR are relatively quite small.

Overall, the highest values seen for the first eleven months of 2013 in the composited monthly precipitation samples for each of the three ORR stations, were all well below the MCLs set by the EPA for drinking water. In fact, all the results for barium-140, cobalt-60, cesium-137, potassium-40, and radium-228 for this time period were non-detects, with the results less than the minimum detectable concentrations (MDCs). While there are not regulatory limits for radionuclides in precipitation, the comparison to EPA's drinking water limits can be used as a conservative reference value.

Conclusion

The 2013 gamma data also show results well below EPA drinking water limits and often below detection limits. These data indicate that levels of radiation in precipitation at the three monitored locations are much lower than EPA drinking water limits and thus can be considered protective of human health and the environment.

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BIOLOGICAL MONITORING

Benthic Macroinvertebrate Monitoring

Principal Authors: John Wojtowicz and Gerry Middleton

Abstract

The biotic integrity of streams originating on the Oak Ridge Reservation (ORR) was determined during 2013 by collecting semi-quantitative benthic macroinvertebrate kick samples (i.e., “SQKICK”) from thirteen stream stations in four watersheds impacted by Department of Energy (DOE) operations. In addition, seven reference stream stations were sampled. Benthic samples were collected and processed following the State of Tennessee standard operating procedures for macroinvertebrate surveys. Generated data was analyzed using applicable metrics. An assessment score was calculated from the metrics and a site rating was assigned for all stream stations. Results indicate the biotic integrity at a number of the impacted sites in all four stream systems is less than optimal compared to reference conditions. Continued benthic macroinvertebrate monitoring is necessary to provide a more thorough and accurate assessment of stream conditions. The effectiveness of DOE remedial activities can be assessed with long term monitoring efforts.

Introduction

Benthic macroinvertebrates include insects, crustaceans, annelids, mollusks, and other organisms with long aquatic life cycles (i.e., multiple stages of larval instars) that inhabit the bottom substrates of aquatic systems, and can be easily collected using aquatic sampling nets of ≤500 µm (Hauer and Resh 1996). Occupying the primary consumer trophic level in aquatic ecosystems, macroinvertebrates serve as a link between producers (e.g. algae) and decomposers (e.g. microorganisms) in a food chain, provide a major food source for fisheries, and maintain a diverse spectrum in species composition (Song 2007). Because they are ubiquitous and sedentary, and sensitive in varying degrees to anthropogenic pollutants and other stressors, macroinvertebrate communities can provide considerable information regarding the biological condition of water bodies (Davis and Simons 1995, Karr and Chu 1998). Further, aquatic macroinvertebrate assemblages provide a surrogate measure of water chemistry and physical stream conditions (Cummins 1974, Vannote et al. 1980, Rosenberg and Resh 1993, Weigel et al. 2002) to indicate the overall health of the aquatic system (Meyer 1997, Karr 1999).

Introduction of nutrients (organic pollution) and heavy metals into a stream, dilution by tributaries, uptake of contaminants by aquatic organisms, and changes in stream structure/function create a pollution gradient from upstream to downstream, which is superimposed on the natural longitudinal gradient of the stream (Vannote et al. 1980, Clements 1994, Clements and Kiffney 1995, Medley and Clements 1998). Anthropogenic impacts inducing eutrophication (i.e., organic pollution) in aquatic systems are known to have dramatic effects on stream invertebrates (Hynes, 1978; Wiederholm, 1984; Rosenberg and Resh, 1993; Suren, 2000). Thus, nutrient enrichment can decrease species richness (Paul and Meyer, 2001) by elimination of sensitive taxa, most often represented by the insect orders *Ephemeroptera, Plecoptera* and *Trichoptera* (EPT; mayflies, stoneflies, caddisflies, Lenat, 1983). Simultaneously, taxa considered resistant to pollution and adapted to unstable habitats, such as midges (chironomids) and worms (oligochaetes), are enhanced (Hynes, 1978).

In streams where metals concentrations are sufficiently high, benthic macroinvertebrates may be entirely absent or their abundance greatly reduced (Clements 1991). Where metals and organic pollutants do not entirely eliminate the community, however, measures of taxa richness (e.g., total number of species present) or abundance of metals-sensitive taxa provide the most sensitive and reliable measure of community level effects (Barbour et al. 1992, Clements and Kiffney 1995, Kiffney 1996, Carlisle and Clements 1999). Many mayfly species are sensitive to metals contamination (Warnick and Bell 1969), and a reduction in the number of mayfly species present is an effective and reliable measure of metals impacts on benthic macroinvertebrate communities (Ramusino et al. 1981, Specht et al. 1984, Van Hassel and Gaulke 1986, Clements 1991, Clements et al. 1992, Kiffney and Clements 1994). For example, heptageniids (i.e., mayflies) are highly sensitive to heavy metals and are usually absent in metal-polluted streams (Clements 1994, Clements and Kiffney 1995). Hence, macroinvertebrate biomonitoring is a proven method of assessing and documenting stressors and any community and population changes that may occur within the impacted ecosystem.

Semi-quantitative kick net samples (i.e., SQKICK) provide a snapshot of the benthic community population at a particular stream location and the respective taxonomic identifications and taxa counts present at this site are used to calculate the Tennessee Macroinvertebrate Index (TMI, TDEC 2011). Several quantifiable attributes of the biotic assemblage (i.e., “metrics”) that assess macroinvertebrate assemblage structure, composition, and function comprise these indices (Hilsenhoff 1982, 1987, 1988, Fore et al. 1996, Karr and Chu 1998), and metrics are used to measure and calculate an overall score to represent the ecological condition and integrity of stream health. This multimetric index approach is effective for evaluating anthropogenic disturbance and pollution, for standardizing assessment and for communicating the biotic condition of streams (Barbour et al., 1999), because susceptibility to toxic agents varies with the response of individual genera and species (Resh et al. 1988, 1996).

Historically, four aquatic systems originating on the Oak Ridge Reservation (East Fork Poplar Creek, Bear Creek, Mitchell Branch, and the White Oak Creek/Melton Branch watershed) have been impacted by DOE-related activities. East Fork Poplar Creek and Bear Creek have received inputs from the Y-12 Plant, Mitchell Branch from the East Tennessee Technology Park (ETTP), and the White Oak Creek/Melton Branch watershed from the Oak Ridge National Laboratory (ORNL). Contaminant releases to surface water and groundwater vary among these industrial sites, but generally include organic pollutants, heavy metals and radionuclides. Benthic macroinvertebrate samples were collected from various locations on these streams for semi-quantitative analysis. Surface water samples were collected at the sites and analyzed for various constituents in support of the biomonitoring. Parameters analyzed included nutrients, mercury, metals, hardness, residue, and radiological constituents. The objectives of this study were to quantify benthic macroinvertebrate communities and to assess the degree of impact compared to reference conditions.

Methods and Materials

Site Description

The Oak Ridge Reservation (ORR) is a 33,515-acre site owned and operated by the US Department of Energy (DOE) that is nestled in the ridge and valley physiographic province of east Tennessee (Anderson and Roane counties). Geologically, the ORR bedrock consists of

thrust faulted and folded lithostratigraphic units of limestone, siliceous dolomite, siltstone, shale, and sandy shale. The ORR contains three major facilities: the Oak Ridge National Laboratory (ORNL) for energy research and development; the Oak Ridge Y-12 Plant (Y-12) for weapons production; and the East Tennessee Technology Park (formerly the Oak Ridge Gaseous Diffusion Plant), which was utilized for enriching uranium. Major streams impacted by DOE industrial activities include East Fork Poplar Creek (EFK), Bear Creek (BCK), Mitchell Branch (MIK), and White Oak Creek (WOC).

Field Sampling

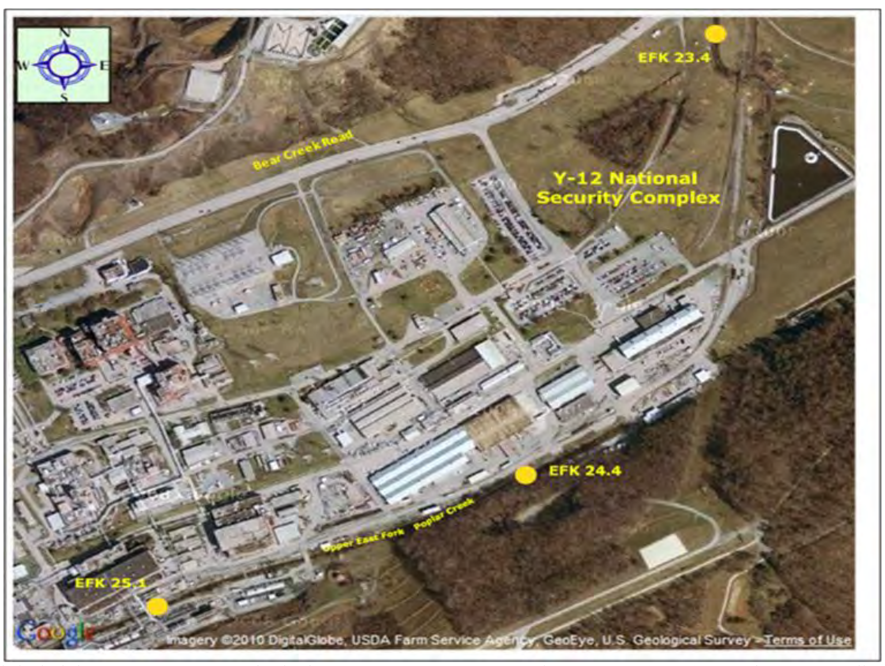
Benthic macroinvertebrate communities were semi-quantitatively sampled (i.e., kick sampling, "SQKICK") between May 1, 2013 and May 22, 2013, using the current US Environmental Protection Agency, US Geological Survey, and Tennessee Department of Environment and Conservation, Division of Water Pollution Control standard operating procedures for macroinvertebrates (Barbour et al. 1999, Moulton et al. 2000, TDEC 2006, 2011). Thirteen stream stations were sampled during 2013 on the ORR from the four main watersheds (i.e., EFK, BCK, MIK, & WOC). Melton Branch (MEK) is a tributary to WOC. Seven other reference streams were also sampled (Table 1, Figures 1-5).

Table 1: Oak Ridge Reservation Benthic Monitoring Sites

Station	Description	Cover	TDEC DWR Designation
EFK 25.1	East Fork Poplar Creek km 25.1	thin canopy	EFPOP015.6AN
EFK 24.4	East Fork Poplar Creek km 24.4	canopy	EFPOP015.2AN
EFK 23.4	East Fork Poplar Creek km 23.4	open	EFPOP014.5AN
EFK 13.8	East Fork Poplar Creek km 13.8	open	EFPOP008.6AN
EFK 6.3	East Fork Poplar Creek km 6.3	canopy	EFPOP003.9RO
HCK 20.6	Hinds Creek km 20.6 Reference	canopy	HINDS012.8AN
CCK 1.45	Clear Creek km 1.45 Reference	thin canopy	ECO67F06
GHK 2.9	Gum Hollow Branch km 2.9 Reference	canopy	GHOLL001.8RO
MIK 1.43	Mitchell Branch km 1.43 Reference	canopy	MITCH000.9RO
MIK 0.71	Mitchell Branch km 0.71	open	MITCH000.4RO
MIK 0.45	Mitchell Branch km 0.45	thin canopy	MITCH000.3RO
BCK 12.3	Bear Creek km 12.3	canopy	BEAR007.6AN
BCK 9.6	Bear Creek km 9.6	canopy	BEAR006.0AN
MBK 1.6	Mill Branch km 1.6 Reference	canopy	FECO67I12
WCK 6.8	White Oak Creek km 6.8 Reference	thin canopy	WHITE004.2RO
WCK 3.9	White Oak Creek km 3.9	thin canopy	WHITE002.4RO
WCK 3.4	White Oak Creek km 3.4	canopy	WHITE002.1RO
WCK 2.3	White Oak Creek km 2.3	canopy	WHITE001.4RO
MEK 0.3	Melton Branch km 0.3	thin canopy	MELTO000.2RO
WWT 0.8	West Wing Tributary km 0.8 Reference	canopy	?

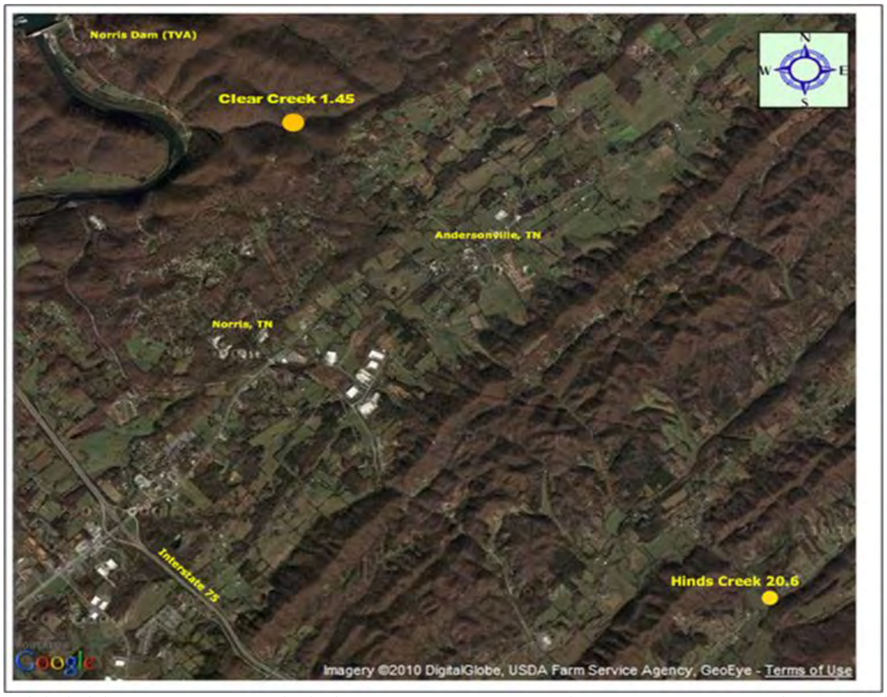
DigitalGlobe, GeoEye, US Geological Survey, USDA Farm Service Agency (2010) Google Maps [online].

Figure 1: 2013 Benthic Sites at ORNL (White Oak Creek / Melton Branch)



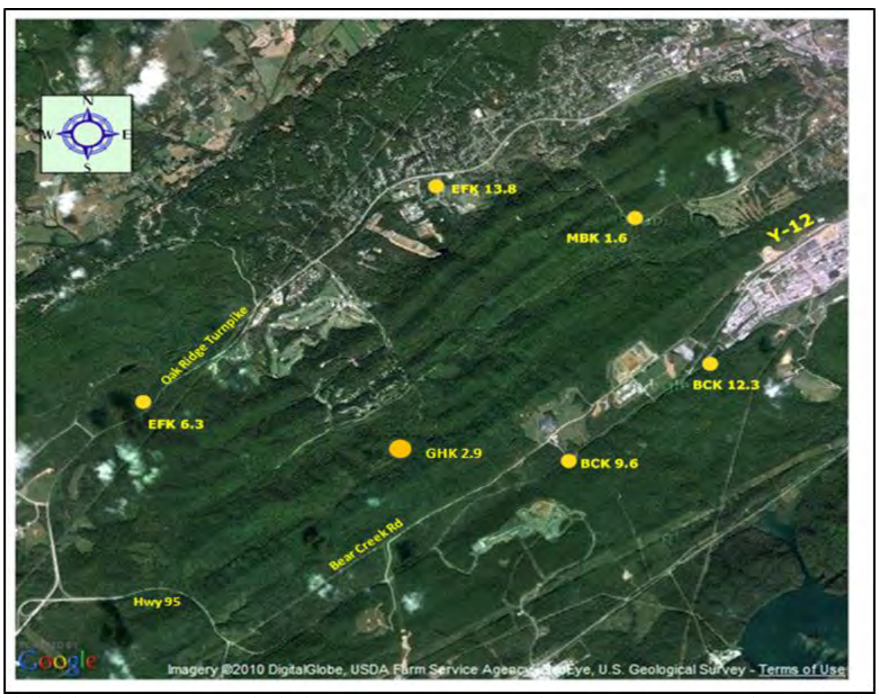
DigitalGlobe, GeoEye, US Geological Survey, USDA Farm Service Agency (2010) Google Maps [online].

Figure 2: 2013 Benthic Sites at Upper East Fork Poplar Creek



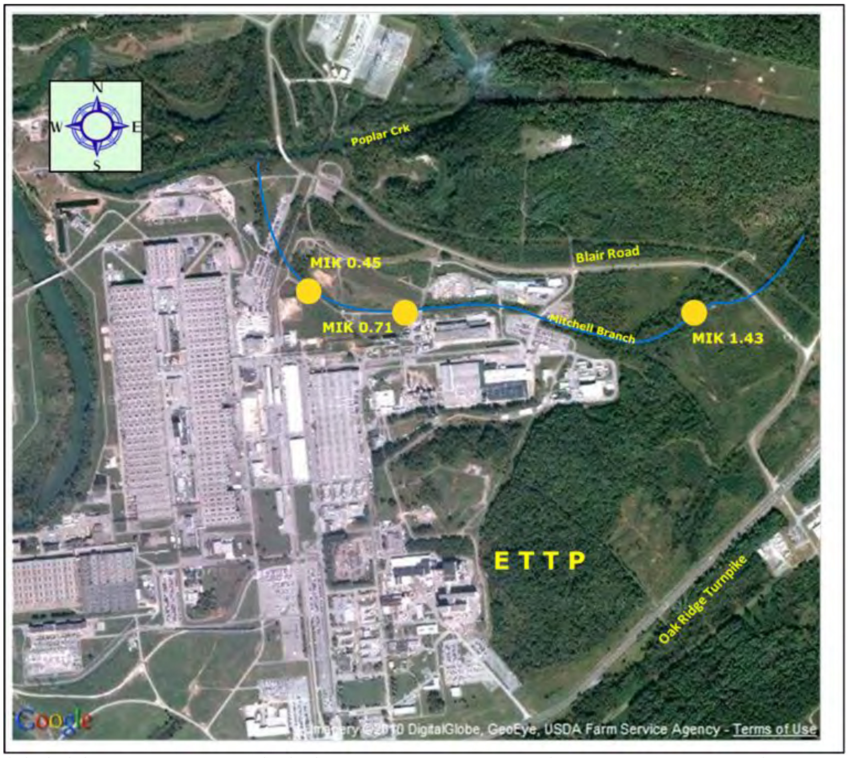
DigitalGlobe, GeoEye, US Geological Survey, USDA Farm Service Agency (2010) Google Maps [online].

Figure 3: 2013 Benthic Sites at the Hinds Creek & Clear Creek Reference Streams



DigitalGlobe, GeoEye, US Geological Survey, USDA Farm Service Agency (2010) Google Maps [online].

Figure 4: 2013 Benthic Sites at Bear Creek, Mill Branch, Gum Hollow Branch, and Lower East Fork Poplar Creek (add WWT 0.8)



DigitalGlobe, GeoEye, US Geological Survey, USDA Farm Service Agency (2010) Google Maps [online].

Figure 5: 2013 Benthic Sampling Sites at Mitchell Branch

Benthic organisms (typically larvae) were collected at each site by combining samples from two similar riffles using a one-square meter kick net (Figures 6-8). Typically the sampling crew consisted of 2-3 staff. One individual held the double-handle kick net perpendicular to the current with the net's weighted bottom resting firmly on the streambed. Another person disrupted the substrate with heavy duty garden rake in a one-square-meter stretch just upstream of the net. The third person recorded field data and provided additional field support. Benthic organisms were dislodged and drifted into the waiting net. After allowing suitable time for all the debris to flow into the net, the person performing the kick lifted the bottom of the net in a smooth, continuous motion while the person holding the net at the top was careful not to let the top edge dip below the water's surface (to prevent losing sample). One end of the kick net was then carefully placed into a 3-gallon sieve bucket (541 μm mesh) and macroinvertebrates and detritus were rinsed from the net and retained in the bucket. After a second riffle kick was completed, organisms and associated detritus were collected in the sieve bucket, picked from the net and transferred into labeled sample jars as a composite sample. Benthic macroinvertebrate samples were preserved in 85% ethanol with internal and external site-specific labels. Labeling information included site name, sampling date, and samplers' initials. If more than one sample container was needed at a site, the debris was split evenly with internal and external labels completed for each container.

Lastly, surface water samples were collected from each 2013 benthic sampling location. The laboratory results are presented in Appendix A. Personnel safety while conducting field and laboratory work followed the guidelines of the TDEC DOE-Oversight Office Health and Safety Plan (Yard 2013).


Figure 6: Kick sampling


Figure 7: Rinsing organisms


Figure 8: Picking organisms

<u>Laboratory Processing</u>

Due to the potential for radioactive contamination associated with the lower White Oak Creek / Melton Branch sediments (WCK 3.9, WCK 3.4, WCK 2.3, MEK 0.6), those benthic samples were picked and sorted at the Environmental Protection and Waste Services' laboratory facility, Building 4500S, Oak Ridge National Laboratory. Benthic material was separated from the detritus of each sample until at least 200 organisms had been counted. The picked organisms were then transferred to sealable plastic vials, labeled and preserved in 85% ethanol**.** The remaining benthic samples (i.e., BCK, EFK, MIK, and reference stations) were stored and later processed following sub-sampling procedures (i.e., picking and sorting) at the TDEC DOE-Oversight laboratory.

In the laboratory, samples were picked and benthic macroinvertebrates were enumerated and microscopically identified (by in-house staff) to the genus and species (where possible) level thus producing raw taxonomic data for each stream station. TDEC Division of Water Pollution Control revision 5 of the macroinvertebrate SOP (TDEC 2011) was used to calculate the metrics and revision 4 (TDEC 2006) was used to aid in interpretation of results. Macroinvertebrate larvae were identified using various taxonomic keys (Edmunds et al. 1976, Simpson and Bode 1980, Brigham et al. 1982, Oliver and Roussel 1983, Stewart and Stark 1988, McAlpine et al. 1981, 1987, Pennak 1989, Wiggins 1996, Needham et al. 2000, Epler 2001, 2006, 2010, Gelhaus 2002, Westfall and May 2006, Merritt et al. 2008, Pfeiffer et al. 2008).

<u>Biological Metrics</u>

Metrics were calculated from the raw data in order to develop an overall site assessment rating. Eight calculated metrics included Taxa Richness, EPT Richness [*Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), *Trichoptera* (caddisflies)], % EPT-*Cheumatopsyche* (% EPT-*Cheum*), % OC (oligochaetes and chironomids), NCBI (North Carolina Biotic Index), % Clingers, % Nutrient Tolerant organisms and Intolerant Taxa (Table 2, Hilsenhoff 1982, 1987, 1988, KDOW 2009, TDEC 2006, 2011). The EPTs are pollution-sensitive to environmental contamination and the OCs are pollution-tolerant. The biometrics used to generate stream ratings and the expected response of each metric to stress introduced to the system are presented in Table 2.

Table 2: Description of Metrics and Expected Responses to Stressors.

Category	Metric	Description	Response to Stress
Richness Metrics	Taxa Richness	Measures the overall variety of the macroinvertebrate assemblage	Number decreases
	EPT Richness	Number of taxa in the orders *Ephemeroptera* (mayflies), *Plecoptera* (stoneflies), and *Trichoptera* (caddisflies)	Number decreases
	Intolerant Taxa	Number of taxa in sample that display a tolerance rating of <3.0	Number decreases
Composition Metrics	% EPT-*Cheum*	% of EPT abundance excluding *Cheumatopsyche* taxa	% decreases
	% OC	% of oligochaetes (worms) and chironomids (midges) present in sample	% increases
Tolerance Metrics	NCBI	North Carolina Biotic Index which incorporates richness and abundance with a numerical rating of tolerance	Number increases
	% Nutrient Tolerant	% of organisms present in sample that are considered tolerant of nutrients	% increases
Habit Metric	% Clingers	% of macroinvertebrates present in sample w/ fixed retreats or attach themselves to substrates	% decreases

Because some of the streams being monitored on the Oak Ridge Reservation do not meet the conditions necessary for comparison of results to Bioregion biocriteria, an Alternative Reference Stream Method cited in the 2011 Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys (TDEC 2011) (with some modifications) was used to evaluate the study's results. The primary condition not met is that certain of the streams in the study were headwater streams (i.e., < 2 sq. mi. of drainage area). The description of the Alternative Reference Stream Method is provided in Section 1.I, Protocol K: Pages 3 & 4 of the Tennessee Standard Operating Procedure for Macroinvertebrates (TDEC 2011).

In order to generate a table of values for use of comparison of Reference Stations to potentially impacted stream stations, the seven metrics were first calculated for all of the Reference Stations (CCK 1.45, GHK 2.9, HCK 20.6, MBK 1.6, MIK 1.43, and WCK 6.8). Based on these average values and using the calculations provided in Section 1.I, Protocol K: Pages 3 & 4 of the Tennessee Standard Operating Procedure for Macroinvertebrates (TDEC 2011), ranges of values for ratings of 6, 4, 2, and 0 for each metric were further determined. The results of these calculations may be found in Table 3.

Table 3: Alternative Reference Stream Metrics.

Alternative Reference Steam Metrics				
Metric	**6**	**4**	**2**	**0**
Taxa Richness	> 23.75	17.81-23.74	13.36-17.80	< 13.36
EPT Richness	>10.88	8.16-10.87	6.12-8.15	<6.12
% EPT- Cheum	>39.61	29.71-39.60	22.28-29.70	<22.28
% OC	<33.92	33.93-50.44	50.45-62.83	>62.83
NCBI	<5.27	5.27-6.45	6.46-7.34	>7.34
% Clingers	>28.93	21.69-28-93	16.27-21.68	<16.27
% TNutol	<36.52	36.52-52.39	52.40-64.29	>64.29

Because some of the streams and stations in the study did not meet the bioregion comparison criteria, some modifications were made to procedures in order to more clearly differentiate among the benthic communities in the streams. Tennessee State SOPs (TDEC 2011) require identification of taxa to only the genus level. Taking certain of the taxa to the species level, where possible, allows for a clearer picture of the health of a site to be developed. Certain genera of mayflies (Ephemeroptera) may have more than one species occurring at a sample site. This is particularly true of the genera *Baetis* and *Maccaffertium*. Reference sites may contain as many as 5 species in these combined genera, whereas impacted site may only have two of these species, if any. Because of this difference the numbers generated for EPT Taxa Richness, and Total Taxa Richness could vary (i.e., increase) when using species level identification versus genus level identification. Species level identification could also be important in other genera including the caddisflies *Pycnopsyche* and *Neophylax*. Calculations of all metrics for this study were done using the species level identifications.

Results and Discussion

Semi-quantitative Assessments (SQKICK Sample Results)

Table 4: Metric Values, Scores and Biological Condition Ratings for Reference Stations

2013 RESULTS	Benthic Macroinvertebrate Reference Stations											
Stream station	CCK 1.45		HCK 20.6		MIK 1.43		GHK 2.9		MBK 1.6		WCK6.8	
METRIC	VAL	SCR	VAL	SCR	VAL	SCR	VAL	SCR	VAL	SCR	VAL	SCR
Taxa Richness	23.3	4	42.5	6	34	6	40	6	41	6	35	6
EPT Richness	8.7	4	18.5	6	10	4	18	6	19	6	15.5	6
% EPT-Cheum	55.89	6	42.74	6	46.12	6	45.89	6	51.76	6	69.06	6
% OC	6.67	6	18.83	6	29.61	6	6.43	6	11.37	6	9.66	6
NCBI	5.04	6	4.4	6	3.56	6	2.89	6	2.9	6	2.21	6
% Clingers	33.92	6	58.86	6	24.27	4	36.6	6	51.37	6	27.96	4
% Nutrient Tolerant	7.69	6	42.41	4	18.45	6	13.27	6	6.67	6	4.69	6
Intolerant Taxa	10	0	11.5	0	10	0	16	0	15	0	10	0
INDEX SCORE (Tenn. Macro. Index)		38		40		38		42		42		40
RATING		A		A		A		A		A		A

Key: VAL = Value
SCR = Score

East Fork Poplar Creek

Benthic laboratory results (i.e., metric values, metric scores, overall TMI scores (Alternative Reference Stream Method) and biological condition ratings) are presented in Table 5 for the EFK watershed. For monitoring purposes, the watershed is herein considered as the upper EFK (UEFK) with three sampling stations (i.e., within Y-12 Plant, EFK 25.1, EFK 24.4, EFK 23.4) and lower EFK (LEFK) with two sampling stations (EFK 13.8, EFK 6.3). The stream numbers represent distances in kilometers that decrease from headwaters (EFK 25.1) towards the mouth downstream (EFK 0.0). The reference streams for the EFK watershed include Hinds Creek (HCK 20.6) and Clear Creek (CCK 1.45). Generally, stream biotic integrity in EFK appeared to be slightly better in the LEFK than in UEFK.

The East Fork Poplar Creek is one of the streams on the Oak Ridge Reservation where impacts occur from the headwaters of the stream to a considerable distance downstream in the watershed. The headwaters of the stream originate from tributaries that flow through storm water conduits in the main industrialized portion of the Y-12 Plant. Downstream the stream flows through urbanized and suburbanized sections of Oak Ridge before flowing through less developed areas prior to its confluence with Poplar Creek. Near its origin, East Fork receives inputs of contaminants such as mercury, uranium, volatile organic compounds (VOAs) and other metals and organics. Once leaving the Y-12 boundary, East Fork receives further contaminant loading from urban and suburban runoff as well as sewage treatment plant discharge. Only near its mouth does East Fork flow through relatively undisturbed terrain. Another significant factor in relation to East Fork is that near its headwaters it continues to receive flow augmentation of approximately 4.5 million gallons per day from the Clinch River (DOE 2013). This flow augmentation which began in 1996 (DOE 2013) has helped improve the biological condition of particularly the Upper East Fork Poplar Creek sample sites. Recently, a proposal has been put forth to either reduce or eliminate flow augmentation to the East Fork Poplar Creek (DOE 2013).

Table 5: Metric Values, Scores and Biological Condition Ratings for East Fork Poplar Creek

2013 RESULTS	**EAST FORK POPLAR CREEK**									
Stream station	EFK 25.1		EFK 24.4		EFK 23.4		EFK 13.8		EFK 6.3	
METRIC	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE
Taxa Richness	23	4	17	2	28	6	33	6	24	6
EPT Richness	4	0	4	0	8	2	7	2	5	0
% EPT-Cheum	11.56	0	18.9	0	3.87	0	27.38	2	14.57	0
% OC	75.72	0	65.24	0	79.01	0	49.4	4	45.28	4
NCBI	5.35	4	5.17	6	5.67	4	4.44	6	7.05	2
% Clingers	32.95	6	35.37	6	35.91	6	35.71	6	48.82	6
% Nutrient Tolerant	34.1	6	44.51	4	52.49	2	16.07	6	16.54	6
INDEX SCORE (Tenn. Macro. Index)		20		18		20		32		24
RATING		C		C		C		A		B

Key: A = Supporting / Non Impaired (Tenn. Macro. Index Scores ≥32)
B = Partially Supporting / Slightly Impaired (TMI Scores 21-31)
C = Partially Supporting / Moderately Impaired (TMI Scores 10-20)
D = Non Supporting / Severely Impaired (TMI Scores <10)

To gain a clearer understanding of the condition of the sampling stations in East Fork the following series of nine graphs comparing Total Score, Taxa Richness, EPT Richness, % EPT-Cheum, % OC, NCBI , % Clingers, % TNUTOL, and Intolerant Taxa have been provided (Figures 9-17). Values for the impacted stations in East Fork are given in Table 5; values for reference stations are provided in Table 4. Their discussion follows the figures below.

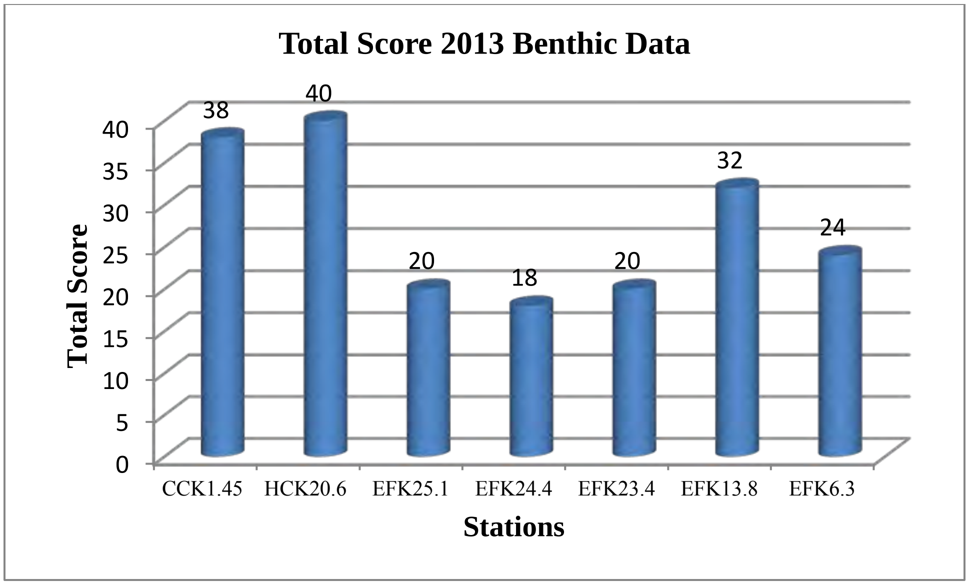


Figure 9: Total Score East Fork.

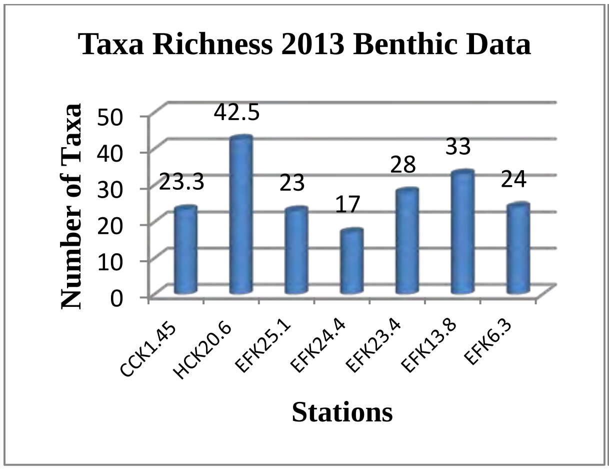


Figure 10: Taxa Richness East Fork.

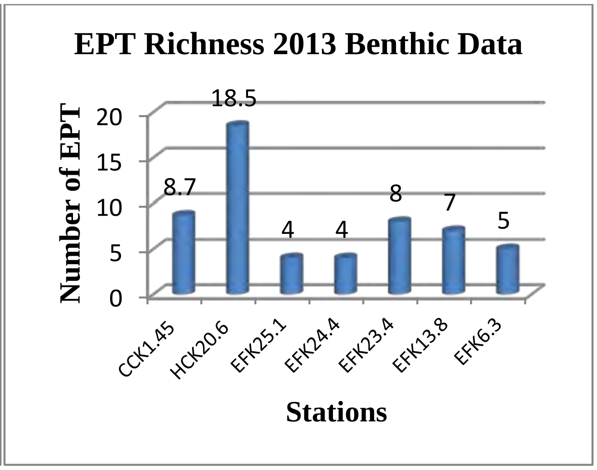


Figure 11: EPT Richness East Fork.

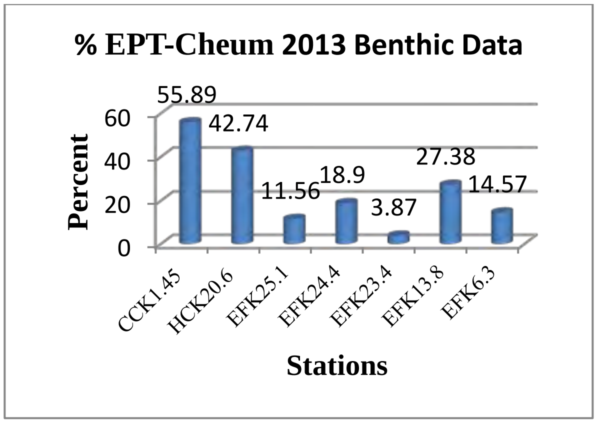


Figure 12: % EPT-Cheum East Fork.

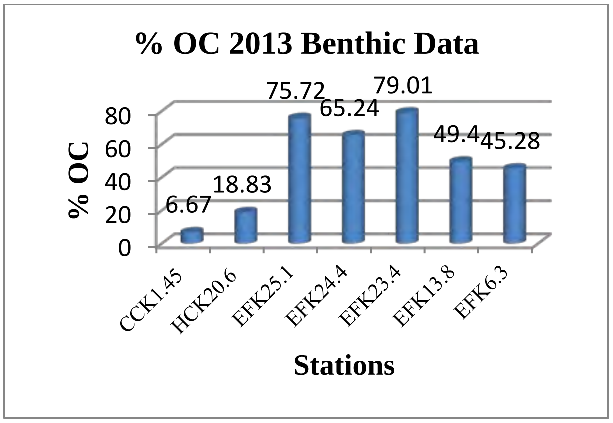


Figure 13: % OC East Fork.

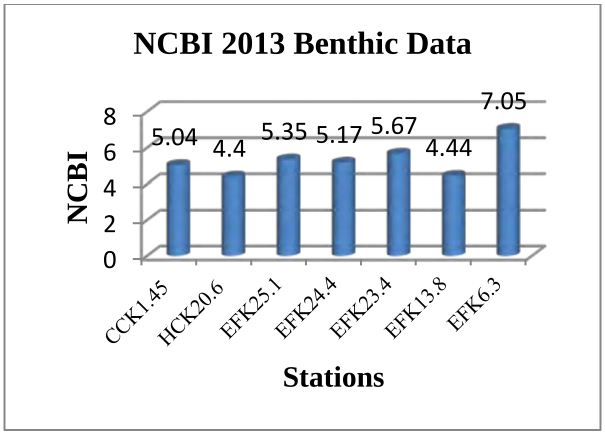


Figure 14: NCBI East Fork.

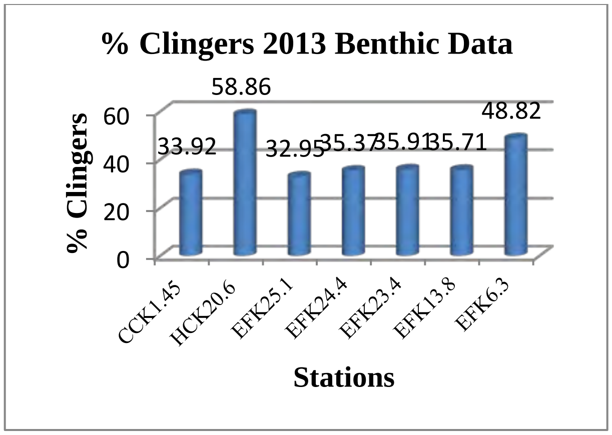


Figure 15: % Clingers East Fork.

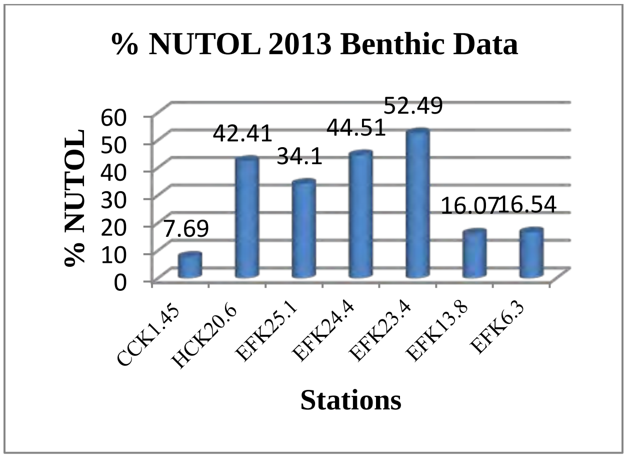


Figure 16: % NUTOL East Fork.

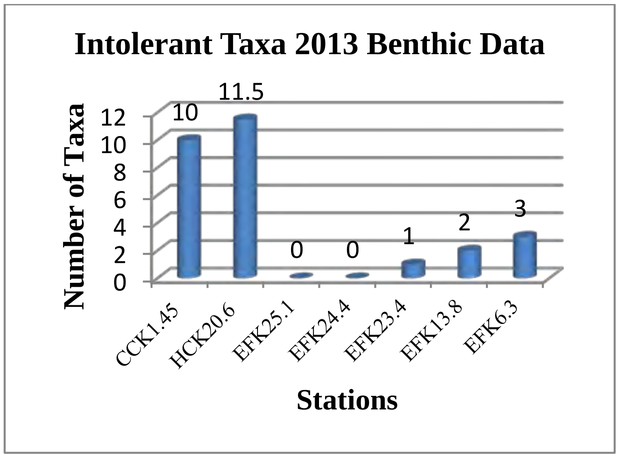


Figure 17: Intolerant Taxa East Fork.

Figure 9 compares the Tennessee Macroinvertebrate Index (TMI; Alternative Reference Stream Method) Total Score results for the two reference sites (CCK 1.45 & HCK 20.6) with the five sampling stations in East Fork Poplar Creek. The scores for the two reference stations clearly exceed those for all stations of East Fork with the exception of EFK 13.8. The metric Taxa Richness (Figure 10) displays an anomalous result where the number of taxa at CCK 1.45 (a reference station and also one of Tennessee's Bioregion streams) is actually roughly equal to or less than the taxa numbers for four of the East Fork stations. The metrics for NCBI (Figure 14), % Clingers (Figure 15) and % NUTOL also fail to clearly distinguish between the reference streams and impacted sites. Both CCK 1.45 and HCK 20.6 display NCBI (Figure 14) values that are virtually indistinguishable from those of the East Fork stations. The rankings of both reference stations and East Fork stations for % Clingers (Figure 15) are all the maximum of 6 (Table 4, Table 5). The metric % NUTOL (Figure 16) also fails to distinguish clearly between reference and impacted stations with the values for EFK 13.8 and EFK 6.3 aligning more closely with that of CCK 1.45 and the values of EFK 25.1, EFK 24.4, and EFK 23.4 aligning more closely with HCK 20.6. The comparison of the number of Intolerant Taxa between reference and impacted streams (Figure 17) shows a dramatic difference between reference and impacted stations.

More is needed than use of the Tennessee Macroinvertebrate Index (TMI; Alternative Reference Stream Method) Total Score in interpreting and understanding the condition of the various impacted stream stations in East Fork Poplar Creek. Based on only that metric, station EFK 13.8 would appear to be approaching the condition of the reference streams. Other metrics, particularly % EPT-Cheum (Figure 12), % OC (Figure 13), and Intolerant Taxa (Figure 17), show this to clearly not be the case. Differences are especially dramatic in terms of the number of Intolerant Taxa present (Figure 17). The lack of or low numbers of Intolerant Taxa in the impacted stations of East Fork are indicative of a stressed environment.

As mentioned above CCK 1.45 is a Tennessee Bioregion stream. Although CCK 1.45 scores well overall in the 2013 Benthic analysis (i.e., a Total Score of 38), some of the metrics are not up to par for a Tennessee Bioregion stream. The result for Total Taxa Richness (Figure 10) is troubling with CCK 1.45 ranking roughly equal to or below four of the five East Fork stations in this metric. In sampling during 2010, 2011 and 2012 CCK 1.45 consistently scored higher in terms of Total Taxa Richness (2010: 27 taxa (not a particularly impressive number); 2011: 40.5 taxa; and, 2012: 32 taxa). Part of the problem could have resulted from sampling taking place after flooding events or other disturbances where adequate recovery time was not allowed before sampling. Sampling of CCK 1.45 during 2014 should help to clarify if 2013 was just an anomalous sample year or if some more significant effect is taking place in the watershed.

Although East Fork Poplar Creek has shown considerable improvement over the time since the 1980's when sampling initially began, improvements have leveled off somewhat in the past few years. Part of this stagnation in improvement may be due to continuing impacts emanating from Y-12, as well as urban inputs and the discharge of the Oak Ridge Sewage Treatment Plant into East Fork downstream of EFK 13.8. However, a large part of this stagnation may also be due, especially in the upper East Fork stations, to a lack of a source for recolonization of aquatic insects. Recolonizaton of aquatic insects into impacted sections of streams may occur by a number of mechanisms (Wallace 1990). Included among these mechanisms are (1) migration from the deeper hyporheic zone to surface substrates; (2) upstream movements; (3) downstream drift from upstream or tributary areas; and (4) aerial recolonization by adults of many insects (Wallace 1990). The hyporheic zone is the area beneath and adjacent to the stream bed where there is a mixing of shallow ground water and surface water. As indicated by Wallace (1990) "In some riverine systems with well-developed hyporheic zones, macrobenthic fauna may be abundant deep (>20 cm) into the substratum as well as many meters laterally from the stream margin (e.g., Coleman and Hynes 1970, Stanford and Gaufin 1974, Bretschko 1981, Pennak and Ward 1986)." In some streams aquatic insects and other invertebrates can move upstream on the stream bed to recolonize impacted areas. Downstream drift form either unimpacted headwater areas or tributaries could potentially be very significant in the recolonization of impacted reaches of streams. Finally, adult aquatic insects migrating from either downstream and tributaries or nearby healthy streams and laying their eggs in the impacted stream could serve as a source for recolonization. Unfortunately, the upper reaches of East Fork lack any of these potential sources for recolonization. Long term impacts from Y-12 have most likely eliminated the hyporheic zone as a source of recolonization. There are no unimpacted headwaters in East Fork with former tributaries now flowing through storm drains. The entirety of East Fork proper has been historically impacted long term and below the upper reaches of East Fork urbanization has impacted many of the tributary sources of potential recolonization (both from upstream

movements of fauna and sources for adult insects for aerial recolonization). A couple of known healthy tributaries do exist along East Fork (i.e., Mill Branch (MBK) and Gum Hollow Creek (GHK). Further study will be necessary to determine if other healthy tributaries exist and also to elucidate any positive effects known sources of recolonization may be having on the East Fork system.

Mitchell Branch

Tennessee Macroinvertebrate Index (TMI; Alternative Reference Stream Method) Total Scores (Figure 18) decrease downstream in Mitchell Branch suggesting deteriorating water quality conditions at MIK 0.71 and MIK 0.45 compared to the upstream reference (MIK 1.43). Mitchell Branch is a small headwater tributary to Poplar Creek at the ETTP. The highest upstream station, which serves as the reference station (MIK 1.43), does not meet the criteria for rating according to the Bioregion concept due to the size of the watershed above it (i.e., < 2 square miles). Because of the small upstream watershed and variable flow conditions depending on annual rainfall, MIK 1.43 does not always provide a clear picture of the impacted condition of the downstream stations (MIK 0.71 & MIK 0.45). Historically, MIK 1.43 has been relatively unimpacted by the presence of ETTP. The lower stations (MIK 0.71 and MIK 0.45) have, however, been impacted not only from former industrial activities at the ETTP, and waste areas, but have also been channelized with much of the channel being replaced with unnatural substrate.

In order to gain a clearer understanding of the condition of the sampling stations in Mitchell Branch the following series of nine graphs comparing Total Score, Taxa Richness, EPT Richness, % EPT-Cheum, % OC, NCBI , % Clingers, % TNUTOL, and Intolerant Taxa have been provided (Figures 18-26). Metric data for all stations including the reference station (MIK 1.43) may be found in Table 6. The discussion of the data follows the table and figures below.

Table 6: Metric Values, Scores and Biological Condition Ratings for Mitchell Branch

2013 RESULTS		MITCHELL BRANCH						
Stream station		MIK 1.43		MIK 0.71		MIK 0.45		
METRIC		VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	
Taxa Richness		34	6	27	6	31	6	
EPT Richness		10	4	8	2	5	0	
% EPT-Cheum		46.12	6	20.67	0	8.82	0	
% OC		29.61	6	55.77	2	66.14	0	
NCBI		3.56	6	5.1	6	4.84	6	
% Clingers		24.3	4	32.21	6	40.41	6	
% Nutrient Tolerant		18.45	6	22.6	6	27.43	6	
Intolerant Taxa		10	0	9	0	3	0	
INDEX SCORE (Tenn. Macro. Index)			38		28		24	
RATING			A		B		B	
Key:	A = Supporting / Non Impaired (Tenn. Macro. Index Scores ≥32)							
	B = Partially Supporting / Slightly Impaired (TMI Scores 21-31)							
	C = Partially Supporting / Moderately Impaired (TMI Scores 10-20)							

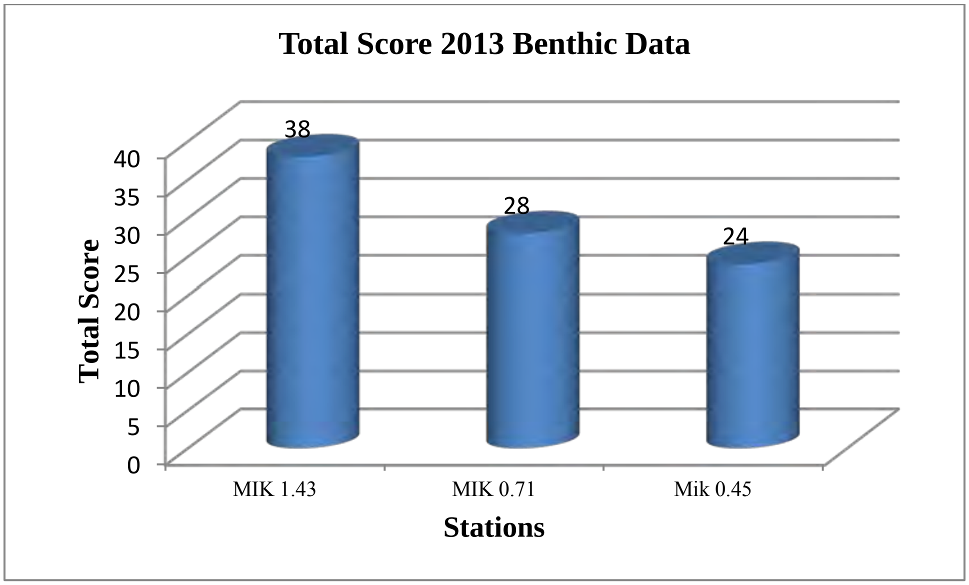


Figure 18. Total Score Mitchell Branch.

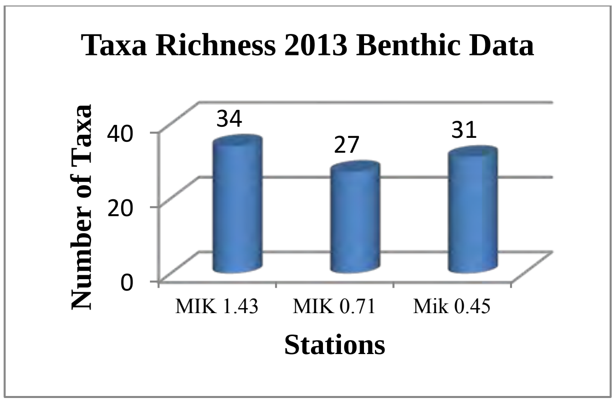


Figure 19: Taxa Richness Mitchell Br.

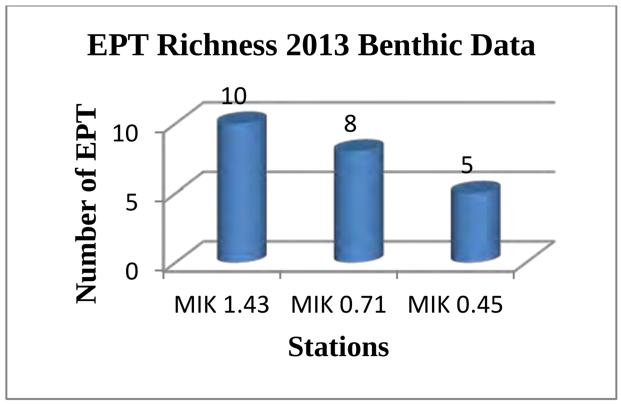


Figure 20: EPT Richness Mitchell Br.

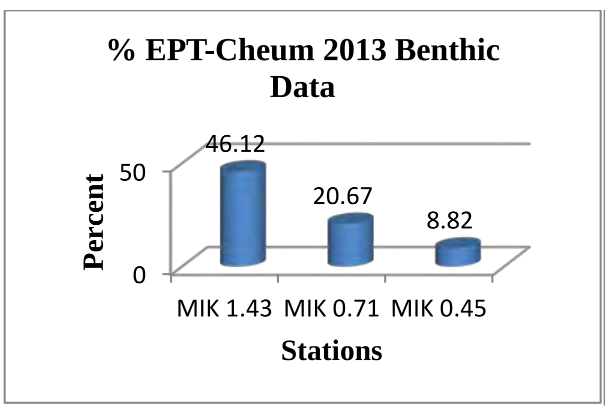


Figure 21: % EPT-Cheum Mitchell Br.

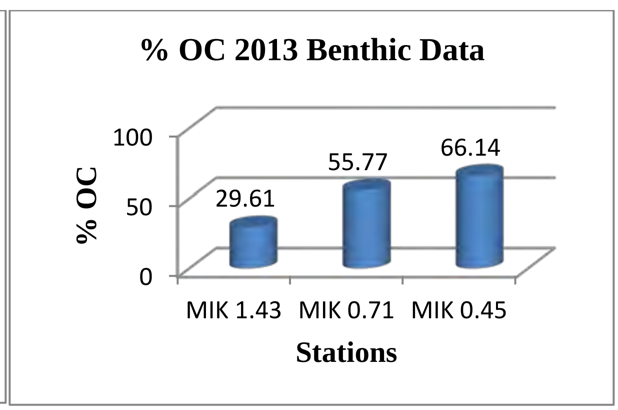
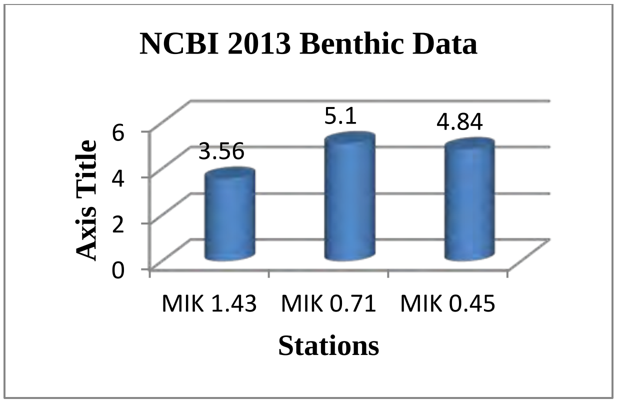


Figure 22: % OC Mitchell Br.



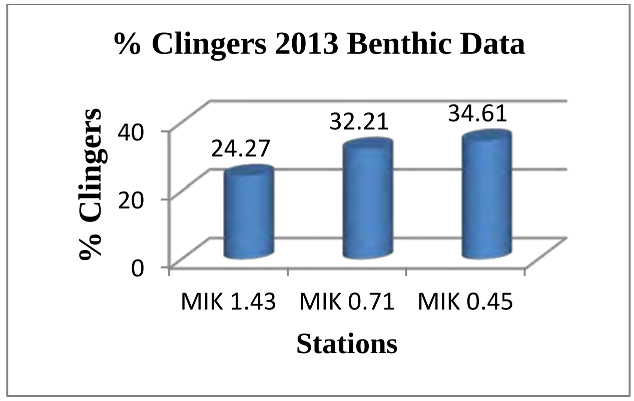
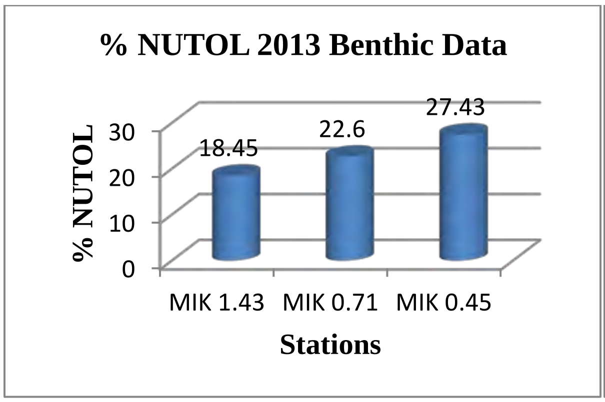


Figure 23: NCBI Mitchell Br. **Figure 24: % Clingers Mitchell Br.**



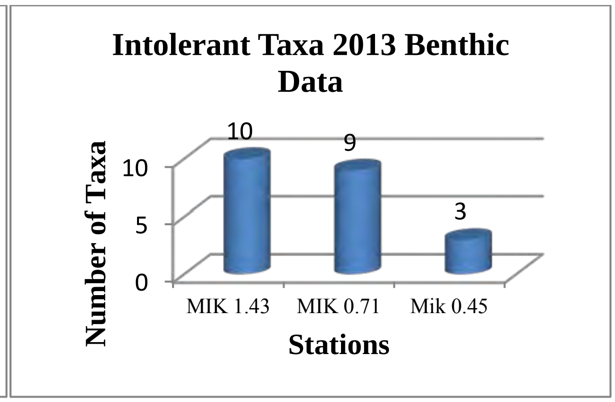


Figure 25: % NUTOL Mitchell Br. **Figure 26: Intolerant Taxa Mitchell Br.**

With the exception of Taxa Richness, all other metrics appear to fairly clearly show the superior condition of MIK 1.43 as opposed to MIK 0.71 and MIK 0.45. Like East Fork Poplar Creek, Mitchell Branch has improved considerably in quality since the 1980's. A part of these improvements are due to reduced industrial and buried waste inputs from the ETTP as remediation has occurred over the years. Another part of the improvement in stations MIK 0.71 and MIK 0.45 is due to a more natural substrate having replaced much of the artificial substrate in Mitchell Branch at those stations. Unlike East Fork, Mitchell Branch has a source for recolonization of aquatic macroinvertebrates in that the headwaters reference station (MIK 1.43) has been relatively unimpacted over the years. Although station MIK 0.71 is overall less healthy than MIK 1.43 based on the majority of the metrics, a closer similarity of MIK 0.71 to the reference station can be seen in such metrics as Taxa Richness (Figure 19), EPT Richness (Figure 20), and Intolerant Taxa (Figure 26) showing, perhaps, the effects of recolonization from upstream. Pollutional inputs from ETTP and current and former waste areas likely still continue to impact MIK 0.71 and MIK 0.45.

<u>Bear Creek</u>

Tennessee Macroinvertebrate Index (TMI; Alternative Reference Stream Method) Total Scores (Figure 27) increase dramatically from BCK 12.3 (with a score of 8) downstream to BCK 9.6 (with a score of 38). Bear Creek is a small to moderate sized stream whose headwaters begin partly in the west end of the industrialized complex at Y-12. Historically, Bear Creek has received a number of pollutional insults from industrial activities, as well as waste disposal activities at the Y-12 complex. Former waste sites such as the S3 ponds (at its very headwaters)

continue to negatively influence the water quality of the stream. Heading downstream from its source Bear Creek continues to be impacted by inputs from various former and current waste sites. Bear Creek is also a stream where shallow groundwater and surface waters mingle freely throughout its length to its confluence with East Fork Poplar Creek. Because Bear Creek is impacted from its very headwaters, two small tributaries to East Fork Polar Creek are utilized as its references (Mill Branch, MBK 1.6; and Gum Hollow Branch, GHK 2.9).

In order to gain a clearer understanding of the condition of the sampling stations in Bear Creek the following series of nine graphs comparing Total Score, Taxa Richness, EPT Richness, % EPT-Cheum, % OC, NCBI , % Clingers, % TNUTOL, and Intolerant Taxa have been provided (Figures 27-35). Metric data for both Bear Creek stations may be found in Table 7. Metric Data for the two reference stations (GHK 2.9 & MBK 1.6) may be found in Table 4. The discussion of the data follows the table and figures below.

Table 7: Metric Values, Scores and Biological Condition Ratings for Bear Creek.

2013 RESULTS	**BEAR CREEK**						
Stream station	BCK 12.3		BCK 9.6				
METRIC	VALUE	SCORE	VALUE	SCORE			
Taxa Richness	17	2	38	6			
EPT Richness	5	0	13	6			
% EPT-Cheum	2.8	0	30.29	4			
% OC	1.63	6	10.46	6			
NCBI	7.42	0	5.17	6			
% Clingers	9.32	0	57.64	6			
% Nutrient Tolerant	92.54	0	40.75	4			
Intolerant Taxa	2	0	8	0			
INDEX SCORE (Tenn. Macro. Index)		8		38			
RATING		D		A			
Key:	A = Supporting / Non Impaired (Tenn. Macro. Index Scores ≥32)						
	B = Partially Supporting / Slightly Impaired (TMI Scores 21-31)						
	C = Partially Supporting / Moderately Impaired (TMI Scores 10-20)						

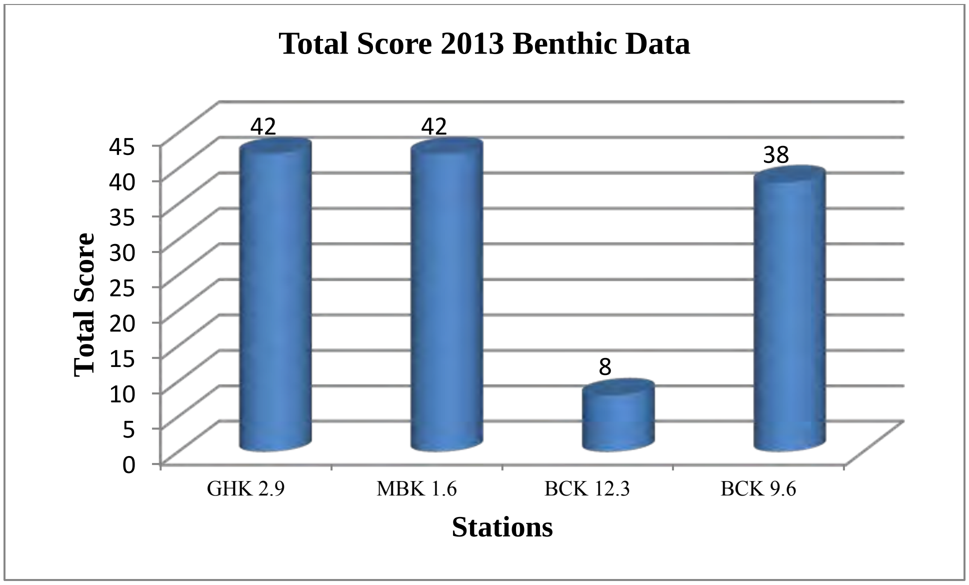


Figure 27. Total Score Bear Creek.

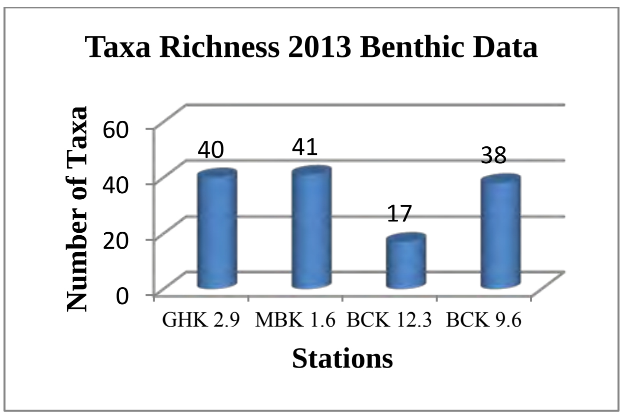


Figure 28: Taxa Richness Bear Creek.

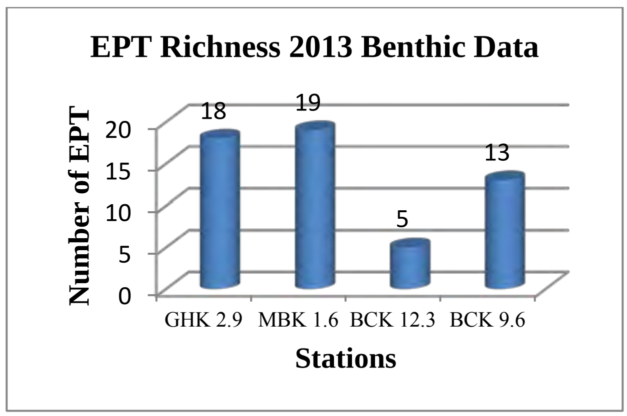


Figure 29: EPT Richness Bear Creek.

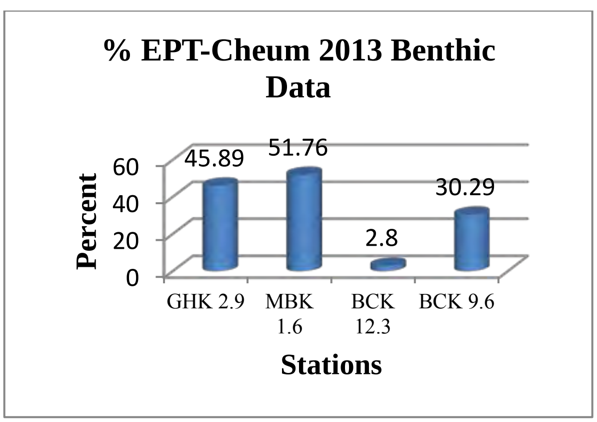


Figure 30: % EPT-Cheum Bear Creek.

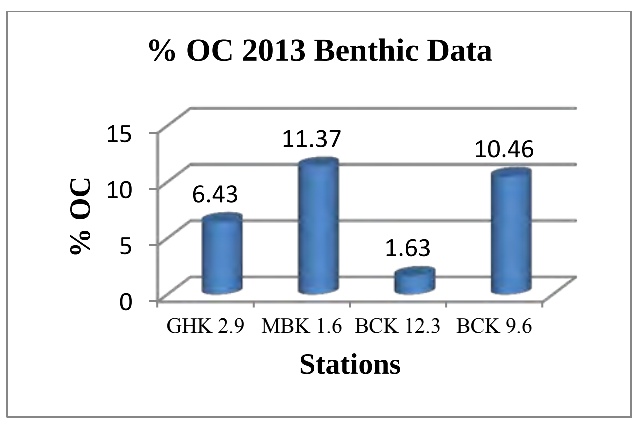
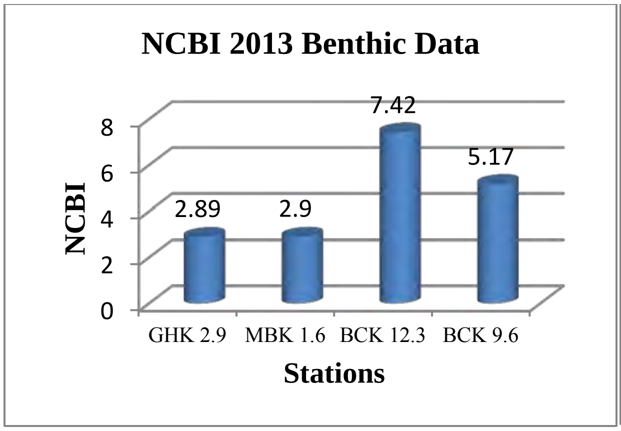


Figure 31: % OC Bear Creek.



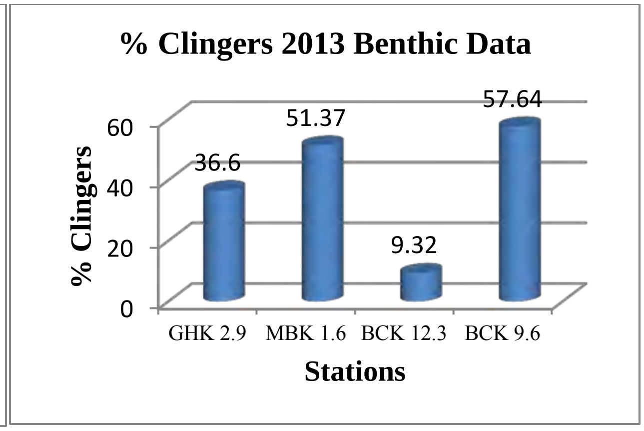
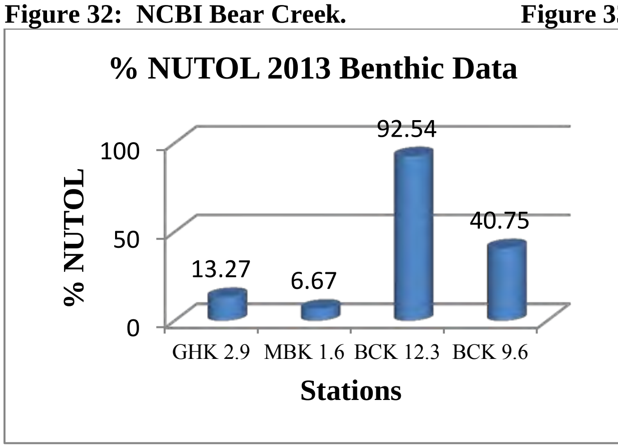


Figure 32: NCBI Bear Creek. **Figure 33: % Clingers Bear Creek.**



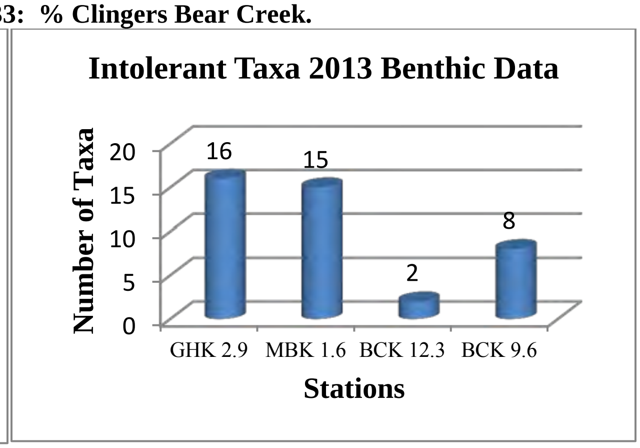


Figure 34: % NUTOL Bear Creek. **Figure 35: Intolerant Taxa Bear Creek.**

Bear Creek 12.3 continues to display a reduced benthic macroinvertebrate community. With a TMI Score (Alternative Reference Stream Method) of only 8 (Figure 27), it is our lowest scoring station. BCK 12.3 also continues to score low on the majority of the metrics in comparison to other healthier stream stations (Figures 28-30; 32-35). Regardless, a couple of Intolerant Taxa (Figure 35) continue to hold on at this station. At least one additional Intolerant Taxon (*Pycnopsyche luculenta*) was noted during field work, but was not picked up in the lab analysis. Bear Creek 12.3 likely continues to receive pollutional inputs from industry and former and current waste sites. However, this is only a part of the problem holding back continued recovery of the station. The watershed upstream of BCK 12.3 is very limited in size, thus affecting the amount of flow at the station, particularly in the summer. Also, as noted previously for East Fork Poplar Creek, BCK 12.3 suffers from a paucity of aquatic macroinvertebrate refuges in its vicinity from which recolonization of the station can occur. Little is currently known of the condition of Bear Creek proper between BCK 12.3 and BCK 9.6; however, a number of the tributaries in that reach of stream have likely been impacted from former and current waste activities. Further study will be necessary to determine if any refugia of aquatic macroinvertebrates exist in the vicinity of BCK 12.3.

BCK 9.6 continues to show improvement as noted in 2012. This station compares well with the two reference stations (GHK 2.9; MBK 1.6) in a number of the metrics. With a TMI (Alternative Reference Stream Method) score of 38 (Figure 27; Table 6), BCK 9.6 lags only slightly behind GHK 2.9 and MBK 1.6. (Figure 27; Table 4). BCK 9.6 also compares favorably

with the reference stations in Taxa Richness (Figure 28), EPT Richness (Figure 29), % EPT – Cheum (Figure 30), % OC (Figure 31) and % Clingers (Figure 33). Although not a bad score, BCK 9.6 has a higher North Carolina Biotic Index (NCBI) score than either GHK 2.9 or MBK 1.6 (Figure 32). BCK 9.6 also shows a considerably higher value for the percent of nutrient tolerant organisms (% NUTOL: Figure 34) and considerably lower value for Intolerant Taxa (Figure 35) than either of the reference stations.

GHK2.9 and MBK 1.6 continue to be some of the higher scoring reference stations being used in this study. With TMI (Alternative Reference Stream Method) scores of 42 (Table 3; Figure 27) they score a maximum ranking on all of the metrics calculated. Particularly notable are the scores for Taxa Richness (Figure 28), EPT Richness (Figure 29), NCBI (Figure32), % NUTOL (Figure 34) and numbers of Intolerant Taxa (Figure 35). In all, these streams appear to have high diversity and little organic loading.

<u>White Oak Creek and Melton Branch</u>

Tennessee Macroinvertebrate Index (TMI; Alternative Reference Stream Method) Total Scores (Figure 36) for the White Oak Creek watershed are highest for the upstream reference site (WCK 6.8) and for the site on Melton Branch a tributary to White Oak Creek in Melton Valley (MEK 0.6). Scores for stations in lower White Oak Creek (WCK 3.9, WCK 3.4, WCK 2.3) are somewhat lower indicating some degree of impairment.

White Oak Creek is the main drainage for the majority of ORNL's disturbed areas. As such, it flows from its headwaters near the Spallation Neutron Source (SNS) and through the main plant area in Bethel Valley, then passing into Melton Valley, flowing through the Solid Waste Storage Areas (SWSAs) and entering White Oak Lake before exiting the reservation through White Oak Embayment and flowing into the Clinch River. The reference station (WCK 6.8) is in the headwaters just below SNS. Station WCK 3.9 is located in the main plant area in Bethel Valley, with both WCK 3.4 and WCK 2.3 located in the SWSAs in Melton Valley. Melton Branch drains the eastern portion of Melton Valley with the sampling station MEK 0.3 being located near the High Flux Isotope Reactor (HFIR) facility. Before the development of the SNS, WCK 6.8 was relatively unimpacted. The construction of the SNS resulted in some sediment inputs into White Oak Creek, but the negative impacts caused by that sedimentation has since dissipated. WCK 3.9 is located on the south side of the ORNL complex and downstream of Fifth Creek which receives inputs from a large part of the main campus of ORNL. This station at one time was impacted heavily by discharges, spills and former waste sites. WCK 3.4 is located on the north side of the SWSAs soon after White Oak Creek passes over into Melton Valley. WCK 3.4 receives inputs from the main portion of White Oak Creek as well as inputs into First Creek. WCK 2.3 is on the south side of the SWSAs and receives added impact from the SWSAs. MEK 0.6 located near the HFIR, historically received impacts from the HFIR and other facilities in the area. Parts of Melton Branch have also been channelized.

In order to gain a clearer understanding of the condition of the sampling stations in White Oak Creek and Melton Branch the following series of nine graphs comparing Total Score, Taxa Richness, EPT Richness, % EPT-Cheum, % OC, NCBI , % Clingers, % TNUTOL, and Intolerant Taxa have been provided (Figures 36-44). Metric data for both all White Oak Creek

stations and Melton Branch may be found in Table 8. The discussion of the data follows the table and figures below.

Table 8: Metric Values, Scores and Biological Condition Ratings for White Oak Creek and Melton Branch.

2013 RESULTS	White Oak Creek and Melton Branch									
Stream station	WCK 6.8		WCK 3.9		WCK 3.4		WCK 2.30		MEK 0.6	
METRIC	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE
Taxa Richness	35	6	29	6	32	6	29	6	48	6
EPT Richness	15.5	6	5	0	9	4	7	2	19	6
% EPT-Cheum	69.01	6	25.45	2	10.96	0	5.46	0	38.62	4
% OC	9.66	6	44.36	4	61.18	2	68.85	0	23.95	6
NCBI	2.21	6	4.49	6	4.83	6	4.34	6	4.29	6
% Clingers	27.96	4	29.45	6	33.11	6	27.87	4	46.11	6
% Nutrient Tolerant	4.69	6	14.91	6	8.77	6	18.58	6	17.96	6
Intolerant Taxa	10	0	4	0	4	0	4	0	12	0
INDEX SCORE (Tenn. Macro. Index)		40		30		30		24		40
RATING		A		B		B		B		A

Key: A = Supporting / Non Impaired (Tenn. Macro. Index Scores ≥32)
B = Partially Supporting / Slightly Impaired (TMI Scores 21-31)
C = Partially Supporting / Moderately Impaired (TMI Scores 10-20)

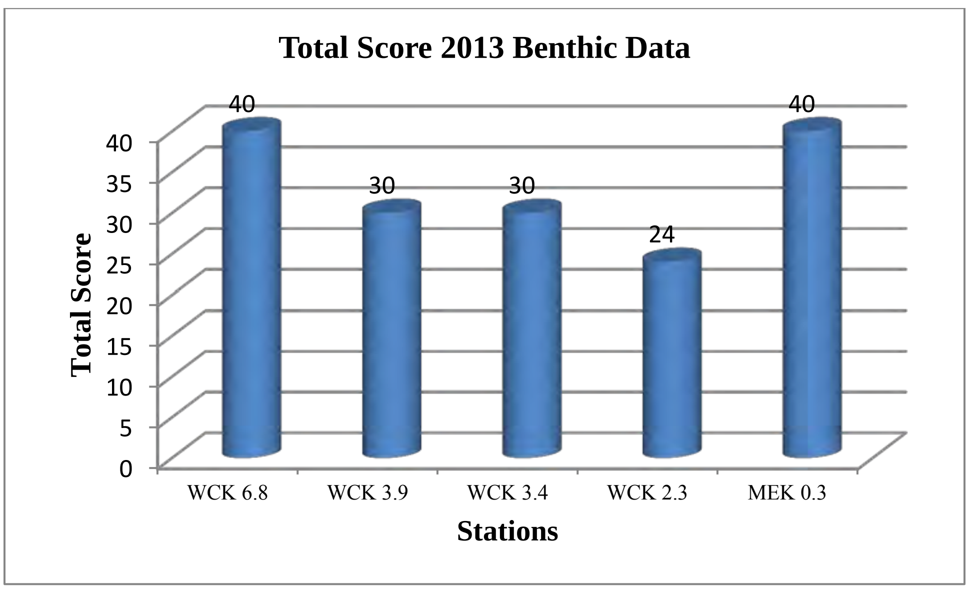


Figure 36. Total Score White Oak Creek and Melton Branch.

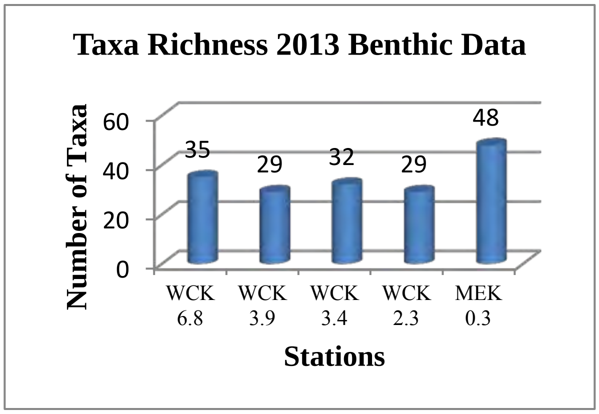


Figure 37: Taxonomic Richness White Oak Creek and Melton Br.

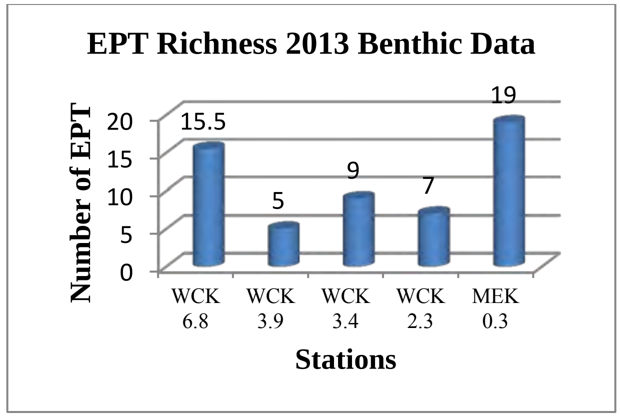


Figure 38: EPT Richness White Oak Creek and Melton Br.

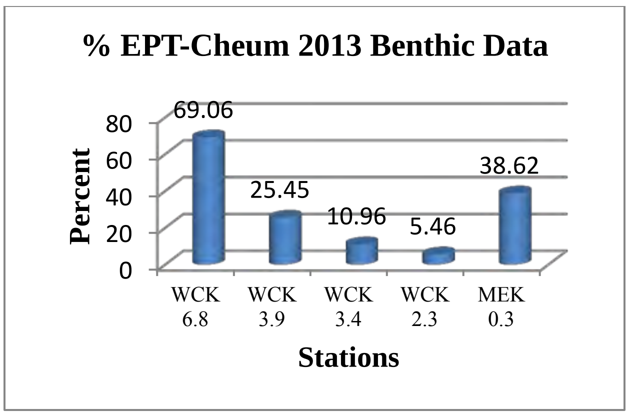


Figure 39: % EPT-Cheum White Oak Creek and Melton Br.

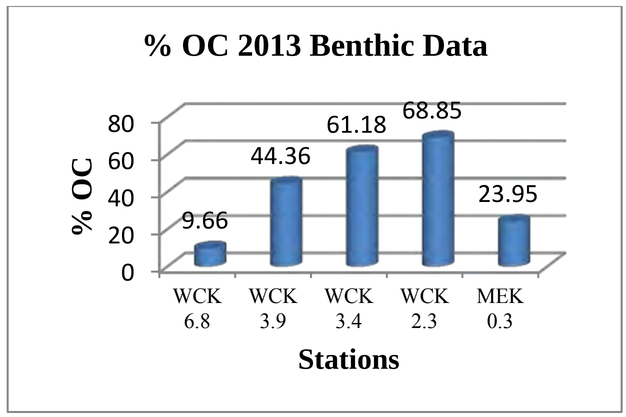


Figure 40: % OC White Oak Creek and Melton Br.

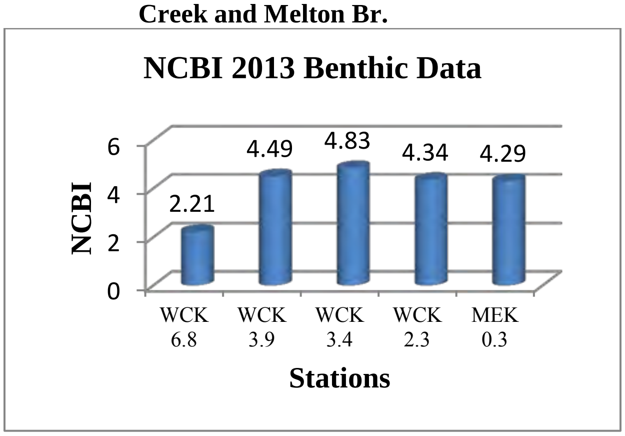


Figure 41: NCBI White Oak Creek and Melton Br.

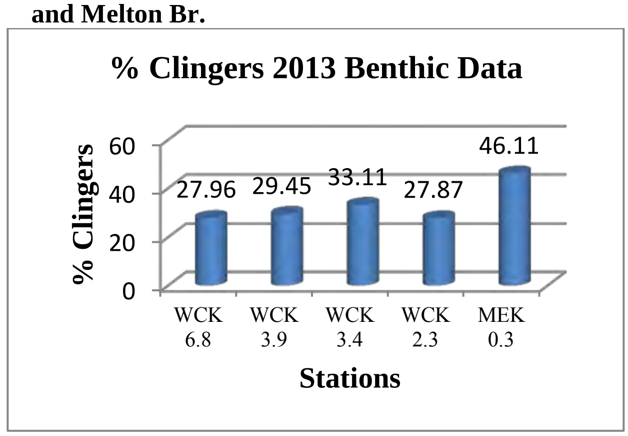
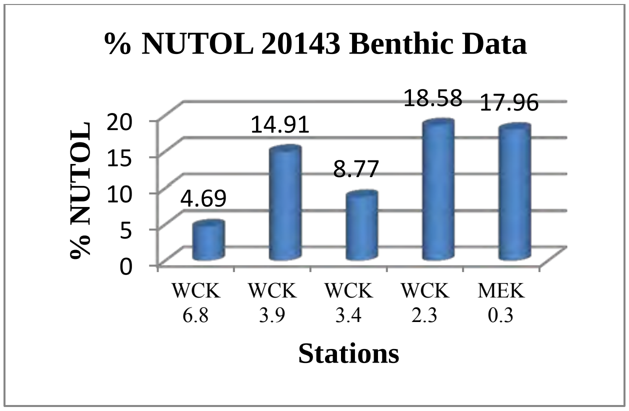


Figure 42: % Clingers White Oak Creek and Melton Br.



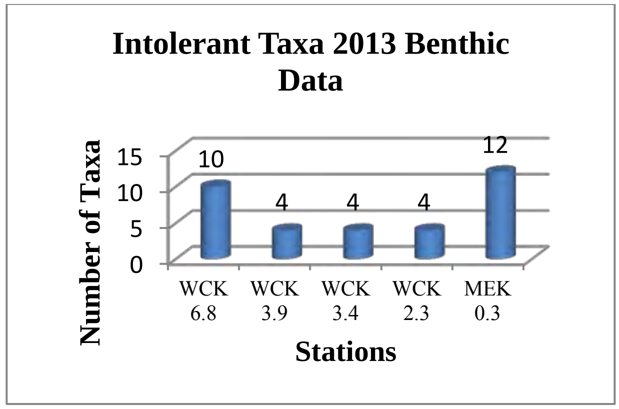


Figure 43: % NUTOL White Oak Creek And Melton Br.

Figure 44: Intolerant Taxa White Oak Creek and Melton Br.

As indicated above, both the reference station WCK 6.8 and MEK 0.6 score equally high on the Tennessee Macroinvertebrate Index (TMI; Alternative Reference Stream Method) (Figure 36). The remaining White Oak Creek stations also score fairly well; however, their scores are indicative of some degree of impairment. Taxa Richness is fairly similar for the reference station (WCK 6.8) and the remaining White Oak Creek stations (WCK 3.9, WCK 3.4, WCK 2.3), with MEK 0.6 displaying a considerably higher taxonomic diversity (Figure 37). WCK 6.8 and MEK 0.6 compare well in terms of EPT Richness (Figure 38), %OC (Figure 40), and Intolerant Taxa (Figure 44). In terms of % NUTOL (Figure 43), NCBI (Figure 41), and % EPT-Cheum (Figure 39) MEK 0.6 is more similar to the other White Oak Creek stations (WCK 3.9, WCK 3.4 & WCK 2.3) than to the reference station WCK 6.8. These last three metrics may be indicative of somewhat greater organic loading being present at MEK 0.6. The major differences between the impacted White Oak Stream Stations (WCK 3.9, WCK 3.4, & WCK 2.3) and the reference station (WCK 6.8) are apparent in the reduced number of EPT taxa at impacted stations (Figure 38), the decrease in the % EPT-Cheum (Figure 39) at the impacted stations, the increased % OC at the impacted stations (Figure 40), the significantly higher NCBI score at the impacted stations (Figure 41) and the decreased number of Intolerant Taxa at the impacted stations (Figure 44). All these differences indicate that the White Oak Creek stations (WCK 3.9, WCK 3.4, & WCK 2.3) continue to be biologically impaired.

White Wing Tributary

The original intention of sampling in White Wing Tributary was to include an additional reference station in the Bear Creek Watershed. Although, as will be discussed, the results of the sampling will preclude the use of WWT 0.8 as a reference stations, the information garnered could be valuable in gaining a better understanding of the future recovery of Bear Creek. WWT 0.8 tributary flows from the vicinity of the former White Wing Scrap Yard area to its confluence with Bear Creek at about BCK 4.0. The tributary was sampled cursorily in 2012 and the field survey showed that it contained a healthy fauna with a number of EPT taxa. Although this is a headwater tributary in a small watershed the decision was made to formally sample WWT 0.8 during the 2013 sampling season. Other than residual impacts possibly emanating from the former White Wing Scrap Yard, no other impacts were expected.

In order to gain a clearer understanding of the condition of the sampling station in WWT 0.8 Tributary the following series of nine graphs comparing Total Score, Taxa Richness, EPT

Richness, % EPT-Cheum, % OC, NCBI , % Clingers, % TNUTOL, and Intolerant Taxa have been provided (Figures 27-35). Data are presented for both the first sample taken at WWT 0.8 Tributary and its Duplicate (i.e., WWT 0.8 DUP). Metric data for both WWT 0.8 Tributary samples and the Bear Creek watershed reference samples (GHK 2.9 & MBK 1.6) may be found in Table 9. The discussion of the data follows the figures and table below.

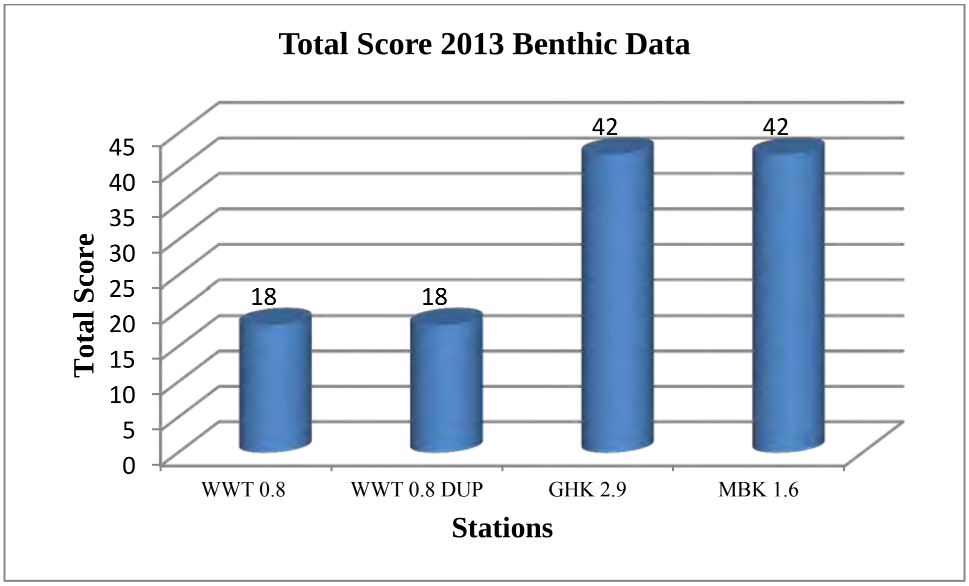


Figure 45. Total Score WWT 0.8 Tributary.

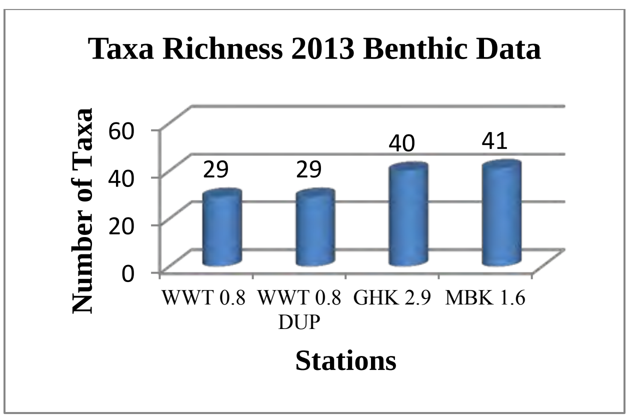


Figure 46: Taxa Richness WWT 0.8 Trib.

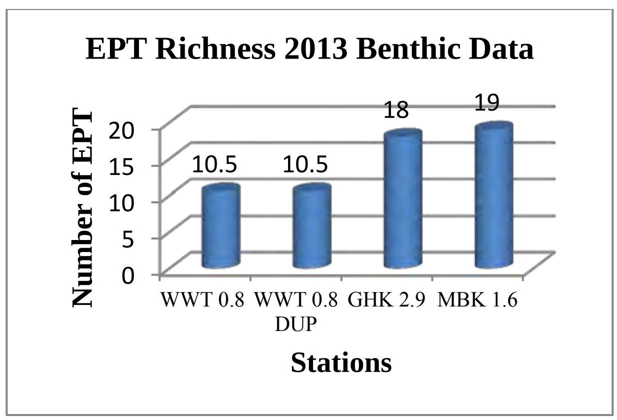
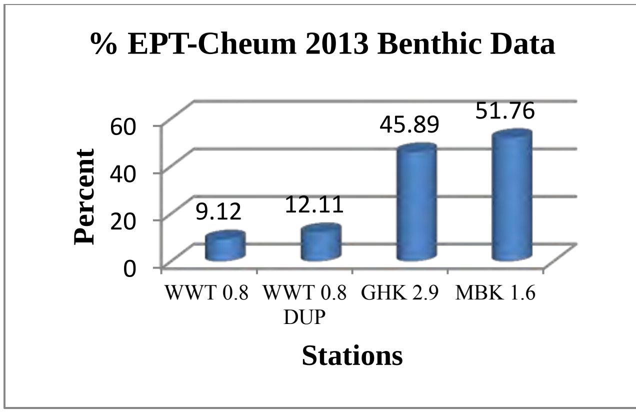


Figure 47: EPT Richness WWT 0.8 Trib.



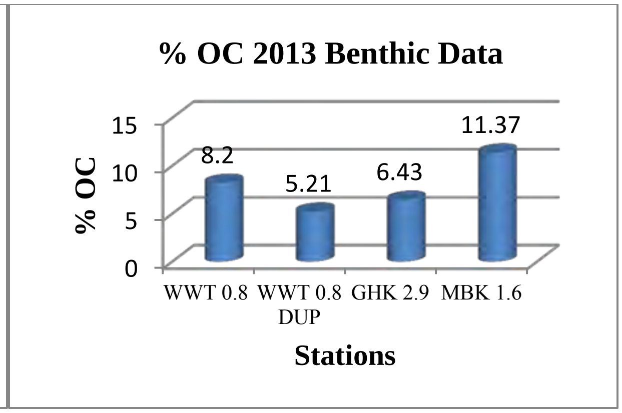
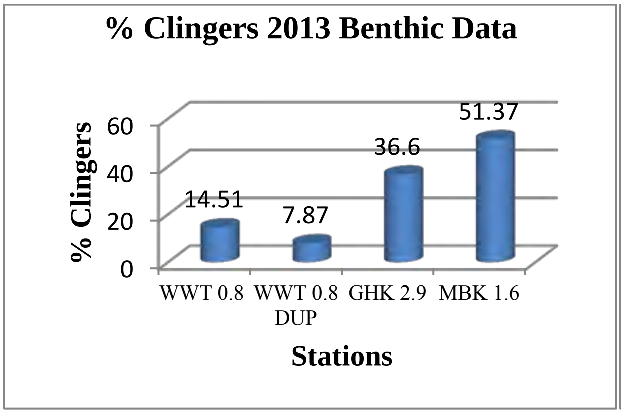


Figure 48: % EPT-Cheum WWT 0.8 Trib. **Figure 49: % OC WWT 0.8 Trib.**



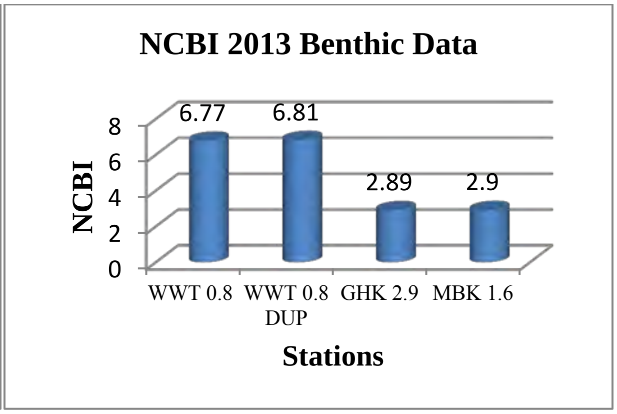
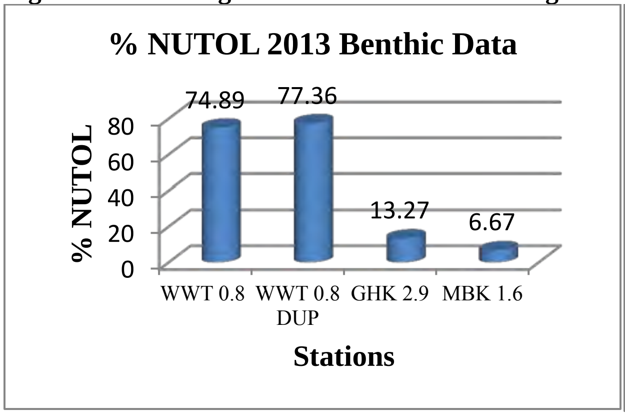


Figure 50: % Clingers WWT 0.8 Trib. **Figure 51: NCBI WWT 0.8 Trib.**



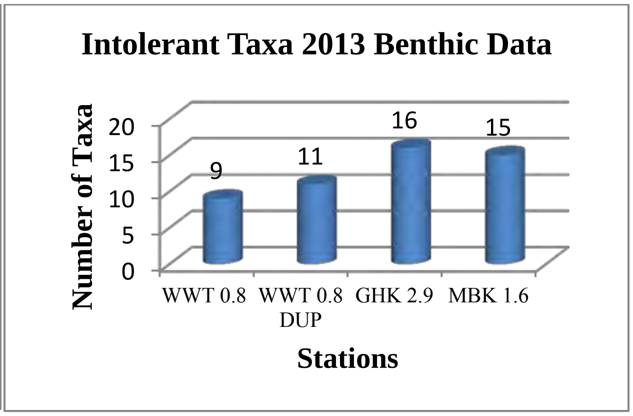


Figure 52: % NUTOL WWT 0.8 Trib. **Figure 53: Intolerant Taxa WWT 0.8 Trib.**

Table 9: Metric Values, Scores and Biological Condition Ratings for WWT 0.8 Tributary.

2013 RESULTS	**WWT 0.8 Tributary**							
Stream station	WWT 0.8		WWT 0.8 DUP		GHK 2.9		MBK 1.6	
METRIC	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE
Taxa Richness	29	6	29	6	40	6	41	6
EPT Richness	10.5	4	10.5	4	18	6	19	6
% EPT-Cheum	9.12	0	12.11	0	45.89	6	51.76	6
% OC	8.2	6	5.21	6	6.43	6	11.37	6
NCBI	6.77	2	6.81	2	2.89	6	2.9	6
% Clingers	8.2	0	7.87	0	36.6	6	51.37	6
% Nutrient Tolerant	74.89	0	77.36	0	13.27	6	6.67	6
Intolerant Taxa	9	0	11	0	16	0	15	0
INDEX SCORE (Tenn. Macro. Index)		18		18		..		42
RATING		C		C		A		A
Key:	A = Supporting / Non Impaired (Tenn. Macro. Index Scores ≥32)							
	B = Partially Supporting / Slightly Impaired (TMI Scores 21-31)							
	C = Partially Supporting / Moderately Impaired (TMI Scores 10-20)							
	D = Non Supporting / Severely Impaired (TMI Scores <10)							

Figure 49 and Table 9 compare Total Scores for both WWT 0.8 stations, GHK 2.9, and MBK 1.6. As may be seen WWT 0.8 did not score well. A part of the problem in this tributary may be its headwater nature with a limited watershed upstream. The variable flow, particularly in riffle areas could limit the suitability of the habitat to a number of organisms. Flows in this tributary are likely very low during the dry summer months, supported primarily by groundwater flows from springs in the area.

The two samples from the WWT 0.8 Tributary also show considerable difference from the two reference stations in the metrics Taxa Richness (Figure 46), EPT Richness (Figure 47), % EPT – Cheum (Figure 48), % Clingers (Figure 50), NCBI (Figure 51), % NUTOL (Figure 52), and Intolerant Taxa (Figure 53). Of note, however, is that although WWT 0.8 is not quite up to par with GHK 2.9 and MBK 1.6, it does maintain a fairly healthy assemblage of EPT fauna and Intolerant Taxa (Figures 47, 53). As such, tributaries like WWT 0.8 may well serve as refugia and sources of recolonization to Bear Creek. The significance of such tributaries as refugia bears further study.

<u>Quality Control Results</u>

Duplicate samples were collected at two sites as a quality control check for field sampling and laboratory sample processing during 2013. Per Table 10, the Gum Hollow 2.9 sample and its duplicate sample returned remarkably similar results both attaining the same TMI score (Alternative Reference Stream Method). The sample from the White Wing Tributary (WWT 0.8) and its duplicate also shows extremely similar results. Again both the sample and its duplicate scored the same on the TMI (Alternative Reference Stream Method). These results indicate that both field sampling and lab processing were done with a high rate of consistency.

