OAK RIDGE RESERVATION

Annual Site Environmental Report 2020

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Oak Ridge Reservation

Annual Site Environmental Report 2020

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Contents

Figures xii
Tables xx
Appendices xxiv
Acronyms and Abbreviations xxv
Units of Measure and Conversion Factors xxx
Acknowledgments xxxii
In Memoriam xxxiii
Executive Summary xxxiv

1 Introduction to the Oak Ridge Reservation **1-1**
1.1. Background 1-2
1.2. History of the Area around the Oak Ridge Reservation 1-2
1.3. Location and Description 1-3
1.3.1. Population 1-3
1.3.2. Climate 1-5
1.3.3. Regional Air Quality 1-5
1.3.4. Surface Water 1-5
1.3.5. Geological Setting 1-6
1.3.6. Natural, Cultural, and Historic Resources 1-7
1.3.6.1. Wetlands 1-7
1.3.6.2. Wildlife and Endangered Species 1-8
1.3.6.3. Threatened and Endangered Plants 1-13
1.3.6.4. Historical and Cultural Resources 1-15
1.4. Oak Ridge Sites 1-16
1.4.1. Oak Ridge National Laboratory 1-16
1.4.2. Y-12 National Security Complex 1-18
1.4.3. East Tennessee Technology Park 1-20
1.4.4. Environmental Management Waste Management Facility 1-21
1.4.5. Oak Ridge National Environmental Research Park 1-22
1.4.6. Oak Ridge Institute for Science and Education 1-23
1.4.7. National Nuclear Security Administration Office of Secure Transportation, Agent Operations Eastern Command 1-24
1.4.8. Transuranic Waste Processing Center 1-24
1.5. References 1-25

2 Compliance Summary and Community Involvement 2-1

2.1. Laws and Regulations 2-1

2.2. External Oversight and Assessments 2-1

2.3. Reporting of Oak Ridge Reservation Spills and Releases 2-2

2.4. Notices of Violations and Penalties 2-2

2.5. Community Involvement and Resources 2-2

2.5.1. Public Comments Solicited 2-3

2.5.2. Oak Ridge Site Specific Advisory Board 2-3

2.5.3. DOE Information Center 2-3

2.5.4. Other Resources 2-3

2.6. References 2-9

3 East Tennessee Technology Park 3-1

3.1. Description of Site and Operations 3-2

3.2. Environmental Management System 3-4

3.2.1. Sustainable Environmental Stewardship 3-5

3.2.2. Environmental Compliance 3-8

3.2.3. Environmental Aspects/Impacts 3-8

3.2.4. Environmental Performance Objectives and Targets 3-8

3.2.5. Implementation and Operation 3-9

3.2.6. Pollution Prevention/Waste Minimization/Release of Property 3-9

3.2.7. Competence, Training, and Awareness 3-10

3.2.8. Communication 3-10

3.2.9. Benefits and Successes of Environmental Management System Implementation 3-11

3.2.10. Management Review 3-11

3.3. Compliance Programs and Status 3-11

3.3.1. Environmental Permits Compliance Status 3-12

3.3.2. National Environmental Policy Act/National Historic Preservation Act 3-12

3.3.3. Clean Air Act Compliance Status 3-14

3.3.4. Clean Water Act Compliance Status 3-15

3.3.5. National Pollutant Discharge Elimination System Permit Noncompliances 3-15

3.3.6. Safe Drinking Water Act Compliance Status 3-15

3.3.7. Resource Conservation and Recovery Act Compliance Status 3-15

3.3.8. Comprehensive Environmental Response, Compensation, and Liability Act Compliance Status 3-16

3.3.9. East Tennessee Technology Park RCRA-CERCLA Coordination 3-16

3.3.10. Toxic Substances Control Act Compliance Status–Polychlorinated Biphenyls 3-16
3.3.11. Emergency Planning and Community Right-to-Know Act Compliance Status 3-17
3.3.11.1. Chemical Inventories (EPCRA Section 312) 3-17
3.3.11.2. Toxic Chemical Release Reporting (EPCRA Section 313) 3-17
3.4. Quality Assurance Program 3-17
3.5. Air Quality Program 3-18
3.5.1. Construction and Operating Permits 3-18
3.5.1.1. Generally Applicable Permit Requirements 3-18
3.5.1.2. Fugitive Particulate Emissions 3-19
3.5.1.3. Radionuclide National Emission Standards for Hazardous Air Pollutants 3-20
3.5.1.4. Quality Assurance 3-21
3.5.1.5. Greenhouse Gas Emissions 3-21
3.5.1.6. Source-Specific Criteria Pollutants 3-24
3.5.1.7. Hazardous Air Pollutants (Nonradionuclide) 3-25
3.5.2. Ambient Air 3-25
3.6. Water Quality Program 3-27
3.6.1. National Pollutant Discharge Elimination System Permit Monitoring 3-27
3.6.2. Storm Water Pollution Prevention Program 3-28
3.6.2.1. Radiologic Monitoring of Storm Water 3-28
3.6.2.2. Storm Water Monitoring Associated with D&D Activities 3-28
3.6.2.3. Technetium-99 Monitoring of Storm Water Associated with D&D Activities 3-29
3.6.2.4. D&D of the K-1203 Sewage Treatment Plant 3-29
3.6.2.5. D&D of Buildings K-131/K-631 3-30
3.6.2.6. Monitoring Conducted in the Exposure Unit 19 Area 3-30
3.6.2.7. D&D of the J-Labs Complex and Building K-1023 3-31
3.6.2.8. D&D of the K-1210/K-1220 Complex 3-31
3.6.2.9. Monitoring of Outfalls Designated in the CERCLA Phased Construction Completion Reports 3-32
3.6.2.10. Legacy Mercury Investigation Monitoring 3-33
3.6.2.11. Investigation of Powerhouse Area Outfalls 3-36
3.6.2.12. PCB Monitoring at ETTP Storm Water Outfalls 3-37
3.6.2.13. Storm Water Monitoring in the Outfall 690 Drainage Network 3-38
3.6.2.14. Chromium Water Treatment System and Plume Monitoring 3-38
3.6.3. Surface Water Monitoring 3-40

3.6.4. Groundwater Monitoring at ETTP 3-44
3.7. Biological Monitoring 3-49
3.7.1. Task 1: Bioaccumulation Monitoring 3-49
3.7.1.1. Mitchell Branch 3-52
3.7.1.2. 1007-P1 Pond 3-57
3.7.1.3. K-901-A Pond 3-61
3.7.1.4. K-720 Slough 3-63
3.7.2. Task 2: Instream Benthic Macroinvertebrate Communities 3-66
3.7.2.1. Benthic Macroinvertebrates 3-66
3.7.2.2. Mitchell Branch–ORNL and TDEC Protocols 3-67
3.7.2.3. Comparison between Mitchell Branch and Other Reference Sites on ORR 3-73
3.7.3. Task 3: Fish Community 3-76
3.8. Environmental Management and Waste Management Activities 3-80
3.8.1. Waste Management Activities 3-80
3.8.2. Environmental Remediation Activities 3-81
3.8.2.1. Soil Remediation 3-81
3.8.2.2. K-1200 Centrifuge Project Demolition Completed 3-81
3.8.2.3. Building K-1600 Demolition Completed 3-81
3.8.2.4. Smaller Facilities Demolition Completed 3-82
3.8.2.5. Commemoration of the K-25 Site 3-82
3.8.3. Reindustrialization 3-82
3.9. References 3-83

4 The Y-12 National Security Complex 4-1

4.1. Description of Site and Operations 4-1
4.1.1. Mission 4-1
4.1.2. Modernization 4-2
4.1.3. Production Operations 4-3
4.1.4. Support Facilities 4-4
4.1.5. Excess Facility Disposition 4-4
4.2. Environmental Management System 4-5
4.2.1. Integrating with Integrated Safety Management System 4-5
4.2.2. Policy 4-5
4.2.3. Planning 4-7
4.2.3.1. Y-12 Environmental Aspects 4-7

4.2.3.2. Legal and Other Requirements ... 4-7
4.2.3.3. Objectives, Targets, and Environmental Action Plans ... 4-7
4.2.3.4. Programs ... 4-7
4.2.4. Implementing and Operating ... 4-9
4.2.4.1. Roles, Responsibility, and Authority ... 4-9
4.2.4.2. Communication and Community Involvement ... 4-9
4.2.4.3. Emergency Preparedness and Response ... 4-9
4.2.5. Checking ... 4-10
4.2.5.1. Monitoring and Measuring ... 4-10
4.2.5.2. Environmental Management System Assessments ... 4-10
4.2.6. Performing ... 4-10
4.2.6.1. Environmental Management System Objectives and Targets ... 4-11
4.2.6.2. Sustainability and Stewardship ... 4-11
4.2.6.3. Energy Management ... 4-14
4.2.6.4. Dashboard Reporting and the Y-12 Complex Site Sustainability Plan ... 4-15
4.2.6.5. Water Conservation ... 4-18
4.2.6.6. Fleet Management ... 4-18
4.2.6.7. Electronic Stewardship ... 4-19
4.2.6.8. Greenhouse Gases ... 4-19
4.2.6.9. Storm Water Management and the Energy Independence and Security Act of 2007 ... 4-19
4.2.7. Awarding and Recognizing ... 4-19
4.2.7.1. Electronic Product Environmental Assessment Tool Award ... 4-20
4.2.7.2. DOE Sustainability and National Nuclear Security Administration Excellence Awards ... 4-20
4.3. Compliance Status ... 4-20
4.3.1. Environmental Permits ... 4-20
4.3.2. National Environmental Policy Act and National Historic Preservation Act ... 4-24
4.3.3. National Historic Preservation Act ... 4-34
4.3.4. Clean Air Act Compliance Status ... 4-35
4.3.5. Clean Water Act Compliance Status ... 4-36
4.3.6. Safe Drinking Water Act Compliance Status ... 4-36
4.3.7. Resource Conservation and Recovery Act Compliance Status ... 4-36
4.3.7.1. Resource Conservation and Recovery Act Underground Storage Tanks ... 4-37

4.3.7.2. Resource Conservation and Recovery Act Subtitle D Solid Waste 4-38

4.3.8. Resource Conservation and Recovery Act–Comprehensive Environmental Response, Compensation, and Liability Act Coordination 4-38

4.3.9. Toxic Substances Control Act Compliance Status 4-38

4.3.10. Emergency Planning and Community Right-to-Know Act Compliance Status 4-38

4.3.11. Spill Prevention, Control, and Countermeasures 4-39

4.3.12. Unplanned Releases 4-40

4.3.13. Audits and Oversight 4-40

4.3.14. Radiological Release of Property 4-41

4.3.14.1. Property Potentially Contaminated on the Surface 4-41

4.3.14.2. Property Potentially Contaminated in Volume (Volumetric Contamination) 4-42

4.3.14.3. Process Knowledge 4-43

4.4. Air Quality Program 4-44

4.4.1. Construction and Operating Permits 4-44

4.4.1.1. Generally Applicable Permit Requirements 4-45

4.4.1.2. National Emission Standards for Hazardous Air Pollutants for Radionuclides 4-46

4.4.1.3. Quality Assurance 4-47

4.4.1.4. Source-Specific Criteria Pollutants 4-47

4.4.1.5. Mandatory Reporting of Greenhouse Gas Emissions under 40 Code of Federal Regulations 98 4-48

4.4.1.6. Hazardous Air Pollutants (Nonradiological) 4-49

4.4.2. Ambient Air 4-51

4.4.2.1. Mercury 4-51

4.4.2.2. Quality Control 4-55

4.4.2.3. Ambient Air Monitoring Complementary to Y-12 Ambient Air Monitoring 4-55

4.5. Water Quality Program 4-56

4.5.1. National Pollutant Discharge Elimination System Permit and Compliance Monitoring 4-56

4.5.2. Radiological Monitoring Plan and Results 4-60

4.5.3. Storm Water Pollution Prevention 4-63

4.5.4. Y-12 Ambient Surface Water Quality 4-64

4.5.5. Industrial Wastewater Discharge Permit 4-65

4.5.6. Quality Assurance and Quality Control 4-67

4.5.7. Biological Monitoring and Abatement Program 4-68

4.5.7.1. Bioaccumulation Studies 4-70
4.5.7.2. Benthic Invertebrate Surveys 4-73
4.5.7.3. Fish Community Monitoring 4-75
4.6. Groundwater at the Y-12 National Security Complex 4-76
4.6.1. Hydrogeologic Setting 4-77
4.6.2. Well Installation and Plugging and Abandonment Activities 4-79
4.6.3. Calendar Year 2020 Groundwater Monitoring 4-79
4.6.4. Y-12 National Security Complex Groundwater Quality 4-81
4.6.4.1. Upper East Fork Poplar Creek Hydrogeologic Regime 4-81
4.6.4.2. Bear Creek Hydrogeologic Regime 4-88
4.6.4.3. Chestnut Ridge Hydrogeologic Regime 4-93
4.7. Quality Assurance Program 4-95
4.8. Environmental Management and Waste Management Activities 4-97
4.8.1. Environmental Management 4-97
4.8.2. Waste Management 4-99
4.8.2.1. Comprehensive Environmental Response, Compensation, and Liability Act Waste Disposal 4-99
4.8.2.2. Solid Waste Disposal 4-99
4.8.2.3. Wastewater Treatment 4-99
4.9. References 4-101