Table 10: Metric Values, Scores & Biological Condition Ratings for Quality Control Duplicates

2013 RESULTS	**Quality Control Duplicates**							
Stream station	GHK 2.9		GHK 2.9 DUP		WWT 0.8		WWT 0.8 DUP	
METRIC	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE	VALUE	SCORE
Taxa Richness	37	6	43	6	29	6	29	6
EPT Richness	17	6	19	6	10.5	4	10.5	4
% EPT-Cheum	47.33	6	44.44	6	9.13	0	12.12	0
% OC	5.34	6	7.52	6	8.21	6	5.22	6
NCBI	2.96	6	2.81	6	6.77	2	6.81	2
% Clingers	36.26	6	36.93	6	14.52	0	7.88	0
% Nutrient Tolerant	14.12	6	12.42	6	74.89	0	77.37	0
Intolerant Taxa	16	0	16	0	9	0	11	0
INDEX SCORE (Tenn. Macro. Index)		42		42		18		18
RATING		A		A		C		C
Key:	A = Supporting / Non Impaired (Tenn. Macro. Index Scores ≥32)							
	B = Partially Supporting / Slightly Impaired (TMI Scores 21-31)							

Conclusions

The biotic integrity of most impacted streams on the Oak Ridge Reservation is less than optimal compared to reference conditions (Figure 54). Of all sites sampled during 2013, four locations, BCK 12.3, EFK 24.4, EFK 23.4 and EFK 25.1, received the lowest Tennessee Macroinvertebrate Index (Alternative Reference Stream Method) scores and ratings, partially supporting/moderately impaired (TMI = 18-20, C rating). The reasons for these stations ranking far below reference stations in score are varied. In part, the poor scores are likely due to continuing pollutional inputs from Y-12. Another consideration is that these sites lack nearby refugia from which recolonization of aquatic invertebrates and insects can occur. A number of the ORR stream sites had biological condition ratings of partially supporting systems with slight to moderate impairment. These include EFK 6.3, MIK 0.45, MIK 0.71, WCK 2.3, WCK 3.4 and WCK 3.9. Remarkably, three of the impacted stations show scores that favorably compare to those of reference sites. These include BFK 9.6 and MEK 0.6 with scores directly comparable to reference sites, and EFK 13.8 with a score only slightly below that of the reference sites. The high ranking of some of the impacted sites is encouraging and, hopefully, shows the positive results of the remediation work that has been completed at both Y-12 and ORNL. The continued low ranking of some of the impacted sites shows not only that further remediation will be required, but also, that more study will be needed to help determine if the simple answer to increasing recovery is less pollution, or if factors such as a lack of nearby refugia may also play a hand in the slowed recovery of these systems.

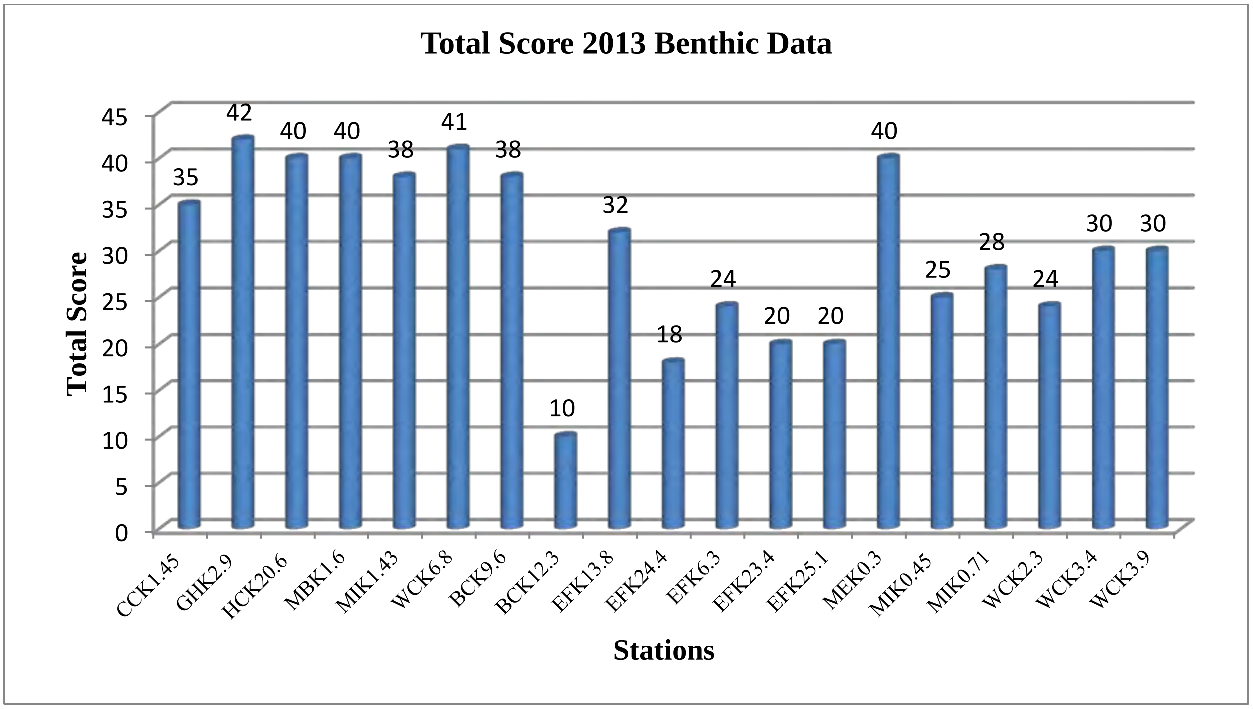


Figure 54. Total Scores for All Reference and Impacted Stations in 2013.

Future benthic monitoring will include a closer look at what healthy tributaries exist in the impacted watersheds as refugia for recolonizers of impacted streams. Ongoing CERCLA remedial activities on the ORR continue to have an impact on the aquatic biological communities in East Fork Poplar Creek, Mitchell Branch, the White Oak Creek watershed and Bear Creek. Future benthic monitoring should capture temporal and spatial changes by documenting changes in the macroinvertebrate communities on the ORR.

A searchable database (Microsoft® Access 2010) of all 2010-2013 benthic taxa collected and identified from ORR streams is available upon request.

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Acoustic Monitoring of Bat Echolocation Calls
on the Oak Ridge Reservation (Pilot Study)
2013 Environmental Monitoring Report

Abstract

Following emergence from winter hibernation, bats were monitored by conducting surveys to record echolocation calls using ultra-high frequency Anabat detectors. Bat call files obtained from the detectors were then analyzed with specialized bat identification software (i.e., BCID-East, Kaleidoscope PRO) to enable acoustic identification of species. A combination of active and passive ultrasonic field surveys were used beginning April 15, 2014, and continuing through October 31, 2014.

During 2013, TDEC processed 6,231 bat call files (out of >12,000 total files) collected from ≥75 nights of Anabat surveys at forty-seven (47) ORR sites. The Anabat files were analyzed using the automated software program: BCID-East (plus Kaleidoscope PRO for verification). Our analysis of identified calls suggests thirteen (13) bat species are present on the reservation including two federally endangered species (i.e., Gray Bat, Indiana Bat). Previous ORR bat studies were limited to 3-4 night mist-net and acoustic surveys. This study, along with a concurrent ORNL Environmental Science Division bat project, was the first comprehensive, large-scale (multi-nights) acoustic bat community investigation on the ORR.

Introduction

Little information is available regarding the distribution and occurrence of bats in the southeastern United States, including knowledge of bat species on the Oak Ridge Reservation (ORR). Although the presence of the federally endangered gray bat has been documented on the ORR, the status of the federally endangered Indiana bat and knowledge of the overall bat community is not well known. Previous ORR bat investigations have been limited to short term 2-4 night surveys of mist-netting and acoustic surveys, and thus no long term, intensive bat monitoring data is available. Our study is unique because the serious lack of bat community information was addressed by providing comprehensive, multi-night acoustic surveys thus allowing characterization of bat diversity and occurrence at numerous ORR sites.

Bats (Microchiropterans) are fundamental ecosystem components for insect suppression, pollination and seed dispersal (Britzke et al. 2011). Microchiropteran bats are also known as "echolocating bats" because they have the ability to use echolocation as a navigation tool in obstacle avoidance and hunting (Simmons and Conway 1997). Echolocating bats typically emit an ultrasonic (over 15 kilohertz) pulse, and analyze the returning echo to determine the distance to the object as well as what type of object it is (Fenton 1992). Bats in the eastern United States use ultrasonic echolocation to locate prey and navigate in their surroundings. Echolocation calls of most bats are species specific. Ultrasonic detectors are widely used for bat censuses (i.e., inventory) and have improved conservation efforts by: (1) providing increased knowledge of bat ecology, and (2) characterizing bat communities (Britzke et al. 2011). Numerous researchers have used detectors to conduct bat species surveys and assess habitat use, and the method is especially valuable for species that are difficult to capture (Ahlen 1999, Murray et al. 1999, O’Farrell and Gannon 1999, Duffy et al. 2000, Russo and Jones 2003). The application of bat ultrasonic monitoring devices such as the Anabat™ SD-2 bat detector (Titley Scientific USA,

Columbia, MO) has allowed ecologists to quickly and efficiently characterize and inventory bat communities at multiple areas (O'Farrell and Gannon 1999, Owen et al. 2004), and transform those calls into frequencies which are audible to humans (Parsons et al. 2000).

Microchiropteran bats use tonal signals that show structured change in frequency over time (Fenton 1984). Humans listening to slowed-down recordings of echolocating microchiropterans can readily distinguish between different sounding pulses allowing them to recognize the calls of different species. People also can recognize 'feeding buzzes'; attacks on prey that are signaled by high pulse repetition rates (Schnitzler & Kalko 2001).

The TDEC (Tennessee Department of Environment and Conservation) Division of Remediation, DOE-Oversight Office (DOEO), initiated a pilot project in 2013 to investigate the bat community present on the ORR. The Tennessee Oversight Agreement mandates a comprehensive and integrated monitoring and surveillance program for all media (i.e., air, surface water, soil sediments, groundwater, drinking water, food crops, fish and wildlife, and biological systems) and the emissions of any materials (hazardous, toxic, chemical, radiological) on the ORR and environs. Accordingly, monitoring the ecological recovery progress of wildlife and environmental restoration of habitat are important aspects of remedial activities on the ORR.

Following emergence from winter hibernation, bats were monitored by conducting surveys to record echolocation calls using ultra-high frequency Anabat detectors. Bat call files obtained from the detectors were then analyzed with specialized bat identification software (i.e., BCID-East, Kaleidoscope PRO) to enable acoustic identification of species. A combination of active and passive ultrasonic field surveys were used beginning April 15, 2014, and continuing through October 31, 2014.

During 2013, TDEC processed 6,231 bat call files (out of >12,000 total files) collected from ≥75 nights of Anabat surveys at forty-seven (47) ORR sites. The Anabat files were analyzed using the automated software program: BCID-East (plus Kaleidoscope PRO for verification). Our analysis of identified calls suggests thirteen (13) bat species are present on the reservation including two federally endangered species (i.e., Gray Bat, Indiana Bat). Previous ORR bat studies were limited to 3-4 night mist-net and acoustic surveys. This study, along with a concurrent ORNL Environmental Science Division bat project, was the first comprehensive, large-scale (multi-nights) acoustic bat community investigation on the ORR.

Study Site

The study was conducted on the Oak Ridge Reservation, Oak Ridge, Tennessee, which consists of approximately 34,500 acres (14,000 ha) within Anderson and Roane counties. The reservation is bound on the north and east by residential areas of the City of Oak Ridge and on the south and west by the Clinch River. The reservation is underlain predominantly by thrust-faulted Cambro-Ordovician sedimentary rocks (e.g., limestone, dolostone, siltstones, etc.). More than 20 caves have been identified on the ORR and most are developed within dolostones of the Knox Group. Mitchell et al. (1996) surveyed seven of the caves (Copper Ridge, Flashlight Heaven, Walker Branch, Big Turtle, Little Turtle, Pinnacle, and Bull Bluff), but no gray bats were found. There is an unverified report of ten gray bats roosting in Little Turtle Cave in September 1996 (Webb 2000). Therefore, Anabat surveys of ORR cave entrances were also

conducted on multiple nights to determine species, if present. It should be noted that ORR caves will not be entered at any time due to wildlife health concerns.

Temperate bat species are nocturnal and exhibit nightly and seasonal activity patterns that vary among species and individuals (Hirshfield et al. 1977, Anthony et al. 1981). Bats in the eastern United States typically enter hibernation in mid-September and emerge in mid-April (Britzske et al. 2006). During summer nights, bat roost-emergence activity commonly peaks immediately after sunset and can continue for several hours (Kunz 1973, Barcla 1982). Typically, a lesser activity peak occurs before sunrise as bats return to their diurnal roosts after foraging (Kunz 1973). During the night, bats roost at intervals, either at their diurnal roosts or at night-roosts nearer their foraging areas (Adam and Hayes 2000, Johnson et al. 2002, Daniel et al. 2008). For example, *Myotis sodalis* (Indiana bat) may forage in forests with intact canopies, near headwater streams (Menzel et al. 2005, Schirmacher et al. 2007), and within riparian zones (Webb 2000, Ford et al. 2005). The Indiana bat may form maternity roosts in shaggy-barked trees and snags with exfoliating bark during summer and then hibernates in caves during winter (Menzel et al. 2001, Timpone et al. 2010). Prior to 2013, the occurrence of the Indiana Bat had not been documented on the ORR since 1950.

Females of many bat species form maternity colonies in anthropogenic (e.g., buildings, bridges) and/or natural (e.g., tree or snag, caves) structures (Barbour and Davis 1969, Lewis 1995). During the maternity season, particularly during the lactation period, females return to their diurnal roosts several times during the night to nurse their young (Henry et al. 2002; Ormsbee et al. 2007). Accordingly, the USFWS has developed bat monitoring guidelines and criteria for site selection in the Indiana Bat Summer Survey Plan (USFWS 2013). Bat acoustic monitoring sites were selected based upon satellite imagery / topographic maps, consultation with the ORNL Environmental Sciences Division and TWRA, following the USFWS criteria, and the literature (LaVal et al. 1977, Racey 1998, Grindal and Brigham 1999, Menzel et al. 2005) to include:

- Mature forest corridors
- Forest/field edge
- Powerline ROWs
- Rocky bluffs & outcrops
- Forest access roads, hiking trails
- Open fields
- Waterway corridors (streams, ponds, wetlands, riparian, river shoreline)
- Anthropogenic structures (abandoned buildings, bridges, large culverts)
- Trees with exfoliating bark or dead snags (minimum diameter of 5 inches at breast height) exposed to direct sunlight
- Caves and karst features

Objectives

- Conducted passive overnight fixed-point Anabat surveys at multiple ORR sites
- Conducted active Anabat surveys for 4-5 hours, 30 minutes/station
- Focus on identifying the presence of federally endangered bats on the ORR
- Identify Indiana Bat roost trees and other roosting habitats (i.e., bridges, rock crevices, abandoned buildings, etc.)

Methods

Anabat SD-2 (Titley Electronics, Ballina, Australia) broadband, frequency-division, bat detectors were used to passively and actively monitor for bat echolocation passes, i.e., a series of echolocation pulses, at carefully selected ORR sites before, during, and after the pregnancy and lactation periods (Sasse and Pekins 1996). Microchiropterans use a wide range of frequencies in echolocation, from around 10 kHz to over 200 kHz. Bat calls are produced by a single mode of vibration and consist of a series of harmonics which are multiples of the sound frequencies used by the bat, further assisting in pinpointing the location of prey (flying insects). Bats emit echolocation sounds in pulses that vary in properties depending on the species, and can be correlated with different hunting strategies and mechanisms of information processing (Grinnell 1995). Echolocation calls of bats consist of three phases: search, approach, and terminal (Griffin et al. 1960). Search phase calls are produced to locate prey, approach phase calls are produced to identify exact locations of prey, and terminal phase calls are produced just prior to capture. Search phase calls are useful in the study of bat echolocation because they constitute a majority (ca. 90%) of calls produced by bats, exhibit consistency in structure throughout the call sequence, and may possess species-specific characteristics (Betts 1998, Fenton and Bell 1981, O'Farrell et al. 1999). Most bat families use short, downward frequency-modulated (FM) sounds that sweep through about an octave. An example of an FM bat is the Big Brown Bat. Another common echolocation signal pattern is constant-frequency (CF) signals. Long CF/FM pulses are a hybrid of the two and are used by a much smaller number of species belonging to three different families. These signals have a long (10–100 ms) constant-frequency component preceding an FM sweep (Grinnell 1995).

The Anabat SD-2 uses an advanced form of frequency division without amplitude retention, to provide the cleanest output signals with the lowest possible data rate (Corben 2014). These are frequency dividing (FD) detectors which provide a broadband frequency down-conversion, which generates audio signals with frequencies directly related to those the bat is producing (Corben 2014). Furthermore, the nature of the data generated by Anabat detectors is ideally suited to analysis using Zero-Crossings Analysis (ZCA). The ZCA system counts incoming echolocation calls (pulses) along their oscillations between positive and negative values each time a sound wave passes the zero point at a present number of crossings (i.e., Division Ratio, often 8 or 16), and a time measurement (time-frequency) is made allowing representative species-specific frequencies to be recorded, thus providing efficient analysis of representative call parameters for species identifications (Corben 2014).

The quantity of echolocation passes recorded is an index of activity and does not necessarily reflect the quantity of bats being recorded, i.e., one bat can be recorded more than one time (Broders, 2003). Following the survey methods described by O'Farrell et al. (1999) and Johnson et al. (2002), TDEC actively monitored sites with Anabat detectors for 30-min periods between the end of twilight up to 5 hrs. thereafter (Sherwin et al., 2000). Staff slowly swept the detector back and forth to scan for activity under a closed forest, within a forest canopy gap or forest harvest area, or along a stream. When bat activity was detected, the Anabat was oriented and followed the flight path to capture as complete a call sequence as possible. Acoustical sampling during evenings when bat activity was likely to be low due to meteorological conditions such as high winds, precipitation or temperatures below 10 °C was avoided (Wear 2004, Ford et al. 2005, Schirmacher et al. 2007).

Bat echolocation calls were recorded passively with 1-3 Anabat™ SD-2 detectors at ORR study sites. It is recommended by the U.S. Fish and Wildlife Service (USFWS 2011) that a project area of suitable bat habitat (phase II) would require at least 3 detector sites per 124-acre area over the course of at least two survey nights per area. The Titley Roost Logger™ detector was also used to monitor bats at some ORR sites and usually deployed for 5-10 consecutive nights. The Anabat SD-2 unit (or its detached microphone) must be deployed on a tripod or on a long pole so as to avoid ground surface clutter and insect ultrasonic clutter (Weller and Zabel 2002) whereas the Roost Logger can be easily strapped to a tree. Our passive Anabat surveys began approximately 30 minutes before sunset and ended 30 minutes after dawn (Martin and Britzke 2010). Anabat SD-2 detector systems placed into the field for remote, passive sampling are often housed in waterproof containers with an aperture through which the microphone can be fitted (Britzke et al. 2010).

This project will generally follow the bat monitoring guidance and protocols of Kuenzi and Morrison (1998), Murray et al. (1999), Jones et al. (2004), Szewczak 2004, Manley et al. (2006), Britzke et al. (2011), and the U.S. Fish and Wildlife Service (USFWS 2011, 2013). This research will be in cooperation with the Division of Natural Areas (TDEC Bureau of Parks and Conservation), Tennessee Wildlife Resources Agency, the Forestry, Wildlife and Fisheries Department of the University of Tennessee, the US Fish and Wildlife Service, and the Oak Ridge National Laboratory Environmental Sciences Division. Field work followed the guidance in the division's health and safety plan (Yard 2013).

White Nose Syndrome

White-nose Syndrome (WNS positive, WNS+) is a disease that has been implicated for the decimation of several million cave-hibernating bats in North America and is believed to be caused by the psychrophillic fungus, *Geomyces destructans* (Kannan et al. 2010, Figure 1). This pathogen first appeared in eastern New York in 2006 and has since spread throughout the Northeast (Ford et al. 2011), and unfortunately into cave populations of bats in several southern states including Tennessee. This fungus, which may appear as a white coating on the bat muzzle, invades the epidermis of the bats (causes damage to wing membranes), unlike many other fungal infections (Meteyer et al. 2009). A leading hypothesis is that *G. destructans* infections affect the arousal periods of hibernating bats, causing them to use their fat reserves prior to emergence, essentially starving the bats (TBWG 2014). Examples of East Tennessee hibernating cave bat colonies infected with WNS include: Grindstaff Cave (Carter County) and Worley's Cave (Sullivan County, Holliday 2012). Grindstaff Cave bat numbers were down 99.5% compared to 2010 when WNS was first discovered there. Worley's Cave hibernating bats were down 96.6% from 2011 (Holliday 2011). White Oak Blowhole Cave in the Great Smoky Mountains National Park is Tennessee's largest Indiana bat hibernaculum and the bats have been found to be WNS-positive. East Fork Saltpeter Cave in Fentress County has been surveyed and bats there have been documented to be WNS+ (Holliday 2012). Lastly, Figure 2 shows 33 Tennessee counties (red-shading) that contain WNS+ infected bats in caves (or other hibernacula).

Figure 1: Bat with wing damage due to WNS (Holliday 2012)

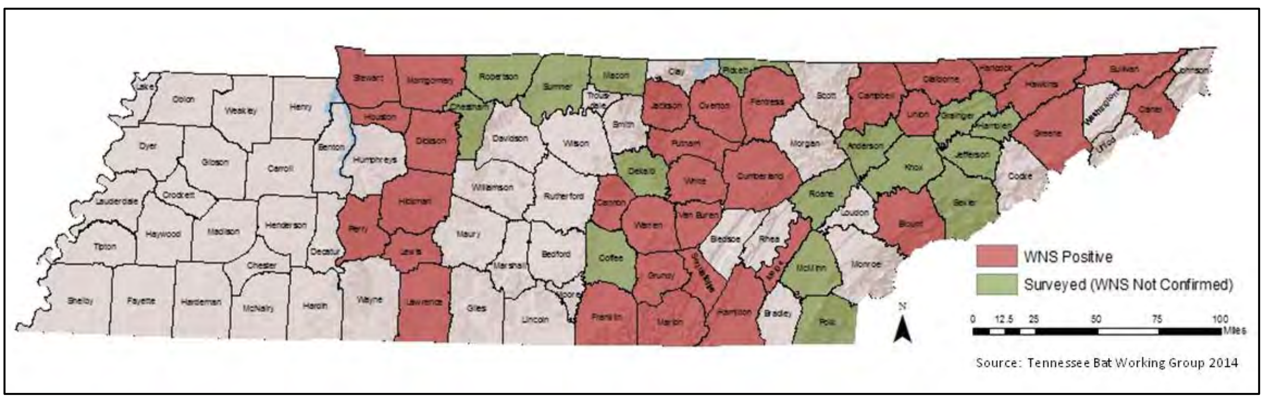

Figure 2: White Nose Syndrome Positive Counties 2013

Results and Discussion

For purposes of this report, the ORR was subdivided into 10 study sections (with 2-10 Anabat monitoring stations per section):

1. Bearden Creek / Park City Section (ORNL; 2 bat monitoring stations)
2. Bear Creek Burial Grounds / EMWMF Section (Y-12; 4 bat monitoring stations)
3. Bull Bluff / Freels Bend Section (TWRA Three Bends; 4 bat monitoring stations)
4. Duct Island / ETTP Ponds / Grassy Creek Section (ETTP; 10 bat monitoring stations)
5. Horizon Center / Lower East Fork Poplar Creek / White Wing Section (7 stations)
6. Jones Island / WAG 13 Section (ORNL; 4 bat monitoring stations)
7. Scarboro Disc Park / Turtle Park (City of Oak Ridge; 2 bat monitoring stations)
8. Solway Bend (TWRA Three Bends) / UT Arboretum Section (6 bat monitoring stations)
9. Walker Branch Section (ORNL; 3 bat monitoring stations)
10. West Bear Creek Valley Section (Y-12; 5 bat monitoring stations)

At the beginning of each section, a map of the site locations is provided plus a table is included summarizing the bat species detected at each Anabat survey station. In the summary tables, note that the numbers underneath each bat species represent number of bat calls, not the number of bats. The BCID-East and Kaleidoscope PRO software cannot quantify how many bats are present, but rather can only provide an analysis of the bat species that may be present at a site. The software programs utilize bat call libraries to analyze the Anabat files.

Following each section summary table, please find a representative graph detailing the bat species detected at each Anabat monitoring station. Some graphs represent passive overnight surveys (dusk until dawn) while others are active +/- 5 hour surveys (dusk until midnight or until 2:00 am).

BEARDEN CREEK / PARK CITY SECTION

Figure 3: Bearden Creek / Park City Section (ORNL)
** The exact location of bat detector site #2 is not shown due to its ecological sensitivity.

	BAT TAXA DETECTED													ADDITIONAL SOFTWARE OUTPUT					
Bat Monitor Station ID	COTO	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	UNKN	LOW FREQ	MID FREQ	MYOTIS	NUMBER OF BAT CALLS	TOTAL PULSES
Park City Bat Site 1		6	3			11	6	41	12	17	15	27		8	6	49	91	146	2407
Park City Bat Site 2			12			1		17	1	3	2	16		6		36	22	58	1146

Table 1: Summary Table of Bats Detected
Bearden Creek / Park City Section

Note: The numbers in each *bat taxa detected* column represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. A call is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). Pulses are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. All Anabat files were processed using the BCID-East software program (validated with Kaleidoscope PRO program).

Taxonomic Codes: COTO = *Corynorhinus townsendii* (Townsend's Big-eared Bat), EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat).

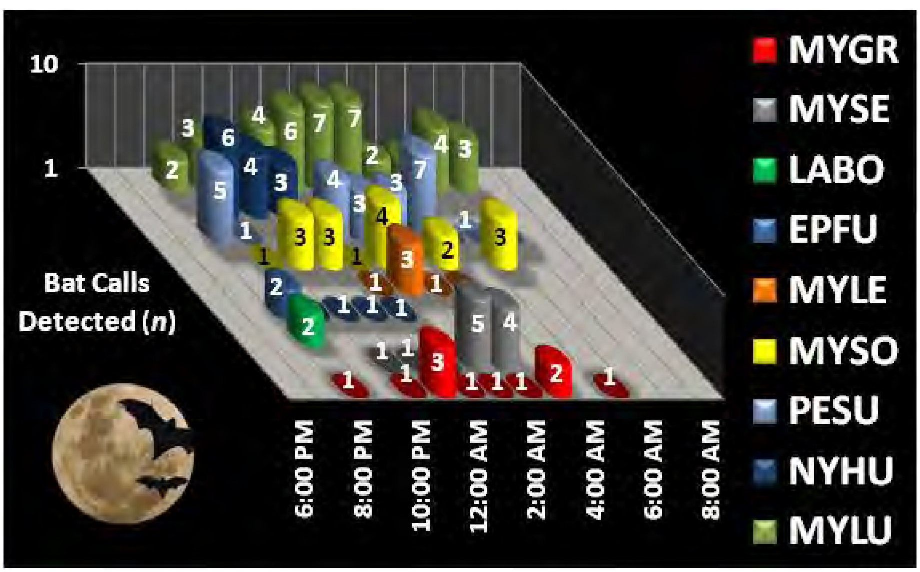

Figure 4: Bat Detector Site 1— Park City / Shagbark Hickory Site
Anabat Data / 9-19-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

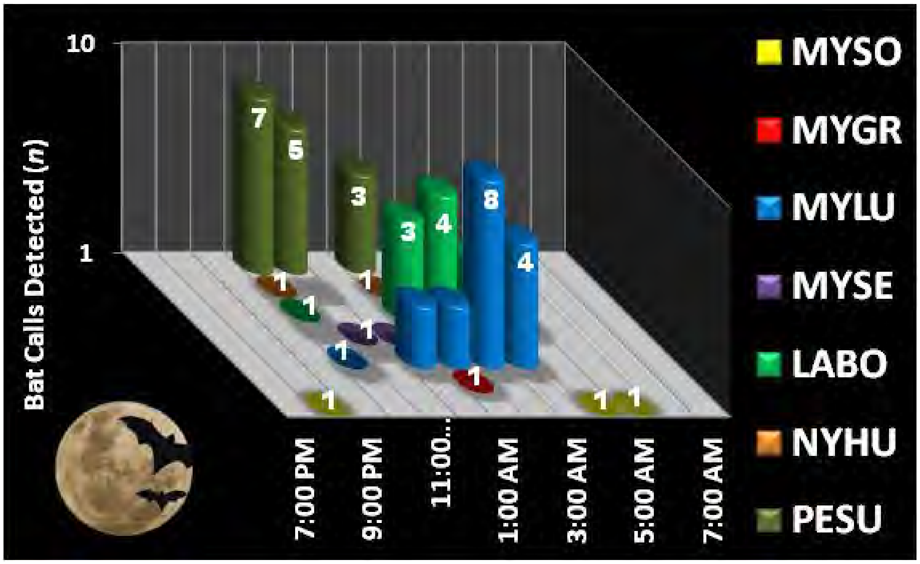

Figure 5: Bat Detector Site 2— Park City Area (Pinnacle Cave **entrance**)
Anabat Data / 9-19-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

BEAR CREEK BURIAL GROUNDS / EMWMF SECTION

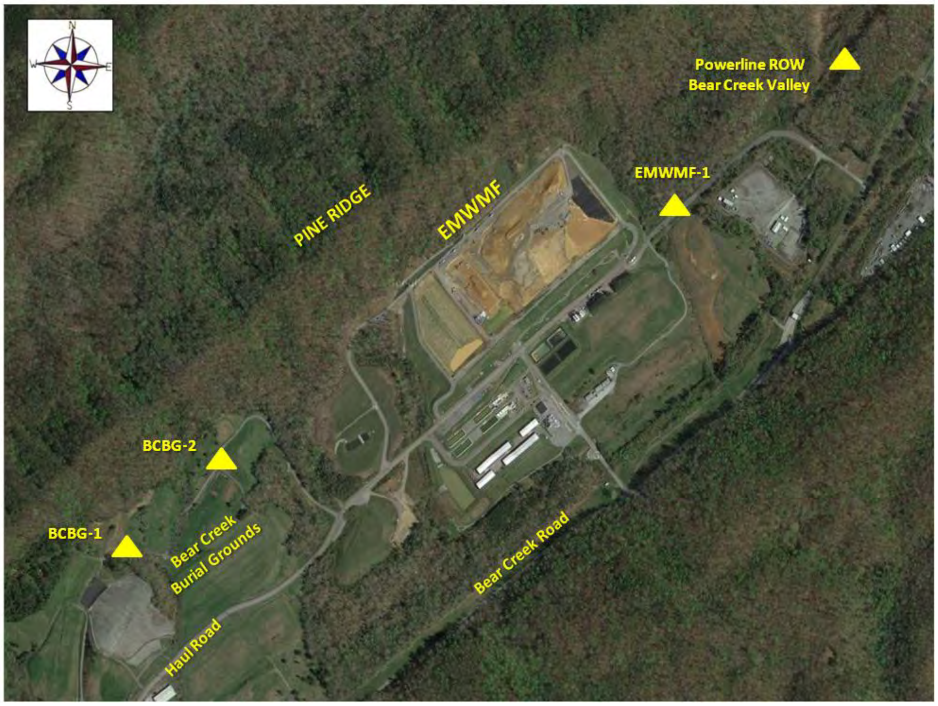

Figure 6: Bear Creek Burial Grounds / EMWMF (Y-12) Section

	BAT TAXA DETECTED													ADDITIONAL SOFTWARE OUTPUT					
Bat Monitor Station ID	COTO	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	UNKN	LOW FREQ	MID FREQ	MYOTIS	NUMBER OF BAT CALLS	TOTAL PULSES
BCBG-1		3	1	1	8	4		39		4	5	29		1	13	35	47	95	1418
BCBG-2				1							1	3			1	4		5	47
EMWMF-1		1	6	2	9	11		2			4	20		3	12	31	14	58	624
BCK Valley Powerline ROW		1	1		2							3			3	4		7	66

Table 2: Summary Table of Bats Detected
Bear Creek Burial Grounds / EMWMF Section

Note: The numbers in each *bat taxa detected* column represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. A call is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). Pulses are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. All Anabat files were processed using the BCID-East software program (validated with Kaleidoscope PRO program).

Taxonomic Codes: COTO = *Corynorhinus townsendii* (Townsend's Big-eared Bat), EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat).

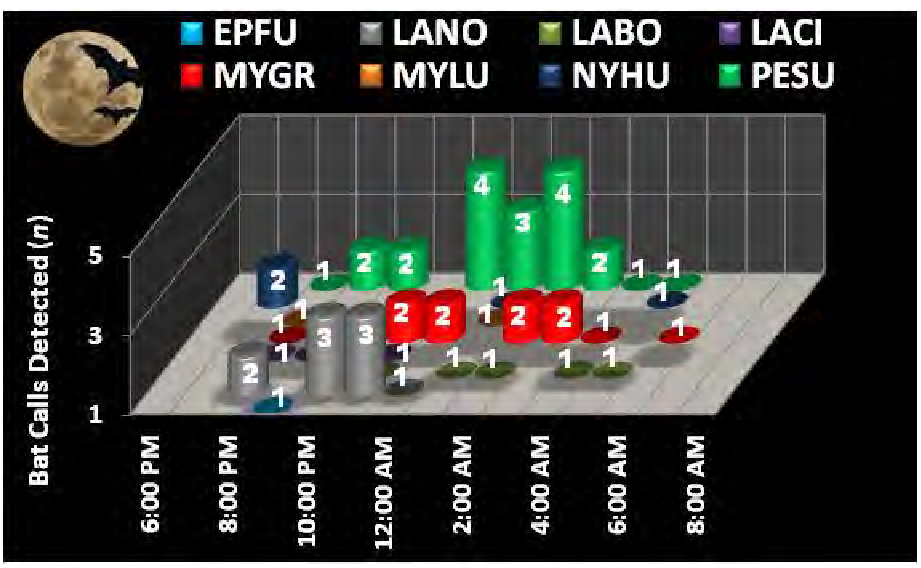

Figure 7: EMWMF-1: East end of EMWMF access road @ barrier
Anabat Data / 9-19-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

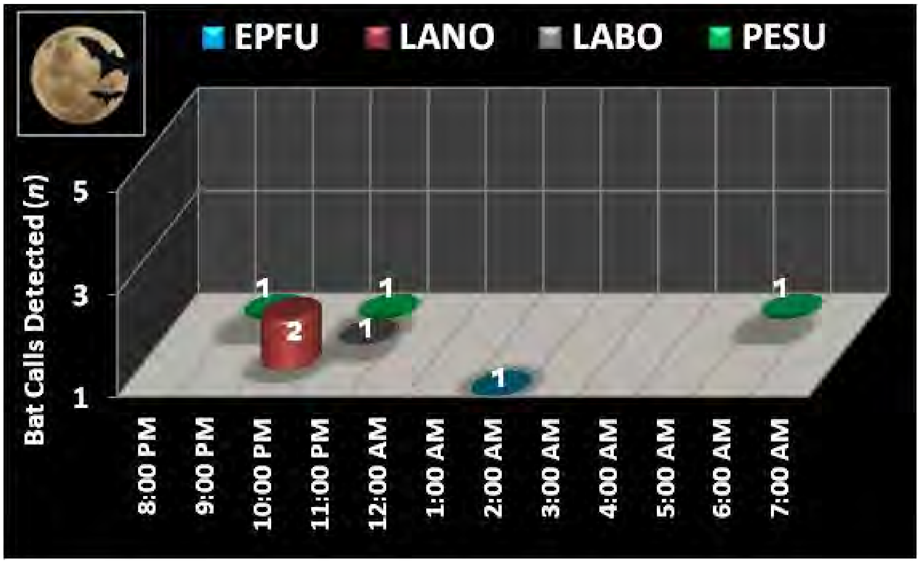

Figure 8: Bear Creek Valley @ powerline ROW (E/NE of EMWMF)
Anabat Data / 9-24-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

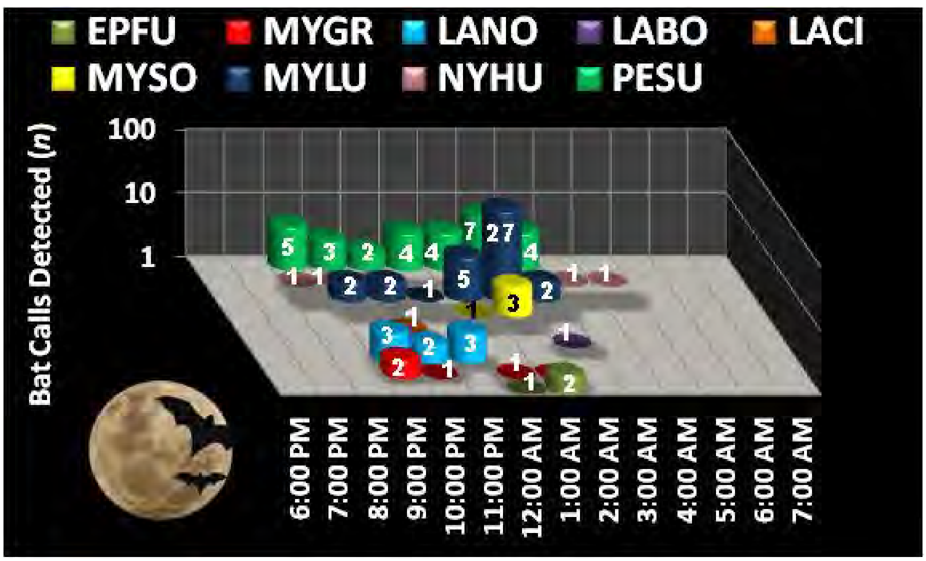

Figure 9: BCBG-1 — Bear Creek Burial Grounds / Walk-In-Pits
Anabat Data / 9-17-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

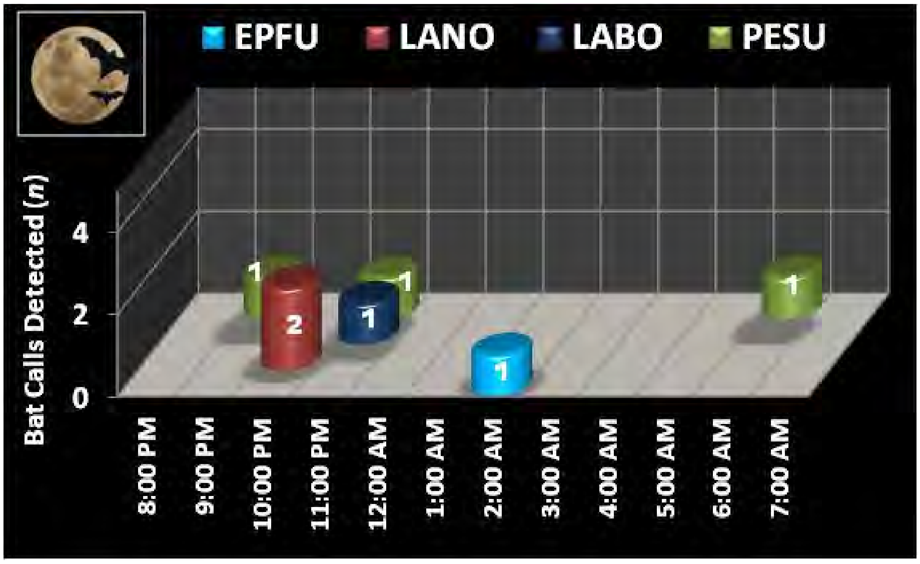

Figure 10: BCBG-2 — Bear Creek Burial Grounds (West of EMWMF)
Anabat Data / 9-24-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

BULL BLUFF / FREELS BEND SECTION

Figure 11: Bull Bluff / Freels Bend (TWRA 3 Bends) Section

	BAT TAXA DETECTED													ADDITIONAL SOFTWARE OUTPUT					
Bat Monitor Station ID	COTO	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	UNKN	LOW FREQ	MID FREQ	MYOTIS	NUMBER OF BAT CALLS	TOTAL PULSES
Greenway-1		4	1	2		2					2			1	6	4	2	12	180
Greenway-2		2		3	4						1				9	1		10	234
Clark Park			2					1			6	2				10	1	11	133
Freels Bend			1	1		8	1	70	2	31	32	6		2	1	39	113	154	3829

Table 3: Summary Table of Bats Detected
Bull Bluff / Freels Bend (TWRA 3 Bends) Section

Note: The numbers in each *bat taxa detected* column represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. A call is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). Pulses are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. All Anabat files were processed using the BCID-East software program (validated with Kaleidoscope PRO program).

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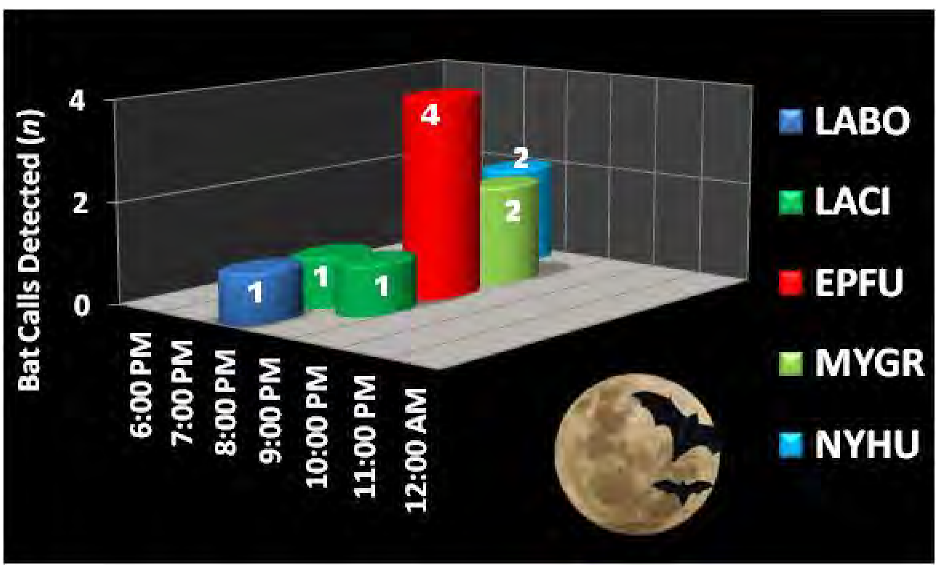

Figure 12: Greenway-1 – Bull Bluff Greenway
(Isthmus / Melton Lake backwater cove) Anabat Data / 4-26-2013
(Active Survey: Dusk until Midnight)
Bat calls/hour per species

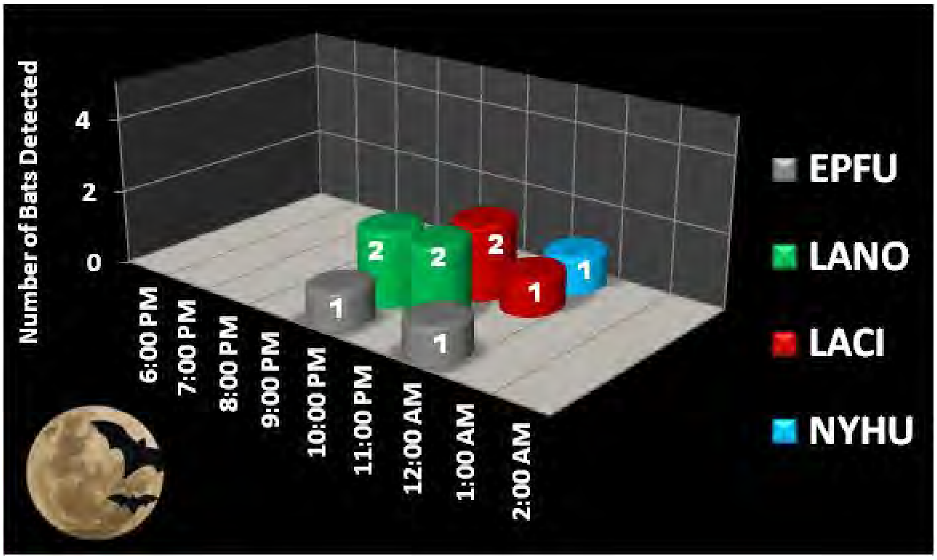

Figure 13: Greenway-2 – Bull Bluff Greenway
(open field on ridge top at trail terminus) Anabat Data / 4-26-2013
(Active Survey: Dusk until 2:00 am)
Bat calls/hour per species

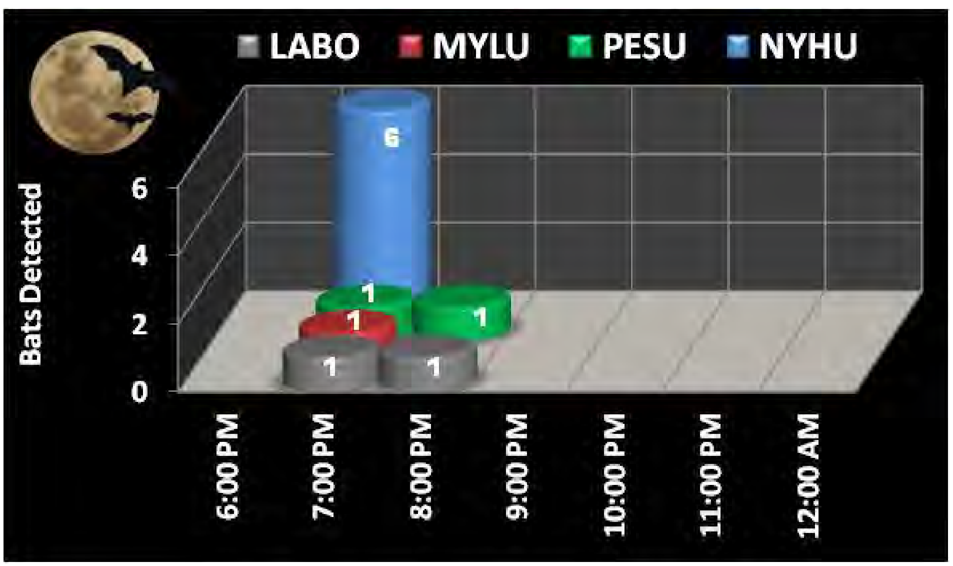

Figure 14: Clark Park (Carbide Park)
(McCoy Branch backwater causeway) Anabat Data / 10-26-12
(Active Survey: Dusk until Midnight)
Bat calls/hour per species

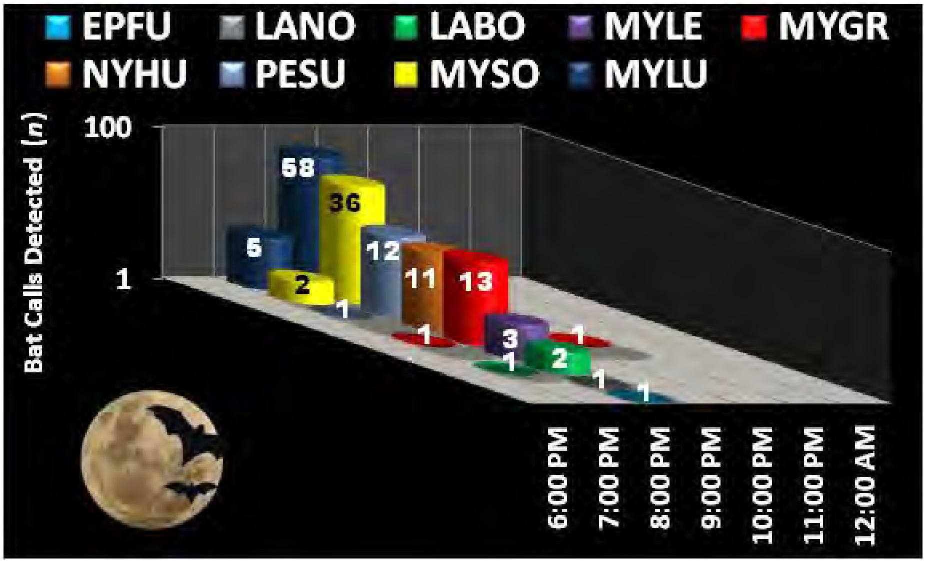

Figure 15: Freels Bend / Melton Lake backwater causeway
(south of Freels cabin) Anabat Data / 6-23-2013
(Active Survey: Dusk until Midnight)
Bat calls/hour per species

DUCT ISLAND/ETTP PONDS/GRASSY CREEK SECTION

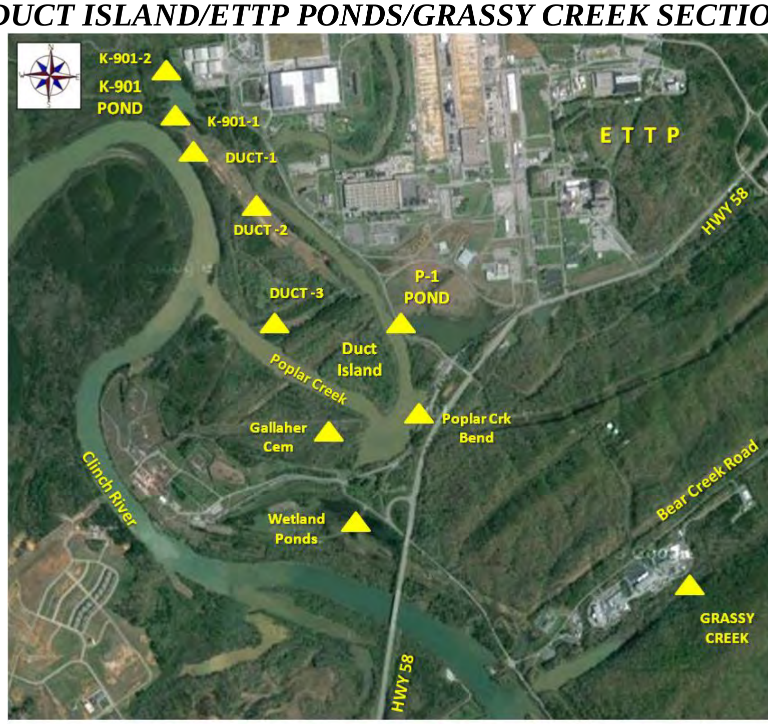

Figure 16: Duct Island / ETTP Ponds / Grassy Creek (ETTP) Section

	BAT TAXA DETECTED													ADDITIONAL SOFTWARE OUTPUT					
Bat Monitor Station ID	COTO	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	UNKN	LOW FREQ	MID FREQ	MYOTIS	NUMBER OF BAT CALLS	TOTAL PULSES
BCK Wetlands			17		1						10	199		4	1	230		231	8620
DUCT-1		1			1	2				1		17			2	17	3	22	297
DUCT-2						7						3		1		4	7	11	121
DUCT-3			1			6						2		2		4	7	11	138
Gallaher Cem			1	1		6		1		1	15			1	1	16	9	26	266
Grassy Creek			6			22	7	2	11	6		88		6		95	50	148	1579
K-901-1 Pond		2			1	1		4		3	1	68		1	3	69	8	81	1551
K-901-2 Pond		3	1		2	2		3			1	13		1	5	16	5	26	286
P-1 Pond				2		3					2	30			2	32	3	37	601
Poplar Cr			34		1			1			10	372		7	1	423	1	425	14435

Table 4: Summary Table of Bats Detected
Duct Island / ETTP Ponds / Grassy Creek Section

Note: The numbers in each *bat taxa detected* column represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. A call is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). Pulses are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. All Anabat files were processed using the BCID-East software program (validated with Kaleidoscope PRO program).

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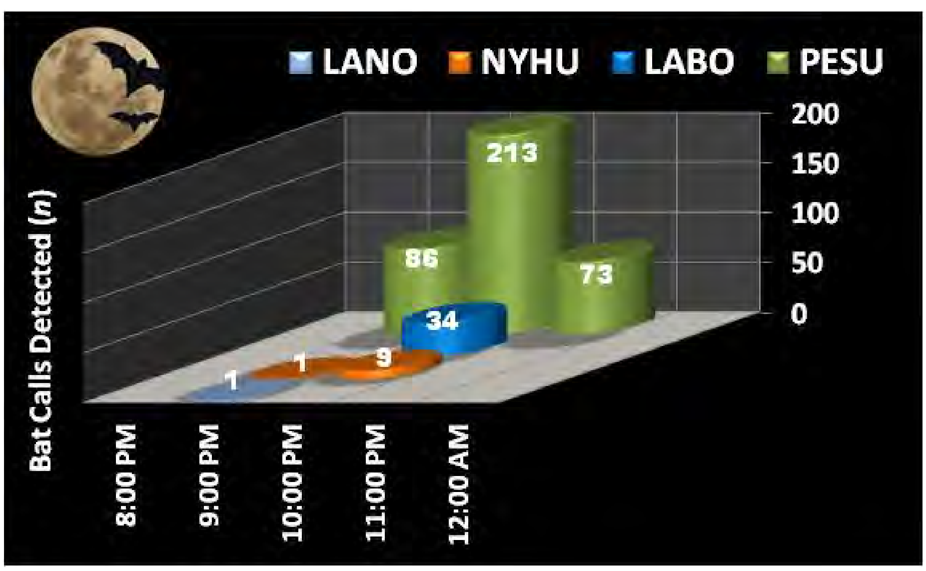

Figure 17: Poplar Creek ("big bend" south of Duct Island)
Anabat Data / 6-4-2013
(Active Survey: Dusk until Midnight)
Bat calls/hour per species

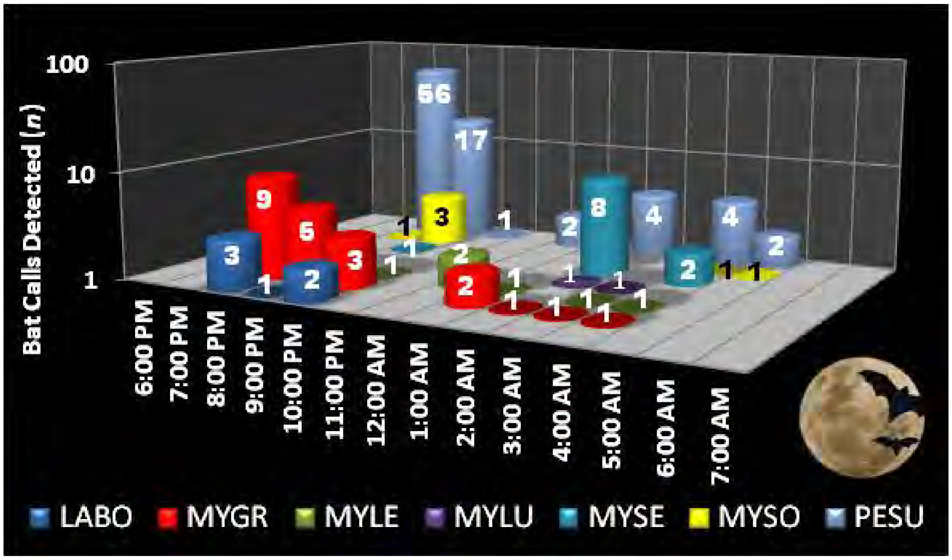

Figure 18: Grassy Creek (TDEC surface water station)
Anabat Data / 5-25-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

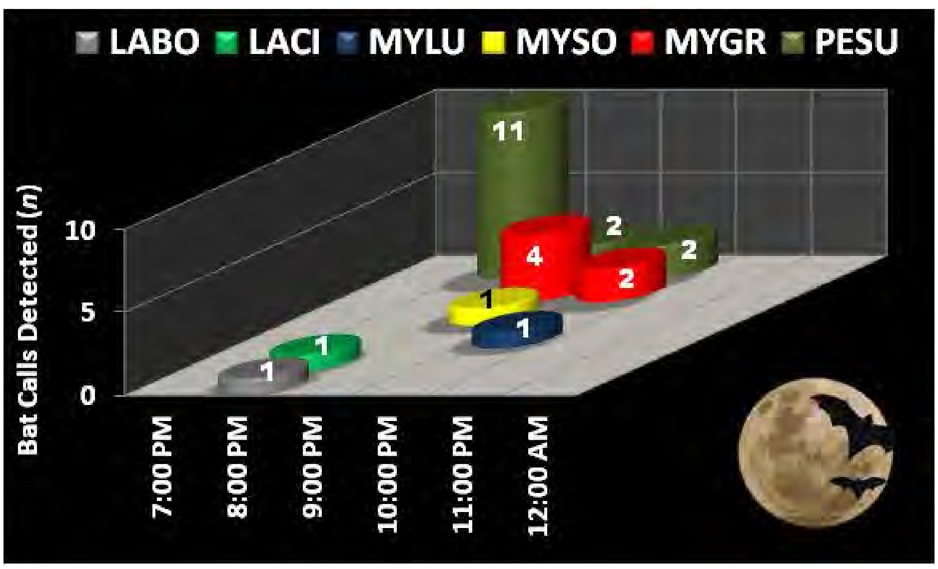

Figure 19: Gallaher Cemetery/Powerline ROW (ETTP)
Anabat Data / 9-18-2013
(Active Survey: Dusk until Midnight)
Bat calls/hour per species

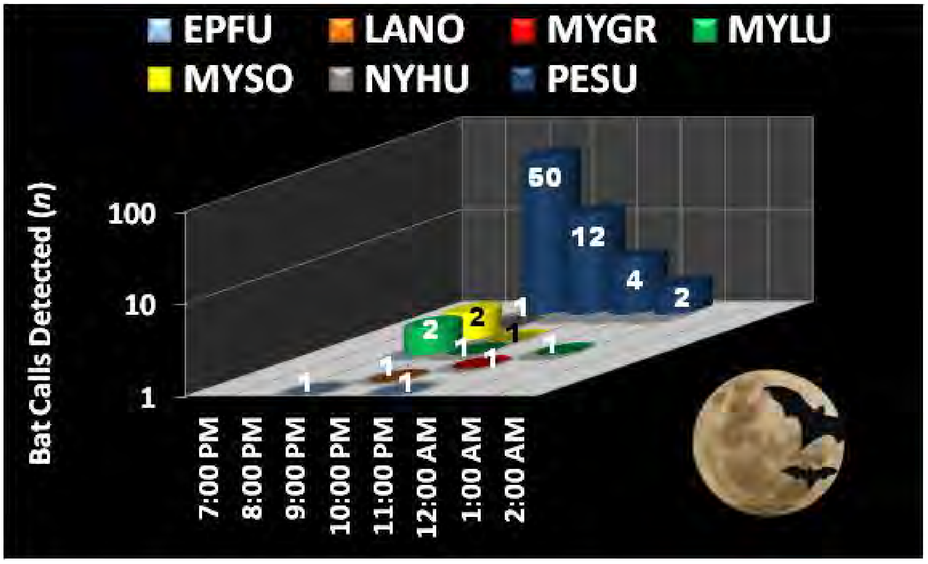

Figure 20: K-901-1 (K-901 Pond)
(Weir outfall at Clinch River; ETTP) Anabat Data / 7-11-2013
(Active Survey: Dusk until 2:00 am)
Bat calls/hour per species

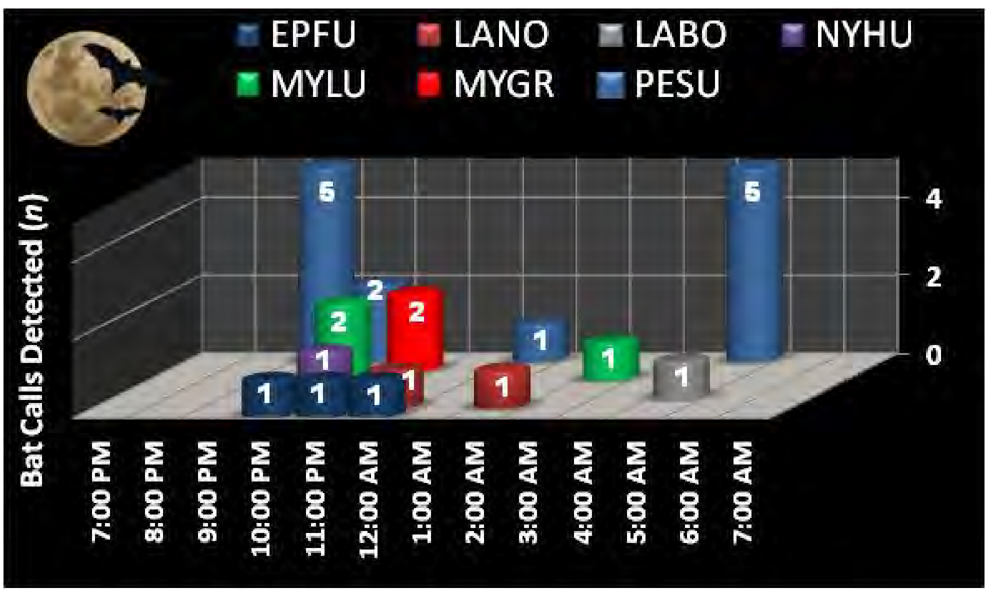

Figure 21: K-901-2 (K-901 Pond)
(North end of pond on hill above backwater area; ETTP)
Anabat Data / 7-11-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

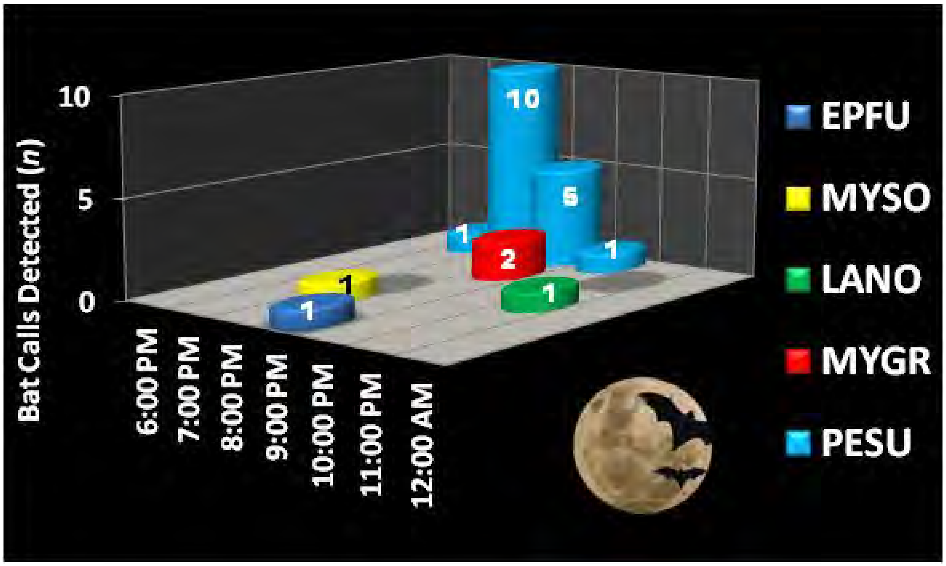

Figure 22: DUCT-1 (weir station on bluff above Clinch River / ETTP)
Anabat Data / 9-28-2013
(Active Survey: Dusk until Midnight)
Bat calls/hour per species

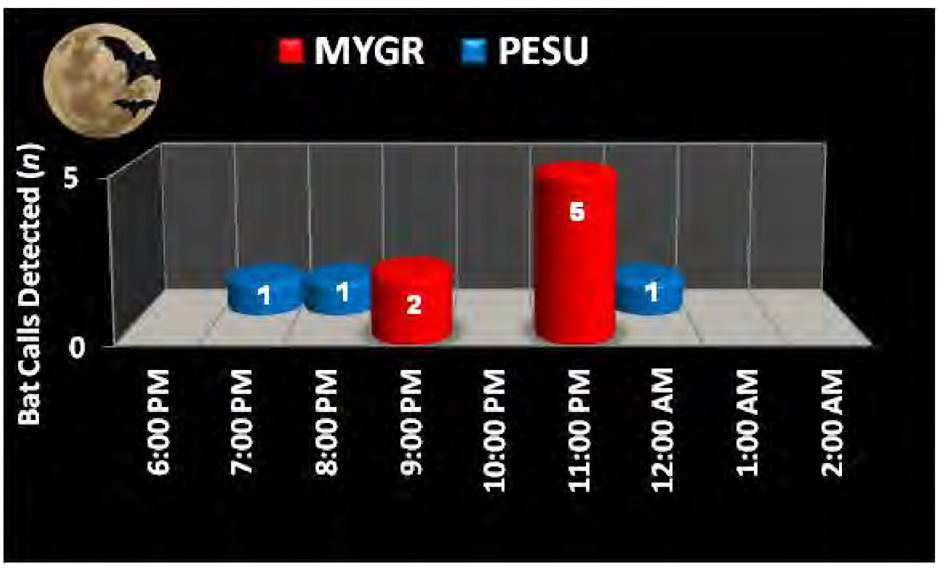

Figure 23: DUCT-2 (powerline ROW on Poplar Creek floodplain / ETTP)
Anabat Data / 9-28-2013
(Active Survey: Dusk until 2:00 am)
Bat calls/hour per species

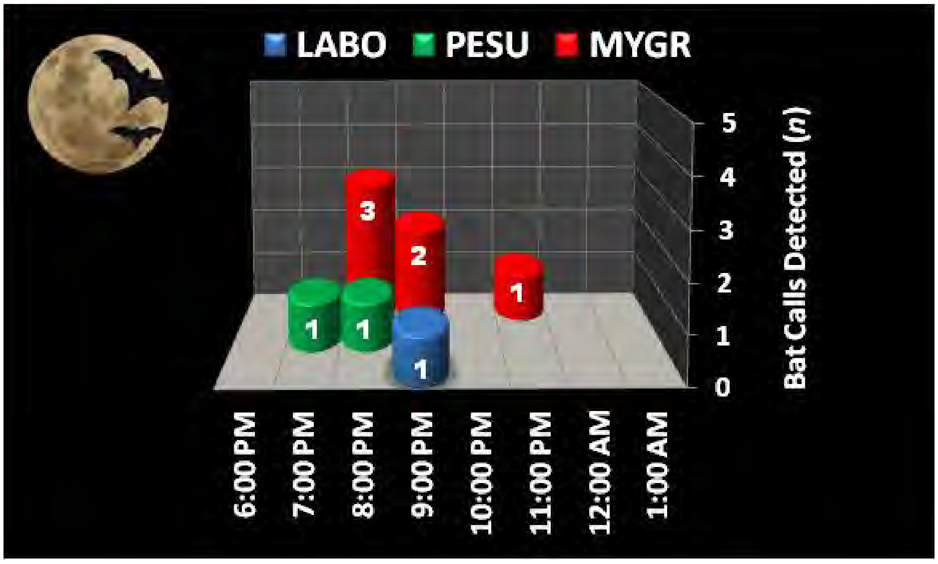

Figure 24: DUCT-3 (shoreline / duct crossing @ Poplar Creek / ETTP)
Anabat Data / 9-28-2013
(Active Survey: Dusk until 2:00 am)
Bat calls/hour per species

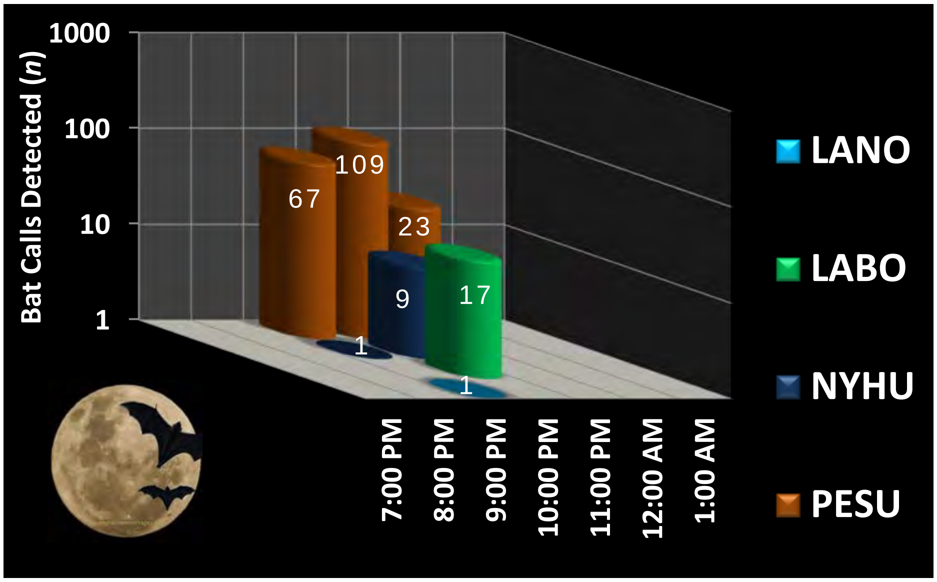

Figure 25: Bear Creek Road Wetland Ponds/ETTP (north of HWY 58)
Anabat Data / 6-4-2013
(Active Survey: Dusk until 2:00 am)
Bat calls/hour per species

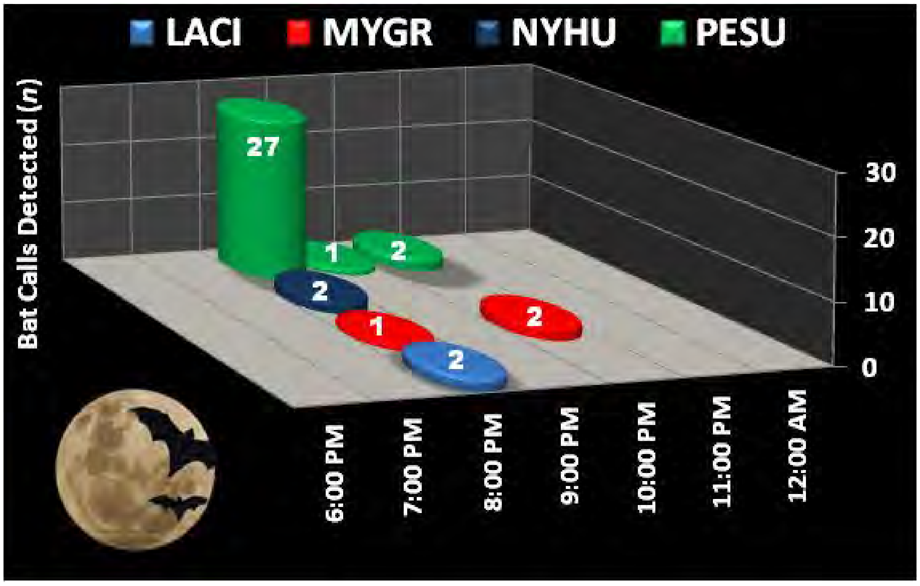

Figure 26: P-1 Pond
(Weir outfall at Clinch River / ETTP) Anabat Data / 7-9-2013
(Active Survey: Dusk until 2:00 am)
Bat calls/hour per species

HORIZON CENTER / LEFPC / WHITE WING SECTION

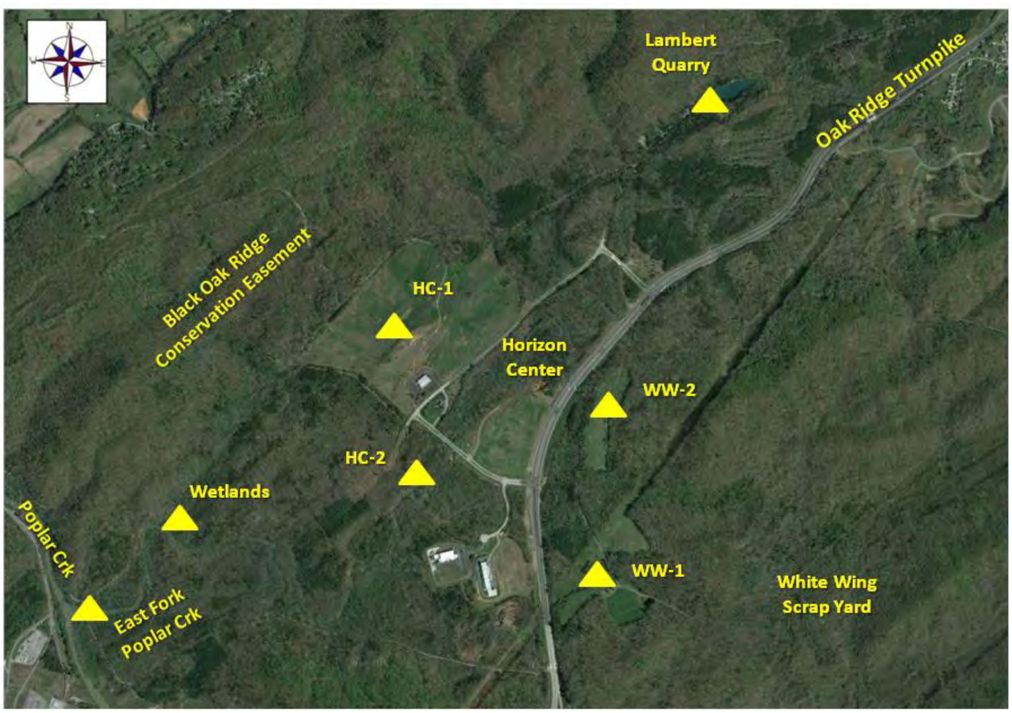

Figure 27: Horizon Center / Lower East Fork Poplar Creek / White Wing Section

	BAT TAXA DETECTED													ADDITIONAL SOFTWARE OUTPUT					
Bat Monitor Station ID	COTO	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	UNKN	LOW FREQ	MID FREQ	MYOTIS	NUMBER OF BAT CALLS	TOTAL PULSES
EFPC Wetlands		2	6		1	16		1			19	308		10	3	337	22	363	4633
EFPC/Poplar Cr Confluence			35			116						271		21		307	116	443	20867
Horizon Ctr HC-1		11		1	1	10						4			13	4	10	27	661
Horizon Ctr HC-2		7	8		12	2					6	18		2	19	33	3	55	1160
Lambert Quarry	3	14	6		8	98					3	201		2	22	215	98	335	14987
White Wing WW-1		36	17	1	15	8		4			14	72		3	52	106	12	170	5256
White Wing WW-2		45	12	4	3	29			1			26		3	52	41	30	123	2413

Table 5: Summary Table of Bats Detected
Horizon Center / Lower East Fork Poplar Creek / White Wing Section

Note: The numbers in each *bat taxa detected* column represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. A call is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). Pulses are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. All Anabat files were processed using the BCID-East software program (validated with Kaleidoscope PRO program).

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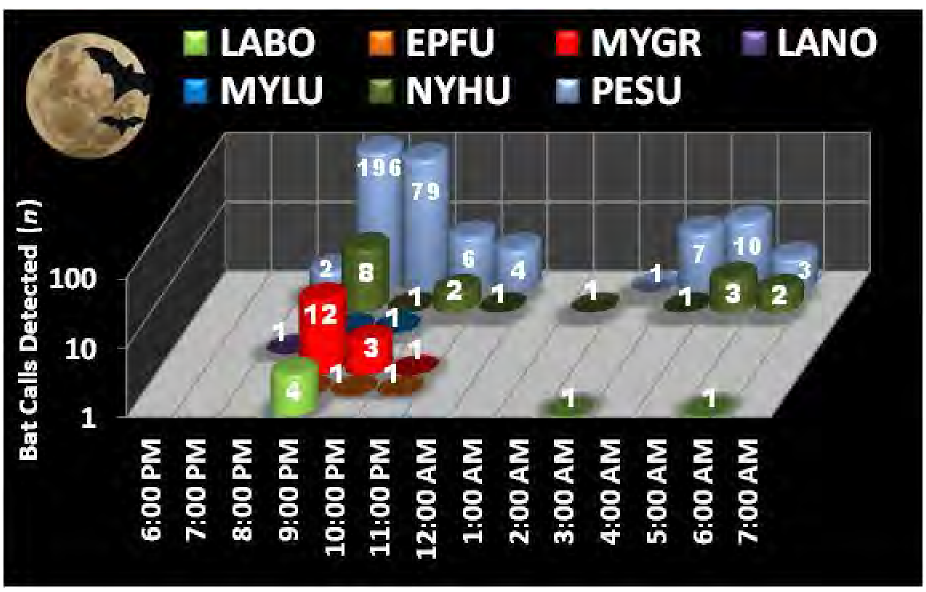

Figure 28: East Fork Road Wetlands (ED-1 Site)
Anabat Data / 7-19-13
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

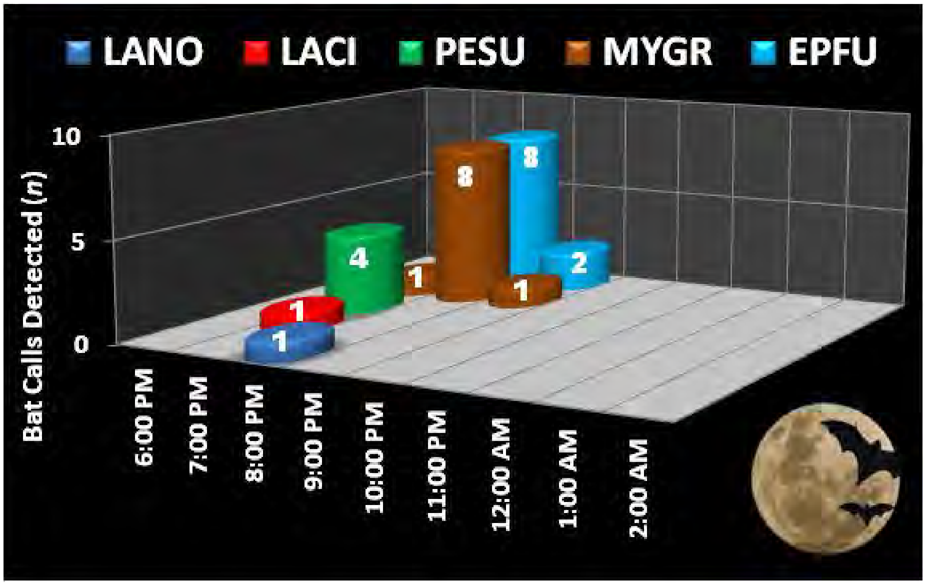

Figure 29: HC-1 — Horizon Center expansion area (north of center)
Anabat Data / 9-27-12
(Active Survey: Dusk until 2:00 am)
Bat calls/hour per species

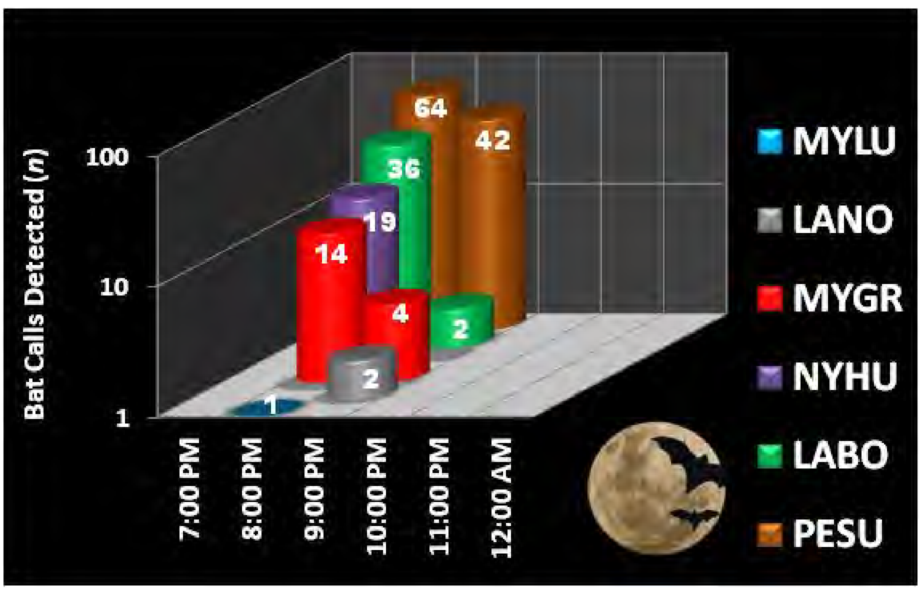

Figure 30: HC-2 — Horizon Center /Lower East Fork Poplar Creek
(Near Novus Dr. bridge at record Sycamore) Anabat Data / 8-30-2013
(Active Survey: Dusk until Midnight)
Bat calls/hour per species

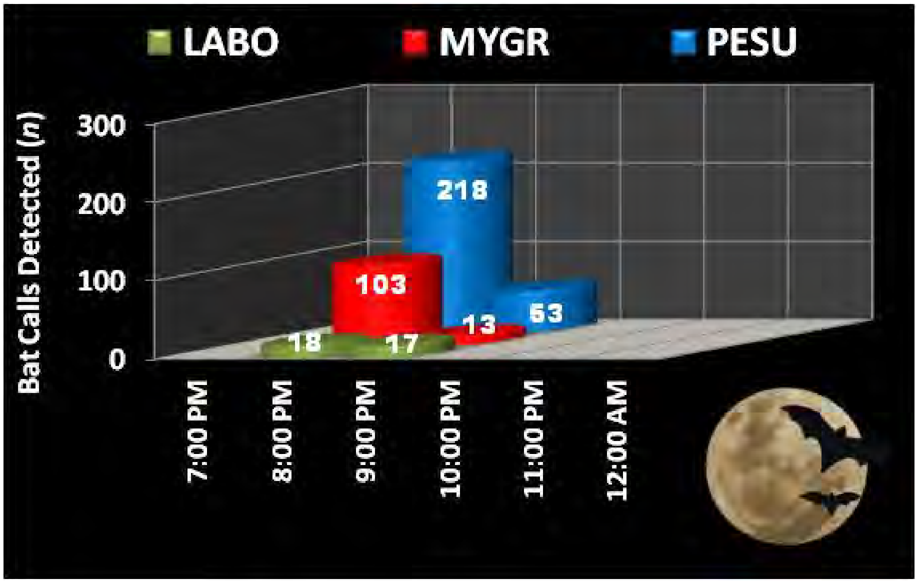

Figure 31: Poplar Creek Bridge / North Boundary Greenway (confluence of EFPC with Poplar Creek) Anabat Data / 9-3-12
(Active Survey: Dusk until Midnight)
Bat calls/hour per species

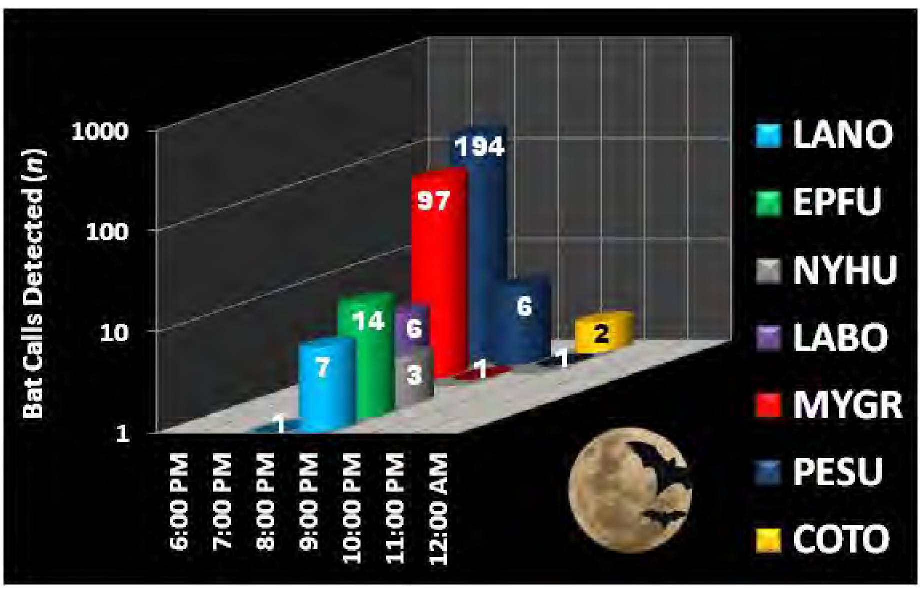

Figure 32: Lambert Quarry (west end ramp at shoreline)
Anabat Data / 9-11-2013
(Active Survey: Dusk until Midnight)
Bat calls/hour per species

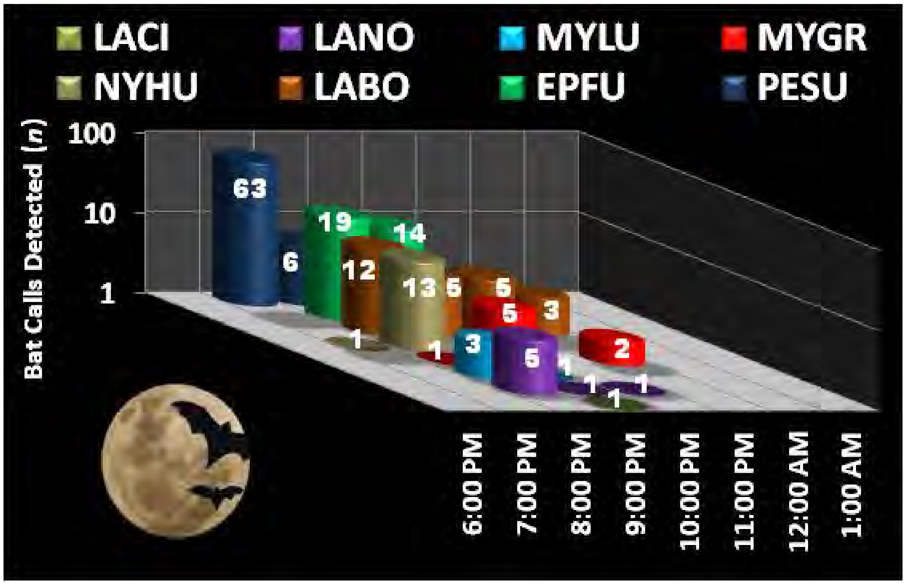

Figure 33: WW-1 — White Wing open grassy fields /forest edge
(City of Oak Ridge sludge application fields) Anabat Data / 9-24-2013
(Active Survey: Dusk until 2:00 am)
Bat calls/hour per species

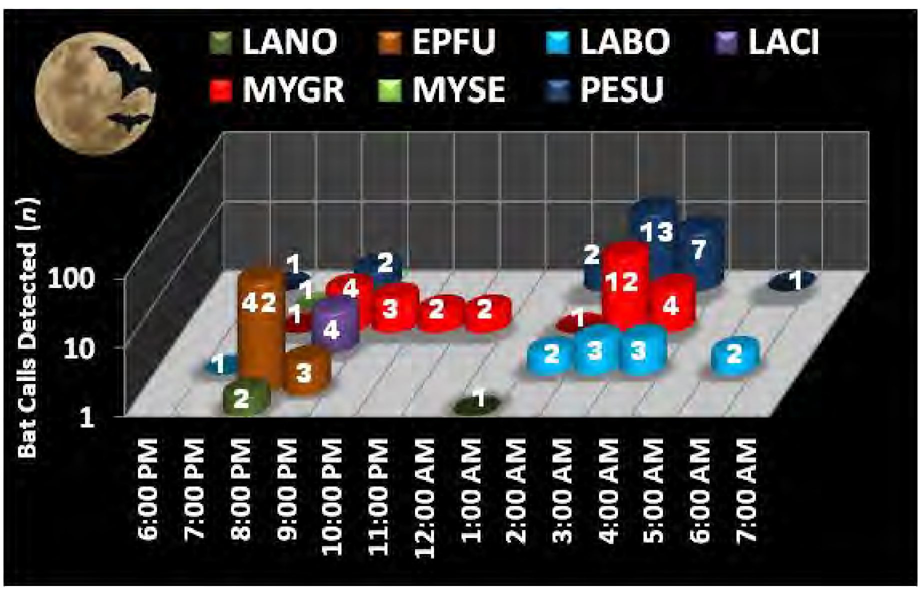

Figure 34: WW-2— White Wing Cemetery
(Forested hill above City Oak Ridge sludge fields) Anabat Data / 9-24-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

JONES ISLAND / WAG 13 SECTION

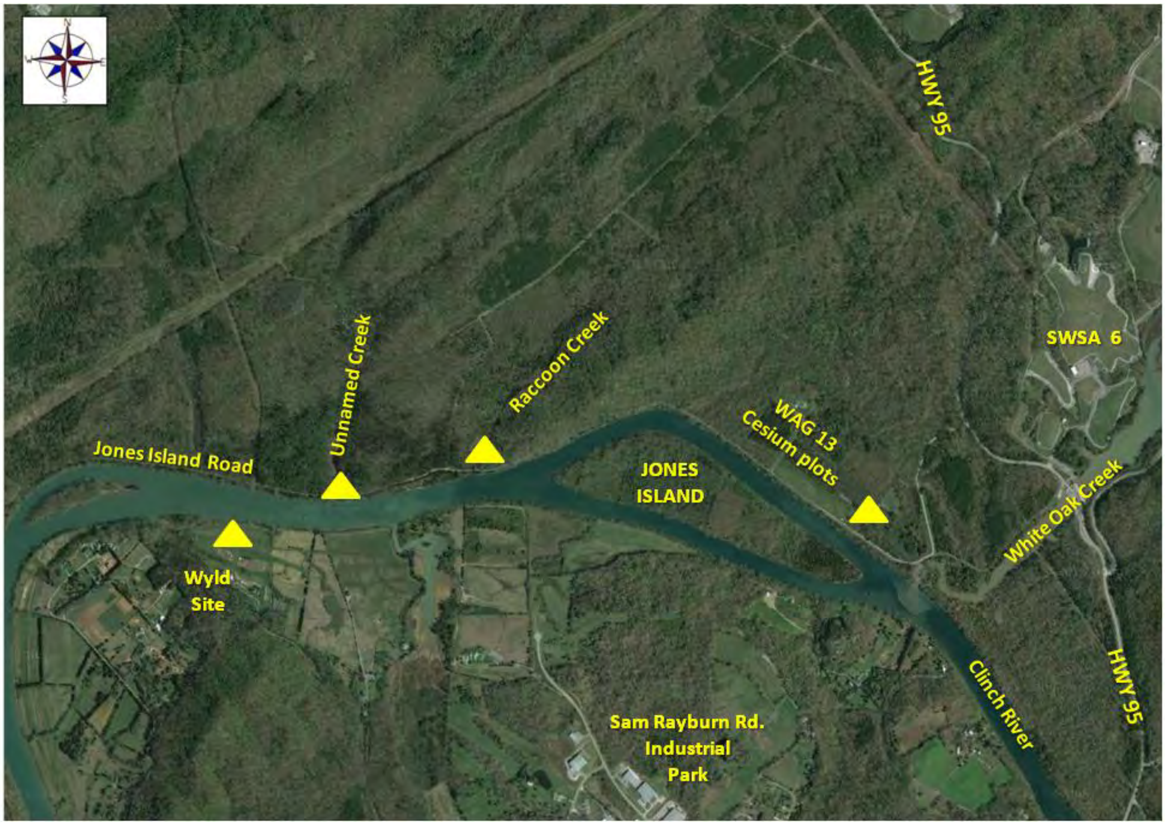

Figure 35: Jones Island / WAG 13 Section (ORNL)

	BAT TAXA DETECTED													ADDITIONAL SOFTWARE OUTPUT					
Bat Monitor Station ID	COTO	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	UNKN	LOW FREQ	MID FREQ	MYOTIS	NUMBER OF BAT CALLS	TOTAL PULSES
Raccoon Cr		1	27	1	4						3	214		11	6	254	1	261	7578
Unnamed Cr		3	4	2	5	1					8	66		2	10	78	2	90	2415
WAG 13 Site			11	1	8	3		3			15	27		5	9	56	8	73	983
Wyld Site		3	5			2		3			1	40		1	3	47	5	55	499

Table 6: Summary Table of Bats Detected
Jones Island / WAG 13 Section

Note: The numbers in each *bat taxa detected* column represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. A call is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). Pulses are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. All Anabat files were processed using the BCID-East software program (validated with Kaleidoscope PRO program).

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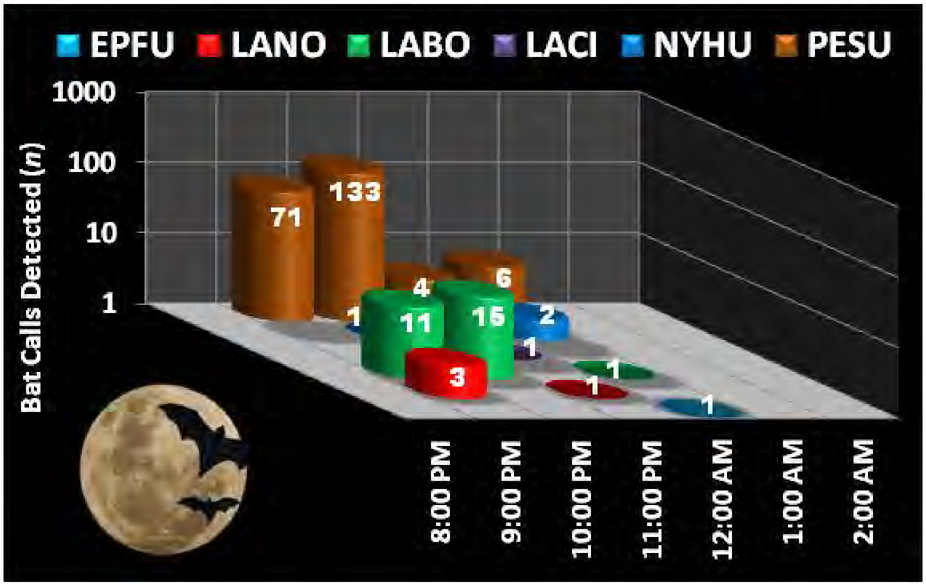

Figure 36: Jones Island— Raccoon Creek at Jones Island Road
Anabat Data / 5-31-2013
(Active Survey: Dusk until 2:00 am)
Bat calls/hour per species

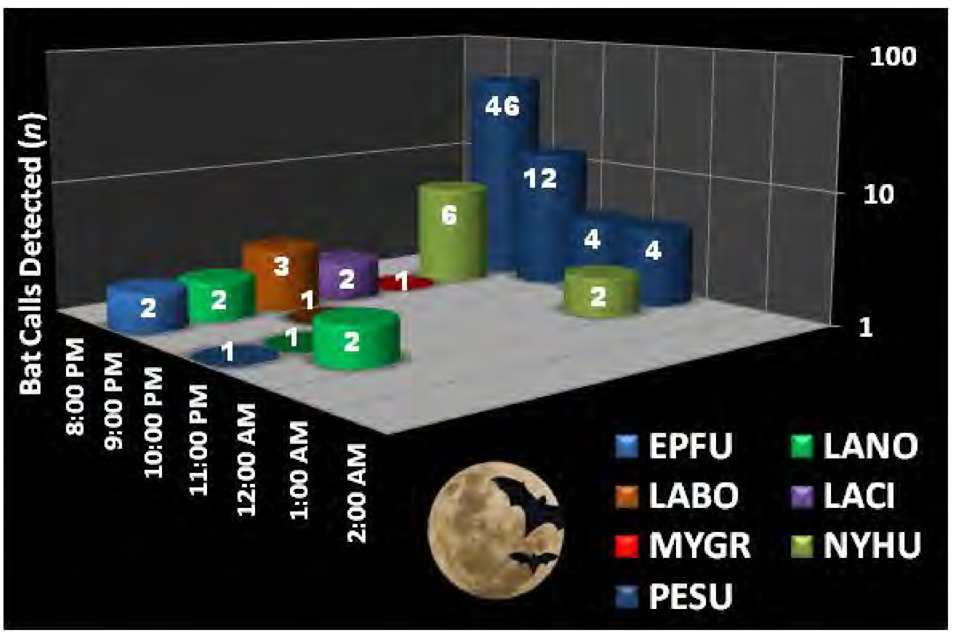

Figure 37: Jones Island— Unnamed Creek at Jones Island Road
Anabat Data / 5-31-2013
(Active Survey: Dusk until 2:00 am)
Bat calls/hour per species

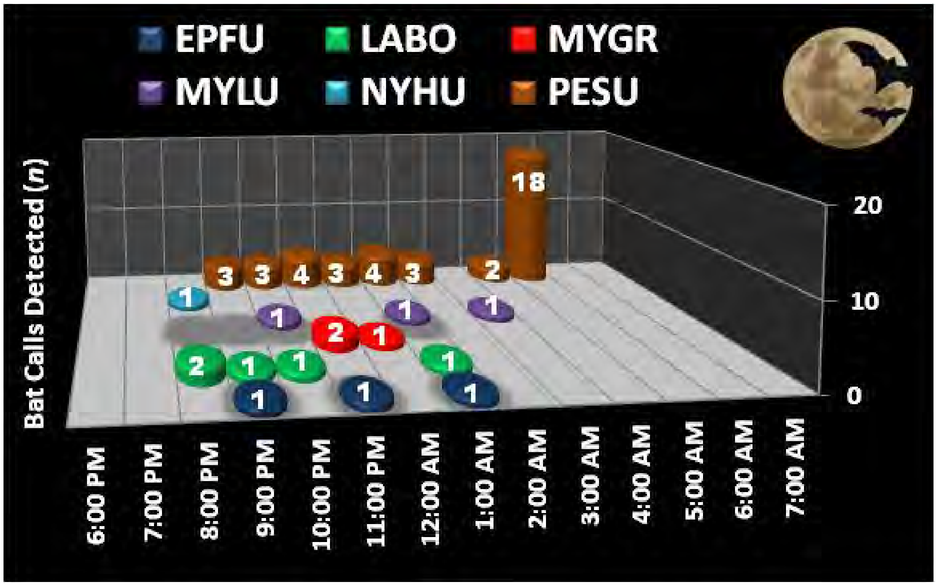

Figure 38: Jones Island (Wylde site – Roost Logger-2)
Anabat Data / 8-21-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

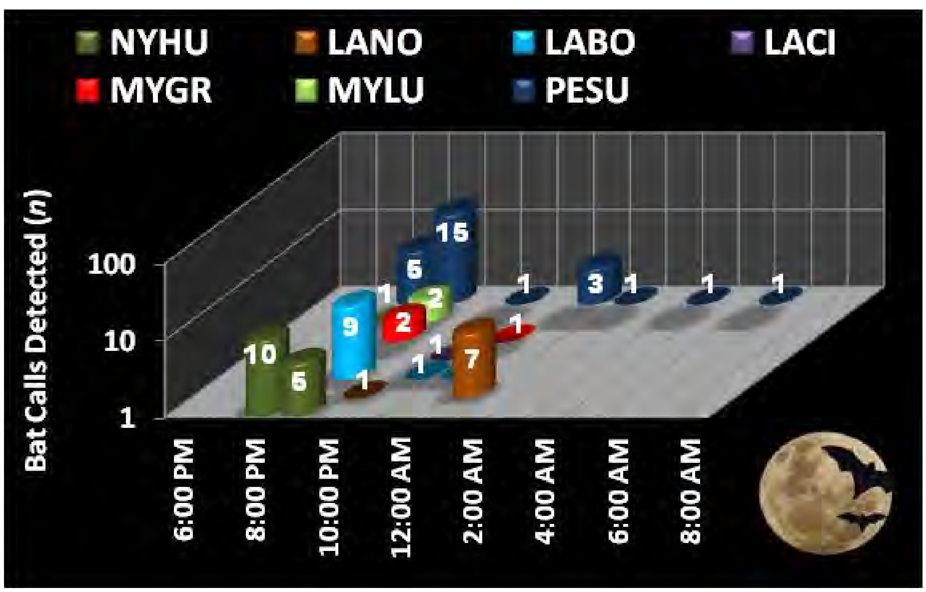

Figure 39: Jones Island WAG 13 Area (near Clinch River)
Anabat Data / 5-31-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

SCARBORO DISC PARK / TURTLE PARK SECTION

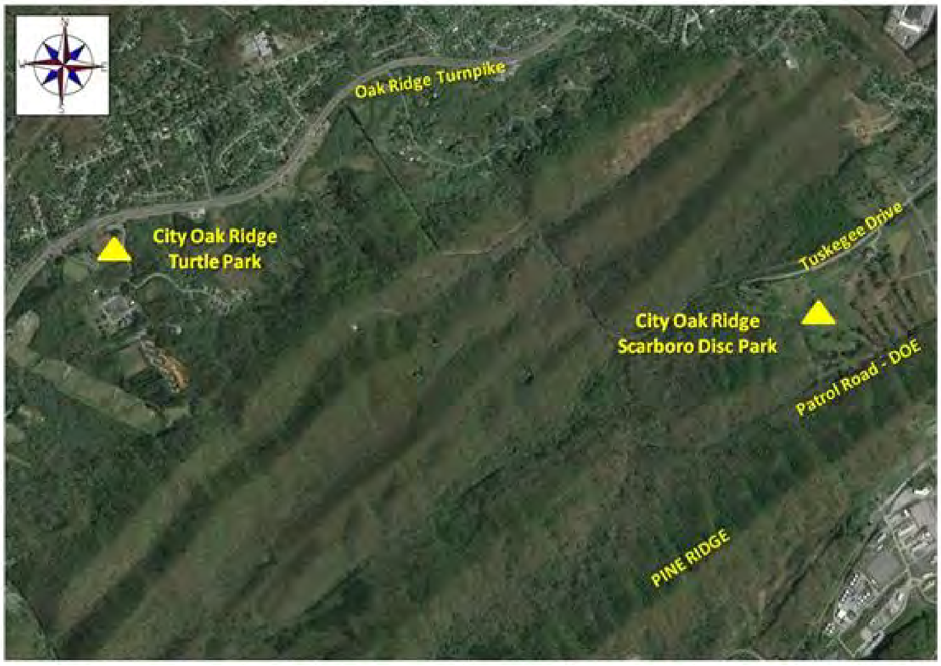

Figure 40: Scarboro Disc Park / Turtle Park Section (City Oak Ridge) Section

	BAT TAXA DETECTED													ADDITIONAL SOFTWARE OUTPUT					
Bat Monitor Station ID	COTO	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	UNKN	LOW FREQ	MID FREQ	MYOTIS	NUMBER OF BAT CALLS	TOTAL PULSES
Scarboro Park			17	1	5	8					4	203		4	6	227	8	242	8009
Turtle Park		10			9	1					2	46			19	48		68	2734

Table 7: Summary Table of Bats Detected
Scarboro Disc Park / Turtle Park (City of Oak Ridge) Section

Note: The numbers in each *bat taxa detected* column represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. A call is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). Pulses are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. All Anabat files were processed using the BCID-East software program (validated with Kaleidoscope PRO program).