5 Oak Ridge National Laboratory 5-1

5.1. Description of Site, Missions, and Operations 5-2
5.2. Environmental Management Systems 5-4
5.2.1. UT-Battelle Environmental Management System 5-5
5.2.1.1. Integration with the Integrated Safety Management System 5-5
5.2.1.2. UT-Battelle Environmental Policy for ORNL 5-5
5.2.1.3. Environmental Management System Planning 5-5
5.2.1.4. Site Sustainability 5-7
5.2.1.5. Storm Water Management and the Energy Independence and Security Act of 2007 5-12
5.2.1.6. Emergency Preparedness and Response 5-13
5.2.1.7. Environmental Management System Performance Evaluation 5-13
5.2.2. Environmental Management System for the Transuranic Waste Processing Center 5-14
5.2.3. Environmental Management System for Isotek 5-15

5.3. Compliance Programs and Status 5-15
5.3.1. Environmental Permits 5-16
5.3.2. National Environmental Policy Act/National Historic Preservation Act 5-18
5.3.3. Clean Air Act Compliance Status 5-18
5.3.4. Clean Water Act Compliance Status 5-19
5.3.5. Safe Drinking Water Act Compliance Status 5-21
5.3.6. Resource Conservation and Recovery Act Compliance Status 5-21
5.3.7. ORNL RCRA-CERCLA Coordination 5-23
5.3.7.1. CERCLA Activities in Bethel Valley 5-23
5.3.7.2. RCRA Underground Storage Tanks 5-23
5.3.8. CERCLA Compliance Status 5-24
5.3.9. Toxic Substances Control Act Compliance Status 5-24
5.3.10. Emergency Planning and Community Right-to-Know Act Compliance Status 5-24
5.3.10.1. Safety Data Sheet/Chemical Inventory (Section 312) 5-25
5.3.10.2. Toxic Chemical Release Reporting (EPCRA Section 313) 5-25
5.3.11. US Department of Agriculture/Tennessee Department of Agriculture 5-25
5.3.12. Wetlands 5-26
5.3.13. Radiological Clearance of Property at ORNL 5-26
5.3.13.1. Graded Approach to Evaluate Material and Equipment for Release 5-26
5.3.13.2. Authorized Limits Clearance Process for Spallation Neutron Source and High Flux Isotope Reactor Neutron Scattering Experiment Samples 5-27
5.4. Air Quality Program 5-28
5.4.1. Construction and Operating Permits 5-28
5.4.2. National Emission Standards for Hazardous Air Pollutants—Asbestos 5-28
5.4.3. Radiological Airborne Effluent Monitoring 5-28
5.4.3.1. Sample Collection and Analytical Procedure 5-29
5.4.3.2. Results 5-31
5.4.4. Stratospheric Ozone Protection 5-32
5.4.5. Ambient Air 5-33
5.5. ORNL Water Quality Program 5-33
5.5.1. Treatment Facility Discharges 5-35
5.5.2. Residual Bromine and Chlorine Monitoring 5-36
5.5.2.1. Leaks and Emergency Repairs 5-36
5.5.2.2. Outfalls and Cooling Tower Discharge 5-38
5.5.3. Radiological Monitoring 5-41

5.5.4. Mercury in the White Oak Creek Watershed 5-47
5.5.4.1. Buildings 3592 and 3503 5-47
5.5.4.2. Ambient Mercury in Water 5-48
5.5.4.3. Water Quality Protection Plan Mercury Investigation 5-50
5.5.4.4. Legacy Outfall Source Investigation 5-53
5.5.4.5. Baseline Preconstruction Investigation of 207 and 304 Storm Catch Basins 5-57
5.5.5. Storm Water Surveillances and Construction Activities 5-59
5.5.6. Biological Monitoring 5-59
5.5.6.1. Bioaccumulation Studies 5-59
5.5.6.2. Benthic Macroinvertebrate Communities 5-61
5.5.6.3. Fish Communities 5-68
5.5.7. Polychlorinated Biphenyls in the White Oak Creek Watershed 5-69
5.5.8. Oil Pollution Prevention 5-71
5.5.9. Surface Water Surveillance Monitoring 5-71
5.5.10. Carbon Fiber Technology Facility Wastewater Monitoring 5-73
5.6. ORNL Groundwater Monitoring Program 5-74
5.6.1. Summary of US Department of Energy Office of Environmental Management Groundwater Monitoring 5-74
5.6.1.1. Bethel Valley 5-74
5.6.1.2. Melton Valley 5-76
5.6.2. DOE Office of Science Groundwater Surveillance Monitoring 5-76
5.6.2.1. Exit Pathway Monitoring 5-77
5.6.2.2. Active Sites Monitoring—High Flux Isotope Reactor 5-82
5.6.2.3. Active Sites Monitoring—Spallation Neutron Source 5-82
5.6.2.4. Emerging Contaminant Assessment—Potential for Per- and Polyfluoroalkyl Substances in ORNL Area Groundwater 5-86
5.7. Quality Assurance Program 5-86
5.7.1. Work/Project Planning and Control 5-87
5.7.2. Personnel Training and Qualifications 5-87
5.7.3. Equipment and Instrumentation 5-87
5.7.3.1. Calibration 5-87
5.7.3.2. Standardization 5-88
5.7.3.3. Visual Inspection, Housekeeping, and Grounds Maintenance 5-88
5.7.4. Assessment 5-88
5.7.5. Analytical Quality Assurance 5-88