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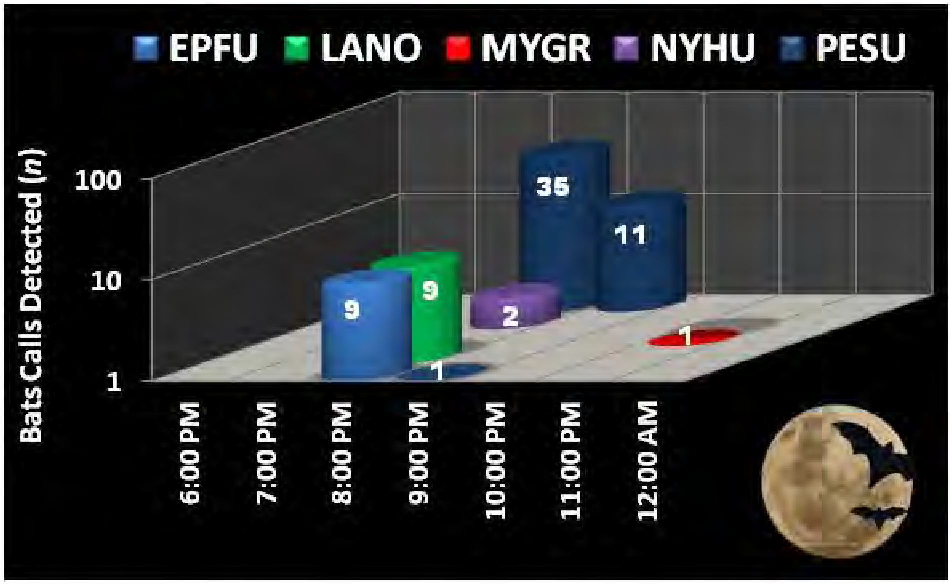

Figure 41: Turtle Park / East Fork Poplar Creek Bridge
(City of Oak Ridge) Anabat Data / 4-10-2013
(Active Survey: Dusk until Midnight)
Bat calls/hour per species

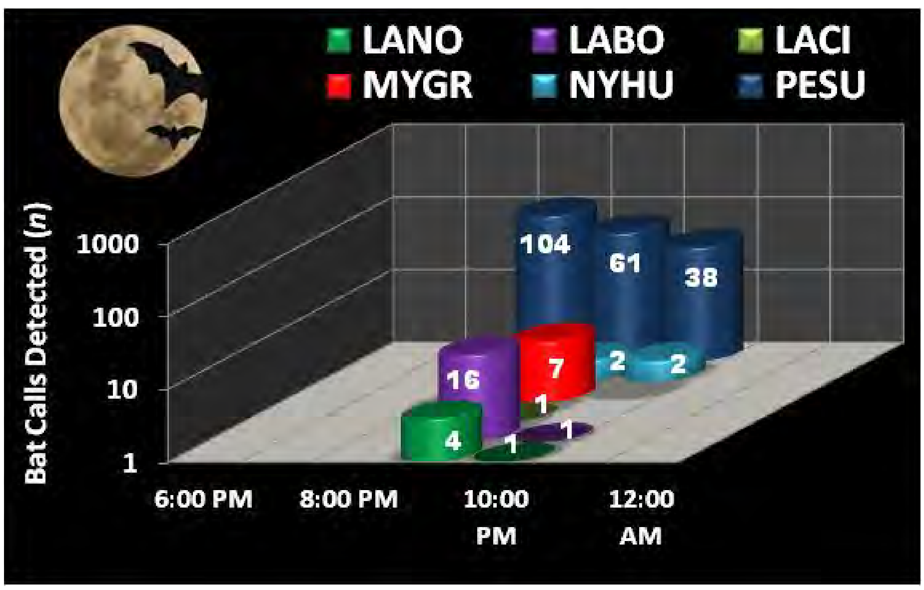

Figure 42: Scarboro Disc Park (City of Oak Ridge)
Anabat Data / 5-2-2013
(Active Survey: Dusk until Midnight)
Bat calls/hour per species

SOLWAY BEND / UT ARBORETUM SECTION

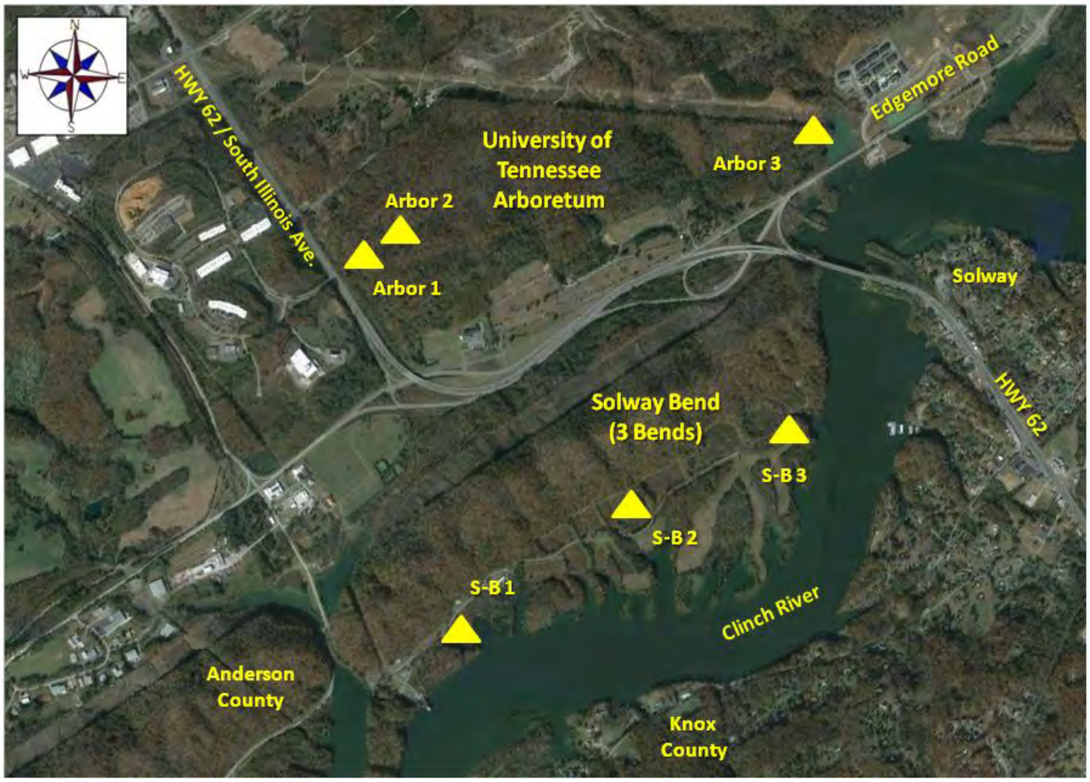

Figure 43: Solway Bend (TWRA 3 Bends) / UT Arboretum Section

	BAT TAXA DETECTED													ADDITIONAL SOFTWARE OUTPUT					
Bat Monitor Station ID	COTO	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	UNKN	LOW FREQ	MID FREQ	MYOTIS	NUMBER OF BAT CALLS	TOTAL PULSES
Arbor-1		1	11			5	2	16	1	9	13	14		4	1	39	36	76	1333
Arbor-2		6				1		7	11	85	15	25		7	6	40	110	157	3348
Arbor-3			5			13	1	77		2	2	81		2		89	94	183	11852
Solway SB-1		22	11		10			3			15	146		1	32	173	3	208	7662
Solway SB-2			7		2	2		3			1	7	1		5	12	5	23	192
Solway SB-3		42	2	2	51	3		1			3	128		1	95	134	4	233	4483

Table 8: Summary Table of Bats Detected
Solway Bend (TWRA 3 Bends) / UT Arboretum Section

Note: The numbers in each *bat taxa detected* column represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. A call is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). Pulses are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. All Anabat files were processed using the BCID-East software program (validated with Kaleidoscope PRO program).

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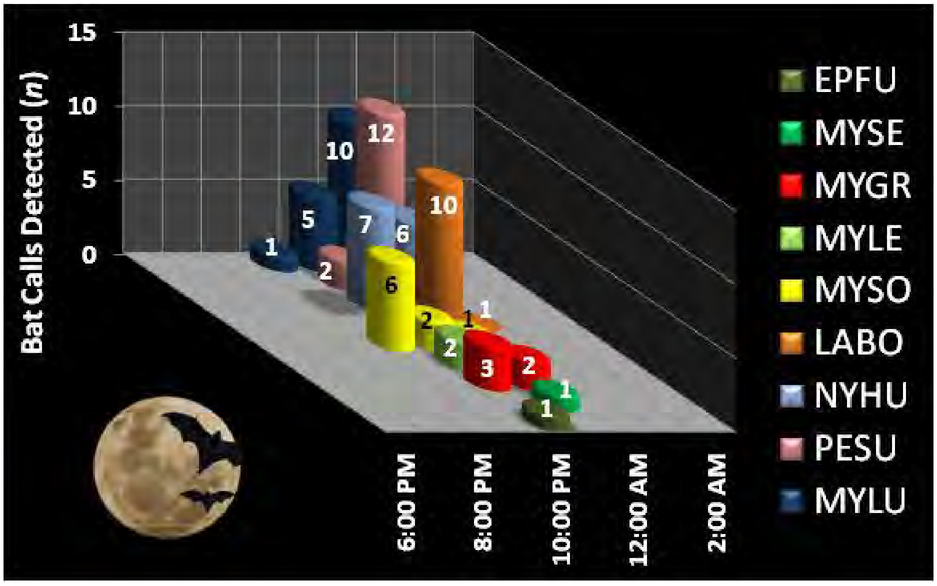

Figure 44: Arbor-1 (UT Arboretum)
Anabat Data / 6-3-2013
(Active Survey: Dusk until 2:00 am)
Bat calls/hour per species

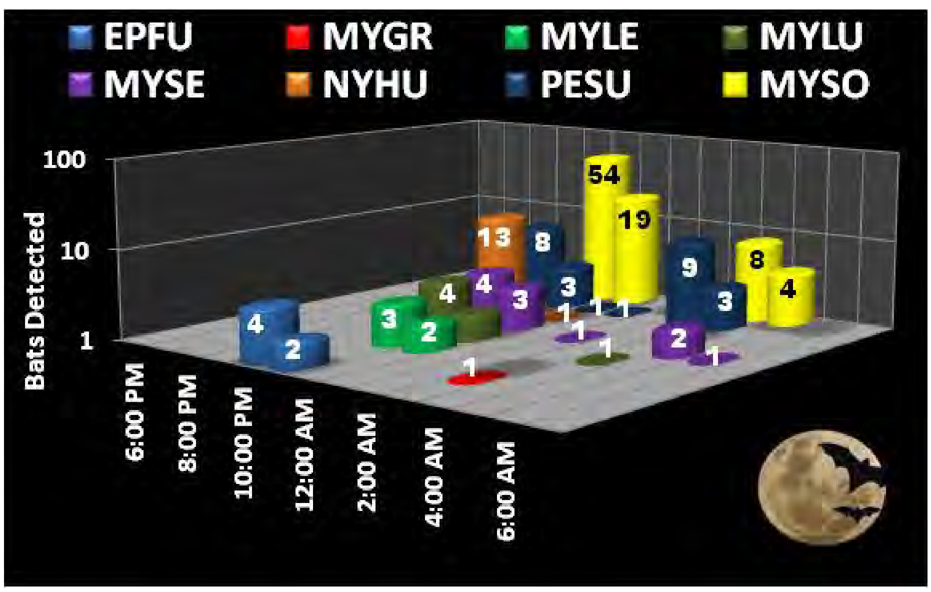

Figure 45: Arbor-2 (UT Arboretum)
Anabat Data / 7-8-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

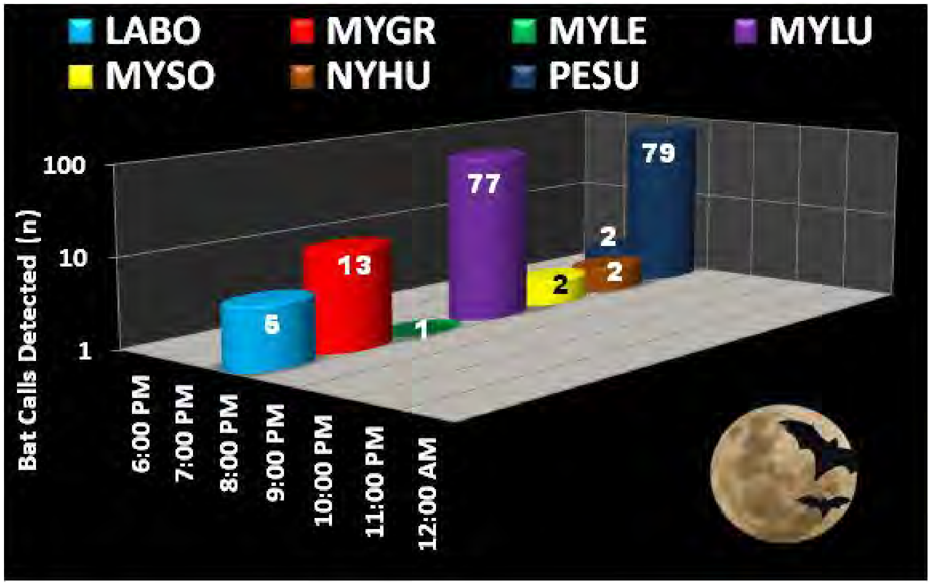

Figure 46: Arbor-3 (UT Arboretum)
Anabat Data / 9-13-12
(Active Survey: Dusk until Midnight)
Bat calls/hour per species

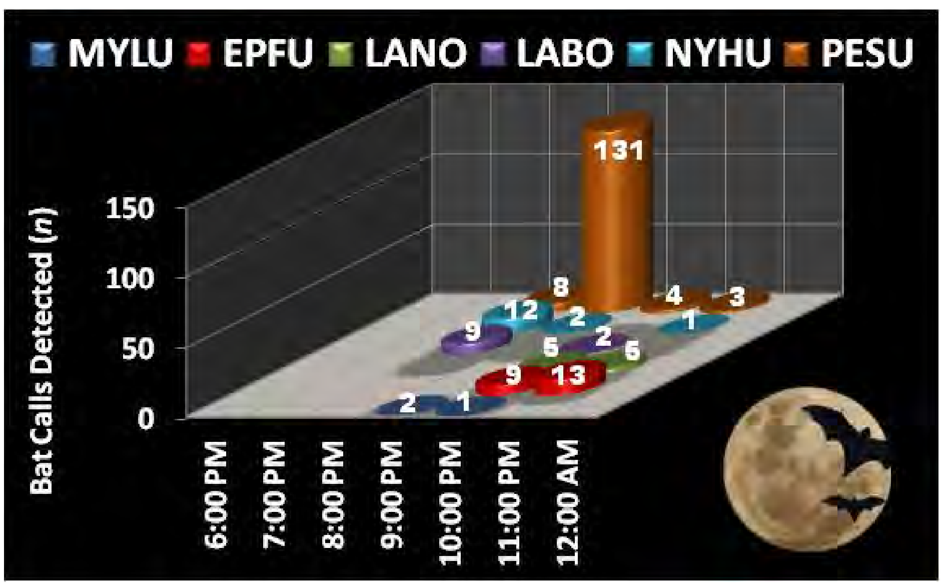

Figure 47: SB-1 (Solway Bend)
Anabat Data / 8-25-2013
(Active Survey: Dusk until Midnight)
Bat calls/hour per species

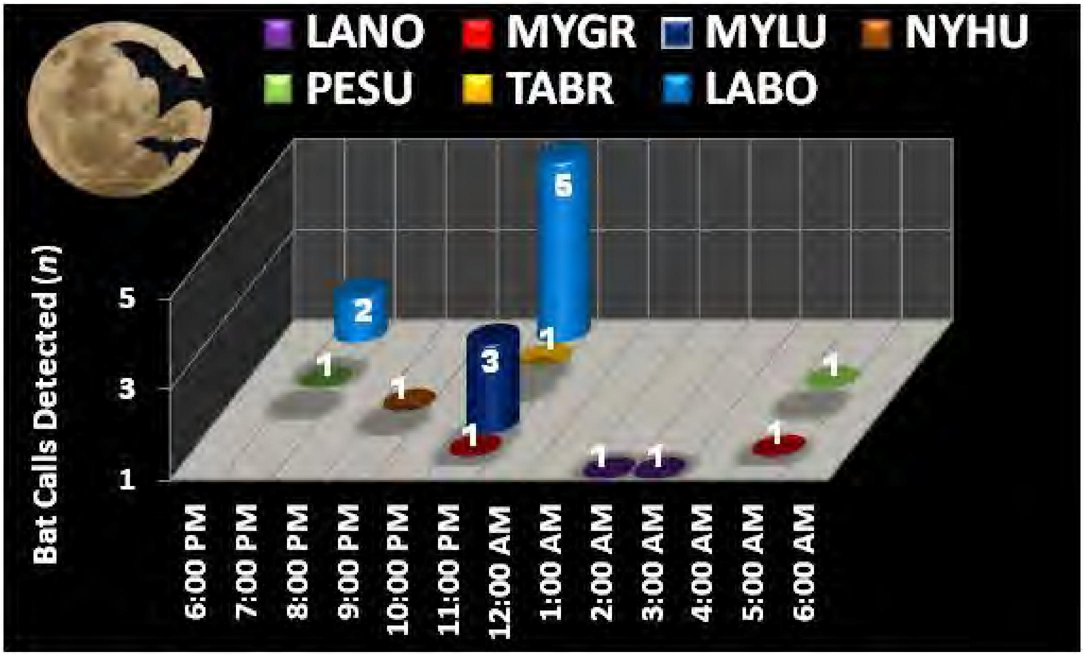

Figure 48: SB-2 (Solway Bend)
Anabat Data / 10-11-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

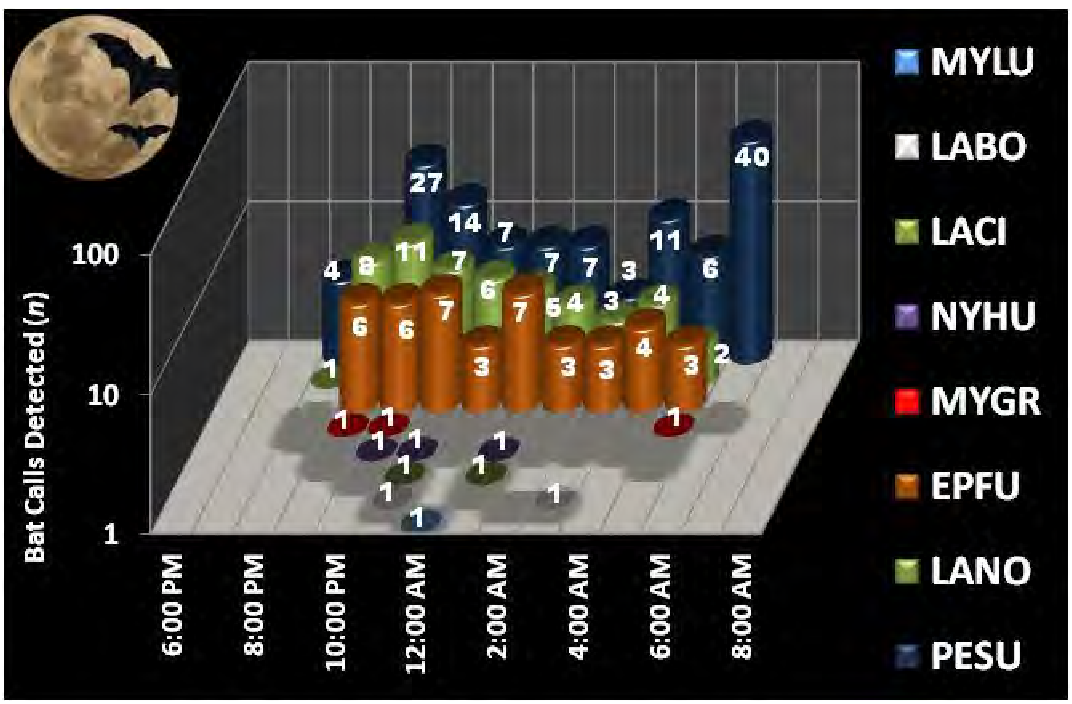

Figure 49: SB-3 (Solway Bend)
Anabat Data / 8-15-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

WALKER BRANCH SECTION

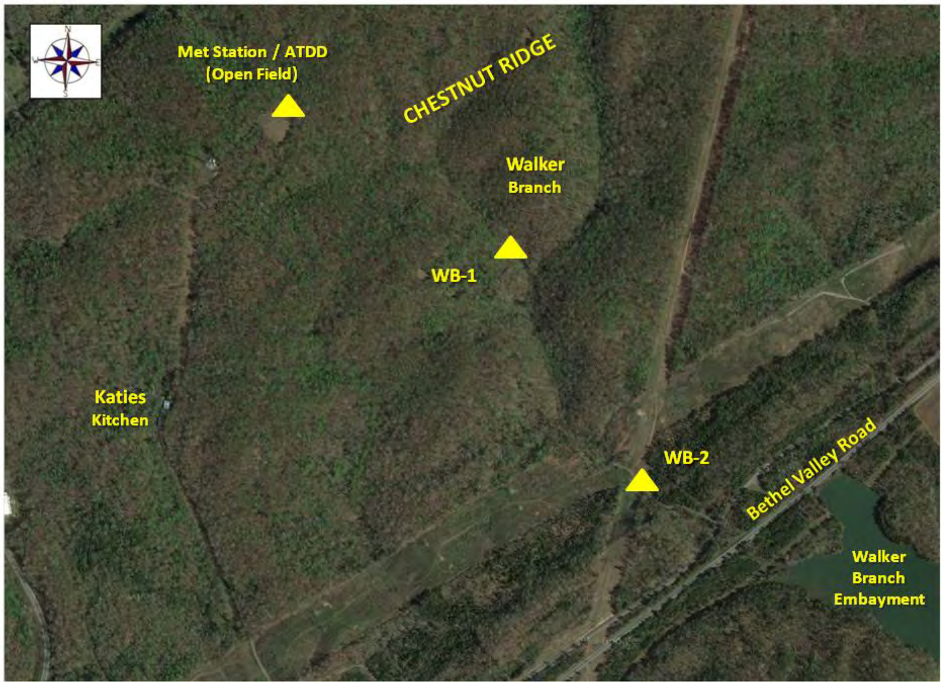

Figure 50: Walker Branch (ORNL) Section

	BAT TAXA DETECTED													ADDITIONAL SOFTWARE OUTPUT					
Bat Monitor Station ID	COTO	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	UNKN	LOW FREQ	MID FREQ	MYOTIS	NUMBER OF BAT CALLS	TOTAL PULSES
MET / ATDD			1		39			2			2	8		2	40	11	2	54	523
WB-1		1				33	5	21	2	13	1	23		7	1	25	80	106	1835
WB-2	1	18			3	1			3		2	1		3	21	4	4	32	262

Table 9: Summary Table of Bats Detected
Walker Branch (ORNL) Section

Note: The numbers in each *bat taxa detected* column represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. A call is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). Pulses are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. All Anabat files were processed using the BCID-East software program (validated with Kaleidoscope PRO program).

Taxonomic Codes: COTO = *Corynorhinus townsendii* (Townsend's Big-eared Bat), EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat).

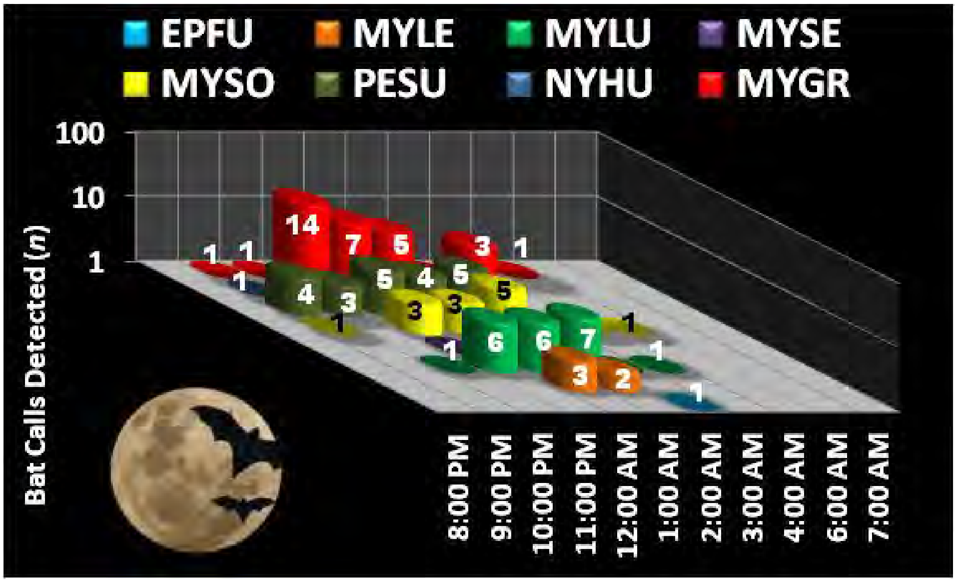

Figure 51: WB-1— Walker Branch (west fork; 100 yards north of weir)
Anabat Data / 6-21-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

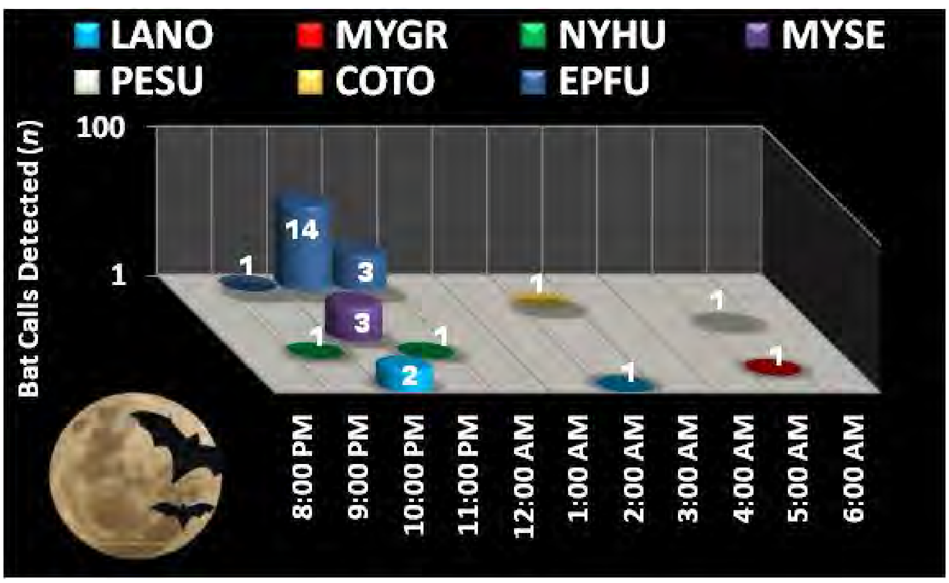

Figure 52: WB-2— Walker Branch (Powerline ROW—access road/forest edge)
Anabat Data / 7-24-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

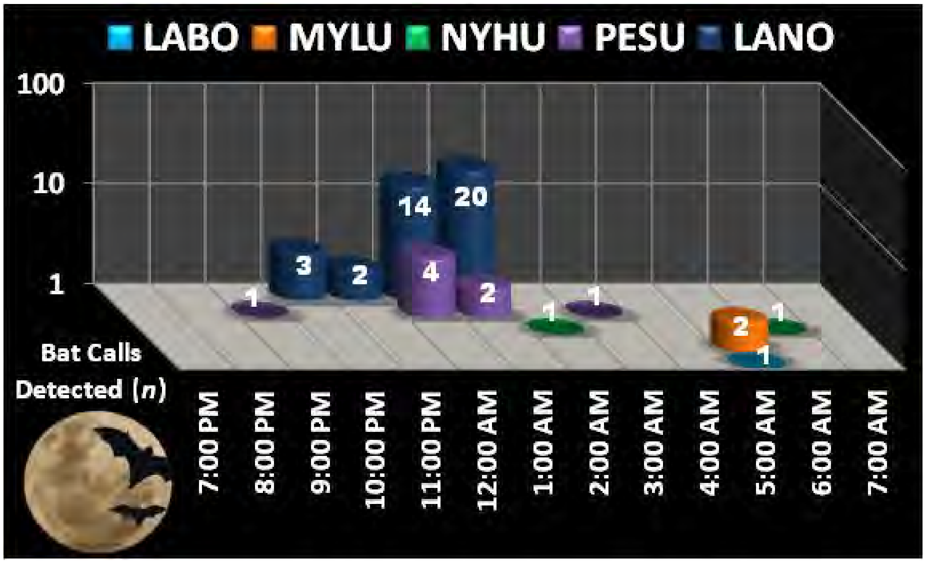

Figure 53: Meteorological / ATDD Station (open field)
Anabat Data / 6-21-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

WEST BEAR CREEK VALLEY SECTION

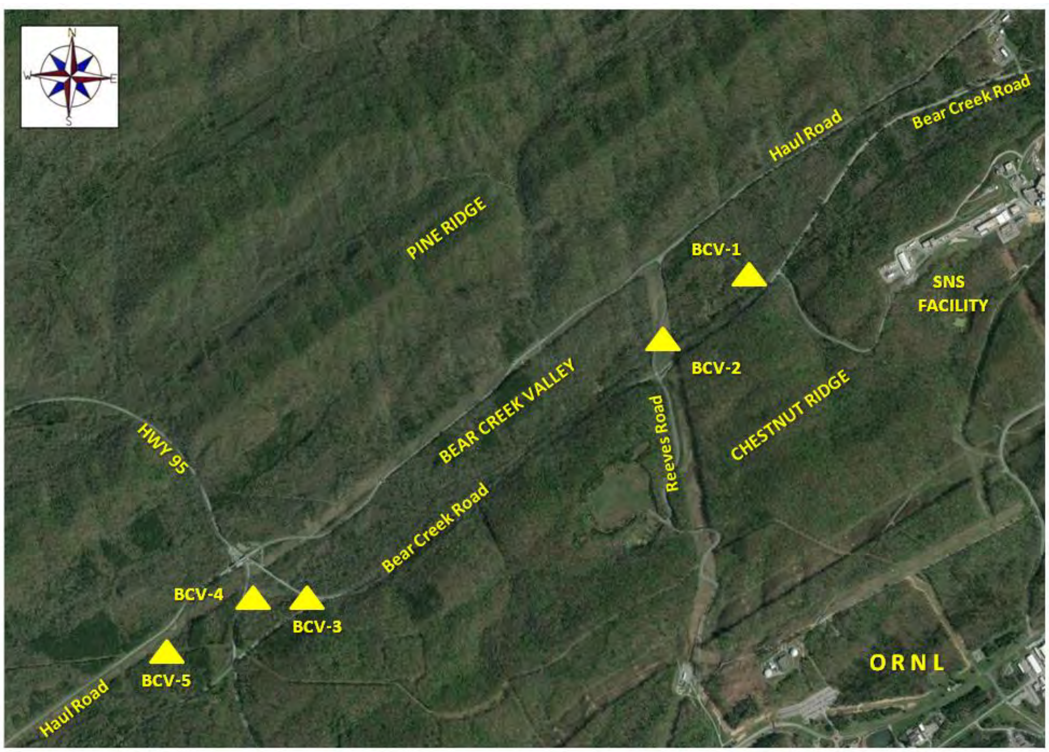

Figure 54: West Bear Creek Valley (Y-12) Section

	BAT TAXA DETECTED													ADDITIONAL SOFTWARE OUTPUT					
Bat Monitor Station ID	COTO	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	UNKN	LOW FREQ	MID FREQ	MYOTIS	NUMBER OF BAT CALLS	TOTAL PULSES
BCV-1		144	37	1	297	21	1	23	2	1	18	479		19	443	542	56	1043	22209
BCV-2		8			9	1		2		2	1	6			17	7	5	29	278
BCV-3		5			4	5			1		2	68		5	9	71	8	90	1537
BCV-4		10	2	1	7	13		7		1	10	30		10	18	51	22	91	1029
BCV-5		1	1		5	2		2		2	1	13			6	15	6	27	285

Table 10: Summary Table of Bats Detected
West Bear Creek Valley (Y-12) Section

Note: The numbers in each *bat taxa detected* column represent the number of bat calls recorded at each monitoring station, **not** the number of bats present. A call is the series of frequency sweeps which a bat emits for navigation or location of a prey item (McCracken et al. 2013). Pulses are a rapid series of echolocation vocalizations emitted during the search, approach and feeding buzz phases as a bat searches and locates prey items. All Anabat files were processed using the BCID-East software program (validated with Kaleidoscope PRO program).

Taxonomic Codes: COTO = *Corynorhinus townsendii* (Townsend's Big-eared Bat), EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat).

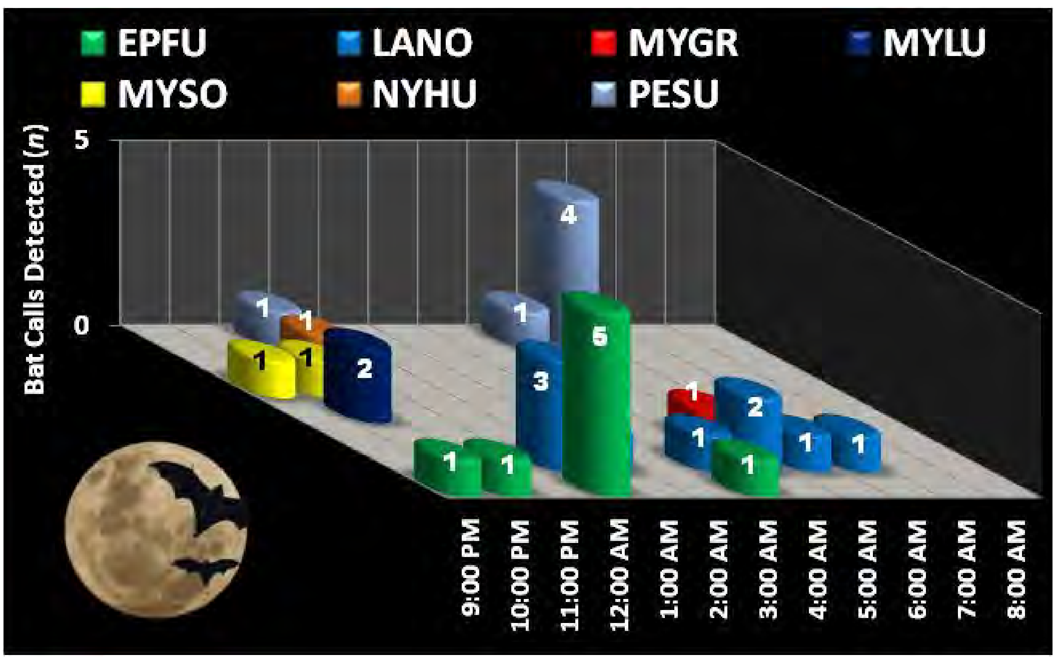

Figure 55: BCV-1—Bear Creek Wetland (SS-6 spring)
Anabat Data / 8-9-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

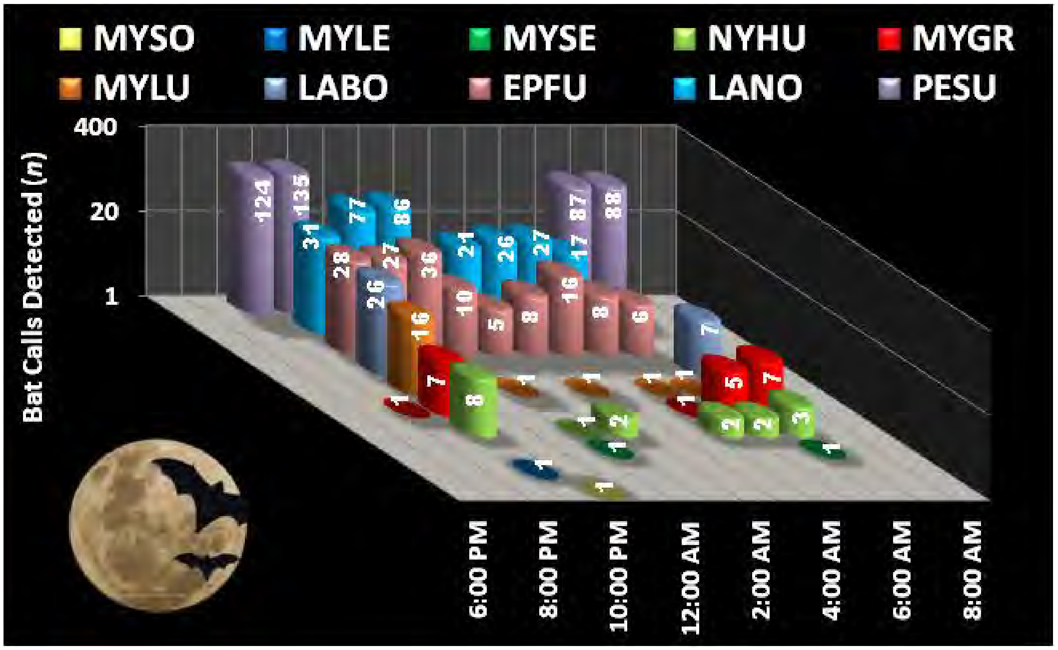

Figure 56: BCV-2— Bear Creek at Reeves Road bridge
Anabat Data / 8-9-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

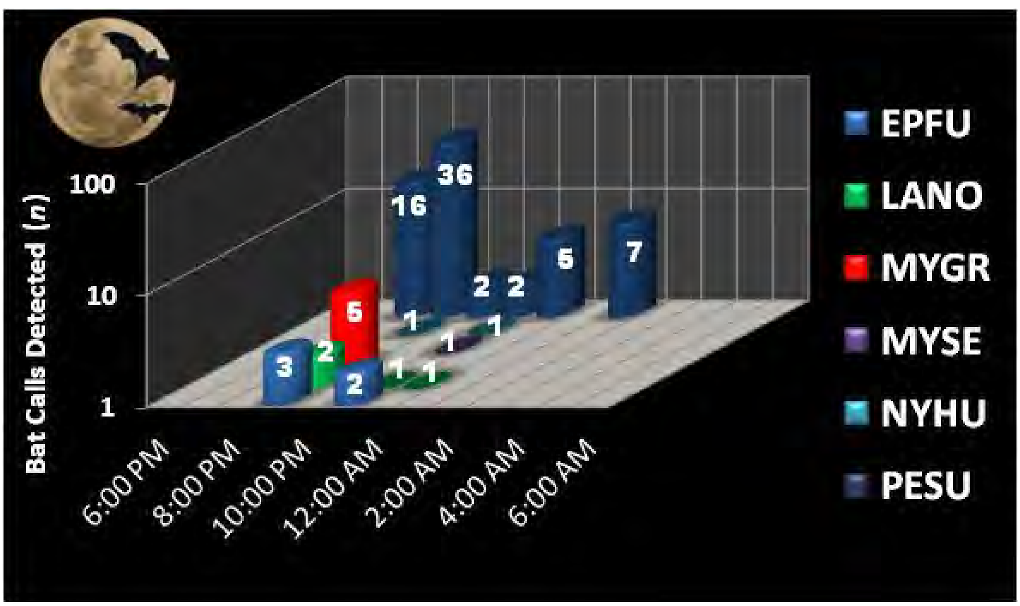

Figure 57: BCV-3—Bear Creek Wetland
(east side BCK 4.5 km @ SS-7 spring) Anabat Data / 7-26-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

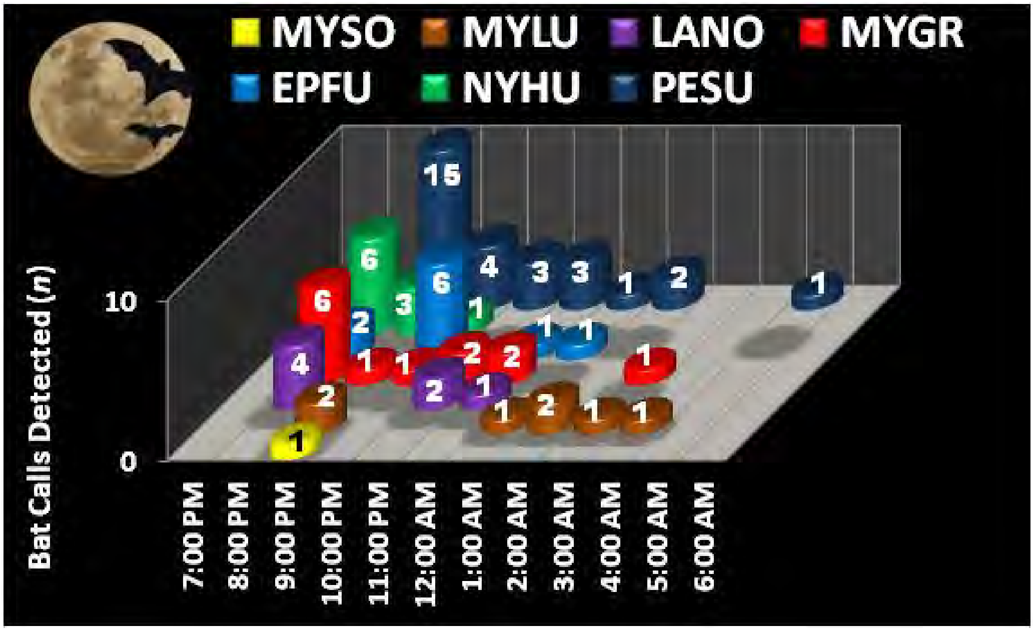

Figure 58: BCV-4—Bear Creek Wetland
(West side BCK 4.5 km @ old weir) Anabat Data / 9-28-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

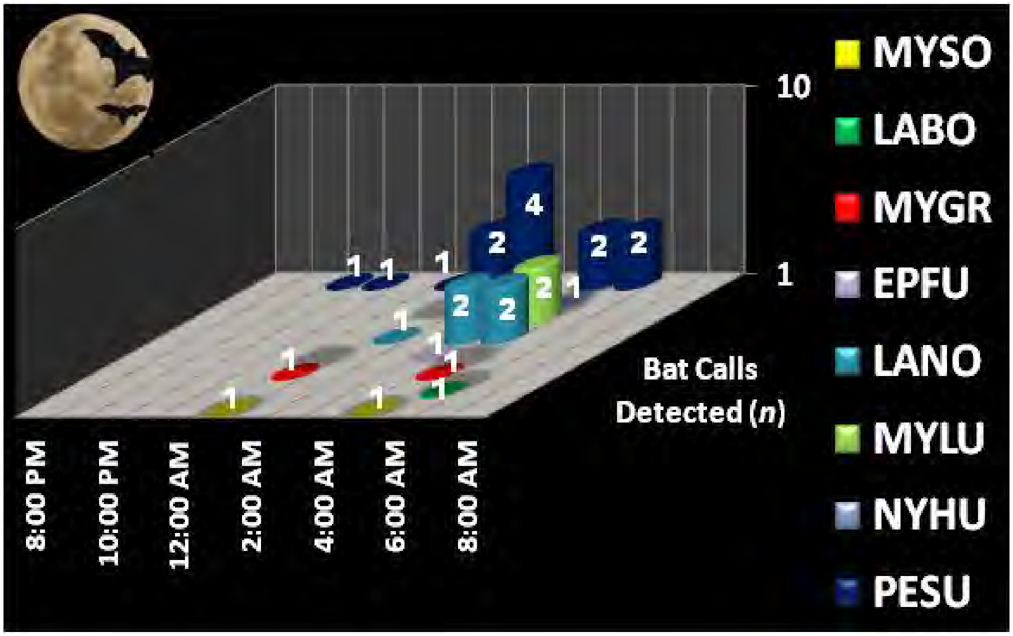

Figure 59: BCV-5— Haul Road
(West of HWY 95 overpass/pipeline ROW) Anabat Data / 8-30-2013
(Passive Survey: Dusk until Dawn)
Bat calls/hour per species

Results Summary

During 2013, DOEO processed 6,231 bat call files (167,001 total pulses) collected from 47 Anabat monitoring sites on the ORR. Although we monitored bats for ≥75 survey nights (between April 15-October 31), and due to the tremendous volume of bat files about 50% of the data is actually recorded (>12,000 bat call files). Twenty-three (23) survey sites were passively monitored from dusk until dawn and 24 sites were actively monitored between dusk until midnight (or dusk until 2:00 am). DOEO used the automated software program: BCID-East (plus Kaleidoscope PRO for verification) for analysis of the Anabat files. Our analysis of identified calls suggests thirteen (13) bat species are present on the reservation including two federally endangered species (i.e., Gray Bat, Indiana Bat). DOEO also detected *Myotis leibii* (Eastern Small-footed bat) and *Myotis septentrionalis* (Northern Long-eared Bat) which have been under consideration by the USFWS for listing as federally endangered species. Although *M. leibii* has been temporarily dropped from consideration for listing, *M. septentrionalis* continues in the process of becoming listed as federally endangered. Moreover, DOEO collected 4 bat calls identified as *Corynorhinus townsendii* (Townsend's Big-eared Bat) recorded at Lambert Quarry and Walker Branch, and a single call identified as *Tadarida brasiliensis* (Brazilian Free-tailed Bat) recorded at Solway Bend. Approximately 66% of all bat calls recorded were mid frequency calls. *Perimyotis subflavus* (Tri-colored Bat) calls represented 56% (3423 calls) of all bat calls recorded followed by *Lasionycteris noctivagans* (Silver-haired Bat) = 9% (525 calls), *Myotis grisescens* (Gray Bat) = 8% (480 calls), *Eptesicus fuscus* (Big Brown Bat) = 7% (413 calls), *Myotis lucifugus* (Little Brown Bat) = 6% (356 calls), *Lasiurus borealis* (Eastern Red Bat) = 5% (312 calls), *Nycticeius humeralis* (Evening Bat) = 4% (268 calls), and *Myotis sodalis* (Indiana Bat) = 3% (181 calls). This study, along with a concurrent ORNL Environmental Science Division bat project, was the first long term, large-scale acoustic bat community investigation on the ORR.

COTO	EPFU	LABO	LACI	LANO	MYGR	MYLE	MYLU	MYSE	MYSO	NYHU	PESU	TABR	UNKN	LOW FREQ	MID FREQ	MYOTIS FREQ	NO. OF BAT CALLS	TOTAL PULSES
4	413	312	28	527	480	23	356	47	181	268	3423	1	169	974	4085	1133	6231	167001

Table 11: Summary Table (Combined Bat Calls for All Taxa)

Taxonomic Codes: COTO = *Corynorhinus townsendii* (Townsend's Big-eared Bat), EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat).

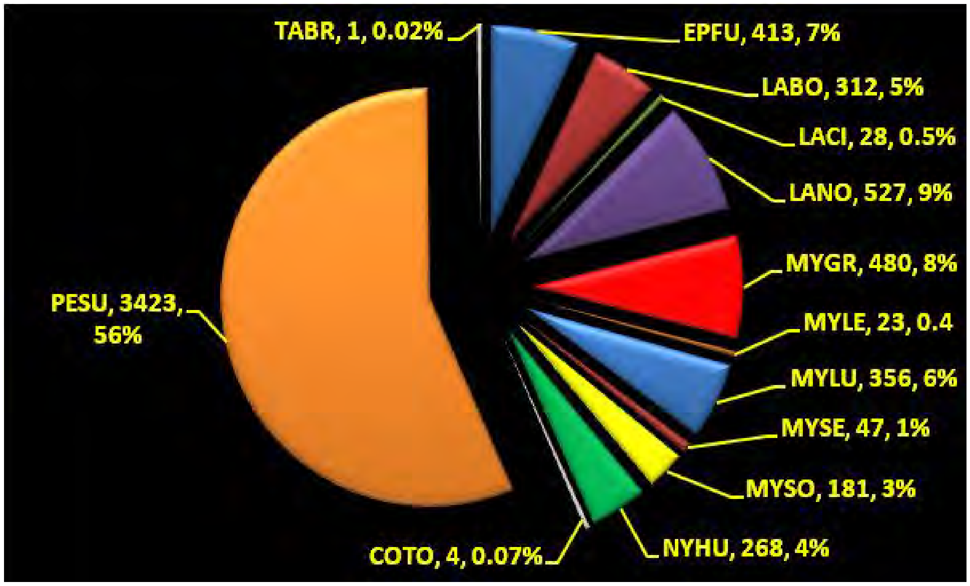

Figure 60: Summary Pie Chart
Combined 2013 Anabat Data (Total Bat Calls Per Taxon)

Taxonomic Codes: COTO = *Corynorhinus townsendii* (Townsend's Big-eared Bat), EPFU = *Eptesicus fuscus* (Big Brown Bat), LABO = *Lasiurus borealis* (Eastern Red Bat), LACI = *Lasiurus cinereus* (Hoary Bat), LANO = *Lasionycteris noctivagans* (Silver-haired Bat), MYGR = *Myotis grisescens* (Gray Bat), MYLE = *Myotis leibii* (Eastern Small-footed Bat), MYLU = *Myotis lucifugus* (Little Brown Bat), MYSE = *Myotis septentrionalis* (Northern Long-eared Bat), MYSO = *Myotis sodalis* (Indiana Bat), NYHU = *Nycticeius humeralis* (Evening Bat), PESU = *Perimyotis subflavus* (Tricolored Bat; Eastern Pipistrelle), TABR = *Tadarida brasiliensis* (Brazilian Free-tailed bat).

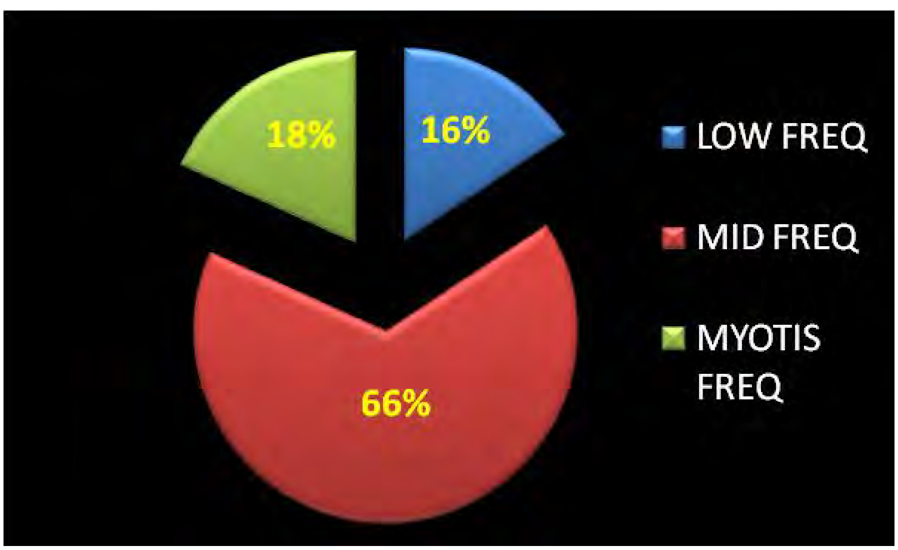

Figure 61: Summary Pie Chart
Combined 2013 Anabat Data (Total Bats Per Frequency)

Although the federally endangered *M. sodalis* (Indiana Bat) has not been documented on the ORR since 1950, DOEO detected this bat at 16 of our 47 study sites during 2013 Anabat

surveys. Further supporting our analysis, a male Indiana Bat was captured on the ORR during a mist-net survey at Freels Bend in June 2013 (McCracken et al. 2013). DOEO also detected the federally endangered *Myotis grisescens* (Gray Bat) at 38 of 47 sites and *Myotis septentrionalis* (Northern Long-eared Bat) at 11 of 47 sites during 2013 Anabat surveys. The Northern Long-eared Bat is currently under consideration by the US Fish & Wildlife Service for listing as a federally endangered species.

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Periphyton Environmental Monitoring (2013)

Abstract

Diatom communities colonizing artificial substrates were sampled to assess the water quality and ecological condition of Bear Creek impacted by Department of Energy (DOE) activities on the Oak Ridge Reservation, especially the tributaries around the Environmental Management Waste Management Facility (EMWMF). Periphyton samples were collected from artificial substrates between April and November 2013 at four impacted Bear Creek sites. The goal was to use diatoms as biomonitoring tools for the ecological assessment and scoring of the water quality and to examine the recovery of Bear Creek as compared to historical periphyton data extracted from a reference stream. Water quality parameters (i.e., conductivity, pH, etc.) were also collected during each sampling event. Laboratory work was not completed on this project by publication time.

Introduction

Periphyton is an assemblage of algae, fungi, bacteria and other organisms (i.e., micro-community) that colonize benthic substrates in aquatic ecosystems and are primary producers in the aquatic food chain (Stevenson et al. 2002, Carr et al. 2005). An important component of the periphyton community is diatoms (Bacillariophyceae), which are unicellular photosynthetic protists with frustules constructed of silicon sequestered from the water column (Round et al. 2007). Periphytic diatoms exist within narrow environmental conditions (light, temperature, pH, turbidity, water chemistry), and are thus powerful indicators of different levels and causes of anthropogenic stress due to industrial pollution and high nutrient loads (Sabater et al. 1987, Dixit et al. 1992, Bahls 1993, Stevenson et al. 2002, Wehr and Sheath 2003, Smol 2008).

Communities of benthic algae (periphyton) contain many taxa that exhibit individual tolerances to anthropogenic stress such as elevated concentrations of metals and nutrients in streams and lakes (Genter et al. 1988, Pérès 1996, St-Cyr 1997, Medley and Clements 1998, Ivorra et al 1999). Previous studies have documented negative impacts to periphyton communities in response to industrial pollution with several species being extirpated and never reappearing, whereas others were more resistant to pollution and remained (Ruggiu et al. 1998, Guilizzoni et al. 2001). Thus, community composition of periphyton can be useful in identifying degraded water quality conditions (Genter et al. 1988).

Methods and Materials

Study Site

Periphyton was collected during 2013 at four benthic locations in Bear Creek Valley [BCK km 12.3, BCK 11.5 (North Tributary 3 (NT-3) confluence, BCK 10.6 (North Tributary 5 (NT-5), & BCK km 9.6); Table 1] to quantify and evaluate Oak Ridge Reservation (ORR) diatom community composition and taxa richness. Samples were collected from artificial substrates six times (June, July, September, October, November, and December). Historical diatom information was also integrated from the Hinds Creek km 20.6 site (Andersonville, TN area) for reference stream data.

Artificial Substrates

Characterization of diatom taxa present in a sample and their disproportionate abundance can be analyzed to determine biotic integrity and diagnose specific stressors (Davis and Simon 1995). Artificial substrates are commonly used to quantify diatom communities in aquatic systems which colonize substrates rapidly (Kevern et al. 1966, Korte and Blinn 1983, Lane et al. 2003). Introduced or artificial substrates provide precise assessments of diatom populations in streams with highly variable environmental conditions, create a standardized or uniform surface for periphyton growth, and minimize problems associated with substrate comparability among sampling stations (Porter et al.1993, Stevenson et al. 2002). The goal was to obtain a sample that is a miniature replica of the standing crop of periphytic algae that is present at each site (Bahls 1993). After initial placement of artificial substrates, 2-4 weeks were allowed for periphyton recruitment and colonization before leadoff tile samples were collected (Aloi 1990, Porter et al. 1993, Barbour et al. 1999, KDOW 2002).

Artificial substrates were constructed of standard red masonry bricks (w/ 10-holes) and 12 beige ceramic tiles (23.04 centimeter square [cm^2] each) that were affixed to the top of each brick with silicon glue. Bricks (with tiles face-up) were secured to the streambed (i.e., fairly deep riffles) by driving 1.5-foot sections of rebar approximately 1-foot deep into the substrate (Hill and Middleton 2006). Thus, to prevent loss of the artificial substrates during storm surge events, one of the holes of the masonry brick was fitted over the top of the rebar, slid down, and submerged. At each BCK sampling site, the colonized brick was raised from the streambed, and one colonized tile was randomly selected and carefully pried off with a pocketknife. The tile sample was placed in a labeled plastic container, creek water was added to cover the tile, and the container was sealed and packed in an ice chest for transport to the laboratory. Once tiles were extracted, the brick was re-submerged to its original position and orientation in the creek for future sampling. Upon returning to the laboratory, samples were stored in dark refrigeration at 4°Celcius (C) until processing (less than or equal [≤] 24 hours, Flotemersch et al. 2006).

Water Quality and Photosynthetic Light

Ambient water parameters were measured at each location using the YSI® 556 Water Quality Meter (pH, temp, conductivity, dissolved oxygen). Field data were recorded in a logbook at each sampling site. HOBO® light meters (Onset Computer Corporation) were deployed in July 2012 for 1 week to characterize photosynthetic light received as an estimate of canopy cover at each sampling station. Surface water quality laboratory data (i.e., nutrients, metals, radiological) was sequestered from a sister benthic project for inclusion in this report.

Field sampling methods and protocols employed during this project included Tennessee Department of Environment and Conservation's (TDEC) *Quality System Standard Operating Procedure for Periphyton Stream Surveys* (TDEC 2010), U.S. EPA's *Periphyton Sampling Protocol* (Barbour et al. 1999), the Kentucky Division of Water (KDOW 2008, 2009), the *New Jersey Protocol Manual* (Ponader & Charles 2005), and the United States Geological Survey (USGS) *Methods for Collecting Algal Samples as Part of the National Water Quality Assessment Program* (Moulton et al. 2002). Field sampling followed the division's health and safety plan (Yard 2013).

Laboratory Processing

Periphyton was brushed from tiles and carefully rinsed with 20-25 milliliter (mL) deionized water into a clean laboratory pan. The initial slurry volume of each sample was carefully measured in a graduated cylinder and recorded in the laboratory logbook. Using a clean funnel, the resultant algal slurry was poured into 30 m; dark brown Nalgene® high density polyethylene bottles. The slurry was preserved with 3 drops of Lugol's solution and kept in cold, dark storage (4°C) until identification and quantification of taxa (Wunsam et al. 2002, Hill et al. 2009). Sample identification labels with site specific information was attached to each slurry sample container. Laboratory sample preparation protocols follow the methods of Bahls (1993), Barbour et al. (1999), KDOW (2008, 2009), and Moulton et al. (2002). Enumeration of periphyton taxa to genus was not completed in time to meet the EMR publishing deadline.

Bioassessment Metrics

According to the guidance presented in the *Quality System Standard Operating Procedure for Periphyton Stream Surveys* (TDEC 2010), we used the TDEC Diatom Bioassessment Index (DBI) to determine water quality scores as calculated from six taxonomically-derived metrics to make inferences on the environmental conditions at each impacted Bear Creek sampling site (Winter and Duthie 2000, KDOW 2008, 2009). What is a metric? A metric is a quantifiable attribute or characteristic of the aquatic community that is ecologically relevant and responds predictably along an environmental disturbance gradient (Barbour et al. 1995, Karr and Chu 1999, US EPA 1996). Typically, several metrics are combined to obtain a composite index that has greater utility than each of the component metrics. The TDEC-DBI is similar to the indices for fish and macroinvertebrates in streams (Karr 1981, Hilsenhoff 1982, 1987) in that it is a multimetric index (Table 2). Basically, the diatom enumeration data is plugged into the metrics and calculated. Each individual metric provides a sub-score which is then assigned a calculated score (range 0-100) based upon the standard metric value (95th percentile thresholds for each metric). The mean of the six metrics is the final TDEC-DBI score that characterizes the periphyton assemblage and ecological integrity of each stream site (Bahls 1993, Griffith et al. 2002, KDOW 2008, 2009). Further details describing the Kentucky Index can be found in KDOW (2008).

Results and Discussion

Laboratory processing of periphyton samples were not completed in time to meet the EMR publishing deadline. Hence, the 2013 Periphyton EMR will be presented in the 2014 environmental monitoring report.

Table 1: 2013 periphyton study sites (including light & biomass)

Station (stream km)	Description	Vegetation Cover	Minimum / Maximum Light Intensity (units = Lux)	June 2012 Cell Density (Biomass; units = cells/cm^2)
BCK 12.3	Bear Creek km 12.3 (headwaters)	75% canopy cover	120,000-140,000	2,037,707
BCK 11.5	Bear Creek km 11.5 near NT-3 outfall	50% canopy cover	220,000-275,000	2,337,695
BCK 10.6	Bear Creek km 10.6 near NT-5 outfall	100% canopy cover	30,000-150,000	1,123,445
BCK 9.6	Bear Creek km 9.6	100% canopy cover	42,000-74,000	1,133,529

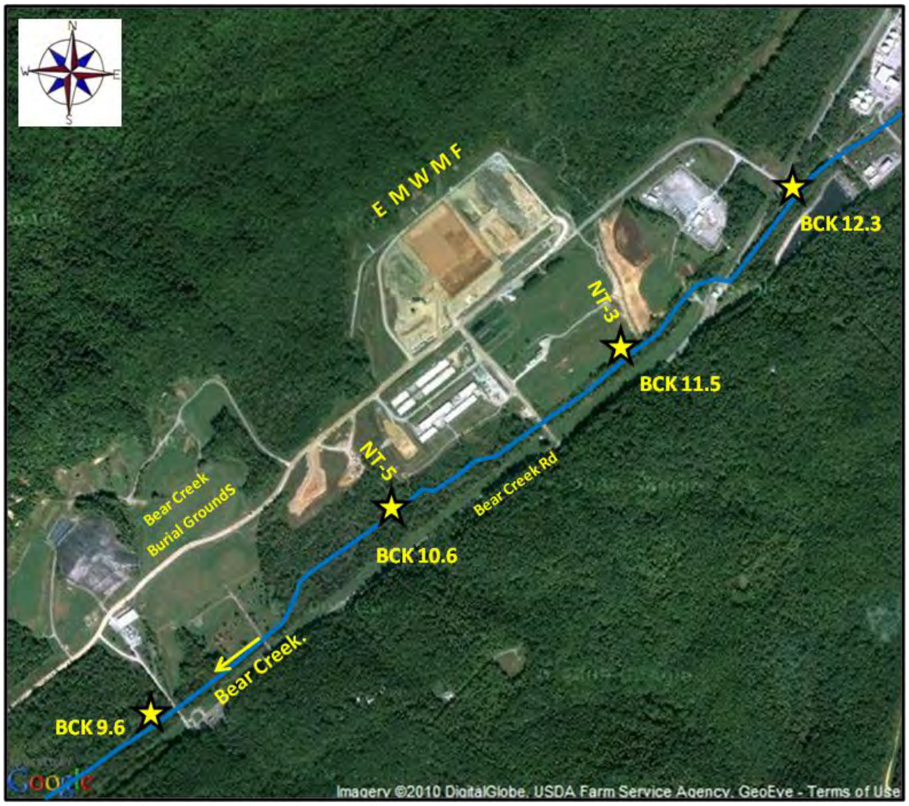
Lux is defined as the measure of luminous flux per unit area (luminous emittance); 1 Lux = 1 lumen/m^2.

DIATOM BIOASSESSMENT INDEX (METRICS) TDEC DIVISION OF WATER POLLUTION CONTROL
(1) **Total Number of Diatom Taxa (TNDT)** = total number of periphyton taxa identified in a sample; this number also indicates an estimate of diatom taxa richness. The TNDT is expected to decrease with increasing pollution.
(2) **Shannon Diversity (H')** = index to characterize species diversity (species proportion for all species in a particular ecosystem). Using this metric, H'=0 when only 1 species is present in the biotic assemblage (i.e., poor water quality), and H' is at its maximum when all individuals are evenly distributed among a population (i.e., clean water quality).
(3) **Pollution Tolerance Index (PTI)** = each taxa is assigned a tolerance value based on their tolerance to increased pollution; tolerance values range from 1 (most tolerant) to 4 (most sensitive). The tolerance values are derived from periphyton protocols of the Kentucky Division of Water (2008, 2009). Low PTI scores reflect impaired water quality whereas higher scores reflect clean water quality conditions.
(4) ***Cymbella* Group Richness (CGR)** = Total number of taxa from the following genera: *Cymbella, Cymbopleura, Encyonema, Encyonemopsis, Navicella, Pseudoencyonema*, & *Reimeria*. As water pollution increases, the CGR score is expected to decrease.
(5) ***Fragilaria* Group Richness (FGR)** = Total number of taxa from the following genera: *Ctenophora, Fragilaria, Fragilariforma, Pseudostaurosira, Punctastriata, Stauroforma, Staurosira, Staurosirella, Synedra*, & *Tabularia*. As water pollution increases, the FGR score is expected to decrease.
(6) **% *Navicula, Nitzschia, Sururella* (%NNS)** = The sum of the relative abundances of all *Navicula, Nitzschia*, & *Sururella* taxa. The relative abundances of these 3 main taxa within an assemblage reflect the degree of sedimentation at a reach. As sedimentation increases, the %NNS is expected to increase.

Table 2: TDEC-WPC Diatom Bioassessment Index (TDEC 2010).

PERIPHYTON FAMILIES AND TAXA PRESENT IN OAK RIDGE RESERVATION STREAMS				
DIATOMS	DIATOMS	DIATOMS	DIATOMS	DIATOMS
ACHNANTHACEAE	**COSCINODISCACEAE**	**CYMBELLACEAE**	**EPITHEMIACEAE**	**GOMPHONEMATACEAE**
Achnanthidium (S)	Coscinodiscus (T)	Amphora (S)	Denticula (S)	Gomphonema (T)
Cocconeis (S)	Melosira (T)	Cymbella (S)	Epithemia (T)	Reimeria (S)
Rhoicosphenia (S)		Encyonema (S)	Rhopalodia (T)	
DIATOMS	DIATOMS	DIATOMS	GREEN ALGAE	BLUE-GREEN BACTERIA
NAVICULACEAE	**NITZSCHIACEAE**	**SURIRELLACEAE**	**CHLOROPHYTA**	**CYANOPHYTA**
Diploneis (S)	Hantzschia (T)	Campylodiscus (T)	Chlorella (T)	Anabaena (T)
Frustulia (S)	Nitzschia (T)	Cymatopleura (T)	Cosmarium (S)	Anacystis (T)
Gyrosigma (T)		Surirella (T)	Desmidium (S)	Chroococcus (T)
Navicula (T)			Oedogonium (T)	Cylindrospermum (T)
Neidium (S)			Pediastrum (T)	Gloeotrichia (T)
Pinnularia (S)			Scenedesmus (T)	Microcystis (T)
			Spirogyra (S)	Oscillatoria (T)
			Staurastrum (S)	Phormidium (T)
			Stigeoclonium (S)	Scytonema (T)
EUGLENOIDS				
EUGLENOPHYTA				
Euglena (T)		NOTE:		
Phacus (T)		"S" = Pollution Sensitive		
Trachelomonas (T)		"T" = Pollution Tolerant / Moderately Poll. Tolerant		

Table 3: Periphyton taxonomic families and genera in ORR streams.



yellow arrow indicates direction of stream flow.

Figure 1: EMWMF facility and Bear Creek periphyton sampling locations

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Aquatic Vegetation Sampling on the Oak Ridge Reservation

Principal Author: Natalie Pheasant

Abstract

As a part of its obligations under the Tennessee Oversight Agreement, the DOE Oversight Office of the Tennessee Department of Environment and Conservation's Division of Remediation conducts monitoring of aquatic vegetation on and near the Department of Energy's Oak Ridge Reservation. In this program, DOE Oversight staff members collect vegetation at locations near or in water, with the potential for radiological contamination. If surface water bodies have been impacted by radioactivity, aquatic organisms in the immediate vicinity may uptake radionuclides, bioaccumulating radiological contaminants. The vegetation is analyzed for gross alpha, gross beta, and for gamma radionuclides and is compared to the radiological analysis of vegetation taken from background locations. The sampling conducted during 2013 suggests limited areas of elevated radionuclide concentrations in the vegetation associated with surface water on the ORR. In 2013, metals analysis was also completed for up to three metals at most locations. Elevated metals results were seen at some locations.

Introduction

As a part of its obligations under the Tennessee Oversight Agreement, the DOE Oversight Office of the Tennessee Department of Environment and Conservation's Division of Remediation conducts monitoring of aquatic vegetation on and near the Department of Energy's Oak Ridge Reservation. Aquatic vegetation (e.g., watercress and cattails) can be bioaccumulators and due to this, they can be potential pathways by which contaminants infiltrate the ecosystem and food chain creating ecological and human health risks. Watercress (*Nasturtium officinale)*, a floating, rooted, aquatic plant can be used as a food source and is often present downstream of springs on the ORR. If the emerging spring or stream is impacted by radiological contaminants, these substances can be deposited in the sediment. The plants may then uptake the radionuclides from the water or the sediment. Cattails (*Typha sp.)*, willows (*Salix sp.)*, and box elders (*Acer negundo)*, were also sampled in 2013 and are generally found in or near surface water and can also uptake radionuclides from the water or sediment. Since many plants uptake and accumulate calcium naturally, they may also uptake the radionuclide strontium-90, which is similar to calcium chemically. Other radionuclides and metals may also be accumulated in the plant tissue if present in the water or soils.

Methods and Materials

Twenty-two sites, including a background location for each vegetation type (watercress, cattail, willow, and box elder), were sampled in 2013. Samples were collected from Oak Ridge Reservation surface water sites, including springs, creeks, and wetlands to determine if radioactive contaminants have accumulated in the associated vegetation. Metals analysis was also completed for up to three metals (strontium, uranium, mercury) at most locations. The approximate locations are shown in Figure 1 and described in Table 1. Each sample for 2013 is labeled with the number of the sample (1 through 22) followed by a dash and a letter indicating the type of vegetation collected at that site. Cattail (*Typha* sp.) samples are labeled C , box elder (*Acer negundo*) samples are labeled with BE, willow (*Salix* sp.) samples are labeled with WL, and watercress (*Nasturtium officinale*) samples are labeled with W in the map in Figure 1 and in Table 1 through Table 3.

Aquatic vegetation samples are taken by collecting at least one gallon of vegetation for radiological analysis and another gallon for metals analysis, including minimal other debris. The samples are then scanned with a radiological instrument for beta and gamma radiation, double-bagged in re-sealable plastic bags, labeled, and transported on ice to the state environmental laboratory in Knoxville. The Knoxville Regional Laboratory forwards all radiological samples to the State of Tennessee Department of Health Environmental Laboratory in Nashville for analysis. Samples are analyzed for gross alpha, gross beta, and gamma radionuclides. Metals analysis for mercury was performed on the first sample at all locations (some sites had a second sample collected later in the year) and strontium and uranium analysis was included for sites where there was a greater potential for strontium 90 and uranium contamination. The total strontium and uranium metals analyses were done to see if these analyses could be used as screening tools to determine if contaminants might be present and might warrant additional analysis.

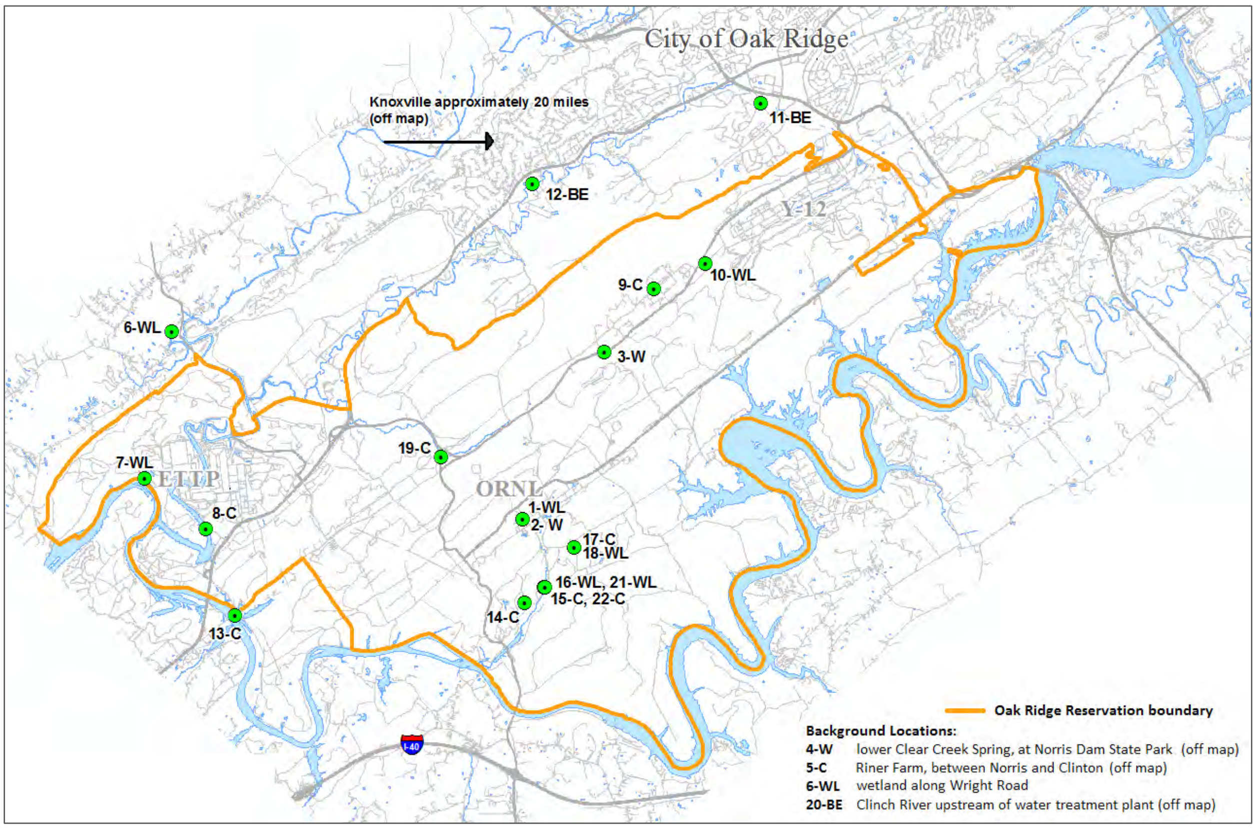

Figure 1: Location Map of Aquatic Vegetation Sites Sampled in 2013

Table 1: 2013 Vegetation Sampling Locations

1-WL	willow	ORNL Bethel Valley- First Creek
2-W	watercress	ORNL Bethel Valley- First Creek
3-W	watercress	Y-12- SS-5 Spring
4-W	watercress	Background- lower Clear Creek Spring, Norris
5-C	cattail	Background- Riner Farm Pond, Clinton
6-WL	willow	Background- Wright Road Wetland
7-WL	willow	ETTP- K-901-A Holding Pond
8-C	cattail	ETTP- K-1007 P-1 Pond
9-C	cattail	EMWMF Contact Water Release Ditch
10-WL	willow	Y-12 Bear Creek Below S-2
11-BE	box elder	East Fork Poplar Creek Bridge on Tulsa Rd
12-BE	box elder	East Fork Poplar Creek at Turtle Park
13-C	cattail	Clinch River flats near Bear Creek Rd
14-C	cattail	ORNL Melton Valley (MV)- East Seep Tributary
15-C	cattail	ORNL MV-above lower White Oak Creek Weir
16-WL	willow	ORNL MV-above lower White Oak Creek Weir
17-C	cattail	ORNL Melton Valley- HRE wetland
18-WL	willow	ORNL Melton Valley- HRE wetland
19-C	cattail	Bear Creek Rd & HWY 95 triangle wetland
20-BE	box elder	Background- Clinch River upstream of Clinton WTP
21-WL	willow	ORNL MV-above lower White Oak Creek Weir
22-C	cattail	ORNL MV-above lower White Oak Creek Weir

Results and Discussion

Radiological Analysis

The EPA does not currently regulate radionuclide levels in vegetation. The Food and Drug Administration (FDA) has established guidelines called Derived Intervention Levels (DILs) to describe radionuclide concentrations at which the introduction to protective measures should be considered (FDA 1998). These values are meant to be very protective in the case that a nuclear incident occurs and food is radioactively contaminated and are specific to certain radionuclides, and are not directly comparable to gross alpha, gross beta, and gamma activity, which were the analyses run on the vegetation samples for this project. Perhaps more useful for comparison are the background levels of radionuclides for each vegetation type and the average background levels across all vegetation types sampled this year.

The objectives of this oversight activity and study are to detect and characterize radionuclides bioaccumulated by aquatic vegetation in and near ORR surface water. Staff gathered twenty-two aquatic vegetation samples during 2013. All samples were collected in the summer and fall of 2013, from June 13th through October 8th. Table 2 provides the results of the radiochemical analysis of each sample collected, divided into three groups based on vegetation type or background levels. Table 3 presents the same results but averages the background results for the three vegetation types with background locations and compares all data to these averaged background values. The data suggest limited areas of elevated radionuclide concentrations in the aquatic vegetation on the ORR.

The yellow and blue bars shown in Table 2 for gross alpha and gross beta, respectively, are to visually assist you in seeing which values are lower and which are higher; the longer the bar, the higher the result. The cattail and box elder alpha and beta values are shown in the first part of the table, and are compared separately from the willow and watercress for both alpha and beta values. The values representing two times those seen at the background locations for each vegetation type are shown at the bottom of each table for further comparison, but since they are not actual results, they are not compared by the blue and yellow bars. Values greater than twice background are shown in bold to make them easier to find in the tables below.

Table 2: Results for Radiochemical Analysis of 2013 Vegetation Samples (pCi/g wet weight)

stn	location	gross alpha	gross beta	gamma Cs-137	K-40	Pb-212	PB-214	Bi-214	Tl-208	Be-7
5-C	**background:** Riner Farm Pond Clinton	0.04	2.6		3.10		0.189			
8-C	ETTP K-1007 P-1 Pond	0.06	1.1		3.08					
9-C	EMWMF contact water release ditch	**0.13**	2.7		3.64				0.030	
11-BE	East Fork Poplar Creek bridge on Tulsa Rd	0.02	2.4		2.09					
12-BE	East Fork Poplar Creek Turtle Park	0.03	2.4		2.08					
13-C	Clinch River flats near Bear Creek Rd	**0.15**	2.3		1.91		0.089	0.106		
14-C	ORNL Melton Valley (MV) east seep tributary	0.06	3.5		2.81					
15-C	ORNL MV above lower White Oak Creek weir	**0.29**	**11.2**	2.90	2.11					
17-C	ORNL Melton Valley HRE wetland	**3.2**	**213**		3.13					
19-C	Bear Creek and HWY 95 triangle wetland	**0.70**	**41.0**		2.31					1.76
22-C	ORNL MV above lower White Oak Creek weir	-0.04	**11.8**	1.421	1.83					
	2 x background:	0.08	5.2		6.2		0.378			

stn	location	gross alpha	gross beta	gamma Cs-137	K-40	Pb-212	PB-214	Bi-214	Tl-208	Be-7
4-W	lower Clear Creek Spring Norris	0.21	1.7		1.09		0.049			
2-W	ORNL Bethel Valley First Creek	0.17	1.8	0.130	2.16		0.044	0.062		
	2 x background:	0.42	3.4		2.18		0.098			

stn	location	gross alpha	gross beta	gamma Cs-137	K-40	Pb-212	PB-214	Bi-214	Tl-208	Be-7
6-WL	Wright Road Wetland	0.03	1.4		1.66		0.268	0.259		
1-WL	ORNL Bethel Valley First Creek	**0.21**	2.4	0.229	1.97	0.028		0.083		
7-WL	ETTP K-901-A Holding Pond	**0.07**	1.5						0.037	
10-WL	Y-12 Bear Creek below S-2	0.03	**4.0**		3.58					3.27
16-WL	ORNL MV above lower White Oak Creek weir	**0.15**	**9.3**	2.60	2.12					3.38
18-WL	ORNL Melton Valley HRE wetland	0.04	**3.1**		3.07					
21-WL	ORNL MV above lower White Oak Creek weir	-0.09	**12.8**	3.11	2.19					3.0
	2 x background:	0.06	2.8		3.32		0.536	0.518		

values greater than 2X background in bold; not detected in sample; background location

C cattail; BE box elder; WL willow; W watercress

The green and light blue bars shown in Table 3 for gross alpha and gross beta, respectively, are also to visually assist you in seeing which values are lower and which are higher; the longer the bar, the higher the result. In Table 3 though, gross alpha results for all stations are compared directly, regardless of vegetation type. The same is true for the gross beta results in Table 3. At the bottom of Table 3, the averaged results for the three background locations is given for each radiation type and isotope. The values representing two times the average background values are shown below this. Values greater than twice the average background are shown in bold to make them easier to find in Table 3. The total averages for all the non-background sites are shown below this for comparison.

Table 3: Results for Radiochemical Analysis of 2013 Vegetation Samples (pCi/g wet weight)

stn	location	gross alpha	gross beta	gamma						
				Cs-137	K-40	Pb-212	PB-214	Bi-214	Tl-208	Be-7
5-C	background: Riner Farm Pond Clinton	0.04	2.6		3.10		0.189			
4-W	background: lower Clear Creek Spring Norris	**0.21**	1.7		1.09		0.049			
6-WL	background: Wright Road Wetland	0.03	1.4		1.66		0.268	0.259		
8-C	ETTP K-1007 P-1 Pond	0.06	1.1		3.08					
9-C	EMWMF contact water release ditch	0.13	2.7		3.64				0.030	
11-BE	East Fork Poplar Creek bridge on Tulsa Rd	0.02	2.4		2.09					
12-BE	East Fork Poplar Creek Turtle Park	0.03	2.4		2.08					
13-C	Clinch River flats near Bear Creek Rd	0.15	2.3		1.91		0.089	0.106		
14-C	ORNL Melton Valley (MV) east seep tributary	0.06	3.5		2.81					
15-C	ORNL MV above lower White Oak Creek weir	**0.29**	**11.2**	2.90	2.11					
17-C	ORNL Melton Valley HRE wetland	**3.2**	**213**		3.13					
19-C	Bear Creek and HWY 95 triangle wetland	**0.70**	**41.0**		2.31					1.76
22-C	ORNL MV above lower White Oak Creek weir	-0.04	**11.8**	1.421	1.83					
2-W	ORNL Bethel Valley First Creek	0.17	1.8	0.130	2.16		0.044	0.062		
1-WL	ORNL Bethel Valley First Creek	**0.21**	2.4	0.229	1.97	0.028		0.083		
7-WL	ETTP K-901-A Holding Pond	0.07	1.5						0.037	
10-WL	Y-12 Bear Creek below S-2	0.03	**4.0**		3.58					3.27
16-WL	ORNL MV above lower White Oak Creek weir	0.15	**9.3**	2.60	2.12					3.38
18-WL	ORNL Melton Valley HRE wetland	0.04	3.1		3.07					
21-WL	ORNL MV above lower White Oak Creek weir	-0.09	**12.8**	3.11	2.19					3.0
	average background:	0.093	1.9		1.95		0.1687	0.259		
	2X average background:	0.187	3.8		3.9		0.3373	0.518		
	total average (all non-background sites):	0.305	19.19	1.7317	2.505	0.028	0.0665	0.0837	0.034	2.86

values greater than 2X background in **bold**   background location   not detected in sample

C cattail   BE box elder   W watercress   WL willow

The highest level of gross alpha activity (3.2 pCi/g) and the highest level of gross beta activity (213 pCi/g) for the 2013 aquatic vegetation sampling program were both found in the sample collected at the edge of the wetland area behind the old Homogeneous Reactor Experiment site (HRE) in ORNL's Melton Valley, the same site with the highest levels of alpha and beta contamination found in this program in 2012. In 2012, this same location yielded a sample with gross alpha activity of 2.505 pCi/g and gross beta activity of 189.38 pCi/g. However,

contamination has long been an issue at this site. A number of other sampling locations also had gross beta levels and or gross alpha levels more than twice that found at the background locations. The three locations with highest gross alpha levels in 2013 were: (17-C) the wetland behind HRE in Melton Valley, (19-C) the wetland at the junction of Highway 95 and Bear Creek Road, and (15-C) at First Creek above the Central Ave. bridge at the west end of the ORNL campus. The seven locations with the highest gross beta levels in 2013 (and those with values greater than twice background) were: (17-C) the wetland behind HRE in Melton Valley, (19-C) the wetland at the junction of Highway 95 and Bear Creek Road, two samples taken at different times of the year at (21-WL) above the lower White Oak Creek weir in Melton Valley, (22-C) also taken above the lower White Oak Creek weir in Melton Valley but across the creek, and (10-WL) taken at Y-12 on Bear Creek below S-2. These can all be seen in Table 3. Of the gamma radionuclides seen in the various samples, the most interesting is the Cs-137 as it is not normally seen in nature, except in small amounts due to nuclear testing and some nuclear accidents. In fact, the sites where it was seen were First Creek above the Central Avenue bridge at the west end of the ORNL campus and above the lower White Oak Creek weir in Melton Valley; both locations also exhibited elevated gross alpha and or gross beta contaminant levels.

The 2012 vegetation results are provided in Table 4 for comparison to the 2013 results, though some different locations were sampled each year. Some of the locations were sampled both years though such as the wetland behind HRE, First Creek at ORNL, White Oak Creek weir in Melton Valley, and the S-2 wetland on Bear Creek at Y-12. These were some of the sites with the most elevated results in 2013. While there may appear to be some natural attenuation at some of the sampling sites, it can be hard to tell from only taking one sample a year. While the gross alpha and gross beta results for watercress from First Creek at ORNL seem to have decreased, this could be indicative of greater rainfall and thus greater dilution of the contaminants, the removal of the source of the radiological contaminants (the Corehole 8/Tank W-1A area was remediated), or natural attenuation, it could also have just been a low result.

There are various complicating factors in trying to interpret the data from a sampling project like this. Complicating factors include: only having one sample per location so that variation is not completely accounted for; that the vegetation could be at different stages of development, even if sampled at the same time of year; the time of the sampling could be different; the amount of precipitation just before collection and throughout the growing season; and the type of vegetation could affect the result as certain types of vegetation are better bioaccumulators for various contaminants. Also, having more than one type of vegetation in an area could allow another vegetation type that is not being sampled to preferentially absorb the contaminant of interest so that it would not be detected in the vegetation sampled or at least in lower concentrations than expected based on the levels of contamination present. Many of these variables are difficult to control for, especially with a limited number of samples and types of sampling media. A modest effort was made this year to get a better understanding on a couple of these variables. First, a number of different types of vegetation were sampled, usually with a corresponding background location. A quick survey with radiological instruments was also conducted at one of the sites with the most elevated gross alpha and beta results to determine if one vegetation type seemed to be accumulating more radioactive contamination. This quick survey seemed to indicate that cattails were very effective bioaccumulators, but they were not always present for sampling at all locations. Another method used this year was to sample a couple of vegetation types at one

location for comparison. Again, this test could be complicated by one vegetation type outcompeting the other for the contaminant in question. It could also be misleading if one vegetation type is located slightly closer to the source of the contamination or receives a different flow of water or sediments containing the contamination, had roots at different depths, accumulates certain contaminants but not others, among other issues. Sampling two vegetation types in one area was done four times this year. This was done at First Creek at ORNL with willow and watercress (1-WL and 2-W), where the willow appeared to be the better bioaccumulator. At the ORNL Melton Valley wetland behind HRE, the cattail sample showed significantly more gross beta and gross alpha contamination than the willow sample. Two of the nearby sampling types were sampled twice each in 2013. This was done at the site above the lower White Oak Creek weir in Melton Valley on July 23 (15-C and 16-WL) and October 8 (22-C and 21-WL). The sampling locations were across White Oak Creek from each other and one was a cattail sampling location and the other a willow sampling location. The results appeared to be similar between the two times of year but with the gross beta results being a little higher in the fall and the gross alpha results being a little higher in the summer. The cattails appeared to bioaccumulate more gross alpha and more gross beta in the summer, while the willow showed greater bioaccumulation for gross beta in the fall. Again, there are many complicating factors and not much data for comparison.

Table 4: Results for Radiochemical Analysis of 2012 Vegetation Samples (pCi/g wet weight)

	site	gross α	gross β	K-40	Pb-214	Bi-214	Cs-137	Pb-212
W-1	Norris Municipal Watershed spring	0.479	2.990	3.22	0.056	0.087		
W-2	SS-5	0.356	2.241	2.54	**0.269**	**0.251**		
W-3	1st Creek above Central Ave bridge	0.612	**6.640**	2.35		0.058	0.382	0.044
	2x background:	0.958	5.98	6.44	0.112	0.174		

	site	gross α	gross β	K-40	Pb-214	Bi-214	Cs-137	Co-60	Tl-208	Pb-212	Be-7
C-1	Pond on Riner Farm	0.531	2.890	4.30							
C-2	SS-7 area	0.270	4.310	3.60	0.322	0.35			0.048		
C-3	wetland behind HRE	**2.505**	**189.38**	2.26							
C-4	K-1007 Pond 1, outfall 490	-0.024	**15.76**	2.04	0.113	0.153				0.071	
C-5	Mitchell Branch downstream of CNF	0.084	2.160	3.06					0.079		
C-6	above Melton Branch weir	0.172	**6.100**		0.199	0.297				0.068	
C-7	above lower White Oak Creek weir	**1.49**	**37.35**	4.33	0.71	0.73	57.30				
C-8	above old weir at MVHR mile 2.6	0.75	**44.81**	5.65	0.31		0.48	0.746		0.201	
C-9	Union Valley cattail spring	0.220	2.647	3.72		0.072				0.060	0.53
C-10	NT-3 between BYBY and EMWMF	0.568	4.627	3.96	0.169	0.176					0.81
C-11	wetland downstream of S-2	0.87	**6.0**	3.06		0.079					
	2x background:	1.062	5.78	8.6							

values greater than 2x background in bold; not detected in sample; background location

Metals Analysis

Metals analysis was completed for up to three metals (strontium, uranium, mercury) for samples 1 through 20. Only the October resampling of the locations above the lower White Oak Creek weir in Melton Valley did not receive any metals analysis. The rest of the samples were analyzed for mercury and uranium metals, with the only exception being no analysis for uranium at the background location for box elder along the Clinch River in Clinton, well upstream of the Oak Ridge Reservation (ORR). Strontium analysis was performed at sites where strontium contamination was thought to be the most probable. Testing for mercury was done because of the great interest in mercury contamination from Y-12 and the potential for mercury contamination to be present at any of the sites on the ORR. Also, in the 2010 EMR, there were elevated levels of mercury reported in some deer browse samples. The metals analysis for strontium and uranium was done to see if those results could be used to indicate if contamination was present and further analysis warranted. The results of the 2013 metals sampling effort can be seen in Table 5. The red and blue bars shown in Table 5 for strontium and mercury, respectively, are to visually assist you in seeing which values are lower and which are higher; the longer the bar, the higher the result.

While seemingly high values of strontium were seen at a number of the locations, this was also true for two of the background locations. While the two highest strontium metal results, 40 mg/kg at EMWMF and 47 mg/kg at the Clinch River flats near Bear Creek Rd, may actually have elevated levels of strontium-90 contributing to the overall reported strontium values, it appears that strontium metals analysis is a poor indicator of potential strontium-90 contamination.

The uranium metals results also didn't seem to indicate that this type of analysis would be very useful as an indicator of non-natural uranium, though it still could be. The value of 0.24 mg/kg at the background station at Norris (4-W) seems suspect unless watercress is an exceptionally good at accumulating uranium or if that background location is exposed to geology with higher levels of natural uranium. Regardless, the elevated value of 14.0 mg/kg for uranium metal at the SS-5 spring in Y-12's Bear Creek Valley does seem to indicate that further sampling of the water or sediments for uranium contamination is likely warranted.

The mercury results were interesting in that most of them were below quantifiable amounts but above detection limits, but all the results were well below the EPA screening value of 0.30 mg/kg. This screening value is used for fish consumption advisories though, not vegetation as there do not appear to be regulatory limits for mercury in vegetation. Of interest are the locations where mercury was clearly detected in the vegetation. Unsurprisingly, four of these locations were located downstream from Y-12, with the highest value again from the SS-5 spring in Y-12's Bear Creek Valley. In the 2010 deer browse study done at this office, younger more tender vegetation was used. This seems worthy of some mercury sampling comparing various ages and types of vegetation in 2014.

Table 5: Results for Metals Analysis of 2013 Vegetation Samples (mg/kg)

stn	media	location	Metals: strontium	Metals: uranium	Metals: mercury
20-BE	box elder	background: Clinch River upstream of Clinton WTP			J
11-BE	box elder	East Fork Poplar Creek bridge on Tulsa Rd		U	0.047
12-BE	box elder	East Fork Poplar Creek Turtle Park		U	0.035

stn	media	location	Metals: strontium	Metals: uranium	Metals: mercury
5-C	cattail	background: Riner Farm Pond Clinton	33	U	J
8-C	cattail	ETTP K-1007 P-1 Pond		U	J
9-C	cattail	EMWMF contact water release ditch	40	U	J
13-C	cattail	Clinch River flats near bear creek rd	47	0.058	J
14-C	cattail	ORNL Melton Valley (MV) east seep tributary	24	U	J
15-C	cattail	ORNL MV above lower White Oak Creek weir	27	J	0.044
17-C	cattail	ORNL Melton Valley HRE wetland	26	U	J
19-C	cattail	Bear Creek and HWY 95 triangle wetland		U	J

stn	media	location	Metals: strontium	Metals: uranium	Metals: mercury
4-W	watercress	background: lower clear creek spring Norris	37	0.24	J
2-W	watercress	ORNL Bethel Valley First Creek	14	U	J
3-W	watercress	Y-12 SS-5 Spring		14	0.08

stn	media	location	Metals: strontium	Metals: uranium	Metals: mercury
6-WL	willow	background: Wright Road Wetland	17	U	J
1-WL	willow	ORNL Bethel Valley First Creek	17	U	J
7-WL	willow	ETTP K-901-A Holding Pond		U	0.020
10-WL	willow	Y-12 Bear Creek below S-2		0.25	0.034
16-WL	willow	ORNL MV above lower White Oak Creek weir	16	U	U
18-WL	willow	ORNL Melton Valley HRE wetland	14	U	J

J detected, not quantifiable; U Undetected; (grey) no analysis requested

Conclusions

The data collected suggests limited areas of elevated radionuclide concentrations in the aquatic vegetation on the ORR. The metals analysis indicated some areas of potential concern and the need for further analysis. Future sampling activities will focus on identifying areas of concern within the ORR to evaluate the potential for bioaccumulation of radionuclides in vegetation from the surface waters of the ORR. Areas with previously elevated sampling results will be evaluated to determine if natural attenuation is occurring. Sampling for Mercury contamination will be continued in 2014, focusing along East Fork Poplar Creek and Bear Creek downstream of Y-12 and along White Oak Creek at ORNL.

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Oak Ridge Reservation Threatened and Endangered Species Monitoring (2013)

Abstract

Protection of threatened, endangered and rare species in their natural habitat is a major priority to enable their long-term survival and provide effective stewardship of natural resources on the US Department of Energy's (DOE) Oak Ridge Reservation (ORR). In support of this mission, the Tennessee Department of Environment and Conservation, DOE-Oversight Office, Division of Remediation (TDEC DOE-O) provided monitoring, mapping, inventory and oversight of natural resources (flora and fauna), review of DOE environmental documents, and conducted field assessments of threatened, endangered and rare plant and animal species. Another goal is documentation and mapping of pest-plant invasion areas on the ORR for future eradication efforts. Staff of TDEC DOE-O lends field biology assistance to the Resource Management Division (Natural Areas Program, Bureau of Parks and Conservation) and the Tennessee Wildlife Resources Agency (TWRA) for T&E/Rare Species mapping and inventory at ORR natural areas and TWRA-managed sites [i.e., Black Oak Ridge Conservation Easement (BORCE) and the Three Bends Area]. The Tennessee Oversight Agreement mandates a comprehensive and integrated monitoring and surveillance program for all media (i.e., air, surface water, soil sediments, groundwater, drinking water, food crops, fish and wildlife, and biological systems) and the emissions of any materials (hazardous, toxic, chemical, radiological) on the ORR and environs. Accordingly, during 2013, TDEC DOE-O staff mapped plant species diversity on trails and off-trail areas of the BORCE and sections of the ORR. An important highlight of 2013 was the capture of a male Indiana Bat (*Myotis sodalis*) by an ORNL/UT team during mist-netting activities at Freels Bend. This is the first confirmed documentation of the federally endangered *M. sodalis* on the ORR since 1950.

Introduction

The Oak Ridge Reservation was acquired by the federal government in the 1940s, and approximately 25,000 acres have remained undeveloped in a relatively natural state (Mitchell et al. 1996). Approximately 20,000 acres of the Reservation have been designated a DOE National Environmental Research Park, an International Biosphere Reserve, and part of the Southern Appalachian Man and the Biosphere Cooperative (Baranski 2009).

The ORR's diverse plant and animal life is situated in a relatively intact ecosystem that is highly diverse when compared with surrounding areas in the same physiographic province (Mann et al. 1996). The ORR, consisting of the Oak Ridge National Environmental Research Park and associated lands surrounding DOE facilities at Oak Ridge, Tennessee, is about 15,000 ha of mostly contiguous native forest in the valley and ridge province (Mann et al. 1996). Additional ORR geomorphic and topographic features supporting rare plant communities include wetlands; karst features (caves), rocky bluffs, limestone cedar barrens, and an area of old growth forest. About 70% of the ORR is in forest cover and less than 2% remains as open agricultural fields. Communities are generally characteristic of the intermountain regions of Appalachia (Mann et al. 1996). Oak-hickory forest, which is most widely distributed on ridges and dry slopes, is the dominant association. Minor areas of other hardwood forest cover types are found throughout the ORR; these include northern hardwoods, a few small natural stands of hemlock or white pine, and floodplain forests (Mann et al. 1996). There are numerous TDEC-designated natural areas on the ORR.

Approximately 25 miles of greenway trails are available for hiking, running and bicycling on the Black Oak Ridge Conservation Easement (BORCE, Figure 1) which consists of about 3000 acres of mainly forested uplands including the Dyllis Orchard greenway trail (opened to the public in October 2007). The 3,000 acre site is subdivided into three main management units: (1) the natural area section situated north of the ED-1 industrial park site known as the East BORCE area (Figure 2) which includes ~1,300 acres, (2) the area north of the ETTP known as the West BORCE area (Figure 3) which includes ~1,500 acres, and (3) the McKinney Ridge section with ~230 acres. The north, east and west perimeter of the EBOR is a former patrol gravel road that is known as the North Boundary Greenway trail.

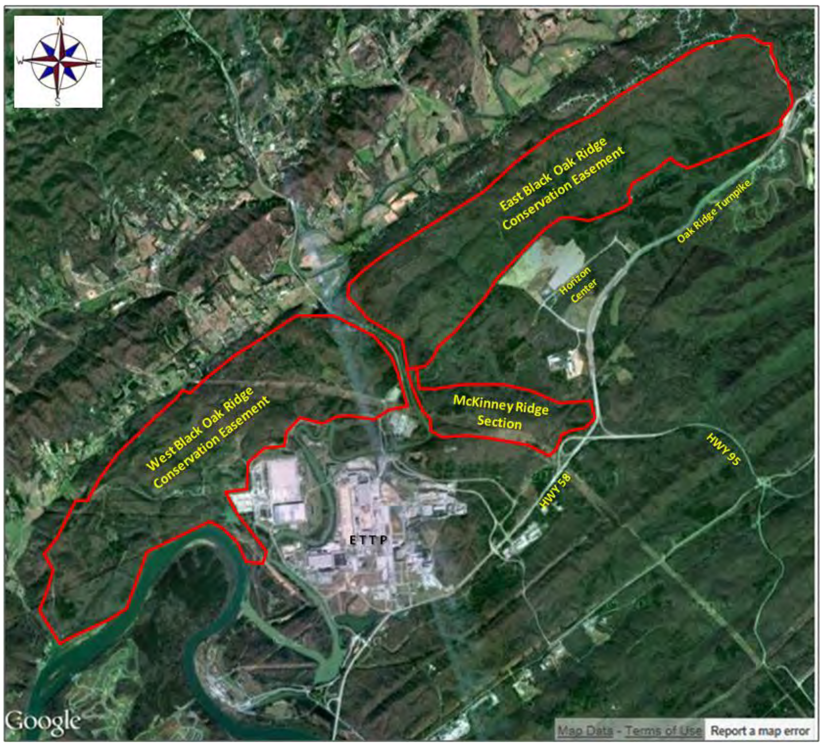

Figure 1: Black Oak Ridge Conservation Easement (BORCE, 3,000 acres; red line approx. BORCE boundary).

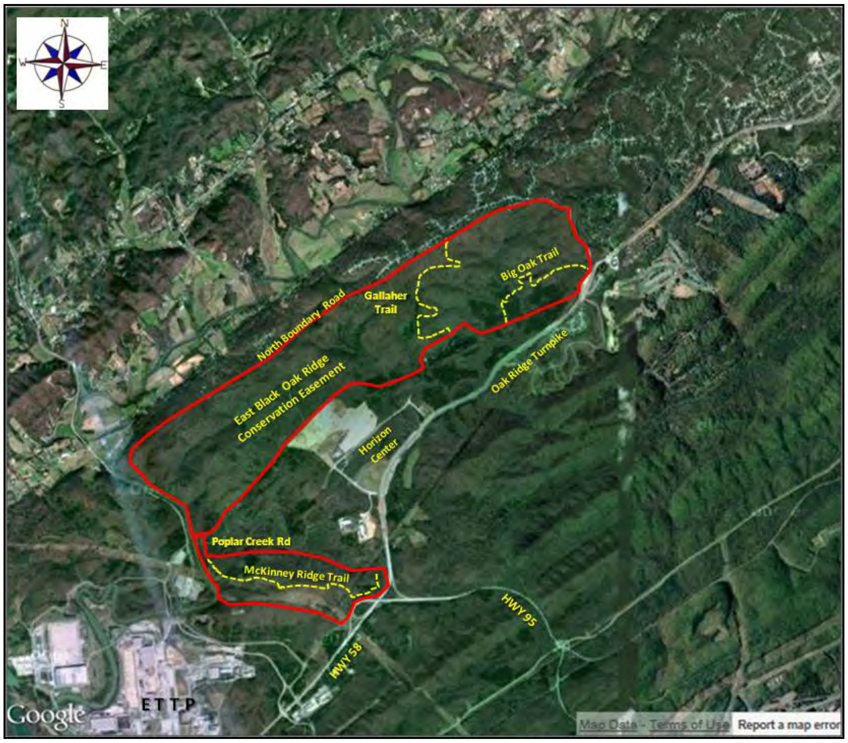

Figure 2: East BORCE (+ McKinney Ridge) and trails surveyed (yellow dashed lines) during 2012 for rare plant species.

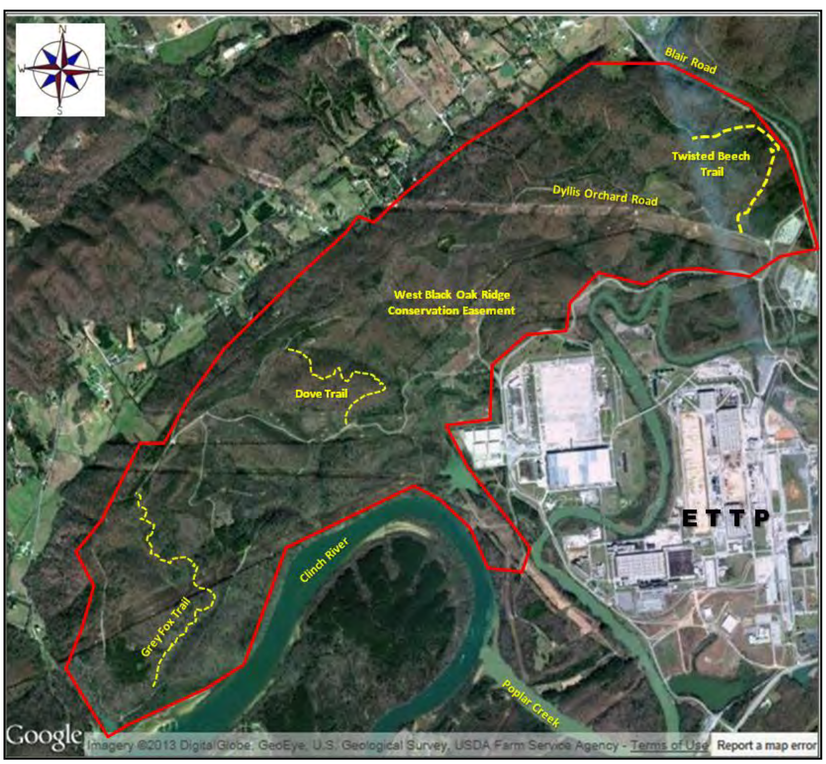

Figure 3: West BORCE and trails surveyed (yellow dashed lines) during 2012 for rare plant species.

Objectives

- Monitor and map populations of state- and federally-listed threatened and endangered plant and animal species (i.e., T&E species) on the BORCE and ORR
- Characterize and document presence of sensitive plant populations (non-listed species) on the BORCE and ORR
- Coordinate T&E species field projects with sister Tennessee agencies such as the TDEC Division of Natural Areas (TDEC DNA) and the Tennessee Wildlife Resources Agency (TWRA)
- Report Oak Ridge Reservation T&E field results to the US Department of Energy (US DOE) and the US Fish and Wildlife Service (USFWS)
- Protect and preserve the biodiversity of the ORR

The project incorporated the division's oversight role of environmental surveillance and monitoring. Additionally, several federal and state laws support this effort: (1) the federal Endangered Species Act of 1973 (ESA), as amended, provides for the inventory, listing, and protection of species in danger of becoming extinct and/or extirpated, and conservation of the habitats on which such species thrive, (2) the National Environmental Policy Act (NEPA), requires that federally-funded projects avoid or mitigate impacts to listed species, (3) the Tennessee Rare Plant Protection and Conservation Act of 1985 (Tennessee Code Annotated Title 11-26, Sects. 201-214), provides for a biodiversity inventory and establishes the State list of endangered, threatened, and special concern taxa, (4) Natural Resource Damage Assessments (NRDA) as directed by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980, as amended by SARA (Superfund Amendments and Reauthorization Act of 1986), relating to damages to natural resources on the ORR.

This report consists of two main sections: (1) ORR fauna, and (2) ORR flora.

I. ORR Fauna

Currently, there are 21 federally-listed vertebrate and invertebrate species in Anderson and Roane counties (Table 1), home of the Oak Ridge Reservation. Of these species, there are 17 molluscs, 3 fish, and 1 mammal. Also, there are an additional 48 vertebrate and invertebrate species listed by the state of Tennessee for Anderson and Roane as either threatened (*n*= 6), endangered (*n*= 20), or deemed in need of management (*n*= 22, Table 1). Tennessee also lists 12 species as "rare, not state listed". Several raptors are listed as deemed in need of management such as the bald eagle, barn owl, and the sharp-shinned hawk. The bald eagle (*Haliaeetus leucocephalus*) was officially removed from the federally threatened list on August 8, 2007. Eagles continue to be protected by the 1940 Bald and Golden Eagle Protection Act and the 1918 Migratory Bird Treaty Act. Bald eagles are occasionally sighted on the ORR, and a breeding pair was nesting adjacent to Poplar Creek in the vicinity of the ETTP during 2011-2012.

VERTEBRATE AND INVERTEBRATE SPECIES OF ANDERSON/ROANE COUNTIES, TENNESSEE**					
Common Name	Scientific Name	Category	Fed. Status	State Status	Habitat
Alabama Lampmussel	Lampsilis virescens	Mollusc	LE	E	Shoal sand & gravel substrates of small-med rivers
Allegheny Woodrat	Neotoma magister	Mammal	--	D	Outcrops, cliffs, talus, crevices, sinkholes, caves
Anthony Riversnail	Athearnia anthonyi	Mollusc	LE,XN	E	Large rivers/creeks, on cob/boul substrates adj. riffles
Ashy Darter	Etheostoma cinereum	Fish	--	T	Small to med rivers with bedrock/gravel & boulders
Bachman's Sparrow	Aimophila aestivalis	Bird	--	E	Dry open pine/oak woods; dense ground cover nests
Bald Eagle	Haliaeetus leucocephalus	Bird	--	D	Large bodies of water; sheltered roosts in winter
Barn Owl	Tyto alba	Bird	--	D	Open & partly open country; farms
Bewick's Wren	Thryomanes bewickii	Bird	--	E	Brushy areas, thickets/scrub in open & riparian wood
Berry Cave Salamander	Gyrinophilus gulolineatus	Amphibian	--	T	Aquatic cave obligate; Ridge & Valley
Birdwing Pearlymussel	Lemiox rimosus	Mollusc	LE	E	Small-med size rivers in riffles w/ sand & gravel
Black Mountain Salamander	Desmognathus welteri	Amphibian	--	D	Spring runs & perm. streams in wooded mountains
Blue Sucker	Cycleptus elongatus	Fish	--	T	Swift waters over firm substrates in big rivers
Cave Obligate Isopod	Amergoniscus nicholasi	Crustacean	--	Rare, Not State Listed	Terrestrial cave obligate; known from 2 caves
Cave Spider	Nesticus paynei	Arachnid	--	Rare, Not State Listed	Terrestrial cave associate; also found on surface
Cerulean Warbler	Dendroica cerulea	Bird	--	D	Mature deciduous forest, floodplains or mesic
Cinereus Shrew	Sorex cinereus	Mammal	--	D	Rich woodlands of many types; open fields
Cracking Pearlymussel	Hemistena lata	Mollusc	LE	E	Med-sized rivers buried in mud/sand/gravel/cobble
Dromedary Pearlymussel	Dromus dromas	Mollusc	LE	E	Med-large rivers w/ riffles & shoals
Eastern Slender Glass Lizard	Ophisaurus attenuatus longicaudus	Reptile	--	D	Dry upland areas (brushy & grassy fields); fossorial
Emerald Darter	Etheostoma baileyi	Fish	--	D	Creeks & small rivers w/ riffles of gravel or rubble
Fanshell	Cyprogenia stegaria	Mollusc	LE	E	Medium to large streams/rivers w/ sd/grav substrates
Finerayed Pigtoe	Fusconaia cuneolus	Mollusc	LE	E	Riffles of fords & shoals of mod grad streams
Flame Chub	Hemitremia flammea	Fish	--	D	Springs & spring-fed streams with lush aquatic veg
Four-toed Salamander	Hemidactylium scutatum	Amphibian	--	D	Woodland swamps/depressions/sphagnum/acid soils
Golden-winged Warbler	Vermivora chrysoptera	Bird	--	D	Early success'l habitats in Appalac. foothill regions
Gray Myotis	Myotis grisescens	Mammal	LE	E	Cave obligate all yr; likes forested areas; migratory
Green Salamander	Aneides aeneus	Amphibian	--	Rare, Not State Listed	Damp crevices in shaded ledges; beneath loose bark
Hellbender	Cryptobranchus alleganiensis	Amphibian	No Status	D	Rocky, clear creeks & rivers with large shelter rocks
Heron Rookery	Heron rookery	Rookery	--	Rare, Not State Listed	No Data
Incurved Cave Isopod	Caecidotea incurva	Crustacean	--	Rare, Not State Listed	Aquatic cave obligate; known fr 2 wet caves in E. TN
Long-tailed Shrew	Sorex dispar	Mammal	--	D	Mountainous, forested areas with loose talus
Meadow Jumping Mouse	Zapus hudsonius	Mammal	No Status	D	Open grassy fields; thick vegetation near water
Northern Pinesnake	Pituophis melanoleucus melanoleucus	Reptile	--	T	Sandy soils in pine-oak woods; dry mountain ridges
Orangefoot Pimpleback	Plethobasus cooperianus	Mollusc	LE	E	Large rivers in sd-grav-cobble substr in deep water
Payne's Cave Beetle	Pseudanophthalmus paynei	Insect	--	Rare, Not State Listed	Terrestrial cave obligate; no. R&V prov; Anderson Co.
Pink Mucket	Lampsilis abrupta	Mollusc	LE	E	Generally large river species, w/ mod-strong currents
Purple Bean	Villosa perpurpurea	Mollusc	LE	E	Creeks to med-sized rivers, headwaters, in riffles
Pyramid Pigtoe	Pleurobema rubrum	Mollusc	--	Rare, Not State Listed	Rivers with strong current & firm sand/gravel substr
Ring Pink	Obovaria retusa	Mollusc	LE	E	Large rivers in gravel/sand bars; many sites inundat'd
Rough Pigtoe	Pleurobema plenum	Mollusc	LE	E	Med-large rivers in sd, grav, & cob substr of shoals
Rough Rabbitsfoot	Quadrula cylindrica strigillata	Mollusc	LE	E	Small-med sized rivers, clear, shallow riffles; upland
Sharp-shinned Hawk	Accipiter striatus	Bird	No Status	D	Forests & open woodlands.
Sheepnose	Plethobasus cyphyus	Mollusc	LE	Rare, Not State Listed	Lrge to med-sized rivers, in riffles w/coarse sd/grav
Shiny Pigtoe	Fusconaia cor	Mollusc	LE	E	Shoals/riffles of sm-med rivers w/ mod-fast current
Slender Chub	Erimystax cahni	Fish	LT	T	Major headwater tribs to TN River/ swift-mod currents
Smoky Shrew	Sorex fumeus	Mammal	--	D	Damp wooded areas include'g conifer/mixed forests
Southeastern Shrew	Sorex longirostris	Mammal	--	D	Habitats: wet meadows, damp woods, & uplands
Southern Bog Lemming	Synaptomys cooperi	Mammal	--	D	Marshy meadows, wet balds, & rich upland forests
Spectaclecase	Cumberlandia monodonta	Mollusc	LE	Rare, Not State Listed	Med to large rivers; mud/sand/grav/cobble/bould
Spiny Riversnail	Io fluvialis	Mollusc	--	Rare, Not State Listed	Shallow waters of shoals that are well-oxygenated
Spotfin Chub	Erimonax monachus	Fish	LT,XN, PXN	T	Clear upland rivers with swift currents & boulders
Swainson's Warbler	Limnothlypis swainsonii	Bird	--	D	Mature, rich, damp, decid floodpl & swamp forests
Tangerine Darter	Percina aurantiaca	Fish	--	D	Large-mod headwater tribs to Tenn River/clear pools
Tennessee Dace	Phoxinus tennesseensis	Fish	--	D	1st order spring-fed streams of woodlands in R&V lime
Tiny Cave Beetle	Pseudanophthalmus pusillus	Insect	--	Rare, Not State Listed	Terrestrial cave obligate; northern Ridge & Valley
Valley Flame Crayfish	Cambarus deweesae	Crustacean	--	E	Primary burrower; open areas with high water tables
Wallace's Cave Beetle	Pseudanophthalmus wallacei	Insect	--	Rare, Not State Listed	Terrestrial cave obligate; Ridge & Val; Anderson Co.
White Wartyback	Plethobasus cicatricosus	Mollusc	LE	E	Presumed to inhabit river shoals & riffles; very rare
Woodland Jumping Mouse	Napaeozapus insignis	Mammal	--	D	Deciduous & coniferous forests with herbaceous cover
Yellowfin Madtom	Noturus flavipinnis	Fish	LT,XN	E	Med size to large creeks & small rivers
**Source: TDEC Division of Natural Areas Accessed 2-29-2013 http://www.tn.gov/environment/na/data.shtml					

Table 1: Vertebrate and Invertebrate Species of Anderson & Roane Counties, TN

The Tennessee Department of Environment and Conservation Division of Natural Areas (TDEC-DNA) lists 8 mammal species as "deemed in need of management": Allegheny woodrat, Cinereus shrew, Long-tailed shrew, Meadow jumping mouse, Smoky shrew, Southeastern shrew, Southern bog lemming, and the Woodland jumping mouse; the Gray Bat is listed by TDEC-DNA as endangered.

Previously, the single federally-listed mammal species known to occur on the ORR was the Gray Bat (*Myotis grisescens*, federally-endangered). However, during the summer of 2013, an ORNL/UT team captured a male Indiana Bat during mist-netting activities at Freels Bend (*Myotis sodalis*). This is the first time since 1950, that a federally-endangered Indiana bat has been confirmed and documented on the ORR.

For additional information regarding 2013 ORR bat studies, see TDEC report: *Acoustic Monitoring of Bat Echolocation Calls on the Oak Ridge Reservation (Pilot Study) 2013 Environmental Monitoring Report* (TDEC 2014), and the ORNL Environmental Sciences Division report: *Bat Summer Report for ORNL: Bat Species Distribution on the Oak Ridge Reservation with Emphasis on the Endangered Indiana Bat, Summer 2013* (McCracken et al. 2013).

II. ORR Flora

Methods

Previous vascular plant investigations have covered much of the ORR (Awl et al. 1996), but some areas of the BORCE remain unmapped. During the spring and summer of 2013, TDEC conducted field botany excursions on trails and backcountry sections of the BORCE. Geomorphic habitats such as small drainage ravines, floodplains, wetlands, watersheds, cedar barrens, rock outcroppings, cliffs, and karst features (springs, caves, sinkholes) were surveyed for rare plant taxa. Field locations of rare plants were mapped and located using a Global Positioning System (GPS) hand-held field unit (Garmin®). Using a grid system based on 10-meter centers, the plan was to identify all plant taxa in the forest canopy, subcanopy, shrub, herbaceous, and groundcover layers. Photographs of plants were taken to document sensitive communities and rare species. Field monitoring methods and health and safety procedures generally followed the guidelines in the TDEC DOE-O Health, Safety, and Security Plan (Yard 2010).

Vascular plant identifications required the use of the following sources and taxonomic keys: Radford et al. (1968), Prescott (1980), Cobb (1984), Lellinger (1985), Wofford (1989), Gleason & Cronquist (1991), Chester et al. (1993), Chester et al. (1997), Holmgren et al. (1998), Smith (1998), Carman (2001), Wofford & Chester (2002), and Weakley (2007).

Results

The 2013 TDEC DOE-O field staff re-surveyed and characterized sections of the BORCE exhibiting rich diversity of species observed on woodland trails (i.e., Big Oak trail, Gallaher trail, McKinney Ridge trail, Twisted Beech trail, Dove trail, Gray Fox trail) and off-trail areas. For the protection of natural resources, specific locations of plant species will not be listed in this report, but we herein present a virtual tour of species identified and documented during 2013 (Figures 4-76). Note that some previously recorded species may be included in this new report. Results of the botanical survey are presented in Table 3 which lists plant species, their respective scientific names, and, if applicable, their state and federal status. A total of 38 species were identified including 12 ferns, 1 tree (American chestnut sprouts), 3 shrubs, and 22 herbaceous plants. Of these, 9 are state-listed species and 1 is federally-listed. Thus the majority of plants that were documented during 2013 are non-T&E species, but collectively represent the tremendous importance of floral diversity present on the ORR.

2012 FLORA DOCUMENTED ON THE BLACK OAK RIDGE CONSERVATION EASEMENT				
Common Name	**Scientific Name**	**Family / Group**	**Fed. Status**	**State Status**
American chestnut (sprouts)	Castanea dentata	Fagaceae		
American ginseng	Panax quinquefolius	Araliaceae		S-CE
Appalachian bugbane	Cimicifuga rubifolia	Ranunculaceae		T
Bee balm	Monarda sp.	Lamiaceae		
Broad beech fern	Phegopteris hexagonoptera	Pteridophyte		
Canada lily	Lilium canadense	Liliaceae		T
Cinnamon fern	Osmunda cinnamomea	Pteridophyte		
Cliffbrake fern	Pellaea atropurpurea	Pteridophyte		
Climbing fern	Lygodium palmatum	Pteridophyte		
Doll's eyes / White baneberry	Actaea pachypoda	Ranunculaceae		
Dutchman's breeches	Dicentra cucullaria	Fumariaceae		
False foxglove	Aureolaria sp.	Scrophulariaceae		
Goldenseal	Hydrastis canadensis	Flowering Plant		S-CE
Grapefern	Botrychium sp.	Pteridophyte		
Ground cedar	Lycopodium sp.	Pteridophyte		
Hart's-tongue fern	Asplenium scolopendrium var. americanur	Pteridophyte	LT	E
Indian pink	Spigelia marilandica	Loganiaceae		
Indian physic	Porteranthus stipulatus	Rosaceae		
Indian pipes	Monotropa uniflora	Monotropaceae		
Maidenhair fern	Adiantum pedatum	Pteridophyte		
Mountain laurel	Kalmia latifolia	Ericaceae		
Mountain mint	Pycnanthemum sp.	Lamiaceae		
Netted chain fern	Woodwardia areolata	Pteridophyte		
New Jersey tea	Ceanothus americanus	Rhamnaceae		
Passion flower	Passiflora incarnata	Passifloraceae		
Pink lady's-slipper	Cypripedium acaule	Flowering Plant		S-CE
Pinkster-bloom	Rhododendron nudiflorum	Ericaceae		
Royal fern	Osmunda regalis	Pteridophyte		
Sensitive fern	Onoclea sensibilis	Pteridophyte		
Showy orchis	Galearis spectabilis	Orchidaceae		
Slender Blazing-star	Liatris cylindracea	Flowering Plant		T
Tall Larkspur	Delphinium exaltatum	Flowering Plant		E
Trailing arbutus	Epigaea repens	Ericaceae		
Trillium	Trillium sp.	Liliaceae		
Tubercled rein-orchid	Platanthera flava var. herbiola	Flowering Plant		T
Walking fern	Asplenium rhizophyllum	Pteridophyte		
White turtlehead	Chelone glabra	Scrophulariaceae		
Yellow aster	Helianthus sp.	Asteraceae		

Table 3: Results for plants documented on the BORCE during 2013

I. CRYPTOGAMS (NON-SEED, SPORE-PRODUCING PLANTS) FERN / FERN ALLY SECTION

Figure 4: Adders-tongue Fern
Credit: TDEC/DOEO (G. Middleton)
Insert: D. Fenwick 2014

Figure 5: Grape Fern (*Botrychium* sp.)
Credit: TDEC/DOEO (G. Middleton)
Insert: S. J. Baskauf 2004

Figure 6: Lady Fern (*Athyrium filix-femina* ssp. *asplenioides*)
Credit: TDEC/DOEO photo (G. Middleton)
Insert: UTK Herbarium (M. Evans)

Figure 7: Netted-chain Fern
Credit: TDEC/DOEO (G. Middleton)

Figure 8: New York Fern
Credit: TDEC/DOEO (G. Middleton)
Insert: Cortland.edu/broyles/fern-guide

Figure 9: Maidenhair fern
Credit: TDEC/DOEO (G. Middleton)

Figure 10: Cliffbrake fern
Credit: TDEC/DOEO (G. Middleton)

Figure 11: Royal fern
Credit: TDEC/DOEO (G. Middleton)

Figure 12: Broad beech fern
Credit: TDEC/DOEO (G. Middleton)

Figure 13: Ground cedar
Credit: TDEC/DOEO (G. Middleton)

Figure 14: Christmas Fern
Credit: TDEC/DOEO (G. Middleton)

Figure 15: Bulblet Bladder Fern
Credit: TDEC/DOEO (G. Middleton)
Insert: UTK Herbarium (M. Evans)

Figure 16: Climbing fern
Credit: TDEC/DOEO (G. Middleton)

Figure 17: Sensitive Fern
Credit: TDEC/DOEO (G. Middleton)
Insert: J. K. Marlow

Figure 18: Glade Fern (*Diplazium*)
Credit: TDEC/DOEO (G. Middleton)
Insert: UTK Herbarium (M. Evans)

Figure 19: Walking Fern
Credit: TDEC/DOEO (G. Middleton)
Insert: UTK Herbarium (M. Evans)

Figure 20: Resurrection Fern
Credit: TDEC/DOEO (G. Middleton)

Figure 21: Spleenwort (*Asplenium*)
Credit: TDEC/DOEO (G. Middleton)

Figure 22: Shining Clubmoss
Credit: TDEC/DOEO (G. Middleton)

Figure 23: Goldie's Wood Fern
Credit: TDEC DOEO /UTK Herbarium

Figure 24: Marginal Wood Fern
Credit: UTK Herbarium (M. Evans)

Figure 25: British Soldier Lichens (*Cladonia*)
Credit: TDEC/DOEO (G. Middleton)
Insert: allofnature.com

II. PHANEROGAMS—FLOWERING SEED PLANTS (ANGIOSPERMS / SPERMATOPHYTES):

Figure 26: Rattlesnake Plantain
Credit: TDEC/DOEO (G. Middleton)

Figure 27: New York Ironweed
Credit: TDEC/DOEO (G. Middleton)
Insert: Delaware Wildflowers (D. Smith)

Figure 28: Dolls Eyes (White Baneberry)
Credit: TDEC/DOEO (G. Middleton)

Figure 29: Large-flowered Trillium
Credit: TDEC/DOEO (A. Robinson)

Figure 30: Yellow Trillium
Credit: TDEC/DOEO (A. Robinson)

Figure 31: Southern Red Trillium
Credit: TDEC/DOEO (A. Robinson)

Figure 32: Thimbleweed (*Anemone*)
Credit: TDEC/DOEO (G. Middleton)

Figure 33: Cardinal Flower (*Lobelia*)
Credit: TDEC/DOEO (G. Middleton)

Figure 34: Showy orchid
Credit: TDEC/DOEO (A. Robinson)

Figure 35: Dwarf Crested iris
Credit: TDEC/DOEO (A. Robinson)

Figure 36: Blue Lobelia
Credit: TDEC/DOEO (G. Middleton)

Figure 37: Mountain laurel
Credit: TDEC/DOEO (G. Middleton)

Figure 38: Pinkster bush
Credit: TDEC/DOEO (G. Middleton)

Figure 39: Sharp-lobed Hepatica
Credit: TDEC/DOEO (G. Middleton)

Figure 40: Wild Bergamont
Credit: TDEC/DOEO (G. Middleton)

Figure 42: American Squawroot
Credit: TDEC/DOEO (G. Middleton)

Figure 43: Trailing arbutus
Credit: TDEC/DOEO (G. Middleton)

Figure 44: Buttonbush
Credit: TDEC/DOEO (G. Middleton)

Figure 45: Touch-me-not (Jewelweed) (Asteraceae)

Figure 46: White Crownbeard

Credit: TDEC/DOEO (G. Middleton)

Credit: TDEC/DOEO (G. Middleton)

Figure 47: American chestnut sprouts
Credit: TDEC/DOEO (G. Middleton)

Figure 48: Broadleaf Arrowhead
Credit: TDEC/DOEO (G. Middleton)
Insert: UTK Herbarium (T. G. Barnes)

Figure 49: Slender blazing star (*Liatris*)
Credit: TDEC/DOEO (G. Middleton)

Figure 50: Black Cohosh (*Cimicifuga*)
Credit: TDEC/DOEO (G. Middleton)
Insert: UTK Herbarium (T. G. Barnes)

Figure 51: Lizard's Tail (*Saururus*)
Credit: TDEC/DOEO (G. Middleton)

Figure 52: Butterfly Weed (*Asclepias*)
Credit: TDEC/DOEO (G. Middleton)
Insert: UTK Herbarium (M. Silver)

Figure 53: Wild Comfrey (*Cynoglossum*)
Credit: TDEC/DOEO (G. Middleton)
Insert: UTK Herbarium (M. Silver)

Figure 54: Bears Foot (*Smallanthus*)
Credit: TDEC/DOEO (G. Middleton)

Figure 55: Groundnut (*Apios*)
Credit: TDEC/DOEO (G. Middleton)
Insert: UTK Herbarium (E. Chester)

Figure 56: Dodder (Love-in-a-tangle)
Credit: TDEC/DOEO (G. Middleton)

Figure 57: St. Johnswort (Clusiaceae)
Credit: TDEC/DOEO (G. Middleton)
Insert: UTK Herbarium (T. G. Barnes)

Figure 58: Phlox (Polemoniaceae)
Credit: TDEC/DOEO (G. Middleton)

Figure 59: Groundcherry (Solanaceae)
Credit: UTK Herbarium (D. D. Horn)
Insert: TDEC/DOEO (G. Middleton)

Figure 60: Pawpaw (*Asimina triloba*)
Credit: TDEC/DOEO (G. Middleton)
Insert: UTK Herbarium (J. Beck)

Figure 61: Fly Poison (Liliaceae)
Credit: TDEC/DOEO (G. Middleton)

Figure 62: Flame Azalea (*R. cumberlandense*)
Credit: TDEC/DOEO (G. Middleton)

Figure 63: Wild Sunflower (*Helianthus*)
Credit: TDEC/DOEO (G. Middleton)

Figure 64: Cranefly Orchid (*Tipularia*)
Credit: TDEC/DOEO (G. Middleton)
Insert: UTK Herbarium (T. G. Barnes)

Figure 65: Blue Mistflower
Credit: TDEC/DOEO (G. Middleton)

Figure 66: Ginseng
Credit: TDEC/DOEO (G. Middleton)

Figure 67: Goldenrod (*Solidago*)
Credit: TDEC/DOEO (G. Middleton)

Figure 68: Bloodroot
Credit: TDEC/DOEO (G. Middleton)

Figure 69: Virginia Bluebells
Credit: TDEC/DOEO (G. Middleton)

Figure 70: Teaberry
Credit: TDEC/DOEO (G. Middleton)

Figure 71: Mountain Mint (*Pycnanthemum*)
Credit: TDEC/DOEO (G. Middleton)

Figure 72: Dittany (*Cunila origanoides*)
Credit: TDEC/DOEO (G. Middleton)

Figure 73: Black-eyed Susan (*Rudbeckia*)
Credit: TDEC/DOEO (G. Middleton)

Figure 74: Fire Pink (*Silene viriginica*)
Credit: TDEC/DOEO (G. Middleton)

Figure 75: Trout Lilies (*Erythronium*)
Credit: TDEC/DOEO (G. Middleton)

Figure 76: Pink Lady's Slipper (Orchid)
Credit: TDEC/DOEO (G. Middleton)

Concluding Remarks

The acoustic detections of both federally-endangered bats (i.e., Gray bat, Indiana bat) and the physical capture of the Indiana Bat provide significant new information to our knowledge of species present on the ORR. Additional acoustic studies are needed to further characterize ORR bat communities for future environmental assessments and ecological studies, such that the information presented to the public is factually correct. High quality Indiana bat roosting habitat on the ORR should be identified and monitored periodically (Mitchell and Martin 2002).

Botanical fieldwork remains to be completed on the ORR and all 3000 acres of the BORCE, particularly to map additional rare habitat and associated plant communities, and document exotic pest-plant invasions. TDEC DOE-O staff will continue to report new rare plant findings to the Resource Management Division (RMD, Natural Areas Program and Natural Heritage Inventory Program) and to the TWRA, and provide field support as needed. Specific information relating to RMD programs is available by contacting: Brian Bowen, Program Administrator, State Natural Areas Program, telephone: (615) 532-0436, brian.bowen@.tn.us; or Silas Mathes, Data Manager, Natural Heritage Inventory Program, telephone: (615) 532-0440, silas.mathes@tn.gov. Alternatively, the RMD representative for the ORR is Lisa Huff, East Tennessee Stewardship Ecologist, Knoxville Field Office, telephone: (865) 594-5601, lisa.huff@tn.gov. The Natural Heritage Inventory Program contact for threatened and endangered animal species: David Withers, Zoologist, (615) 532-0441, david.withers@tn.gov.

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Global Positioning System (GPS) Tracking of White-tailed Deer on the Oak Ridge Reservation (2013)

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Abstract

The DOE-Oversight Office of the TDEC Division of Remediation (TDEC DOEO) continued deer capture activities on the Oak Ridge Reservation (ORR) during 2013. The goal was to chemically immobilize deer and install global positioning system (GPS) collars on them to determine their home range and potential movements outside their home range. The scientific literature provides considerable evidence that wildlife (i.e., carnivores, herbivores, omnivores, piscivores), subsisting in habitats impacted by industrial pollution, are ingesting environmental contaminants from their respective food chains. Humans could potentially be at risk due to unwittingly consuming contaminated game meat and fish which have bioaccumulated metals and other contaminants from the environment. White-tailed deer (*Odocoileus virginianus*) mainly consume vegetation, forbs, nuts, fruits and grasses for nourishment, and ingest soils (i.e., licks) to replenish vitamins and minerals. Oak Ridge Reservation deer, grazing and foraging in contaminated areas such as the Melton Valley solid waste storage areas (SWSAs) at Oak Ridge National Laboratory (ORNL), represent a potentially significant vector for contaminant exposures to the public. This project is part of a multiyear investigation. Our previous 2011-12 GPS collar investigations and results suggest a young buck swam across the Clinch River from ORNL into Knox County. White-tailed deer may temporarily leave their home range during the rut season, or to avoid hunting pressure and other anthropogenic disturbances, and may wander into urban areas to forage. During 2013, division staff captured and successfully collared three deer, all in Melton Valley. Global positioning system (GPS) data was downloaded and home ranges (and excursions from core area) were determined from four recovered collars and presented herein. Hair samples were collected from each captured animal to test for heavy metals. The metals data was not received from the laboratory in time for inclusion in this report.

Introduction

The Oak Ridge Reservation (ORR) contains a large biodiversity of plants, wildlife, and game animals, providing wildlife habitat imbedded in large areas of relatively undisturbed mature eastern deciduous forest, wetlands, old fields, river bluffs, cedar barrens, and grasslands. The United States Department of Energy (DOE) ORR wildlife management plan has historically provided for the management and radiological monitoring of white-tailed deer (*Odocoileus virginianus*) and other game animals during annual hunts on the ORR Wildlife Management Area (WMA, Salk and Parr 2006, Giffen et al. 2007). The ORR WMA annual hunts, managed by the Tennessee Wildlife Resources Agency (TWRA), began in 1985 as a method of population control and to reduce increasing deer/vehicle collisions (Parr and Evans 1992, Pierce 2010). Although harvested deer are scanned radiologically prior to public release during ORR WMA hunts, there has been little or no monitoring of heavy metals in ORR game meat (i.e., venison and organ meat).

Ashwood et al. (1994) reported that contaminated animals (e.g., Canada geese, white-tailed deer, kingfishers, wild turkeys) with large home ranges have been collected at locations outside the boundaries of the ORR. It has been well documented that deer are strong swimmers and have the capability to swim long distances in rivers and lakes (McCulloch 1967, Nelson and Mech 1984,

Lopez 2006, Jordan et al. 2010). Thus, ORR deer that may swim or otherwise migrate offsite (i.e., Knox County, City of Oak Ridge), and if ultimately harvested, represent an exit pathway (i.e., vector) for exposures to the public through the consumption of un-monitored and potentially contaminated venison and liver. Wildlife researchers have reported that ORR contaminated animals (e.g., Canada geese, white-tailed deer, kingfishers, wild turkeys) with large home ranges were collected at locations outside the boundaries of the reservation (Ashwood 1992, Ashwood et al. 1994).

Research specific to red deer (Lazarus et al. 2004) and white-tailed deer (Kocan et al. 1980, Woolf et al. 1982, Sileo and Beyer 1985, Crête et al. 1987, Schultz et al. 1994) have documented uptake of elevated concentrations of metals (i.e., industrial & mining sources) in organs, hair, antler, teeth, bone, tissue and feces. Garten (1995) suggested that elevated levels of strontium 90 (^{90}Sr) in some deer killed during the ORR WMA deer hunts indicate that deer could forage in contaminated areas and then leave the ORR. Grazing wildlife (ruminants) can also ingest metals such as mercury (Hg) either by consuming herbage (browse) that is contaminated (Schwesig and Krebs 2003), or by consuming contaminated soils (mineral licks, Wilkinson et al. 2003). Thus, contaminants may be bioaccumulated by deer during ingestion of contaminated browse and soil (i.e., mineral licks, Grodzińska 1983, Harrison and Dyer 1984, Peles and Barrett 1997, Han et al. 2006, Beyer et al. 2007).

For managed populations of white-tailed deer, understanding dispersal and movements within home ranges is important for effective management (McCoy et al. 2005). Yearling male white-tailed deer are more likely to disperse from their natal home range than other sex and age classes, and dispersal often is the greatest movement of any individual in the population (Hawkins et al. 1971, Nelson and Mech 1984, Tierson et al. 1985). Capturing deer allows biologists to equip individuals with identification tags and global positioning system (GPS) collars in order to study herd demographics, determine home range information and collect biological data (e.g., physical measurements, tissue samples; Vercauteren et al. 1999).

Home ranges in white-tailed deer typically vary from 50-500 hectares (ha) (123-1235 acres [ac], Marchinton and Hirth 1984). Previous investigations on the ORR found that the average home range for radio-collared deer examined (number of [*n*] = 15) was found to be 345 ha (852 ac), and dispersal distances of up to 33 kilometers (km) (20.5 miles [mi]) were recorded (Kitchings and Story 1979, Story and Kitchings 1982, 1985).

White-tailed Deer Behavior and Breeding

White-tailed deer are gregarious with two basic social groups: family groups centered around a matriarch with females (fawns of previous generations), and their fawns and fraternal groups made up of adults and occasionally yearling males (Hawkins and Klimstra 1970). Marking and rubbing behaviors are an integral part of social interactions, especially during the mating season (Moore and Marchinton 1974). Buck rubs and scraping are visual and olfactory signposts displayed by older males to establish dominance and facilitate intersexual communication (Kile and Marchinton 1977). The forehead of males contains sudoriferous glands that are most active in dominant males during the rut (Atkeson and Marchinton 1982). Together with secretions from the preorbital gland and saliva, males mark overhanging branches, twigs, and the bark of small saplings and stems with their head and antlers (Smith 1991).

Temporary movements outside of home ranges have been documented for both yearling and adult male white-tailed deer (Hawkins and Klimstra 1970, Nelson and Mech 1981, Nixon et al. 1991, Skuldt et al. 2008, Clements et al. 2011). White-tailed deer often expand their home ranges and undertake frequent long-distance movements during the hunting season (Downing et al. 1969, Pilcher and Wampler 1982, Root et al. 1988). Sparrowe and Springer (1970) determined that hunting activities influenced deer movements more than any other factor, although adult males apparently do not move to refuge areas to avoid hunters (Hawkins et al. 1971, Kammermeyer and Marchinton 1977, Pilcher and Wampler 1982, Root et al. 1988). Dispersal in white-tailed deer occurs predominantly among yearling males and usually is exhibited by 50 percent (%) of these individuals (Nixon et al. 1994, Rosenberry et al. 1999, Long et al. 2005, Shaw et al. 2006). Yearling males typically disperse 8–12 km, but movements of >150 km have been reported (Nelson 1993, Kernohan et al. 1994, Nixon et al. 1994). However, the hunting season in many areas coincides with rut, and movements associated with breeding activities may confound interpretation of hunting-related deer movements (Sargent and Labisky 1995). Knowledge relating to home-ranges may provide insight into various facets of the species' social organization and foraging ecology (Gallina et al. 1997).

Just before breeding season, male activities intensify (i.e., rubbing, scraping, sparring, and searching for estrous females) and movement and home ranges increase (Guyse 1978, Hawkins and Klimstra 1970, Hosey 1980, Tomberlin 2007). Additionally, white-tailed deer may temporarily leave their home range to avoid hunting pressure and other disturbances (Hood and Inglis 1974, Naugle et al. 1997, Vercauteren and Hygnstrom 1998). Dispersal movements are predominantly made by juvenile (1.5-year-old) male white-tailed deer and often result in permanent emigration (Brinkman et al. 2005, McCoy et al. 2005, Rosenberry et al. 1999, Shaw 2005), whereas excursions are temporary movements outside an established home range. As estrus approaches, females concentrate movement and scent markings within their core areas (Fraser 1968, Holzenbein and Schwede 1989, Ivey and Causey 1981, Marchinton 1968, Nelson and Mech 1981), which may increase the chance of males detecting females by focusing activities within a small area (Holzenbein and Schwede 1989, Ozoga and Verme 1975). By luring courting males into a chase and venturing outside her core area, females might attract attention from other potential mates (Karns et al. 2011). Once engaged in the chase, males might easily be led outside their home range and into unfamiliar territory, possibly bringing multiple males together and stimulating intrasexual competition (Cox and Le Boeuf 1977, Emlen and Oring 1977). After being tended and bred, females will decrease activity, return to core areas, and resume normal levels of movement and activity (Cox and Le Boeuf 1977, Holzenbein and Schwede 1989, Ozoga and Verme 1975). In rare instances, females may make excursions outside their home range during the breeding season even with abundant mature males in the population (Kolodzinski 2008).

Methods and Materials

For 2013, the focus of this investigation was to chemically immobilize (capture) and equip Melton Valley deer with GPS radio-collars to track and document their movements and determine home-ranges. The investigation is attempting to answer the question: Are potentially contaminated Melton Valley deer leaving the ORR and wandering into adjacent urban areas surrounding the ORR (i.e., City of Oak Ridge, Knox Co.)? If so, these animals could be hunted

offsite, and once harvested, contaminated venison could unknowingly be consumed by the public. Further, if ORR deer migrate offsite and are harvested, then they also would not be scanned for radiological contamination (i.e., as per the ORR WMA deer hunt radiological scanning of deer bone and tissue).

Study Area

The ORR consists of three main sites, Y-12 National Security Complex (Y-12), Oak Ridge National Lab (ORNL, or X-10), and the East Tennessee Technology Park, (ETTP, or the K-25 gaseous diffusion plant), and is located in Anderson and Roane Counties, Tennessee. The ORR encompasses 13,855 ha, and lies in an area of thrust-faulted sedimentary rocks of Cambro-Ordovician age creating rolling hills and valleys in eastern Tennessee between the Cumberland Mountains to the northwest and the Blue Ridge Mountains to the southeast (DOE 2002). The Clinch River forms a border to the south, west, and east of the ORR. For 2013, the study area was the ORR solid waste storage areas (SWSAs) of Melton Valley (ORNL). The study area in Melton Valley lies within the remediated White Oak Creek/Melton Branch watershed including a few ponds and White Oak Lake. The watershed has received considerable environmental contamination from previous ORNL operations especially the seepage pits and waste trenches comprising the SWSAs. Browse and forage in the study area are abundant and there are also several mineral licks in both Melton Valley and offsite areas frequented by deer. The offsite study area was the City of Oak Ridge.

Global Positioning System Collars

Each deer was fitted with a releasable Telonics TGW-4500 GPS collar (Telonics, Inc., Mesa, Arizona) which stored location data internally (i.e., store-on-board). Each collar was also equipped with a CR-2A release mechanism and a very high frequency (VHF) transmitter. The GPS collars are located in the field using a VHF receiver following drop-off from the animal. Releasable GPS wildlife collars have been used frequently in the field by other researchers to eliminate the need for re-capture of the animal for collar retrieval (Merrill et al. 1998, Nelson et al. 2004, Demma and Mech 2009). The Telonics deer collars were pre-programmed to record deer locations (i.e., GPS fixes) every 90 minutes and to drop-off (release) either at 1-year or 2-year intervals (Kjær et al. 2007). The collars transmitted VHF telemetry signals at preprogrammed intervals to allow tracking and ultimate recovery, and all GPS fix data were stored for downloading upon collar recovery. Accordingly, VHF radio frequencies programmed in the collar transmitters are as follows: 151.205 megahertz (MHz), 151.250 MHz, 151.295 MHz, and 151.415 MHz. Radio-tracking allows the study of deer spatial dynamics without having to observe deer directly (Nelson and Sargeant 2008). To ensure collars were properly functioning and study animals were alive; deer were monitored weekly via ground triangulation by estimating azimuths from established telemetry stations using the Telonics TR-4 VHF receiver (Brinkman et al. 2002, Cox et al. 2002).

Capture Methods

White-tailed deer were captured during the winter/spring of 2013 in Melton Valley (n=3) using the mobile approach (i.e., drive-by) and dart deer (chemical immobilization) accustomed to the presence of humans in the solid waste storage areas (SWSAs) of Melton Valley at ORNL (controlled access areas). Deer are crepuscular, thus captures were attempted during both dusk and pre-dawn hours, and morning daylight hours between 0700 and 1100. The deer field team

members (i.e., ideally 4: equipment manager, two handlers, data collector) captured deer by means of immobilization drugs administered by a dart projector. Following capture, deer were fitted with a GPS/VHF collar and ear tags. Field procedures also followed the division's health and safety plan (Yard 2013).

Chemical Immobilization (Anesthesia) and Handling

Of the Melton Valley deer captured and collared, one deer was darted by TWRA using the Pneu-Dart Type C, 3-cubic centimeter (cc) gel collar (Pneu-Dart, Inc., Williamsport, PA) delivered to the deer from the Pneu-Dart X-Caliber™ carbon dioxide (CO_2) projector (Pneu-Dart, Inc., Williamsport, PA) at a range of 25 yards. The other two Melton Valley deer were darted by Tennessee Department of Environment and Conservation (TDEC) staff at a range of 30-60 yards with 1.5 cc Pneudart Type C disposable darts fired from a Pneu-Dart Model 389 dart projector (cartridge-powered; Pneu-Dart, Inc., Williamsport, PA). Every attempt was made to deliver the dart to an area of muscle mass at the junction of the neck and shoulder of the deer. Delivering the dart to the neck/shoulder junction provides the fastest induction time (TDEC 2012). The darts were loaded with a 2:1 mixture of 5.0 mg/kg Telazol® (i.e., Cyclohexamine immobilization agent, Fort Dodge Animal Health, Fort Dodge, IA, USA; Safe-Capture 2012) and 2.5 mg/kg Xylazine (i.e., neuroleptic tranquilizer drug, Fort Dodge Animal Health, Fort Dodge, IA, USA; Safe-Capture 2012). This solution is administered at one milliliter (ml) per 85 pounds (lbs). The amount loaded in each dart will vary depending on the estimated weight of the deer. A typical dose for a 120 lb. deer is 1.5 ml of this mixture. When combined with schedule III cyclohexamines (i.e., ketamine or Telazol®), Xylazine works synergistically, improving efficacy and reducing drug volume (Wenkler 1998; Kilpatrick and Spohr 1999; Walsh and Wilson 2002, Miller et al. 2009). Xylazine is partially reversed by available antagonists such as Tolazoline (Greene and Thurmon 1988; Webb et al. 2004).

Following dart delivery, deer were quietly observed from a distance during induction time until effects of the drugs became evident (i.e., 6-10 minutes) and it was determined that the animal was down. The induction time is the interval between initial injection of drugs via dart delivery and immobilization of the animal (Kreeger et al. 1986, Kreeger and Armeno 2007). The field team quietly approached the area where the deer was known to be down or last seen. If the animal was aware of field team's approach (as evidenced by lifting its head or moving its ears or eyes), but was unable to rise off the ground, a dose of Ketamine was administered at 2.5 milligrams per kilogram (mg/kg) (2.5 mg/kg: 1.4 ml of 100 milligram per milliliter [mg/ml] for a 120 lb. deer) intramuscular (IM) syringe into the neck muscle to enhance immobilization of the deer (Safe-Capture 2012).

Deer were generally found recumbent within 50-250 yards from the location where the animal was originally darted. Once immobilization was complete, and safe to approach the deer, the handler positions the deer in a sternal recumbent position, ensures the respiratory pathway (airway) is clear and unobstructed, and holds the deer's head above the level of the gut rumen. The equipment manager applies a sterile ophthalmic lubricant to the deer's eyes (Kjær et al. 2007, Karns et al. 2011), blindfolds the deer, and determines age and sex which is recorded. Next, the equipment manager quickly installed the GPS collar on the deer. Once the collar has been applied, the equipment manager and the handler monitored the deer vital signs. Once the heart rate, temperature and respiration have been measured and recorded, then the equipment

manager applies the numbered ear tags, and removes the dart from the deer. On especially cold days, space blankets were sometimes used to help keep the animal warm during recovery from the immobilizing drugs. The data collector takes photographs and records important details pertinent to the capture (TDEC 2012).

During recovery time, measurements of the deer were taken (i.e., length, girth) and approximately 2-5 grams of hair sample was collected with a curry-comb from the caudal or mid-dorsal region for laboratory analyses (i.e., heavy metals; Stevens et al. 1997, Duffy et al. 2005, Brookens et al. 2007). Analysis of hair samples has been commonly used to assess accumulation of methylmercury in wildlife (Cumbie 1975, Born et al. 1991, Halbrook et al. 1994, Ben-David et al. 2001, Beckman et al. 2002, Harkins and Susten 2003). The deer's vital signs were monitored every 10 minutes while the deer was immobilized. After the effects of Telazol® wear off (80 minutes), the deer was administered Tolazoline with syringe to reverse the effects of Xylazine. Drugged deer are usually aroused and able to walk away in 10-30 minutes after the dose of Tolazoline has been administered. Deer immobilization (captures) and handling followed the standard operating procedures per the *TDEC White-tailed Deer Capture Plan* (TDEC 2012), the *TDEC Health and Safety Plan* (Yard 2011), the *Safe-Capture Training Manual* (Safe-Capture 2012), and additional guidance found in Kreeger et al. (1986), Wisdom et al. (1993), Caulkett and Haigh (2004), Nelson et al. (2004), Gannon et al. (2007), Kreeger and Arnemo (2007), Muller et al. (2007), James and Stickles (2010), Karns et al. (2011), and Sikes et al. (2011). Lastly, the TWRA provided invaluable field support and guidance for this project.

All tissue metals analyses (except methylmercury, MeHg) were conducted by Laboratory Services, Nashville, Tennessee. The MeHg tissue samples were farmed-out and analyzed by Brooks-Rand Laboratory, Seattle, Washington. Sample collecting practices and methods followed recommendations of TWRA staff, and Travis et al. (1989), Sample et al. (1997), O'Hara et al. (2001, 2003), Kierdorf and Kierdorf (2005), Duffy et al. (2005), Gannon et al. (2007), Giffen et al. (2007), and Sikes et al. (2011).

Results and Discussion

White-tailed deer that were captured and collared during 2012-2013 are shown in Figure 1; deer captured and collared during 2014 are shown in Figure 2. During January and February 2013, three Melton Valley deer were chemically immobilized with a dart gun and fitted with GPS collars in the contaminated areas of the ORNL SWSAs (Table 1). Two of these deer died prematurely from disease late in 2013 and collars were retrieved, refurbished, and redeployed during early 2014. The data downloads from each collar are represented in Figures 3-6 to show their respective core areas and excursions from the core area.

Using ArcView GIS program to plot our deer GPS data points, we have strong evidence showing that two of our collared deer swam across the Clinch River several times. The deer code named "Henrietta" (doe) made two lengthy excursions from her core area (Figure 3). On 8/26/2012 she left the core area and proceeded east to the shores of Bearden Creek embayment. There is no evidence she crossed the Clinch River from that location. On New Year's Eve (12-31-2012, approximately 6:00 pm) she left the core area and proceeded west and swam across the Clinch River onto Jones Island; she apparently returned to the core area a few hours later.

The deer code named "Lawrence" (buck) made several excursions from his core area to the northeast to forested locations south of the SNS Facility (Figure 4). Lawrence made no forays across the Clinch River.

The deer code named "Kathy" (doe) made at least two separate excursions, possibly three (February 2, 2013; May 24-25, 2013) from her Melton Valley core area and swan across the Clinch River onto private property located north of the Roane County Industrial Park (Figure 5). It appears that she left private property on the south side of the river and proceeded to Jones Island around 6:00 pm on 5-25-2013, and then returned to private property for several more hours.

The deer code named "Michelle" stayed within her core area which is concentrated mainly on Haw Ridge and along the course of White Oak Creek where its course cuts through the ridge (Figure 6).

During January-March 2014, 5 additional deer were immobilized and collared in Melton Valley (Table 2). One deer remains at large with the collar still attached because the release mechanism failed on the preprogrammed release date of January 15, 2013. There is a risk that the data from this collar may be lost because the VHF transmitter batteries will expire (late April 2014) and then there will be no VHF signal to enable relocating the collared deer. Collar recovery efforts will continue until March of 2016 because two collars recently deployed will continue to collect GPS coordinates for 2 years.

Tables and Figures

Table 1: 2013 Deer Capture Data

Deer	Date captured	Est. Age	Est. Weight (lbs.)	GPS collar	VHF freq	Successful Pulse	Collar Release
Elizabeth*	2/14/2012	3.5 yrs	n/a	2-yr	151.415	60 bpm	1/15/2014
Henrietta**	4/18/2012	1.5 yrs	90	2-yr	151.295	60 bpm	1/15/2014
Kathy	1/31/2013	4.0 yrs	105 lbs	1-yr	151.295	50 bpm	12/15/2013
Lawrence	2/6/2013	10 mos.	65 lbs.	1-yr	151.250	60 bpm	12/15/2013
Michelle**	2/8/2013	2.5 yrs	100 lbs	2-yr	151.205	50 bpm	12/15/2014

bpm - beats per minute; Est. - estimated; GPS - global positioning system; lbs - pounds; VHF - very high frequency; yr - year
* Elizabeth's collar failed to release on 1/15/2014; deer and collar remain at large.

Table 2: 2014 Deer Capture data

Deer	Date captured	Est. Age	Est. Weight (lbs.)	GPS collar	VHF freq	Successful Pulse	Collar Release
Nicole	1/13/2014	2.5 yrs	130 lbs	1-yr	151.415	50 bpm	1/15/2015
Ophelia	1/14/2014	1.5 yrs	110 lbs	2-yr	151.205	60 bpm	1/15/2016
Penelope	1/15/2014	2.5 yrs	118 lbs	1-yr	151.295	50 bpm	1/15/2015
Quey	3/5/2014	1.5 yrs	120 lbs	2-yr	151.295	60 bpm	3/1/2016
Renee	3/19/2014	3.5 yrs	130 lbs	2-yr	151.205	50 bpm	3/1/2016

bpm - beats per minute; Est. - estimated; GPS - global positioning system; lbs - pounds; VHF - very high frequency; yr - year

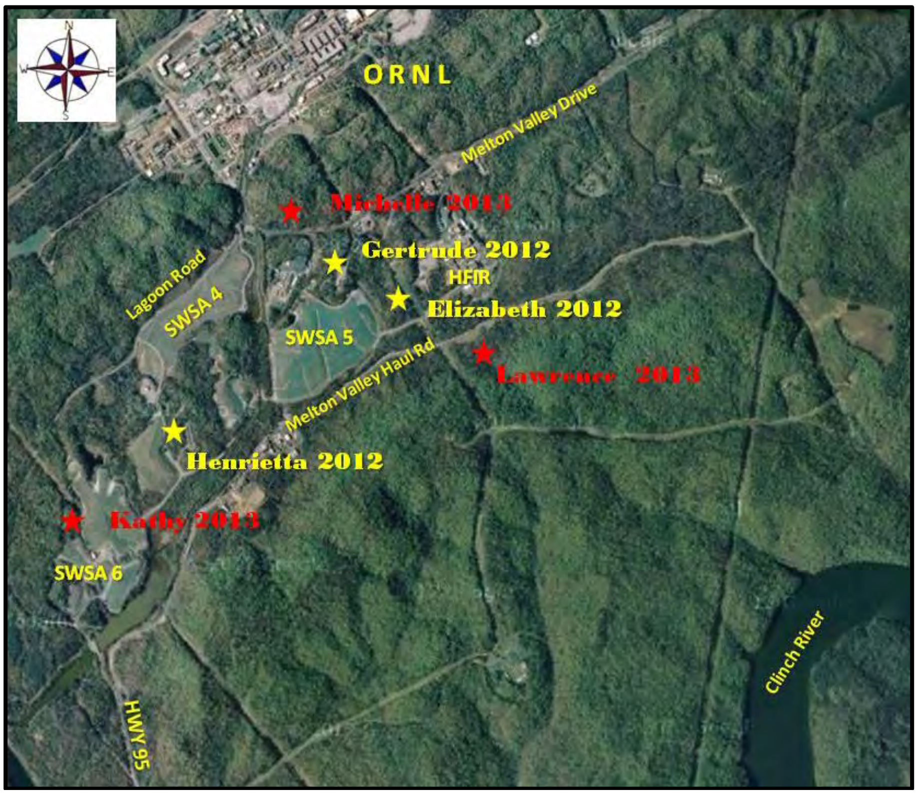

Figure 1: Melton Valley Deer Capture Locations (2012-2013)

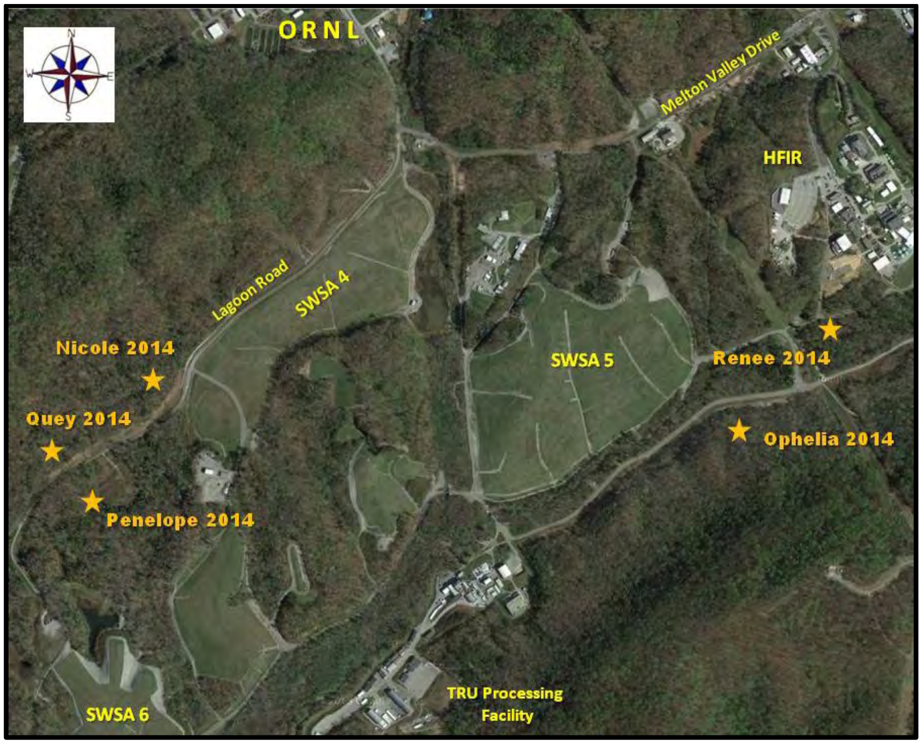

Figure 2: Melton Valley Deer Capture Locations (2014)

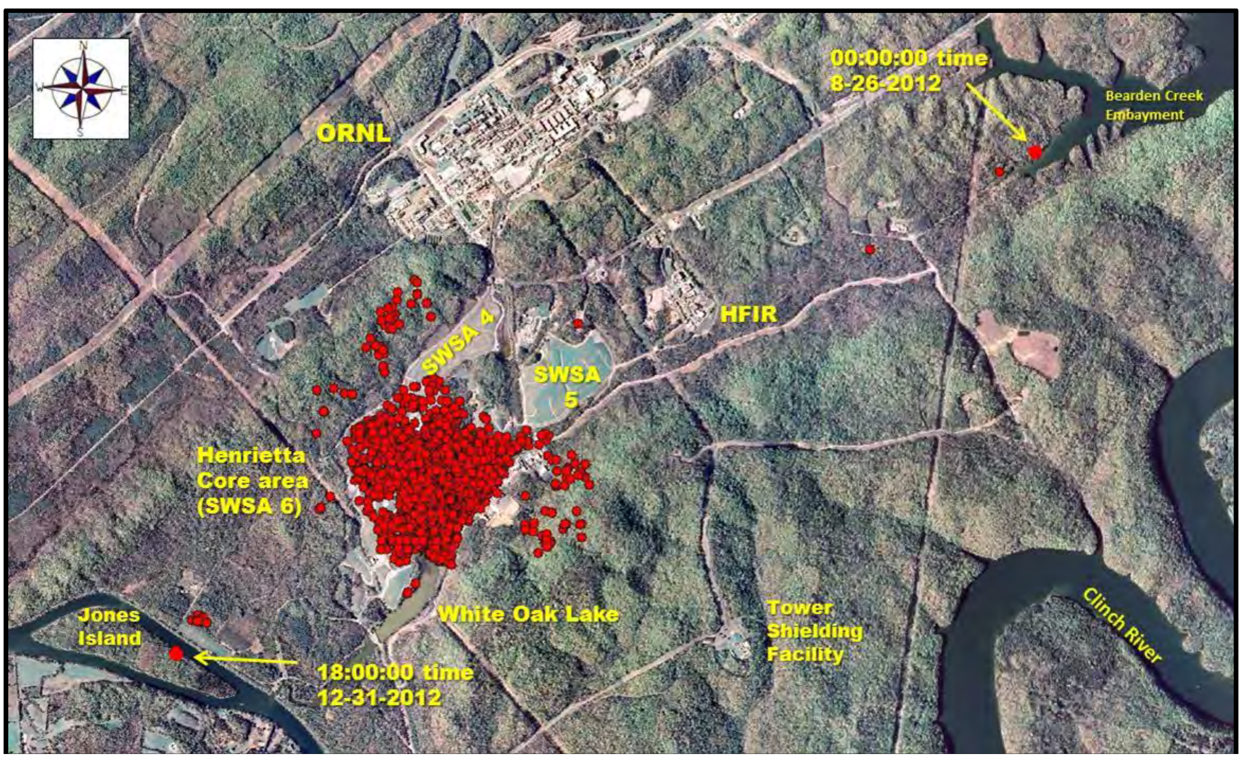

Figure 3: Henrietta core area and excursions

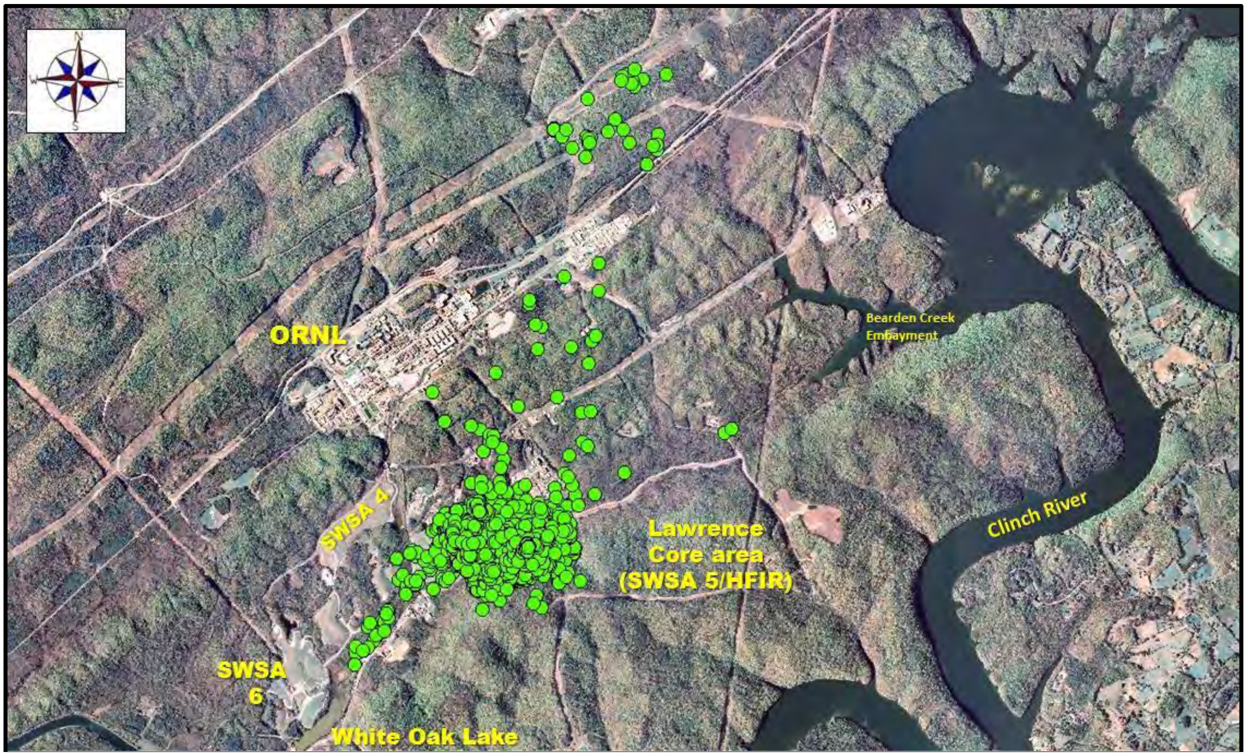

Figure 4: Lawrence core area and excursions

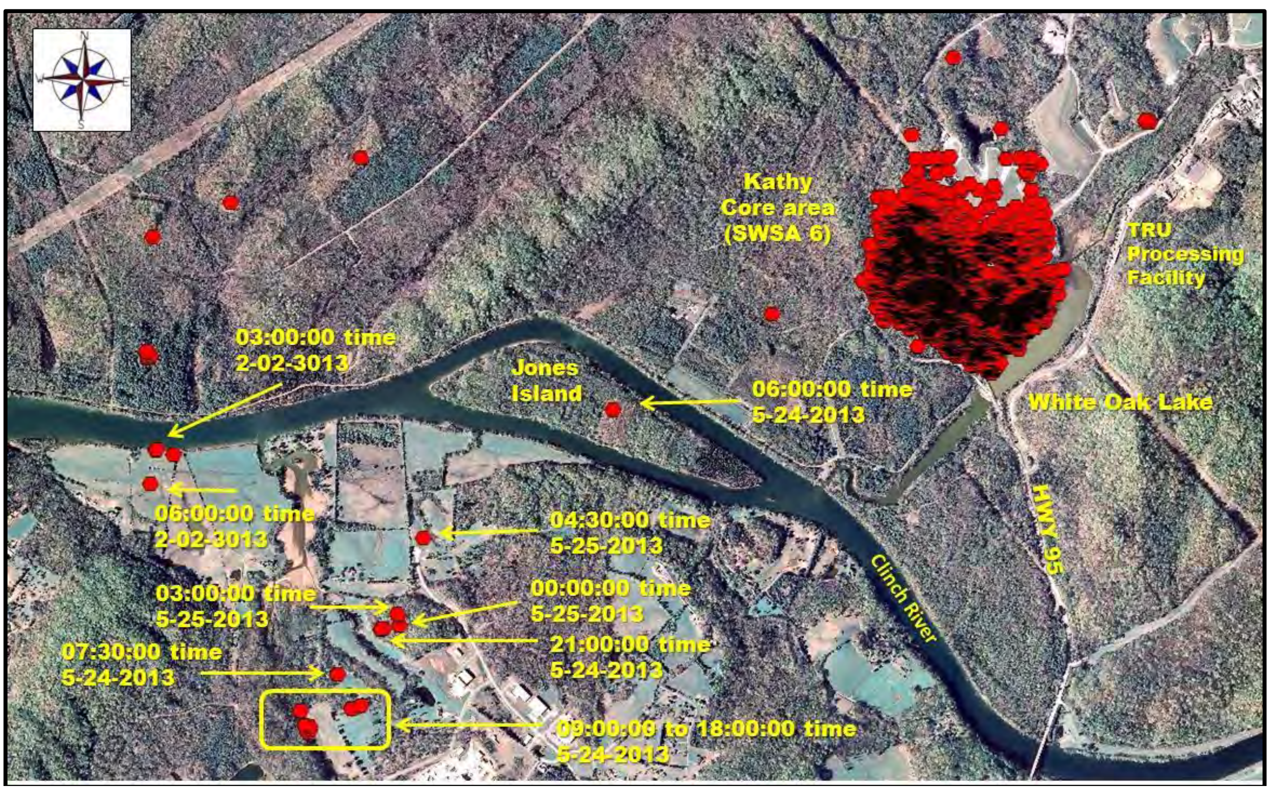

Figure 5: Kathy core area and excursions

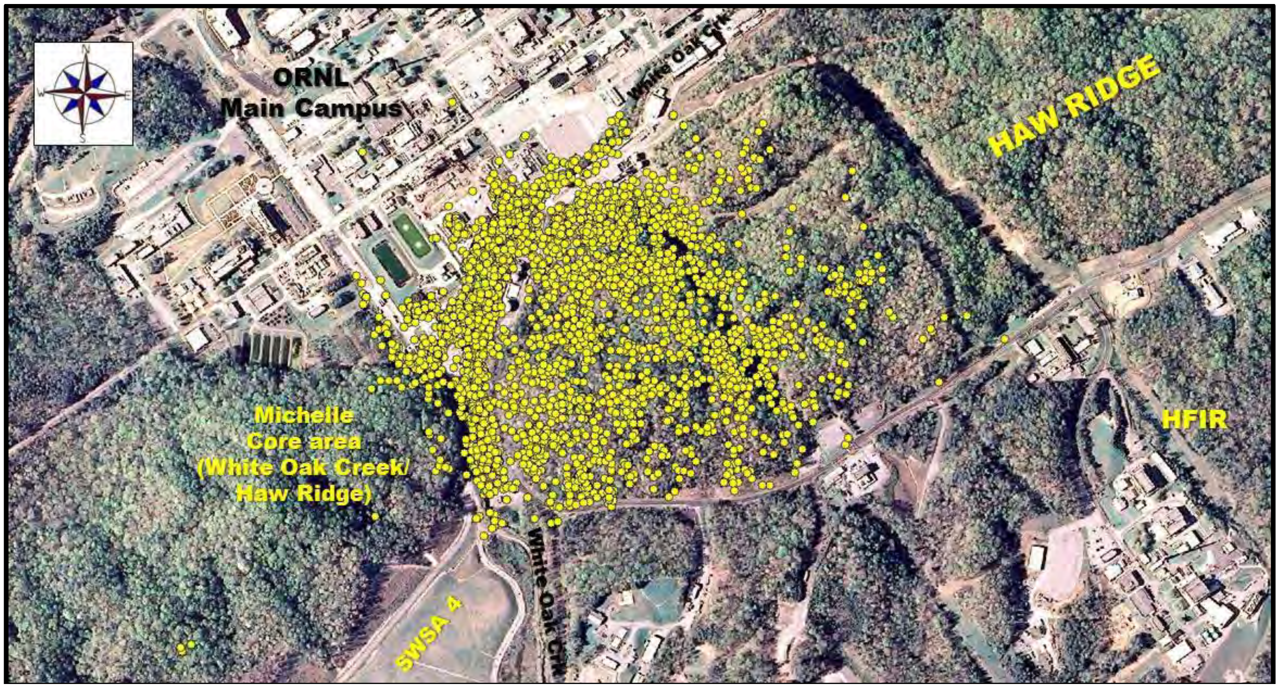

Figure 6: Michelle core area (little if any excursions)

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2013 Benthic Macroinvertebrate Surface Water Monitoring Program

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Abstract

In May 2013, the division conducted surface water monitoring to complement the benthic macroinvertebrate monitoring program at the following Oak Ridge Reservation (ORR) watersheds: Bear Creek (BCK), East Fork Poplar Creek (EFK), Mitchell Branch (MIK), and White Oak Creek (WCK) / Melton Branch (MEK). In all, surface water samples were collected from eleven impacted stream sites and associated reference sites. In addition, monitoring was also conducted at Clear Creek (CCK) near Norris Dam which serves as a reference site for all the ORR watersheds. Samples were delivered to the State of Tennessee Department of Health (TDH) Laboratory for nutrients, metals, and radiological analyses. Conductivity, pH, conductivity, dissolved oxygen, and temperature were measured at each monitoring site using YSI Professional Plus multi-parameter water quality instruments. The surface water data indicate that the surface water quality in the four watersheds was less than optimal when compared to reference streams. The comprehensive stream assessment scores calculated from the benthic macroinvertebrate monitoring program indicated the same conclusion.

Introduction

Due to the presence of areas of extensive anthropogenic point and non-point source contamination on the ORR, there exists the potential for this pollution to impact surface waters on the ORR as well as offsite aquatic systems. The local karst topography and related structural geology influences the fate and transport of contaminants that may further degrade the groundwater and surface water quality of aquatic systems on or adjacent to the ORR. The biotic integrity, "overall biological health", of an associated aquatic system/watershed/stream, is directly influenced by its surface water quality. In general, the better the surface water quality of a stream, the better its biotic integrity. Likewise, the worse the surface water quality of a stream, the worse its biotic integrity. This project complements the Benthic Macroinvertebrate Monitoring Project; assessment of the surface water quality of a stream can more accurately determine the stream's total overall biological health. The evaluation of benthic macroinvertebrate communities is used to determine if a stream is supportive of fish and aquatic life. An integral element of this evaluation is the physical and chemical analysis of the stream's surface water. Relative to the four major Oak Ridge Reservation (ORR) watersheds, Bear Creek (BCK), East Fork Poplar Creek (EFK), Mitchell Branch (MIK), and White Oak Creek (WCK) / Melton Branch (MEK), legacy and present Department of Energy (DOE)/ORR operations have released contaminants to their respective surface waters with mainly these three major chemical families: volatile and semi-volatile organic compounds, nutrients, heavy metals, and radionuclides. These contaminants can have a detrimental effect upon the health of benthic macroinvertebrate communities. When contaminant concentrations in surface water are high enough, the total population of benthic communities can be drastically reduced. Negatively impacted benthic communities indicate a polluted, distressed stream/watershed/aquatic system.

Methods and Materials

In May 2013, the Tennessee Department of Environment and Conservation, Department of Energy Oversight Office (TDEC DOE-O), conducted surface water monitoring at the following impacted ORR watersheds: Bear Creek (BCK), East Fork Poplar Creek (EFK), Mitchell Branch

(MIK), and White Oak Creek (WCK) / Melton Branch (MEK). In all, surface water samples were collected from eleven impacted stream sites and associated reference sites. In addition, monitoring was also conducted at Clear Creek (CCK) near Norris Dam which serves as a reference site for all the ORR watersheds. To enhance the evaluation of each streams' biotic integrity, the surface water sampling program was conducted in conjunction with the 2013 Benthic Macroinvertebrate Monitoring Program. Samples were delivered to the State of Tennessee Department of Health (TDH) Laboratory for nutrients, metals, and radiological analyses. Conductivity, pH, , dissolved oxygen, and temperature were measured at each monitoring site using YSI Professional Plus multi-parameter water quality instruments. The surface water monitoring program followed both the 2011 TDEC WPC Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water and the 2011 TDEC WPC Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys. In addition, all work associated with this program will be conducted in compliance with the office's Health, and Safety Plan.

Samples were taken for the following parameters:

Inorganics: ammonia, nitrate & nitrite (NO^3 & NO^2), residue (dissolved), residue (suspended), specific conductivity, total hardness, total Kjeldahl nitrogen, total phosphorus.

Metals: arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, and zinc.

Radionuclides: gamma radionuclides, gross alpha, and gross beta.

Table 1 lists the nineteen sample locations, and Figures 1-5 shows the benthic surface water sampling sites relative to the ORR aerial maps.

Table 1: 2013 Sample Locations

Stream Location	TDEC-DOE-O Project Site	DWR Site
East Fork Poplar Crk	EFK 25.1	EFPOP015.6AN
East Fork Poplar Crk	EFK 24.4	EFPOP015.2AN
East Fork Poplar Crk	EFK 23.4	EFPOP014.5AN
East Fork Poplar Crk	EFK 13.8	EFPOP008.6AN
East Fork Poplar Crk	***EFK 6.3***	***EFPOP003.9RO***
Bear Creek	***BCK 12.3***	***BEAR007.6AN***
Bear Creek	***BCK 9.6***	***BEAR006.0AN***
Mitchell Branch	***MIK 1.43*** *	***MITCH000.9RO***
Mitchell Branch	MIK 0.71	MITCH000.4RO
Mitchell Branch	***MIK 0.45***	***MITCH000.3RO***
White Oak Creek	***WCK 6.8*** *	***WHITE004.2RO***
White Oak Creek	WCK 3.9	WHITE002.4RO
White Oak Creek	WCK 3.4	WHITE002.1RO
White Oak Creek	***WCK 2.3***	***WHITE001.4RO***
Melton Branch	MEK 0.3	MELTO000.2RO
White Creek	***WHK 3.7*** *	***ECO67F13***
White Wing Tributary	WWK 0.8 *	BEAR1T2.4RO
Clear Creek	***CCK 1.45*** *	***ECO67F06***
Gum Hollow Branch	GHK 2.9 *	GHOLL001.8RO
Hinds Creek	***HCK 20.6*** *	***HINDS012.8AN***
Mill Branch	***MBK 1.6*** *	***FECO67I12***

Stream Location = ORR Stream/Watershed, * = Reference Stream

TDEC-DOE-O Project Site Activities = ***surface water samples collected at ONLY Bold/Italic sites***

TDEC-DOE-O Project Site Activities continued: ***benthic sqkick sampling, stream flow conducted at ALL sites***

TDEC-DOE-O Project Site Activities continued: ***habitat assessment, physical parameters conducted at ALL sites***

DWR Site = Division of Water Resources site designation

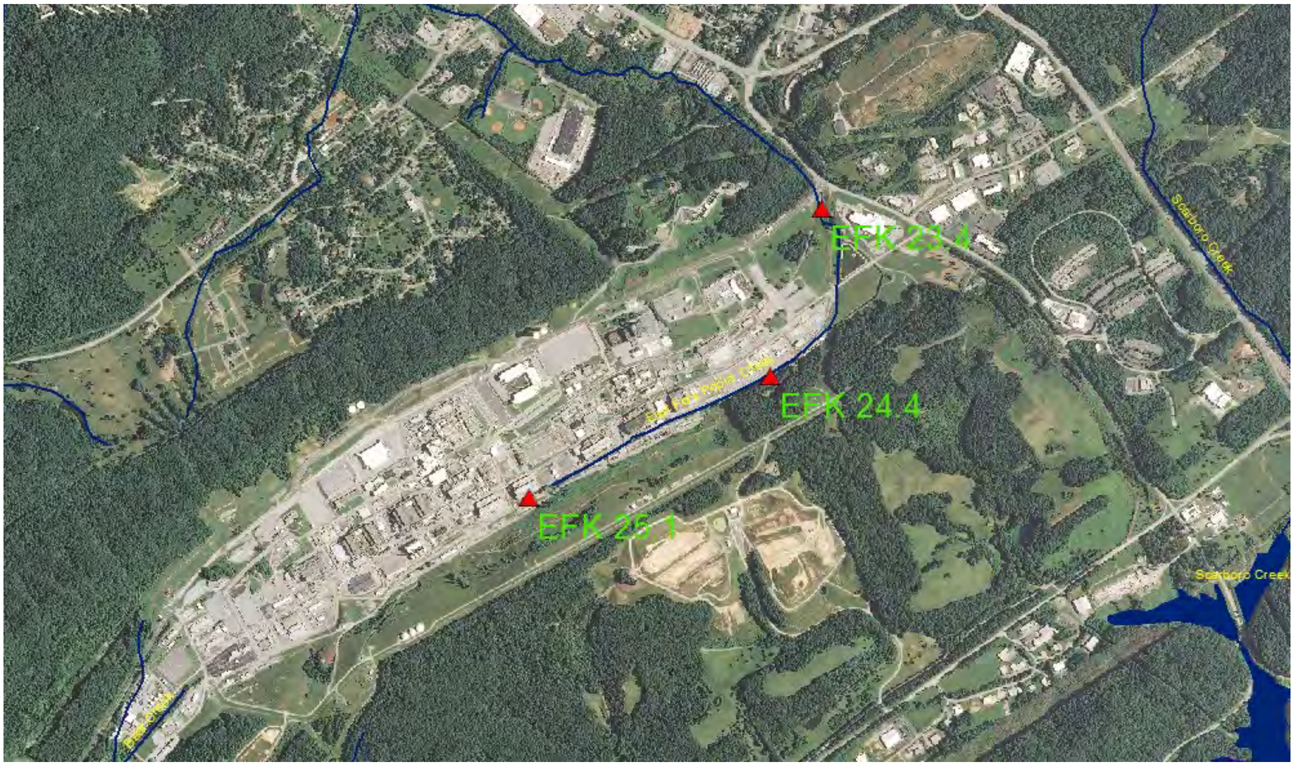

Figure 1: Upper East Fork Poplar Creek / Y-12 Plant

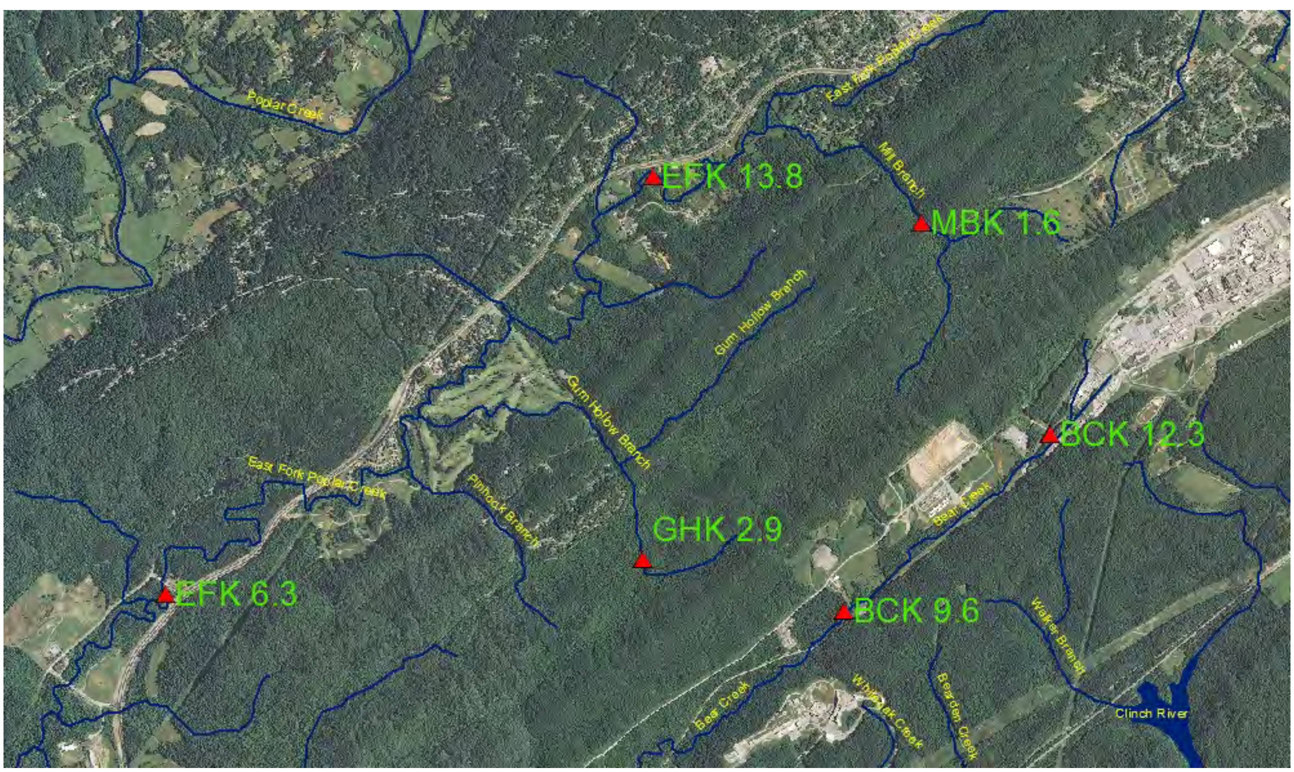

Figure 2: Lower East Fork Poplar Creek / Bear Creek Watersheds

Figure 3: Mitchell Branch Watershed (ETTP)

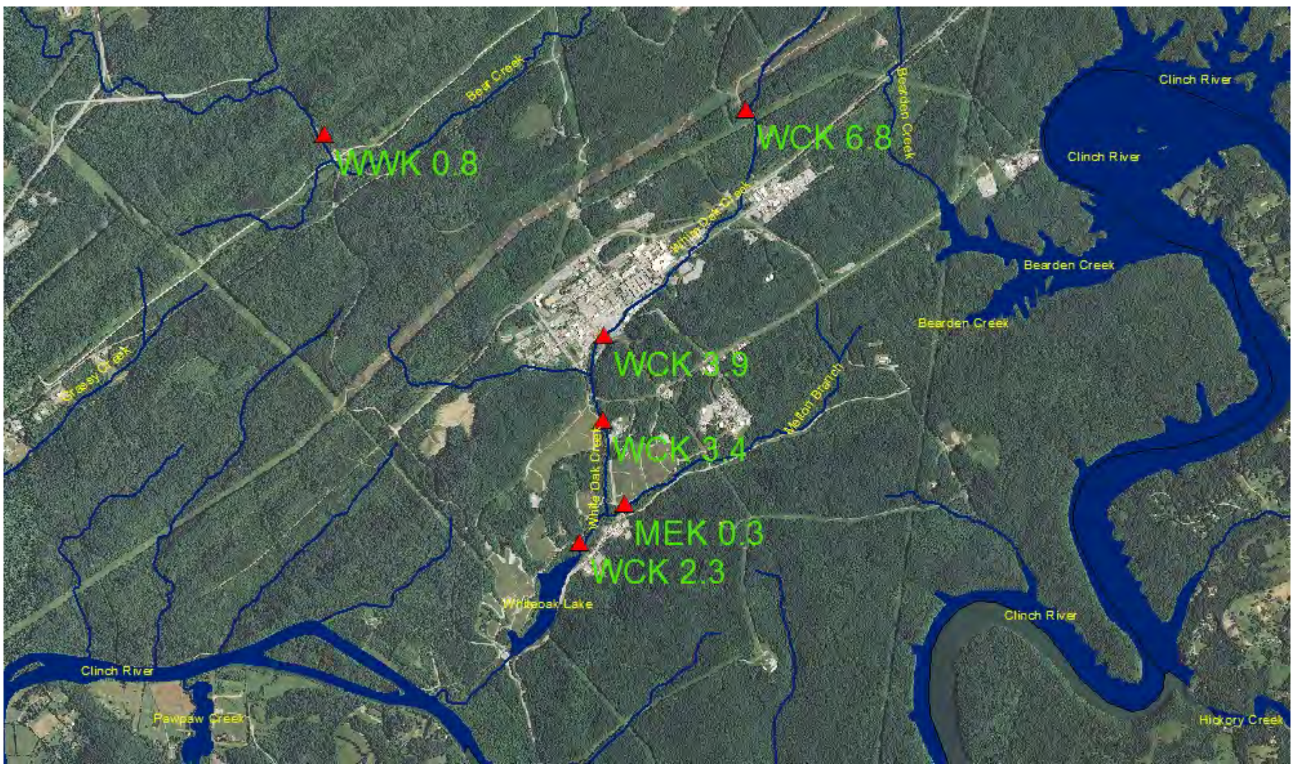

Figure 4: White Oak Creek / Melton Branch Watersheds (ORNL)

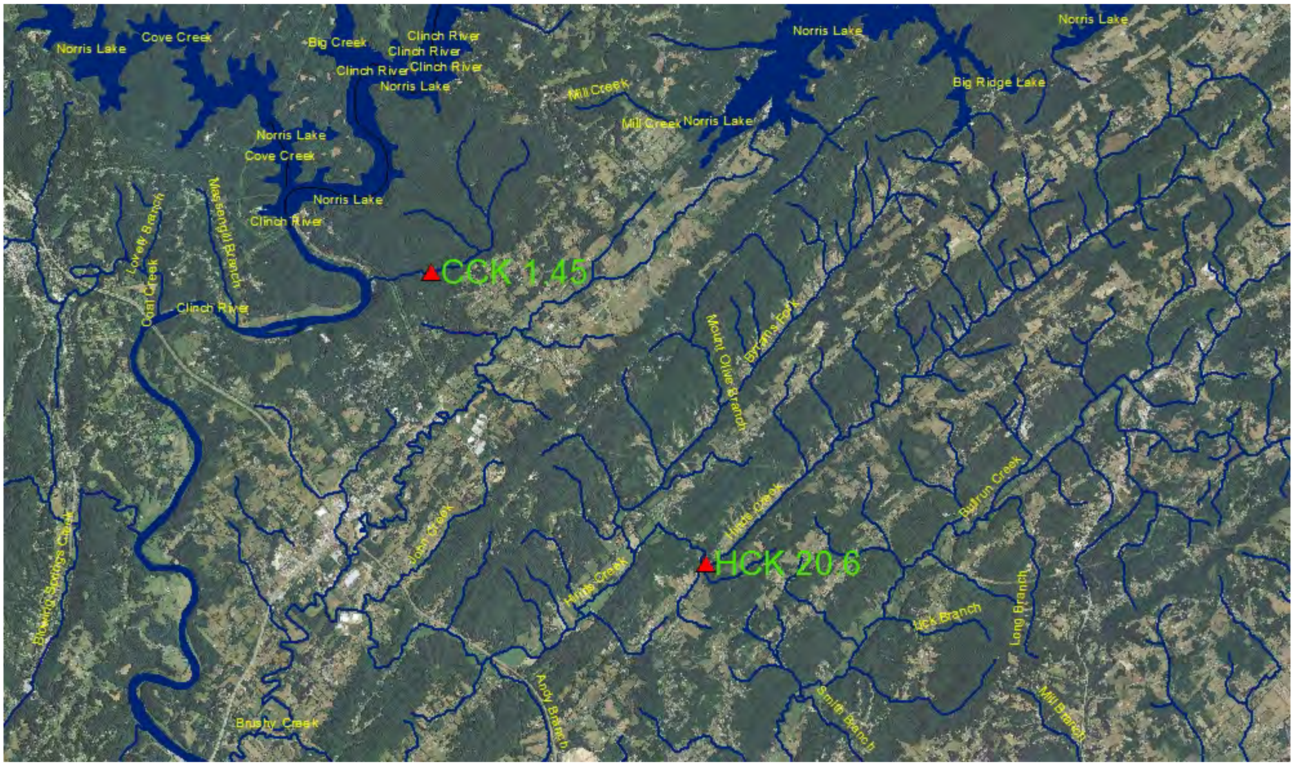

Figure 5: Clear Creek Ecoregion and Hinds Creek Reference Sites

Results and Discussion: The 2013 Benthic TDH laboratory surface water results are discussed in the following order, Bear Creek, East Fork Poplar Creek, Mitchell Branch, and White Oak Creek / Melton Branch.

<u>Bear Creek:</u>

Tables 2 and 3 presents a summary of the 2013 benthic surface water sample results for Bear Creek.

Table 2: 2013 Surface Water Data Summary (non-radiological)

Parameter	BCK 12.3	BCK 9.6	HCK 20.6 (ref.)	CCK 1.6 (ref.)	TWQC*	Units
pH	7.39	7.62	7.93	7.61	5.5-9[a]	None
Specific conductance	707	414	337	191	n.a.	uS/cm
Dissolved oxygen (DO)	9.55	9.69	9.57	10.72	5.0[a]	mg/l
Ammonia-nitrogen	U	U	U	U	n.a.	mg/l
nitrate and nitrite	18	3.6	0.58	0.35	n.a.	mg/l
Total dissolved solids	457	310	175	99	500[b]	mg/l
Total suspended solids	U	U	U	U	n.a.	mg/l
Kjeldahl nitrogen	U	0.49J	0.51	U	n.a.	mg/l
Phosphorus	U	0.026J	0.017J	U	n.a.	mg/l
Iron	270	500	250	46	n.a.	ug/l
Arsenic	U	U	U	U	10[c]	ug/l
Cadmium	0.77J	U	U	U	2.0[d]	ug/l
Chromium	U	U	U	U	16[e]	ug/l
Copper	0.67J	0.79J	U	U	13[d]	ug/l
Lead	U	U	U	U	5[f]/65[a]	ug/l
Manganese	190	51	28	11	n.a.	ug/l
Zinc	3.7J	2.2J	U	U	120[d]	ug/l
Mercury	U	U	U	U	0.051[c]	ug/l
Hardness, Ca, Mg	290	180	160	95	n.a.	mg/l

*Tennessee Water Quality Criteria:

[a] Fish and Aquatic Life (FAL), applies to all sites

[b] Industrial Water Supply, applies only to Clinch River Sites

[c] Recreation (organisms only), applies to all sites

[d] Fish and Aquatic Life (FAL), applies to all sites. This value is for total hardness of 100mg/L

[e] FAL (Chromium VI)

[f] This value is for Domestic Water Supply, which applies only to Clinch River Sites.

Table 3: 2013 Bear Creek Surface Water Data Summary (radiological)

Parameter	BCK 12.3	BCK 9.6	HCK 20.6 (ref.)	CCK 1.6 (ref.)	PRG[1]
Gross alpha radioactivity, (Thorium-230 ref std)	77.7	21	-0.1	1	n.a.
Gross beta radioactivity, (Cesium-137 ref std)	125.8	27.6	2.8	2.6	n.a.
Cesium-137	0	0	0	0	487

Units are pCi/L

[1] DOE Preliminary Remediation Goals (PRGs), Recreator: TR=1.0E-6, last updated 11/20/2013

The specific Bear Creek data results are organized relative to the directional creek flow beginning near the headwaters within Y-12 and then proceeding downstream and to the west towards the Clinch River. Relative to our specific monitoring sites, please note this directional flow where BCK 12.3 is just to the west of the Y-12 secured area and then our additional monitoring sites are to the west and downstream of BCK 12.3:

Directional Flow*:* BCK 12.3 (near headwater and within Y-12) $>^{West}$ BCK 9.6 (2 miles outside of Y-12) $>^{West}$ Clinch River (with reference streams of MBK 1.6, and eco-region CCK 1.6)

BCK 12.3 is just to the west of the Y-12 legacy S-3 ponds, which are now capped. In the past, these ponds were used as holding basins for mainly nitric acid. It is believed that these ponds have created a contaminated groundwater plume of nutrients (likely nitrogen compounds) which has traveled to the west and migrated to the head waters of Bear Creek then migrated further downstream/west of the headwaters. Relative to the solid phase/aqueous phase equilibrium mechanism, the groundwater plume [likely predominately nitrates (NO^3) and nitrites (NO^2)] have partitioned/dissolved into the surface water of Bear Creek. Thus, in the surface water at BCK 12.3, the elevated specific conductivity values are likely due to mainly high nitrogen concentrations. Another main contamination concern in the Bear Creek watershed is the presence of uranium contamination. In the 1980s, within the Bear Creek Burial Grounds, it is estimated that approximately 20,500 tons of depleted uranium were buried. Legacy uranium contamination in the burial grounds has been remediated by employing *Comprehensive Environmental Response, Compensation, and Liability Act* (CERCLA) regulations. Current uranium contamination is disposed of by employing *Resource Conservation and Recovery Act* (RCRA) requirements.

Specific data results observations relative to specific parameters are presented below:

Non-Radiological Parameters:

1.) Compared to the reference sites, specific conductivity was elevated at BCK 12.3 (707 microSiemens per centimeter [µS/cm]), then decreased downstream/west to BCK 9.6 (414 µS/cm). In this area of Bear Creek, specific conductivity levels are typically elevated and remain a health concern.
2.) Compared to the reference sites, total hardness, residue dissolved, and manganese concentrations were the highest at BCK 12.3 and also decreased as the stream flowed downstream/west to BCK 9.6.
3.) Compared to the reference sites, iron exhibited similar concentrations with a flat trend except for a higher spike concentration at BCK 9.6. It is possible that this higher concentration may be due to the nearby Environmental Management Waste Management Facility operations which have possibly dislodged soil into the watershed tributaries which flow into Bear Creek near BCK 9.6.

Radiological Parameters:

1.) Radioactive alpha concentrations were the highest at BCK 12.3 (77.7 picocuries per liter [pCi/L]), and decreased as the stream flowed downstream/west to BCK 9.6 (21.0 pCi/L).

Reference sites HCK 20.6 and CCK 1.45 had alpha values of -0.1 and 1.0 pCi/L, respectively.

2.) Radioactive beta concentrations were the highest at BCK 12.3 (125.8 pCi/L), and decreased as the stream flowed downstream/west to BCK 9.6 (27.6 pCi/L). Reference sites HCK 20.6 and CCK 1.45 had alpha values of 2.8 and 2.6 pCi/L, respectively.

East Fork Poplar Creek:

Tables 4 and 5 present a summary of the 2013 benthic surface water samples results for East Fork Poplar Creek.

Table 4: 2013 East Fork Poplar Creek Surface Water Data Summary (non-radiological)

Parameter	EFK 6.3	HCK 20.6 (ref.)	CCK 1.6 (ref.)	TWQC*	Units
pH	7.92	7.93	7.61	5.5-9[a]	None
Specific conductance	349	337	191	n.a.	uS/cm
Dissolved oxygen (DO)	10.7	9.57	10.72	5.0[a]	mg/l
Ammonia-nitrogen	U	U	U	n.a.	mg/l
nitrate and nitrite	3.1	0.58	0.35	n.a.	mg/l
Total dissolved solids	225	175	99	500[b]	mg/l
Total suspended solids	U	U	U	n.a.	mg/l
Kjeldahl nitrogen	U	0.51	U	n.a.	mg/l
Phosphorus	0.16	0.017J	U	n.a.	mg/l
Iron	98	250	46	n.a.	ug/l
Arsenic	U	U	U	10[c]	ug/l
Cadmium	U	U	U	2.0[d]	ug/l
Chromium	U	U	U	16[e]	ug/l
Copper	1.2	U	U	13[d]	ug/l
Lead	U	U	U	5[f]/65[a]	ug/l
Manganese	11	28	11	n.a.	ug/l
Zinc	4J	U	U	120[d]	ug/l
Mercury	0.07J	U	U	0.051[c]	ug/l
Hardness, Ca, Mg	150	160	95	n.a.	mg/l

*Tennessee Water Quality Criteria:

[a] Fish and Aquatic Life (FAL), applies to all sites

[b] Industrial Water Supply, applies only to Clinch River Sites

[c] Recreation (organisms only), applies to all sites

[d] Fish and Aquatic Life (FAL), applies to all sites. This value is for total hardness of 100mg/L

[e] FAL (Chromium VI)

[f] This value is for Domestic Water Supply, which applies only to Clinch River Sites.