5.7.6. Data Management and Reporting 5-90
5.7.7. Records Management 5-90
5.8. Environmental Management and Waste Management Activities at ORNL 5-91
5.8.1. Wastewater Treatment 5-91
5.8.2. Newly Generated Waste Management 5-91
5.8.3. Transuranic Waste Processing Center 5-91
5.9. References 5-92

6 Oak Ridge Reservation Environmental Monitoring Program 6-1

6.1. Meteorological Monitoring 6-2
6.1.1. Data Collection and Analysis 6-2
6.1.2. Results 6-4
6.2. Ambient Air Monitoring 6-5
6.2.1. Data Collection and Analysis 6-5
6.2.2. Results 6-6
6.3. External Gamma Radiation Monitoring 6-7
6.3.1. Data Collection and Analysis 6-7
6.3.2. Results 6-8
6.4. Surface Water Monitoring 6-9
6.4.1. Data Collection and Analysis 6-9
6.4.2. Results 6-9
6.5. Groundwater Monitoring 6-11
6.5.1. Off-Site Groundwater Assessment 6-11
6.5.2. Regional and Site-Scale Flow Model 6-11
6.6. Food 6-12
6.6.1. Hay 6-12
6.6.1.1. Data Collection and Analysis 6-12
6.6.1.2. Results 6-12
6.6.2. Vegetables 6-12
6.6.2.1. Data Collection and Analysis 6-13
6.6.2.2. Results 6-13
6.6.3. Milk 6-13
6.6.4. Fish 6-13
6.6.4.1. Data Collection and Analysis 6-15
6.6.4.2. Results 6-16
6.6.5. White-Tailed Deer 6-16

6.6.6. Waterfowl 6-16
6.6.6.1. Data Collection and Analysis 6-16
6.6.6.2. Results 6-16
6.6.7. Wild Turkey 6-16
6.7. Invasive Plant Management 6-16
6.8. Fire Protection Management and Planning 6-20
6.9. Quality Assurance 6-22
6.10. References 6-23

7 Dose 7-1

7.1. Radiation Dose 7-2
7.1.1. Terminology 7-2
7.1.2. Methods of Evaluation 7-2
7.1.2.1. Airborne Radionuclides 7-2
7.1.2.2. Waterborne Radionuclides 7-9
7.1.2.3. Radionuclides in Food 7-13
7.1.2.4. Direct Radiation 7-16
7.1.3. Current-Year Summary 7-16
7.1.4. Five-Year Trends 7-18
7.1.5. Doses to Aquatic and Terrestrial Biota 7-18
7.1.5.1. Aquatic Biota 7-18
7.1.5.2. Terrestrial Biota 7-20
7.2. Chemical Dose 7-20
7.2.1. Drinking Water Consumption 7-21
7.2.1.1. Surface Water 7-21
7.2.1.2. Groundwater 7-22
7.2.2. Fish Consumption 7-22
7.3. References 7-24

Figures

Figure *Page*

1 Introduction to the Oak Ridge Reservation

1.1. Location of the Oak Ridge Reservation in Tennessee 1-4

1.2. Map of the Oak Ridge Reservation 1-4

1.3. Location of Oak Ridge Reservation wetlands 1-8

1.4. American woodcock fledgling on ORR 1-12

1.5. Bald eagle photographed on ORR 1-12

1.6. Purple gallinule caught on a trail surveillance camera at ETTP in 2017 1-13

1.7. Aerial view of the Oak Ridge National Laboratory 1-17

1.8. Aerial view of the Y-12 National Security Complex 1-19

1.9. Aerial view of East Tennessee Technology Park 1-21

1.10. Aerial view of the Environmental Management Waste Management Facility 1-22

1.11. Location of the Oak Ridge National Environmental Research Park 1-23

3 East Tennessee Technology Park

3.1. The K-25 Site in 1946 3-3

3.2. East Tennessee Technology Park since the start of decontamination and decommissioning activities in 1991 3-3

3.3. East Tennessee Technology Park in 2020, showing progress in reindustrialization 3-4

3.4. Pollution prevention recycling activities related to solid waste reduction at the East Tennessee Technology Park in calendar year 2020 3-6

3.5. Oak Ridge Powerhouse Six Solar Farm 3-7

3.6. East Tennessee Technology Park National Pollutant Discharge Elimination System permit noncompliances since 2012 3-11

3.7. East Tennessee Technology Park total on-site ozone-depleting substances inventory, 10-year history 3-19

3.8. East Tennessee Technology Park stationary source greenhouse gas emissions tracking history 3-22

3.9. East Tennessee Technology Park greenhouse gas annual emissions (Scopes 1 and 2, including industrial landfills at Y-12) 3-23

3.10. Fiscal year 2020 East Tennessee Technology Park greenhouse gas emissions by scope 3-24

3.11. East Tennessee Technology Park ambient air monitoring station 3-25

3.12. East Tennessee Technology Park ambient air monitoring station locations 3-26

3.13. Storm water outfall monitoring 3-28

3.14. K-1200 Complex before decontamination and demolition 3-32

3.15. K-1200 Complex after decontamination and demolition 3-32

3.16. Mercury concentrations at Outfall 180 3-34

3.17. Mercury concentrations at Outfall 190 3-34

3.18. Mercury concentrations at the K-1700 Weir 3-35

3.19. Mercury concentrations at Outfall 05A-2 3-35

3.20. The Chromium Water Treatment System 3-38

3.21. Total chromium sample results for the chromium collection system 3-39

3.22. Hexavalent chromium sample results for the chromium collection system 3-39

3.23. Surface water surveillance monitoring 3-40

3.24. East Tennessee Technology Park Environmental Monitoring Program surface water monitoring locations 3-40

3.25. Annual average percentage of derived concentration standards at surface water monitoring locations, 2020 3-41

3.26. Trichloroethene concentrations in Mitchell Branch 3-43

3.27. Total chromium concentrations in Mitchell Branch 3-43

3.28. East Tennessee Technology Park volatile organic compound and ^{99}Tc plumes 3-48

3.29. Water bodies at the East Tennessee Technology Park 3-50

3.30. Major storm water outfalls and biological monitoring locations on Mitchell Branch 3-51

3.31. Mean total PCB (Top: µg/g, wet wt; 1993–2020) and mercury (Bottom: µg/g wet wt; 2009–2020) concentrations in the soft tissues of caged Asiatic clams deployed in Mitchell Branch 3-54