Table 5: 2013 East Fork Poplar Creek Surface Water Data Summary (radiological)

Parameter	EFK 6.3	HCK 20.6 (ref.)	CCK 1.6 (ref.)	PRG[1]
Gross alpha radioactivity, (Thorium-230 ref std)	2.2	-0.1	1	n.a.
Gross beta radioactivity, (Cesium-137 ref std)	2.3	2.8	2.6	n.a.
Cesium-137	0	0	0	487

Units are pCi/L

[1] DOE Preliminary Remediation Goals (PRGs), Recreator: TR=1.0E-6, last updated 11/20/2013

The specific East Fork Poplar Creek data results are organized relative to the directional creek flow beginning near the headwaters in Y-12 and then proceeding downstream towards the Clinch River. Relative to our specific monitoring sites, please note this directional flow where EFK 25.1 is within Y-12 and just to the east of the EFK headwaters. Additional downstream monitoring sites are to the east, then north, and finally to the west of EFK 25.1:

Directional Flow*:* EFK 25.1 (near headwater and within Y-12) $>^{East}$ EFK 24.4 (within Y-12) $>^{North}$ EFK 23.4 (just outside of Y-12 east security gate) $>^{North}$ EFK 13.8 (near city of Oak Ridge Waste Water Treatment Plant) $>^{West}$ EFK 6.8 (2 miles east of ETTP) $>^{West}$ Clinch River (with reference streams of HCK 20.6, and eco-region CCK 1.6)

Specific Data Results Observations relative to specific parameters:

Non-Radiological Parameters:

1.) Nitrates and nitrites at EFK 6.3 are slightly elevated in comparison to reference sites, as is phosphorus.
2.) The mercury value was 0.07J for EFK 6.3; the TNWQC for mercury is .051 µg/L. A J value is an estimate between the minimum detection limit (MDL) and the method quantitation limit (MQL).

Radiological Parameters:

3.) The radioactive alpha concentration at EFK 6.3 (2.2 pCi/L) was similar to that of the reference sites; reference sites HCK 20.6 and CCK 1.45 had alpha values of -0.1 and 1.0 pCi/L, respectively.
4.) The radioactive beta concentration at EFK 6.3 (2.3 pCi/L) was similar to that of the reference sites; reference sites HCK 20.6 and CCK 1.45 had beta values of 2.8 and 2.6 pCi/L, respectively.

Mitchell Branch:

Tables 6 and 7 present a summary of the 2013 benthic surface water sampling results for Mitchell Branch.

Table 6: 2013 Mitchell Branch Surface Water Data Summary (non-radiological)

Parameter	MIK 0.45	MIK 1.43 (ref.)	CCK 1.6 (ref.)	TWQC*	Units
pH	7.67	7.66	7.61	5.5-9[a]	None
Specific conductance	358.00	140.00	191	n.a.	uS/cm
Dissolved oxygen (DO)	9.81	10.53	10.72	5.0[a]	mg/l
Ammonia-nitrogen	0.04	U	U	n.a.	mg/l
nitrate and nitrite	0.11	0.05	0.35	n.a.	mg/l
Total dissolved solids	222	102	99	500[b]	mg/l
Total suspended solids	U	U	U	n.a.	mg/l
Kjeldahl nitrogen	U	0.19	U	n.a.	mg/l
Phosphorus	0.02	U	U	n.a.	mg/l
Iron	150	210	46	n.a.	ug/l
Arsenic	U	U	U	10[c]	ug/l
Cadmium	U	U	U	2.0[d]	ug/l
Chromium	1.40	U	U	16[e]	ug/l
Copper	U	U	U	13[d]	ug/l
Lead	U	U	U	5[f]/65[a]	ug/l
Manganese	82	31	11	n.a.	ug/l
Zinc	2.4	U	U	120[d]	ug/l
Mercury	U	U	U	0.051[c]	ug/l
Hardness, Ca, Mg	170	66	95	n.a.	mg/l

*Tennessee Water Quality Criteria:

[a] Fish and Aquatic Life (FAL), applies to all sites

[b] Industrial Water Supply, applies only to Clinch River Sites

[c] Recreation (organisms only), applies to all sites

[d] Fish and Aquatic Life (FAL), applies to all sites. This value is for total hardness of 100mg/L

[e] FAL (Chromium VI)

[f] This value is for Domestic Water Supply, which applies only to Clinch River Sites.

Table 7: 2013 Mitchell Branch Surface Water Data Summary (radiological)

Parameter	MIK 0.45	MIK 1.43 (ref.)	CCK 1.6 (ref.)	PRG[1]
Gross alpha radioactivity, (Thorium-230 ref std)	10.7	0.8	1	n.a.
Gross beta radioactivity, (Cesium-137 ref std)	19	1.4	2.6	n.a.
Cesium-137	0	0	0	487

Units are pCi/L

[1] DOE Preliminary Remediation Goals (PRGs), Recreator: TR=1.0E-6, last updated 11/20/2013

The specific Mitchell Branch data results are organized relative to the directional creek flow beginning near the headwaters and then proceeding downstream and to the west towards Poplar Creek which flows into the Clinch River. Relative to our specific monitoring sites, please note this directional flow where MIK 1.43 is just to the northeast of the secured East Tennessee Technology Park (ETTP) area, previously known as K-25. Additional monitoring sites are to the west and downstream of MIK 1.43:

Directional Flow: MIK 1.43 (very near headwater and reference stream) $>^{\text{Southwest}}$ MIK 0.71 (within secured ETTP/Old K-25) $>^{\text{West}}$ MIK 0.45(within secured ETTP/Old K-25) (with reference streams of MIK 1.43 and eco-region CCK 1.45)

MIK 1.43 is just to the northwest of ETTP, previously known as K-25. In the past the K-25 industrial complex employed a gaseous diffusion process to enrich naturally occurring uranium to the various fissile uranium isotopes such as uranium-233 (^{233}U), and uranium-235 (^{235}U). Currently the old K-25 complex, now known as ETTP, is being deactivated and demolished (D&D). During the D&D, in addition to various uranium isotopes, the radionuclide, technetium-99 (^{99}Tc), has also been found. Also, the non-radiological heavy metal chromium has been found. Chromium (Cr) is a transition metal usually occurring in the environment in its trivalent (Cr^{3+}) state and to a lesser extent in its hexavalent (Cr^{6+}) state. Naturally occurring chromium is almost exclusively in the (Cr^{3+}) state, as the energy required for its oxidation to the (Cr^{6+}) state is quite high. Hence, the (Cr^{6+}) form is usually considered to be a man-made product. The toxicities of the two forms of chromium are very different. (Cr^{3+}) is generally a nontoxic, non-mobile micronutrient; however, (Cr^{6+}) is water soluble, quite toxic, and carcinogenic to human beings.

Specific Data Results Observations relative to specific Parameters:

Non-Radiological Parameters:

1.) Compared to the reference sites, specific conductivity, total hardness, residue (dissolved), and manganese values/concentrations were the lower at MIK 1.43 (reference) and increased as the stream flowed downstream/west into the contaminated footprint of the ETTP / old K-25 area.
2.) Chromium was detected at MIK 0.45 (1.4J), but not detected in the two reference streams.

Radiological Parameters:

5.) The radioactive alpha concentration at MIK 0.45 (10.7 pCi/L) was higher than that of the reference sites; reference sites MIK 1.43 and CCK 1.45 had alpha values of 0.8 and 1.0 pCi/L, respectively.
6.) The radioactive beta concentration at MIK 0.45 (19 pCi/L) was higher than that of the reference sites; reference sites MIK 1.43 and CCK 1.45 had beta values of 1.4 and 2.6 pCi/L, respectively.

White Oak Creek / Melton Branch:

Tables 8 and 9 present a summary of the 2013 benthic surface water sampling results for White Oak Creek / Melton Branch.

The specific White Oak Creek / Melton Branch data results are organized relative to the directional creek flow beginning near the headwaters and then proceeding downstream and west into the Clinch River. Relative to our specific monitoring sites, please note this directional flow where WCK 6.8 is just to the northeast of the Oak Ridge National Laboratory (ORNL). Additional monitoring sites are to the southwest and downstream of WCK 6.8. Specifically, White Oak Creek flows southwest through ORNL and then flows west through the associated contaminated Bethel Valley Burial Grounds. Just southeast of this point Melton Branch flows into White Oak Creek. However, before Melton Branch flows into White Oak Creek, Melton Branch has already flowed through the contaminated Melton Valley Burial Grounds which are located to the northeast of the Bethel Valley Burial Grounds. Just to the southwest of the Melton Branch/White Oak Creek confluence is site WCK 2.3. From this point White Oak Creek flows southwest into the Clinch River.

Table 8: 2013 White Oak Creek Surface Water Data Summary (non-radiological)

Parameter	WCK 2.3	WCK 6.8 (ref.)	CCK 1.6 (ref.)	TWQC*	Units
pH	7	7	7.61	5.5-9[a]	None
Specific conductance	241	196	191	n.a.	uS/cm
Dissolved oxygen (DO)	10	10	10.72	5.0[a]	mg/l
Ammonia-nitrogen	U	U	U	n.a.	mg/l
nitrate and nitrite	1	0	0.35	n.a.	mg/l
Total dissolved solids	164	122	99	500[b]	mg/l
Total suspended solids	U	U	U	n.a.	mg/l
Kjeldahl nitrogen	U	U	U	n.a.	mg/l
Phosphorus	0	U	U	n.a.	mg/l
Iron	140	150	46	n.a.	ug/l
Arsenic	2	U	U	10[c]	ug/l
Cadmium	U	U	U	2.0[d]	ug/l
Chromium	U	U	U	16[e]	ug/l
Copper	1	U	U	13[d]	ug/l
Lead	U	U	U	5[f]/65[a]	ug/l
Manganese	30	16	11	n.a.	ug/l
Zinc	9	3	U	120[d]	ug/l
Mercury	U	U	U	0.051[c]	ug/l
Hardness, Ca, Mg	120	96	95	n.a.	mg/l

*Tennessee Water Quality Criteria:

[a] Fish and Aquatic Life (FAL), applies to all sites

[b] Industrial Water Supply, applies only to Clinch River Sites

[c] Recreation (organisms only), applies to all sites

[d] Fish and Aquatic Life (FAL), applies to all sites. This value is for total hardness of 100mg/L

[e] FAL (Chromium VI)

[f] This value is for Domestic Water Supply, which applies only to Clinch River Sites.

Table 9: 2013 White Oak Creek Surface Water Data Summary (radiological)

Parameter	WCK 2.3	WCK 6.8 (ref.)	CCK 1.6 (ref.)	PRG[1]
Gross alpha radioactivity, (Thorium-230 ref std)	0.1	0	1.0	n.a.
Gross beta radioactivity, (Cesium-137 ref std)	218	0	2.6	n.a.
Cesium-137	18.2	0	0	487

Units are pCi/L

[1] DOE Preliminary Remediation Goals (PRGs), Recreator: TR=1.0E-6, last updated 11/20/2013

Directional Flow: WCK 6.8 (very near headwater and reference stream) $>^{\text{Southwest}}$ WCK 3.9 (within secured ORNL) $>^{\text{Southwest}}$ WCK 3.4 (within secured ORNL/Bethel Valley Burial Grounds) $>^{\text{Southeast}}$ MEK 0.3 (within secured Melton Valley Burial Grounds/ORNL/ Bethel Valley Burial Grounds) $>^{\text{Southwest}}$ WCK 2.3 (within secured ORNL/Bethel Valley Burial Grounds) (with reference streams of WCK 6.8 and eco-region CCK 1.45)

WCK 6.8 is located just to the northwest of the ORNL, previously known as X-10. In the past, the X-10 industrial complex employed thirteen nuclear reactors such as the Graphite (X-10) Reactor, two Aqueous Homogeneous Reactors, and an All-Metal Fast Burst Reactor. All of the others were Light-Cooled and Modulated Reactors. Today, the only remaining operating reactor at ORNL is the High Flux Isotope Reactor (HFIR). Radioactive materials such as ^{233}U, ^{235}U, ^{239}Pu were employed in the operation of these nuclear reactors and to support the production of nuclear weapons at Y-12. In addition, the radionuclide, Strontium-90 (^{90}Sr), is a by-product of nuclear fission reactors. Also, relative to ORNL research projects, other radionuclides were produced. Also in the production of these nuclear materials at ORNL, non-radiological carcinogenic organic volatiles, such as trichoroethylene (TCE), and tetrachloroethylene (PCE) were employed. Specific Data Results Observations:

Non-Radiological Parameters:

1.) There is very little difference in non-radiological parameter values between the WCK 6.8 reference site and WCK 2.3. Conductivity, dissolved solids, manganese and dissolved residue values are only slightly higher at WCK 2.3 than those of the reference streams.

Radiological Parameters:

1.) The radioactive alpha concentration at WCK 2.3 (0.1 pCi/L) was similar to that of the reference sites; reference sites WCK 6.8 and CCK 1.45 had alpha values of 0 and 1.0 pCi/L, respectively.
2.) The radioactive beta concentration at WCK 2.3 (218 pCi/L) was higher than that of the reference sites; reference sites WCK 6.8 and CCK 1.45 had beta values of 0 and 2.6 pCi/L, respectively.
3.) Cesium-137 was measured at 18.2 pCi/L at WCK 2.3; it was not detected at either of the reference streams.

Conclusion

Bear Creek: None of the non-radiological results were greater than the Tennessee General Water Quality Criteria (TWQC) (Table 2). In addition, none of the radiological results were greater than DOE Preliminary Remediation Goals (PRG) goals (Table 3). The field trip and field blank quality control results were in control which indicated that our field sampling technique was correctly conducted. Relative to the majority of the above observations, the main trend is that contaminant levels are highest at BCK 12.3 and decrease as Bear Creek flows downstream and to the west. It is likely that as the contaminants travel farther downstream/west, their concentrations are being decreased due to the water dilution effect.

East Fork Poplar Creek: Except for mercury, none of the other non-radiological results were greater than the TWQC (Table 4). Mercury's TWQC limit in surface water is < 0.051 µg/L. This result was expected due to the Y-12 legacy mercury contamination of EFK. Nonetheless, these

elevated EFK mercury values are of great concern as mercury is highly toxic to human beings. The results from the HCK 20.6 field duplicate sampling showed excellent reproducibility, thus indicating that our field sampling technique was correctly conducted.

Mitchell Branch: None of the non-radiological results were greater than the TWQC (Table 6). The field trip and field blank quality control results were in control which indicated that our field sampling technique was correctly conducted. Relative to the majority of the above observations, the main trend is that contaminant levels are lowest at MIK 1.43 and increase as Mitchell Branch flows downstream and to the west and enters the contaminated footprint of the ETTP/old K-25 complex.

White Oak Creek / Melton Branch: None of the non-radiological results were greater than the TWQC (Table 8). In addition, none of the radiological results were greater than DOE PRG goals (Table 9). The field trip and field blank quality control results were in control which indicated that the field sampling technique was correctly conducted.

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DRINKING WATER MONITORING

Sampling of Oak Ridge Reservation Potable Water Distribution Systems

Principal Author: Clyde E. Worthington, L.P.G.

Abstract

As the three Department of Energy (DOE) Oak Ridge Reservation (ORR) plants become more accessible to the public, the Tennessee Department of Environment and Conservation (TDEC), Department of Energy Oversight Office (the office) is expanding its oversight of DOE facilities' safe drinking water programs. The scope of the office's independent sampling includes oversight of potable water quality potentially impacted by DOE's legacy contamination on the ORR. In 2013, TDEC conducted oversight of the potable water distribution systems and the water quality at ORR facilities. The 2013 results of this oversight revealed that the three reservation systems provide water that meets state regulatory levels.

Introduction

Public consumption of the water on the Oak Ridge Reservation (ORR) continues to increase. In order to facilitate technology transfer, work for non-governmental sectors, and utilization of surplus buildings by private companies, security has been relaxed or reprioritized in recent years at some portions of the sites, most notably at East Tennessee Technology Park (ETTP). In turn, the composition of the workforce at the ORR has changed substantially. Oak Ridge National Laboratory (ORNL) has always hosted foreign dignitaries and accommodated visiting scientists in an openly cooperative manner. The other two facilities, ETTP and Y-12, allowed only limited public visitation until recent years. Current facility use involves a substantial public presence at ETTP and ORNL. Y-12's public presence is not as vast as it is at ETTP or ORNL.

Methods and Materials

The oversight included random inspections of ORNL and Y-12 to check free residual chlorine levels of the distribution systems at ORNL and Y-12.

Results and Discussion

Y-12

Three routine inspections were made at Y-12 during 2013. They focused on the facility's free chlorine residual levels. The dates for the inspections were as follows: March 25, June 26, and September 30. The chlorine residual levels were in compliance with drinking water regulations.

ORNL

Three routine inspections were made at ORNL during 2013. They focused on the facility's free chlorine residual levels. The dates for the inspections were as follows: March 25, June 26, and September 30. The chlorine residual levels were in compliance with drinking water regulations.

ETTP

No routine inspections were made at ETTP in 2013 due to the city of Oak Ridge being responsible for 90 percent of ETTP's system. TDEC DOE-Oversight is not tasked to oversight the city of Oak Ridge's system. The other ten percent is maintained by Operations Management International (OMI) and is located in a classified area of ETTP. OMI sends a copy of their

sampling results to TDEC's Division of Water Supply for regulatory purposes. TDEC DOE Oversight also gets a copy of these results. Personnel fulfilled oversight responsibilities of ETTP's facility by reviewing and filing the results from OMI.

Conclusion

The results of the inspections and document reviews revealed that the three potable distribution systems for the ORR provide water that meets state regulatory levels. However, the potential exists for a cross connection between the distribution systems and contamination from the surrounding environmental media when breaks/leaks occur in the system.

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RadNet Drinking Water on the Oak Ridge Reservation

Principal Author: Natalie Pheasant

Abstract

The RadNet program was developed by the U.S. Environmental Protection Agency to ensure public health and environmental quality as well as to monitor potential pathways for significant population exposures from routine and accidental releases of radioactivity (U.S. EPA, 1988). The RadNet program focuses on nuclear sources and population centers. The RadNet Drinking Water Program in the Oak Ridge area provides for radiochemical analysis of finished water at five public water supplies located near and on the Oak Ridge Reservation. In this effort, quarterly samples are taken by staff from the Tennessee Department of Environment and Conservation and analysis for radiological contaminants is performed at the Environmental Protection Agency's National Air and Radiation Environmental Laboratory in Montgomery, Alabama. Analyses include tritium, iodine-131, gross alpha, gross beta, strontium-90, and a gamma spectrometry, with further analysis performed when warranted. While results for tritium, gross beta, and strontium-90 have tended to be slightly higher at the ETTP Water Treatment Plant, all results generated by the program have remained below regulatory criteria, since its inception in 1996.

Introduction

Radioactive contaminants released on the Oak Ridge Reservation (ORR) can potentially enter local streams and be transported to the Clinch River. While monitoring of the river and local water treatment facilities has indicated that concentrations of radioactive pollutants are below regulatory standards, a concern that area water supplies could be impacted by ORR pollutants remains. In 1996, the Tennessee Department of Environment and Conservation (TDEC) began participation in the Environmental Protection Agency's (EPA) Environmental Radiation Ambient Monitoring System, which is now called RadNet. RadNet is a national network of monitoring stations that collects samples to check for radiological contamination. The RadNet Drinking Water Program provides radiological sampling of finished water at public water supplies near major population centers and nuclear sources throughout the United States. The RadNet program is designed to:

- monitor pathways for significant population exposure from routine and accidental releases of radioactivity,
- provide data indicating additional sampling needs or other actions required to ensure public health and environmental quality and,
- serve as a reference for data comparisons (U.S. EPA, 1988).

The RadNet program also provides a mechanism to evaluate the impact of DOE activities on area water systems and to validate DOE monitoring in accordance with the Tennessee Oversight Agreement (TDEC, 2011).

Methods and Materials

In the Oak Ridge RadNet Drinking Water Program, EPA provides radiochemical analysis of finished drinking water samples taken quarterly by TDEC staff at five public water supplies located on and in the vicinity of the ORR. The samples are collected using procedures and supplies prescribed by EPA protocol (U.S. EPA, 1988; U.S. EPA, 2013). The samples are analyzed at the Environmental Protection Agency's National Air and Radiation Environmental

Laboratory (NAREL) in Montgomery, Alabama. The analytical frequencies and parameters are provided in Table 1.

Table 1: RadNet Drinking Water Analyses

ANALYSIS	FREQUENCY
Tritium	Quarterly
Iodine-131	Annually on one individual sample/sampling site
Gross Alpha, Gross Beta, Strontium-90, Gamma Scan	Annually on composite samples
Radium-226, Uranium-234, Uranium-235, Uranium-238, Plutonium-238, Plutonium-239, Plutonium-240	Annually on samples with gross alpha >2 pCi/L
Radium-228	Annually on samples with Radium-226 between 3-5 pCi/L

The five locations sampled in the Oak Ridge area for the program are the Kingston Water Treatment Plant, the ETTP Water Treatment Plant (run by the city of Oak Ridge), the West Knox Utility District Water Treatment Facility, the Y-12 Water Treatment Plant (run by the city of Oak Ridge), and the Anderson County Water Authority Water Treatment Plant. Figure 1 depicts the approximate locations of the raw water intakes associated with these facilities.

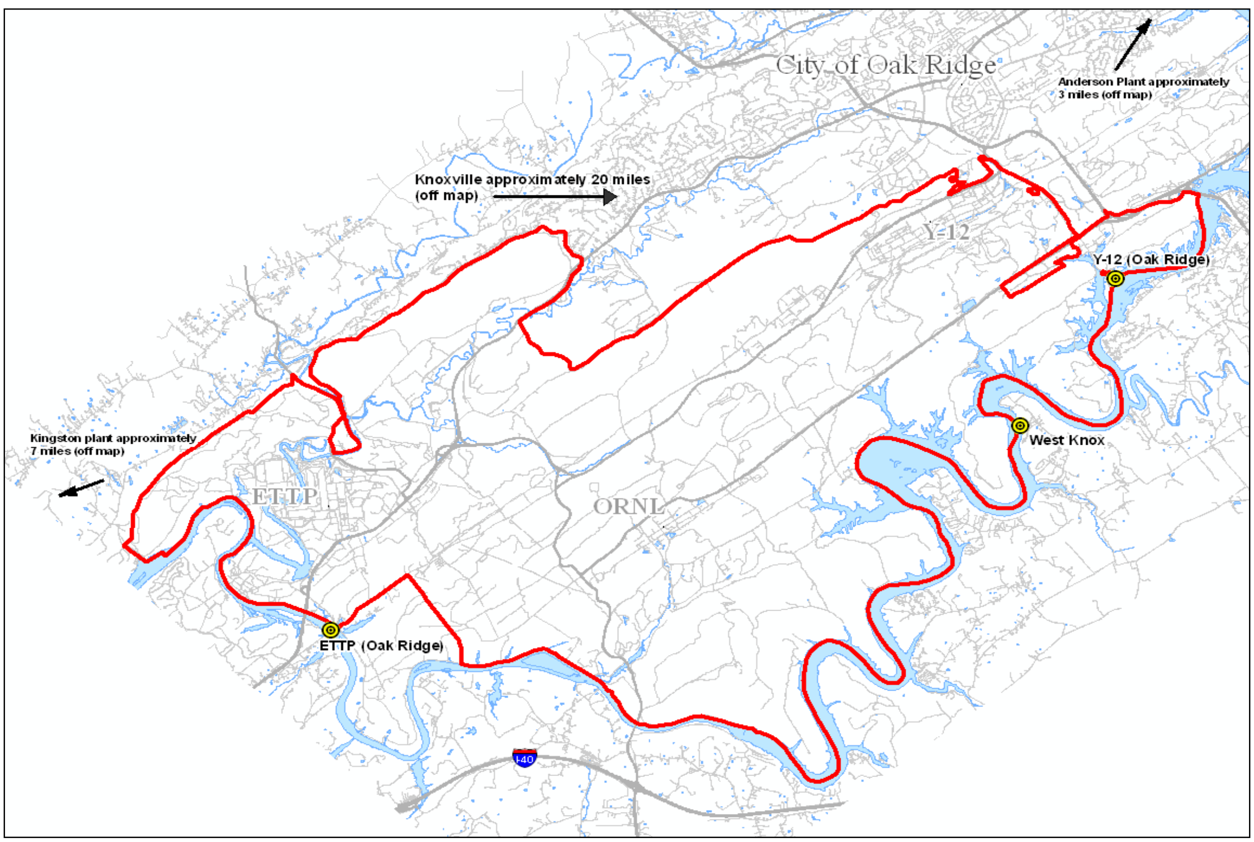

Figure 1: Approximate Locations of the Intakes for Public Water Systems Monitored in Association with EPA's RadNet Drinking Water Program

The results of NAREL's analyses are provided to TDEC annually. Nationwide data is available at NAREL's website in the Envirofacts RadNet Searchable Database, via either a simple or customized search (websites listed in references).

Results and Discussion

A large proportion of the radioactive contaminants that are transported off the ORR in surface water enter the Clinch River by way of White Oak Creek, which drains the Oak Ridge National Laboratory complex and associated waste disposal areas in Bethel and Melton Valleys. When contaminants carried by White Oak Creek and other ORR streams enter the Clinch River, their concentrations are significantly lowered by the dilution provided by the river. With exceptions, contaminant levels are further reduced in finished drinking water by conventional water treatment practices used by area water treatment plants. Consequently, the levels of radioactive contaminants measured in the Clinch River and at area water supplies are far below the concentrations measured in White Oak Creek and many of the other streams on the ORR.

Since the ETTP Water Treatment Plant (transferred to the city of Oak Ridge on May 29, 2008) is the closest water supply downstream of White Oak Creek (approximately 6.5 river miles), this facility would be expected to exhibit the highest concentrations of radioactive contaminants of the five utilities monitored by the ORR RadNet Drinking Water program. Conversely, the Anderson County facility (located upstream of the reservation) would be expected to be the least vulnerable of the facilities to ORR pollutants. The data collected since the Oak Ridge RadNet program began in July of 1996, indicates that this is the case. However, all results for the five water treatment facilities have remained well below applicable Maximum Contaminant Levels (MCL) drinking water standards set by EPA (Table 2).

Table 2: EPA Drinking Water Standards (pCi/L)

Isotope	MCL
Iodine-131	3 pCi/L
Strontium-90	8 pCi/L
Tritium	20,000 pCi/L
Cobalt-60	100 pCi/L
Cesium-137	200pCi/L

Only tritium results have been received from NAREL for 2013. These data are similar to the results received in past years. Due to government shutdown around the time the fourth quarter 2013 samples were collected, I-131 analysis was not performed. NAREL typically performs tritium analysis on each of the quarterly samples taken at the facilities in the program. The 2013 tritium results are shown in Table 3. Tritium is not readily removed by conventional treatment processes and is one of the most prevalent contaminants discharged by White Oak Creek into the Clinch River. Of the four quarterly samples taken in 2013 from each of the five area water treatment plants, all but two were below detection limits. The results above the detection limits for the 2013 samples are in bold and black in Table 3, while those below detection limits are shown in gray. Historically, the results of the tritium analyses are often below detection limits.

The results for tritium at the five sites since the program's inception range from undetected to 1,000 pCi/L. The drinking water standard for tritium is 20,000 pCi/L, so even the highest levels of tritium that have been detected by this program in the Oak Ridge area are well below this limit.

Since the net tritium results are obtained by subtracting the value of a tritium-free sample from that of the actual sample, negative numbers can be present. For a group of samples with no tritium, the results (positive and negative) should be distributed symmetrically around 0 pCi/L. Negative values are especially useful for unbiased statistical data, but can also be used to get a better picture of the range of results. The same is true for the analysis of other isotopes.

Table 3: 2013 Quarterly Tritium Results from the Five Water Treatment Facilities in pCi/L, with Values above the Detection Limits in bold

	2013 RadNet Drinking Water- Tritium			
	QTR 1	QTR 2	QTR 3	QTR 4
Anserson	103	-33	81	-36
Y-12 (OR)	137	19	-27	-67
West Knox	55	-6	-9	-34
ETTP (OR)	**157**	31	12	0
Kingston	**162**	-101	-2	-49

Gross alpha, gross beta, gamma and strontium-90 analyses are performed annually on a composite of the quarterly samples taken from each of the five monitored facilities. Results of the 2013 composite analyses are not yet available, as it can be well into the following year before they are able to be composited. The 2012 annual composite results are now available. Since the annual composite results for strontium-90 for 2011 were not available at the time of the report last year, these results are also mentioned below.

In 2012, there were no gross alpha results above detection limits and no gross beta results above detection limits (the average detection limit for the 2012 gross alpha results was 3.4 pCi/L and 4.06 pCi/L for the gross beta results). EPA's drinking water standard for gross alpha in drinking water is 15 pCi/L (MCL). The five samples from 2012 were all well below this amount. The drinking water standard for beta emitters depends on the specific radionuclides present, but radionuclide specific analysis is generally not required at gross beta measurements below 50 pCi/L. While there are no drinking water limits for gross beta, one can use strontium-90 limits as a conservative comparison, although strontium-90 is unlikely to make up a large percentage of the total gross beta, if any. The gross beta results for the 2012 annual composites from drinking water sampling location near and on the ORR fell well below EPA's drinking water standard for strontium-90 (limit 8.0 pCi/L).

The gamma spectrometry on the annual composites showed no values above detection limits. This was the case for cobalt-60 (Co-60), cesium-137 (Cs-137), radium-228 (Ra-228), and potassium-40 (K-40). The MCL for cobalt-60 is 100 pCi/L and the MCL for cesium-137 is 200 pCi/L. The 2012 results were well below these EPA drinking water standards and in fact even below detection limits.

The annual composite analysis for strontium-90 of drinking water samples for 2011 was not yet available at the time the last report was written, but is now available. The data from 2011 and 2012 all fell below the minimum detectable amounts. The highest strontium-90 result in 2011 for samples collected on and near the ORR was 0.31 pCi/L (from Kingston), and the highest strontium-90 result in 2012 was 0.23 pCi/L (from ETTP). Both were well below the 8.0 pCi/L EPA drinking water limit for strontium-90.

All samples analyzed from this program for the Oak Ridge area since its inception have been well below the associated drinking water standards and often even below detection limits.

Conclusion

Radioactive contaminants migrate from the ORR to the Clinch River, which serves as a raw water source for area public drinking water supplies. The impact of these contaminants is diminished by the dilution provided by the waters of the Clinch River. Contaminant concentrations are further reduced in finished drinking water by conventional water treatment practices employed by area water treatment plants. Results of samples collected from public water supplies on and in the vicinity of the ORR in association with EPA's RadNet program have all been well below drinking water standards, since the inception of the project in 1996. Gross beta, strontium-90, and tritium, while below drinking water standards, have tended to have higher levels in samples taken from the ETTP Water Treatment Plant than at the other facilities monitored by the program. This is not surprising as the ETTP Water Treatment Plant is the closest facility downstream of White Oak Creek, which is the major pathway for radiological pollutants entering the Clinch River from the ORR.

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GROUNDWATER MONITORING

Groundwater Monitoring for the Oak Ridge Reservation and Its Environs 2013

Principal Authors: John E. Sebastian LPG, Gareth Davies LPG, Clyde Edward Worthington LPG.

Abstract

In 2013, Tennessee Department of Environment and Conservation (TDEC), Division of Remediation's DOE Oversight Office (DOE-O) groundwater program concentrated its efforts on the area located southwest, along strike and downgradient of legacy waste sites in Bethel Valley, on the Oak Ridge Reservation (ORR). The area of investigation consisted of the Hood Ridge Area and the TVA Clinch River Breeder Reactor (CRBR) site (Figure 1). The Hood Ridge Area is residential and agricultural and located directly southwest and across the Clinch River from Bethel Valley on the ORR. The TVA site is southwest of the Hood Ridge Area also adjacent and across the Clinch River. Three separate but interrelated investigations were carried out in 2013. The center of one investigation is an open borehole, planned as a residential well, but abandoned, 188 m (610 ft) deep located in the Hood Ridge Area. The borehole is designated RWA-104 (or HD2) and is known from previous TDEC monitoring activities to be contaminated with BTEX, chlorinated solvents, disinfection byproducts, metals, and fluoride. With the assistance of the USGS the open hole was logged and recorded and was sampled at discrete intervals by both TDEC and DOE. DOE-O groundwater staff also sampled discrete intervals with passive diffusive sampling technology, obtained a sample by more conventional methodology, and installed a continuous water level monitor in RWA-104 (HD2).

During the early fall of 2013 TVA as part of preliminary site work for the installation of planned modular reactors on the CRBR site encountered free product (refined petroleum) in an observation well designated OW422L, radiochemical analysis of the free product reported a beta activity at 162 pico-Curies/Liter (PCi/L). TVA allowed DOE-O staff to sample groundwater and product from OW422L, the well is treated as a separate investigation in this report.

Seven residential wells in the Hood ridge Area were sampled on nine differing occasions in 2013. This sampling was conducted to obtain a "background" before TVA carried out an aquifer pumping test on the CRBR site that would have extracted an originally planned volume of 250,000 gallons of groundwater during a three day period. This raised concerns that the pump test of the aquifer might mobilize or further mobilize DOE legacy contaminants downgradient and along geologic strike toward residential wells in the area.

2013 analytic results from all three projects report a broad range of contaminants in groundwater from the area southwest of Bethel Valley (ORNL) on the ORR. Other than tritium which is common in wells on and offsite of the ORR three man-made radionuclides, strontium-90 (^{90}Sr), Technetium-99 (^{99}Tc), and Americium-241 (^{241}Am) were reported at low levels in groundwater analysis. As noted above the TVA well encountered free product which analysis reported as diesel fuel. Analysis of groundwater sampled beneath the free product in the TVA well reported elevated concentrations of metals, BTEX, pH, sodium, fluoride, ammonia and the presence of ^{241}Am. Chlorinated solvents, disinfection byproducts, elevated metals, sodium and fluoride were

reported from unused residential well RWA-104(HD2). Low levels of ^{90}Sr and ^{99}Tc were reported from three residential wells, and increases in reported gross beta concentrations from previous sampling were observed in three residential wells in the area.

A study was made of the geochemistry of wells in the area compared to impacted wells on the ORR. Certain area wells appear unique in that the geochemistry is similar only with contaminated groundwater from wells on the Oak Ridge Reservation and does not resemble geochemistry of groundwater in the Valley and Ridge published before the ORR was created in the early 1940s.

Given the breadth and variety of reported contaminants, the regional southwestern groundwater gradient, that geologic strike in the region is northeast/southwest, that on the ORR strata-bound flow of groundwater is considered dominant, the similar geochemistry of certain on and offsite impacted wells, a complex source of contaminants located to the northeast such as the legacy waste areas associated with Oak Ridge National Laboratory ORNL) is suggested. Unless a significant, complex unknown contaminant source is identified other than the legacy waste areas at the ORNL, then the potential that groundwater in the Hood Ridge Area and TVA CRBR site has been impacted by DOE legacy waste must be considered.

Introduction:

The monitoring portion of this report is organized into five sections. Separate sections are presented detailing the analytical results for: TVA well OW422L, the deep unused residential well RWA-104(HD2), and a review of the reported presence of man-made radionuclides in residential wells in the Hood Ridge Area. Following the discussion of analytical results is a section consisting of geochemical, studies and comparisons of wells from the study areas and wells on the ORR. A section reports on results of continuous water level monitoring for the unused residential well RWA-104(HD2), followed by conclusions.

Methods and Materials

Groundwater assessment by TDEC/DOE-O in 2013 consisted of the collection and analysis of samples from the environs of the ORR. Samples were analyzed for radiochemicals, inorganics, volatile organic compounds (VOCs) and at selected locations samples were collected for stable nitrogen and oxygen isotopes. Samples were analyzed either by the state of Tennessee's Department of Health Laboratories or by contract laboratory (for isotopes of uranium, nitrogen and oxygen). All contaminants were screened against Environmental Protection Agency (EPA) Maximum Contaminant Levels (MCL), EPA secondary MCLs, EPA Health Advisories, EPA Maximum Contaminant Level Goal (MCLG) (EPA, 2011), and the 90^{th} percentile results for the National Water Quality Assessment (NWQA) United States Geological Survey (USGS) groundwater study (DeSimone 2009).

TVA Well OW422L:

TVA observation well OW422L installed late summer 2013, located at the Clinch River Breeder Reactor site (CRBR) approximately 7 kilometers southwest of Oak Ridge National Laboratory (Figure 1), was found to have encountered refined petroleum (free product). Due to the proximity to the Oak Ridge Reservation and that TVA's analysis of the product indicated the presence of

beta emitting radionuclides the DOE-Oversight office groundwater staff was asked to assist in determining the nature and source of the contamination.

Location:

The proposed site of the TVA modular reactors is the Clinch River Breeder Reactor Site on the Clinch River southwest of Bethel Valley on the ORR. The site is located on geologic strike and downgradient from Bethel Valley on the ORR, and shares the same carbonate formations (Ordovician Chickamauga Group Limestones) that underlie ORNL (Waste Area Group 1 (WAG 1)), WAG 2 the 7000 Area (WAG 17), and WAG 3.

Discussion:

The following is a discussion of selected analytical results from TDEC, and TVA sampling of Well OW422L. Results shown are selected on the basis of exceeding: an EPA primary or secondary maximum contamination limit (MCL), a 90th percentile result from the National Water Quality Assessment (NWQA) (DiSimone 2007) or by professional judgment that the analyte is important in understanding well OW422L. Associated with each table will be a discussion regarding possible origins of reported contaminants/constituents and similarities to other wells in the area.

Background:

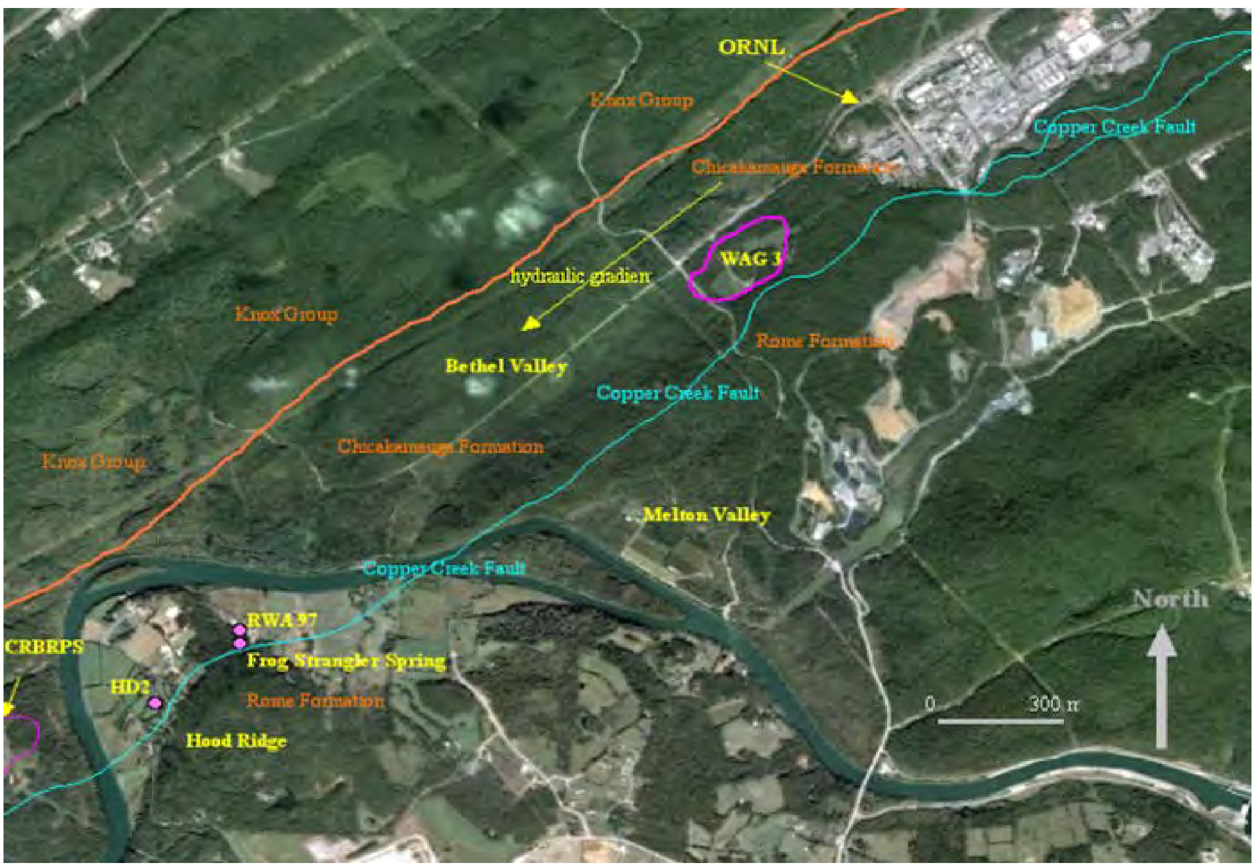


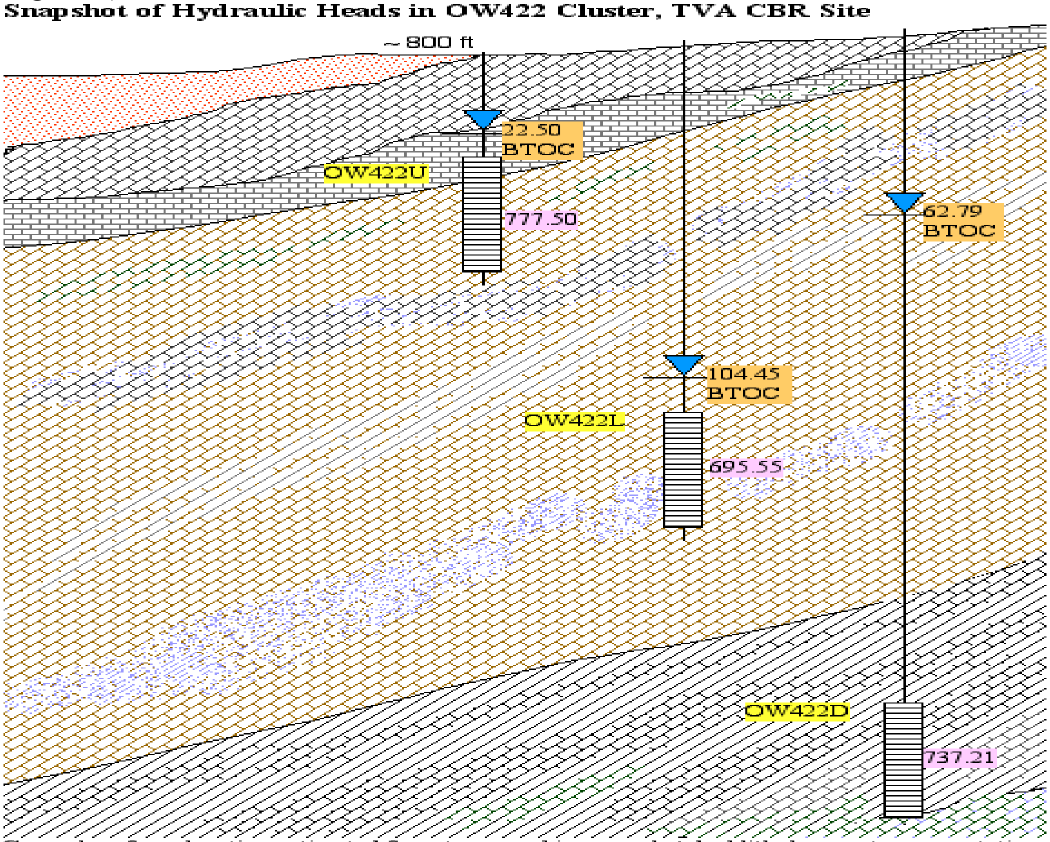
Figure 1. Satellite Image showing Bethel Valley, CRBR Site (labeled CRBRPS), ORNL, WAG 3, and selected Residential Wells

TVA has installed over 100 site investigation wells (for geophysical, geotechnical, and environmental monitoring) at the proposed modular reactor site (former Clinch River Breeder Reactor Project location (CRBR)). One of these wells OW422L was found to be contaminated with free product (LNAPL) TVA analysis of the product reported the presence of gross Beta at 162 pCi/L, with no alpha, or gamma radiation reported (Rhonda Hooper personal communication, 2013).

Well OW422L is part of a three-well cluster consisting of a deep well OW422D 95 m (313 ft) below ground surface (m, ft bgs) and shallow well (17 m, 50 ft deep) OW422U and OW422L the medium depth well ~55 m, ~180 ft bgs (Figure 2). After the discovery of contaminants in OW422L TVA decided to delay the development of OW422L, however both the deep and the shallow well in the cluster have subsequently been developed. During TDEC sampling of OW422L groundwater from OW422L was observed to have become turbid after development work on adjacent well OW422D. TVA and its contractors later reported that OW422L had "gone dry" after the further development of the deeper well, suggesting a possible connection between the deeper well and OW422L. TVA shared hydraulic head information from the cluster of wells Figure 3, shows a time-related plot of the heads and an interpretation of the changes during development, sampling and monitoring. It appears that when the deep well was developed the head also dropped in the intermediate well. TVA personnel also commented during the development of the deep well there was a "strong sulfur and petroleum smell," so it seems likely that there is a connection between it and OW422L.

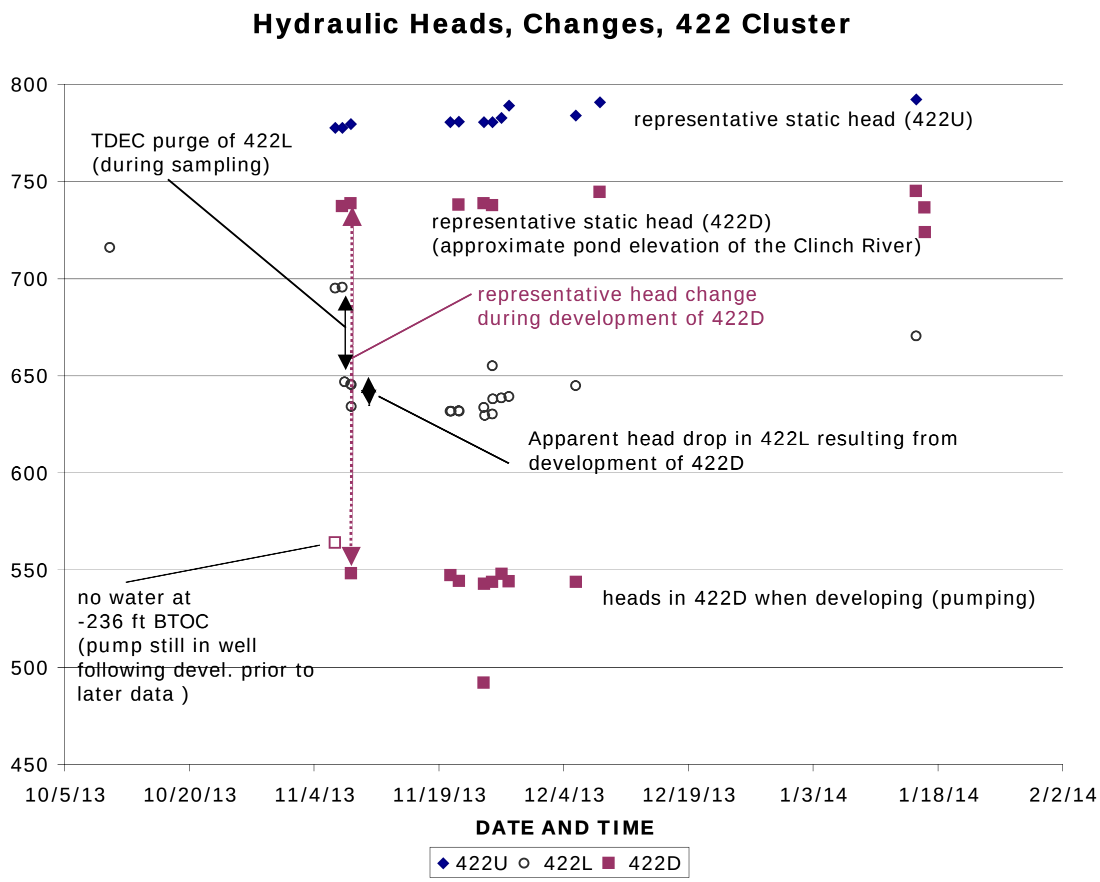
Figure 2)

Snapshot of Hydraulic Heads in OW422 Cluster, TVA CBR Site



Ground surface elevation estimated from topographic map, sketched lithology not representative of the actual lithology, elevation heads (ft) are moved and plotted at mid screen elevations, not to scale

Figure 3) OW422 Well Cluster Heads vs. Time



OW422L is constructed to a total depth of ~180 ft. bgs and screened between 48 m, (158 ft) bgs and 54 m, (178 ft) bgs, mid screen is approximately 51 m, (168 ft) bgs. Construction consists of 5.1 cm (2-inch) pvc pipe grouted into place and screened as indicated above. The well was originally intended for environmental monitoring but has since been removed from that program by TVA. Surface elevation of the three well clusters is approximately 800 ft msl.

TVA sampled groundwater from OW422L on two occasions after the initially sampling the free product. The TVA sampling events on 10/08/2013 and 10/09/2013 consisted of two samples, one of the groundwater samples was taken near the bottom of OW422L, the exact depth of the other sample is not known. TDEC groundwater staff sampled the well on 11 /07/2013, the TDEC sample was obtained from near the bottom of the well.

In general many of the same constituents in groundwater were reported from analysis of both the TVA samples and the TDEC sample. Potassium, sodium, chromium and a number of metals as well as gross beta were reported at higher concentrations in TVA's results. However considering the development work that was ongoing around well OW422L some difference in results should

be expected. Two common laboratory solvents 2-Butanone and 2-Hexanone were reported in TVA results and not in the TDEC results. The presence of these two common laboratory solvents may be suggestive of possible origins of the contaminants and they are included in a separate table (Table 6) following the TDEC organic result (Table 5).

Refined Petroleum (Free Product) in OW422L:
Analysis of the free product recovered from OW422L by TDEC staff reported the substance as diesel fuel, review of chromatograms and subsequent discussion with the analytic Lab and TDEC experts (Table 1) suggests the free product is more likely a mixture of diesel and kerosene.

Eddie Worthington TDEC Geologist Inspecting Free Product from OW422L

Table 1: TDEC Analysis of Free Product TVA Well OW422L

Analyte	Result	Units	Lab	MRL	MDL	Notes
Diesel	2,100,000	mg/kg dry	MM	880,000	440,000	Free Product - Possibly diesel kerosene mix*

*personnel communication Robin Heriges (former Organics Laboratory Supervisor, Tennessee Department of Health), and McCoy Laboratories MM: McCoy and McCoy Laboratories
MRL: Minimum Reporting Limit MDL: Minimum Detection Limit

Possible sources for refined petroleum products in TVA well OW422L:

1. Extensive quarrying operations were conducted during the effort to build the Clinch River Breeder Reactor at the site (1976-1983). Considerable quantities of diesel fuel must have been handled and used on site for excavation and construction.
2. Fifty-six petroleum underground storage tanks (UST) were located upgradient and along geologic strike at ORNL and the associated 7000 area within Bethel Valley on the ORR ASER 1998). The tanks contained a variety of refined petroleum products, the majority being diesel fuel, tanks also held gasoline, heating oil, waste oils, two tanks were reported to contain trimethylbenzene. The various tanks were operational for different time periods between 1943 and 1996. Their capacities ranged from 380 L (100 gallons) to 91,000 L (24,000 gallons). Solvent based isotope separation processes were developed at ORNL (Runion 1950). Many of these processes such as the PUREX (plutonium uranium recovery by extraction) were based on mixtures of tributyl phosphate (TBP) and a hydrocarbon dilatant often kerosene. ORNL also hosted projects for coal to oil research and recovery of alternative sources of fossil fuel such as shale oils (Carlson 1999).
3. An unknown source.

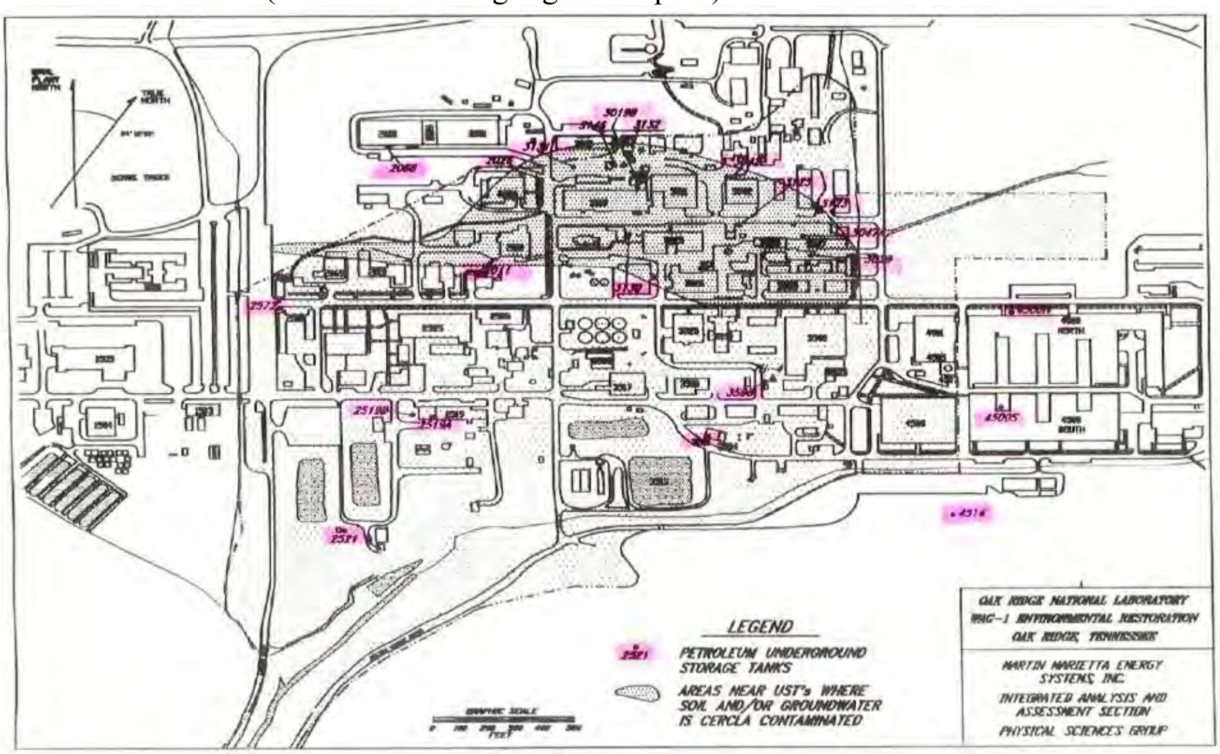
No records of diesel or kerosene USTs were found for the CRBR site, one record was located of a 945 L (250 gallon) gasoline UST at the CRBR site that was remediated in 1995 (ASER 1998). Large amounts of diesel powered vehicles were used in the excavation process for the CRBR pit (approximately 400x500x100 feet) but TVA has not reported free product from any of the other wells (over 100) recently (2013) constructed at the site. TVA also reports that interviews conducted with retired personnel who had worked at the site during the excavation revealed no knowledge of a spill or other source of diesel or other fuels during excavation or construction (TVA 2013).

Purge water from TVA Well OW422L mixture water, sediment, and free product (courtesy TVA)

Fifty-six petroleum USTs were located at ORNL and the 7000 Area (ASER 1998). The tanks were 6-9 kilometers to the northeast upgradient and along geologic strike. Petroleum USTs were operational at ORNL from 1943-1996 (Figure 5).

Solvent based isotope extraction based largely on a TBP and kerosene mix was pioneered at ORNL and various research and pilot projects involving coal to oil, and extraction of petroleum from unconventional sources, such as shale oil, were hosted at ORNL (Carlson 1999). Free product has been reported from the 7000 area (citation needed) and tentatively identified compounds listed as "unknown hydrocarbons" are common in analytic records of groundwater analysis from wells at ORNL (OREIS). An example would be Core Hole 6 (CH-6) located on the ORNL main campus which lists 13 unknown hydrocarbons (OREIS). Well logs from CH-8 report hydrocarbons to be present in fractures and organics are reported from a number of locations at ORNL (SCSR 1992) and CH-4 also located on the main campus is reported to have encountered approximately one half barrel of a petroleum hydrocarbon (R. H. Ketelle personal communication). DOE has maintained that substances identified in these reports are natural hydrocarbons, but analytic reports have not at this time been made available.

Figure 5) Petroleum Underground Storage Tanks Up-Gradient and Along Geologic Strike From TVA Well OW422L (Tank numbers highlighted in pink) 7000 AREA tanks not shown



Radiochemicals:

Radiochemical analysis of groundwater by TDEC from OW422L (Table 2.) reported significant gross beta, gross alpha, and a low concentration of the transuranic nuclide, americium 241 ^{241}Am.

Table 2: Selected Radiochemical Results from TDEC Analysis TVA Well OW422L

Analyte	Result	Units	CSU	SSMDC or MDA	EPA MCL	Note
Americium-241	1.68E-01	pCi/L	8.45E-02	7.82E-02		Small Cm, Np peaks also present
Gross Alpha by LSC	18	pCi/L	5.4	8.1	15.0	
Gross Beta by LSC	102		47	6	50	Accounted for by result for potassium metal 140 mg/L
Neptunium-237	8.08E-02		4.46E-02	3.96E-02		

CSU: combined standard uncertainty at 1 sigma
ssMDC: sample specific Method Detection Limit
MDA: Minimum Detectable Activity
EPA MCL: Maximum Contaminant Level
Highlighted Red: exceeds EPA Primary MCL

The gross beta reported in the TDEC analysis can be accounted for by the beta emitting natural isotope potassium-40 (^{40}K) as a component of the reported total potassium in mg/L derived from the metals analysis (Table 3.) The empirical formula (0.82 x mg/L) of potassium metal is utilized to determine the contribution of beta radiation from (^{40}K). In the TDEC analysis all the reported gross beta can be attributed to the reported potassium metal in the groundwater sample potassium-derived beta radiation is not considered in calculating the EPA MCL for gross beta (EPA). Understanding the relationship of beta emitting radionuclides in groundwater in this well is complicated in that previous TVA analysis reported gross beta in excess of that which could be accounted for by the presence of potassium metal in solution. This may suggest that at the time of the TVA sample another beta emitting isotope was present or this may be an artifact due to the high dissolved solids content of the groundwater affecting the TVA gross beta analysis. Of note, DOE-O groundwater staff prefers gross beta analysis be done by liquid scintillation spectrometry because of higher efficiency and other advantages (R. Read, personal communication). Leaving the different analytical methods aside however, a question is posed by the elevated potassium reported in TDEC and TVA analytic results from OW422L. This topic will be discussed in the next section.

The reported 18 pCi/L gross alpha exceeds the EPA MCL 15 pCi/L. No specific alpha-emitting nuclide was identified in the analysis, and results for uranium and transuranics failed to account for the measured alpha radioactivity. Further analysis will be requested on the remaining sample volume that is archived at the State Radiochemical laboratory in Nashville.

Americium-241 (^{241}Am) is reported at a low concentration but at a level that is statistically significant. Neptunium 237 (^{237}Np) is also included in Table 2 as it is the daughter of ^{241}Am, and along with Cm would be expected to be separated with Am **(cite method ref)** . ^{237}Np is above the CSU and the ssMDC, but not at a level of statistical significance. A duplicate sample was analyzed for transuranic nuclides, in the duplicate the ^{241}Am while above the CSU and ssMDC is not statistically significant. At this point in time no problems have been identified in the laboratory procedure, nor has the analytical laboratory made any official retraction of the results for ^{241}Am. The presence of ^{241}Am or any transuranic would, suggest that groundwater in OW422L originated at ORNL, although other sources of transuranics cannot be totally eliminated the feasibly that another other source for these isotopes would seem insignificant.

Metals OW422L:
A number of anomalously high concentrations of metals (Table 3.) were reported from both TDEC and TVA analysis of OW422L groundwater. Arsenic was reported above an EPA primary MCL, and aluminum and iron were reported above the EPA's secondary MCLs. Boron, aluminum, iron, potassium, sodium, antimony, arsenic, chromium, copper, and lithium were reported in excess of the 90th percentile concentrations as reported in the 2007 USGS National Water Quality Assessment (NWQA). Oversight groundwater staff utilizes the 90th percentile concentrations from the USGS NWQA study (DeSimone 2007) in the absence of background data from a site in order to identify constituents that are present in anomalously high concentrations. Metals reported from the TVA analysis were similar to those reported in the TDEC analysis although concentrations were generally higher.

The TDEC sample may have had suspended sediments in the acidified container for metals analysis and there is reasonable speculation that the sediments may have contributed to the concentrations reported. However TDEC staff observed the collection of a groundwater sample from OW422L by TVA staff on 10/08/13, the sample did not appear turbid and results from the TVA analysis were similar to those from TDEC, with a notable exception that the concentrations of aluminum and iron were higher in the TDEC results. Aluminum and iron are common constituents of suspended sediments and this may account for the elevated concentrations of these two analytes.

Table 3: Selected Metals from TDEC Analysis TVA Well OW 422L

Analyte	Result TDEC	Result TVA - 02 10/09	Result TVA-01	Reporting Limit TVA	MDL TDEC	MQL TDEC	EPA MCL Primary	EPA MCL Secondary	NWQA 90th percentile
Boron	0.990	0.963	1.02	0.0001	0.0063	50			0.218
Calcium	20	9.15	9.16	0.050	0.045	0.1			
Iron	1.900	0.197	ND	0.060	0.0053	.010		300	1.1
Magnesium	5.7	0.138		0.050	0.013	0.1			
Potassium	140	239	261	0.250	0.110	1.0			6.6
Sodium	1200	614	647	5.00	1.900	10.0			78.7
Aluminum	2.600	2.14	1.84	0.100	0.054	0.100		200	).00528
Antimony	0.0022	ND	ND	0.020	0.25	0.001	0.006		<0.001
Arsenic	0.012	0.0165	0.0143	0.010	0.00072	0.005	0.010		0.00753
Barium	0.120	0.0536	0.0573	0.010	0.00028	0.005			
Chromium	0.010	0.404	0.431	0.010	0.00095	0.005	0.100		0.004
Copper	0.062	ND	0.005	0.005	0.00051	0.001			0.0123
Lithium	310	0.202		0.010	0.052	0.001			0.0438
Strontium	1.400	NA	NA	NA	0.051	0.001			2.240
Vanadium	0.017	0.345	0.0369		0.0014	0.005			0.0204

EPA MCL: Maximum Contaminant Level
Highlighted Red: exceeds EPA Primary MCL
Highlighted Green: exceeds EPA Secondary MCL
Highlighted Blue: exceeds USGS NWQA 90th Percentile
MDL: Minimum Detection Limit
MQL: Minimum Quantifiable Limit
NA: not analyzed
ND: non-detect
DF: Dilution Factor
j: estimated result value

Metals continued:
Alternatively the suggestion has been made that elevated pH of groundwater in OW422L (pH 11-13) may have leached the metals from the country rock into the groundwater. This still requires an explanation for the elevated pH as the natural range of pH in groundwater is 6.5-8.5 (Hem, 1985), and its typically not this high in waters in contact with the same rock types (White et al., 1963). Grout from installation of the monitoring well has been suggested as a possible explanation of the elevated pH (TVA personal communication). The development report of TVA well OW422D (100m, 313 ft BGS) in the same well cluster also reports elevated pH throughout well development activities. In OW422D the pH remained between 9.5-9.6 units during development. Ten well volumes, (more than 1,500 L) were purged from OW422D in ~30 days in a total of ten separate purge events. This suggests that elevated pH in groundwater in the area is probably more widespread than the site scale.

It is possible that some of the data from OW422L may suggest a connection with deeper waters, possibly brines, which would suggest they originated further away. Hydraulic heads show a steep upward gradient from depth (Figure 2).

Brines however, are generally acidic or neutral although some are as high as 9.0, but very seldom as high as 9.5 units (White et al., 1963). Measurements in OW422L has pH that varies between, 11 and13 units, adjacent deep (100m, 313 ft bgs) well OW422D consistently has a pH of 9.5-9.6 during and following development of that well (see discussion above).

The metals present in OW422L cannot be eliminated as contaminants because they are also reported as constituents of low level liquid wastes generated at ORNL (Autrey, 1989) during legacy operations. Liquid waste streams at ORNL with some exceptions were purposely adjusted to an elevated pH (Spaulding, 1987). Legacy radioactive liquid wastes on the ORNL were stored in large underground gunite holding tanks, before being transferred to unlined ponds in Bethel Valley where some of the liquid was released to White Oak Creek. Alternatively liquid radioactive wastes were transferred by truck or pipeline to Melton Valley for disposal either in unlined shallow trenches **(cite pits and trenches)** or by deep well injection **(cite hydrofrac).**
Given that the origins of legacy liquid wastes in both Bethel and Melton Valley are the same it is reasonable to expect certain similarities the constituents observed in offsite groundwater impacted by ORR legacy waste. Comparison of metals results from offsite contamination reported from Melton Valley is similar to metal results obtained from analysis of groundwater from OW422L, and the elevated pH from both OW422L and OW422D are consistent with anomalous pH levels reported from a number of monitoring wells (pH~9.5 to pH~12.5 units) and certain residential wells (pH 9.5 to pH 10.76 units) offsite of Melton Valley (TDEC 2010).

The most significant difference in observed contamination in OW422L and that observed in offsite Melton Valley groundwater is the presence of free product in OW422L. BTEX (benzene, toluene, ethyl benzene and xylenes) are reported from contaminated groundwater offsite of Melton Valley however, free product has yet to be observed. While fuels and liquid scintillation fluids were disposed of in Melton Valley the same fuel handling infrastructure (57 petroleum USTs) was not present in Melton Valley as it was in Bethel Valley (ASER, 1998). Solvent based isotope separation processes have occurred in both valleys and is ongoing in Melton Valley, however, isotope separation operations in Melton Valley are more recent and waste handling procedures more stringent.

General Inorganics OW422L:
Chloride, fluoride, sulfate, total dissolved solids (TDS), and pH exceeded secondary EPA drinking water standards. Secondary EPA standards deal with the potential of constituents in water to have aesthetic and cosmetic effects. Fluoride at 3.6 mg/L approached the EPA primary drinking water standard (4 mg/L), pH as measured with pH paper was between 12 and 13 and may have crossed the threshold of the EPA definition for hazardous corrosive waste at pH 12.5 (CFR??). Each of these constituents was above the NWQA reported 90th percentile concentrations exceeding what might be expected in groundwater (DeSimone, 2009). Possible sources for these constituents are deeper waters, and ORNL legacy liquid process waste (cite tank waste). However it is difficult to attribute the reported pH in OW422L and OW422D to deeper waters or brines. Christopher and Wilcock (1981) say that in normal deep circulating

groundwater potassium should be low. Waters from HD2, OW422L and RWA-97 have the most unusually signatures and do not look similar to brines. This suggests that the elevated potassium in only a moderately deep well is not easily explained. The concentration of potassium in OW422L is as high as some oil field-related waters (White et al., 1963), but the other principal chemical components to not fit the same pattern as that of a brine (Figure 13).

Ammonia was reported at a concentration of 6.8 mg/L, natural levels in groundwaters are usually below 0.2 mg of ammonia per liter (WHO 2003). Ammonia which may be derived from nitrate in a reducing environment (An, 2002) is a possible indicator that the contamination present in OW422L originated from a source which contained nitrates, this can be possibly be further explained with ^{15}N and ^{18}O isotope analysis. There are many possible sources of nitrate in the environment (Kendall and McDonald, 2000) but, in addition at ORNL, one additional source. Process waste at ORNL is reported to have high concentrations of nitrates (Autrey 1989). .

Phosphorus was detected in the groundwater from OW422L, phosphorus was reported above the 75th NWQA percentile. Its presence however is consistent with a waste source containing tributyl phosphate such as process waste from ORNL.

Table 4: TDEC Analysis TVA Well OW422L General Inorganics and Water Parameters of Interest

Analyte	Result	Units	MDL	MQL	EPA Primary MCL	EPA Secondary	NWQA 90th Percentile
Ammonia	6.5	mg/L	0.074	0.20			
Chloride	1500	mg/L	14.50	125.0		250	62.8
Fluoride	3.6	mg/L	0.150	0.500	4.0	2.0	1.1
TDS	3349	mg/L	10	10		500	590
Sulfate	300	mg/L	2.90	25.0		250	94
Total Phosphorus	0.080	mg/L	0.012	0.050			
pH Field	12	Standard units				8.5	7.9

EPA MCL: Maximum Contaminant Level
Highlighted Red: exceeds EPA Primary MCL
Highlighted Green: exceeds EPA Secondary MCL
Highlighted Blue: exceeds USGS NWQA 90th Percentile
MDL: Minimum Detection Limit
MQL: Minimum Quantifiable Limit
NA: not analyzed
ND: non-detect
DF: Dilution Factor
j: estimated result value

Organics:
Toluene and benzene are reported above their respective EPA MCLs in groundwater from OW422L (Table 5); 13 different organic compounds were reported from the TDEC analysis.

TVA organic analysis also reported the presence of two common industrial solvents MEK (2-butanone) and 2-hexanone (Table 6). MEK and 2-hexanone are reported from analysis of well water from Bethel Valley particularly associated with the 7000 Area (WAG 17).

Table 5: TDEC Organic Analysis of Groundwater TVA Well OW422L

Contaminant	Result	Units	MDL	MQL	DF	EPA Primary MCL
1,2,4-Trimethylbenzene	126	ug/L	0.33	0.50	1	
1,3,5-Trimethylbenzene	48.0	ug/L	0.680	10.00	20	
4-Isopropyltoluene	13	ug/L	0.580	10	20	
Benzene	315	ug/L	0.800	8	20	5.0
Carbon Disulfide	4.60j	ug/L	0.640	10.00	20	
Cyclohexane	488	ug/L	2.60	10.00	20	
Ethylbenzene	136	ug/L	0.600	10.00	20	700
Isopropylbenzene	27.8	ug/L	0.540	10.00	20	
Methylcyclohexane	409	ug/L	2.60	10.00	20	
Naphthalene	5.6j	ug/L	0.600	10.00	20	
n-Butylbenzene	13	ug/L	0.900	10.00	20	
n-Propylbenzene	36	ug/L	0.740	10.00	20	
0-Xylene	266	ug/L	0.720	10.00	20	
Toluene	1007	ug/L	0.840	10.00	20	1000

Highlighted Red: exceeds EPA Primary MCL
MDL: Minimum Detection Limit
MQL: Minimum Quantifiable Limit
DF: Dilution Factor
j: estimated result value

Table 6: TVA Organic Analysis where qualitatively different from TDEC

Contaminant	Result	Units	Reporting Limit	DF	EPA Primary MCL
2-Hexanone	13.1	ug/L	5	1	
2-Butanone (MEK)	59.6	ug/L	50	1	

RWA-104(HD2) RWA-103

TDEC Geologists Gareth Davies and Eddie Worthington preparing to sample RWA-104(HD2)

During spring and early summer of 2013 TDEC groundwater efforts were concentrated on one key residential well RWA-104(HD2) (not in use) located offsite, along geologic strike and downgradient of Bethel Valley (DOE sites -ORNL, WAG3, 7000 Area) (Figures 1 & 4).

Previous results (2010) for the 188m, 615 ft deep well report the presence of a number of VOAs (50+), heavy metals, and inorganic non-metals. In 2013 geophysical logs of RWA-104(HD2) were recorded by the USGS with the assistance of TDEC DOE-O groundwater staff. Using the geophysical data three discrete depths were chosen for sampling (250', 440', 510'). USGS provided equipment and deployed a thief sampler to the chosen depths. Samples for analysis were obtained by both TDEC and DOE and are reported below in Table 7.

Location:
RWA-104(HD2) is located within an area bounded by Hood Ridge on the east and a meander of the Clinch River on the west, north and south (Figure 4). The area is adjacent to and across the Clinch River southwest from Bethel Valley on the Oak Ridge Reservation (ORR). RWA-104(HD2) is located on geologic strike and downgradient from various legacy waste disposal sites associated with Oak Ridge National Laboratory on the ORR. Waste sites are located in an

area between 5 to 9 kilometers northeast of the well. The land in the Hood Ridge area is currently used for residential and agricultural purposes, until 2013 the area was dependent on groundwater resources for domestic and agricultural use, at this time three homes are known to be using wells for domestic and agricultural purposes.

Geology:
RWA-104(HD2) a well drilled in 2008 into the Witten Formation, part of the Ordovician Chickamauga Group. Geological projection and geophysical logging confirms the borehole penetrates through the Witten into the underlying Bowen Formation. The well terminates in the top of the underlying Benbolt Limestone Formation. Regional Strike is northeast to southwest and dip varies 20-30 degrees to the southeast. Lithology of both the Witten and the Benbolt is dominated by carbonates with the intermediate Bowen Formation (Hatcher et al., 1992) is described as a thin 5-10 meter thick (16-32 feet) calcareous and shaly siltstone. RWA-104(HD2) is along geologic strike and downgradient of legacy waste disposal areas on the ORR.

The well owner reported that water was encountered at a rate of about a half-gallon per minute at a depth of 510 ft bgs in the well and that it was immediately observed to have had an "offensive" odor which continued during well development and persisted after a Clorox^{tm} shock of the well was attempted. The objectionable nature of the water, lead to the abandonment of RWA-104(HD2). Reportedly the well has never been used as a source of water.

Sampling: RWA-104(HD2) was sampled on four occasions during 2013. Below are tables and discussions describing the sampling events and analytic results.

TDEC and DOE thief sampling at discrete depths on 5/8/13:
Table 7 compares certain analytes reported from TDEC and DOE "co-sampling" of the domestic well RWA-104(HD2) (not in use). Samples were obtained from discrete depths with the use of a thief sampler and the assistance of the USGS. Samples were obtained from 250, 440, and 510 feet below ground surface (ft bgs). With the exception of samples for VOAs, the TDEC and DOE samples were obtained from different passes of the thief sampler to the same depth in the well. Radiological samples were not obtained by TDEC staff.

As can be seen from Table 7 there are a number of discrepancies between TDEC and DOE data. Results with a difference of a multiple of two or more (about) are highlighted in yellow. The 550 ft bgs level has significant differences in certain metals (copper, lead, zinc).

Antimony, fluoride, benzene, copper and lead were reported over an EPA MCL. Aluminum, fluoride, manganese, iron, pH, zinc were reported over secondary EPA MCLs.

Inorganic analytes are also compared to 90th percentile results from DeSimone's *Quality of Water from Domestic Wells in Principal Aquifers of the United States 1991-2004 (USGS)*. RWA-104(HD2) results reported from both TDEC and DOE included in the table are with the exception of manganese at or above the 90th percentile reported in DeSimone, 2009.

TDEC organic results indicated the presence of sixteen different compounds generally acetone and petroleum compounds. DOE reported seven differing organic compounds again consisting of acetone and petroleum compounds. This probably reflects differences in reporting methodology.

Table 7. TDEC and DOE Results from USGS Thief Sampling 05/08/2013

Depth ft BGS	Analyte	DOE Result in mg/L or pCi/L	TDEC Result in mg/L	Primary MCL mg/L	Secondary MCL mg/L	NWQA 90th Percentile mg/L
250	Bromide	0.2	0.034j	n/a	n/a	0.2 mg/L
250	Fluoride	1.27	1.1	4.0	2.0	1.1
250	pH	9.43 field standard units	9.60 Lab standard units	n/a	8.5	7.9
250	Aluminum	2.47	1.0	n/a	0.20	0.00528
250	Antimony	0.00145	U	0.006	n/a	<0.001
250	Boron	0.322	0.290	2.0 Health advisory	n/a	0.218
250	Chromium	0.0138	0.0070j	0.100	n/a	0.004
250	Copper	0.0281	0.016	1.3	1.0	0.0123
250	Lead	0.004	0.0015j	0.015	n/a	0.00109
250	Manganese	0.344	0.070	n/a	0.050	0.172
250	Sodium	152	140.0	20 health advisory	n/a	78.7
250	Zinc	0.465	0.270	n/a	5.0	0.0999
250	Acetone	U	0.013j	n/a		
250	Benzene	0.00671	0.0089	0.005	n/a	
440	Bromide	13.6	1.9	n/a	n/a	0.2 mg/L
440	Fluoride	4.91	2.1	4.0	2.0	1.1
440	pH	9.14 field standard units	9.62 Lab standard units	n/a	8.5	7.9
440	Aluminum	0.843	1.40	n/a	0.20	0.00528
440	Antimony	0.00341	U	0.006	n/a	<0.001
440	Boron	1.4	0.720	2.0 Health advisory	n/a	0.218
440	Chromium	0.00597j	0.0073j	0.100	n/a	0.004
440	Copper	3.58	0.012	1.3	1.0	0.0123
440	Lead	0.363	U	0.015	n/a	0.00109
440	Manganese	0.0792	0.087	n/a	0.050	0.172
440	Nickel	0.0385	0.006j	n/a	n/a	0.003
440	Sodium	1470	560	20 health advisory	n/a	78.7
440	Zinc	0.235	0.220	n/a	5.0	0.0999

440	Acetone	0.186	0.122	n/a	n/a	n/a
440	Benzene	0.0803	0.036	0.005	n/a	n/a
510	Bromide	21.9	22	n/a	n/a	0.2 mg/L
510	Fluoride	4.69	5.3	4.0	2.0	1.1
510	pH	8.25 field standard units	7.84 Lab standard units	n/a	8.5	7.9
510	Aluminum	1.04	1.60	n/a	0.20	0.00528
510	Antimony	0.00937	U	0.006	n/a	<0.001
510	Boron	1.68	U	2.0 Health advisory	n/a	0.218
510	Chromium	0.009j	0.013	0.100	n/a	0.004
510	Copper	13.2	0.0076j	1.3	1.0	0.0123
510	Iron	23	20	n/a	0.30	1.110
510	Lead	1.73	0.0022j	0.015	n/a	0.00109
510	Manganese	0.115	0.100	n/a	0.050	0.172
510	Nickel	0.066	0.0087j	n/a	n/a	0.003
510	Sodium	2120	2100	20 health advisory	n/a	78.7
510	Zinc	13.6	0.240	n/a	5.0	0.0999
510	Benzene	0.133	0.133	0.005	n/a	n/a

On May 29th 2013 Eontm passive samplers were deployed by TDEC groundwater staff at 150, 400, 470, 560, and 605 ft bgs. Samplers were retrieved from the well on July 16th 2013. Results are compiled in Table 8 below. Passive samplers such as the Eontm are designed specifically to provide samples for VOC analysis the samplers are filled with nanopure water and a membrane allows contaminants to equilibrate over a period of at least two weeks. The results obtained from the passive samplers represent an average concentration over the time period for which the samplers are deployed.

Reported results from the passive samplers show that contaminants in the well are not distributed evenly throughout the water column. Thirty-five of the thirty-six reported VOCs were found near the bottom of RWA-104(HD2) at the 605 ft bgs level. As might be expected the majority of DNAPLs (denser than water) such as carbon tetrachloride were found near the bottom and were absent from the upper portions.

he largest reported concentration of benzene was reported from a sample obtained at the 510 ft bgs level. USGS Geophysics for RWA-104(HD2) identifies the lithology at this depth as a more pure limestone which probably corresponds to a sub-unit of the Witten Limestone Formation identified in DOE literature as the “Big Lime” (R.H., Ketelle personal communication). The hydrostratigraphy, and geochemistry of RWA-104(HD2) and other wells in the area are discussed extensively below.

Benzene and carbon tetrachloride exceeded their respective EPA primary drinking water MCLs from groundwater sampled at the 605 ft depth. Benzene exceeded the primary EPA MCL at all

depths sampled except for the sample obtained at a 150 ft bgs. Thirty-six different organic substances were reported from analysis from the seven depths at which samples were obtained. All the reported constituents were present near the bottom of the well at the 605 ft bgs depth with the exception of acetone.

Table 8. TDEC results for Passive Samplers 07/16/2013

VOAs	RWA-104(HD2) Passive Samplers 07/16/13 g/L						
Analyte	150 ’	RWA-104(HD2) 400’	RWA-104(HD2) 440’	RWA-104(HD2) 470’	RWA-104(HD2) 510’	RWA-104(HD2) 560’	RWA-104(HD2) 605’
Acetone		11.4j	12.5j				
Benzene	0.74	**36.2**	**99.8**	**128**	**155**	**119**	**83.5**
Bromochloromethane							6.20
Bromodichloromethane						0.49j	132
Bromoform						0.57	56.8
Carbon disulfide						1.11	44.8
Carbon tetrachloride							**28.6**
Chlorobenzene							0.65
Chloroethane						0.73	26.6
Chloroform		0.970.91	1.40	6.72	21.8	130	6370
Chloromethane			0.43j	0.62		1.03	4.20
Cyclohexane		5.22	0.59	0.36j	1.25	1.80	30.8
Dibromochloromethane							63.7
Dibromomethane						0.44j	8.88
Ethylbenzene		1.10	2.11	3.57	9.41	4.31	4.98
Isopropylbenzene				0.27j	0.98	0.30j	0.59
m&p xylene		2.99	0.46j	1.12	19.3	5.18	11.1
Methylene Chloride		0.61			1.13	4.81	47.3
Methylcyclohexane		0.88					4.18
Naphthalene		0.27j			0.52		1.07
n-Propylbenzene				0.29j	1.17	0.34j	0.88
o-Xylene		1.58	1.73	3.04	12.1	5.49	7.15
sec-Butylbenzene							
Toluene	0.30j	14.0	4.61	2.97	5.83	3.47	27.3
1,1,1 Trichlorethane							1.35
1,1,2, Trichloroethane							2.37
1,1 Dichloroethane							18.2
1,1 Dichlorethene							0.48j
1,1 Dichloropropene							0.30j
1,2,4							

Trichlorbenzene							
1,2,4 Trimethylbenzene		0.33j			2.23	0.34j	1.41
1,2 Dichloroethane						0.62	1.49
1,2 Dichloropropane							4.65
1,3,5 Trimethylbenzene					0.67		0.57
1.3 Dichloropropane							1.31
2-Chlorotolene							1.22
2-Hexanone MBK							4.30j
4-Chlorotolene							0.54

Highlighted Red: exceeds an EPA Primary MCL
j: estimated result value

RWA-104(HD2) was sampled with Gore[tm] passive sampling devices which were emplaced on July 29th and retrieved on July 30th 2013. The Gore[tm] devices are utilized for qualitative analysis but have the advantage of reporting certain SVOCs. Groundwater staff deployed the devices as a test of the technology in a known contaminated well and to attempt to determine the presence or absence of SVOCs. No SVOCs were reported and the list of VOCs was generally equivalent to those reported from the Eon[tm] passive samplers. As no differing contaminant was identified from this sampling event no table of data is presented.

RWA-104(HD2) was sampled by TDEC for the final time in 2013 on November 29th. This particular sampling was part of a multi-phase sampling program designed to monitor residential wells in the Hood Ridge Area (Figures 1 & 4) for the potential of induced migration of ORR legacy waste contamination resulting from a proposed groundwater extraction TVA “pumping test” planed at the CRBR site (see the discussion of TVA well OW422L above). RWA-104(HD2) was sampled to provide a reference before the initiation of TVA’s pump test. The intent was to obtain samples before the hydrogeology of the area is impacted by planned groundwater extraction. It should be noted that TVA has installed and developed or are in the process of developing on the order of a hundred wells at the CRBR site, It is probable that the further development of these wells has involved the extraction of additional amounts of groundwater from the system.

It had been the intent of groundwater staff to use a portable bladder pump in conjunction with a drop tube to obtain samples within 5 ft of the bottom of the well RWA-104(HD2). Due to irregularities in the open bore of the well and that the well bore is considerably skewed from the vertical it was only possible to reach a depth of ~493 ft with the drop tube.

The total number of contaminants and their concentrations are considerably diminished from earlier sampling events. It is suggested that this is probably a result of not having been able to place the end of the drop tube near the bottom of the well where the greatest range and

concentrations of contaminants are generally seen in past analytical results. Benzene is reported above a primary EPA MCL, 12 different organic compounds were reported.

Table 9: Results for Organics Analysis from RWA-104(HD2) 10/29/2013

Analyte	Result mg/L	MDL mg/L	MQL mg/L
1,2,4-Trimethylbenzene	0.00084	0.000020	0.00050
1,3,5-Trimethylbenzene	0.00031j	0.000034	0.00050
Benzene	0.104	0.000040	0.00050
Chloroform	0.0111	0.00021	0.00050
Chloromethane	0.00049j	0.00017	0.00050
Cyclohexane	0.00018j	0.00013	0.00050
Ethylbenzene	0.00293	0.000030	0.00050
Isopropylbenzene	0.00033j	0.000027	0.00050
m&p-xylene	0.00330	0.00010	0.00050
n-Propylbenzene	0.00036j	0.00037	0.00050
o-Xylene	0.00328	0.000036	0.00050
Toluene	0.00099	0.000042	0.00050

Highlighted Red: exceeds EPA Primary MCL
MDL: Minimum Detection Limit
MQL: Minimum Quantifiable Limit
j: estimated result value

Metals RWA-104(HD2):
Results for metals reported Iron above the secondary EPA drinking water standard and nine metals above the NWQA 90th percentile.

Analyte	Result mg/L	MDL mg/L	MQL mg/L	EPA MCL Primary	EPA MCL Secondary	NWQA 90th percentile
Boron	1.600	0.0063	0.050			0.218
Calcium	31	0.045	0.100			95.3
Iron	1.900	5.3	10		.300	0.0011
Magnesium	24	0.013	0.100			36
Potassium	22	0.011	0.100			6.6
Sodium	1900	1.900	10.0			78.7
Aluminum	0.068	0.0054	0.010		200	0.00528
Copper	0.062	0.00051	0.001			0.0123
Lithium	0.500	0.00052	0.001			0.0438
Selenium	0.037	0.00091	0.005			0.0032
Strontium	3.5	0.00051	0.001			0.002240

Highlighted Green: exceeds EPA Secondary MCL
Highlighted Blue: exceeds USGS NWQA 90th Percentile
MDL: Minimum Detection Limit
MQL: Minimum Quantifiable Limit
j: estimated result value

General Inorganics and Water Parameters RWA-104(HD2):
Analysis reported fluoride at 4.9 mg/L above the EPA primary drinking water standard (4 mg/L), chloride, and total dissolved solids exceeded the EPA secondary water quality limits (Table 10). Ammonia at 1.3 mg/L exceeds the 0.2 mg/L that is expected in natural groundwater (WHO 2003) and is suggestive that the contaminants in RWA-104(HD2) may have originated from a nitrate rich source (see ammonia discussion in OW422L section above).

Table 10. General Inorganics and Water Parameters 10/29/2013

Analyte	Result Mg/L	MDL mg/L	MQL mg/L	EPA Primary MCL	EPA Secondary	NWQA 90^{th} Percentile
Alkalinity	350	10	10			325
Ammonia	1.6	0.074	0.10			
Chloride	3200	58.00	500.0		250	62.8
Fluoride	4.9	0.075	0.250	4.0	2.0	1.1
Nitrate and Nitrite	U	0.017	0.10			
TDS	4900	10	10		500	590
Sulfate	83	2.90	25.0		250	94
pH Field	8.06				8.5	7.9

EPA MCL: Maximum Contaminant Level
Highlighted Red: exceeds EPA Primary MCL
Highlighted Green: exceeds EPA Secondary MCL
Highlighted Blue: exceeds USGS NWQA 90^{th} Percentile
MDL: Minimum Detection Limit
MQL: Minimum Quantifiable Limit

Radiochemicals RWA-104(RWA-104(HD2)):

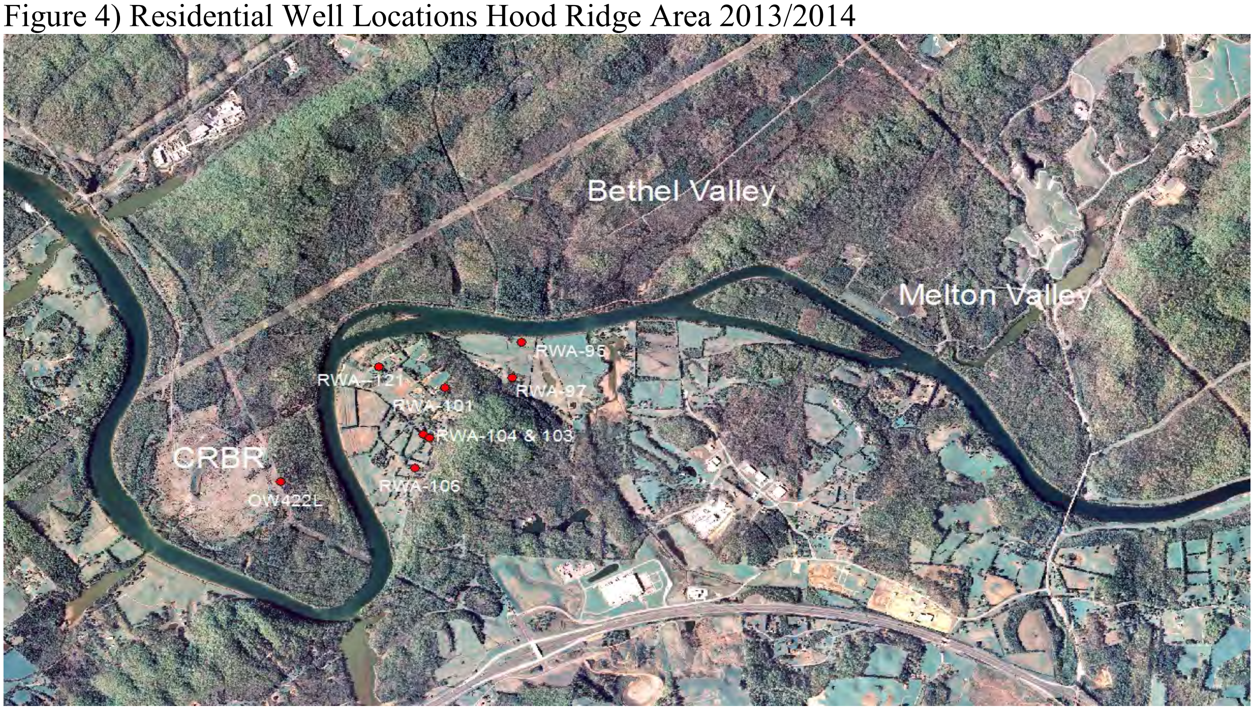
Gross beta was reported at 17 pCi/L CSU 11 pCi/L and ssMDC of 6 pCi/L. This is significant in that it represents an increase over a previous gross beta result of 12pCi/L. Again with two radiochemical results the significance of such an increase might not seem apparent. However three other wells in the area have reported either an increase in gross beta results from ground water or the presence of man-made radiochemicals ^{90}Sr and ^{99}Tc in results of analysis from groundwater. The observed increase in gross beta from RWA-104(HD2) may be indicative that groundwater extraction at the CRBR site associated with well development (100+ wells) has mobilized or increased the mobilization of contaminants from legacy waste on the ORR.

Hood Ridge Area Residential Well Sampling 2013:

TDEC Geologists sampling well RWA-95

In 2013 seven different residential wells in the Hood Ridge Area (Figure 4) were sampled on nine different occasions. Previous to 2013 all the wells with the exception of RWA-104 (RWA-104(HD2)) and RWA-95 were in use as residential water supplies. RWA-104 has reportedly never been used for domestic or any other purpose (see discussion above). During 2013 the Hood Ridge Area was supplied with municipal water, all but two of the wells (RWA-97 and RWA-122(PN)) have been removed from service.

Figure 4) Residential Well Locations Hood Ridge Area 2013/2014



2013 results from analysis of residential well groundwater reported the presence of man-made radionuclides on four occasions. Strontium-90 (^{90}Sr) was reported from three wells; RWA-97, RWA-101(TW), and HD1(RWA-103), all detections were less than 4 pCi/L. Technetium-99 (^{99}Tc) was detected once in RWA-101 well at under 3 pCi/L (Table 11). The EPA primary MCL for ^{90}Sr is 8 pCi/L and the primary MCL for ^{99}Tc is 900 pCi/L.

Table 11) Selected Radiochemical Results Hood Ridge Area 2013 Residential Wells

Location and Date	Analyte	Result pCi/L	CSU pCi/L	ssMDC pCi/L	EPA MCL pCi/L
HD1 RWA-103	^{90}Sr	2.24	7.80E-01	1.14	8.0
RWA-104(HD2) 10/29/2014	Gross Beta by LSC	17	11	6	50.0
RWA-97 06/04/2013	^{90}Sr	2.86	7.98E-01	1.19	8.0
RWA-97 11/04/13	Gross Beta by LSC	17.3	3.4	6.2	50.0
TW RWA-101 06/04/2013	^{90}Sr	3.81	9.19E-01	1.19	8.0
TW RWA-101 11/18/2013	Gross Beta by LSC	11.0	2.7	5.9	50.0
	^{99}TC	2.26	0.32	0.72	900

Results from 2013 gross beta analysis of groundwater from three residential wells: RWA-97, RWA-101, and RWA-104(HD2) sampling was noted to have increased relative to past analytic results from these wells. RWA-97 and RWA-101(TW) reported gross beta results of 17 pCi/L and 11.0 pCi/L respectively (Table 11), previous results for gross beta from these two wells were all less than 5 pCi/L and most results were less than 3 pCi/L. The increase observed in RWA-104(HD2) is more problematic in that only one previous result is available for gross beta RWA-104(HD2) is discussed in detail above).

Samples obtained from these residential wells had been intended to establish a background for monitoring any potential effect on the mobilization of legacy DOE contamination located to the northeast in Bethel Valley by the planned TVA withdrawals of groundwater from their CRBR site (Figures 1 & 4) as part of activities designed for the installation of modular reactors. Development work on CRBR site wells by TVA had by the time monitoring plans were in place already extracted an unknown amount of groundwater.

It is possible that pumping of groundwater from the TVA site during well development activities may have contributed to the presence of anthropogenic radionuclides and the observed increase in gross beta from wells in the Hood Ridge Area. DOE has used a similar rational to explain the presence of offsite contaminants in adjacent areas offsite of DOE burial grounds in Melton Valley (R.H. Ketelle, core team presentations).

The presence of ^{90}Sr and ^{99}Tc in Hood Ridge Area groundwater indicates that legacy DOE waste has impacted the groundwater resource in the Hood Ridge Area. Given the significance and the low concentrations reported, quality control/quality (QA/QC) documents were reviewed by both TDEC groundwater and laboratory staff. At this time no problems have been identified in procedures that would suggest that laboratory or sampling error that would affect the reported results had occurred. Past analysis of groundwater sampled from well RWA-97 and a spring in the area (Frog Strangler Spring) also reported the presence of low concentrations of ^{99}Tc.

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RADIOLOGICAL MONITORING

Facility Survey Program and Infrastructure Reduction Work Plan

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Abstract

Like other Department of Energy (DOE) research facilities across the nation, the Oak Ridge Reservation (ORR) released large quantities of hazardous chemicals and radiological contamination into the surrounding environment during nearly five decades of nuclear weapons research and development. Since most of this contamination was released directly from operational buildings, the Tennessee Department of Environment and Conservation's Department of Energy Oversight Office developed a Facility Survey Program to document the full histories of facilities on the reservation. The survey program examines each facility's physical condition, process history, inventory of hazardous chemical and radioactive materials, relative level of contamination, past contaminant release history and, present-day potential for release of contaminants to the environment under varying conditions ranging from catastrophic (i.e. earthquake) to normal everyday working situations. This broad-based assessment supports the objectives of Section 1.2.3 of the Tennessee Oversight Agreement, which was designed to inform local citizens and governments of the historic and present-day character of all operations on the reservation. This information is also essential for local emergency planning purposes. Since 1994, the office's survey team has characterized 206 facilities and found that forty-two percent have either historically released contaminants, or pose a relatively high potential for release of contaminants to the environment today. In many cases, this high potential-for-release is related to legacy contamination that escaped facilities through degraded infrastructures over decades of continuous industrial use (e.g. leaking underground waste lines, substandard sumps and tanks, or unfiltered ventilation ductwork). Since the inception of the program, DOE corrective actions, including demolitions, have removed thirty-nine facilities from the office's list of high Potential Environmental Release (PER) facilities. In 2013 no facilities were removed due to the expiration of American Recovery and Reinvestment Act funds. During 2013, staff conducted four full facility surveys, all at Y-12 (see Table 3).

Beginning in 2002, facility survey staff also began focusing some of their efforts on the oversight of facilities slated for demolition and/or decontamination at ORNL and Y-12. This activity was in response to formal, accelerated infrastructure reduction (demolition) programs at each of those sites. After a downturn in demolition activities in 2008 due to funding short falls, activity was escalated in 2009 with the inception of the American Recovery and Reinvestment Act (ARRA). During 2012, ARRA money expired and D&D activities came to a halt. During 2013 staff made 20 site visits to observe D&D related activity (see Table 3). Four facility surveys were completed and sent to DOE in 2013: Y9720-32, Y9720-32A, Y9720-33, and Y9401-1.

Introduction

The Tennessee Department of Environment and Conservation's Department of Energy Oversight Office, in cooperation with the Department of Energy (DOE) and its contractors, conducts a Facility Survey Program (FSP) on the Oak Ridge Reservation (ORR). The program provides a comprehensive, independent assessment of active and inactive facilities on the reservation based on their 1) physical condition, 2) inventories of radiological materials and hazardous chemicals, 3) levels of contamination, and 4) operational history. The ultimate goal of the program is to

fulfill the commitments agreed to by the state of Tennessee and the Department of Energy in Section 1.2.3 of the Tennessee Oversight Agreement, which states that "*Tennessee will pursue the initiatives in attachments A, C, E, F, and G. The general intent of these action items is to continue Tennessee's: (1) environmental monitoring, oversight and environmental restoration programs; (2) emergency preparedness programs; and (3) to provide a better understanding by the local governments and the public of past and present operations at the ORR and impacts on human health and/or the environment by the ORR*."

The overall objective of the Facility Survey Program is to provide a detailed assessment of all potential hazards affecting, or in any way associated with, facilities on the Oak Ridge Reservation. To this end, the program evaluates facilities' potential for release of contaminants to the environment under varying environmental conditions ranging from catastrophic (i.e. tornado, earthquake) to normal everyday working situations. This information is also incorporated into local emergency preparedness planning.

Methods and Materials

Survey program staff members take a historical research approach to evaluating each facility. Prior to commencing fieldwork they examine engineering documents, past contaminant release information, hazard-screening and safety basis documents, drain databases, and radiological and chemical inventory data. They then perform a walk-through of the facility with the facility manager to gather additional information and to validate information acquired from previously reviewed documents. During the field visit, calibrated, industry standard, radiation survey instruments are used to estimate radiation contamination and dose levels in and around the footprint of each facility. At the end of the document review and walk-through process, a final report is produced and information is entered into the office's Potential for Environmental Release (PER) database. This database helps the team characterize conditions at each facility based on its physical condition and potential for release of contaminants to the environment.

The PER database is composed of ten categories that relate directly to the contents and condition of the operational infrastructure within and around each facility (Table 1). Each category is assigned a score from 0 to 5 (5 reflects the greatest potential for release) for each of the ten categories. As facilities are scored, totaled, and compared with each other, a relative ranking emerges. Special circumstances, such as legacy releases and professional judgment also influence category scoring. Scores are not intended to reflect human health risk. Rather, their sole purpose is to help characterize facilities based on the conditions in and around them. This information is used within the office for emergency preparedness planning, information, comparison, and review purposes only.

Table 1: Categories to be Scored

1.	Sanitary lines, drains, septic systems
2.	Process tanks, lines, and pumps
3.	Liquid low-level waste tanks, lines, sumps, and pumps
4.	Floor drains and sumps
5.	Transferable radiological contamination
6.	Transferable hazardous materials contamination
7.	Ventilation ducts and exit pathways to create outdoor air pollution
8.	Ventilation ducts and indoor air/building contamination threat
9.	Radiation exposure rates inside the facility elevated
10.	Radiation exposure rates outside the facility elevated

The final facility survey report notifies DOE of the office's findings so that DOE has the opportunity to respond and formulate corrective actions. When the office receives written confirmation from DOE of corrective actions taken at a specific facility, the rankings for that facility are modified accordingly in the PER database. The scoring criteria for each category are presented below in Table 2. Table 3 provides a program summary.

Table 2: Potential Environmental Release Scoring Guidelines

Score	**Score is based on observations in the field and the historic and present-day threat of contaminant release to the environment/building and/or ecological receptors.**
0	**No potential**: no quantities of radiological or hazardous substances present.
1	**Low potential**: minimal quantities present, possibility of an insignificant release, very small probability of significant release, modern maintained containment.
2	**Medium potential**: quantities of radiological or hazardous substances present, structures stable in the near- to long-term, structures have integrity but are not state-of-the-art, adequate maintenance.
3	**Medium potential**: structures unstable, in disrepair, containment failure clearly dependent on time, integrity bad, maintenance lacking, containment exists for the short-term only.
4	**High potential**: quantities of radiological or hazardous substances present, containment for any period of time is questionable, migration to environment has not started.
5	**Release:** radiological or hazardous substance containment definitely breached, environmental/interior pollution from structures detected, radiological and/or hazardous substances in inappropriate places like sumps/drains/floors, release in progress, or radiological exposure rates above Nuclear Regulatory Commission (NRC) guidance.
Note: A score of 0 or 1 designates a low Potential Environmental Release rank; a score of 2 or 3 designates a moderate rank; a score of 4 or 5 designates a high rank.	

Discussion and Results

The Facility Survey Program entered its twentieth year in January 2013. Since the beginning of the program, many facilities at ETTP have been privatized. In accordance with past office policy,

an individual survey conducted on a facility at ETTP that has been leased to private industry might only address those portions of the facility that are leased. Consequently, some older reports may not include adjacent areas in the same facility or related facilities. These adjacent areas and related facilities may be contaminated and/or exhibit infrastructure problems that are not reflected in the report. Therefore, when reviewing these reports, it is important to look for the phrase “leased area of the facility.” This phrase indicates that the survey report covers only the leased area of the facility specifically, and is not intended to assess the entire facility or related facility problems (such as drain lines) that may exist outside of the leased area.

Since program staff members are continually in the process of evaluating DOE corrective actions taken to address facility concerns, any current ranking may not reflect the most recent corrective actions. Since the inception of the FSP, corrective actions (mostly demolitions), have removed thirty-nine facilities (X3550, X2017, X3525, X7823-A, X7827, X7819, X3505, X7055, X7700, X7700C, X7701, X2011, X3085, Y9404-3, Y9208, Y9620-2, Y9616-3, Y9959, Y9959-2, Y9736, Y9720-8, Y9201-3, Y9738, Y9769, Y9210, Y9224, Y9211, K1025-A, K1025-B, K1015, K1004-E, K1004-A, K1004-B, K1098-F, K1200-C and K1401-L3) from the office’s list of “high” Potential Environmental Release facilities.

Table 3: Facility Survey Program Summary

Survey Year	Total Facilities Surveyed	High PER Facilities	Removed from High PER list	Facilities Resurveyed	D & D Visits
1994	15	9	0	0	0
1995	35	11	0	0	0
1996	34	9	0	0	0
1997	23	8	0	0	0
1998	8	3	1	2	0
1999	14	3	0	0	0
2000	14	5	3	0	0
2001	17	8	1	1	0
2002	8	5	5	0	90
2003	4	4	0	0	236
2004	0	0	2	1	463
2005	4	2	7	0	380
2006	2	2	7	4	123
2007	7	7	1	0	99
2008	0	0	0	1	15
2009	3	2	1	0	30
2010	7	5	6	0	30
2011	4	2	5	0	28
2012	3	1	0	1	22
2013	4	0	0	0	20
Totals	**206**	**86**	**39**	**10**	**1536**

Description of the 53 Highest Scoring Facilities (1994-2013)

The PER database attempts to reflect the overall condition of a facility and the potential for release of contaminants to the environment. However, it is not the total score of the ten categories that is always the best indicator of potential for environmental release. Rather, what appears to be the most accurate indicator is the number of categories for which a facility scores a four or five. Of the 206 facilities scored since 1994, 86 stood out with one or more categories scoring a four or five (Table 3). The remaining 53 high-scoring facilities are arranged in descending order of total numbers of fours and fives in the PER database (Table 4).

At **Y-12**, nine facilities had at least one category score of 4 or 5: Y9731, Y9204-3, Y9201-4, Y9401-2, Y9213, Y9743-2, Y9203, Y9401-1 and, Y9207.

Facility Y9731 is the oldest facility in the Y-12 complex. It originally housed the pilot project for the prototype calutron, and the original production facilities for stabilized metallic isotopes, which were used in nuclear medicine. It received four category scores of 5, two category scores of 4, and a total score of 37. Most of the facility (outside the office area) today is not receiving preventative maintenance. Process tanks and lines have leaked radiological and hazardous materials throughout the building. Asbestos-containing pipe insulation is peeling and flaking, as is lead-bearing interior and exterior paint. The exhaust fans for the building are not HEPA filtered, and therefore pose a direct pathway to the environment.

Facility Y9204-3 (Beta 3) is one of the original isotope enrichment facilities at Y-12. It received two category scores of 5, three category scores of 4, and a total score of 33. This 250,000 square-foot facility is now inactive and locked. The largest concerns are leaking PCB-contaminated mineral oil (Z-oil), and radiological contamination. The building has not been sampled above eight feet for radiological contamination, even though the probability of finding it is great. The building historically and presently vents directly to the environment without HEPA filtration.

Facility Y9201-4 (Alpha 4) is also one of the original Y-12 uranium enrichment buildings. It received three category scores of 5, one category score of 4, and a total score of 28. The containment integrity of the original process system is weak. This has resulted in breaches that have deposited contaminants in unwanted places throughout the building. Evidence suggests that open (non-filtered) exhaust fans have also released contaminants from the interior of the building to the environment for decades. PCBs, asbestos insulation, and chipping/flaking lead-based paint are also found deposited throughout the building.

Facility Y9401-2 (Plating Shop) received four category scores of 4, one category score of 5, and a total score of 25. All of these scores relate to a variety of chemical contamination issues.

Facility Y9213 (Criticality Experiment Facility) received two category scores of 5, and a total score of 24. This facility was built in 1951 and contains two underground neutralization tanks and an underground pit. The tanks and pit present a very high potential for radiological and chemical soil contamination. The areas around the tanks have not been sampled for contamination. The facility also exhibits extensive flaking of exterior lead-based paint.

Facility Y9203 (Instrumentation, Characterization Department and Manufacturing Technology Development Center) received three category scores of 4 and a total score of 22.5. Despite much work that has been done to re-route process drains in order to prevent them from terminating in the storm sewer system, these drains now go to the sanitary sewer system. This termination still presents a potential pathway to the environment and the public.

Facility Y9743-2 (Animal Quarters) received two category scores of 5, and a total score of 23. These scores reflect the uncertainty associated with the lack of radiological and chemical sampling surveys, the complete lack of institutional and process knowledge and the fact that there are interior tanks and bottles with unknown contents. The probability of biological and chemical contamination is high. There is also a total lack of facility maintenance.

Facility Y9207 (Biology Complex) received one category score of 4, and a total score of 13. In this facility, the sinks in a radiological area drain directly to the Oak Ridge sewer system, and thus represent a potential pathway for radiological materials to the city sewage and sludge.

Facility Y9401-1 received two category scores of 5 and one category score of 4. The primary issue with this facility is radiological contamination; the furnace room is contaminated and not enterable. Also, there are small amounts of external contamination around the building from past operations.

At **ETTP,** five facilities had at least one category score of four or five: K1037-C, K633, K1200-S, K1004-J, and K1220-N.

Facility K633 received five category scores of 5, two category scores of 4 and a total score of 39. There is extensive radiological contamination throughout the building, and extensive peeling of exterior and interior paint, which contains PCBs, asbestos, and lead. External soil contamination suggests radiological material has moved to the environment.

Facility K1037-C (Nickel Smelter House) received five category scores of 5, one category score of 4, and a total score of 29. This is an old facility in general disrepair. It has numerous roof leaks and is heavily contaminated, both radiologically and chemically. Large scrubber-type vessels located on the east end of the second floor of the barrier production area contain internal radioactive contamination. Discarded contaminated equipment is stored in the building. The facility is posted as a PCB hazard. No corrective actions have been completed at this facility.

Facility K1200-S (Centrifuge Preparation Laboratory, South Bay) received two category scores of 4 and a total score of 26.5. The high score is primarily attributable to the uncertainty of radiological contamination associated with the ventilation system. The interior ductwork and portions of the roof where air is exhausted have not been surveyed for contamination. The potential for airborne release appears great. Equipment inside the facility contains uranium hexafluoride and other hazardous chemicals, and there are numerous radiologically-contaminated storage areas. Confined space entry requirements prevented the office from performing a survey of the pits below the centrifuges. The greatest release potential for contaminants would be during decontamination and decommissioning activities. *Equipment removal and cleanup is ongoing at*

this facility. It is expected that the facility will be removed from the office's "high rankers" list in the future.

Facility K1004-J received two category scores of 5, one category score of 4, and a total score of 19. This facility was constructed in 1948 and was originally used for uranium recovery from spent fuel solutions and centrifuge research. It originally included a hot cell, reinforced concrete vaults, a 750-gallon "hot" tank, a 5,500-gallon underground low-level liquid waste tank, and a laboratory. The facility was ranked high in the PER database because of the insufficient knowledge concerning facility infrastructure. First, there is considerable uncertainty over the location and number of active storage vaults under the facility. It is also unknown whether any of these vaults contain radioactive materials or contamination. There is considerable uncertainty over drainpipe connections and their contribution of radiological and chemical contaminants to general area contamination. During 2011 all the combustibles and most other equipment was removed from this facility. During 2014 staff observed that the roof has degraded to the point that extensive rain water enters the facility any time it rains.

Facility K1220-N (Centrifuge Plant Demonstration Facility, North) received one category score of 4 and a total score of 18. The interior ductwork has not been surveyed for radiological contamination and the score reflects a high degree of uncertainty concerning the presence of radionuclides. Uranium residuals are present inside the centrifuge systems. After the centrifuge systems are removed and the criticality and security concerns are addressed, this facility is a candidate for reuse. No corrective actions have been conducted at this facility.

At **ORNL,** thirty-three facilities had at least one category score of four or five: X3026, X3029, X3033, X3028, X4507, X3517, X3005, X3030, X7019, X3508, X3031, X3118, X3033-A, X3019-B, X3032, X7720, X7700-B, X2545, X3020, X3108, X3091, X3592, X3504, X3001, X7706, X7707, X2531, X3002, X3003, X3018, X7602, X7019, and X7025/48.

Facility X3517 received five category scores of 5, one category score of 4, and a total score of 39. Despite these relatively high scores, the physical condition of this facility is good, and much effort has gone into decontamination and cleanup work inside the facility. Still, breaches in containment/process systems in the facility resulted in low levels of radiological contamination being distributed throughout. The liquid low level waste system has contributed radiological contamination to the soil and groundwater outside the building.

Facility X3029 (Radioisotope Production Area/Source Development Lab) received five category scores of 5, three category scores of 4, and a total score of 38. This entire hot cell facility is a posted radiological contamination zone that also contains interior, posted radiation areas. During operation, radiological contamination migrated from hot cells and found its way into floor drains and lines. There is a very high probability that this contamination migrated from drain lines and contributed to soil and ground water contamination. The facility also exhibits old, broken floor tiles (containing asbestos) and extensive peeling of lead-based interior and exterior paint. During its operation, X3029 handled Co-60, Cs-137, Sr-90, Ir-192, C-14, Tc-99, I-131, as well as other radioisotopes. The facility was shut down in the late 1960s.

Facility X3033 (Krypton and Tritium Facility) received three category scores of 5, four category scores of 4, and a total score of 37. This is another surplus Isotope Circle facility. It was placed in standby mode in the 1990s. The facility also includes a five-foot tall cinder block containment structure that houses four, charcoal-filled stainless steel tanks used for permanent storage of Kr-85. Radiation dose rates are still relatively high around and above the top edge of the wall of this structure. During its operational history, this facility processed C-14, Kr-85, H-3 and probably other radioisotopes. The entire facility is a posted radiological contamination zone, and there is a high probability that the facility has contributed to soil and groundwater contamination via leaky process and low level wastewater collection lines. In a man-hole type of sump near the S.W. corner of the building, radiological dose rates approach 10 mR/hr. from Cs-137 contamination.

Facility X3028 received two category scores of 5, five category scores of 4, and a total score of 36. The primary issue with this facility was the relatively large quantity of radiological contamination distributed throughout the building. It also shows extensive peeling and chipping of interior wall paint that is supposed to serve as containment for plutonium contamination. Ongoing corrective actions are occurring at this facility.

Facility X3005 (Low-Intensity Test Reactor) received three category scores of 5, one category score of 4, and a total score of 35. The primary issues with this facility are activation products associated with the reactor, reactor infrastructure, and reactor shielding materials. Radioactive contamination also exists throughout the facility. A leaky roof on the eastern half of the facility has caused excessive, interior mold and mildew buildup. Another concern is the large quantities of flaking and peeling lead-based, PCB-containing paint on the interior and exterior of the building.

Facility X4507 (High-Radiation Level Chemical Development Facility) and adjoining X4556 (Filter Pit), received five category scores of 4, one category score of 5, and a total score of 35. The primary concern with this facility is radiological contamination. The entire building is a posted contamination zone, with several areas of elevated radiation dose. There are four contaminated hot cells. There was a significant curium-244 spill adjacent to Cell 4. Contamination has historically leaked from degraded low level liquid waste lines into surrounding soil and groundwater.

Facility X3508 (High-Level Alpha Radiation Lab) received seven category scores of 4, two category scores of 5, and a total score of 38. This facility has a history of beryllium use/storage. There are two separate banks of hot cells. (There are low levels of radiological contamination scattered throughout the building that generate elevated radiological dose rates.)

Facility X3019-B (High-Level Radiation Analytical Laboratory) at ORNL received four category scores of 4, one category score of 5, and a total score of 33. The primary concern with this facility is the very high levels of radiological contamination. The eight hot cells in this facility are “Very High Radiation Areas” and contain many different radionuclides from past operations. The in-cell steam pipes, the off-gas ventilation system, and the ventilation ductwork on the roof are also radiologically contaminated. Also, the laboratory off-gas ductwork located above the hot cells contains perchlorates six times above the maximum recommended by the ORNL Perchloric

Acid Committee. Perchlorates are shock sensitive and have the potential to react violently when disturbed. Signage identifying this hazard is posted.

Facility X3030 (Radioisotope Production Lab) received four category scores of 5, one category score of 4, and a total score of 31. This surplus Isotope Circle facility processed a wide range of radioisotopes during its 50-year operational history, including Co-56, Co-57, Au-198, Fe-55, Np-234, Se-75, Sr-90, Sn-119m, U-237, P-33, and Ir-192. All operations were stopped in the late 1990s. The facility contains "High Contamination" as well as "High Radiation" areas. As with most other Isotope Circle processing facilities, there is a very high probability that X3030 contributed radiological contamination to soil and groundwater via exfiltration from leaky wastewater and process lines. And like many other of these nonoperational surplus facilities, it also exhibits extensive peeling of exterior lead-based paint that is moving into the environment.
Facility X7019 (Storage Facility) received three category scores of 5 and one category score of 4. The entire facility is an airborne radiological zone and requires a respirator for entry. There is one spot of radiological contamination in the surrounding yard. The building is also a beryllium contamination zone.

Facility X3033-A (Actinide Fabrication Facility) received four category scores of 4, one category score of 5, and a total score of 31. This facility contributed to soil and groundwater contamination via leaky process and liquid low-level waste lines. Most of the remaining radiological contamination is present in small, fixed hot spots of alpha-emitting transuranics, including plutonium, americium, and curium.

Facility X3032 (Radioisotope Production Lab E) received three category scores of 4, one category score of 5, and a total of 29. These scores are primarily related to the fact that leaky process and liquid low-level waste lines contributed to soil and ground water contamination. Also, lead-based paint that was used as wall covering throughout the facility is peeling and flaking excessively.

Facility X3001 (Graphite Reactor) at ORNL received two category scores of 4, and a total score of 28. The primary concern with this facility is that there is considerable radiological contamination. The air exhaust shaft that vented the reactor pile is contaminated with cesium-137, strontium-90 and fission products. This is a source releasable to the outside environment if a fire or other event occurred in the ventilation system. Several corrective actions, such as the plugging of drains that went to the sewer system, were recently implemented at this facility.

Facility X3031 (Radioisotope Production Lab) received four category scores of 4, one category score of 5, and a total score of 27. This facility was built in 1950 as part of the Isotopes Program and was deactivated in 1997. During its active history, it processed a wide variety of radioisotopes. Today it contains fixed and removable radiological contamination located in "High Contamination" and "Radiation" areas. Leaky process and low-level waste water collection lines have contributed to soil and groundwater contamination.

Facility X3118 (Radioisotope Production Lab) received four category scores of 4, one category score of 5, and a total score of 27. The primary issues with this building are a leaky roof, a leaky

process waste-water line that has contributed to soil and groundwater contamination and, flaking and peeling lead-based paint throughout the facility.

Facility X3592 (Coal Conversion Facility) received two category scores of 4, and a total score of 27. Its original mission was to explore the potential for utilizing liquefied coal as an alternative fuel source. But in later years the facility performed lithium isotope separation using massive quantities of mercury. The scores were given for transferable radiological contamination and mercury contamination found in the drains.

Facilities X7706, X7720, X7700-B and X7707 (Cooling House, Civil Defense Bunker, Below-ground Outside Source Storage Area) are all part of the Tower Shielding Complex. A survey of this group of facilities resulted in seven category scores of 4. The primary issues at this complex of facilities are soil contamination, uncovered activated and contaminated concrete rubble, and drain lines that have direct connections to the environment.

Facility X2545 (Coal Yard Runoff Collection Basins) at ORNL received one category score of 5, two category scores of 4, and a total score of 21. Orphaned, 2- and 6-inch diameter, cast iron low-level liquid waste (LLLW) lines run through the facility property, and a LLLW line box is posted as a “Radiation Area”. The area has been chained off and is overgrown with vegetation. Due to the radiological postings, the cast iron LLLW lines are assumed to be degraded and leaking to the environment. ORNL Environmental Restoration staff has been notified of these lines and their condition, but TDEC has not received written confirmation concerning planned corrective actions.

Facility X2531 (Radiological Waste Evaporator Facility) received one category score of 5, one score of 4, and a total score of 21. This ranking includes X2537 (Evaporator Pit) and X2568 (HEPA filter bldg.). Even though this is a relatively clean, modern facility, it earned these scores because of several areas of transferable radiological contamination and high radiological dose rates surrounding the evaporator pit.

Facility X3504 (Geosciences Lab) received one category score of 5, one score of 4, and a total of 20. The entire building is a posted “Contamination Area”. There is also underground and soil contamination outside of the building.

Facility X3026 received one category score of 5, one category score of 4, and a total score of 19. Although this building was demolished in 2009, the two banks of contaminated hot cells and building pad still remain. The hot cells were encapsulated in 2009, as was the floor. The liquid low-level waste lines to which the hot cells and building were attached remain. They historically leaked and contributed to soil contamination at the northwest corner (and elsewhere) of the facility. The subterranean, contaminated trench, once a canal, is still intact. Additional decontamination of the hot cells occurred in 2011.

Facility X3003 and ventilation stack X3018. Facility X3003 received two category scores of 5, five category scores of 4 and a total score of 35. Stack X3018 received three category scores of 5, and a total score of 17. Both facilities’ scores reflect radiological contamination, exterior soil

contamination zones, contaminated, underground LLLW lines and contaminated ventilation ductwork.

Facility X3002 (HEPA Filter House for the Graphite Reactor) received one category score of 4 and a total score of 18. The primary hazards associated with this building are related to the high level of airborne and other radiological contamination in the roughing filter room, the HEPA filter bank, and the ventilation system. Several corrective actions recommended by the office were implemented at this facility.

Facility X3020 (Radiological stack for bldgs. 3019A-B) received three category scores of 5 and a total score of 18. All of the major concerns noted for this facility were related to legacy features that are not part of the present-day operational infrastructure. There is an antiquated, contaminated drain line that was part of the ORNL LLLW system. This line leaked and contributed to surface and subsurface contamination of the general area from the 1940's through the 1970's. It was capped in the late 1970's, but is possibly still contributing contamination. There is also a contaminated, above-grade, single-walled concrete sump box attached to the floor drain system.

Facilities X3108 and X3091 (HEPA filter houses for buildings X3019A-B and Radiological Stack X3020) each received three category scores of 5; X3108 received a total score of 23, and X3091 received a total score of 25. These two facilities are physically connected to the X3020 stack. And like the X3020 stack situation described above, all major concerns noted with these facilities are related to their non-operational infrastructure. Associated with both facilities is a contaminated drain system that went to the LLLW system. This line leaked and contributed to general-area surface and subsurface contamination from the 1940's through the 1970's. It was capped in the late 1970's, but is possibly still contributing to contamination. Both facilities also contain significant levels of radiological contamination, considerable contaminated aboveground ductwork, and contaminated lower-level HEPA filter pits. Both facilities are non-state-of-the-art structures that are adequately maintained.

Facility X7602 (Integrated Process Development Lab.) received one category score of 4 and a total score of 17. The primary concern with this building was the extensive transferable radiological contamination throughout the facility.

Facility X7019 received four category scores of 5. The entire building is a respirator zone due to beryllium contamination. It is also radiologically contaminated. Radiological contamination has escaped into the surrounding environment in at least one place.

Facility X7025/48 received one category score of 5 and one category score of 4. These scores were assigned because of interior and exterior radiological contamination.

Conclusion

The historic release of chemical and radiological materials from buildings and other facilities on the Department of Energy's Oak Ridge Reservation has led to elevated levels of contaminants in regional terrestrial and aquatic ecosystems. In an effort to understand more about the sources of these contaminants, the DOE-O office investigates the historic and present-day potential for

release of contaminants from facilities through its Facility Survey Program. During its twenty-year history the program has examined 206 facilities and found that forty-two percent (86) have either contributed to, or pose a relatively high potential for, release of some contaminant to the environment. These facilities are referred to as “high rankers” in the program’s Potential for Environmental Release database.

In many cases, legacy contamination from degraded facility infrastructure, such as underground waste lines, substandard sumps and tanks, or ventilation ductwork, is generating high scores in the database. This will continue until deteriorating facilities and infrastructure are fully remediated. This is particularly the case at Oak Ridge National Laboratory where many facilities were connected to an aging, leaky underground low-level liquid waste line system. Inactive facilities that are no longer receiving adequate exterior or interior maintenance are also driving high scores. On many buildings, peeling lead-based paint is extensive, and leaky roofs are common. These conditions will only worsen as time passes if not remediated. On the other hand, formal infrastructure reduction programs that began at Y-12 and ORNL in 2002 and at ETTP in 2003 have alleviated some of these problem areas.

When facility concerns are noted by the DOE-O office, they are relayed to the Department of Energy via the Facility Survey Report so that corrective actions can be formulated. To date, many corrective actions and demolitions have occurred. A total of thirty-nine facilities have been removed from the office’s list of high Potential Environmental Release facilities. Those concerns that have not been corrected to the extent that the office has reduced the Potential Environmental Release score to less than a “4” are reflected in this report. The rankings are changed when written documentation is received by the office from DOE. Since the evaluation of corrective actions is an ongoing, time-consuming process, present scores may in some cases not reflect the most recently completed corrective actions.

Table 4: Potential for Environmental Release for High-Scoring Facilities

Scoring Categories	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		
BUILDING	**DRAIN LINES SANI.**	**TANKS LINES PROC.**	**TANKS LINES LLLW**	**SUMPS DRAINS FLOOR**	**TRANSF RAD. CONT.**	**TRANSF HAZ. CONT.**	**VENT TO OUTSIDE AIR**	**VENT INSIDE SYSTEM**	**INT.EXP. RAD. SURVEY**	**O. EXP. RAD. SURVEY**	**NUMBER OF 4 and 5’s**	**SURVEY YEAR**
X3508	4	4	4	4	4	5	0	4	5	4	9	2009
X3003	4	4	4	4	5	1	2	2	5	4	7	2010
*X3550	0	0	0	0	0	0	0	0	0	0	0	2006
X3029	0	4	4	5	5	5	1	4	5	5	8	2007
X3033	1	4	4	4	4	5	3	2	5	5	7	2007
X3028	0	4	4	3	4	4	4	5	5	3	7	1997
X4507	1	4	4	4	4	5	2	2	5	4	6	2009
X3517	3	5	5	2	5	3	4	2	5	5	6	2005
Y9731	4	5	1	4	3	5	5	5	3	2	6	2003
K1037-C	0	0	0	0	5	5	5	5	5	4	6	1998
X7019	0	0	0	0	5	5	0	0	5	5	0	2011
X3030	1	5	5	5	4	5	1	1	1	3	5	2007
X3031	1	4	4	4	4	5	1	1	1	2	5	2007
X3118	1	4	4	4	4	5	1	1	1	2	5	2007
X3033A	0	4	4	4	4	5	3	3	2	2	5	2007
Y9401-2	1	4	1	4	1	5	4	4	1	0	5	2001
Y9204-3	3	5	2	3	4	5	4	4	2	1	5	2000
X3019-B	2	2	5	3	2	3	4	4	4	4	5	1995
K633	3	5	1	4	5	5	2	5	4	5	5	2002
X3032	0	4	4	4	2	5	3	3	2	2	4	2007
Y9201-4	2	5	0	2	2	4	5	5	2	1	4	1998
X3005	2	3	3	2	3	5	3	5	5	4	4	2006

K1004-J	5	5	0	4	3	0	0	0	1	1	3	2000
Y9203	4	2	0	4	2	4	2	2	2	0.5	3	1995
X2545	0	3	5	0	4	2	3	0	0	4	3	1995
X3020	0	0	5	5	5	0	2	0	0	1	3	1997
X3108	0	0	5	5	5	0	2	2	2	2	3	1997
X2061	0	0	0	0	5	5	3	3	5	0	3	2010
X3018	0	0	0	0	5	0	2	5	5	0	3	2011
X3091	0	0	5	5	5	1	2	2	3	2	3	1997
Y9743-2	0	3	0	5	3	5	2	2	2	1	2	2001
X3592	0	3	3	2	4	4	3	3	3	2	2	2001
X3504	1	3	0	4	5	0	2	1	2	2	2	2001
X2531	1	1	2	1	5	2	2	1	2	4	2	2001
Y9213	3	1	5	3	3	5	1	1	1	1	2	2000
*X3026	2	3	5	4	3	0	0	0	1	1	2	2005
X3001	3	1	2	3	3	2	4	4	3	3	2	1995
K1200-S	2	3	0	3	3	2	3	4	2.5	4	2	1995
X7706	4	3	0	4	2	0	2	2	2	2	2	1996
X7707	4	0	0	4	2	3	2	2	0	0	2	1996
X7720	0	0	0	0	4	0	0	0	0	4	2	1997
*X3085	0	0	0	0	0	0	0	0	0	0	0	1994
X7602	0	2	0	2	4	2	1	3	2	1	1	1997
K1220-N	0	2	0	0	3	2	2	4	2	3	1	1995
X3002	0	2	0	2	3	1	2	3	4	1	1	1996
Y9207	2	0	0	1	1	4	3	1	1	0	1	1995
X7700-B	0	0	0	0	3	0	2	0	0	4	1	1996
*X2011	0	0	0	0	0	0	0	0	0	0	0	2010
*X2017	0	0	0	0	0	0	0	0	0	0	0	2010
X7019	0	0	0	0	0	5	0	5	4	5	3	2011
X7025	3	3	3	0	0	0	0	0	5	4	2	2011
X7048	0	0	0	0	0	0	0	0	3	0	0	2011
Y9401-1	0	0	0	0	5	0	0	0	5	4	3	2011

*Facility demolished.
**Facility partially demolished (see text entry).

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Haul Road Radiological Surveys

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Abstract

The Haul Road was constructed for, and is dedicated to, trucks transporting CERCLA radioactive and hazardous waste from remedial activities on the Oak Ridge Reservation to the Environmental Management Waste Management Facility in Bear Creek Valley for disposal. To account for wastes that may have blown or dropped from the trucks in transit, personnel from the Tennessee Department of Environment and Conservation perform walk over inspections of the different segments of the nine mile road Haul Road and associated access roads weekly. Anomalous items noted are surveyed for radiological contamination, documented, and their description and location submitted to DOE for disposition. During 2013, fifty-four items that had potentially fallen from trucks transporting waste to the EMWMF were documented. None of the items exhibited radioactivity in excess of free release limits and all were removed expeditiously after being reported to the Department of Energy.

Introduction

The Tennessee Department of Environment and Conservation's Division of Remediation DOE Oversight Office, with the cooperation of the U.S. Department of Energy (DOE) and its contractors, perform weekly surveys of the Haul Road and other roads used to transport waste on the Oak Ridge Reservation. The Haul Road was constructed for and is dedicated to trucks transporting Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) radioactive and hazardous waste from remedial activities on the Oak Ridge Reservation (ORR) to the Environmental Management Waste Management Facility (EMWMF) in Bear Creek Valley for disposal. To account for wastes that may fall or be blown from the trucks in transit, DOE Oversight personnel perform walk over inspections of different segments of the nine mile long Haul Road and associated access roads weekly (weather permitting). Anomalous items noted along the roads are scanned for radiation, logged, marked with contractor's ribbon, and their description and location submitted to DOE for disposition. If anomalous items remain from previous inspections, they are included in subsequent reports, until removed or DOE advises the items have been found to be free of radioactive or hazardous contamination.

Methods and Materials

As previously noted, the nine mile long Haul Road is surveyed in segments typically consisting of one to two miles on a weekly basis (weather permitting). For safety and by agreement with DOE and its contractors, staff members performing the inspections log onto the Haul Road at the East Tennessee Technology Park transportation hub and advise site personnel they intend to enter onto the road to perform the survey. The DOE contractor responsible for the road briefs staff members on any known conditions that could present a safety hazard and provides a two-way radio to division staff to maintain communication should unforeseen conditions arise that could present a safety hazard while on the road. When the DOE contractor is not working staff members call into the designated DOE site safety office for the segment being surveyed. Should excessive traffic present a safety concern, the survey is postponed to a later date. Alternate entrances are sometimes used to access the road with DOE approval, but the basic requirements remain in effect.

When staff arrive at the segment of the road to be surveyed, the vehicle is parked completely off the road, as far away from vehicular traffic as possible. No less than two people perform the surveys, each walking in a serpentine pattern along opposite sides of the road to be surveyed or one person walking in a serpentine pattern across the entire road accompanied by an approved safety buddy. Typically, a Ludlum Model 2221 Scaler Ratemeter with a Model 44-10 2”X2” NaI Gamma Scintillator probe held approximately six inches above the ground surface is used to scan for radioactive contaminants as the walkover proceeds. A Ludlum 2224 Scaler with a Model 43-93 Alpha/Beta dual detector is used to investigate potential contamination on the road surfaces or anomalous items noted along the road that may be associated with waste shipments. The other radiological instruments available to staff are used as warranted (Table 1). Any areas or items with contamination levels exceeding 200 dpm/100 cm^2 removable beta, 1000 dpm/100 cm^2 total beta, 20 dpm/100 cm^2 removable alpha, and / or 100 dpm/100 cm^2 total alpha are required to be further investigated.

Anomalous items found during the survey are marked with contractor’s ribbon at the side of the road and a description of the item and its location logged and reported to DOE and its contractors for disposition. A survey form or equivalent is maintained for each walkover survey and is retained at the division’s office. When staff members return to the road for the next weekly inspection, they perform a follow-up inspection of items found and reported in previous weeks. If any items remain, they are included in subsequent reports, until removed or staff are advised the item(s) have been determined to be free of radioactive and hazardous constituents.

Table 1: DOE Oversight Division Portable Radiation Detection Equipment

Radiological Detection Instruments	Radiological Detection Probes	Radioactivity Measured
Ludlum Model 2221 Scaler Ratemeter	Ludlum Model 44-10 2x2” NaI Gamma Scintillator	Gamma
Ludlum Model 2224 Scaler / Ratemeter	Ludlum 43-93 Alpha / Beta Scintillation Detector	Alpha, Beta
Ludlum Model 3 Survey Meter	Ludlum Model 44-9 Pancake G-M Detector	Alpha, Beta, Gamma
Ludlum Model 3 Survey Meter	Ludlum Model 43-65 50 cm^2 Alpha Scintillator	Alpha
Ludlum Model 48-2748	Gas proportional detector Floor Monitor	Alpha, Beta
Bicron Micro Rem	Internal 1x1” NaI Gamma Scintillator	Tissue Dose Equivalent, Gamma (μRem/hr)
Identifinder-NGH	Isotopic Identifier and Ratemeter	Gamma Spectroscopy and Dose Rate Meter

Results and Discussion

The Haul Road walkover surveys identified 54 items in 2013, potentially originating from hazardous and / or radioactive waste being transport to the EMWMF. No surface contamination readings exceeding free release limits and all ambient high energy gamma readings were within

the range of normal background for the area. The items were marked as previously described, DOE notified of the findings, and the material was removed by DOE's contractors expeditiously.

Conclusions

The weekly inspections of the roads used to haul waste to the EMWMF, indicates waste items routinely fall or are blown from trucks transporting the waste. Based on these findings, it is planned to continue the Haul Road Survey Program in 2014.

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Ambient Radiation Monitoring on the Oak Ridge Reservation Using Environmental Dosimetry

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Abstract

The Tennessee Department of Environment and Conservation began monitoring ambient radiation levels on the Oak Ridge Reservation in 1995. The program provides conservative estimates of the dose to members of the public from exposure to gamma and neutron radiation attributable to Department of Energy activities on the reservation and baseline values for measuring the need and effectiveness of remedial activities. In this effort, environmental dosimeters have been placed at selected locations on and near the reservation. Results from the dosimeters are compared to background values and the state dose limit for members of the public. While all the doses reported in 2013 at off-site locations were below the dose limit for members of the public, several locations on the reservation that are considered to be potentially accessible to the public had results in excess of the limit. As in the past, doses above 100 mrem were associated with various sites located in access-restricted areas of the reservation.

Introduction

Radiation is emitted by various radionuclides that have been produced, stored, and disposed on the Department of Energy's (DOE) Oak Ridge Reservation (ORR), since the Manhattan Era of World War II. Associated contaminants are evident in ORR facilities and surrounding soils, sediments, and waters. In order to assess the risks posed by these radioactive contaminants, the DOE Oversight Office of the Tennessee Department of Environment and Conservation's Division of Remediation began monitoring ambient radiation levels on and in the vicinity of the ORR in 1995. The program provides:

- conservative estimates of the potential dose to members of the public from exposure to gamma radiation attributable to DOE activities/facilities on the ORR;
- baseline values used to assess the need and/or effectiveness of remedial actions;
- information necessary to establish trends in gamma radiation emissions; and
- Information relative to the unplanned release of radioactive contaminants.

In this effort, environmental dosimeters are used to measure the radiation dose attributable to external radiation at selected monitoring stations. Associated data are compared to background values and the state's primary dose limit for members of the public.

Methods and Materials

The dosimeters used in the program are obtained from Landauer, Inc., of Glenwood, Illinois. Each of the dosimeters uses an aluminum oxide photon detector to measure the dose from gamma radiation (minimum reporting value = 1 millirem (mrem). At locations where there is a potential for the release of neutron radiation, the dosimeters also contain an allyl diglycol carbonate based neutron detector (minimum reporting value = 10 mrem). The dosimeters are collected quarterly and shipped to the vendor for processing.

To account for exposures received in transit, control dosimeters are provided with each shipment of dosimeters received from the Landauer Company. These dosimeters are stored in a lead

container at the DOE Oversight Office during the monitoring period and returned to Landauer for processing with the associated field deployed dosimeters. Any dose reported for the control dosimeters is subtracted from the results for the field-deployed dosimeters prior to being reported.

As the quarterly data are received from the vendor, DOE Oversight staff review the results and compile a quarterly report, which is distributed to DOE and other interested parties. At the end of the year, the quarterly results are summed for each location and the resultant annual dose compared to background values and the state's primary dose limit for members of the public (100 mrem/year above background concentrations and medical applications). Each year, a report of the results and findings is compiled and presented in DOE Oversight's annual Environmental Monitoring Report.

Results and Discussion

The Atomic Energy Act exempts DOE from outside regulation of radiological materials at its facilities, but requires DOE to manage these materials in a manner protective of the public health and the environment. Since access to the reservation has in the past been predominately restricted to employees of DOE or their contractors, locations within the fenced areas of the reservation have traditionally been viewed as inaccessible to the general public. With the reindustrialization and revitalization of portions of the reservation, there has been an influx of workers employed by businesses not directly associated with DOE operations and, in some cases, property deeded to private entities within the reservation boundaries. Under state regulations, a member of the public is considered to be any individual, unless employed to perform duties that involve exposures to radiation. The state regulations go on to limit the dose to members of the public to 100 mrem/year (above background and medical applications) and the release of radiation to unrestricted areas to a dose of two mrem in any one-hour period. In this context, a restricted area is defined as an area with access limited for the purpose of protecting individuals against undue risks from exposure to radiation and radioactive materials.

The dose of radiation an individual receives at any given location is dependent on the intensity and the duration of the exposure. For example, an individual standing at a site where the dose rate is one mrem/hour would receive a dose of two mrem if he or she stayed at the same spot for two hours. If that person was exposed to the same level of radiation for eight hours a day for the approximately 220 working days in a year (1,760 hours), the individual would receive a dose of 1,760 mrem in that year. It is important to note that the doses reported in the program are based on the exposure an individual would receive if he or she remained at the monitoring station twenty-four hours a day for one year (8,760 hours). Since this is very unlikely to be the actual case, the doses reported should be viewed as conservative estimates of the maximum dose an individual could receive at each location.

Table 1 (attached) provides the dosimetry results for 2013, alone with the total dose in 2012 for comparison. The results have been organized according to location and are summarized below.

Stations off the Oak Ridge Reservation

In 2013, the results for off-site locations ranged from 11 to 89 mrem and averaged 29 mrem. The highest results reported for off-site locations were for station 47 (89 mrem), station 66 (50 mrem) and station 91 (65 mrem). Station 47 is actually located at the boundary of the reservation near a

privately owned waste processing facility at the west end of Bear Creek Road that is licensed and regulated by the state. Station 66 is located adjacent to the Emory Valley Greenway approximately one hundred feet from the Emory Valley Pump Station and Station 91 is on the fence surrounding the pump station. It is believed the slightly elevated results (compared to other off-site locations) may be an artifact of the use of contaminated sediments from the East Fork Poplar Creek Flood Plain downstream of Y-12 used as fill during the construction of portions of the Oak Ridge sewer system (1982, MMES).

East Tennessee Technology Park (ETTP)

The K-25 Gaseous Diffusion Plant, now known as the East Tennessee Technology Park, was constructed during World War II to produce enriched uranium for use in the first atomic weapons and later to fuel commercial and government owned reactors. Other activities at the site included: uranium enrichment by liquid thermal diffusion; development and testing of the gas centrifuge method of uranium enrichment; laser isotope separation research and development; and the incineration of 35 million pounds of hazardous and radioactive waste at the Toxic Substance Control Act (TSCA) Incinerator (1991-2012). The original gaseous diffusion facilities were put in stand-by mode in 1967 and the plant permanently shut down in 1987. The focus subsequently turned to remediation of the site and its reindustrialization, with a long-term goal of transitioning ETTP into an industrial park. Under the reindustrialization program, portions of ETTP may be leased or sold to private entities for use or development. During 2013, the results for dosimeters stationed at ETTP ranged from 5 to 63 mrem and averaged 23 mrem. The highest results (63, 61, and 53 mrem) were all reported for dosimeters placed near uranium storage vaults (stations 180, 181, and 182). Otherwise the results were similar to background values.

The Y-12 National Security Complex (Y-12)

Similar to K-25, the Y-12 Plant was constructed during World War II to produce enriched uranium, in this case by the electromagnetic separation process. In ensuing years, the facility was expanded and used to produce fuel for naval reactors, conduct lithium/mercury enrichment operations, manufacture components for nuclear weapons, dismantle nuclear weapons, and store enriched uranium. Due to the nature of its mission, the Y-12 plant is the least accessible to members of the public of the three Oak Ridge facilities. There are three locations within the Y-12 complex currently being monitored. These are the Uranium Oxide Storage Vaults, the Walk-In Pits, and the East Perimeter Air Monitoring Station. The results for the Y-12 locations ranged from 14 to 20 mrem/year and averaged 18 mrem/year.

Environmental Management Waste Management Facility (EMWMF)

Located immediately to the west of the Y-12 complex, the Environmental Management Waste Management Facility was constructed in 2002 to dispose of radioactive and hazardous waste generated by remedial activities on the ORR. The facility is operated under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and waste approved for disposal is limited by waste acceptance criteria agreed upon by DOE, the State, and EPA. Monitoring stations have been established at the boundary of the waste disposal cells and at secondary waste management systems. During 2013, the results ranged from 19 to 56 mrem and averaged 43 mrem.

Oak Ridge National Laboratory (ORNL)
Like the K-25 and Y-12 facilities, ORNL was also established during the World War II Manhattan ERA. Its war time mission focused on reactor research and the production of plutonium and other radionuclides that were chemically extracted from uranium irradiated in ORNL's Graphite Reactor and later other ORNL and Hanford reactors. Over the years, thirteen reactors were constructed and operated at the ORNL site, including the currently active High Flux Isotope Reactor. Since its inception, ORNL has evolved into DOE's largest multi-program national science and energy laboratory. As such, it hosts thousands of visitors a year. In addition, land adjacent to ORNL's main campus has been deeded to organizations outside of DOE; buildings have been constructed using private funds; and facilities are now occupied by non-DOE contractors (ORAU, 2003). Many of the facilities constructed during World War II and the cold war eras that remain are highly contaminated and have fallen into disrepair, complicating remediation. Access to the site is controlled for security purposes, but admittance is allowed with the appropriate visitor's pass and associated training. Within the access controlled areas, certain locations have been designated as radiation areas and access restricted for safety, including legacy burial grounds and associated facilities.

Due to the nature of some of the radioactive contaminants at ORNL (e.g., high energy gamma emitters), the highest dose rates in the dosimetry program are typically associated with ORNL stations. The dose rates measured at ORNL in 2013 ranged from 0 to 14,764 mrem/year and averaged 1,303 mrem for the year, which is considerably less than the average for 2012 (2,034 mrem). It should be reiterated that the dose rates reported here reflect the dose that could be received if a hypothetical person remained at the monitoring station for 24 hours a day for the 365 days in a year. Consequently, the results are conservative estimates of the *potential* dose at the monitoring locations, which are used to identify locations that merit further evaluation. The actual dose any individual would receive is dependent on the time spent at the location, which in all cases would be a fraction of that assumed for the dose estimates.

In 2013, nineteen monitoring stations at ORNL had results exceeding 100 mrem over the year. Twelve of these sites are at remote locations with access limited or restricted to the general public. These include:

- Station 25 (the Molten Salt Reactor Experiment),
- Station 168 (the New Hydrofracture Facility),
- Station169 (Melton Valley Haul Road near White Oak Creek),
- Station 170 (the Cask Storage Containment Area),
- Station 87 (Solid Waste Storage Area 5 near the new storage tank area),
- Station 55 (Solid Waste Storage Area 5 Transuranic Waste Trench),
- Station 35 (the confluence of White Oak Creek and Melton Branch),
- Station 27 (White Oak Creek Weir at Lagoon Road),
- Station 75 (the Hot Spot on Haw Ridge),
- Station 33 (the Cesium Forest satellite plot),
- Station 31 (the Cesium Forest), and,
- Station 32 (Cesium Forest on tree).

As in previous years, the highest dose reported in the program for 2013 (14,764 mrem) was at station 32, which is located on a tulip poplar tree in ORNL's Cesium Forest. In 1962, a group of

trees at this location were injected with a total of 360 millicuries of cesium-137, as part of a study on the isotope's behavior in a forest ecosystem (Witkamp, 1964). The Cesium Forest is located in a remote gated area of the reservation posted as a radiation area. The dosimeter, which is placed on or very near the trunk of the tree, is exchanged remotely with the assistance of ORNL personnel. It should be noted that the variability in the results that can be noted in the quarterly and 2012 results (29,875 mrem/year) in Table 1 is primarily due to the inexact nature of the remote apparatus in placing the dosimeter near the tree.

In 2013, seven locations on ORNL's main campus exceeded 100 mrem/year in areas believed to be potentially accessible to members of the public. These include:

- Station 166 (North Central Avenue),
- Station 171 (Building 3038 North),
- Station 172 (Building 3607 Material Storage Area),
- Station 173 (the TH-4 Tank area,
- Station 174 (the Hot Storage Garden),
- Station 175 (Building 3618), and
- Station 176 (the Neutralization Plant).

Overall, the dose rates at the above locations decreased in 2013 when compared to 2012 results. Most of these locations are associated with legacy facilities that are either undergoing or scheduled for remediation. As the clean-up continues the dose rates measured are expected to be further reduced. While all the locations exceeding 100 mrem warrant continued monitoring, special attention needs to be given to the materials storage area at Building 3607, south of the irradiated fuels building (Building 3525), which had an annual dose of 14,552 mrem. Vehicles often park next to the monitoring station, which is located at the radiation boundary of the storage area.

Spallation Neutron Source (SNS)

Located near ORNL, the SNS is a one of a kind research facility that produces the most intense pulsed neutron beam in the world. During the process, electrons are removed from hydrogen ions in a linear particle accelerator (linac) converting the ions into protons. The protons are passed into an accumulator ring, which releases them as high-energy pulses directed toward a liquid mercury target. When the protons strike the nucleus of the mercury atoms, neutrons are "spalled" or thrown off, along with other spallation products. Radiation is generated throughout the process, as protons interact with the nuclei of other atoms, converting the struck nuclei into different isotopes, which are often radioactive. DOE Oversight staff have located dosimeters outside the linac, accumulator ring, target building, central exhaust stack, and other locations of interest. During 2013, the results ranged from 6 to 178 mrem and averaged 33 mrem. The only result to exceed 100 mrem in 2013 was for a dosimeter located on the central exhaust stack.

Conclusion

Overall, the radiation doses measured in the Environmental Dosimetry Program in 2013 decreased or remained statistically the same as in 2012. A total of twenty locations exceeded the 100 mrem screening level over the year: nineteen at ORNL and one at SNS. The majority of these sites were associated with legacy facilities undergoing or scheduled for remediation, which is expected to significantly lower the measured doses as the clean-up progresses.

Table 1: 2013 Results for TDEC monitoring on the Oak Ridge Reservation using Environmental Dosimetry

2013 Results for TDEC monitoring on the Oak Ridge Reservation using Environmental Dosimetry

Station # (Dosimeter)	**Location** *Optically Stimulated Luminescent Dosimeter (OSLs) and neutron dosimeters are reported quarterly.*	Type of Radiation	Dose Reported for 2013 in mrem *M = Below Minimum Reportable Quantity* 1st Quarter	2nd Quarter	3rd Quarter	4th Quarter	2013 Total Dose **	2012 Total Dose **
Off Site								
9 (OSL)	Norris Dam Air Monitoring Station (Background)	Gamma	4	3	5	M	12	12
86 (OSL)	Loudoun Dam Air Monitoring Station (Background)	Gamma	3	4	5	3	15	11
		Gamma	3	3	3	2		
86a (Neutron)	Loudoun Dam Air Monitoring Station (Background)	Neutron	M	M	M	M	11	11
66 (OSL)	Emory Valley Greenway	Gamma	13	13	14	10	50	74
80 (OSL)	Elza Gate	Gamma	4	2	4	3	13	10
65 (OSL)	California Ave.	Gamma	4	2	2	4	12	29
64 (OSL)	Cedar Hill Greenway	Gamma	4	4	4	M	12	28
63 (OSL)	Key Springs Road	Gamma	3	1	3	13	20	39
62 (OSL)	East Pawley	Gamma	4	4	6	7	21	12
67 (OSL)	West Vanderbilt	Gamma	6	8	5	10	29	43
70 (OSL)	Scarboro Perimeter Air Monitoring Station	Gamma	9	8	5	10	32	22
91 (OSL)	Emory Valley Pump House	Gamma	15	16	17	17	65	63
East Tennessee Technology Park								
43 (OSL)	K-1401 Building (West Side)	Gamma	8	6	8	6	28	29
48 (OSL)	K-1420 Building	Gamma	2	1	2	M	5	5
44 (OSL)	K-25 Building	Gamma	3	2	3	6	14	13
160 (OSL)	K-27 Building (Southwest Corner)	Gamma	2	1	M	8	11	36
159 (OSL)	K-27 Building (South Side)	Gamma	M	1	2	8	11	4

East Tennessee Technology Park (Continued)								
158 (OSL)	K-27 Building (Southeast Corner)	Gamma	3	1	2	5	11	11
155 (OSL)	K-27 Building (Northwest Corner)	Gamma	6	6	6	11	29	15
156 (OSL)	K-27 Building (North Side)	Gamma	3	4	3	8	18	6
157 (OSL)	K-27 Building (Northeast Corner)	Gamma	2	M	1	5	8	18
16 (OSL)	K-901 Pond	Gamma	3	3	3	10	19	18
15 (OSL)	K-1070-A Burial Ground	Gamma	4	3	4	11	22	12
79 (OSL)	ED1 On Pole	Gamma	7	5	6	4	22	26
58 (OSL)	K-25 Portal 5	Gamma	3	4	4	4	15	13
177 (OSL)	TSCA West Gate	Gamma	2	2	1	9	14	10
178 (OSL)	TSCA North Gate	Gamma	3	1	2	10	16	6
72 (OSL)	ETTP Visitors Overlook	Gamma	10	10	Absent	10	30	27
45 (OSL)	K-770 Scrap Yard	Gamma	3	1	M	2	6	12
47 (OSL)	Bear Creek Road ~ 2800 Feet From Clinch River	Gamma	22	19	25	23	89	89
11 (OSL)	Grassy Creek Embayment On The Clinch River	Gamma	6	Absent	4	6	16	30
21 (OSL)	White Wing Scrap Yard	Gamma	9	9	10	12	40	71
179 (OSL)	Uranium Storage Yard (East)	Gamma	5	5	5	5	20	23
180 (OSL)	Uranium Storage Yard (South)	Gamma	13	14	12	24	63	67
181 (OSL)	Uranium Storage Yard (South)	Gamma	13	12	14	22	61	69
182 (OSL)	Uranium Storage Yard (West)	Gamma	11	9	13	20	53	42
Oak Ridge National Laboratory								
20 (OSL)	Freels Bend Entrance	Gamma	4	2	2	5	13	25
69 (OSL)	Graphite Reactor	Gamma	5	7	6	11	29	37
167 (OSL)	South Side Of Central Ave.	Gamma	21	22	21	30	94	96
166 (OSL)	North Side Of Central Ave. Building 3038	Gamma	63	57	62	67	249	250
41 (OSL)	Not Deployed	Gamma	3	2	2	5	12	0
30 (OSL)	X-3513 Impoundment	Gamma	6	7	9	Absent	22	18

Oak Ridge National Laboratory (Continued)

28	(OSL)	White Oak Dam @ Highway 95	Gamma	M	2	3	3	8	10
34	(OSL)	SWSA 6 On Fence @ Highway 95	Gamma	5	4	3	3	15	21
75	(OSL)	Hot spot on Haw Ridge	Gamma	39	40	42	49	170	189
25	(OSL)	Molten Salt Reactor Experiment	Gamma	168	146	170	211	695	802
27	(OSL)	White Oak Creek Weir @ Lagoon Rd	Gamma	28	30	33	41	132	157
24	(OSL)	Building X-7819	Gamma	7	7	7	5	26	25
35	(OSL)	Confluence of White Oak Creek & Melton Branch	Gamma	120	108	118	125	471	613
56	(OSL)	Old Hydrofracture Pond	Gamma	13	13	15	17	58	74
23	(OSL)	SWSA 5 (South 7828)	Gamma	3	4	2	9	18	17
46	(OSL)	Homogeneous Reactor Experiment Site	Gamma	3	3	3	8	17	49
22	(OSL)	High Flux Isotope Reactor	Gamma	8	7	9	7	31	27
55	(OSL)	SWSA 5 TRU Waste Trench	Gamma	23	22	27	36	108	110
			Gamma	65	69	82	32		
87	(Neutron)	SWSA 5 Near Storage Tank Area	Neutron	M	M	M	M	248	216
168	(OSL)	New Hydrofracture Facility	Gamma	98	107	100	109	414	463
169	(OSL)	Melton Valley Haul Road Near Creek	Gamma	150	157	167	196	670	709
170	(OSL)	Cask Storage Containment Area	Gamma***	1,480	1,403	1,420	1,658	5,961	5,510
171	(OSL)	Building 3038 N	Gamma	357	149	Absent	136	642	4,240
172	(OSL)	Building 3607 Material Storage Area	Gamma	3,426	3,431	3,653	4,042	14,552	16, 243
173	(OSL)	TH4 Tank	Gamma	135	128	137	161	561	561
174	(OSL)	Hot Storage Garden (3597)	Gamma	1,084	1,170	1,141	1,458	4,853	5,185
175	(OSL)	Building 3618	Gamma	88	73	75	88	324	379
84	(OSL)	Tower Shielding Facility @ Gate (West)	Gamma	4	4	4	11	23	29
85	(OSL)	Tower Shielding Facility (North Side)	Gamma	3	4	2	4	13	19
176	(OSL)	Neutralization Plant	Gamma	1,848	1,940	345	825	4,958	5,487
68	(OSL)	White Oak Creek @ Coffer Dam	Gamma	M	M	M	M	0	7
26	(OSL)	Cesium Fields	Gamma	7	6	8	9	30	24
31	(OSL)	Cesium Forest Boundary	Gamma	15	17	17	29	78	72
31a	(OSL)	Cesium Forest Boundary (Duplicate)	Gamma	14	17	15	15	61	59

Oak Ridge National Laboratory (Continued)								
32	(OSL)	Cesium Forest On Tree	Gamma	4,694	5,246	2,092	2,732	14,764	29,875
33	(OSL)	Cesium Forest Satellite Plot	Gamma	94	96	97	105	392	471
183	(OSL)	ORNL Melton Valley Trench 7	Gamma	10	13	15	15	53	N/A
		Not Deployed	Gamma	3	1	M	M		
184	(Neutron)	Not Deployed	Neutron	M	M	M	M	4	N/A
		ORAU Pumphouse Road (3rd And 4th Quarter Only)	Gamma	9	Absent	12	30		
185	(Neutron)	ORAU Pumphouse Road (3rd And 4th Quarter Only)	Neutron	M	Absent	M	M	51	17
Spallation Neutron Source									
			Gamma***	39	29	47	63		
53	(Neutron)	Central Exhaust Facility	Neutron	M	M	M	M	178	194
			Gamma	5	5	4	10		
93	(Neutron)	Ring Building Perimeter Fence	Neutron	M	M	M	M	24	22
			Gamma	3	4	5	6		
17	(Neutron)	Beam Dump Bldg # 8520	Neutron	M	M	M	M	18	16
73	(OSL)	SNS Water Tower (Overlook) North	Gamma	3	5	5	9	22	22
			Gamma	7	7	6	12		40
101	(Neutron)	LINAC Beam Tunnel Berm West (#1)	Neutron	M	M	M	M	32	
			Gamma	8	7	8	8		
102	(Neutron)	LINAC Beam Tunnel Berm (#2)	Neutron	M	M	M	M	31	45
			Gamma	6	5	6	12		
103	(Neutron)	LINAC Beam Tunnel Berm (#3)	Neutron	M	M	M	M	29	38
			Gamma	7	6	7	9		
100	(Neutron)	LINAC Beam Tunnel Berm (#4)	Neutron	M	M	M	M	29	34
			Gamma	7	8	6	14		
99	(Neutron)	LINAC Beam Tunnel Berm (#5)	Neutron	M	M	M	M	35	25
			Gamma	7	9	8	17		
98	(Neutron)	LINAC Beam Tunnel Berm (#6)	Neutron	M	M	M	M	41	35

Spallation Neutron Source (Continued)									
			Gamma	6	6	7	15		
97	(Neutron)	LINAC Beam Tunnel Berm East (#7)	Neutron	M	M	M	M	34	43
74	(OSL)	SNS Cooling Tower South	Gamma	4	2	3	10	19	14
			Gamma	2	1	M	5		
52	(Neutron)	Target Bldg West	Neutron	M	M	M	M	8	5
			Gamma	2	1	M	3		
51	(Neutron)	Target Bldg South	Neutron	M	M	M	M	6	18
			Gamma	6	3	2	2		
12	(Neutron)	Target Bldg East	Neutron	M	M	M	M	13	27
			Gamma	2	1	2	2		
104	(Neutron)	SNS Administrative Building	Neutron	M	M	M	M	7	16
Y-12 National Security Complex									
71	(OSL)	Y-12 East Perimeter Air Monitoring Station	Gamma	4	4	3	3	14	20
39	(OSL)	Y-12 @ back side of Walk In Pits	Gamma	3	4	5	8	20	23
38	(OSL)	Y-12 Uranium Oxide Storage Vaults	Gamma	5	4	3	7	19	18
Environmental Management Waste Management Facility									
90	(OSL)	Waste Cell Perimeter Fence @ Gate	Gamma	6	Absent	3	10	19	14
92	(OSL)	Contact Water Ponds Fence @ Gate	Gamma	7	6	6	5	24	44
105	(OSL)	Contact Water Ponds Fence (Northwest Side)	Gamma	8	9	11	24	52	37
106	(OSL)	Contact Water Ponds Fence (Northeast Side)	Gamma	8	9	9	15	41	35
109	(OSL)	Contact Water Ponds Fence (Southeast Side)	Gamma	7	10	10	13	40	33
110	(OSL)	Contact Water Ponds Fence (Southwest Side)	Gamma	9	11	9	20	49	61
112	(OSL)	Contact Water Tanks Fence (Northeast Side)	Gamma	10	5	5	11	31	35
113	(OSL)	Contact Water Tanks Fence (Northwest Side)	Gamma	9	3	5	6	23	43
116	(OSL)	Contact Water Tanks Fence (Southwest Side)	Gamma	8	7	8	19	42	56

Environmental Management Waste Management Facility (Continued)								
117 (OSL)	Contact Water Tanks Fence (Southeast Side)	Gamma	8	7	8	11	34	29
118 (OSL)	Waste Cell Perimeter Fence (Southeast Corner)	Gamma	8	8	9	12	37	54
119 (OSL)	Waste Cell Perimeter Fence (South Side)	Gamma	8	9	8	13	38	37
120 (OSL)	Waste Cell Perimeter Fence (South Side)	Gamma	10	8	9	18	45	56
121 (OSL)	Waste Cell Perimeter Fence (South Side)	Gamma	9	9	9	21	48	50
122 (OSL)	Waste Cell Perimeter Fence (South Side)	Gamma	10	9	9	18	46	43
123 (OSL)	Waste Cell Perimeter Fence (South Side)	Gamma	12	13	10	16	51	76
124 (OSL)	Waste Cell Perimeter Fence (South Side)	Gamma	10	12	11	23	56	45
125 (OSL)	Waste Cell Perimeter Fence (South Side)	Gamma	9	11	10	17	47	61
126 (OSL)	Waste Cell Perimeter Fence (South Side)	Gamma	10	10	9	16	45	62
127 (OSL)	Waste Cell Perimeter Fence (South Side)	Gamma	10	11	10	24	55	47
128 (OSL)	Waste Cell Perimeter Fence (South Side)	Gamma	5	6	6	9	26	49
129 (OSL)	Waste Cell Perimeter Fence (Southwest Corner)	Gamma	11	12	10	18	51	41
130 (OSL)	Waste Cell Perimeter Fence (West Side)	Gamma	11	11	11	23	56	62
131 (OSL)	Waste Cell Perimeter Fence (West Side)	Gamma	10	11	9	23	53	52
132 (OSL)	Waste Cell Perimeter Fence (West Side)	Gamma	9	10	10	14	43	56
133 (OSL)	Waste Cell Perimeter Fence (West Side)	Gamma	9	10	9	12	40	44
134 (OSL)	Waste Cell Perimeter Fence (West Side)	Gamma	9	10	9	21	49	49
135 (OSL)	Waste Cell Perimeter Fence (West Side)	Gamma	9	10	10	13	42	56
136 (OSL)	Waste Cell Perimeter Fence (NW Corner)	Gamma	10	12	11	16	49	49
137 (OSL)	Waste Cell Perimeter Fence (North Side)	Gamma	11	9	10	15	45	57
138 (OSL)	Waste Cell Perimeter Fence (North Side)	Gamma	9	11	12	21	53	49
139 (OSL)	Waste Cell Perimeter Fence (North Side)	Gamma	10	10	10	18	48	37
140 (OSL)	Waste Cell Perimeter Fence (North Side)	Gamma	10	12	10	15	47	48
141 (OSL)	Waste Cell Perimeter Fence (North Side)	Gamma	9	12	12	13	46	45
142 (OSL)	Waste Cell Perimeter Fence (North Side)	Gamma	8	7	8	12	35	32
143 (OSL)	Waste Cell Perimeter Fence (North Side)	Gamma	9	9	11	23	52	48
144 (OSL)	Waste Cell Perimeter Fence (North Side)	Gamma	8	9	11	20	48	34
145 (OSL)	Waste Cell Perimeter Fence (North Side)	Gamma	9	12	10	14	45	51

Environmental Management Waste Management Facility (Continued)								
146 (OSL)	Waste Cell Perimeter Fence (North Side)	Gamma	8	11	8	14	41	65
147 (OSL)	Waste Cell Perimeter Fence (NE Corner)	Gamma	9	Absent	12	20	41	53
148 (OSL)	Waste Cell Perimeter Fence (East Side)	Gamma	7	9	7	7	30	64
149 (OSL)	Waste Cell Perimeter Fence (East Side)	Gamma	8	10	8	12	38	51
150 (OSL)	Waste Cell Perimeter Fence (East Side)	Gamma	8	10	8	20	46	55
151 (OSL)	Waste Cell Perimeter Fence (East Side)	Gamma	8	9	8	21	46	39
152 (OSL)	Waste Cell Perimeter Fence (East Side)	Gamma	8	9	8	12	37	45
153 (OSL)	Waste Cell Perimeter Fence (East Side)	Gamma	8	8	9	20	45	38
154 (OSL)	Waste Cell Perimeter Fence (East Side)	Gamma	9	10	9	18	46	33

Notes: Two types of dosimeters are used in the program, optically stimulated luminescent dosimeters (OSLs) and neutron dosimeters. The OSLs measure the dose from gamma radiation, which is considered sufficient for most of the monitoring stations. The neutron dosimeters, which have been placed at selected locations, measure the dose from neutrons in addition to the gamma radiation. At the locations where the neutron dosimeters have been deployed, the total dose is the sum of the doses reported for neutrons and the dose reported for gamma radiation.

The primary dose limit for members of the public specified in both DOE Orders and 10 CFR Part 20 (Standards for Protection Against Radiation) is 100 mrem total effective dose equivalent in a year, exclusive of the dose contributions from background radiation, any medical administration the individual has received, or voluntary participation in medical research programs. The NRC limit for a decommissioned facility is 25 mrem/yr.

NEW = Data for the period does not exist for this station is new.

M = Below minimum reportable quantity (1 mrem for gamma, 10 mrem for thermal neutrons)

NA = Not analyzed or not deployed at location.

Absent = The dosimeter was not found at the time of collection.

Damaged = The dosimeter was physically damaged, and the results were not consistent with historical values.

*The dose reported is for the first two quarters for these stations due to completion of the Tank W-1A (Corehole-8) project and a request to remove the dosimeters by the DOE contractor to remove a fence.

** A control dosimeter is provided with each batch of dosimeters received from the vender. The control dosimeters are used to identify the portion of the dose reported due to radiation exposures received in storage and transit. The dose reported for the control dosimeter is subtracted from the dose reported for each field deployed dosimeter.

*** Dosimeter was relocated to the point of highest public dose for the area being monitored or relocated to an area warranting monitoring.

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Real Time Monitoring of Gamma Radiation on the Oak Ridge Reservation

Principal Author: Gary Riner, Howard Crabtree

Abstract

In 2013, the Tennessee Department of Environment and Conservation placed gamma radiation exposure rate monitors at six locations on the Department of Energy's Oak Ridge Reservation. These units measure and record gamma radiation levels at predetermined intervals over extended time periods, providing an exposure rate profile that can be correlated with activities and/or changing conditions. Monitoring with the units focuses on the measurement of exposure rates under conditions where gamma emissions can be expected to fluctuate substantially over relatively short periods and/or where there is a potential for an unplanned release of gamma emitting radionuclides to the environment. In 2013, five locations were monitored in the program: the ORNL Central Campus Remediation; the exhaust stack at the Spallation Neutron Source Facility; the Molten Salt Reactor at the Oak Ridge National Laboratory; the Environmental Management Waste Management Facility; and a background station located at Fort Loudoun Dam in Loudon County. All results were below limits specified by state and Nuclear Regulatory Commission regulations, which require their licensees to conduct operations in such a manner that the external dose in any unrestricted area does not exceed 2.0 millirem (2,000 μrem) in any one-hour period.

Introduction

The DOE Oversight Office of the Tennessee Department of Environment and Conservation's Division of Remediation (the division) has deployed gamma radiation exposure rate monitors equipped with microprocessor controlled data loggers on the Oak Ridge Reservation (ORR) since 1996. While the environmental dosimeters used in the division's ambient radiation monitoring program provide the cumulative dose over the time period monitored, the results cannot account for the specific time, duration, and magnitude of fluctuations in the dose rates. Consequently, when using dosimeters alone, a series of small releases cannot be distinguished from a single large release. The exposure rate monitors measure and record gamma radiation levels at predetermined intervals (e.g., minutes) over extended periods of time, providing an exposure rate profile that can be correlated with activities and/or changing conditions. The instruments have primarily been used to record exposure rates during remedial and waste management activities to supplement the integrated dose rates provided by the division's environmental dosimetry program.

Methods and Materials

The exposure rate monitors deployed in the program are manufactured by Genitron Instruments and are marketed under the trade name GammaTRACER®. Each unit contains two Geiger Mueller tubes, a microprocessor controlled data logger, and lithium batteries sealed in a weather resistant case to protect the internal components. The instruments can be programmed to measure gamma exposure rates from 1 μrem/hour to 1 rem/hour at predetermined intervals (one minute to two hours). The results reported are the average of the measurements recorded by the two Geiger Mueller detectors, but data from either detector can be accessed if needed. Information recorded by the data loggers is downloaded to a computer using an infrared transceiver and associated software.

Monitoring in the program focuses on the measurement of exposure rates under conditions where gamma emissions can be expected to fluctuate substantially over relatively short periods and/or there is a potential for an unplanned release of gamma emitting radionuclides to the environment. Candidate monitoring locations include remedial activities, waste disposal operations, pre and post operational investigations, and emergency response activities. Results recorded by the monitors are evaluated by comparing the data to background measurements and state radiological standards. In 2013, the exposure rate monitors were used to monitor gamma emissions at the five locations listed below and depicted in Figure 1.

- Fort Loudoun Dam (background location)
- Environmental Management Waste Management Facility (EMWMF) in Bear Creek Valley southwest of the Y-12 National Security Complex
- Oak Ridge National Laboratory (ORNL) Central Campus Remediation (Radioisotope Development Lab Removal Action)
- ORNL Molten Salt Reactor Experiment (MSRE)
- Spallation Neutron Source (SNS) exhaust stack

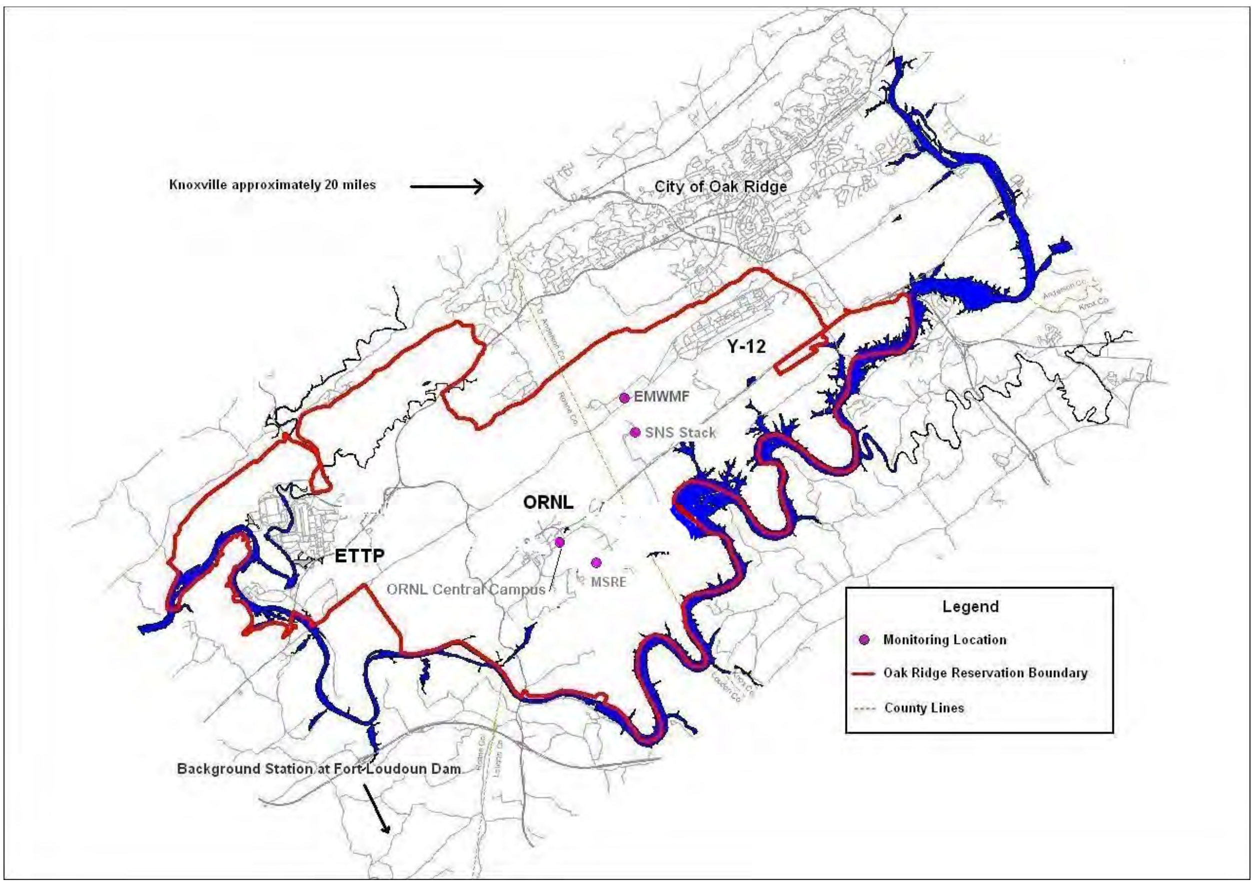


Figure 1: Gamma exposure rate monitoring locations in 2013.

Results and Discussion

The amount of radiation an individual can be exposed to is restricted by state and federal regulations. The primary dose limit for members of the public specified by these regulations is a total effective dose equivalent of 100 mrem in a year. Since there are no agreed upon levels

where exposures to radiation constitute zero risk, radiological facilities are also required to maintain exposures as low as reasonably achievable (ALARA). Table 1 provides some of the more commonly encountered dose limits.

Dose Limit	Application
5,000 mrem/year	Maximum annual dose for radiation workers
100 mrem/year	Maximum dose to a member of the general public
25 mrem/year	Limit required by state regulations for free release of facilities that have been decommissioned
2 mrem in any one hour period	The state limit for the maximum dose in an unrestricted area in any one hour period

Table 1: Commonly encountered dose limits for exposures to radiation

The unit used to express the limits (rem) refers to the dose of radiation an individual receives (the amount of radiation absorbed by the individual). For alpha and neutron radiation, the measured quantity of exposure, roentgen (R), is multiplied by a quality factor to derive the dose. For gamma radiation, the roentgen and the rem are generally considered equivalent. The more familiar unit, rem, is used in this report to avoid confusion. It is important to note that the monitors used in this program only account for the doses attributable to external exposures from *gamma* radiation. Any dose contribution from alpha, beta, or neutron radiation would be in addition to the measurements reported.

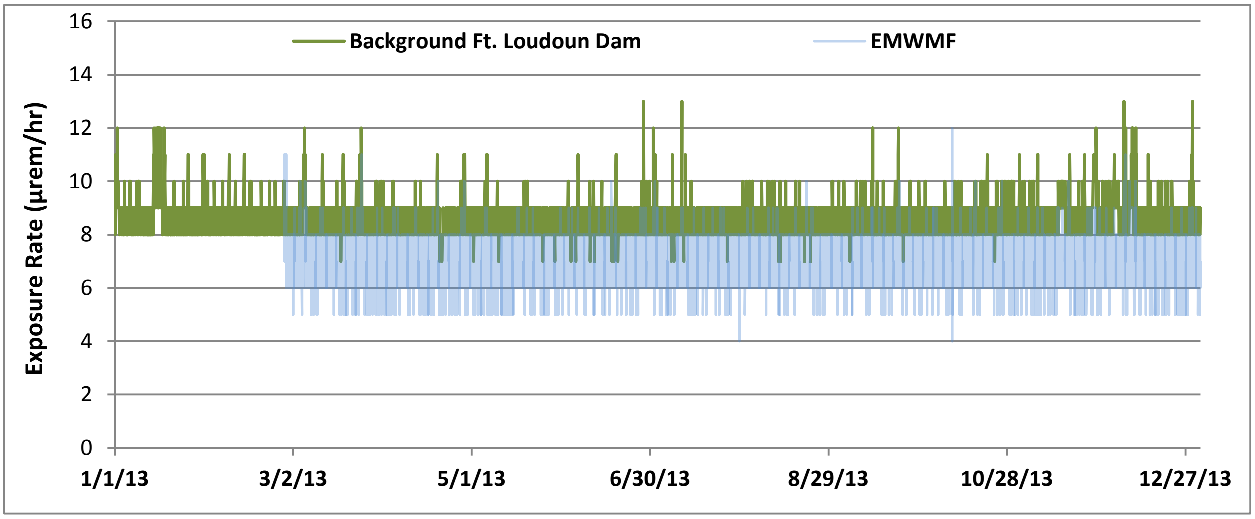
Fort Loudoun Dam Background Station

On average, individuals in the United States receive a dose of approximately 300 mrem in a year from naturally occurring radiation. Most of this dose is from internal exposures received as a result of breathing radon and associated daughter radionuclides. Background exposure rates fluctuate over time due to various phenomena that alter the quantity of radionuclides in the environment and/or the intensity of radiation being emitted by these radionuclides. For example, the gamma exposure rate above soils saturated with water after a rain are expected to be lower than the rate over dry soils because the moisture shields radiation released by terrestrial radionuclides. To better assess exposure rates measured on the reservation and the influence that natural conditions have on these rates, division staff maintain one of the division's gamma monitors at Fort Loudoun Dam in Loudon County to collect background information (Figures 2-5). During the 2013 calendar year, exposure rates averaged 8.6 μrem/hour and ranged from 7 to 13 μrem/hour, which is equivalent to a dose of approximately 76 mrem/year.

The Environmental Management Waste Management Facility (EMWMF)

The EMWMF was constructed in Bear Creek Valley (near the Y-12 Plant) to dispose of wastes generated by CERCLA activities on the ORR. The EMWMF relies on a waste profile provided by the generator to characterize waste disposed of in the facility. This profile is based on an average of the contaminants in a waste lot. Since the size of waste lots can vary from a single package to many truckloads of waste, the averages reported are not necessarily representative of each load of waste transported to the facility. That is, some loads may have highly contaminated

wastes, while other loads may contain very little contamination. Historically, the exposure rate monitors were used to identify waste potentially exceeding waste acceptance criteria as it was transported into the disposal cells, which was subject to audit. In 2011, the division replaced the unit with a radiation portal monitor (RPM). On 02/26/2013, one of the exposure rate monitor was returned to the site and placed alongside the RPM to assess the performance of each and confirm associated results. Measurements taken with the unit from 02/26/2013 to 12/31/2013 averaged 6.9 μrem/hour and ranged from 4 to 12 μrem/hour, which was very similar to the background measurements collected during the period (Figure 2).



The state dose limit in an unrestricted area is 2 mrem (2,000 μrem) in any one-hour period. The state dose limit for members of the public is 100 mrem (100,000 μrem) in a year.

Figure 2: 2013 Results of gamma exposure rate monitoring at the weigh-in station for the Environmental Management Waste Management Facility and at the background station.

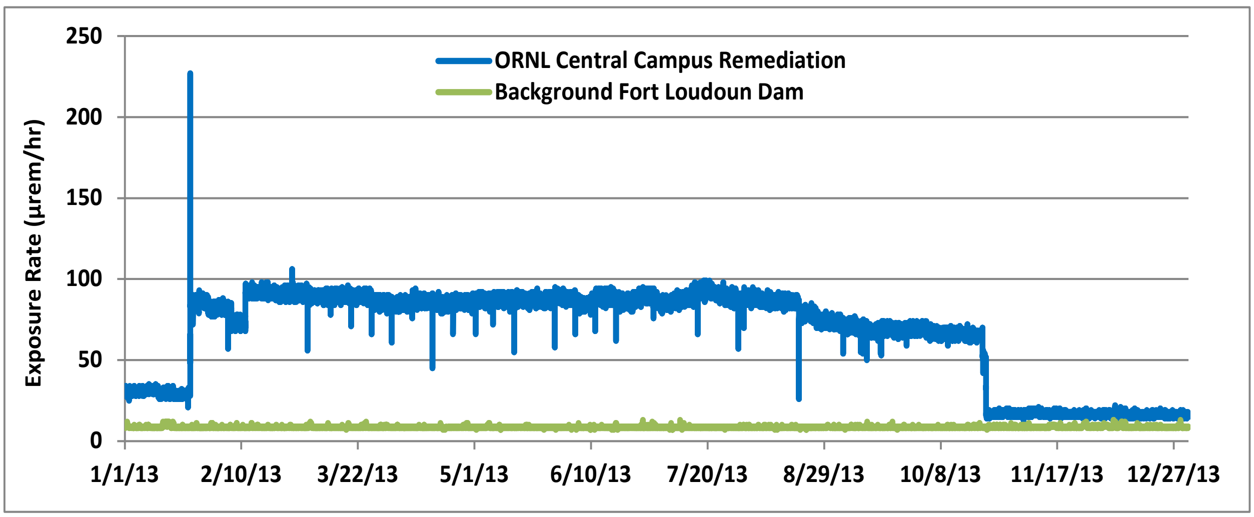
ORNL Central Campus Remediation/Building 3026 Radioisotope Development Lab

Monitoring of the ORNL Central Campus Remediation began 09/01/2011 and continued through 2013. Concerns include potential releases during the demolition of high risk facilities centrally located on ORNL's main campus in close proximity to pedestrian and vehicular traffic, privately funded facilities, and active ORNL facilities. Many of these facilities were constructed during the Manhattan Era to produce radioisotopes in support of the development of the first nuclear weapons and later for medical research and commercial applications. Among these facilities is the Radioisotope Development Laboratory, a wooden structure comprised of the 3026-C and 3026-D facilities, which are being addressed as a CERCLA time critical removal action.

The 3026 facilities were constructed in the 1940s to house operations for the separation of barium-140 from uranium fuel slugs irradiated in ORNL's Graphite Reactor and later Hanford reactors. Over the years, the facilities were modified for various uses, including the separation of radioisotopes from liquid wastes generated by the processing of irradiated fuel elements for uranium and plutonium in the 3019 Radiochemical Chemical Development Lab. In the 1960s, 3026-C was equipped to enrich Krypton-85 by thermal diffusion and in the 1970s a tritium lab was added to package, store, and test radio-luminescent lights. 3026-D was modified in the 1960s to support processing of fuel from the Sodium Reactor Experiment and examine irradiated metallurgical reactor components. Both facilities were shut down in the late 1980s. In the

interim, the wood frame structures experienced significant physical deterioration, to the point of failure. As a consequence of the hazards presented by radioactive contamination present in the facilities, the condition of the structures, and their location, a time critical removal action was initiated in 2009 to include demolition of the 3026 wooden frame structure and stabilization of the hot cells contained in each of the two facilities. The 3026 wooden superstructure was demolished in 2010 and demolition of the 3026-C hot cells was completed in 2012. The 3026-D hot cell demolition was completed in 2013, although higher than expected radiation levels hindered the project. Due to the nature of historical operations in the facilities, potential contaminants include a long list of radionuclides including Cesium-137, Strontium-90, Carbon-14, Nickel-59 & 63, Iron-55 & 59, Krypton-85, Promethium-147, Silver-110m, Tritium, Technetium-99, Zinc-65, Americium-241, and Neptunium-239, along with isotopes of Europium (153, 154, & 155), Plutonium (239, 240, & 241), and Uranium (233, 234, 235, 236, & 238).

One of the division's exposure rate monitors was at placed at the 3026 demolitions site on 01/11/2012 (prior to the demolition of the 3026-C hot cell) and has remained at the site through 2013. In 2012, the levels of gamma radiation measured ranged from 12 to 88 µrem/hour and averaged of 24.7 µrem/hour. As the removal action turned to the more contaminated 3026-D hot cells in 2013, the exposure rates increased substantially then declined near the end of the year as the waste was removed for disposal (Figure 3). During 2013, gamma radiation measured at the site ranged from 13 to 227 µrem/hour and averaged of 67 µrem/hour.



The state dose limit in an unrestricted area is 2 mrem (2,000 µrem) in any one-hour period. The state dose limit for members of the public is 100 mrem (100,000 µrem) in a year.

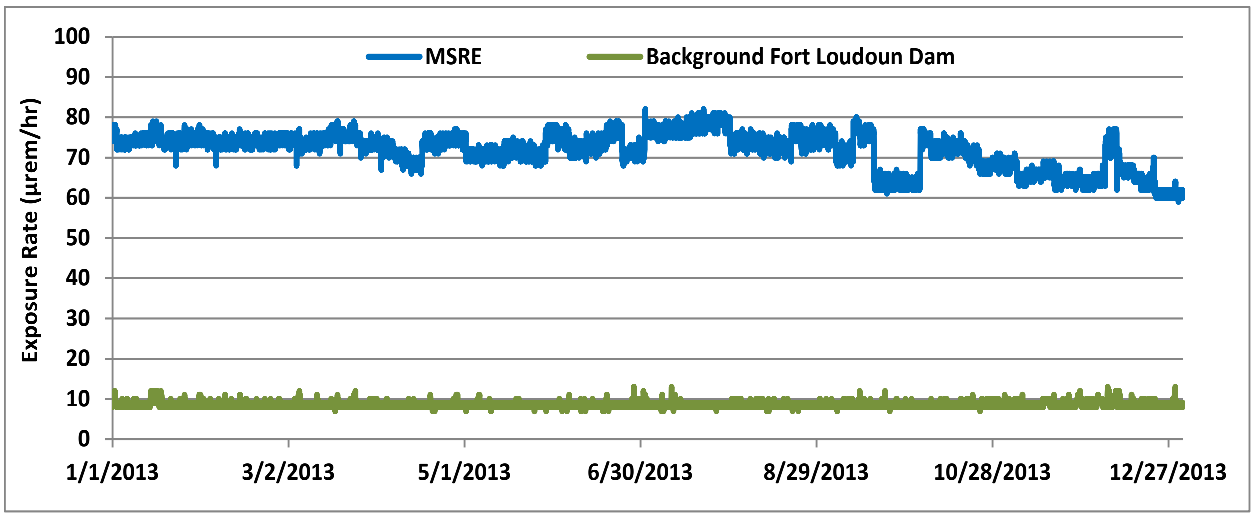
Figure 3: 2013 Results of gamma exposure rate monitoring at the ORNL Central Campus Removal Action and at the background station.

The Molten Salt Reactor Experiment (MSRE)

The concept of a molten salt reactor was first explored at ORNL in association with a 1950s campaign to design a nuclear powered airplane. After interest in an atomic airplane subsided, the MSRE was constructed to evaluate the feasibility of applying the technology to commercial power applications. The concept called for circulating uranium fluoride (the fuel) dissolved in a molten salt mixture through the reactor vessel. The MSRE achieved criticality (a chain reaction resulting in a release of radiation) in 1965 and was used for research until 1969.

When the reactor was put into shutdown mode, the molten fuel salts and flush salts were transferred to drain tanks and allowed to solidify. In 1994, an investigation of the MSRE revealed elevated levels of uranium hexafluoride and fluorine gases throughout the off-gas piping connected to the drain tanks. Among other problems, uranium had migrated through the system to the auxiliary charcoal bed, creating criticality concerns. Actions were taken subsequently taken to stabilize the facility and a CERCLA Record of Decision was issued in July 1998, requiring the removal, treatment, and safe disposition of the fuel and the flushing of salts from the drain tanks.

From 11/01/2012 through end of 2013, the division has recorded gamma exposure rates with a gamma monitor that was placed near the gate where trucks containing radioactive materials (e.g., fuel removed from the drain tanks) exit the MSRE. The location is also near a radiation area that is used to store equipment used in the remediation. During the 2013 monitoring period, the average exposure rate measured ranged from was 59 to 81 µrem/hour and averaged 76.1 µrem/hour (Figure 4). The major source of the radiation measured is believed to a salt probe stored in the radiation area adjacent to the monitoring station.



The state dose limit in an unrestricted area is 2 mrem (2,000 µrem) in any one-hour period. The state dose limit for members of the public is 100 mrem (100,000 µrem) in a year.

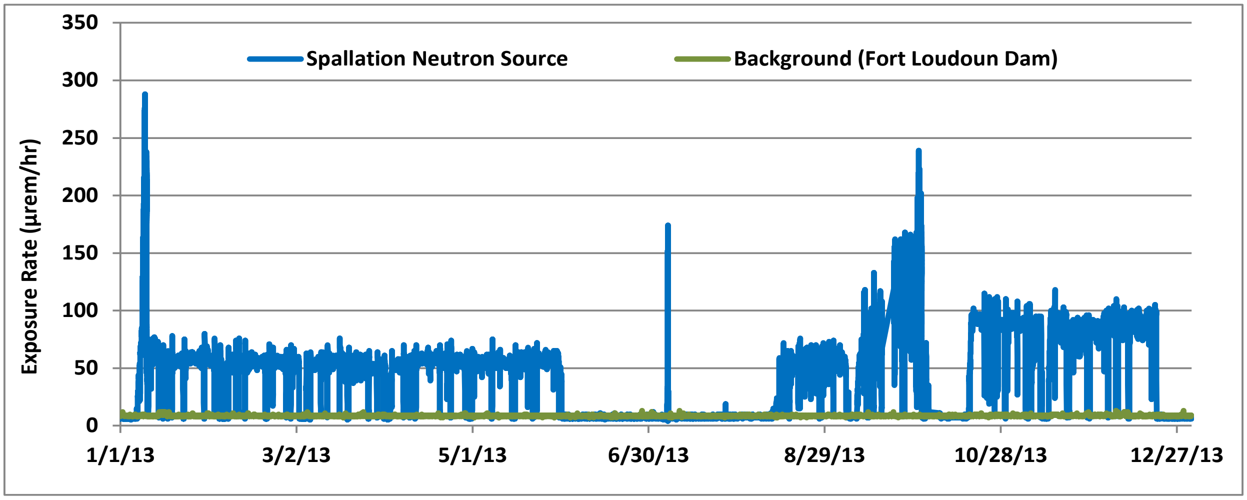
Figure 4: 2013 Results of gamma exposure rate monitoring at the ORNL MSRE and at the background station.

Spallation Neutron Source (SNS)

The SNS is a one of a kind research facility that produces the most intense pulsed neutron beans in the world. The facility was designed and built in partnership with six DOE national laboratories, including Lawrence Berkeley in California, Los Alamos in New Mexico, Argonne in Illinois, Brookhaven in New York, Thomas Jefferson in Virginia, and ORNL in Tennessee. In the most of basic terms, the process begins with a source that produces negatively charged hydrogen ions, consisting of one proton and two electrons. The hydrogen ions are injected into a linear particle accelerator (linac) where they are accelerated to very high energies and passed through a magnetic foil that strips off the electrons, converting, the ions into protons. The protons pass into an accumulator ring, which releases them in high-energy pulses directed toward

a liquid mercury target. When the protons strike the nucleus of the mercury atoms in the target, neutrons are "spalled" or thrown off, along with other spallation products. The neutrons released by the spallation process are guided through beam lines to areas containing specialized instruments for conducting experiments. During the process, high-energy protons interact with nuclei of the accelerator components and materials in the air inside the facility, converting the struck nucleus to that of a different isotope, which is often radioactive. Air evacuated from the facility is held to allow short-lived radioisotopes to decay, filtered to remove particulates, and released to the atmosphere through the central exhaust stack.

To assess the gamma component of air releases from the SNS, one of the division's exposure rate monitors has been located on the central exhaust stack used to vent air from process areas inside the linac and target building. As might be expected, the exposure rates vary with the operational status of the accelerator. During periods when the accelerator is not on line, the rate is similar to background measurements, with much higher levels recorded during operational periods. The exposure rates measured in 2013 ranged from 4 to 288 µrem/hour and averaged 69 µrem/hour (Figure 5).



The state dose limit in an unrestricted area is 2 mrem (2,000 µrem) in any one-hour period. The state dose limit for members of the public is 100 mrem (100,000 µrem) in a year.

Figure 5: 2013 Results of gamma exposure rate monitoring at the SNS stack and at the background station.

Conclusion

The use of gamma radiation exposure rate monitors equipped with microprocessor controlled data loggers has proven to be a flexible and reliable method for monitoring gamma radiation on the reservation. Based on the data collected in 2013, the following conclusions were reached.

- Environmental Management Waste Management Facility gamma levels were consistent with background measurements.
- ORNL Central Campus D&D (3000 Area) gamma levels were within anticipated levels.
- Measurements taken at the MSRE were not indicative of any releases during the period. Exposure levels measured during the year have been attributed to a contaminated salt probe stored near the monitor.

- Gamma levels at SNS were within expected levels and consistent with measurement collected in previous years.

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Surplus Material Verification

Principle Author: John Wojtowicz

Abstract

The Department of Energy (DOE) offers a wide range of surplus items for auction/sale to the general public on the Oak Ridge Reservation (ORR). The Tennessee Department of Environment and Conservation, Department of Energy Oversight Office's Radiological Monitoring and Oversight Program conducted independent radiological monitoring of these surplus materials prior to each auction/sale. During 2013, a total of seven inspection visits were conducted at the ORR facilities. Four visits were made for ORNL sales and three visits were made for Y-12 sales. No sales were conducted at the East Tennessee Technology Park (ETTP) facility. A total of three items, two at ORNL and, one at Y-12 were observed that required further evaluation. All three of these items exhibited elevated alpha and beta radioactivity, and were withdrawn from the sales until further evaluations were conducted.

Introduction

The Tennessee Department of Environment and Conservation, Department of Energy Oversight Office (the office; DOE-O), in cooperation with the U.S. Department of Energy (DOE) and its contractors, conducts radiological surveys of surplus materials that are destined for sale to the public on the ORR. In addition to performing the surveys, the office reviews the procedures used for release of materials under DOE radiological regulations. DOE currently operates their surplus materials release program under **DOE O 458.1 Admin Chg 3, Radiation Protection of the Public and the Environment**. Some materials, such as scrap metal, may be sold to the public under annual sales contracts, whereas other materials are staged at various sites around the ORR awaiting public auction/sale. The office, as part of its larger radiological monitoring role on the reservation, conducts these surveys to help ensure that no potentially contaminated materials reach the public. In the event that elevated radiological activity is detected (greater than twice background), a quality control check is made with a second meter (if possible). If both meters show elevated activity, the office immediately reports the finding to the responsible supervisory personnel of the surplus sales program. Later, readings are converted to dpm/100 cm^2 (dpm = disintegrations per minute) and included in a report for the survey. TDEC-DOE Oversight then follows the response of the sales organizations to see that appropriate steps (removal of items from sale, resurveys, etc.) are taken to protect the public.

Methods and Materials

Staff members make biased surveys of items using standard radiological monitoring meters; Sodium Iodide for gamma radiations, Zinc Sulfide scintillator (alpha)/plastic scintillator (beta) dual detection, or equivalent meters. The alpha/beta scintillator dual detection meters have been found to be the most likely to find increased activity (i.e., most increased activity found is either alpha or beta). Inspections are scheduled just prior to sales after the material has been staged. Items range from furniture and equipment (shop, laboratory and computer) to vehicles and construction materials. Particular attention is paid to items originating from shops and laboratories. Where radiological release tags are attached, radiation clearance information is compared to procedural requirements. If any contamination is detected during the on-site survey, the surplus materials manager is notified immediately.

Staff also reviewed DOE Policy 458.1 to evaluate whether DOE's surplus sales procedures meet the intent of the Policy. According to DOE Policy 458.1, the following requirements must be met in releasing materials to the public:

Public Notification of Clearance of Property.

(a) Field Element Managers must, as appropriate, incorporate information on site clearance policies and protocols, process knowledge decisions, approved Authorized Limits, any approved revised Authorized Limits, use of pre-approved Authorized Limits, and property control and clearance programs into effective site public notification and communications programs.

(b) Information on approved Authorized Limits, any approved revised Authorized Limits, use of pre-approved Authorized Limits, results of radiological monitoring and surveys of cleared property with type and quantity of property cleared, and independent verification results must be summarized in the Annual Site Environmental Report.

(c) The responsible field element must make documentation on clearance of property available to the public and to the property owner or recipient as appropriate.

Staff will be tracking whether these requirements of DOE Policy 458.1 are being implemented in Oak Ridge.

Results and Discussion

A total of seven inspections were conducted, four at ORNL and three at Y-12. No sales were held at ETTP. Elevated levels of alpha and beta radiological contamination were discovered on three items during the DOE-O surveys. One observation requiring further evaluation was made at the Y-12 surplus sales facility. Upon notification by DOE-O staff, the items were removed from the auction for further review by Y-12 Radiation Control personnel. Two observations requiring further evaluation were made at the ORNL surplus sales. These items were also removed from the auction for further evaluation by ORNL Radiation Control.

Items removed from auctions are reevaluated to ensure that they meet the appropriate Y-12 or ORNL release criteria for release of items to the public and in the event they do, they may be later returned to the auction. The elevated levels of activity were often determined to be due to an accumulation of radon; however, in at least two of the instances, the activity was found to be due to contaminants other than radon.

Conclusion

During 2013, hundreds of surplus materials items were sold through ORNL and Y-12 surplus sales organizations in separate sales events. And while DOE does a good job of preventing radiological contamination from reaching the public, minor radiological contamination was

detected on three items staged for release to the public. All three of the items were removed from the auction list for further evaluation.

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Monitoring of Waste at the Environmental Management Waste Management Facility (EMWMF) using a Radiation Portal Monitor

Principal Author: Gary Riner, Howard Crabtree

Abstract

The EMWMF was constructed for the disposal of low level radioactive waste and hazardous waste generated by remedial activities on the DOE's Oak Ridge Reservation. The facility is operated under the authority of CERCLA and required to comply with regulations contained in the Record of Decision authorizing the facility. Only radioactive waste with concentrations below limits imposed by waste acceptance criteria (WAC) agreed to by FFA parties are authorized for disposal in the facility. To help ensure compliance with the WAC, the DOE Oversight Office of the Tennessee Department of Environment and Conservation's Division of Remediation has placed a Radiation Portal Monitor (RPM) at the check-in station for trucks transporting waste into the facility. As the waste passes through the portal, radiation levels are measured and monitored by DOE Oversight staff. When anomalies are noted, DOE and EMWMF personnel are notified and basic information on the nature and source of the waste passing through the portal at the time of the anomaly is reviewed. If the preliminary review fails to identify a cause for the anomalous results, associated information is provided to DOE Oversight's Audit Team for review and disposition. In 2013, the only anomalies observed in the results were due to a nuclear density gauge which contains sealed cesium-137 and americium-241 sources. The density gauge is not a waste, but a tool transported into the EMWMF disposal cells as needed and otherwise stored outside the facility.

Introduction

The Environmental Management Waste Management Facility (EMWMF) was constructed for, and is dedicated to, the disposal of low level radioactive waste (LLW) and hazardous waste generated by remedial activities on the Department of Energy's (DOE) Oak Ridge Reservation (ORR). Operated under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the facility is required to comply with regulations contained in the Record of Decision authorizing the construction of the facility (DOE, 1999). Only low level radioactive waste as defined in TDEC 0400-02-11.03(21) with concentrations below limits imposed by Waste Acceptance Criteria (WAC) agreed to be FFA parties is approved for disposal in the EMWMF. DOE is accountable for compliance with the WAC and has delegated responsibility of WAC attainment decisions to its prime contractor, which it supervises. This includes waste characterization and approval for disposal in the EMWMF (DOE, 2001). The state and EPA oversee and audit associated activities, including decisions authorizing waste lots for disposal.

To help ensure compliance with the WAC, the DOE Oversight Office of the Tennessee Department of Environment and Conservation's Division of Remediation (DOE-Oversight) placed a Radiation Portal Monitor (RPM) at the check-in station for trucks transporting waste into the EMWMF for disposal. As the trucks pass through the portal, gamma radiation levels are measured and transmitted to a secure website monitored by DOE-Oversight staff and available to DOE and its authorized contractors for review. When anomalous measurements are observed, DOE is notified and basic information as to the nature and source of the waste passing through the portal at the time of the measurements are obtained from EMWMF personnel. If preliminary

information indicates the facility's WAC may have been violated, the information is submitted to DOE Oversight's Audit Team for review and disposition.

Methods and Materials

A Canberra RadSenrty Model S585 portal monitor is used in the program. The system is comprised of two large area gamma-ray scintillators, an occupancy sensor, a control box, a computer, and associated software. The gamma-ray scintillators and instrumentation are contained in radiation sensor panels (RSPs) mounted on stands located on each side of the road at the check-in station for trucks hauling waste into the disposal area (Figure 1). Measurements (one per 200 milliseconds) are initiated by the occupancy sensor when a truck enters the portal. Results are transmitted from the RSPs to the control box, where it is stored, analyzed, and uploaded to a secure website, along with associated information (e.g., date, time, and background measurements). Data on the website is monitored by TDEC staff and available for review by DOE and their authorized contractors. If radiation levels exceed a predetermined level, the RPM sends an alert notification to TDEC staff members by email. When an alert notification is received or anomalies are noted in review of the data, DOE and EMWMF personnel are contacted and the source of the waste passing through the portal monitor at the time of the measurements determined. If available information suggests WAC may have been violated, the information is submitted to DOE Oversight's Audit Team for review and disposition. The Audit Team is led by DOE Oversight's Waste Management program with support provided by other Oversight programs as required.

Figure 1: TDEC Portal Monitor at the Environmental Management Waste Management Facility

Results and Discussion

Over the 70 years since the ORR was established, a variety of production and research activities have generated numerous radioactive wastes, most of which are eligible for disposal at the EMWMF. Contaminants include activation and fission products from isotope production facilities, reactor operations, and nuclear research at the Oak Ridge National Laboratory (ORNL), as well as uranium (U), technetium-99 (Tc-99), and associated radionuclides generated by uranium enrichment operations and the manufacturing of nuclear weapons components at the K-25 and Y-12 plants respectively. As these radionuclides decay, they emit one or more types of ionizing radiation.[4] Of these, three are most often considered of concern at the EMWMF: alpha (large positively charged particles), beta (smaller negatively charged electrons), and gamma/x-rays (small packets of energy called photons). Due to their size, weight, and charge, alpha and beta particles tend to interact with nearby atoms over short distances. Consequently, alpha and beta radiation are easily shielded and would not be expected to penetrate the steel side walls of truck beds carrying waste into the EMWMF for disposal or, to a large degree, the waste itself. However, gamma radiation is pure electromagnetic energy with no mass or charge, capable of traveling long distances through various materials before depleting its energy. The radiation portal monitor is only capable of measuring gamma radiation.

Most radionuclides emit gamma radiation, although the frequency of emissions and associated energies vary, depending on the nuclear characteristics of the particular radionuclide. Radionuclides that are predominately alpha emitters emit gamma less frequently than beta emitters and radionuclides considered pure alpha or beta emitters only give off gamma radiation a very small percentage of the time, or not at all. The waste lots disposed in the EMWMF contain mixtures of radionuclides that as a whole emit all three kinds of radiation. Since there are no pure gamma emitters, it is assumed for screening purposes that anomalous increases in gamma measurements are accompanied by increased alpha/beta radiation and concentrations of associated radionuclides. The higher the energy of the gamma emissions, the more likely the gamma photons of any given radioisotope will penetrate through the waste and truck bed to be counted by the portal monitor‘s detectors. The higher the frequency of emissions and concentrations of gamma emitting radioisotopes in the waste, the greater the number of counts measured (the count rate).