3.32. Total (top panel) and methylmercury (bottom panel) concentrations in the soft tissues of caged Asiatic clams deployed in Mitchell Branch (µg/g wet wt; 2009–2020) 3-55

3.33. Mean PCB (top panel) and mercury (bottom panel) concentrations (µg/g, wet wt) in redbreast sunfish fillets in Mitchell Branch (MIK 0.2) 3-56

3.34. Mean aqueous total PCB concentrations, total suspended solids, and vegetation cover in the K-1007-P1 Pond, 2007–2020 3-57

3.35. Mean total PCB concentrations (µg/g, wet wt) in caged clams placed at K-1007-P1 outfalls compared with reference stream clams (Little Sewee Creek), 1993–2020 3-58

3.36. Mean PCB concentrations (µg/g, wet wt) in fish from the K-1007-P1 Pond, 2007–2020 3-59

3.37. Mean (+1 standard error) total PCB concentrations (µg/g, wet wt) in whole body fish from K1007-P1 Pond, K-901-A Holding Pond, and K-720 Slough, 2009–2020 3-61

3.38. Mean total PCB concentrations in largemouth bass from the K-901-A Pond and the K-720 Slough 3-62

3.39. Mean total PCB (µg/g, wet wt; 1993–2020) concentrations in the soft tissues of caged Asiatic clams deployed in the K-901-A Pond for a 4-week period 3-63

3.40. Mean total PCB (µg/g, wet wt; 2009–2020) concentrations in the fillets of largemouth bass, common carp, and smallmouth buffalo collected from the K-720 Slough 3-64

3.41. Collecting an invertebrate sample using Oak Ridge National Laboratory Biological Monitoring and Abatement Program protocols 3-66

3.42. Sampling for benthic macroinvertebrates with TDEC protocols 3-66

3.43. Mean (± 95% confidence interval) total taxonomic richness (top) and richness of the pollution-intolerant taxa per sample (bottom) for Mitchell Branch sites, April 1987–2020 3-69

3.44. Mean percent density of pollution-intolerant taxa and of the pollution-tolerant Orthocladiinae midge larvae (Chironomidae) at Mitchell Branch sites, April 1987–2020 3-70

3.45. Temporal trends in the TDEC Macroinvertebrate Index (top) and Stream Habitat Index (bottom) scores for four Mitchell Branch sites, August 2008–2020 3-71

3.46. Mean total taxonomic richness (top) and pollution-intolerant taxa per sample (bottom) for the benthic macroinvertebrate community at Mitchell Branch and reference sites, April 2005–2020 3-74

3.47. Mean percent density of pollution-intolerant taxa (top) and pollution-tolerant Chironomidae (bottom) in Mitchell Branch, with reference site mean values, April 2005–2020 3-75

3.48. Construction of lined section of Mitchell Branch, MIK 0.7, in 1998 3-76

3.49. More recent habitat conditions at Mitchell Branch in 2020 3-76

3.50. Species richness for the fish communities at sites in Mitchell Branch and in reference streams Mill Branch, Scarboro Creek, and Ish Creek, 1987–2020 3-77

3.51. Density for the fish communities at sites in Mitchell Branch and in reference streams Mill Branch, Scarboro Creek, and Ish Creek, 1987–2020 3-78

3.52. Biomass for the fish communities at sites in Mitchell Branch and in reference streams Mill Branch, Scarboro Creek, and Ish Creek, 1987–2020 3-78

3.53. Sensitive fish species observed in lower Mitchell Branch 3-79

3.54. Changes in the K-1007-P1 Pond fish community from 2007 to 2020 3-81

3.55. Exhibit at the K-25 History Center 3-82

4 **The Y-12 National Security Complex**

4.1. Age of facilities at Y-12 4-3

4.2. The Environmental Management System plan-do-check-act cycle of continual improvement 4-6

4.3. Y-12's environment, safety, and health policy 4-6

4.4. Cost efficiencies from Y-12 pollution prevention activities 4-11

4.5. Y-12 pollution prevention initiatives 4-12

4.6. Y-12 recycling results 4-13

4.7. Y-12 energy intensity chart with baseline 4-14

4.8. Water intensity reduction with baseline 4-18

4.9. National Environmental Policy Act—an umbrella law 4-24

4.10. Conceptual layout of Oak Ridge Enhanced Technology and Training Center facilities at the proposed site 4-27

4.11. Proposed location of the Oak Ridge Enhanced Technology and Training Center 4-28

4.12. Proposed Oak Ridge Enhanced Technology and Training Center location and land transfers 4-29

4.13. Artist rendering of proposed Oak Ridge Enhanced Technology and Training Center 4-30

4.14. Biology Complex on the east side of Y-12 4-31

4.15. Lithium Processing Facility construction footprint 4-32

4.16. Artist rendering of the Lithium Processing Facility 4-33

4.17. Horizon Center Industrial Park 4-33

4.18. 103 Palladium Way facility and surrounding 21 acres 4-34

4.19. Path to eliminate Y-12's legacy mixed waste inventory by fiscal year 4-37

4.20. Hazardous waste generation, 2016–2020 4-38

4.21. Total curies of uranium discharged from Y-12 to the atmosphere, 2015–2020 4-46

4.22. Locations of ambient air monitoring stations at Y-12 4-52

4.23. Temporal trends in mercury vapor concentration for boundary monitoring stations at Y-12 4-54

4.24. Major Y-12 National Pollutant Discharge Elimination System outfalls and monitoring locations 4-57

4.25. Surface water and sanitary sewer radiological sampling locations at Y-12 4-61

4.26. Six-year trend of Y-12 uranium releases to East Fork Poplar Creek ... 4-62

4.27. Y-12 storm water monitoring locations, East Fork Poplar Creek ... 4-64

4.28. Surface Water Hydrological Information Support System monitoring locations ... 4-65

4.29. Biological monitoring sites locations on East Fork Poplar Creek relative to Y-12 ... 4-69

4.30. Biological monitoring reference sites locations relative to Y-12 ... 4-70

4.31. Semiannual average mercury concentration in muscle fillets of redbreast sunfish and water from East Fork Poplar Creek, fiscal year 2020 ... 4-71

4.32. Annual mean concentrations of polychlorinated biphenyls in rock bass muscle fillets, fiscal year 2020 ... 4-72

4.33. Benthic macroinvertebrate communities in three sites along East Fork Poplar Creek and the 95 percent confidence interval for two nearby reference streams ... 4-74

4.34. Comparison of mean sensitive species richness collected each year from four sites in East Fork Poplar Creek and a reference site ... 4-75

4.35. Fish density for two sites in Upper East Fork Poplar Creek and a reference site, 1996–2020 ... 4-76

4.36. Known or potential contaminant source areas where groundwater is monitored at the Y-12 National Security Complex ... 4-77

4.37. Hydrogeologic regimes, flow directions, perimeter/exit pathway locations, and position of Maynardville Limestone at the Y-12 National Security Complex ... 4-78

4.38. Groundwater elevation contours and flow directions at the Y-12 National Security Complex ... 4-79

4.39. Groundwater monitoring well sampling at the Y-12 National Security Complex ... 4-81

4.40. Nitrate in groundwater at the Y-12 National Security Complex, 2020 ... 4-82

4.41. Summed volatile organic compounds in groundwater at the Y-12 National Security Complex, 2020 ... 4-83

4.42. Gross-alpha activity in groundwater at the Y-12 National Security Complex, 2020 ... 4-84

4.43. Gross-beta activity in groundwater at the Y-12 National Security Complex, 2020 ... 4-85

4.44. Summed volatile organic compounds for GW-382 and GW-383 in the East Fork regime ... 4-85

4.45. Summed volatile organic compounds for GW-151 and GW-220 in the East Fork regime ... 4-86

4.46. Nitrate and gross-beta trends for GW-537 in the Bear Creek regime ... 4-89

4.47. Volatile organic compounds in GW-627 at the Bear Creek Burial Ground waste management area ... 4-90

4.48. Volatile organic compounds in GW-082 at the Bear Creek Burial Grounds ... 4-91

4.49. Concentrations of selected contaminants in exit pathway monitoring wells in the Bear Creek hydrogeologic regime 4-92

5 Oak Ridge National Laboratory

5.1. Location of ORNL within ORR and its relationship to other local DOE facilities 5-3

5.2. Carbon Fiber Technology Facility 5-4

5.3. Recent, current (FY 2020), and projected energy use intensity at ORNL 5-9

5.4. Historical and current (FY 2020) water use intensity at ORNL 5-11

5.5. The rare earth recycling process at ORNL 5-11

5.6. Locations of major radiological emission points at ORNL, 2020 5-30

5.7. Total curies of tritium discharged from ORNL to the atmosphere, 2016–2020 5-32

5.8. Total curies of ^{131}I discharged from ORNL to the atmosphere, 2016–2020 5-32

5.9. Total curies of ^{41}Ar, ^{138}Cs, and ^{212}Pb discharged from ORNL to the atmosphere, 2016–2020 5-33

5.10. Diagram of the adaptive management framework with step-wise planning specific to the ORNL Water Quality Protection Plan 5-34

5.11. Application of stressor identification guidance to address mercury impairment in the White Oak Creek watershed 5-35

5.12. Selected surface water, National Pollutant Discharge Elimination System, and reference sampling locations at ORNL, 2020 5-44

5.13. Outfalls and instream locations at ORNL with average radionuclide concentrations greater than 4 percent of the relevant derived concentration standards in 2020 5-45

5.14. Cesium-137 discharges at White Oak Dam, 2016−2020 5-46

5.15. Gross alpha discharges at White Oak Dam, 2016−2020 5-46

5.16. Gross beta discharges at White Oak Dam, 2016−2020 5-46

5.17. Total radioactive strontium discharges at White Oak Dam, 2016−2020 5-46

5.18. Tritium discharges at White Oak Dam, 2016−2020 5-47

5.19. Annual flow volume at White Oak Dam, 2016−2020 5-47

5.20. Outfalls 211 and 207 and associated storm drain connections that are potential mercury sources 5-48

5.21. Instream mercury monitoring and data locations, 2020 5-49

5.22. Aqueous mercury concentrations at sites in White Oak Creek downstream from ORNL, 1998–2020 5-50

5.23. Total mercury concentration in discharges to Outfall X01 from the Sewage Treatment Plant, 2010–2020 5-51

5.24. Total mercury concentrations and fluxes in Process Waste Treatment Complex discharges to Outfall X12, 2008–2020 5-51

5.25. Locations and data for instream sampling sites coordinated with treatment plant sampling 5-52

5.26. Mercury concentrations and fluxes of treatment plant discharges compared with instream values at WCK 4.4 (no flux available), WCK 3.4, and X15 (White Oak Dam) 5-53

5.27. Dissolved and total mercury concentrations of legacy outfalls compared to instream (total mercury) values at WCK 4.4, WCK 3.4, and X15 (White Oak Dam) 5-55

5.28. Outfall 211 dry-weather flow, concentration, and flux 2012–2020 5-56

5.29. Outfall 211 storm flow, dissolved and total mercury flux 2015–2020 5-56

5.30. Outfall 207 storm flow, dissolved Hg flux, and total Hg flux 5-57

5.31. Preconstruction surveillance of Outfalls 207 and 304 storm drainage catch basins 5-58

5.32. Mean mercury concentrations in muscle tissue of sunfish and bass sampled from the White Oak Creek watershed, 1998–2020 5-60

5.33. Mean total PCB concentrations in fish sampled from the White Oak Creek watershed, 1998–2020 5-61

5.34. Benthic macroinvertebrate communities in First Creek 5-62

5.35. Benthic macroinvertebrate communities in Fifth Creek 5-63

5.36. Benthic macroinvertebrate communities in Walker Branch, Melton Branch, and White Oak Creek 5-64

5.37. Temporal trends in Tennessee Department of Environment and Conservation Tennessee Macroinvertebrate Index scores for White Oak Creek watershed streams, August sampling 5-66

5.38. Fish species richness (number of species) in upper White Oak Creek and lower Melton Branch compared with two reference streams, Brushy Fork and Mill Branch, 1985–2020 5-68