To a large degree, the mixture of radionuclides in wastes from the different ORR facilities are characteristic of the primary mission at each site. For example, wastes from ORNL typically include a long list of man-made radionuclides produced by irradiating uranium in reactors, along with their progeny (radionuclides to which they decay). Included in this mix are the most prolific gamma emitters typically found on the ORR (e.g., cesium-137, cobolt-60), along with many other radionuclides produced during nuclear reactions. Consequently, ORNL wastes are expected to have higher count rates than the other sites and typically a larger variety of isotopes in the mix. Conversely, uranium isotopes and technetium-99 are the dominate radionuclides in waste from the ETTP and Y-12 facilities. Uranium isotopes are primarily alpha emitters and technetium-99 is a pure beta emitter. Decay products of uranium are removed during processing of the ore, so only the immediate progeny of the uranium isotopes that grow-in over relatively short time periods are generally present in ETTP and Y-12 wastes (e.g., thorium-231, thorium-234, and protactinium-234m). As a result, the count rates are expected to be much lower and

[4] *Ionizing radiation* is any form of radiation that has enough energy to knock electrons out of atoms or molecules, creating ions.

anomalies more difficult to detect. When reviewing the results generated by the RPM, staff attempt to identify deviations from the norm, which, for the reasons above, change from site to site and from waste lot to waste lot. In most cases, the anomalous results can be resolved based on preliminary information, in others it cannot. In such instances, the results and preliminary information is submitted to the DOE Oversight Audit Team, for disposition.

In 2013, no anomalies were noted in any of the wastes delivered from the three ORR facilities, much of which consisted of demolition material from the D&D of the K-25, K-27, and K-33 Process Buildings at ETTP. These facilities housed production facilities for the enrichment of uranium, initially for nuclear weapons and later to fuel commercial and government owned reactors. In most cases, a large proportion of the demolition waste is clean material mixed with surficially contaminated material during the demolition process. So the concentrations would be expected to be low, compared to process equipment, which typically contains the higher concentrations of contaminants. While there were no anomalous increases observed in the results, it was noted that in some instances the measurements for ETTP wastes were less than the background measurements reported by the RPM, as well as clean soils carried into the site for fill. The only anomalies observed in the results during 2013 where due to a nuclear density gauge which contains sealed and shielded cesium-137 and americium-241 sources. The instrument is used to measure compaction of the waste: a requirement to assure stability of the facility over time. The density gauge is not a waste, but a tool transported into the EMWMF disposal cells as needed and otherwise stored outside the facility.

In the 2012 Environmental Monitoring Report, it was noted that anomalous results had been received for two waste shipments composed of material derived from the demolition of the ORNL's 3026-C Radiochemical Development Laboratory, which had been submitted to the DOE Oversight's Waste Audit Team. 3026-C was a wood frame structure constructed in the 1940s to house operations for the separation of barium-140 from uranium fuel slugs irradiated in ORNL's Graphite Reactor. Over the years, the facility was modified for various uses, including the separation of radioisotopes from liquid wastes generated by processing of irradiated fuel elements for uranium and plutonium, piped to the facility from the 3019 facility (ORAU, 2007).. Based on the review of information associated with the waste lot, it is speculated the elevated readings may have been due to process piping that was not sampled during the effort. However, available information was insufficient to confirm this to be the case.

Conclusions

In 2013, most of the waste delivered to the EMWMF for disposal was derived from the demolition of uranium enrichment facilities at ETTP, constructed to produce uranium enriched in the U-235 isotope for nuclear weapons and later to fuel commercial and government owned reactors. Associated contaminants were primarily uranium isotopes (predominately alpha emitters) and technetium-99 (a pure beta emitter). As might be expected the radiation levels measured were low. The only elevated results observed were due to a nuclear density gauge that contains sealed and shielded cesium-137 and americium-241 sources used to measure compaction of the waste. The density gauge is not a waste, but a tool transported into the EMWMF disposal cells as needed and otherwise stored outside the facility.

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SURFACE WATER MONITORING

Surface Water Monitoring at the Environmental Management Waste Management Facility

Principle Authors: Robert Storms, Wesley White

Abstract
The Tennessee Oversight Agreement requires the State of Tennessee to provide monitoring to verify Department of Energy (DOE) data and to assess the effectiveness of DOE contaminant control systems on the Oak Ridge Reservation. During 2013, the Tennessee Department of Environment and Conservation's (TDEC) DOE Oversight Office monitored groundwater elevations, effluents, surface water runoff, and sediments at DOE's Environmental Management Waste Management Facility (EMWMF). The monitoring has shown the potential for groundwater levels to be above the geologic buffer along the north and northeast portion of the disposal cells. The incursion near PP-02 was identified from the 2011 water level data. This addition has progressed throughout the year. Additional monitoring is warranted to determine if the incursion near PP-02 is due to issues with the underdrain, the northern trench drain, or a function of the additional waste cells. Results from radiological water samples suggest that radionuclides are being discharged from operations conducted at EMWMF. However, those discharges are in compliance under TDEC Rule 1200-2-11-.16. Results from radiological sediment samples suggest that radiological discharges are not impacting the sediments of NT-5 and Bear Creek.

Introduction
The Tennessee Oversight Agreement requires the State of Tennessee to provide monitoring to verify Department of Energy (DOE) data and to assess the effectiveness of DOE contaminant control systems on the Oak Ridge Reservation (ORR). During 2013, Tennessee Department of Environment and Conservation's (TDEC) DOE Oversight Office (DOE-O) monitored groundwater elevations, effluents, surface water runoff, and sediments at DOE's Environmental Management Waste Management Facility (EMWMF). This facility was constructed to dispose of waste generated by remedial activities on the ORR and is operated under the authority of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA). While the facility holds no permit from any state or federal agency, it is required to comply with applicable or relevant and appropriate requirements (ARARs) in the CERCLA Record of Decision (DOE, 1999) and with requirements associated with responsibilities delegated to the DOE by the Atomic Energy Act.

While the availability of onsite disposal capacity of the EMWMF has expedited remedial activities, the East Tennessee region presents environmental challenges for landfill design, including the height of the groundwater table, the quantity of surface water runoff, and the porosity of local soils. Modifications to the initial design of the landfill included the installation of a French drain under the facility to lower the water table, which had risen to levels that approached the liner of the disposal cells. Issues with pooling effluent (contact water), a mixture of rainwater runoff and drainage from wastes, required a modification of procedures. The water is sampled, and based on results either released to a ditch that discharges into a sediment basin or

sent for treatment at the Oak Ridge National Laboratory (ORNL) Process Waste Treatment Facility. The sediment basin discharges to a local tributary of Bear Creek.

It is the intent of this project to verify that the design, operations, and associated contaminant control mechanisms of the facility are consistent with criteria agreed to by the state, Environmental Protection Agency (EPA), and DOE.

Methods and Materials

To verify that EMWMF is meeting its design, a program was initiated to monitor discharges and groundwater locations. This program includes reviewing groundwater elevations, observing water quality parameters at two discharge locations, collecting analytical radiological sediment samples along North Tributary (NT) 5 and Bear Creek, and collecting analytical radiological water samples at EMWMF-1 (GW-918), EMWMF-2, EMWMF-3, EMWMF-4B, EMWMF-6 (NT-4), EMWNT-3, EMWNT-5 at the Contact Water Ponds (CWPs) and at the Contact Water Tanks (CWTs). An acute and chronic toxicity test was performed to determine if the contact water being discharged to the sediment pond and eventual discharge to NT-5 and Bear Creek would meet the substantive requirements of an NPDES program. EMWMF-4 was not sampled in 2013. The radiological sample locations are provided in Figure 1.

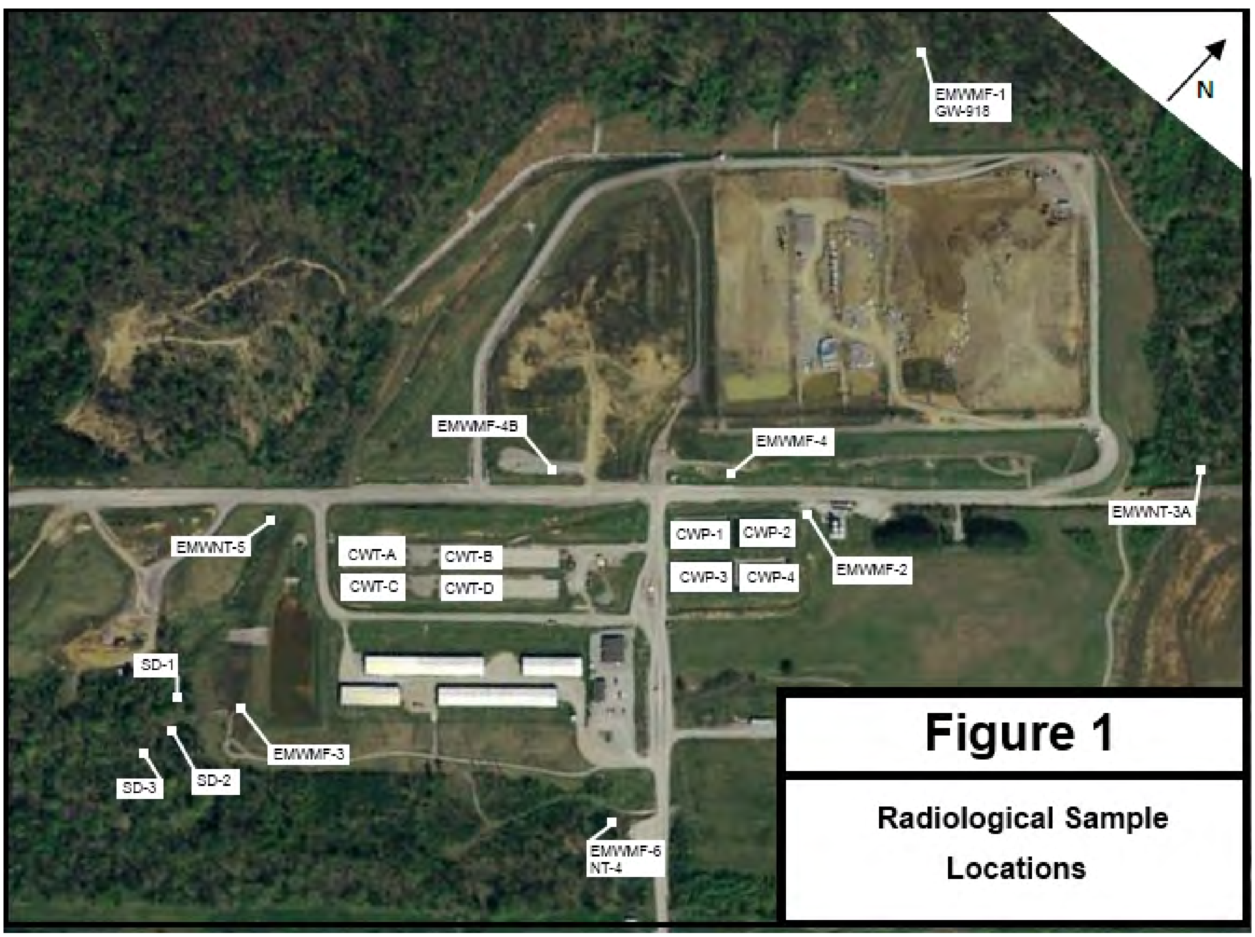


Figure 1: Radiological Sample Locations **(basemap reproduced Google Maps (DigitalGlobe, et al., 2011)**

Groundwater Review

Prior to the construction of EMWMF, Federal Facilities Agreement (FFA) parties agreed on a contingency plan to be implemented if the water table rose to within ten feet of the liner (the fundamental barrier that prevents contaminants from migrating out of the facility into the groundwater) [URS/CH2M Oak Ridge (UCOR), 2012]. The intent of the contingency plan was to prevent the liner from damage caused by hydrostatic pressures from the water table rising to levels above the liner. In 2003, state geologists taking water level measurements near the filled NT-4 channel observed the water table had risen into the ten-foot buffer below the facility. DOE was advised and the contingency plan was implemented. The continued rise of the water table subsequently led to the construction of a French drain running north to south underneath the facility and a northern trench drain to lower the water table that had periodically risen to the facility's liner in some areas.

This groundwater review obtained data collected from BJC (available on the Oak Ridge Environmental Information System - OREIS). Therefore, the data reviewed is from the previous year. The data is analyzed to determine its validity, and is then contoured utilizing a surface contouring program (Surfer®). Engineering data was utilized to contour a surface feature 10 feet below the top of the geologic buffer (a 10 foot soil buffer below the liners) and data from the underdrain installation was utilized to further refine the groundwater contours.

Water Quality Parameters

Water quality parameters were taken at two locations at EMWMF: EMWMF-2 (Underdrain) and EMWMF-3 (Sediment Basin V Weir Discharge). Water quality parameters were collected utilizing a YSI Professional Plus and an In-Situ® Troll 9500 multiparameter water quality monitoring probe. The YSI Professional Plus has been used throughout the year on a scheduled basis. The In-Situ® Troll 9500 was utilized at the EMWMF-2 from January 1 through December 31. Another In-Situ® Troll 9500 was deployed at EMWMF-3 to monitor the sediment basin discharge from March 21 to October 29. Parameters monitored include temperature, specific conductivity, pH, dissolved oxygen (DO), turbidity, and discharge flow rate.

Results and Discussion

Groundwater Review

A groundwater review was performed in 2013 based on historical data up to May 2013. The groundwater elevation data and 10 feet below the top of the geologic buffer were modeled utilizing Surfer®. The resulting groundwater potentiometric contours were compared against 10 feet below the top of the geologic buffer to show areas that might intersect. Figure 2 shows the groundwater potentiometric contours for May 2013, the bottom of the geologic buffer contours, and the areas of potential incursion of groundwater within 10 feet from the top of the geologic buffer. The modeling yielded similar results for all four quarters of water level data. However, the incursion near piezometer PP-01 and PP-02 was increasing in size with each quarterly measurement. This change could be caused by several different factors and all are speculative at this time. Further monitoring of this situation is warranted.

When comparing the Surfer® groundwater potentiometric contours with 10 feet below the top of the geologic buffer contours, generally the water elevations are below the 10 foot buffer. Unfortunately, the data for the northeastern portion of the disposal cells is limited. An additional

well would be necessary to properly define the groundwater potentiometric surface for disposal cells one and two. However, any additional wells to refine the water elevation data for these two disposal cells are not recommended as it could compromise the integrity of the already filled disposal cells. A well (GW-949) along the east side was considered dry, and as a function of Surfer®, GW-950, GW-947, and GW-948 groundwater elevations are providing a local bias for the contouring. This bias along with a need for more groundwater level data from the northern drainage trench makes it difficult to generate an accurate model, thus the observed incursion. The incursion that includes piezometers PP-01 and PP-02 was examined and is shown in figures 3 through 5 could be due to several factors. Additional monitoring is warranted to determine if it is due to the construction of cells 5 and 6. Other potential causes include issues with the underdrain, a leaky cell liner, waste cell loading of the underlying geology creating a damming effect from Pine Ridge, or waste cell loading increasing the pore pressure of the piezometers.

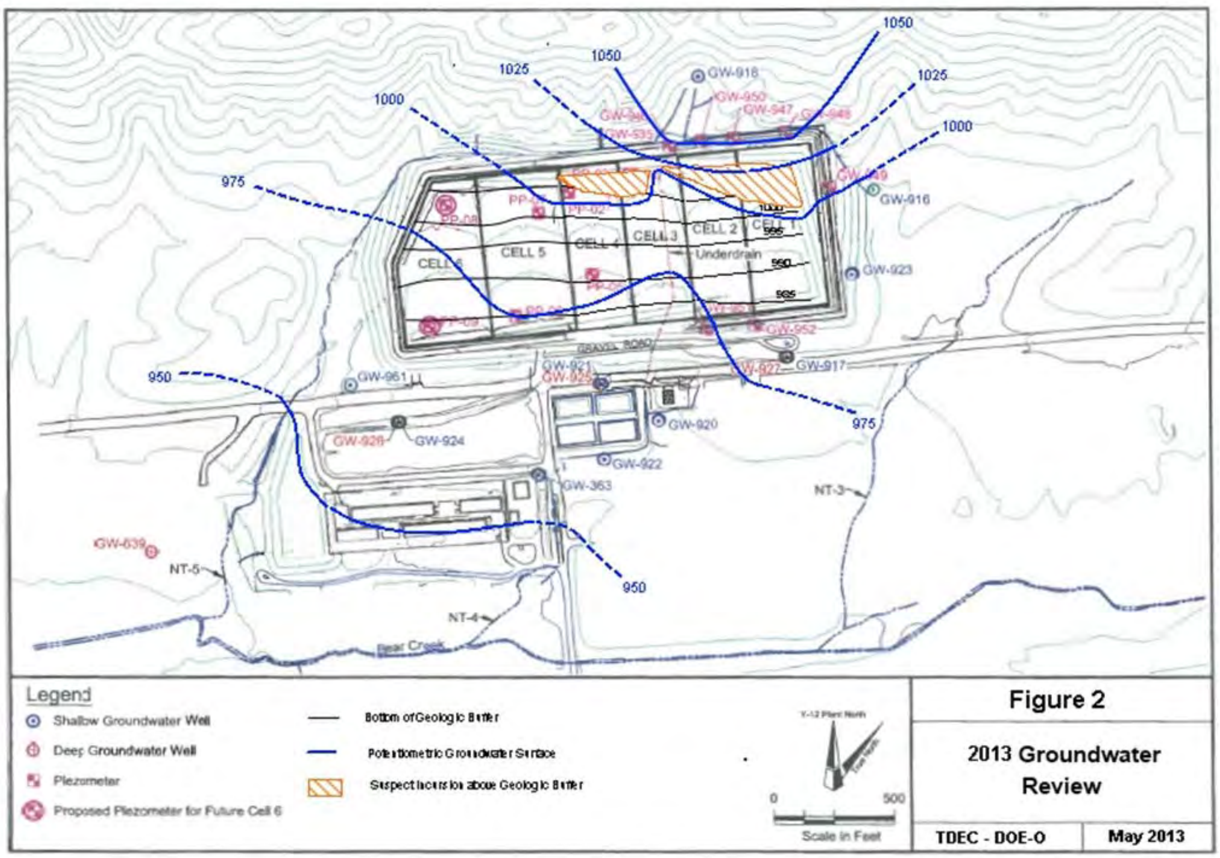


Figure 2: 2013 Groundwater Review

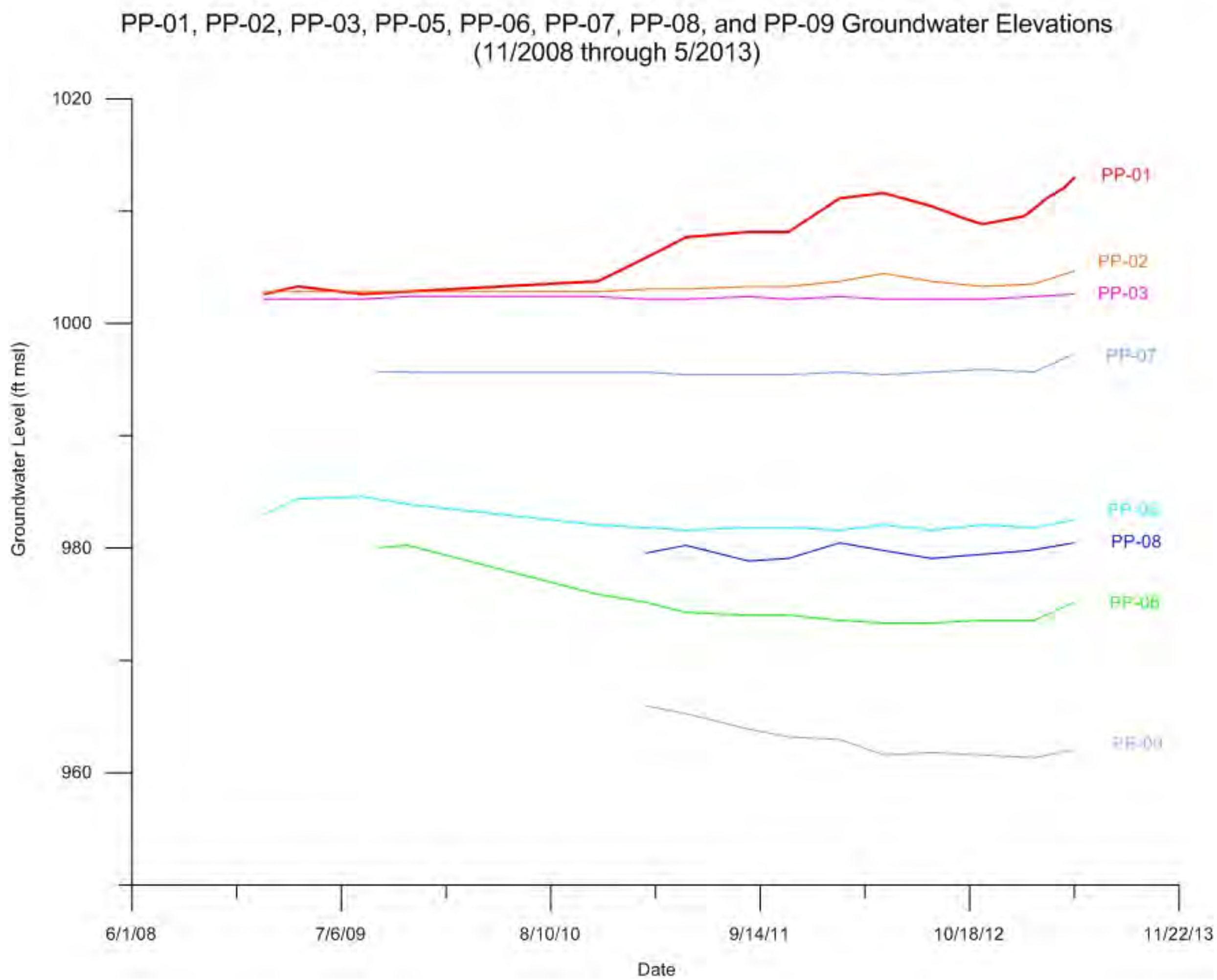
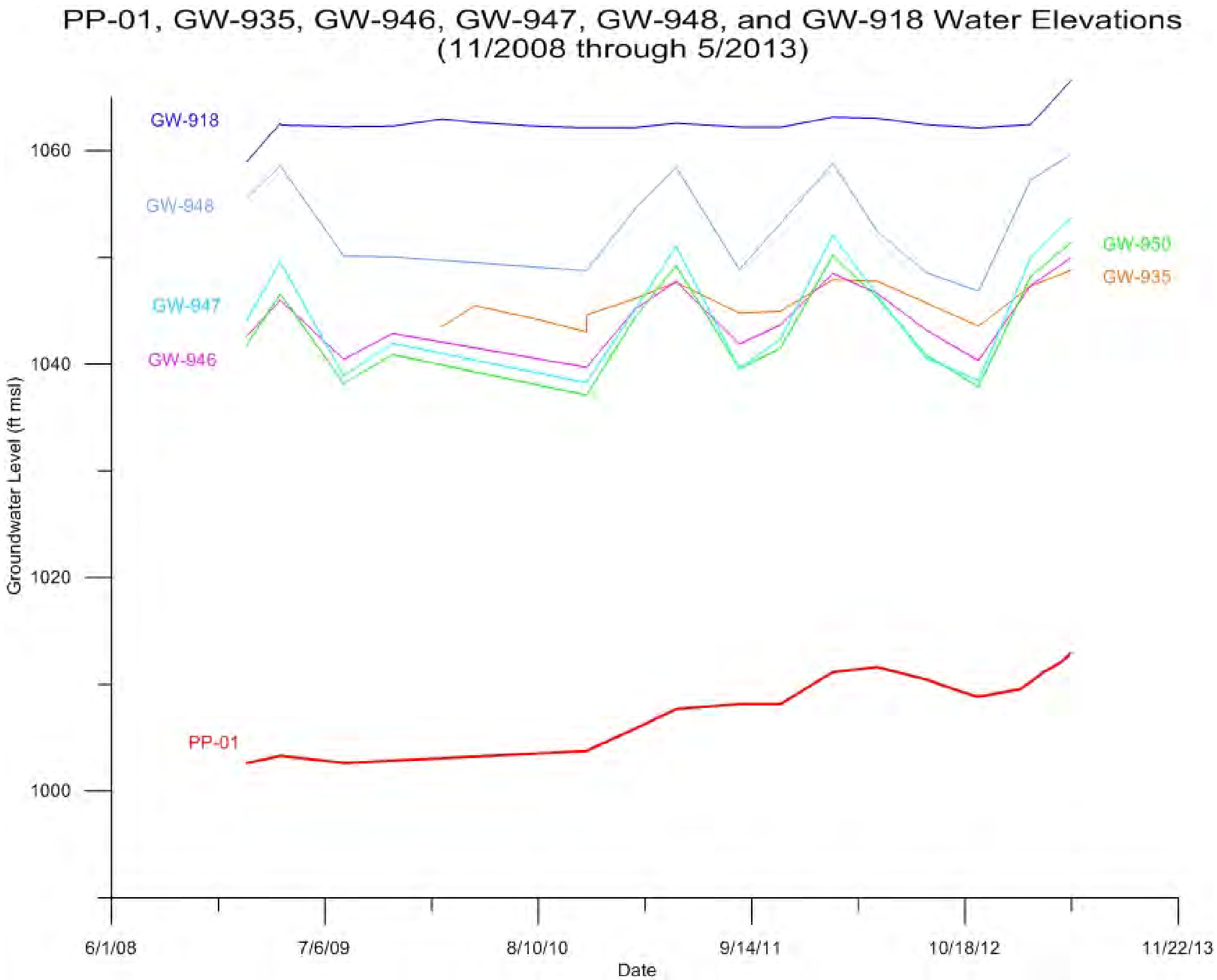
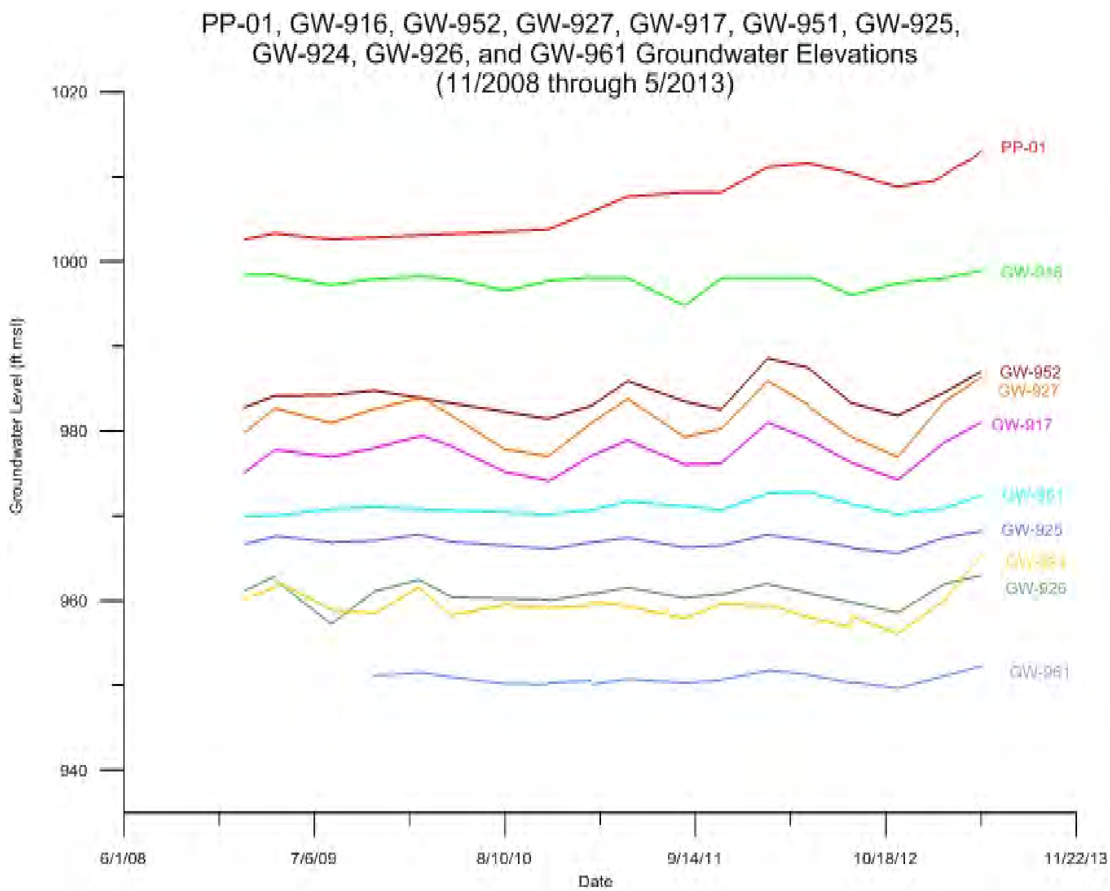


Figure 3: PP-01 Water Elevations in Relations to Piezometers at EMWMF from November 2008 to May 2013



ft msl – feet mean sea level

Figure 4: PP-01 Water Elevations in relations to Upgradient Wells at EMWMF from November 2008 to May 2013



ft msl – feet mean sea level

Figure 5: PP-01 Water Elevations in relations to Downgradient Wells at EMWMF from November 2008 to May 2013

Water Quality Parmeters

Between one or two times a week, TDEC staff recorded water quality parameters at the EMWMF-2 and EMWMF-3 with a YSI-Pro. Table 1 provides a summary of the data recorded at the two sites with the YSI-Pro water quality meter.

Table 1: 2013 Data Summary of the Water Quality Parameters collected with the YSI-Pro Water Quality Meter

UNDER DRAIN

	PH			DO			COND			TEMP			ORP			
	high	low	avg	high	low	avg	high	low	avg	high	low	avg	high	low	avg	visits
Jan	6.78	6.28	6.56	6.48	2.76	4.66	597	452	525	15.9	14.4	15	287.4	178	239.2	9
Feb	6.62	6.45	6.57	5.43	3.19	4.73	532	511	522	15.5	14.1	14.9	249.1	199	224.2	8
Mar	6.7	6.42	6.59	5.72	3.73	4.53	559	487	517	15.6	13.9	14.6	261.8	207.5	222.8	6
Apr	6.71	6.29	6.45	5.83	2.86	4.5	574	503	534	16.1	14.8	15.6	296.7	176	228.8	9
May	6.66	6.19	6.46	4.54	2.36	3.31	626	533	557	16.5	15.8	16.25	314.2	177.4	244.6	8
Jun	6.7	6.42	6.54	3.74	1.88	2.33	552	512	530	17.2	16.4	16.74	211.1	278.4	230.6	7
Jul	6.6	6.27	6.51	5.06	2.2	3.51	594	522	547	17.7	17.1	17.3	316.6	130.6	189.7	7
Aug	6.39	6.3	6.34	3.3	0.6	1.78	571	518	538	18	17.3	17.7	341.4	216	260.7	9
Sep	6.37	6.27	6.33	1.84	1.01	1.44	548	497	516	18.2	17.8	17.9	355.7	192.1	264.8	8
Oct	6.57	6.31	6.4	5	2.24	3.2	518	453	501	18	16.7	17.5	271.6	143.5	194.5	10
Nov	6.59	6.37	6.46	4.9	3.35	4.45	581	476	496	17.4	15.2	16.4	315.8	194.9	267.9	7
Dec	6.69	6.45	6.6	6.02	3.41	4.38	582	494	539	16.8	14.1	14.5	324.1	146.1	243.1	7

OUT FALL

	PH			DO			COND			TEMP			ORP			
	high	low	avg	high	low	avg	high	low	avg	high	low	avg	high	low	avg	visits
Jan	8.09	6.82	7.52	13.16	11.12	11.98	732	195	477	9	5.3	7.11	254.5	148.7	213.6	9
Feb	7.95	7.37	7.58	13.25	10.17	11.74	977	520	762	10.2	6.2	7.34	239.3	198.7	215.9	8
Mar	7.96	7.38	7.66	12.27	8.95	10.92	829	162	424	14.7	6	9.9	254.7	189.1	218	6
Apr	8.41	7.34	7.68	11.08	7.44	9.13	648	274	480	21.1	10.7	16.3	342.9	172.3	232	9
May	7.9	6.96	7.46	10.54	5.2	7.16	712	310	577	29.7	15.7	22.9	301	173.9	235.9	8
Jun	8.41	7.49	7.7	4.65	7.95	6.06	678	285	487	27.9	25.3	26.4	269.7	193	221.6	7
Jul	8.6	7.46	7.96	8.12	5.74	6.95	695	332	516	29.1	25	26.8	252.1	113.5	162.6	7
Aug	8.79	7.9	8.36	7.34	5.76	6.42	830	346	541	27.7	24.1	26.2	289.4	185.4	226.1	9
Sep	8.44	7.42	7.85	7.4	4.2	6.02	822	238	536	25.9	20.3	23.5	268.5	142.3	221.4	7
Oct	8.58	7.93	8.2	11.08	6.58	8.23	697	228	456	22.5	11.2	17.3	211	117.3	163.9	8
Nov	7.95	7.54	7.67	13.36	8.94	10.84	417	142	255	14	4.3	8.65	291.5	190.2	242.7	4
Dec	7.84	7.55	7.66	13.55	10.08	12.31	565	148	291	11.9	4.9	7.76	318.1	212.4	247.9	7

X – no water flow; DO – Dissolved Oxygen; COND – Specific Conductivity; TEMP - temperature

PH is an important limiting chemical factor for aquatic life. If the water in a stream is too acidic or basic, the H+ or OH- ion activity may disrupt aquatic organism's biochemical reactions by either harming or killing the stream organisms. Streams generally have a PH value ranging from 6 to 9, depending upon the presence of dissolved substances that come from bedrock, soils and other materials in the watershed.

Dissolved Oxygen is expressed as a concentration in water. A concentration is the amount of in weight of a particular substance per a given volume of liquid. The DO concentration in a stream is the mass of the Oxygen gas present, in milligrams/liter of water or ppm. This number can be affected by temperature, flow, aquatic life, altitude, dissolved or suspended solids or human activity.

Specific Conductivity is a measure of how well water can pass an electrical current. It is an indirect measure of the presence of inorganic dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, iron and aluminum. The presence of these substances increases the specific conductivity in water. Conversely substances like oil or alcohol will lower the specific conductivity.

Temperature of water is a controlling factor for aquatic life. It controls the rate of metabolism, reproduction activities and therefore, life cycles. Temperature can be influenced by seasonal fluctuations and flow rate.

ORP or Redox potential, is a measurement of water's ability to oxidize contaminants. The higher the ORP, the greater the number of oxidizing agents.

EMWMF-2:
The PH was relatively constant as expected with groundwater. The DO dropped a little during the summer months as expected with slightly higher temperatures. The conductivity kept a consistent average, also expected with groundwater.

EMWMF3:
The PH was fairly stable throughout the year and appeared normal. The DO dropped as the temperatures rose during the weather cycle. Conductivity displayed a spike in February. This was during a low flow period.

In addition to the YSI- Professional Plus water quality meter whose monitoring data is listed in Table 1, an In-Situ® Troll 9500 multiparameter water quality data logger was at EMWMF-2 from January 1 through December 31 and at EMWMF-3 from March 21 through October 29. To complement the water quality parameter graphs, a precipitation graph was created from the ORNL precipitation data from the meteorological station at Y-12 West. The meteorological data was collected approximately one mile northeast from EMWMF. Graphs of EMWMF-2 and EMWMF-3 are presented in Figures 3 and 4, respectively.

There are three data gaps at EMWMF-2. The data gaps occurred from equipment servicing and equipment expiration. The data gap from June 2-July 30 was due to an equipment malfunction that required factory servicing. The data gap from August 27 - October 29 was to make way for construction activities to upgrade the underdrain. The third data gap is from December 17 - December 19 was due to replacement of the rugged dissolved oxygen sensor and calibration.

There is one data gap at EMWMF-3. The unit was placed in service on March 21 after the threat of stagnant freezing water which might damage the probes was eliminated. The unit was pulled from this location on October 29 when there was an increased potential for the water at EMWMF-3 to freeze. The one data gap occurred from April 23-April 25 due to equipment maintenance and cleaning.

At EMWMF-2:
The parameters monitored with the In-Situ® multiparameter water quality data logger were temperature, pH, DO, specific conductivity, water surface height (calculated to discharge), and turbidity. Monitoring was to determine the integrity of the liners of the disposal cells. Any leaks in the liner should have shown changes (whether gradual or sudden) to pH, DO, specific conductivity, and possibly discharge. Monitoring the discharge in conjunction with the surrounding groundwater levels should help determine the long term effectiveness of the underdrain. Currently, there has been a slight increase in pH from last year, however, that could

be due a cooler, wetter year. Future monitoring should be compared to see if there are trends of these parameters on an annual basis (See Figure 3).

Temperature:

There is a diel cycle (a regular 24 hour daily cycle) with the data. This fluctuation is due to the fact that the underdrain is monitoring groundwater discharge which is being exposed to atmospheric conditions at the discharge point. There is a gentle temperature increase beginning from March to mid September. In September the temperature is slightly decreasing. This gentle temperature change is expected and is seasonal.

pH:

The pH data has a slight diel cycle. Generally the groundwater pH was between 6.18 to 6.75 standard units. The only noted peaks with the pH data were associated with a sizeable precipitation event. These pH spikes are thought to be the result of surface water runoff.

Dissolved Oxygen (DO):

Dissolved oxygen has a slight diel cycle and it varies with temperature. As the temperature decreases, more oxygen can be dissolved in solution. The DO probe appeared more sensitive to temperature and this could be due to the limited water column above the probe. Groundwater typically has low DO values. The spikes in DO were associated with the groundwater runoff during precipitation events. The lowest dissolved oxygen values were consistently recorded from July 30 through August 27.

Specific Conductivity:

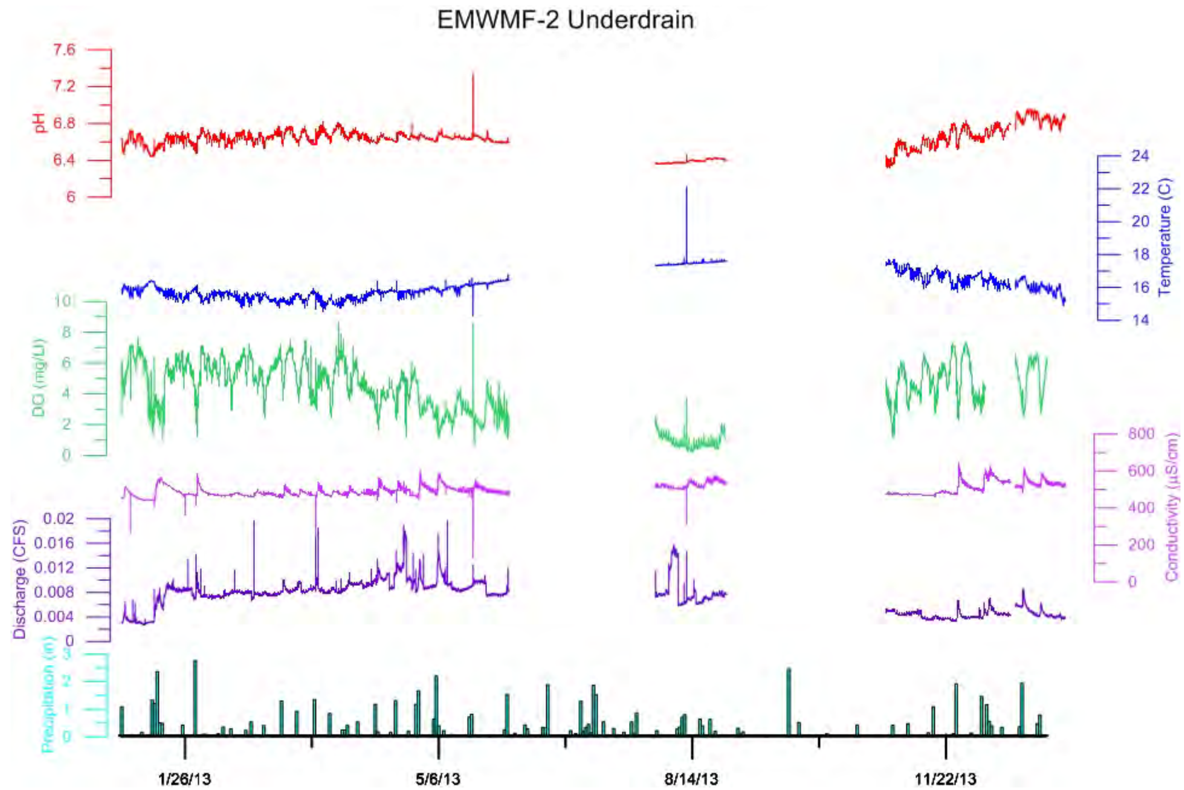
Specific conductivity varies based on the length of time the groundwater is exposed to stratigraphic units (rock formations). The specific conductivity values at the underdrain indicate a recessional curve after several major rain events. When there was a recessional curve, there was a seven- to 12-hour lag before higher conductivity values peaked. This higher conductive groundwater (older water) is being displaced from the infiltration of fresh rainwater within a few hours of the precipitation event. However, there are several other rain events with no observed recessional curve. It is possible that during the dry periods as shown during the fall of 2013, that the rain water percolated into storage and did not displace the older formation water.

Turbidity:

The turbidity values were recorded but are not shown in the Figure 3. The turbidity values were somewhat misleading. EMWMF-2 is near surface water runoff, open to the atmosphere, and shallow. During all rain events, movement of the YSI water quality meter, or servicing of the data logger the turbidity values were anomalously high. All other turbidity readings were consistently below 10 NTUs.

Discharge:

There is a V-weir associated with EMWMF-2. The discharge was fairly constant, with some increase during wetter periods. There were slight recessional curves noted with the discharge data with major precipitation events. The discharge peaks observed on Figure 3 were associated with precipitation events and water entering EMWMF-2 from surface water runoff.



C –Centigrade; **mg/L** – milligrams per liter; **µS/cm** – microSiemens per centimeter; **NTU** - nephelometric *turbidity units; CFS – cubic feet per second; in – inches.*

Figure 3: Water Quality Parameters (temperature, pH, DO, specific conductivity, discharge, and turbidity) and Precipitation at EMWMF-2

At EMWMF-3:

The parameters monitored (see Figure 4) with the In-Situ® multiparameter water quality data logger at EMWMF-3 from March 21 to October 29 were temperature, pH, DO, specific conductivity, water surface height (calculated to discharge), and turbidity.

<u>Temperature:</u>

As evident from the temperature graph, the water temperatures were elevated. The increased temperature was expected for a surface water impoundment when the ambient air temperatures were the highest. The ambient air temperature increase was observed during June through August of 2013. The daily temperature fluctuations (diel cycle) were subdued during times when the flow at the V-weir stopped. Radiant heating from the sun at the outfall also affected temperatures. Along with the daily temperature fluctuations, seasonal temperature fluctuations were observed.

<u>pH:</u>

The pH data has a pronounced diel cycle. This cycle was especially evident in late July through mid-September 2013. The pH data can vary with temperature. Generally, the surface water pH during times of discharge varied between 6.63 and 9.91 standard units, with the average pH around 8.06 standard units. The pH was observed above 9.0 standard units at the V-Weir during

discharge 31 times as shown in Table 2. These thirty-one discharges were above the stormwater release criteria noted in Table 3.

Table 2. pH Above 9 Standard Units	
Start	**Stop**
8/11/13 6:52 PM	8/11/13 7:42 PM
8/12/13 7:22 PM	8/12/13 8:12 PM
8/16/13 3:32 PM	8/16/13 7:52 PM
8/17/13 2:42 PM	8/17/13 10:02 PM
8/18/13 3:02 PM	8/19/13 1:02 AM
8/19/13 1:12 PM	8/20/13 4:12 AM
8/20/13 11:32 AM	8/21/13 4:12 AM
8/21/13 10:32 AM	8/22/13 4:12 AM
8/22/13 3:02 PM	8/22/13 9:22 PM
8/25/13 2:02 PM	8/26/13 12:32 AM
8/26/13 11:42 AM	8/27/13 1:52 AM
8/27/13 11:11 AM	8/28/13 1:41 AM
8/28/13 11:21 AM	8/29/13 2:31 AM
8/29/13 12:21 PM	8/30/13 12:51 AM
8/30/13 1:51 PM	8/31/13 12:01 AM
8/31/13 2:01 PM	8/31/13 11:41 PM
9/1/13 1:01 PM	9/2/13 12:01 AM
9/2/13 1:21 PM	9/3/13 12:21 AM
9/3/13 12:41 PM	9/4/13 4:11 AM
9/4/13 10:51 AM	9/5/13 3:31 AM
9/5/13 10:51 AM	9/6/13 4:11 AM
9/6/13 10:31 AM	9/7/13 2:31 AM
9/7/13 11:11 AM	9/8/13 2:11 AM
9/8/13 1:11 PM	9/9/13 12:51 AM
9/9/13 1:51 PM	9/10/13 12:01 AM
9/10/13 2:11 PM	9/10/13 11:41 PM
9/11/13 3:11 PM	9/11/13 9:31 PM
9/12/13 4:11 PM	9/12/13 9:31 PM
9/13/13 4:01 PM	9/13/13 8:31 PM
9/24/13 2:51 PM	9/25/13 6:41 AM
9/25/13 5:31 PM	9/25/13 7:31 PM

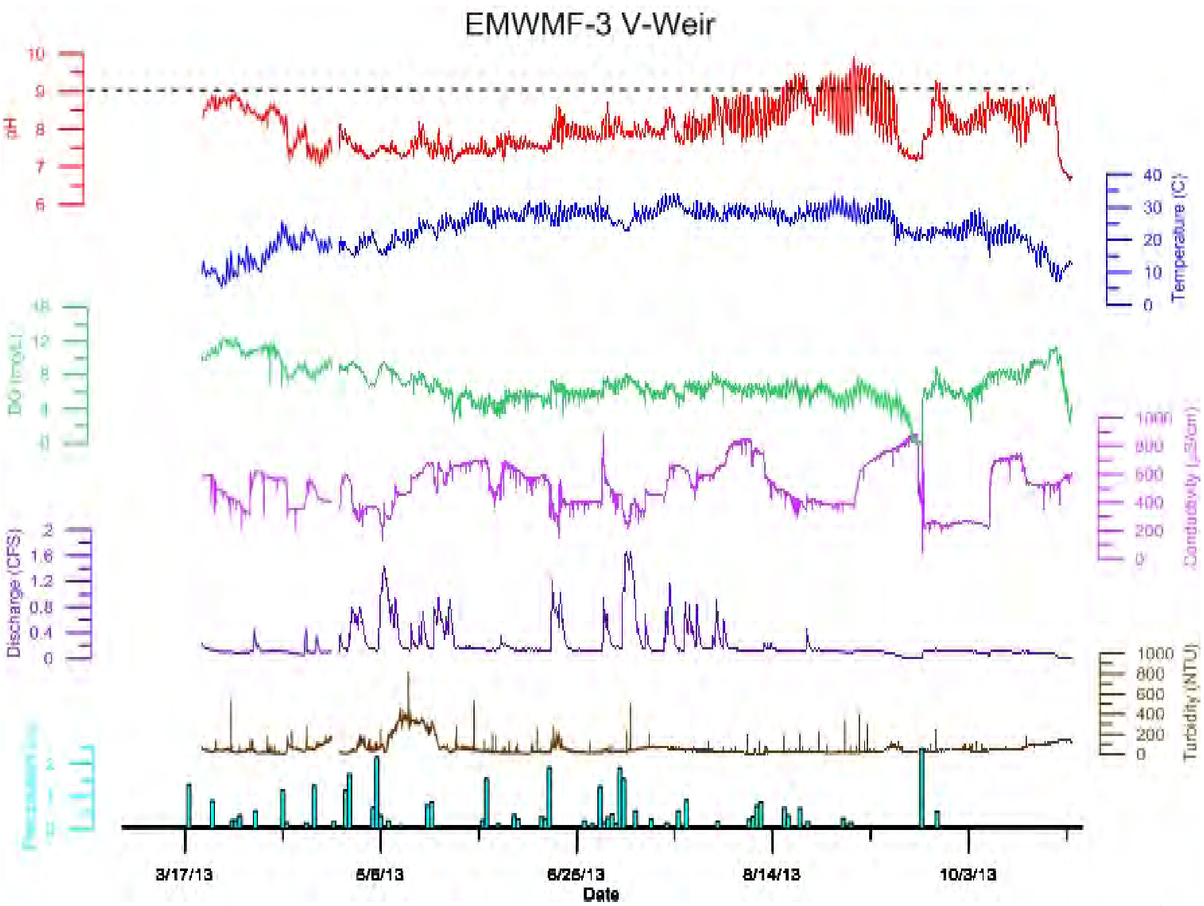
There are possible explanations for the observed higher pH values based on the data collected with the In-Situ® Troll data logger. The high pH was associated with a warm dry August. Dissolved Oxygen increases as does the temperature and pH. This connection shows a biological input with the sediment basin. This increase in pH was associated with algal growth during periods of high photosynthetic activity with little fresh rain water being added during this time. Algal growth in the sediment basin and in the contact water basins have all played a role in the

elevated pH levels observed at the V-Weir. Several algal remedies were employed in 2013, and those remedies at the V-Weir itself are working for the V-Weir only as observed when there was no flow at the V-Weir and the sudden drop in pH in September.

Dissolved Oxygen (DO):
The DO has a diel cycle and it varies with temperature. Generally as the temperature decreases, more oxygen is dissolved from the atmosphere to the surface water. However, at the sediment basin, DO increases as temperature increases. The observed DO increase is biological (photosynthesis) or rapid non laminar flow conditions. However, the lower levels of DO are probably associated with the elevated atmospheric and water temperatures. The higher observed DO readings during the day helps support the conclusion about the observed pH issue as being biological in nature.

Specific Conductivity:
Specific Conductivity also has a slight diel cycle; the warmer the water, the more ions in solution. The graph shows this fluctuation with temperature. There were also changes in conductivity due to significant rain events, the length of time the water was exposed to soil in the sediment basin, and the origin of the surface water (contact water pond discharge or precipitation).

Turbidity:
There were several peaks in the graph for turbidity which were confirmed with visual observations. There is not a release criteria for turbidity. However, the EPA proposed (then vacated said proposal) that an effluent limitation for sites that disturb 20 acres be required to comply with a turbidity limit of 280 nephelometric *turbidity units* (NTUs). The data logger recorded turbidity values above 280 NTU on March 28, May 9 through May 19, May 29, and September 7. The high turbidity values in May were related to the high discharge of stored surface water from the previous precipitation events. The other high turbidity values were associated with sudden precipitation events.



C –Centigrade; **mg/L** – milligrams per liter; **μS/cm** –microSiemens per centimeter; **NTU** - nephelometric *turbidity units; CFS – cubic feet per second; in – inches.*

Figure 4: Water Quality Parameters (temperature, pH, DO, specific conductivity, discharge, and turbidity) and Precipitation at EMWMF-3

<u>Discharge:</u>

The discharge at EMWMF-3 corresponded with precipitation events, Contact Water Ponds/Contact Water Tank discharges, and uncontaminated storm water discharges.

The parameters of discharge, pH, DO, and turbidity showed that there were potential issues at EMWMF-3, particularly with biological activity (high pH and DO) and surface water runoff (high turbidity). Algal blooms or mats have the potential to increase the pH above the release criteria at EMWMF-3.

Table 3: Stormwater Monitoring Criteria	
Parameter	**Release Criteria Level**
5-day Biological Oxygen Demand	40 mg/L
Total Suspended Solids (TSS)	110 mg/L
Ammonia as Nitrogen	0.2 mg/L
Oil and Grease	30 mg/L
pH	6.0-9.0 (standard units)
Gross Alpha	15 pCi/L
Gross Beta	50 pCi/L
Radiological COCs	25% of Nuclide specific DCG from DOE Order 5400.5

(Safe Drinking Water Act, TDEC 1200-4-3-.03(3(g)) and 1200-2-11-.16)
mg/L – milligram per liter
pCi/L – picocuries per liter
COC – contaminants of concern
DCG – derived concentration guides
DOE – Department of Energy

Radiological Sediment Samples

Two sediment grab samples were collected from the sediment basin as shown in Figure 1. The samples were collected to determine if any deposition of radiological contaminants has occurred in the sediment basin. Two sediment samples were collected in 2013 and compared to two sediment samples taken in 2012. Based on the minimal data return, there appears to be an accumulation of contamination in the sediments. Samples were analyzed for gross alpha, gross beta, strontium-90, total uranium, and Technetium-99. The results are provided in Table 2. Staff will monitor the situation in 2014.

	Table 2: EMWMF Sediment Basin Sampling Results					
Station ID	**Date**	**Gross Alpha (pC/g)**	**Gross Beta* (pC/g)**	**Technetium-99 (pC/g)**	**Strontium-90* (pC/g)**	**Total Uranium (pCi/g)**
SB-1	6/22/12	5.53	5.9	1.22	0	2.80
SB-2	9/14/12	5.73	11.8	1.54	0.53	4.27
SB-1	9/19/13	19.5	36.2	0.56	0.42	19.32
SB-2	9/19/13	14.0	24.4	0.45	0.73	23.25

pC/g – picocurie per gram

Radiological Water Samples

Five location groupings were consistently sampled at EMWMF. The samples were analyzed for radionuclides. The analyses varied and included gross alpha, gross beta, strontium-90, technetium-99, tritium, and isotopic uranium.

EMWMF-1 (GW-918)

A total of four samples were collected at the background location, EMWMF-1. This location was co-sampled during the quarterly groundwater sampling events for EMWMF-1 at GW-918. The samples were analyzed for gross alpha, gross beta, gamma radionuclides, strontium-90, technetium-99, isotopic uranium, and tritium. In addition, staff members were able to sample GW-922 on one occasion which is down gradient from the cell and the Contact Water Ponds.

Initial analysis from 8/14/13 indicated elevated levels Strontium-90. These samples were analyzed a second time for confirmation purposes using a portion of the sample water held in reserve. The second (confirmatory) analysis did not show elevated levels of Strontium-90.

Table 4: EMWMF-1 (GW918) Sample Results

Date	Gross Alpha (pCi/L)*	Gross Beta (pCi/L)		Strontium-90 (pCi/L)*	Technetium-99 (pCi/L)	Total Uranium (pCi/L)	Tritium (pCi/L)
2/25/13	0.13	3.2		-0.08	0.53	0.19	139
5/14/13	0	0		1.56	0	0.55	152
8/14/13	-0.4	10.7		4.61	0.54	0.31	0
8/14/13 (GW922)	2.6	2.4		3.51	0	0.21	0
11/13/13	-0.34	8.0		0.17	0.54	0.17	150
8/14/13 reanalysis				-0.14			
8/14/13 (GW922) reanalysis				-0.18			

NA – not analyzed
pCi/L – picocurie per liter
Pending – Data not available from the Laboratory

EMWMF-2 (Underdrain Discharge)

A total of seven samples were collected at EMWMF-2. The samples were analyzed for technetium-99, tritium, strontium-90, and isotopic uranium. The sample results are presented in Table 5. The sample results are comparable to background or EMWMF-1. Initial analysis from 8/14/13 indicated elevated levels Strontium-90. These samples were analyzed a second time for confirmation purposes using a portion of the sample water held in reserve. The second (confirmatory) analysis did not show elevated levels of Strontium-90.

Date	Technetium-99 (pCi/L)	Tritium (pCi/L)	Strontium-90 (pCi/L)	Uranium (pCi/L)
1/15/13	0.55	138	-0.25	0.85
2/4/13	0	138	-0.25	0.50
4/13/13	-0.54	0	-0.22	0.41
5/14/13	-0.56	0	1.04	0.78
7/11/13	0.54	293	3.02	0.76
8/22/13	0	148	6.08	0.50
11/7/13	0	0	0.04	0.33
8/22/13 reanalysis			-0.07	

NA – not analyzed
pCi/L – picocurie per liter

EMWMF-3 (Sediment Basin Discharge)

A total of nine samples were collected at EMWMF-3. The samples were analyzed for gross alpha, gross beta, strontium-90, technetium-99, isotopic uranium, and tritium. The sample results are presented in Table 6. The results at EMWMF-3 were elevated in the all analyses indicating, some radionuclides are being discharged at EMWMF-3.

Table 6: EMWMF-3 Sample Results							
Date	**Gross Alpha (pCi/L)**	**Gross Beta (pCi/L)**		**Strontium-90 (pCi/L)**	**Technetium-99 (pCi/L)**	**Total Uranium (pCi/L)**	**Tritium (pCi/L)**
12/19/12	NA	NA		0.77	1.08	8.72	0
1/15/13	93	32.7		3.9	9.31	24.99	138
4/3/13	82	14.7		0.39	3.00	28.08	138
5/23/13	21.5	16.2		1.78	2.19	20.90	301
6/20/13	4.8	7.6		4.90	1.08	4.70	304
7/11/13	2.3	8.0		4.02	1.05	3.26	449
8/22/13	22.8	7.9		8.32	1.40	21.77	292
10/14/13	25.7	55.1		12.0	4.48	21.12	451
11/7/13	12.1	20.3		7.60	1.70	13.24	298

NA – not analyzed
pCi/L – picocurie per liter

This location is subject to the release criteria shown in Table 2. There are exceedences to the gross alpha release criteria. However, DOE Order 5400.5 establishes DCGs for radionuclides in process effluents (Table 7), which are used as reference concentrations for conducting environmental protection programs. Per DOE agreement with TDEC, annual average (sum of fractions) SOF calculations for storm-water discharge into Bear Creek are based on 25% of the 100 millirem per year DCG specified under DOE Order 5400.5, which corresponds to a SOF of 1.042. In addition to the TDEC limit for SOF, a modified annual average sum of fractions of 0.625 serves as the environmental as low as reasonably achievable (ALARA) goal for EMWMF. The storm-water SOF is calculated each calendar year using radiological contaminants of concern (COC) results reported for monthly surface water, monthly storm-water, other storm-water, quarterly surface water, and miscellaneous surface water samples collected at the discharge point of the EMWMF storm-water retention and sedimentation pond. The annual storm-water sum of factions result is 0.42, and is within compliance with the TDEC limit of 25 millirem per year (mrem/yr) specified under TDEC Rule 1200-2-11-.16.

Table 7: Derived Concentration Guides (DCGs) for selected isotopes		
Isotope	**DCG (100 mrem/year)**	**¼ of DCG (25 mrem/year)**
Tritium	2,000,000 pCi/L	500,000 pCi/L
Strontium-90	1,000 pCi/L	250 pCi/L
Technetium-99	100,000 pCi/L	25,000 pCi/L
Uranium-234	500 pCi/L	125 pCi/L
Uranium-235	600 pCi/L	150 pCi/L
Uranium-238	600 pCi/L	150 pCi/L

pCi/L – picocurie per liter
mrem/year – millirem per year

EMWMF-4/4B (Uncontaminated Storm-water Discharge)

Three samples were collected at EMWMF-4B. The samples were analyzed for gross alpha, gross beta, strontium-90, total uranium, and tritium. The sample results are presented in Table 8.

Table 8: EMWMF-4/4B Sample Results							
Date	**Gross Alpha (pCi/L)**	**Gross Beta (pCi/L)**		**Strontium-90 (pCi/L)***	**Technetium-99 (pCi/L)**	**Total Uranium* (pCi/L)**	**Tritium (pCi/L)**
1/15/13	NA	NA		-0.14	-0.55	0.71	138
4/16/13	1.6	2.5		1.81	-1.11	0.81	140
12/3/13	1.84	13.0		-0.10	0	0.58	0

NA – not analyzed
pCi/L – picocurie per liter

This location is subject to the release criteria shown in Table 2, as it is discharged to EMWMF-3. The samples at EMWMF -4B did not exceed their release criteria.

Surface Water Runoff

A total of six samples were collected at tributaries NT-3, NT-4 and NT-5. The samples were analyzed for gross alpha, gross beta, strontium-90, technetium-99, isotopic uranium, and tritium. The sample results are presented in Table 9. The results from the tributaries indicate minimal contamination potential from total uranium is observed at NT-3. NT-4 is also down-gradient to the capped Oil Landfarm and the Sanitary Landfill 1 in Bear Creek Valley, thus the results could indicate potential problems with the site. Staff will continue to monitor the tributaries for changing conditions.

Table 9:Surface Water Results								
Station ID	**Date**	**Gross Alpha (pCi/L)***	**Gross Beta (pCi/L)**		**Strontium-90 (pCi/L)***	**Technetium-99 (pCi/L)**	**Total Uranium (pCi/L)***	**Tritium (pCi/L)**
NT-3	12/19/12	NA	NA		0.18	1.08	8.72	0
NT-4	1/10/13	NA	NA		-0.17	0	1.96	140
NT-3B	3/21/13	NA	NA		-0.56	-0.55	0.09	0
NT-5	3/21/13	NA	NA		-0.48	-0.55	0.30	0
NT-3A	10/1/13	2.20	13.7		0.36	0	0.46	0
NT-5	10/1/13	-3.19	11.6		0.25	0.57	0.32	0

NA – not analyzed
pCi/L – picocurie per liter
Pending – Data not available from the Laboratory

This location is subject to the release criteria shown in Table 3 the surface water runoff enters Bear Creek. The initial location sample results of NT-3 is most likely related to the Bone-yard/Burn-yard site.

Contact Water Pond/Tank samples

A total of six samples were collected at the contact water ponds or contact water tanks. The samples were analyzed for gross alpha, gross beta, strontium-90, technetium-99, isotopic uranium, and tritium. In addition to the radionuclide analyses, one acute and chronic toxicity test was performed at CWT-C. The results showed that no acute or chronic toxicity was demonstrated with that sample. The radionuclide sample results are presented in Table 10. The results from the CWPs or CWTs are elevated in gross alpha, gross beta, strontium-90, technetium-99, uranium, and tritium compared to background. The disposition of the contact water was based on a more detailed sampling program. Contact water was either disposed of at the ORNL Process Waste Treatment Facility or was discharged to the sediment pond. The

release criteria for Uranium from the contact water is 480 pCi/L. All contact water pond samples met or were conditioned to meet the release criteria and were discharged to the sediment pond. The sediment pond discharge then follows the procedures discussed for EMWMF-3.

Table 10: Contact Water Pond Sample Results

Station ID	Date	Gross Alpha (pCi/L)*	Gross Beta (pCi/L)		Strontium-90 (pCi/L)	Technetium-99 (pCi/L)	Total Uranium (pCi/L)	Tritium (pCi/L)
CWP-1	1/8/13	198	25.2		1.64	14.24	47.66	140
CWP-3	2/21/13	44.9	43.2		0.67	6.43	46.31	833
CWP-3	2/27/13	52.6	38.2		1.06	6.72	45.22	835
CWP-4	4/25/13	91	22.8		1.79	7.92	75.22	420
CWP-4	7/8/13	26.6	26.6		3.58	5.42	22.83	300
CWT-D	8/13/13	22.9	52.7		2.00	7.04	18.50	298

NA – not analyzed
pCi/L – picocurie per liter
Pending – Data not available from the Laboratory

Conclusion

Groundwater review has shown a potential for groundwater levels to be above the geologic buffer along the northern and northeast portion of the disposal cells. Additional wells to refine the water elevation data for disposal cells one and two are needed but not recommended. Those two disposal cells are nearly full and any intrusive activities could compromise the integrity of the disposal cell liners. Near PP-02 the water level has risen throughout the year. Further monitoring is needed to see if this incursion is stable or increasing.

There still are problems with pH at the EMWMF-3. Continuous water quality parameters are important for documenting discharges, changing conditions, and monitoring releases at EMWMF-2 and EMWMF-3. Continuous monitoring does reveal conditions that require closer scrutiny and oversight and have brought changes, such as introducing algal remedies to reduce the pH at the V-Weir.

The results from the radiological water samples suggest that radionuclides are being discharged from EMWMF-3 and EMWMF-4. However, those discharges are within compliance under TDEC Rule 1200-2-11-.16. The results from radiological sediment samples suggest that radiological discharges from EMWMF-3 are not impacting the sediments of NT-5 and Bear Creek.

TDEC will continue to monitor sediments in the sediment basin to determine if levels of contaminants are increasing to numbers that could cause ecological risks. DOE will be notified of and potential concerns. TDEC and DOE contractors will continue to monitor the sampling and analysis methods used for Strontium-90. Quality Assurance/Quality Control merits additional scrutiny of elevated samples.

Based on reanalysis of suspect samples, at present there is not a concern with Strontium-90 levels at GW-918, GW-922 or the underdrain. Although initial analyses from 8/14/13 indicated elevated levels Strontium-90. These samples were analyzed a second time for confirmation purposes using a portion of the sample water held in reserve. The second (confirmatory) analyses did not show elevated levels of Strontium-90.

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Ambient Sediment Monitoring

Principle Author: John (Tab) Peryam

Abstract

Sediment samples from six Clinch River sites and one Poplar Creek site were analyzed for metals and radiological parameters. The mercury levels in the Clinch River sediment samples upstream of the mouth of Poplar Creek were less than the Consensus-based Sediment Quality Guidelines (CBSQGs) Probable Effects Concentration (PEC) of 1.06 mg/kg (MacDonald et al. 2000). The mercury values at these upstream sites range from 0.028 to .056 mg/kg. The two Clinch River sites downstream of the mouth of Poplar Creek were Clinch River Mile (CRM) 9.3 and CRM 11.2; these sites had mercury values of 0.98 mg/kg and 1.7 mg/kg, respectively. The CRM 11.2 mercury value, as well as that of Poplar Creek Mile (PCM) 1.2 (1.6 mg/kg) both exceed the mercury PEC of 1.06 mg/kg. Mercury was the only metal to exceed the PECs. Although Cesium-137 was detected in Clinch River sediment samples taken downstream of the mouth of White Oak Creek, the levels are low and do not pose a threat to human health.

Introduction

Sediment is an important part of aquatic ecosystems. Anthropogenic chemicals and waste materials introduced into aquatic systems often accumulate in sediments. Sediment is often a depository for contaminants such as metals, radionuclides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and agricultural chemicals. Concentrations of contaminants can be much higher in sediments than in the water column. Many aquatic organisms depend on sediment for habitat, sustenance, and reproduction. Some sediment contaminants may be directly toxic to benthic organisms or may bioaccumulate in the food chain, creating health risks for wildlife and humans. Sediment analysis is an important aspect of environmental quality and impact assessment for rivers, streams, and lakes.

Contaminants from past DOE activities on the ORR have made their way into several streams that feed into Poplar Creek and the Clinch River. The major pathways of concern are White Oak Creek (WOC) and East Fork Poplar Creek (EFPC). The major contaminants of concern from White Oak Creek are strontium-90 and cesium-137. East Fork Poplar Creek is contaminated with mercury from past activities at Y-12. In order to characterize and monitor the impact from these streams, The Tennessee Department of Environment and Conservation's DOE Oversight Office (TDEC DOE-O) sampled sediment in the Clinch River and Poplar Creek. Sediment samples were analyzed for metals and radiological parameters. TDEC/DOE-O conducted sediment monitoring at 7 sites in May, 2013 (see Table 1 and Figure 1). Six sites were on the Clinch River and one site was on Poplar Creek. Since there are no federal or state sediment cleanup levels, the metals data were compared to Consensus-based Sediment Quality Guidelines (CBSQGs) (MacDonald et al. 2000). Radiological data were compared to DOE's Preliminary Remediation Goals (PRGs) (DOE 2013). PRGs are upper concentration limits for specific chemicals in environmental media that are intended to protect human health. PRGs are often used at Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) sites for risk assessment (Efroymson et al. 1997).

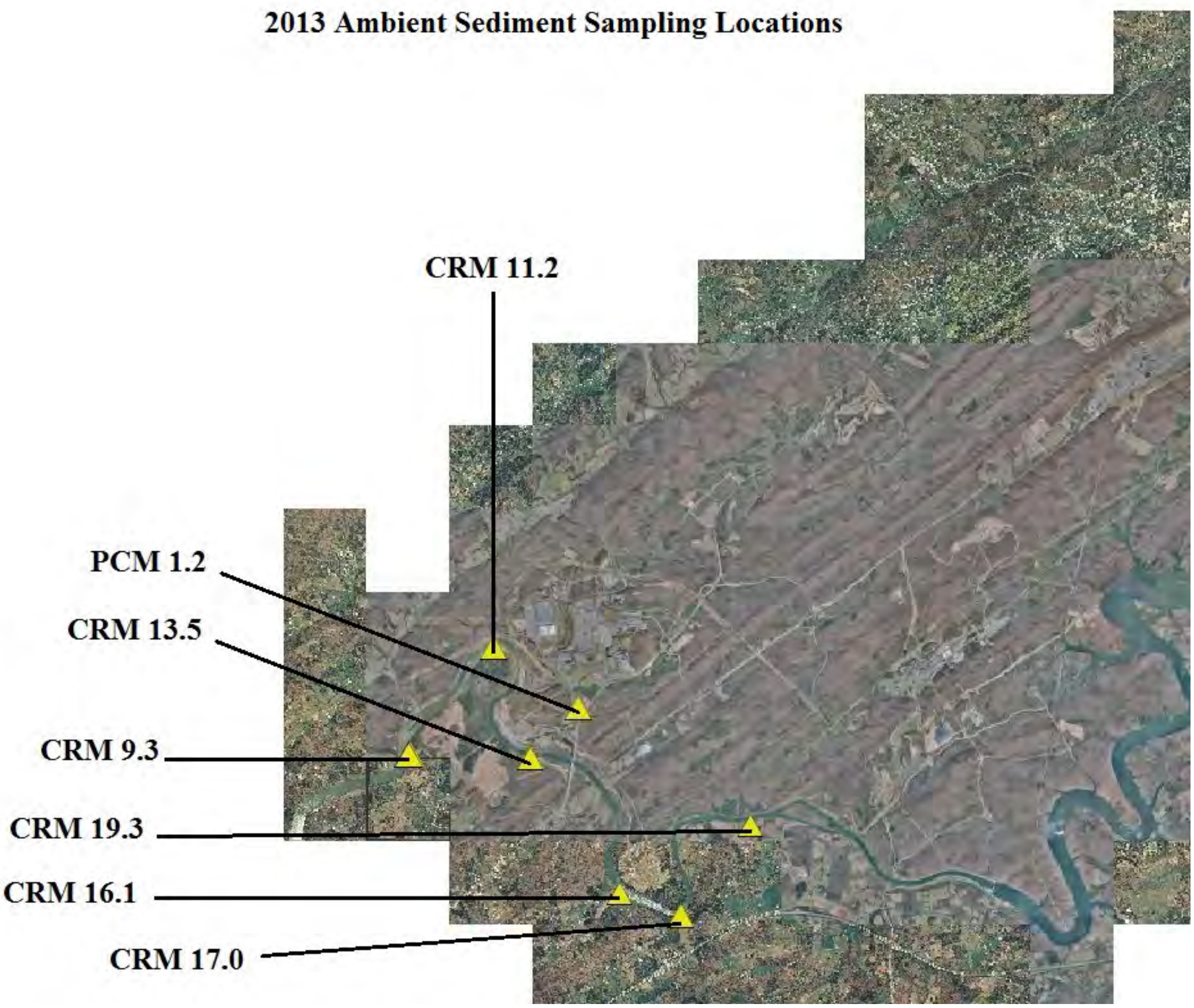

Figure 1: Sediment Sampling Sites

Methods and Materials

Sediment samples were taken during June using the methods described in the DOE-O Sediment Monitoring Standard Operating Procedure. Sediment samples were taken with a petite PONAR dredge. At least three grabs were taken at each site; the grabs were combined and containerized for transport to the analytical laboratory. Separate containers were used for metals, mercury and radiological samples. The Tennessee State Laboratories processed the samples, according to EPA-approved methods. Samples were analyzed for aluminum, arsenic, cadmium, chromium, copper, iron, lead, magnesium, manganese, mercury, nickel, and zinc. In addition, samples were analyzed for gross alpha, gross beta and gamma radionuclides.

Table 1: Sampling Sites

Sampling Location	DWR Designation	DOE-O Designation
Clinch River Mile 19.3	CLINC019.3RO	CRM 19.3
Clinch River Mile 17.0	CLINC017.0RO	CRM 17.0
Clinch River Mile 16.1	CLINC016.1RO	CRM 16.1
Clinch River Mile 13.5	CLINC013.5RO	CRM13.5
Clinch River Mile 11.2	CLINC011.2RO	CRM 11.2
Clinch River Mile 9.3	CLINC009.3RO	CRM 9.3
Poplar Creek Mile 1.2	POPLA001.2RO	PCM 1.2

CRM – Clinch River Mile
PCM – Poplar Creek Mile

Results and Discussion

Metals Analyses

The only metal found above the Probable Effects Concentration (PEC) was mercury (Table 2). The PECs are Consensus-Based Sediment Quality Guidelines (CBSQGs) that were established as concentrations of individual chemicals above which adverse effects in sediments are expected to frequently occur (Ingersoll et al. 2000). Adverse effects, in this case, refer to effects to benthic macroinvertebrate species only (WDNR 2003). The CBSQGs are considered to be protective of human health and wildlife except where bioaccumulative or carcinogenic organic chemicals, such as PCBs or methylmercury, are involved. In these cases other tools such as human health and ecological risk assessments, bioaccumulation-based guidelines, bioaccumulation studies, and tissue residue guidelines should be used in addition to the CBSQGs to assess direct toxicity and food chain effects (WDNR 2003). The threshold effects concentrations (TECs) are concentrations below which adverse effects are not expected to occur (Ingersoll *et al.* 2000). The Poplar Creek Mile 1.0 sediment mercury value (1.6 mg/kg) exceeds the PEC of 1.06 mg/kg (MacDonald *et al.* 2000). The mercury in Poplar Creek sediments results from historical activities at Y-12 and to a lesser extent ETTP. Figure 2 shows the effect of the Poplar Creek mercury contamination on the Clinch River sediments. The mouth of Poplar Creek is at approximately Clinch River mile (CRM) 12 and the sampling sites downstream show mercury contamination: Clinch River Mile (CRM) 11.2 (1.7 mg/kg), CRM 9.3 (0.98 mg/kg). The mercury value at CRM 11.2 exceeds the PEC. Figure 3, Metals in Sediment Grab Samples (2013), shows the data for the metals arsenic, chromium, copper, lead, nickel and zinc; all values for these metals are below their respective PECs.

Table 2: Summary of Metals Data

Parameter	Units	Mean	Std. Dev.	Median	Range	Minimum	Maximum	Count	EPA*	TEC**	PEC***
Aluminum	mg/kg	6500	1976.5	6100	5200	4000	9200	7			
Arsenic	mg/kg	2.9	1.1	3.3	2.7	1.5	4.2	7	9.8	9.79	33
Chromium	mg/kg	11.3	3.4	11	9.6	8.4	18	7	43.4	43.4	111
Copper	mg/kg	9.1	2.8	8.9	8.1	4.9	13	7	31.6	31.6	149
Iron	mg/kg	13429	4649.6	13000	14000	9000	23000	7			
Lead	mg/kg	13.6	3.6	13	9.8	9.2	19	7	35.8	35.8	128
Magnesium	mg/kg	1166	231.2	1200	730	770	1500	7			
Manganese	mg/kg	900	390.1	940	1090	310	1400	7			
Mercury	mg/kg	0.634	0.775	0.056	1.672	0.028	1.7	7	0.18	0.18	1.06
Nickel	mg/kg	10.6	2.3	10	6.5	7.5	14	7	22.7	22.7	48.6
Zinc	mg/kg	34	6.7	36	18	24	42	7	124	121	459

*USEPA. 2001. Supplemental Guidance to RAGS: Region 4 Bulletins, Ecological Risk Assessment. Originally published November 1995.
Website version last updated November 30, 2001: http://www.epa.gov/region4/waste/ots/ecolbul.htm

**Consensus Based Sediment Quality Criteria, Threshold Effects Concentration (McDonald *et al.* 2000)

***Consensus Based Sediment Quality Criteria, Probable Effects Concentration (McDonald *et al.* 2000)

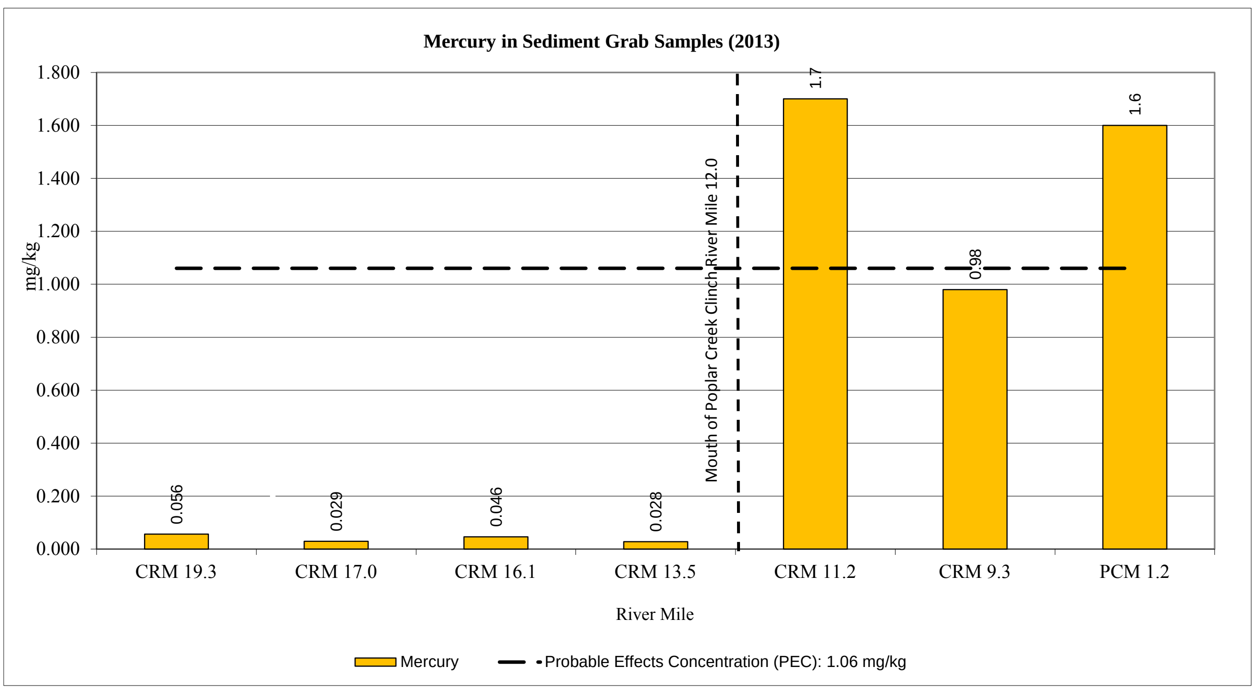

Figure 2: Mercury in Clinch River and Poplar Creek Sediment Grab Samples

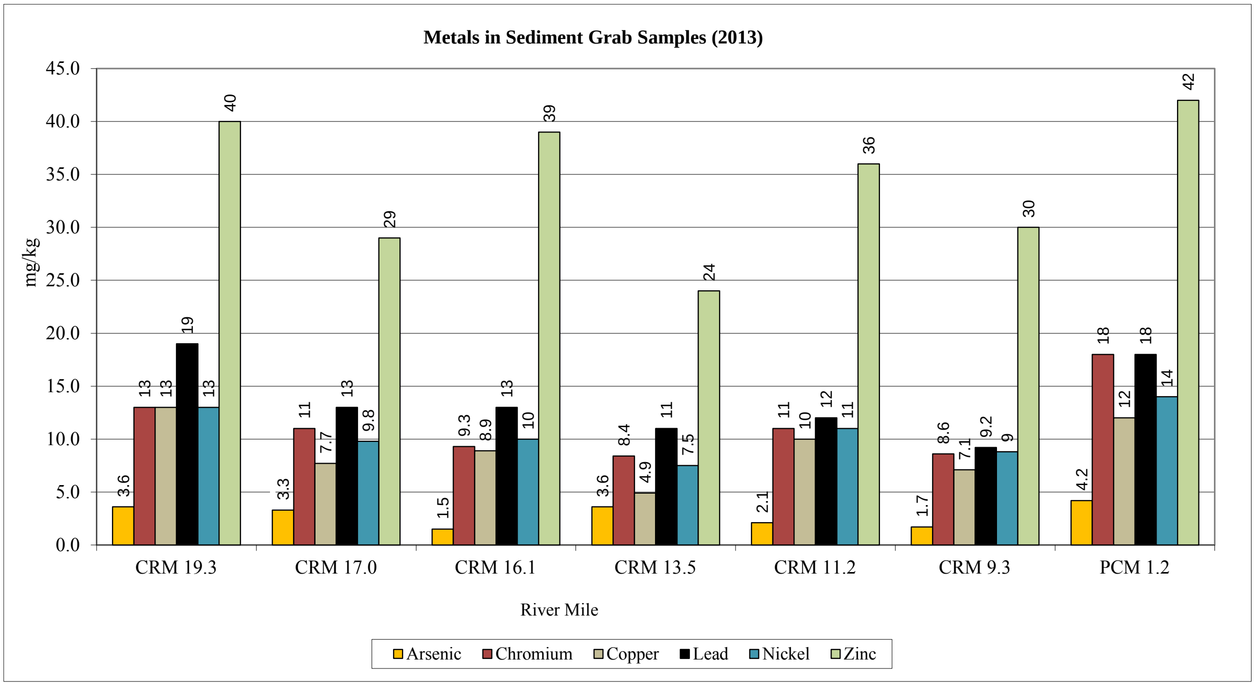

Figure 3: Metals in Sediment Grab Samples (2013)

Radiological Analyses

The radiological sediment data show no reason for human health concerns; all parameters are well below DOE PRGs. The recreational PRG for Cs-137 is 117 pCi/g (total soil/sediment TR 1.0E-06) (DOE 2013) while the highest Cs-137 value was 2.12 pCi/g at CRM 11.2. In 2013, Cesium-137 was detected in all of the Clinch River samples, but not in the Poplar Creek sample. Cesium-137 results for the Clinch River and Poplar Creek are shown in Figure 4. Cs-137 contamination of the Clinch River from White Oak Creek is indicated by the Cs-137 sample results for these sites which are downstream of the mouth of White Oak Creek (CRM 20.8).

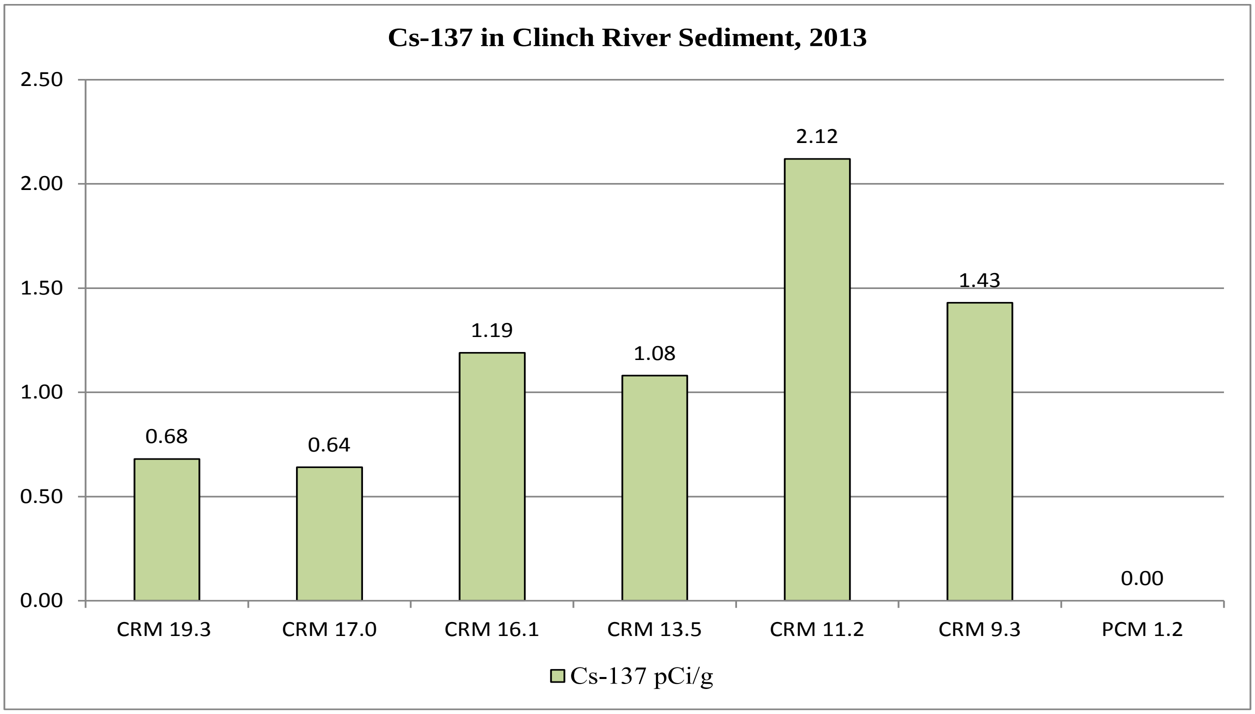

Figure 4: Cesium 137 in Clinch River and Poplar Creek Sediments

Conclusion

The mercury levels in the two Clinch River sediment samples taken downstream of the mouth of Poplar Creek were slightly elevated. The mercury levels at CRM 11.2 (1.7 mg/kg) and at Poplar Creek Mile 1.0 (1.6 mg/kg) both exceed the PEC (1.06 mg/kg). CRM 9.3 had a mercury value of 0.98 mg/kg. Mercury levels at the Clinch River sites upstream of the mouth of Poplar Creek were very low in comparison (see figure 2). Other metals in both Poplar Creek and the Clinch River samples were below their respective PECs.

Cs-137 is found in low concentrations in the sediment at Clinch River sites below the mouth of White Oak Creek. The levels are very low and do not pose a threat to recreation or human health. Cs-137 was not detected at Poplar Creek Mile 1.0. 2013 Sediment data show no levels of radiological contamination that exceed DOE Preliminary Remediation Goals (PRGs) for recreation and, based on these criteria, do not pose a threat to human health. If in the future, these sediments are to be used for agricultural or other purposes, analysis should be performed to determine the suitability for these new purposes.

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2013 Ambient Surface Water Monitoring

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Abstract

The division conducts semi-annual surface water sampling to detect possible contamination from Department of Energy (DOE) sites. Sampling is conducted at six sites on the Clinch River and four sites on tributaries of the Clinch River (McCoy Branch, Raccoon Creek, Grassy Creek, and Poplar Creek). Samples were analyzed for alpha, beta, and gamma emissions, ammonia, dissolved residue, NO^3 & NO^2 nitrogen, suspended residue, total hardness, total Kjeldahl nitrogen, total phosphate, arsenic, cadmium, copper, iron, lead, manganese, mercury, chromium, and zinc. Other than dissolved oxygen at Clinch River Mile (CRM) 78.7, the data were either non-detects or the values were within bounds of Tennessee Water Quality Criteria (TNWQC). Dissolved oxygen was measured at 4.82 mg/L on 10/08/2013 at Clinch River Mile (CRM) 78.7; this value is below the TNWQC of 6.0 mg/L (fish and aquatic life, trout stream). Factors that may have affected the low D.O. value were that the sampling location is upstream of the aerating weir dam and a short distance from Norris Dam where the discharge water comes from a great depth from Norris Lake. Strontium-90 specific analysis from the samples collected at Raccoon Creek showed 2.41 pCi/L in the second quarter and 1.42 pCi/L in the fourth quarter. These values are below the EPA strontium-90 MCL for drinking water of 8 pCi/L. Raccoon Creek is believed to be impacted by contaminated groundwater from SWSA 3; the primary radiological contaminant is strontium-90. Radiological data, other than the strontium-90 detection mentioned previously, show nothing of concern. Gross alpha and gross beta values were typical of background conditions.

Introduction

The ORR Clinch River tributaries of Raccoon Creek, Grassy Creek, Poplar Creek, and McCoy Branch drain into the Clinch River. The public municipalities and ORR nuclear processing industrial plants which are located in this area of the Clinch River are: the city of Norris, the city of Clinton, Knox County, the city of Oak Ridge, the Y-12 complex, the Oak Ridge National Laboratory (ORNL) (old X-10 complex), the East Tennessee Technology Park (ETTP) (old K-25 complex), and the city of Kingston. To obtain public drinking water and industrial plant processing water, all of these areas utilize the surface waters of the Clinch River. The division conducts semi-annual surface water sampling at six sites on the Clinch River and four tributary sites to detect possible contamination from ORR DOE facilities.

Sampling was conducted during May-June and October (see Figure 1 and Table 1 for the sampling locations). Samples were analyzed for alpha, beta, and gamma emissions, ammonia, dissolved residue, NO^3 & NO^2 nitrogen, suspended residue, total hardness, total Kjeldahl nitrogen, total phosphate, arsenic, cadmium, copper, iron, lead, manganese, mercury, chromium, and zinc. In addition, samples from Raccoon Creek were analyzed for strontium-90 and technetium-99. Contaminants in surface water samples are rarely detected. The data provide an ambient data set for evaluation of possible future contaminant discharges. Data are available from the Environmental Protection Agency's (EPA) WQX/STORET database online.

Methods and Materials

In the spring and fall of 2013, the Tennessee Department of Environment and Conservation, Department of Energy Oversight Office (TDEC DOE-Oversight), conducted surface water monitoring at six sites on the Clinch River and four Clinch River tributaries, McCoy Branch (MCM), Grassy Creek (GCM), Raccoon Creek (RCM), and Poplar Creek (PCM). The surface water samples were taken to the State of Tennessee Department of Health Laboratory (TDH) for nutrients, metals, and radionuclide analyses. YSI Professional Plus and YSI 556 multi-probe system field instruments were used to measure the parameters of pH, conductivity, dissolved oxygen, and temperature at each monitoring site. This surface water monitoring program followed both the WPC Quality System Standard Operating Procedure for Chemical and Bacteriological Sampling of Surface Water (TDEC 2011) and the WPC Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys (2011 TDEC). In addition, all work associated with this program was conducted in compliance with the office's 2013 Health, Safety, and Security Plan.

Table 1 lists the ten sampling locations and the samples collected during each sampling event, and Figures 1 and 2 show the sampling sites relative to the ORR map. Table 2 lists the analytical parameters of interest:

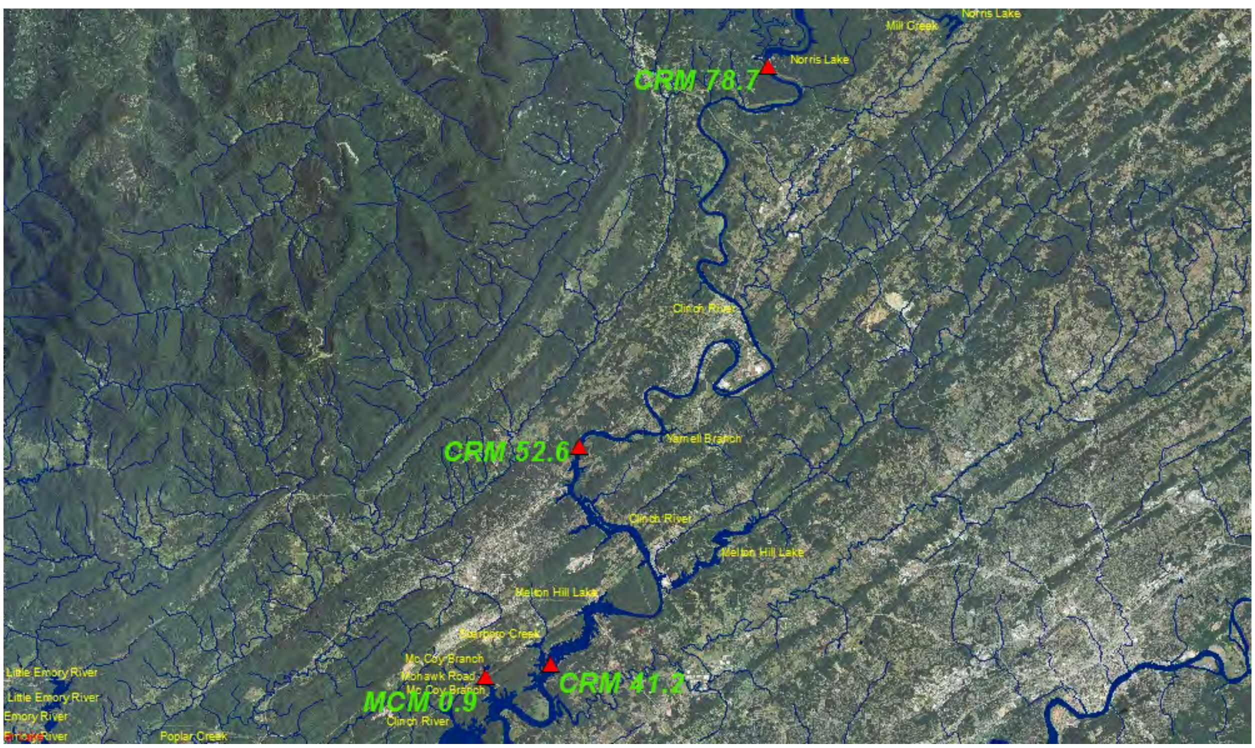

Figure 1: Surface Water Sampling Sites

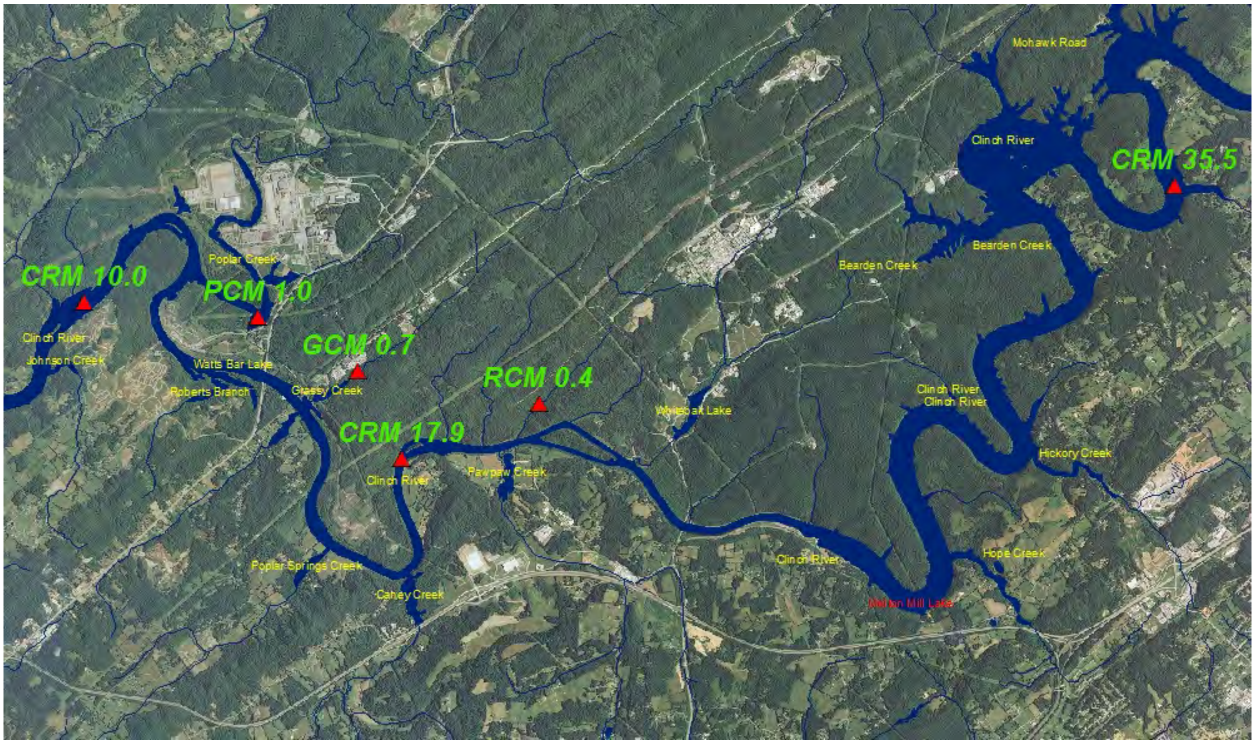

Figure 2: Surface Water Sampling Locations

Table 1: Sample Locations

Project Site #	Stream Location	DWR Site	Stream Mile	Clinch River Mile	Spring Event	Fall Event
1	Clinch River	CLINC078.7AN	CRM 78.7	78.7	X	X
2	Clinch River	CLINC052.6AN	CRM 52.6	52.6	X	X
3	Clinch River	CLINC035.5AN	CRM 35.5	35.5	X	X
4	Clinch River	CLINC017.9RO	CRM 17.9	17.9	X	X
5	Clinch River	CLINC010.0RO	CRM 10.0	10.0	X	X*
7	Clinch River	CLINC041.2AN	CRM 41.2	41.2	X	X
10	*McCoy Branch	MCCOY000.9AN	MCM 0.9	37.5	X	X
18	*Raccoon Creek	RACCO000.4RO	RCM 0.4	19.5	X	X
20	*Grassy Creek	GRASS000.7AN	GCM 0.7	14.6	X	X
33	*Poplar Creek	POPLA001.0RO	PCM 1.0	12.0	X	X

Project Site# = TDEC-DOE-Ovesight Office Project Site number.

Stream Location = Clinch River or one of its *tributaries.

DWR Site = Division of Water Resources site designation.

Stream Mile = Specific streams' mile.

Clinch River Mile = distance (miles) of stream location from the Clinch River/Tennessee River confluence.

X = Stream Location was sampled.

* = only rad data

Table 2: Test analyses, MDLs, Units, Methods

Test	MDL	Units	Method
Digestion Metals	n.a.	n.a.	USEPA 200.2
Specific conductivity	0.1	µS/cm	USEPA 120.1
Dissolved oxygen (DO)	0.01	mg/l	USEPA 360.1
pH	0.01	None	USEPA 150.1
Temperature, water	0.01	deg C	USEPA 170.1
Nitrogen, ammonia (NH3) as NH3	0.028	mg/l	USEPA 350.1
Hardness, carbonate	1	mg/l	USEPA 130.2
Nitrogen, Nitrite (NO2) + Nitrate (NO3) as N	0.016	mg/l	TDEC A.18.4
Dissolved Solids	10	mg/l	USEPA 160.1
Total Suspended Solids (TSS)	10	mg/l	USEPA 160.2
Nitrogen, Kjeldahl	0.14	mg/l	USEPA 351.2
Phosphate	0.0065	mg/l	TDEC A.18.9.1
Iron	varies	µg/l	USEPA 236.2
Manganese	varies	µg/l	USEPA 243.2
Zinc	varies	µg/l	USEPA 289.2
Arsenic	varies	µg/l	USEPA 206.2
Cadmium	varies	µg/l	USEPA 213.1
Chromium	varies	µg/l	USEPA 218.1
Copper	varies	µg/l	USEPA 220.1
Lead	varies	µg/l	USEPA 239.1
Mercury	varies	µg/l	USEPA 245.1

Results and Discussion

Chromium values were either non-detects or very low J values and do not present health or ecological concerns. A J value is an estimated value between the Minimum Detection Limit (MDL) and the Method Quantification Limit (MQL). Lead results were either non-detects with the exception of one sample at Grassy Creek mile 0.7. The result from this analysis showed lead at 1.4µg/L, which is well below the Tennessee Water Quality Criteria (TNWQC) of 65 µg/L for Fish and Aquatic Life. Cadmium was not detected at any of the sites. Copper and zinc were detected at very low concentrations at several sites; the values were well below Tennessee Water Quality Criteria (TNWQC). The spring mercury figure for Poplar Creek Mile (PCM) 1.0 was 0.044J µg/L; this value is less than the TNWQC (0.051 µg/L, recreation, organisms only). Mercury contamination of Poplar Creek is a recognized problem. East Fork Poplar Creek is impacted by mercury from Y-12 and is a tributary of Poplar Creek. PCM 1.0 is located downstream of the mouth of East Fork Poplar Creek.