5.39. Locations of monitoring points for First Creek source investigation 5-70

5.40. ORNL surface water sampling locations, 2020 5-72

5.41. UT-Battelle exit pathway groundwater monitoring locations at ORNL, 2020 5-78

5.42. Groundwater monitoring locations at the Spallation Neutron Source, 2020 5-83

5.43. Simple hydrograph of spring discharge vs. time after initiation of rainfall 5-84

6 Oak Ridge Reservation Environmental Monitoring Program

6.1. The ORR meteorological monitoring network, including sonic detection and ranging (SODAR) devices....6-4

6.2. ORR ambient air station....6-5

6.3. Locations of ORR perimeter air monitoring stations....6-6

6.4. External gamma radiation monitoring locations on ORR....6-8

6.5. ORR surface water surveillance sampling locations....6-10

6.6. Fish-sampling locations for the ORR Surveillance Program....6-14

6.7. Map of invasive plant treatment areas on ORR for 2020....6-19

6.8. Wildland management units on ORR....6-21

7 Dose

7.1. Location of the maximally exposed individual for ORR (2020 data)....7-5

7.2. Nuclides contributing to effective dose at Y-12 Complex, 2020....7-6

7.3. Nuclides contributing to effective dose at ORNL, 2020....7-7

7.4. Nuclides contributing to effective dose at ETTP, 2020....7-7

Tables

Table *Page*

1 Introduction to the Oak Ridge Reservation

1.1. Animal species of special concern reported on the Oak Ridge Reservation....................................1-9

1.2. Vascular plant species listed by state or federal agencies and sighted or reported on or near the Oak Ridge Reservation.. 1-14

2 Compliance Summary and Community Involvement

2.1. Applicable environmental laws and regulations and 2020 status 2-4

2.2. Summary of regulatory environmental audits, evaluations, inspections, and assessments conducted at ORR, 2020 2-9

3 East Tennessee Technology Park

3.1. Surface contamination values and DOE Order 458.1 authorized limits for surface activity 3-10

3.2. East Tennessee Technology Park environmental permits, 2020.. 3-13

3.3. Regulatory oversight, assessments, inspections, and site visits at East Tennessee Technology Park, 2020.. 3-14

3.4. Radionuclides in ambient air at East Tennessee Technology Park, January 2020 through December 2020 3-20

3.5. Radionuclides released to off-site waters from the East Tennnessee Technology Park storm water system in 2020.. 3-28

3.6. Analytical results exceeding reference standards from the Outfall 05A-2 sampling effort, February 6, 2020.. 3-29

3.7. Analytical results exceeding reference standards from quarterly SWPPP monitoring at Outfall 05A-2, March 3, 2020, May 19, 2020, August 13, 2020, and October 29, 2020 3-30

3.8. Analytical results exceeding reference standards from Outfall 382 monitoring, February 10, 2020.. 3-30

3.9. Analytical results exceeding reference standards from samples collected at Outfall 362, February 11, 2020 3-31

3.10. Analytical results for monitoring of storm water runoff from building slabs................................... 3-32

3.11. Quarterly NPDES/SWPP Program mercury monitoring results, calendar year 2020.................. 3-33

3.12. Analytical results from mercury sampling at selected storm water outfalls.................................... 3-36

3.13. Analytical results exceeding reference standards from samples collected at Powerhouse storm water outfalls 3-36

3.14. Results exceeding reference standards for the Outfall 780 monitoring effort 3-37

3.15. Analytical results from fiscal year 2020 SWPP Program PCB sampling 3-37

3.16. Analytical results from Outfall 690 network sampling, December 14, 2020 3-38

3.17. East Tennessee Technology Park Site PFAS (PFOA/PFOS) surface water reconnaissance results 3-44

3.18. Average concentrations of total PCBs in fillets and whole-body composites of fish collected in 2020 near the East Tennessee Technology Park 3-65

3.19. Stream sites included in the comparison between Mitchell Branch and other reference sites on the Oak Ridge Reservation 3-67

3.20. Tennessee Macroinvertebrate Index metric values and scores and index score for Mitchell Branch, August 19, 2020 3-72

4 The Y-12 National Security Complex

4.1. Fiscal year 2020 sustainability goals and performance 4-15

4.2. Summary of external regulatory audits and reviews, 2020 4-20

4.3. Y-12 environmental permits, calendar year 2020 4-21

4.4. National Nuclear Security Administration-approved categorical exclusions 4-26

4.5. Emergency Planning and Community Right-to-Know Act Section 313 toxic chemical release and off-site transfer summary for Y-12, 2019–2020 4-39

4.6. Summary of materials released, 2020 4-41

4.7. DOE Order 458.1 preapproved authorized limits 4-42

4.8. Actual versus allowable air emissions from the Y-12 steam plant, 2020 4-45

4.9. Greenhouse gas emissions from Y-12 stationary fuel combustion sources 4-49

4.10. Data summary for Y-12's Ambient Air Monitoring Program for mercury, calendar year 2020 4-53

4.11. National Pollutant Discharge Elimination System compliance monitoring requirements and record for Y-12, January–December 2020 4-58

4.12. Radiological parameters monitored at Y-12, 2020 4-60

4.13. Summary of Y-12's radiological monitoring plan sample requirements and 2020 results 4-61

4.14. Uranium release from Y-12 to the off-site environment as liquid effluent, 2014–2020 4-62

4.15. Mercury concentrations at Outfall 014 4-64

4.16. Y-12 discharge point SS6 4-66

4.17. Serial dilutions for whole effluent toxicity testing, as a percent of effluent.................................... 4-67

4.18. Y-12 biomonitoring program summary information for Outfalls 200 and 135, 2020 4-68

4.19. Summary of groundwater monitoring at the Y-12 National Security Complex, 2020................. 4-80

4.20. Nitrate and uranium concentrations in Bear Creek... 4-90

4.21. PFAS concentrations 4-95

5 Oak Ridge National Laboratory

5.1. Summary of regulatory environmental audits, evaluations, inspections, and assessments conducted at ORNL, 2020.. 5-15

5.2. Environmental permits in effect at ORNL in 2020 5-16

5.3. National Environmental Policy Act activities, 2020 5-18

5.4. National Pollutant Discharge Elimination System compliance at ORNL, January through December 2020... 5-20

5.5. ORNL Resource Conservation and Recovery Act operating permits, 2020 5-22

5.6. Main elements of the Emergency Planning and Community Right-to-Know Act.............................. 5-25

5.7. Excess items requested for release and/or recycling, 2020.. 5-27

5.8. Radionuclide concentrations measured at ORNL air monitoring Station 7, 2020.......................... 5-33

5.9. Total residual oxidant mitigation summary: Emergency repairs, 2020... 5-37

5.10. Total residual oxidant mitigation summary: Cooling tower outfalls exceeding the total residual oxidant NPDES action level, 2020.. 5-40