McCoy Branch continues to show some effects of the Filled Coal Ash Pond (FCAP) upstream; arsenic values were 3.0J µg/L and 3.6J µg/L for 2013. These figures for McCoy Branch are below the TNWQC of 10 µg/L (recreation, organisms only). Summarized metals and nutrient data are shown in Table 3. Dissolved oxygen was measured at 4.82 mg/L on 10/08/2013 at Clinch River Mile (CRM) 78.7; this value is below the TNWQC of 6.0 mg/L (fish and aquatic life, trout stream). This sampling location is just a short distance from Norris Dam and the water coming from the dam is from a great depth and is low in dissolved oxygen. In 1984, TVA installed auto venting turbines to provide for more aeration and at about the same time they built an aerating weir dam one mile below Norris Dam. Factors that affected the low D.O. value may

have been that the sampling location is above the aerating weir dam and at the time the D.O. measurement was taken the dam was not generating.

Raccoon Creek is believed to be impacted by contaminated groundwater from SWSA 3; the primary radiological contaminant is strontium-90. Strontium-90 specific analysis from the samples collected at Raccoon Creek showed 2.41 pCi/L in the second quarter and 1.42 pCi/L in the fourth quarter. These values are below the EPA strontium-90 MCL for drinking water of 8 pCi/L. Radiological data, other than the strontium-90 detection mentioned previously, show nothing of concern. Gross alpha and gross beta values were typical of background conditions. Radiological data are shown in Table 4.

Table 3: 2013 Surface Water Data Summary (non-radiological)

Parameter	Units	Minimum	Maximum	Mean	Median	Standard Deviation	Count	TWQC*
ammonia	mg/L	0	0.120	0.0308	0	0.0396	19	n.a.
dissolved oxygen	mg/L	4.82	13.70	8.763	8.76	1.903	19	5.0[a]
dissolved residue	mg/L	124	260	165.6	150	30.1	19	500[b]
NO_3 & NO_2	mg/L	0	2.5	0.46	0.38	0.53	19	n.a.
pH		7.21	8.17	7.702	7.655	0.268	18	5.5-9[a]
specific conductivity	µs/cm	193	448.9	292.1	289.6	56.0	19	n.a.
suspended residue	mg/L	0	18	2.5	0	5.3	19	n.a.
total hardness	mg/L	100	240	142.6	140	31.1	19	n.a.
total Kjeldahl nitrogen	mg/L	0	0.22	0.038	0	0.077	19	n.a.
total phosphate	mg/L	0	0.057	0.0153	0.015	0.0177	19	n.a.
arsenic	µg/L	0	3.6	0.35	0	1.05	19	10[c]
cadmium	µg/L	0	0	0	0	0	19	2.0[d]
chromium	µg/L	0	1.5	0.15	0	0.44	19	16[e]
copper	µg/L	0	4.2	0.49	0	0.97	19	13[d]
iron	µg/L	33	560	157.1	110	146.1	19	n.a.
lead	µg/L	0	1.4	0.07	0	0.32	19	5[f]/65[a]
manganese	µg/L	6.7	360	60.8	37	81.8	19	n.a.
mercury	µg/L	0	0.044	0.0023	0	0.0101	19	0.051[c]
zinc	µg/L	0	8.3	1.74	0	2.31	19	120[d]

*Tennessee Water Quality Criteria:

[a] Fish and Aquatic Life (FAL), applies to all sites

[b] Industrial Water Supply, applies only to Clinch River Sites

[c] Recreation (organisms only), applies to all sites

[d] Fish and Aquatic Life (FAL), applies to all sites. This value is for total hardness of 100mg/L

[e] FAL (Chromium VI)

[f] This value is for Domestic Water Supply, which applies only to Clinch River Sites.

Table 4: 2013 Radiological Surface Water Data Summary

Parameter	Mean	Minimum	Maximum	Median	Standard Deviation	Range	Count	EPA[1]
Strontium-90*	1.915	1.42	2.41	1.915	0.700	0.99	2	8
Technetium-99*	0.075	-0.55	0.7	0.075	0.88	1.25	2	900
Radioactivity, alpha	0.4315	-0.23	2.55	0	0.987	2.78	20	n.a.
Radioactivity, beta	1.98	-0.3	5.6	1.85	2.20	5.9	20	n.a.

Units are pCi/L

[1]EPA Maximum Contaminant Level for drinking water

*Detected only at Raccoon Creek

Conclusion

In 2013, there was only one case in which TNWQC were not met: dissolved oxygen at Clinch River Mile 78.7. Dissolved oxygen was measured at 4.82 mg/L on 10/8/2013 at Clinch River Mile (CRM) 78.7; this value is below the TNWQC of 6.0 mg/L (fish and aquatic life, trout stream). This sampling location is just a short distance from Norris Dam and the water discharged from the dam comes from a great depth and is low in dissolved oxygen. Factors that affected the low D.O. value may have been that the sampling location is upstream of the aerating weir dam and at the time the measurement was taken the dam was not generating. All other metals, nutrients, and physical parameter measurements were within acceptable limits of the TNWQC.

Raccoon Creek is believed to be impacted by contaminated groundwater from SWSA 3; the primary radiological contaminant is strontium-90. Strontium-90 specific analysis from the samples collected at Raccoon Creek showed 2.41 pCi/L in the second quarter and 1.42 pCi/L in the fourth quarter. These values are below the EPA strontium-90 MCL for drinking water of 8 pCi/L. Radiological data, other than the strontium-90 detection mentioned previously, show nothing of concern. Gross alpha and gross beta values were typical of background conditions.

References

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Quality System Standard Operating Procedure for Macroinvertebrate Stream Surveys. Tennessee Department of Environment and Conservation, Division of Water Pollution Control. Nashville, Tennessee. 2011.

State of Tennessee Water Quality Standards, Rules of the Department of Environment and Conservation, Use Classifications for Surface Waters, Chapter 1200-4-3 General Water Quality Criteria, Chapter 1200-4-4. Bureau of Environment, Division of Water Pollution Control, Tennessee Department of Environment and Conservation. Nashville, TN. 2008.

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Surface Water (Physical Parameters) Monitoring

Principal Author: John (Tab) Peryam and Wesley White

Abstract

Due to the presence of areas of extensive anthropogenic point and non-point source contamination on the Oak Ridge Reservation (ORR), there exists the potential for this pollution to impact surface waters on the ORR as well as offsite aquatic systems. The local karst topography and related structural geology influences the fate and transport of contaminants that may further degrade the groundwater and surface water quality of aquatic systems adjacent to the ORR. Therefore, during 2013, the Tennessee Department of Environment and Conservation, Department of Energy Oversight Office (TDEC DOE-O, or office), collected ambient water quality data at six ORR stream locations and one offsite reference stream location. In addition, Upper East Fork Poplar Creek (UEFPC) was instrumented with continuous water quality data logger to observe water quality data and to determine if water quality parameters are impacted during fish kills. One fish kill was reported along UEFPC, but the source of the fish kill discharged just downgradient from the continuous monitoring location.

Introduction

Two separate tasks are covered with the surface water physical parameter monitoring program. The tasks include the 1) planned ambient surface water physical monitoring 2) a special project see if water quality parameters could be identified during reported fish kills.

Ambient Surface Water Physical Monitoring

The first task was to collect ambient, real time water quality monitoring data at seven stream sites located in several watersheds during 2013. The main ORR watersheds include portions of East Fork Poplar Creek, Bear Creek, and Mitchell Branch. Field data was also collected from Mill Branch, a small reference stream located in the City of Oak Ridge. The EFK (East Fork Poplar Creek) 13.8 km monitoring site is located outside the ORR. Specifically, it is located approximately ten km downstream of the Y-12 National Security Complex. The project objectives were to create a baseline of water quality monitoring data, physical stream parameters, which were measured on a monthly basis, and to determine possible water quality impairment issues. Furthermore, this monitoring task was directed toward determining long-term water quality trends, assessing attainment of water quality standards and providing background data for evaluating stream recovery due to toxicity stressors. Table 1 and Figure 1 show locations that were selected for data collection. Figure 2 shows TDEC staff conducting monitoring on the ORR.

Table 1: Sample Locations in Kilometers (mile equivalents)

Site	Location
EFK 23.4 (14.5)	East Fork Poplar Creek (Station 17)
BCK 12.3 (7.6)	Bear Creek (near Y-12 west guard entrance)
BCK 9.0 (6.0)	Bear Creek (near Walk-in Pits)
BCK 4.5 (2.8)	Bear Creek (Weir at Hwy. 95)
MIK 0.1 (0.06)	Mitchell Branch (Weir at ETTP)
EFK 13.8 (8.6)	East Fork Poplar Creek (near Big Turtle Park)
MBK 1.6 (1.0)	Mill Branch (Reference)

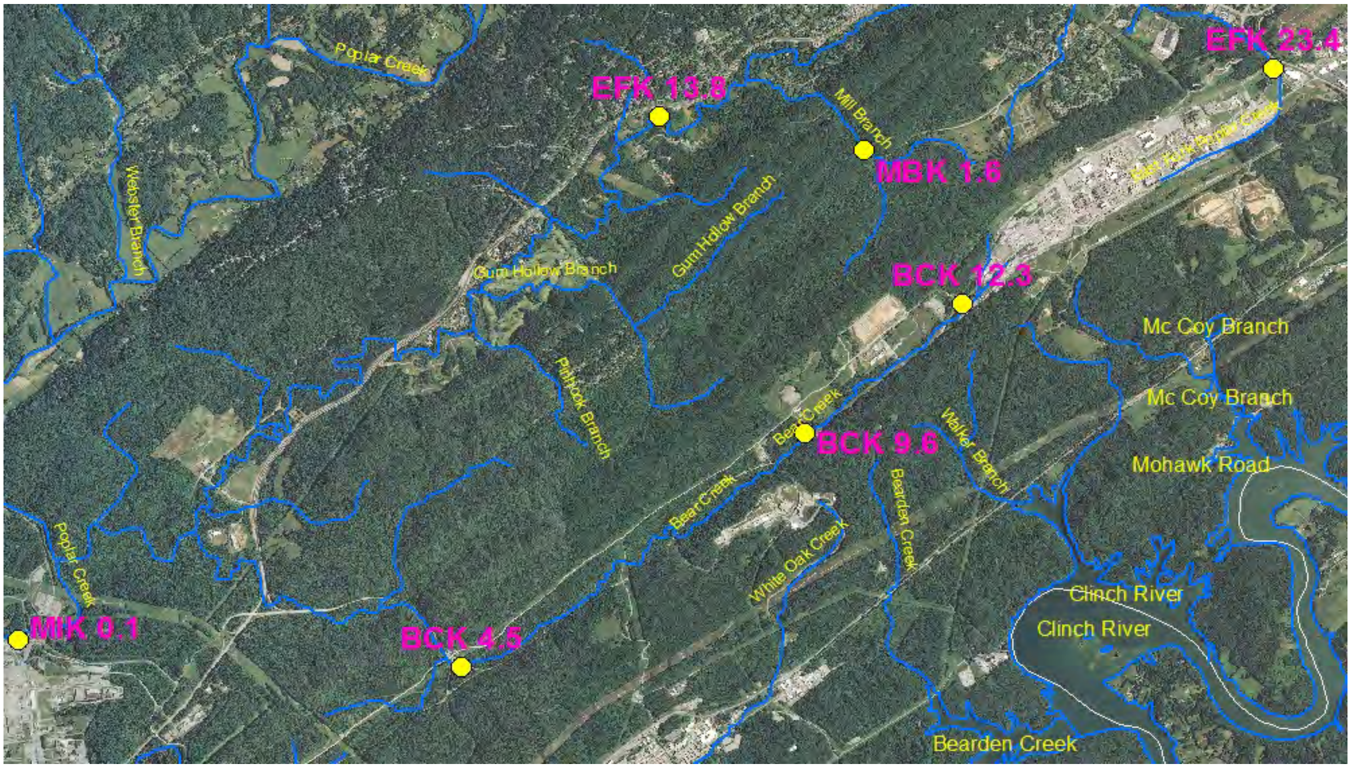


Figure 1: Oak Ridge Reservation Physical Parameter Monitoring Locations

Upper East Fork Poplar Creek Monitoring

The second task was a special project for continuous monitoring of the Upper East Fork Poplar Creek (UEFPC).This task was to observe water quality conditions and to identify changing conditions during fish kills.

Figure 3: Upper East Fork Poplar Creek Continuous Monitoring Location

Methods and Materials

Ambient Surface Water Physical Monitoring

The measured parameters were temperature, pH, conductivity, and dissolved oxygen. Both YSI 556 MPS and YSI Professional Plus field multi-parameter water quality instruments were used to collect the data. The instruments were calibrated prior to operation in the field. During each stream examination, the data was recorded in a field notebook including time, date and weather conditions. One team member recorded the instrument readings and other field notes, while the other person operated the instrument. Unusual occurrences relating to stream conditions were duly noted.

In case field readings such as pH and conductivity were beyond benchmark ranges, then the following actions were taken: 1) wait 24 hours, re-calibrate the instrument, and collect new physical parameter readings; 2) if readings are still deviant, investigate possible causes (e.g., defective equipment, storm surge/rain events, releases that may have affected pH, etc.); 3) following the investigation, report findings to appropriate program(s) within the office to determine if further action is needed. Field and monitoring methods, and health and safety procedures were followed per the Tennessee Department of Health's Standard Operating Procedures (TDH 1999), and the TDEC DOE-O Health, Safety, and Security Plan (Yard 2011).

Upper East Fork Poplar Creek Monitoring

Continuous water quality parameters were recorded at stilling well at the Third Street Bridge on Y-12 along UEFPC. Water quality parameters were collected utilizing an In-Situ® Troll 9500 multiparameter water quality monitoring probe. An YSI-556/YSI Professional Plus was used periodically to check the performance of the In-Situ® Troll 9500.

Results and Discussion

Ambient Surface Water Physical Monitoring

Field data was collected on a monthly basis from the seven monitoring sites. The 2013 monthly monitoring dates were January 9th, February 15th, March 12th, April 12th, May 3rd, June 6th, July 10th, August 9th, September 20th, October 11th, November 14th, and December 19th. Within Tables 2 thru 5, one can find the summarized 2013 temperature, pH, conductivity, and dissolved oxygen data. In addition, Figures 4 thru 7 provide monthly temperature, pH, conductivity, and dissolved oxygen data.

Table 2: Summary of 2013 Temperature Data

Site	Units	Mean	Minimum	Maximum	Standard Deviation	Range	Count	TWQC*
EFK 23.4	°C	15.67	10.74	20.6	3.41	9.86	12	<= 30.5[a]
BCK 12.3	°C	13.36	5.7	21.6	5.61	15.9	12	<= 30.5[a]
BCK 9.6	°C	12.81	5.3	19.4	5.31	14.1	12	<= 30.5[a]
BCK 4.5	°C	12.91	5.4	20.8	5.43	15.4	12	<= 30.5[a]
MIK 0.1	°C	14.64	9.2	19.7	4.07	10.5	12	<= 30.5[a]
EFK 13.8	°C	14.47	6.9	21.5	5.45	14.6	12	<= 30.5[a]
MBK 1.6	°C	12.79	5.9	18.77	4.59	12.87	12	<= 30.5[a]

*Tennessee Water Quality Criteria:

[a] Fish and Aquatic Life (FAL), applies to all sites.

Table 3: Summary of 2013 pH Data

Site	Units	Mean	Minimum	Maximum	Standard Deviation	Range	Count	TWQC*
EFK 23.4	none	7.75	7.11	8.1	0.300	0.99	12	between 6-9[a]
BCK 12.3	none	7.36	6.83	7.76	0.327	0.93	12	between 6-9[a]
BCK 9.6	none	7.71	7.06	8.04	0.291	0.98	12	between 6-9[a]
BCK 4.5	none	7.59	6.75	7.84	0.302	1.09	12	between 6-9[a]
MIK 0.1	none	7.54	7.31	7.72	0.148	0.41	12	between 6-9[a]
EFK 13.8	none	7.84	7.46	8.22	0.201	0.76	12	between 6-9[a]
MBK 1.6	none	7.60	7.01	8.03	0.287	1.02	12	between 6-9[a]

*Tennessee Water Quality Criteria:

[a] Fish and Aquatic Life (FAL), applies to all sites.

Table 4: Summary of 2013 Conductivity Data

Site	Units	Mean	Minimum	Maximum	Standard Deviation	Range	Count	TWQC*
EFK 23.4	uS/cm	358.3	326	402	27.15	76	12	n.a.
BCK 12.3	uS/cm	935.5	369	1511	389.39	1142	12	n.a.
BCK 9.6	uS/cm	516.6	203	742.4	175.66	539.4	12	n.a.
BCK 4.5	uS/cm	323.5	143	435	90.52	292	12	n.a.
MIK 0.1	uS/cm	382.6	232	473	62.97	241	12	n.a.
EFK 13.8	uS/cm	330.1	181	389.1	55.64	208.1	12	n.a.
MBK 1.6	uS/cm	213	87	294	64.83	207	12	n.a.

*Tennessee Water Quality Criteria:

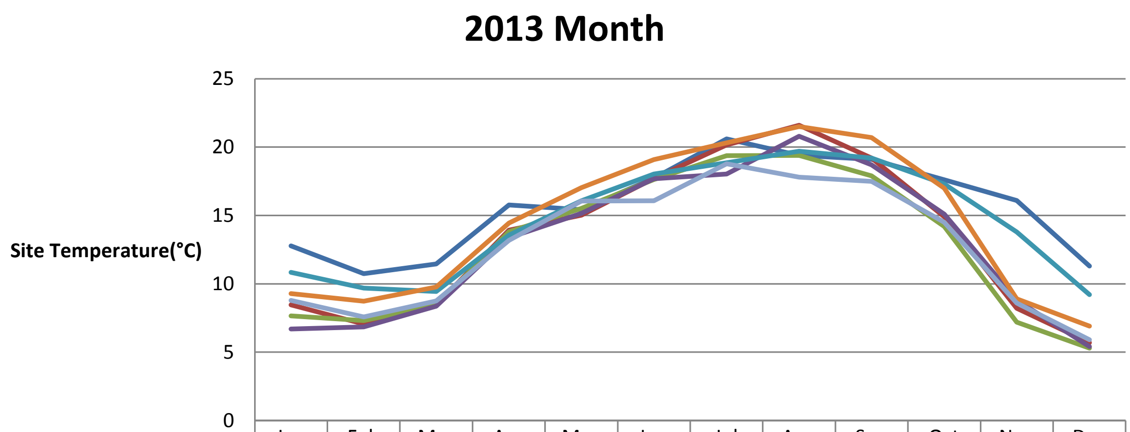
n.a. = Not applicable.

Table 5: Summary of 2013 Dissolved Oxygen Data

Site	Units	Mean	Minimum	Maximum	Standard Deviation	Range	Count	TWQC*
EFK 23.4	mg/L	9.92	8.67	11.72	1.036	3.05	12	> 5.0[a]
BCK 12.3	mg/L	9.62	7.14	12.66	1.822	5.52	12	> 5.0[a]
BCK 9.6	mg/L	10.00	7.04	12.99	1.949	5.95	12	> 5.0[a]
BCK 4.5	mg/L	9.27	5.72	12.75	2.303	7.03	12	> 5.0[a]
MIK 0.1	mg/L	8.23	5.34	11.8	1.951	6.46	12	> 5.0[a]
EFK 13.8	mg/L	9.85	7.05	12.26	1.669	5.21	12	> 5.0[a]
MBK 1.6	mg/L	10.04	8.16	12.71	1.531	4.55	12	> 5.0[a]

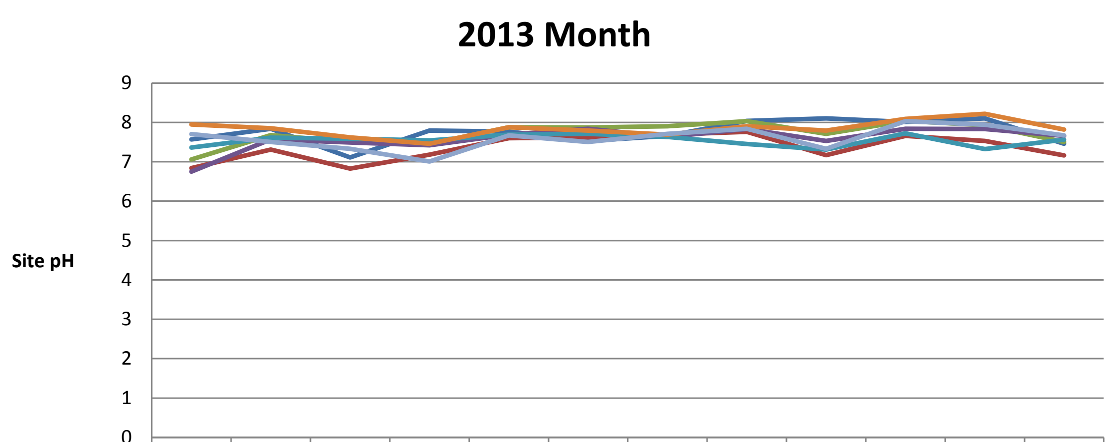
*Tennessee Water Quality Criteria:

[a] Fish and Aquatic Life (FAL), applies to all sites.



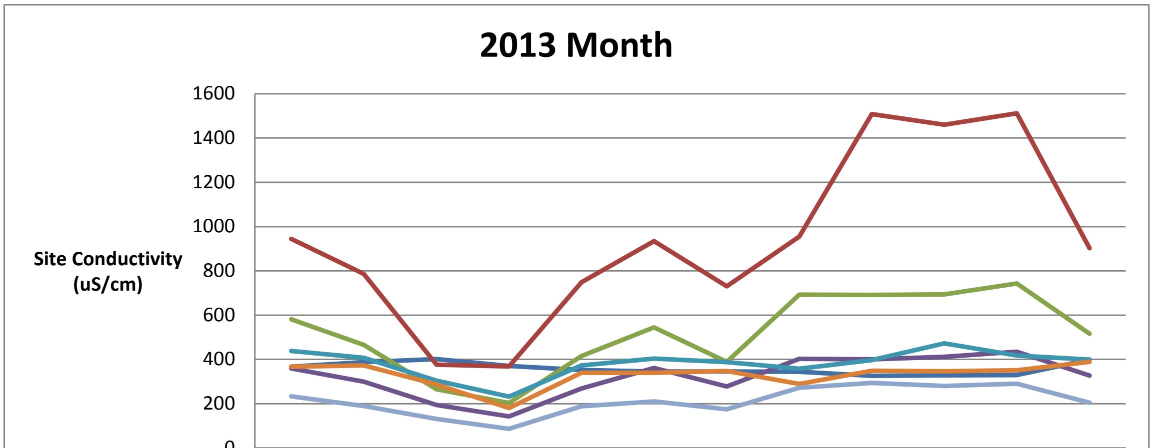
	Jan 1/9/13	Feb 2/15/13	Mar 3/12/13	Apr 4/12/13	May 5/3/13	Jun 6/6/13	Jul 7/10/13	Aug 8/9/13	Sep 9/20/13	Oct 10/11/13	Nov 11/14/13	Dec 12/19/13
EFK 23.4	12.78	10.74	11.45	15.77	15.42	17.73	20.6	19.4	19.1	17.6	16.1	11.3
BCK 12.3	8.45	7.05	8.44	13.93	15.02	17.71	20.15	21.6	19.2	14.9	8.2	5.7
BCK 9.6	7.66	7.31	8.43	13.82	15.51	17.63	19.37	19.4	17.9	14.2	7.2	5.3
BCK 4.5	6.69	6.84	8.37	13.36	15.16	17.69	18.03	20.8	18.7	15.1	8.8	5.4
MIK 0.1	10.83	9.68	9.43	13.56	16.07	18.03	18.86	19.7	19.2	17.3	13.8	9.2
EFK 13.8	9.29	8.72	9.77	14.45	17.04	19.08	20.31	21.5	20.7	17	8.9	6.9
MBK 1.6	8.79	7.57	8.74	13.17	16.05	16.08	18.77	17.8	17.5	14.5	8.6	5.9

Figure 4: 2013 Monthly Site Temperature



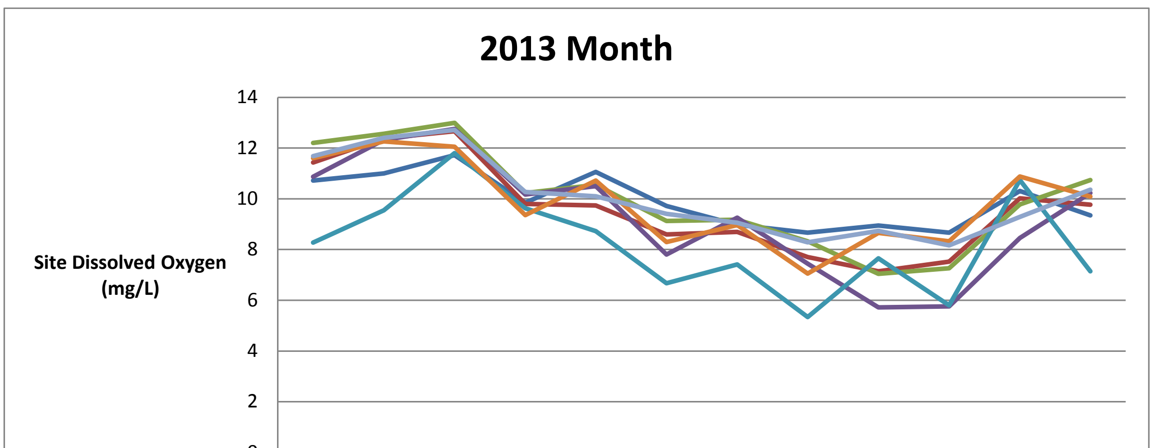
	Jan 1/9/13	Feb 2/15/13	Mar 3/12/13	Apr 4/12/13	May 5/3/13	Jun 6/6/13	Jul 7/10/13	Aug 8/9/13	Sep 9/20/13	Oct 10/11/13	Nov 11/14/13	Dec 12/19/13
EFK 23.4	7.57	7.84	7.11	7.79	7.77	7.53	7.66	8.04	8.1	8.01	8.1	7.46
BCK 12.3	6.84	7.31	6.83	7.18	7.6	7.62	7.69	7.76	7.17	7.66	7.53	7.16
BCK 9.6	7.06	7.68	7.5	7.45	7.88	7.87	7.9	8.03	7.71	8.04	7.93	7.5
BCK 4.5	6.75	7.57	7.49	7.42	7.69	7.84	7.63	7.83	7.53	7.84	7.83	7.66
MIK 0.1	7.36	7.61	7.59	7.54	7.69	7.71	7.63	7.45	7.31	7.72	7.32	7.56
EFK 13.8	7.95	7.85	7.62	7.46	7.88	7.79	7.69	7.9	7.79	8.09	8.22	7.82
MBK 1.6	7.7	7.5	7.33	7.01	7.67	7.5	7.71	7.84	7.33	8.03	7.94	7.67

Figure 5: 2013 Monthly Site pH



	Jan 1/9/13	Feb 2/15/13	Mar 3/12/13	Apr 4/12/13	May 5/3/13	Jun 6/6/13	Jul 7/10/13	Aug 8/9/13	Sep 9/20/13	Oct 10/11/13	Nov 11/14/13	Dec 12/19/13
EFK 23.4	367	388	402	371	353	345	346	344	326	328	329.5	399.9
BCK 12.3	945	786	377	369	749	934	730	955	1508	1460	1511	902
BCK 9.6	581	466	265	203	415	545	389	692	691	694	742.4	515.8
BCK 4.5	359	300	194	143	269	362	278	403	400	412	435	327.2
MIK 0.1	438	407	304	232	373	404	388	358	397	473	418	399.1
EFK 13.8	367	373	287	181	340	340	348	289	349	347	350.8	389.1
MBK 1.6	233	190	131	87	189	210	175	272	294	280	290.9	204.5

Figure 6: 2013 Monthly Site Conductivity



	Jan 1/9/13	Feb 2/15/13	Mar 3/12/13	Apr 4/12/13	May 5/3/13	Jun 6/6/13	Jul 7/10/13	Aug 8/9/13	Sep 9/20/13	Oct 10/11/13	Nov 11/14/13	Dec 12/19/13
EFK 23.4	10.72	11	11.72	9.85	11.06	9.72	8.98	8.67	8.95	8.67	10.31	9.35
BCK 12.3	11.43	12.38	12.66	9.8	9.74	8.6	8.7	7.7	7.14	7.52	10.02	9.77
BCK 9.6	12.2	12.56	12.99	10.23	10.55	9.13	9.18	8.32	7.04	7.26	9.78	10.74
BCK 4.5	10.87	12.32	12.75	10.17	10.5	7.8	9.26	7.44	5.72	5.76	8.45	10.23
MIK 0.1	8.27	9.55	11.8	9.63	8.73	6.67	7.41	5.34	7.65	5.8	10.74	7.14
EFK 13.8	11.6	12.26	12.05	9.36	10.72	8.29	8.97	7.05	8.66	8.32	10.88	10.09
MBK 1.6	11.68	12.4	12.71	10.27	10.1	9.41	9.06	8.28	8.74	8.16	9.29	10.36

Figure 7: 2013 Monthly Site Dissolved Oxygen

Sites BCK 12.3, BCK 9.0, and BCK 4.5 (all in Bear Creek) continue to consistently exhibit elevated conductivity values. There is no Tennessee General Water Quality Criteria for Fish and Aquatic Life Criterion Maximum Concentration for conductivity. Elevated conductivity levels indicate elevated nutrient levels which suggest degraded surface water quality in Bear Creek. All three Bear Creek sites are located downstream and to the west of the legacy capped S-3 nitric acid holding ponds and the Y-12 West End water treatment facility. The S-3 capped ponds are very close to the headwaters of Bear Creek. Site BCK 12.3 is the closest site to the headwaters of Bear Creek and is located within the western area of the Y-12 complex, site BCK 9.0 is located approximately 1 mile to the west of BCK 12.3, and site BCK 4.5 is located approximately two miles to the west of site BCK 12.3. One observes the elevated conductivity values to decrease as one travels further downstream and to the west of site BCK 12.3. A continuous data logger could be employed at this location to help determine the cause of the observed conductivity values.

Upper East Fork Poplar Creek Monitoring

Upper East Fork Poplar Creek (UEFPC) was instrumented with continuous water quality data logger to observe water quality data and to determine if water quality parameters are impacted during fish kills. One fish kill was reported along UEFPC, but the source of the fish kill discharged just downgradient from the continuous monitoring location.

The parameters monitored with the In-Situ® multiparameter water quality data logger were temperature, pH, DO, specific conductivity, and ORP. The data for this location is presented in Figure 8. To complement the water quality parameter graphs, a precipitation graph was created from the ORNL precipitation data from the meteorological station at Y-12 PSS. The meteorological data was collected approximately 1000 feet west from Third Street Bridge and UEFPC. There are data gaps associated with DO, which are due to the DO sensor malfunctioning.

<u>Temperature:</u>

There is a diurnal cycle (a regular 24 hour daily cycle) with the data. There is a gentle temperature increase beginning from March to mid September. In September the temperature is slightly decreasing. This gentle temperature change is expected and is seasonal. In addition to the seasonal and daily changes, temperature shifts were observed when the augmentation water was off. This shift is due to the near constant temperature of the groundwater.

<u>pH:</u>

The pH data has a diurnal cycle. pH ranged from 7.3 to 8.7, with an average of 7.8 standard units. There is a shift down that happened right when the augmentation was shut off beginning April 4. However, the shift back happens back in July. This shift looks as if it might be uncorrected drift, however, the instrument was not serviced at the shift dates and therefore the reason for this shift is unknown. The only noted peaks with the pH data were associated with a sizeable precipitation event.

<u>Dissolved Oxygen (DO):</u>

Dissolved oxygen has a diurnal cycle and it varies inversely with temperature. As the temperature decreases, more oxygen can be dissolved in the water. Groundwater typically has

low DO values and when the augmentation water was off in April there is a shift, however, that could be associated with the temperature increase.

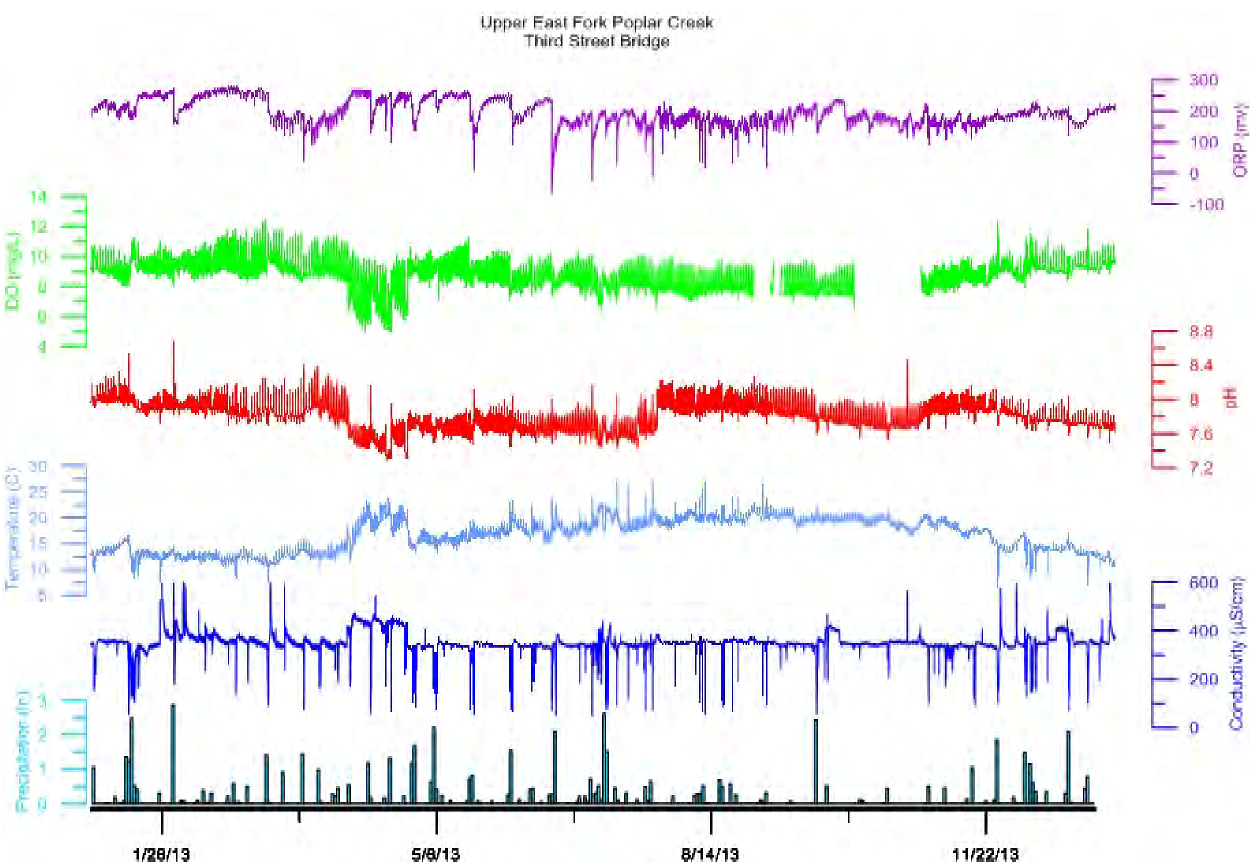
Specific Conductivity:

Specific conductivity of the augmentation water is fairly consistent. Shifts closer to 400 mircroSiemens per centimeter are indications that the augmentation water is off, and the conductivity values are closely related to groundwater conductivity. Augmentation water was off from April 4 through April 25, September 24 through September 29, and December 17 through December 21. There were several spikes in the data that were cropped in Figure 12 in order to show the effect of augmentation water has on conductivity. The reason for these high conductivity values are associated with salting of the roads during freezing conditions and surface water run-off from that activity.

Oxidation Reduction Potential (ORP):

The oxidation reduction potential values were normalized this year to the verification instrument. Last year we did not do that, but we did see that the data could be comparable. Lower ORP values occur during rain events and there are recessional curves associated with the rain events.

Currently, the office will continue to monitor to see if water quality parameters are impacted during fish kills or discharges.



C –Centigrade; **mg/L** – milligrams per liter; **mv** - millivolts; **µS/cm** –microSiemens per centimeter; *in – inches.*

Figure 8: Water Quality Parameters (temperature, pH, DO, specific conductivity, ORP) and Precipitation at Upper East Fork Poplar Creek and Third Street Bridge

Conclusion

The surface water physical parameters data met the Tennessee water quality criteria for the parameters observed at the seven monitoring stations on the ORR. The elevated conductivity values observed in Bear Creek are of concern. The upper Bear Creek location may be a candidate for continuous monitoring to see how conductivity behaves thorough out the year. As legacy DOE ORR pollution has negatively impacted East Fork Poplar Creek, Bear Creek, and Mitchell Branch, continued physical parameter monitoring is justified and needed at the seven monitoring creek stations.

Along UEFPC, continuous monitoring of the physical parameters revealed the effects that augmentation water have on the stream. The office continues to monitor the stream to determine if fish kills or other discharges at Y-12 can be identified with continuous monitoring. Additional locations along UEFPC and possibly Bear Creek might be continuously monitored.

References

Standard Operating Procedures. Tennessee Department of Health Laboratory Services. Nashville, Tennessee. 1999.

Yard, C.R. Health and Safety Plan. Tennessee Department of Environment and Conservation, Department of Energy Oversight Office. Oak Ridge, Tennessee. 2013.

Ambient Trapped Sediment Monitoring

Principle Author: John (Tab) Peryam

Abstract

In order to monitor for changes in contaminant flow through sediment transport, passive sediment samplers (traps) were deployed at three locations: Mitchell Branch km 0.1 (MIK 0.1), Bear Creek Tributary NT5, and East Fork Poplar Creek km 6.3 (EFK 6.3). The sample from EFK 6.3 (21 mg/kg) exceeded the consensus-based sediment quality guidelines (CBSQGs) Probable Effects Concentration (PEC) (1.06 mg/kg) for mercury. The PECs are CBSQGs that were established as concentrations of individual chemicals above which adverse effects in sediments are expected to frequently occur (Ingersoll et al. 2000). The CBSQGs are considered to be protective of human health and wildlife except where bioaccumulative or carcinogenic organic chemicals, such as PCBs or methylmercury, are involved. In these cases other tools such as human health and ecological risk assessments, bioaccumulation-based guidelines, bioaccumulation studies, and tissue residue guidelines should be used in addition to the CBSQGs to assess direct toxicity and food chain effects (WDNR 2003). The threshold effects concentrations (TECs) are concentrations below which adverse effects are not expected to occur (Ingersoll *et al.* 2000). Lead and Iron from the sample at EFK 6.3 exceeded the Threshold Effects Concentration (TEC). The sediment traps at Mitchell Branch km 0.1 and Bear Creek Tributary NT5 did not yield enough sediment for analysis. Radiological results indicated background conditions, with traces of only two naturally occurring gamma radionuclides, Bi-214 (1.60 ± 0.64 pCi/g) and Pb-212 (1.26 ± 0.31 pCi/g).

Introduction

Sediment is an important part of aquatic ecosystems. Many aquatic organisms depend on sediment for habitat, sustenance, and reproduction. Sediment is also a depository for contaminants such as metals, radionuclides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and agricultural chemicals. Concentrations of contaminants can be much higher than that in the water column. Some sediment contaminants may be directly toxic to benthic organisms or may bioaccumulate in the food chain, creating health risks for wildlife and humans. Sediment analysis is an important aspect of environmental quality and impact assessment for rivers, streams, and lakes. TDEC DOE-O past sediment sampling activities have shown that Poplar Creek has elevated levels of mercury in sediments. This mercury can be attributed to historical discharges from Y-12, and, to a lesser extent, ETTP. This project focuses on the sediments that are currently being transported in East Fork Poplar Creek, Mitchell Branch and NT5 by utilizing passive sediment collectors.

Methods and Materials

A passive sediment sampler was deployed at EFK 6.3 on May 13th, 2013. On July 2, 2013, a passive sediment sampler was installed at the weir at MIK 0.1. A third sampler was installed in Bear Creek tributary NT5 on July 8, 2013, just downstream of the sediment settling pond outfall.

Table 1: Sampling Sites

Location	Latitude	Longitude
East Fork Poplar Creek km 6.3	35.966734	-084.350700
Mitchell Branch km 0.1	35.94146	-084.3922
NT5	35.966026	-084.290237

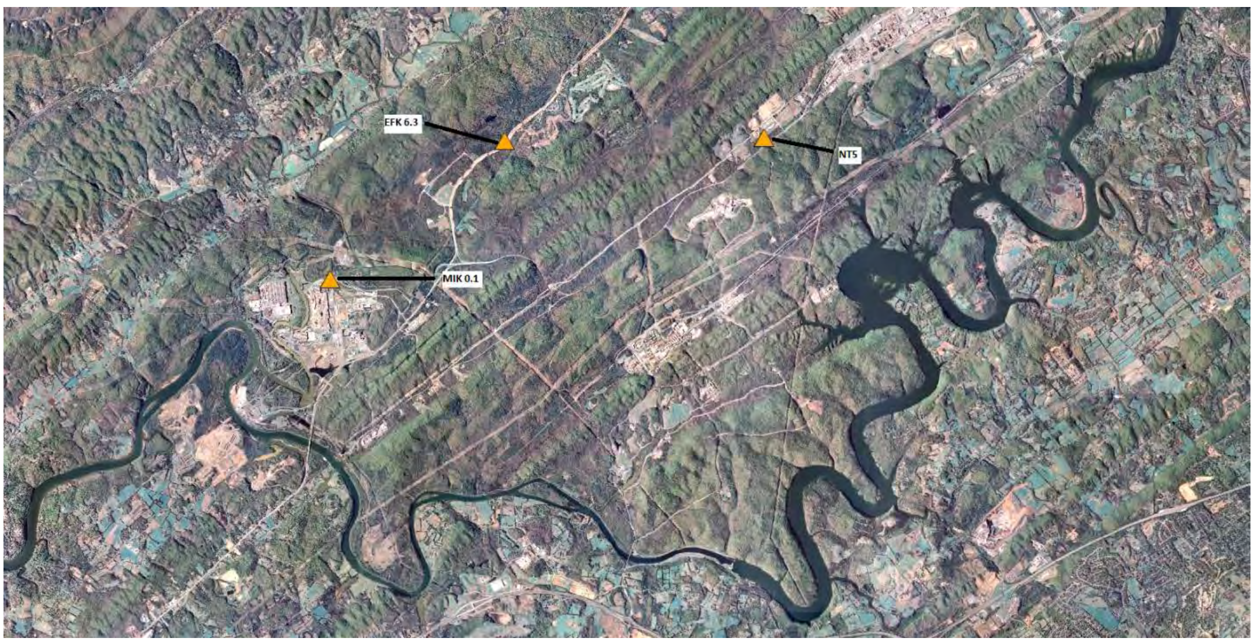


Figure 1: Sampling Site Locations

Figure 2: Photo of Sediment Trap

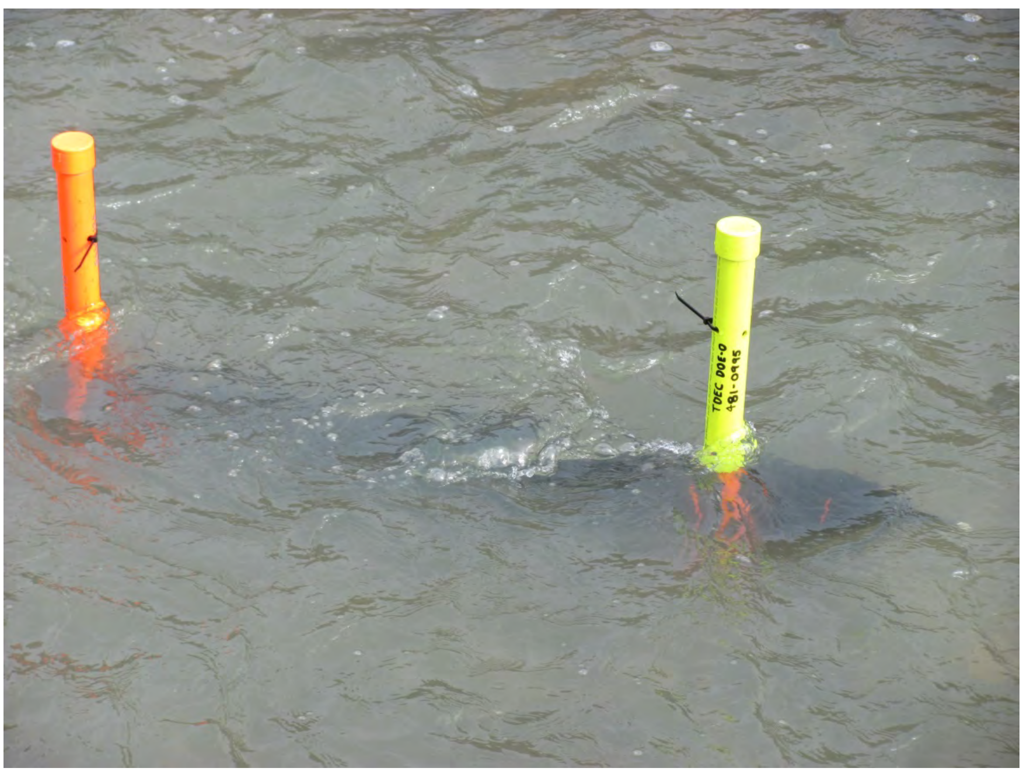
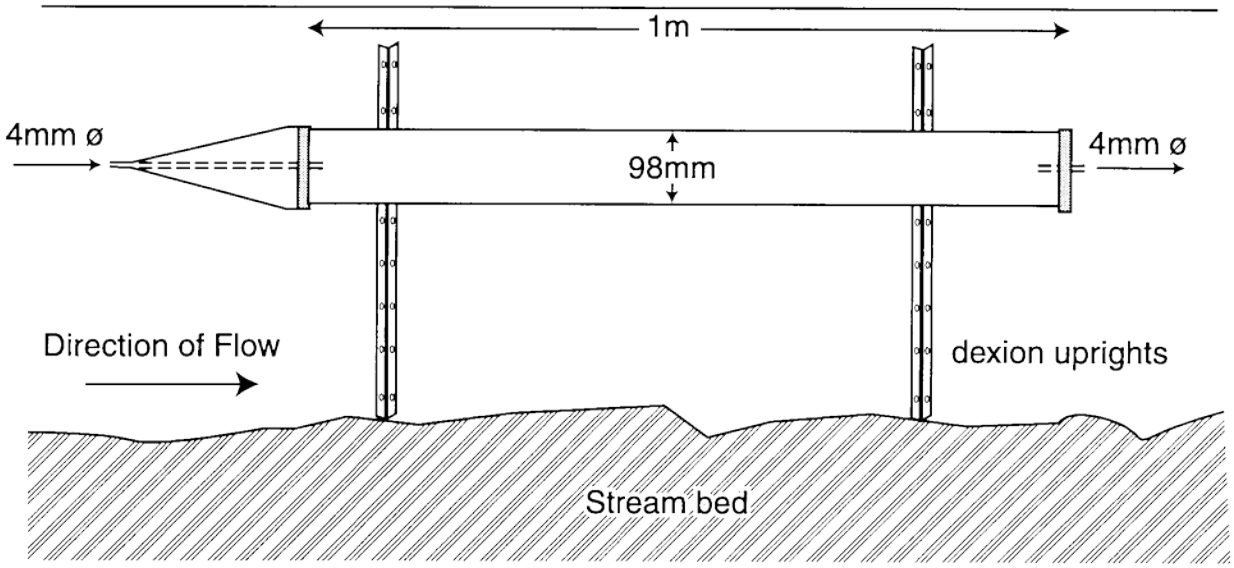


Figure 3: Sediment trap deployed

The passive sediment samplers were modeled after a design described by Phillips *et al.* (2000).



Phillips *et al.* (2000)

Figure 4: Sediment trap design

Results

The only sediment trap that yielded enough sediment for analysis was the one at East Fork Poplar Creek kilometer 6.3. The sediment trap metals data from East Fork Poplar Creek are shown in Table 2. Trapped sediment results were compared with the Consensus Based Sediment Quality Guidelines (CBSQGs) Probable Effects Concentrations (PECs) for each metal. The PECs are CBSQGs that were established as concentrations of individual chemicals above which adverse effects in sediments are expected to frequently occur (Ingersoll et al. 2000). Adverse effects, in this case, refer to effects to benthic macroinvertebrate species only (WDNR 2003). The CBSQGs are considered to be protective of human health and wildlife except where bioaccumulative or carcinogenic organic chemicals, such as PCBs or methylmercury, are involved. In these cases other tools such as human health and ecological risk assessments, bioaccumulation-based guidelines, bioaccumulation studies, and tissue residue guidelines should be used in addition to the CBSQGs to assess direct toxicity and food chain effects (WDNR 2003). The threshold effects concentrations (TECs) are concentrations below which adverse effects are not expected to occur (Ingersoll *et al.* 2000). The mercury PEC was exceeded at EFK 6.3 (21 mg/kg); lead and iron exceeded the Threshold Effects Concentration (TEC) (table 2). Radiological results indicated background conditions, with traces of only two naturally occurring gamma radionuclides, Bi-214 (1.60 pCi/g) and Pb-212 (1.26 pCi/g).

Table 2: EFK 6.3 Metals Data

Analyte	Result[1]	MDL[2]	MQL[3]	EPA[4]	TEC[5]	MEC[6]	PEC[7]
Aluminum	12000	54.00	100	n.a.	n.a.	n.a.	n.a.
Arsenic	U	7.200	50.00	9.8	9.8	21.4	33
Barium	120	2.800	50.00	n.a.	n.a.	n.a.	n.a.
Beryllium	U	3.200	10.00	n.a.	n.a.	n.a.	n.a.
Boron	70	0.96	5	n.a.	n.a.	n.a.	n.a.
Cadmium	U	2.900	10.00	0.99	0.99	3.0	4.98
Chromium	24J	9.500	50.00	43.4	43	76.5	111
Copper	58	5.100	10.00	31.6	32	91	149
Iron	27000	7.60	10	20,000	20,000	30,000	40,000
Lead	48	5.100	10.00	35.8	36	83	128
Magnesium	2700	1.3	10	n.a.	n.a.	n.a.	n.a.
Manganese	1600	3.100	10.00	460	460	780	1100
Mercury	21	0.3400	2.000	0.18	0.18	0.64	1.06
Uranium	6.0J	5.00	10.00	n.a.	n.a.	n.a.	n.a.
Zinc	190	22.00	50.00	124	120	290	459

[1]mg/kg - milligrams per kilogram

[2]Minimum Detection Level

[3]Minimum Quantification Level

[4]EPA Sediment Screening Values USEPA. 2001.

[5]Threshold Effects Concentration (TEC) (MacDonald *et al.* 2000)
Iron & Manganese TEC values from (Persaud *et al.* 1993)

[6]Median Effects Concentration (MEC) (MacDonald *et al.* 2000)
Iron & Manganese MEC values from (Persaud *et al.* 1993)

[7]Probable Effects Concentration (MacDonald *et al.* 2000)
Iron & Manganese PEC values from (Persaud *et al.* 1993)

Conclusion

Passive sediment samplers were deployed at EFK 6.3, Bear Creek Tributary NT5, and at Mitchell Branch km 0.1. Only the sediment sampler at EFK 6.3 collected enough sediment for analysis. Mercury analysis of the sediment sample collected at EFK 6.3 showed the concentration to be 21 mg/kg, a value that exceeds the CBSQG PEC of 1.06. Values that exceed the PECs indicate that there may be adverse effects to benthic macroinvertebrates living there. The results for all of the other metals analyzed for EFK 6.3 were less than their respective CBSQG TECs, with the exception of lead and iron; this indicates that there is little impact from these metals to the benthic macroinvertebrates there. Radiological results were unremarkable and typical of background conditions.

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APPENDIX A

RWA-104 (HD2) Well, Geochemistry, Hydrology,
Gareth Davies LPG

1. Introduction

HD2 is an abandoned residential well, that was drilled to depth of about ~190 m (~615 ft) bls in 2005 to serve as a domestic well. However, as recollected by the owner, the borehole produced "sulfur water" or "bad water." Even though it was initially treated with what was probably a hypochlorite solution the well was never completed. The drillers report says that the borehole made water at 155m (510 ft) at about 0.5 gal/min (1.7 L/min). A replacement borehole was drilled nearby and a well (HD) constructed therein.
In 2010 the TDEC groundwater staff, understanding the significance of a deep well almost directly along strike and downgradient of waste areas at ORNL, initially collected a suite of samples from what was considered the total depth of the borehole using a stainless steel bailer. The results showed a considerable number of VOCs. The list included gasoline compounds, refrigerants, solvents, organic synthesis compounds, well treatment, degradation products, several metals, many exceeding the MCL or relevant public health criteria.

The list of VOCs reported in the HD2 borehole includes 13 out of the 20 most abundant organic compounds found at 183 waste disposal sites in the United States (Domenico and Schwartz, 1983, p. 582) plus 29 other volatile compounds.

2. Well Logging

During January, 2012 the United States Geological Survey (USGS) Nashville, TN, office helped TDEC DOE-O log the borehole with a well-logging tool. The logging work confirms the total depth to be (188 m; 615 ft). The casing extends to a depth of about 36 m (120 ft) and static water level on this day was at about ~ 21 m (70 ft) bls.

The first log measured was a gamma log which reveals lithology. The results confirm that the borehole penetrates the Witten Formation and ends at ~188 m just below the top of the Bowen Formation (for complete stratigraphic information see Hatcher et al., 1992). A portion of the log obtained is a close match to the gamma log obtained on the ORR by Hatcher et al., (1992) for the same formations.

In the log obtained for HD2, an 18 m (~60 ft) thick carbonate unit is recognizable just below the saline water. Another thinner carbonate is recognized, about 3 m (~10ft) thick. It appears that (if the descriptions are consistent) that these are the Big Lime and Little Lime, respectively (R.H. Ketelle, R.D. Hatcher Jr., personal communication). The lower carbonate is near the reported interval at ~155 m (~ 510 ft) where water was first encountered when the borehole was drilled.

The logging results reveal a "normal" looking water quality in and just beneath the casing (EC, ~350 μS/cm, temperature 14.3 C). However, as the logging tool descended the hole, the EC and temperature both increased until a very high electrical conductivity layer was encountered beginning at about 134 m (440 ft). The EC data eventually exceeded the measuring limit of the device. Based upon the specifications of the device, the layer has EC > 999,999 μS/cm. At about 144 m (470 ft) the EC trace moves back toward being on scale, showing that the high EC is a layer sitting between certain depth intervals. When the logging tool was removed from the

borehole the data trace was essentially a mirror image below, through the high EC layer, and above that.

Such a differentiation of saline and fresh water in rocks in the Valley and Ridge province should be considered fairly typical (geologist and driller, Scott Gilbert, personal communication).

3. Slug Test

A slug test was conducted on February 7, 2013. Unfortunately the test was done at the water level that was within the top part of the well casing with no direct connections to the surrounding bedrock. The use of slug tests in fractured rocks can be problematic anyway (van Tonder and Vermeulen, 2005). The results show no response other than a change in water level from the slug displacing its own volume and then returning to near the original water level. Although the USGS suggested the well being not connected with the surrounding bedrock, the results of further monitoring and its pitfalls, need further discussion, this is done below.

The nature of hydraulic heads in a borehole which is open from the surface casing to its total depth, is controlled by many factors:

1. Atmospheric pressure

2. Hydraulic head in individual fractures that connect with the borehole

3. Hydraulic head in larger conduits connected to the borehole, and other subsidiary conduits

4. In the HD2 borehole, the heads above and below the saline water at the ~ 128m (~420 ft) to ~ 140 m (~460 ft) interval, and any other interactions with connections in the open interval from the lower part of the saline layer to the total depth of the borehole at ~ 188 m (~ 615ft).

A large amount of work must be done in the borehole: continuous profiling of EC, T, and discharge in small discrete intervals simultaneously. Smart (1999) shows that an analysis of, and interpretation of only the changes in head in a borehole is only possible on a limited basis, particularly in carbonates and fractured rock settings. One reason for this is the existence of primary and subsidiary conduits, which should be expected in any unconfined carbonate such as the Witten Formation. Primary conduits are not easily intersected with boreholes even when planning to do so. Primary conduits collect ground water from subsidiary conduits and the latter feature is often intersected more often by boreholes. The hydraulic interaction between subsidiary conduits and primary trunk conduits and boreholes is very complicated (Smart, 1999) and presents challenges in data interpretation.

In the HD2 borehole, the saline layer is probably playing a role in transmitting (or not transmitting) the hydraulic head at the water surface. If, as would be assumed, it is acting as a diffusive cap, what happens beneath the saline layer maybe more significant than the head above. The hydraulic head in the Big Lime interval and hydraulic head in the Little Lime interval, maybe reacting most of the time, almost independently of the hydraulic head in any connections above the saline layer. This may not be in phase with or have the amplitude of the changes in the Big and Little Limes

Additional details have emerged after the USGS conducted the slug test and since the well was logged and sampled several times in several different ways.

It is obvious that the Big and Little Limes are transmissive zones as confirmed by many changes in water quality and contaminants at those zones in the different TDEC sampling and USGS/TDEC logging events. The Little Lime is also consistently discharging VOCs (e.g., benzene at > 100 ug/L) into the borehole, and there appears to be interaction between the Little Lime and the Big Lime; the pH and water quality changed between these two intervals between sampling events. The other consideration is that the zones of highest hydraulic conductivity are probably the Big and Little Limes even though they sit beneath the saline layer. As the hydraulic heads change, one of those two hydrostratigraphic units may be at a lower hydraulic head than the other and some flow between the two occurs, completely independent of what happens above the saline layer. It should be noted that this is a completely normal situation in open boreholes regardless of whether they have saline layers or not (Professor Chris Smart, personal communication). There is also the hydraulic head of the connection to the saline layer itself. This is obviously a very complicated situation.

Also, since doing the slug test, there have been documented changes in the water level in the borehole (manual, measured occasionally at the water surface, and transducer measurements measured every 15 mins), some of several meters or so, that were not apparent before attempting the slug test. The net change in hydraulic head in the well at the water surface, will be a function of all the head changes in the links between the borehole and conduits and the surrounding bedrock and the changes transmitted upwards from below and through the saline layer. A change in hydraulic head of a given magnitude maybe responding differently above to changes in head of different magnitudes at, below, and through the saline layer.

Other factors are: the reservoir capacity connected through a presumed linking via fissures and macrofissures, the size of the connecting fissures, macrofissures, channels or conduits. Also, whether they are partially blocked or not, and whether there is more than one link to more than one conduit (Smart, 1999).

There are at least populations of head variation, one large (~3 m or so) and another small (a few mm or so) (note to GJD, make log-prob plot and check this).

4. Discussion about Interpreting Hydrological Data with Reference to Connections to Subsidiary Conduits (subsidiary conduits are conduits tributary to main conduits)

Significantly Quinlan et al., (1996) make sense (for the first time in print that the authors of that paper believe) about the scale of openings in karst and other hydrostratigraphic intervals (in terms of triple-porosity settings) with a definition that says (in the context of any triple-porosity settings): *".....macrofissures or conduits (can) have hydraulic radii of at least as large as a few millimeters."* The point here is that it is not necessary to have large diameter conduits and macrofissures to have rapid groundwater velocities and other concomitant effects.

The hydraulics of wells connected with conduits, primary and subsidiary are modeled, using a variety of links and tandem connections, by Smart (1999) and show that:

a. *“If subsidiary conduits systems are sparse as modeled then few wells maybe compatible with the model.”*

b. *“If subsidiary conduits are of higher density then near continuum hydraulics maybe apparent and diagnostic testing almost impossible.”*

c. Discharge patterns are far more useful than water level data. (the implication here is that it is essential to vertical profile [continuously measure at small intervals EC, T and discharge by gently pumping] a borehole before investigating it). N.B., typically there are vertical gradients and flows in most open boreholes, and these have to be accounted for.

d. *“Variation of fluxes at different inlets in a well will alter the apparent hydrostratigraphy, confusing attempts to identify a coherent point of sampling. In addition, activation of a large overflow pathway may significantly reduce flow through a lower pathway.*

e. “*Significant breaks in discharge patterns at overflow thresholds often do not have a concomitant change in head.”* [overflow thresholds involve tiers of conduits where those higher in the vertical tier system discharge mostly only discharge when stage is highest.]

f. “*A large radius overflow conduit (that may not be apparent in the well bore but be connected to it) permits the reservoir head to match the well and conduit head. Also, the radii of connecting links have an influence on how suspended particles and dissolved solutes can be transported into and out of all that the well bore is connected to.”*

g. Large-radius boreholes *increase the magnitude of “errors’”* of head measurements and create interpretive challenges. Discharge measurements are always better.

h. The head in a well that has penetrated a subsidiary conduit is a function of the head in the surrounding bedrock, the primary conduit and all the links in between.

i. A well drilled in a fractured-rock, carbonate or karst setting has an extremely low probability of penetrating a primary conduit.

j. Sampling for tracers and contaminants in wells linked to subsidiary conduits is fraught with variability and is often not representative of the neither the subsidiary nor the primary conduit.

However, if contaminants are detected in wells, even at low concentrations (i.e., what are referred to as *left centered data*) a robust method of evaluating their significance and a good dose of common sense must be employed, and done within the context of understanding that wells are likely to be connected mostly to subsidiary conduits. However, it should be made clear, that the data obtained by purging partially penetrating wells in fractured rocks may be an underestimation of actual concentrations (Robbins, 1989).

In light of the information in the previous discussion, the hydraulic conditions outside the borehole and its links maybe significantly tied to concentrations in both subsidiary and primary conduits and the surrounding bedrock, which maybe be significantly higher, but may fluctuate significantly.

In the HD2 borehole, it should be noted, it is now evident that the majority of the contaminants are consistently associated only with two hydrostratigraphic intervals below the saline layer. In fact it appears that they are being discharged into the borehole mostly though the Big and Little Limes.

These two intervals are documented on the ORR as having been directly contaminated in trenches and other waste disposal areas, and so greatly simplifies one possible interpretation about the origin of such a large suite of organic contaminants. Such differentiation from a complete source suite at their potential point of origin is difficult to conceptualize until it is realized that great effort was made to mitigate the migration of radio nuclides, e.g., NaOH, (N.B., there is high Na in HD2 and high pH), far beyond the efforts made to mitigate the migration of other contaminants, such as the organics.

5. Geochemistry

Introduction

Six principal chemical components can be effectively used in comparing fundamental water quality: Ca, Mg, Na+K, SO4, Cl and HCO3. When these components are plotted data from different waters can be compared directly and easily (Schoeller, 1962). Other ratios and data provide useful information, for example: low K (deep circulating groundwater), high K would suggest shale contact waters, high Na, shale contact and contaminated sinking stream waters. High partial pressure of CO2 (pCO2) should mean open conduits, and the saturation index of calcite; undersaturated would be mixed sinking stream waters and rapid recharge and circulation, and saturated SI mineralized and deeper waters (Christopher and Wilcock, 1981).

Interpretation of Fundamental Water Chemistry

Plots of the variation of the six components have been made for several onsite and offsite wells. Several plots show what waters upgradient of the ORR should look like. Other plots show what waters on and off the reservation look like. It can be clearly seen that the pattern of variation of the principal chemical components in HD2 is atypical of carbonates in general (the borehole is advanced through the Witten Limestone), and is also not similar to waters in the same general lithology upgradient of the ORR (Figures 7 - 12).

The saline layer in HD2 needs further explanation. A plot of Cl vs Br has been made in conjunction with samples from (Warner et al., (2012) from an Appalachian Brine. Note that the three samples from the three zones sampled (250ft, 440ft, and 510ft) plot as a linear trend toward a data cloud from Appalachian Brine samples. Note, that sea water and rain water is also included for comparison.

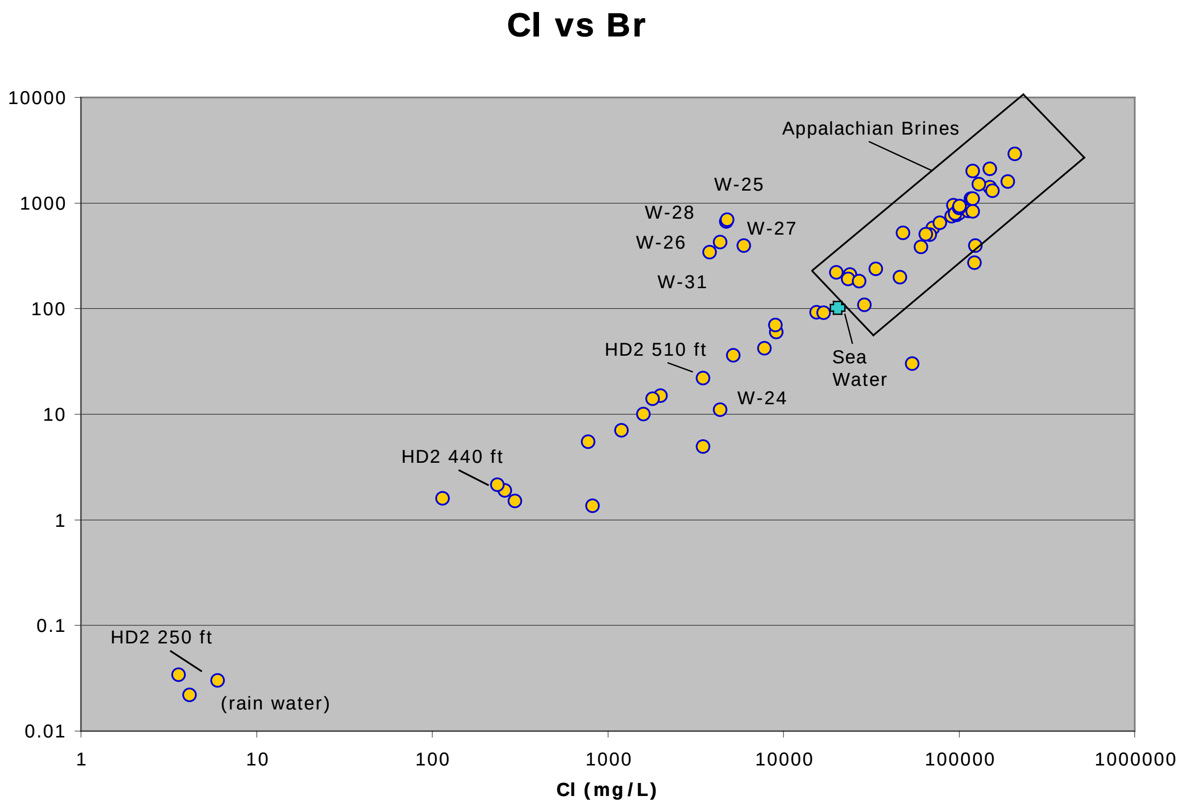


Figure 6. Cl vs Br for samples from an Appalachian Brine (Warner et al., 2012), including samples from Nativ et al., (1997) and selected samples collected by TDEC DOEO (HD2, RWA-97, and other ORR GW wells).

Figure 6. shows that results from HD2, (collected using a thief [discrete interval] sampling device, supplied and operated by M. Bradley, USGS Nashville) plot along a strongly linear trend between rain water and an Appalachian brine, therefore they mostly appear to be part of a two component mixture of those two water types. Of note is that the sample from the highest elevation (~ 250ft) is > 90% rain water composition, and the sample from deepest (~ 510ft) is about 60% brine and 40% rain water.

Note that most results from Melton Valley waste tanks (W-25 etc, comparable waste was disposed of also in Bethel Valley) do not plot along the same mixing line, in fact they form a cluster that plots to the left of and above the inferred two-component mixing line. Only liquid from one tank, W-24, plots near the line and that result is clearly different from the results from the other tanks.

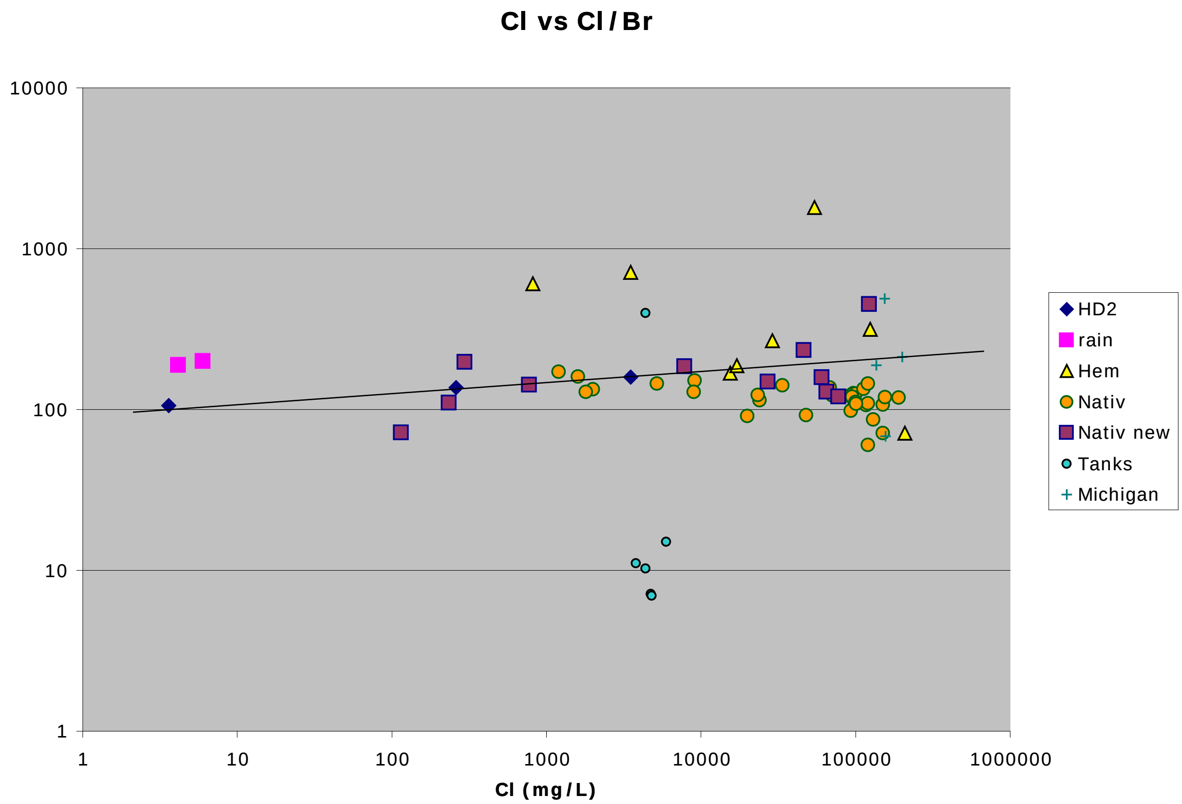
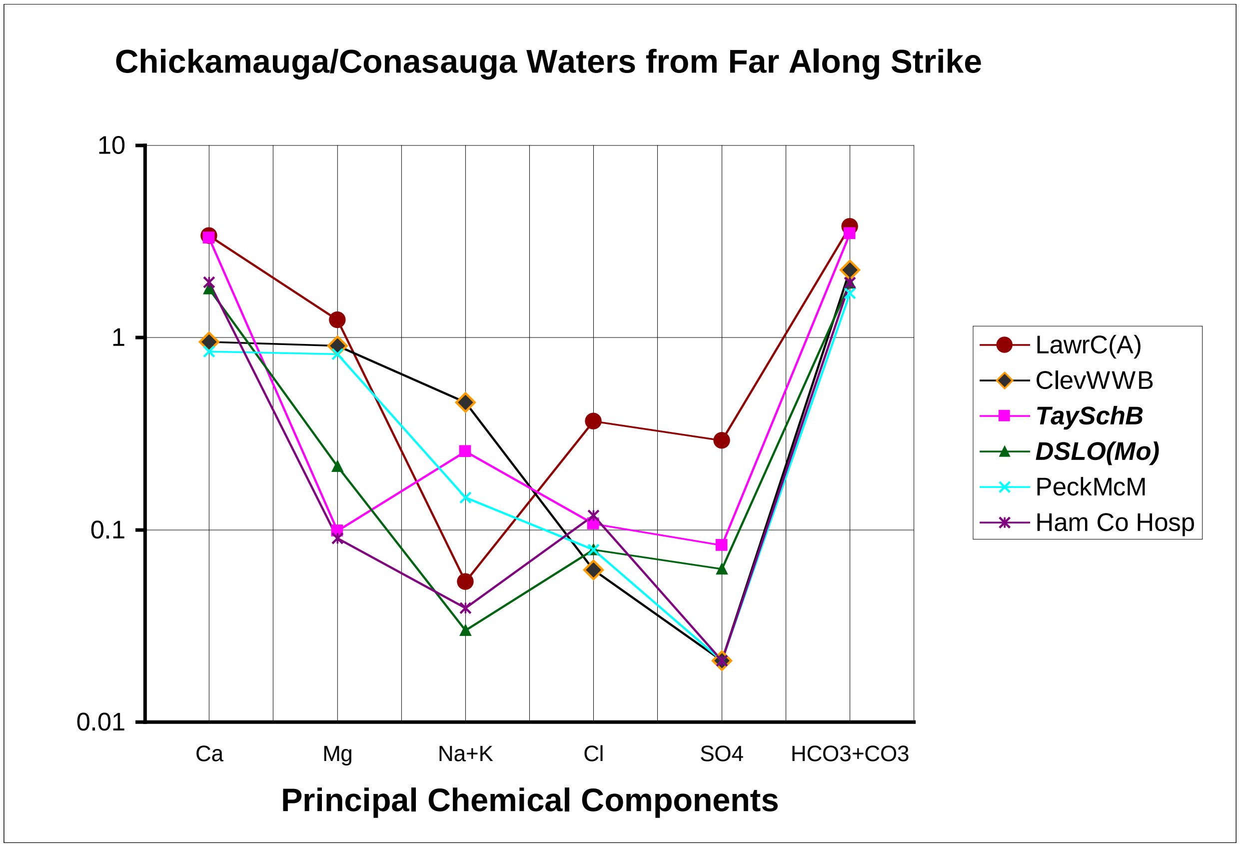


Figure 7. Plot of Cl vs Cl/Br for waters from the ORR, Melton Valley (Nativ, et al., 1997) the scientific literature, e.g., Michigan, from (White et al., 1963) and the ORR Melton Valley waste tanks and well HD2.

In Figure 7 again, there is an obvious linear trend that connects waters that are fresh (rain water) and typical brines (Michigan types). These brines could well be quite representative (Davies et al., 2013; Garven et al., 1993). Other data plot either above or below the line, notable most of the liquids in the waste tanks and other brine data from (White et al., 1963). Note that waters from the three zones in well HD2 plot along a strongly linear trend that originates near rain water and ends in a water type from Melton Valley/ORR water type as sampled by (Nativ et al.,1997); several (Nativ et al.,1997) data are from Bethel Valley.

Figure 8-13 (below) show comparisons of the fundamental chemistry of groundwater in wells in Bethel Valley and Melton Valley, with waters from far up and down gradient, and typical limestone, dolostone, sandstone, shale waters and a typical brine (Data from TDEC, White et al., 1963; DeBuchananne and Richardson, 1956).

Figure 8)



Chickamauga/Conasauga Waters from Far Along Strike
10
1
0.1
0.01
Ca
Mg
Na+K
Cl
SO4
HCO3+CO3
Principal Chemical Components
LawrC(A)
ClevWWB
TaySchB
DSLO(Mo)
PeckMcM
Ham Co Hosp

Figure 9)

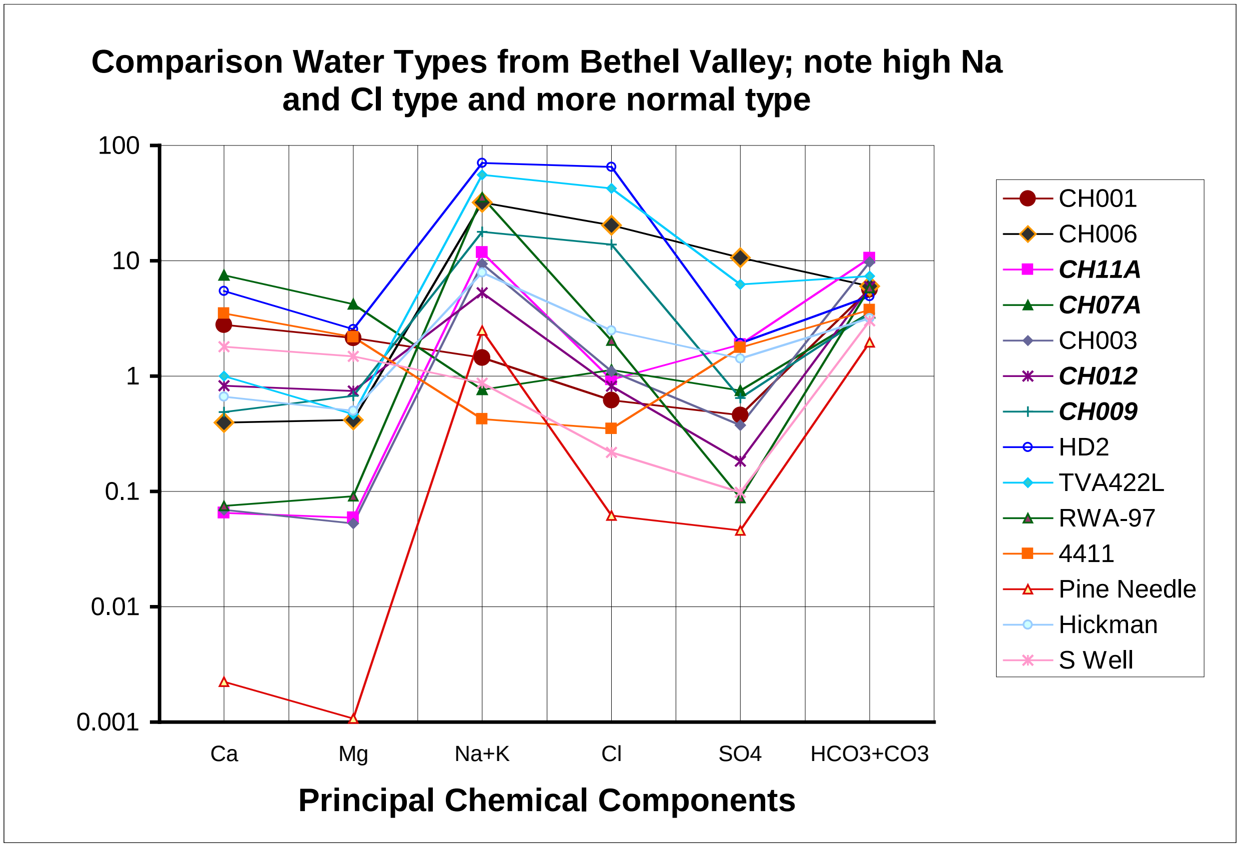
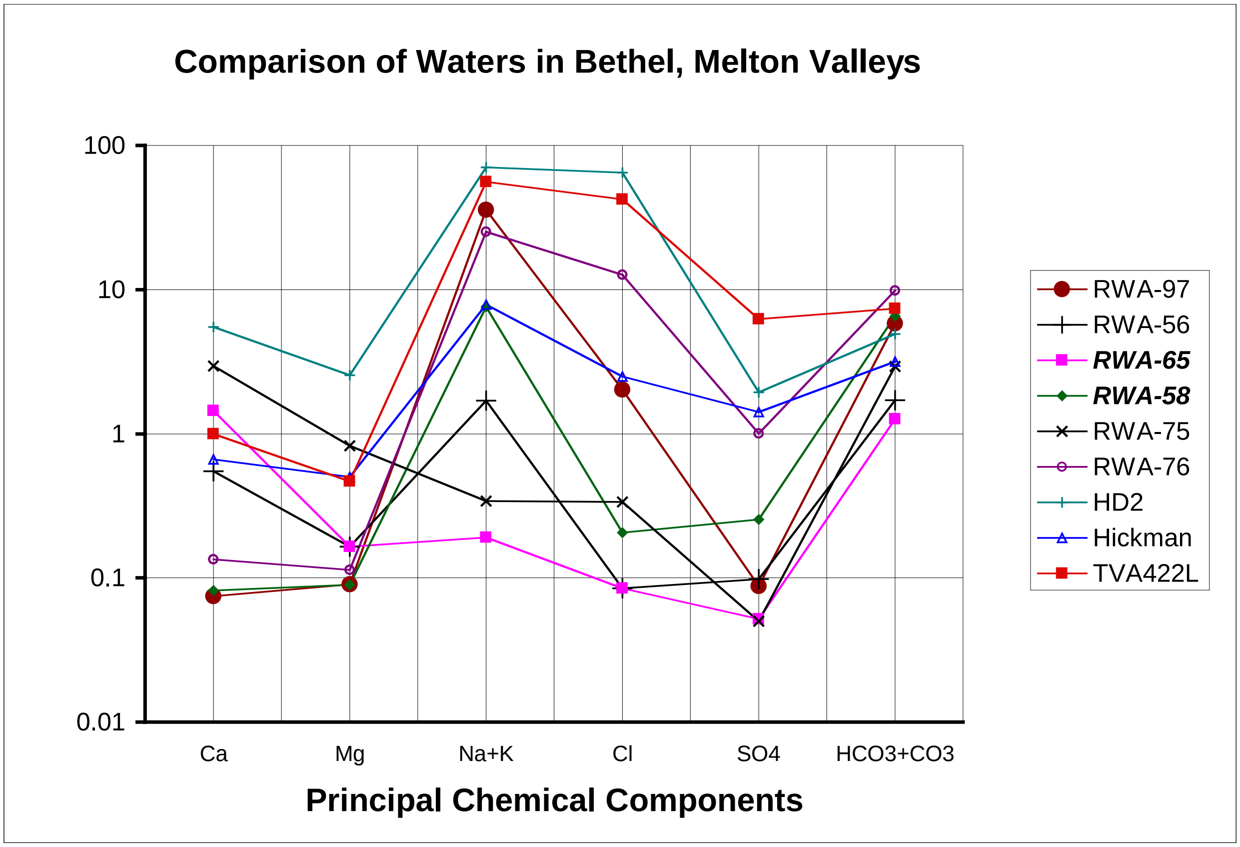
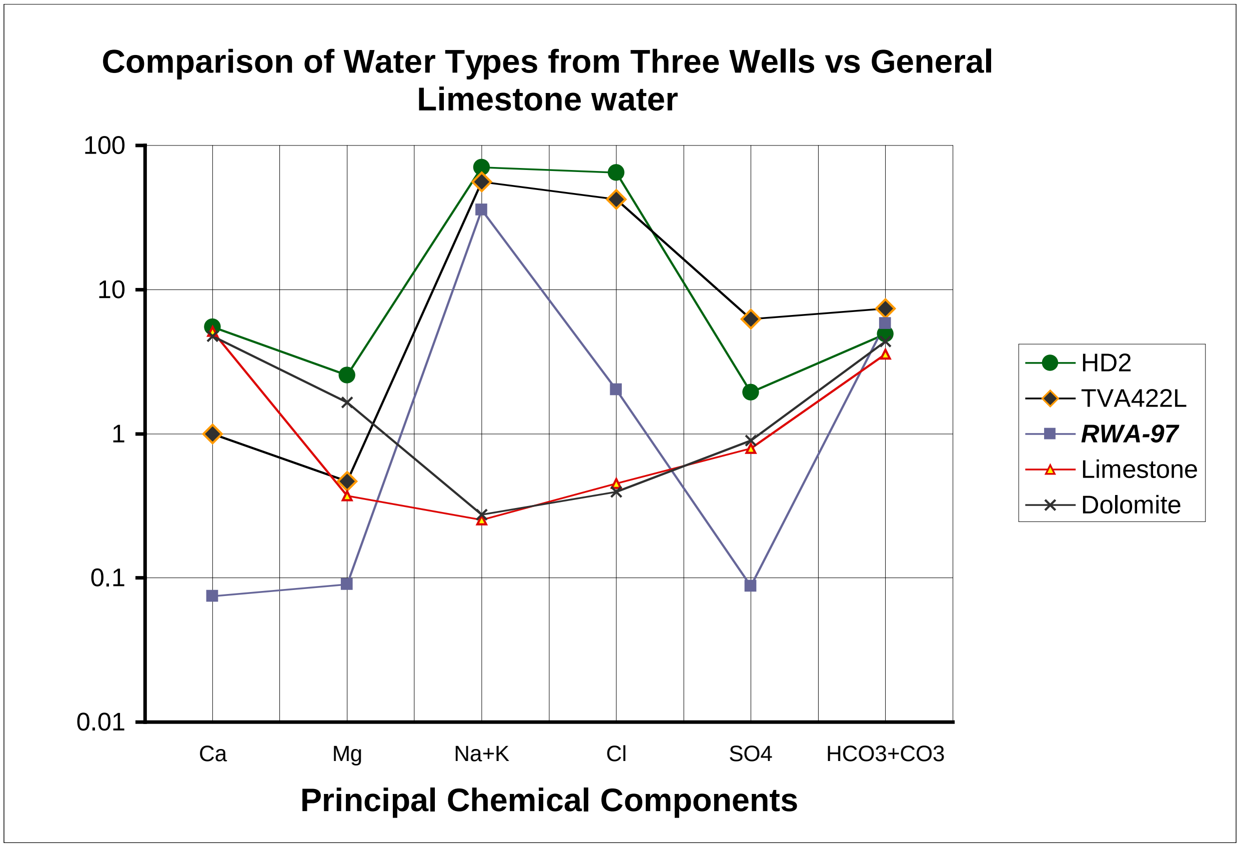

Comparison Water Types from Bethel Valley; note high Na and Cl type and more normal type
100
10
1
0.1
0.01
0.001
Ca
Mg
Na+K
Cl
SO4
HCO3+CO3
Principal Chemical Components
CH001
CH006
CH11A
CH07A
CH003
CH012
CH009
HD2
TVA422L
RWA-97
4411
Pine Needle
Hickman
S Well

Figure 10)



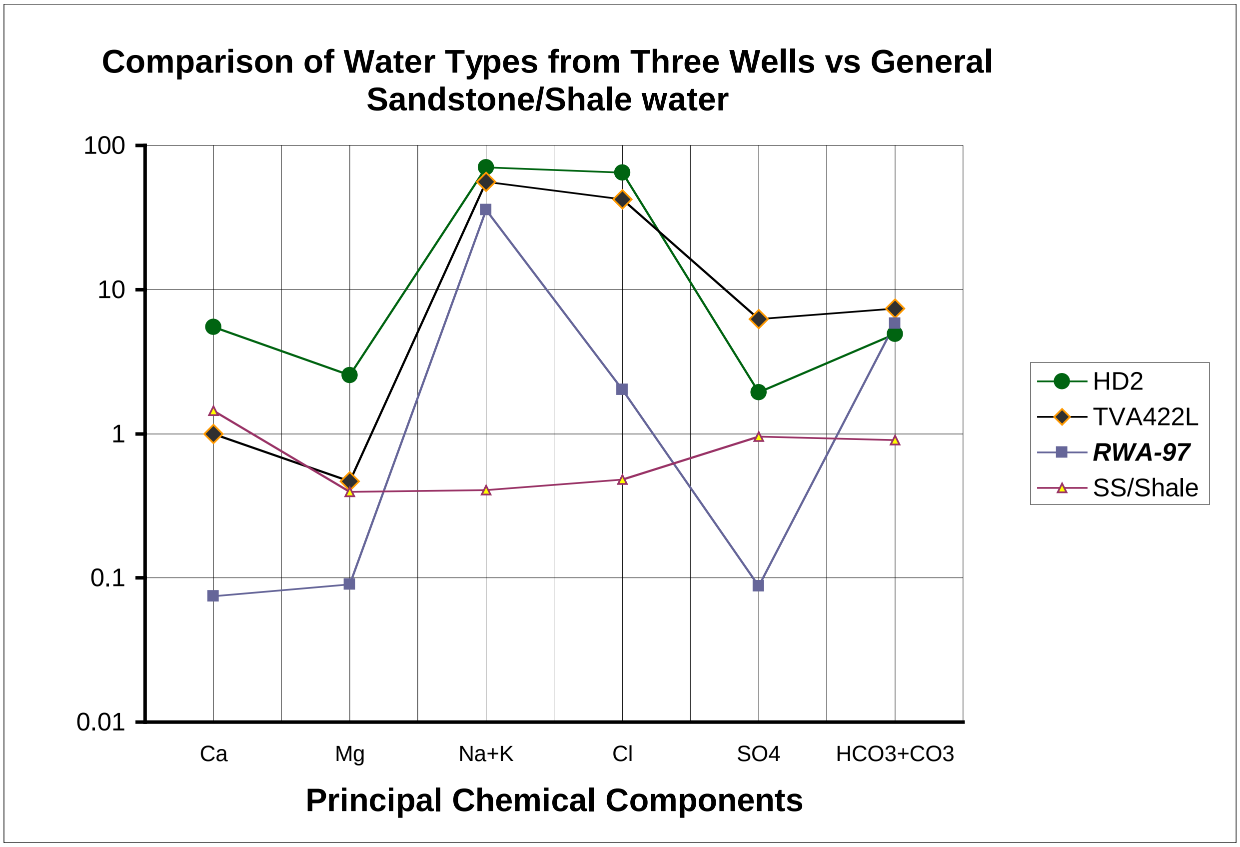
Comparison of Waters in Bethel, Melton Valleys
100
10
1
0.1
0.01
Ca
Mg
Na+K
Cl
SO4
HCO3+CO3
Principal Chemical Components
RWA-97
RWA-56
RWA-65
RWA-58
RWA-75
RWA-76
HD2
Hickman
TVA422L

Figure 11)



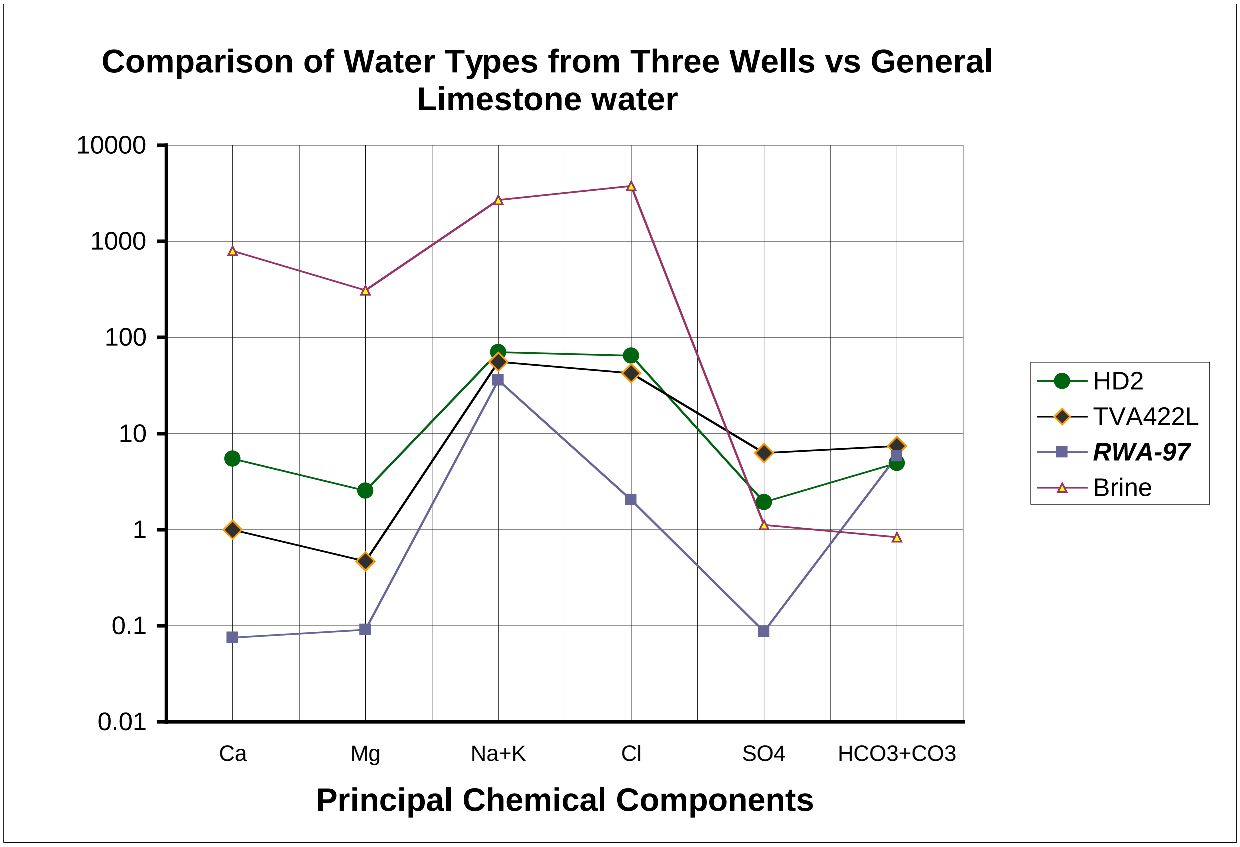
Comparison of Water Types from Three Wells vs General Limestone water
100
10
1
0.1
0.01
Ca
Mg
Na+K
Cl
SO4
HCO3+CO3
Principal Chemical Components
HD2
TVA422L
RWA-97
Limestone
Dolomite

Figure 12)



Comparison of Water Types from Three Wells vs General Sandstone/Shale water
100
10
1
0.1
0.01
Ca
Mg
Na+K
Cl
SO4
HCO3+CO3
Principal Chemical Components
HD2
TVA422L
RWA-97
SS/Shale

Figure 13)

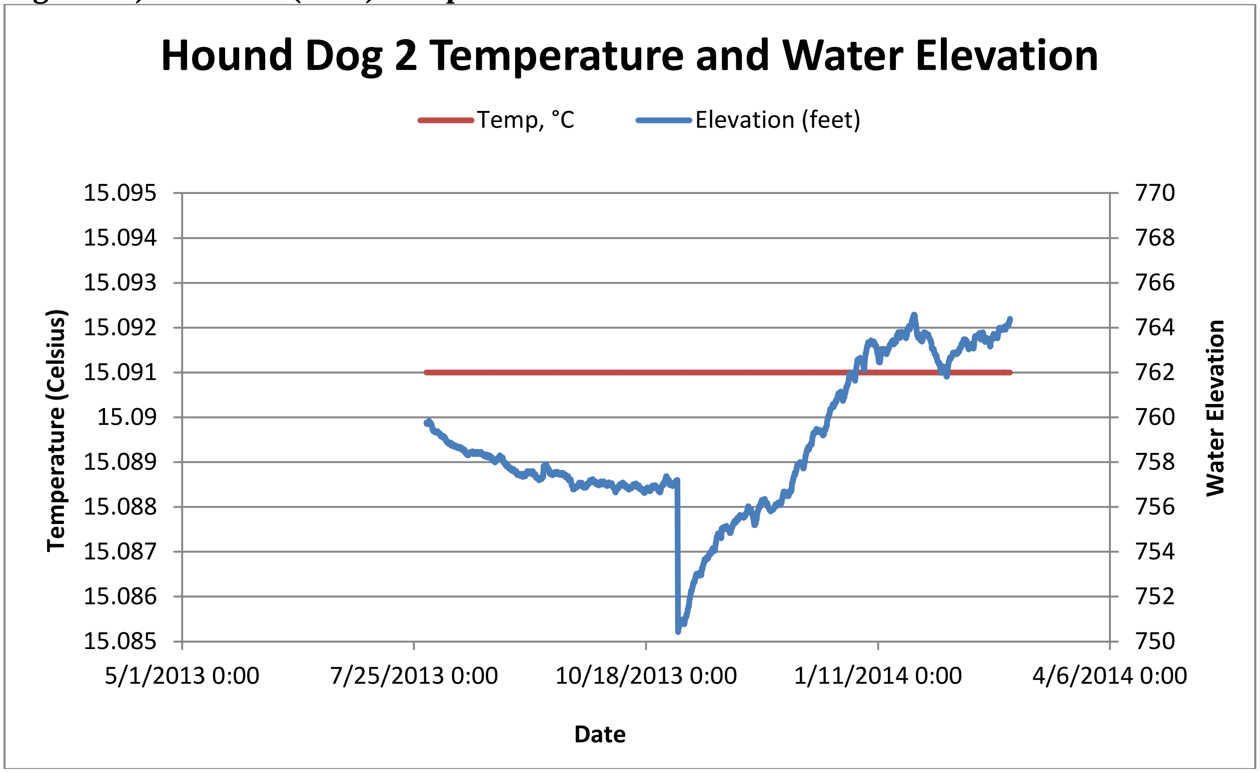


It is quite clear that the set of plots (Figures 8-13) shows that there are waters of principally two different types in Bethel and Melton Valleys. The chemistry of natural waters that are upgradient and some far downgradient of the ORR are distinctly different from waters in at least three different wells (HD2, TVA Well 422L, and RWA-97) shown here.

Significantly, these wells have waters that are characterized by: high Na, high pH, either radionuclide or VOC constituents; all are acknowledged signatures characteristic of contamination at ORNL both in Melton and Bethel Valleys. These wells are either in the same formations as waste areas at ORNL (or Melton Valley) and are often in predominantly carbonate formations that are acknowledged to be directly contaminated in waste disposal areas on the ORR (Bethel and Melton Valleys).

Continuous Water Level and Temperature Monitoring in RWA-104(HD2):

Figure 14) RWA-104(HD2) Temperature and Water Elevation



The above graph (Figure 14) depicts the data recorded by an Onset® HOBO®U20 Water Level Logger that was deployed in the Hound Dog 2 (HD2) well on July 29, 2013 and retrieved from the HD2 well on February 28, 2014. The logger recorded the water elevation in the well as well as the temperature of the water in the well. The logger was set to record measurements at an interval of 60 minutes (min.)

The water elevation ranged from 750.43 feet (ft.) to 764.58 ft. From the time of deployment on July 29, 2013, the water level fell until approximately the end of September when it began to level off until DOE-O groundwater staff sampled the well on October 29, 2013. At which time, it displayed its lowest water level of 750.43. On that day the water level was lowered approximately 7 ft. while sampling. The well recovered over the next several days and continued to rise to a high point of 764.58 ft., and then fell once again approximately 2 ft., and recovered to a level of 764.37 at the time of retrieval on February 28, 2014. Also, these water elevations correspond well to the changes seen when water levels were manually collected during sampling or when deploying and retrieved the logger. This demonstrates that there may be a dry season/wet season fluctuation signal to HD2. However, more data needs to be collected to make any definitive statements concerning this.

The temperature portion of the logger appears to have malfunctioned as it only recorded a temperature of 15.091˚C. Because of the constant 15.091 ^{0}C data, and as variations had been seen previously, we do not feel comfortable using the temperature data for any interpretation.

Conclusions:
The sites under investigation are all located southwest, downgradient and along geologic strike of the legacy waste areas in Bethel Valley on the ORR. Anthropogenic factors may have influenced the movement of contaminants toward the Hood Ridge and TVA CRBR sites from the ORR.

During the 1980's dewatering the large excavation made as part of the CRBR Project would have put pressure on the system to move contaminants along geologic strike toward the southwest. Activities in 2013 for the planned construction of TVA's modular reactors at the CRBR site such as well development would have added to the extraction of groundwater from the aquifer. Agricultural and domestic extraction of groundwater in the area, have constantly exerted a pumping pressure on the aquifer.

The breadth and variety of reported contaminants from the TVA site and the Hood Ridge Area suggests a large and complex source of contamination upgradient.

A geochemistry dominated by sodium is shared by certain on and offsite wells that are contaminated, although not all wells that show contamination share this geochemistry. This geochemistry is not what pre-reservation data would suggest these aquifers should be and is not what would be expected from rapidly conducting meteoric waters in marine carbonates.
A complex source of contaminants located to the northeast such as the legacy waste areas associated with Oak Ridge National Laboratory is suggested. Unless a significant, complex unknown contaminant source is identified other than the legacy waste areas at the ORNL, then the potential that groundwater in the Hood Ridge Area and TVA CRBR site has been impacted by DOE legacy waste must be considered.

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