5.11. Radiological monitoring conducted under the ORNL Water Quality Protection Plan, 2020 5-43

5.12. Tennessee Macroinvertebrate Index metric values, metric scores, and index scores for White Oak Creek, First Creek, Fifth Creek, and Melton Branch, August 15 and 16, 2020 5-67

5.13. ORNL surface water sampling locations, frequencies, and parameters, 2020.............................. 5-73

5.14. Industrial and commercial user wastewater discharge permit compliance at the ORNL Carbon Fiber Technology Facility, 2020.. 5-73

5.15. Exit pathway groundwater monitoring conducted in 2020 5-79

5.16. Radiological parameters detected in 2020 exit pathway groundwater monitoring..................... 5-80

5.17. 2020 Spallation Neutron Source monitoring program schedule 5-84

5.18. Radiological concentrations detected in samples collected at the Spallation Neutron Source during 2020 5-85

6 Oak Ridge Reservation Environmental Monitoring Program

6.1. ORR meteorological towers 6-3

6.2. Radionuclide concentrations at ORR perimeter air monitoring stations, 2020 6-7

6.3. External gamma exposure rate averages for ORR, 2020 6-9

6.4. ORR surface water sampling locations, frequencies, and parameters, 2020..................... 6-11

6.5. Concentrations of radionuclides detected in hay, July 2020 (pCi/kg) 6-13

6.6. Concentrations of radionuclides detected in tomatoes, 2020 (pCi/kg).......................... 6-14

6.7. Tissue concentrations in catfish and sunfish for detected mercury, PCBs, and radionuclides, 2020 6-15

6.8. Ten most problematic invasive plants on the ORR 6-17

6.9. Invasive plant control on ORR, 2003–2020 6-18

7 Dose

7.1. Emission point parameters and receptor locations used in the dose calculations, 2020.................. 7-3

7.2. Meteorological towers and heights used to model atmospheric dispersion from source emissions, 2020 7-4

7.3. Calculated radiation doses to maximally exposed individuals from airborne releases from ORR, 2020 7-6

7.4. Calculated collective effective doses from airborne releases, 2020 7-6

7.5. Hypothetical effective doses from living near ORR and ETTP ambient air monitoring stations, 2020.. 7-8

7.6. Summary of annual maximum individual (mrem) and collective (person-rem) effective doses from waterborne radionuclides, 2020 7-13

7.7. Summary of maximum estimated effective doses from ORR activities to an adult by exposure pathway, 2020.. 7-17

7.8. Trends in effective dose from ORR activities, 2016–2020 (mrem)............................... 7-18

7.9. Chemical hazard quotients and estimated risks for drinking water from the Clinch River at CRK 23 and 16, 2020.. 7-21

7.10. Chemical hazard quotients and estimated risks for fish caught and consumed from locations on ORR, 2020.. 7-23

Appendices

A. Glossary A-1

B. Climate Overview of the Oak Ridge Area B-1

C. Reference Standards and Data for Water C-1

D. National Pollutant Discharge Elimination System Noncompliance Summaries for 2020 .... D-1

E. Radiation E-1

F. Chemicals F-1

G. Radiological Airborne Emissions at Oak Ridge National Laboratory G-1

Acronyms and Abbreviations

A	ACM	asbestos-containing material
	AFFF	aqueous film-forming foams
	ANSI	American National Standards Institute
	AOEC	Agent Operations Eastern Command
	AROD	amended record of decision
	ASER	*Oak Ridge Reservation Annual Site Environmental Report*
	AWQC	ambient water quality criterion
B	BCG	biota concentration guide
	BCK	Bear Creek kilometer
	BFK	Brushy Fork kilometer
	BMAP	Biological Monitoring and Abatement Program
C	CAA	Clean Air Act
	CAP-88	Clean Air Act Assessment Package (software)
	CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act of 1980
	CFR	*Code of Federal Regulations*
	CFTF	Carbon Fiber Technology Facility
	CNS	Consolidated Nuclear Security, LLC
	COLEX	column exchange
	CRK	Clinch River kilometer
	CROET	Community Reuse Organization of East Tennessee
	CWA	Clean Water Act
	CWTS	ETTP Chromium Water Treatment System
	CY	calendar year
D	DCE	dichloroethene/dichloroethylene
	DCS	derived concentration standard
	DMRQA	Discharge Monitoring Report Quality Assurance Study
	DOD-ELAP	US Department of Defense Environmental Laboratory Accreditation Program
	DOE	US Department of Energy
	DOECAP	DOE Consolidated Audit Program
	DU	depleted uranium
E	EA	environmental assessment
	EC&P	environmental compliance and protection
	ECD	Y-12 Environmental Compliance Department
	ED	effective dose
	EESP	Energy Efficiency and Sustainability Program

	EFK	East Fork Poplar Creek kilometer
	EFPC	East Fork Poplar Creek
	EM	DOE Office of Environmental Management
	EMS	environmental management system
	EMWMF	Environmental Management Waste Management Facility
	EO	executive order
	EPA	US Environmental Protection Agency
	EPCRA	Emergency Planning and Community Right-to-Know Act
	EPEAT	Electronic Product Environmental Assessment Tool
	EPSD	UT-Battelle Environmental Protection Services Division
	EPT	ephemeroptera, plecoptera, and trichoptera (taxa)
	e-RICE	emergency reciprocating internal combustion engine
	ES&H	environment, safety, and health
	ESPC	Energy Savings and Performance Contract
	ESS	ORNL Environmental Surveillance System
	ETTP	East Tennessee Technology Park
	EU	exposure unit
F	FCK	First Creek kilometer
	FFK	Fifth Creek kilometer
	FMD	ORNL Facilities Management Division
	FWS	US Fish and Wildlife Service
	FY	fiscal year
G	GHG	greenhouse gas
H	HFIR	High Flux Isotope Reactor
	HPSB	high-performance sustainable building
	HQ	hazard quotient
	HVC	ORNL Hardin Valley Campus
I	IC_{25}	25-percent inhibition concentration
	ISMS	integrated safety management system
	ISO	International Organization for Standardization
	Isotek	Isotek Systems, LLC
L	LEED	Leadership in Energy and Environmental Design
	LLW	low-level radioactive waste
	LPF	Lithium Processing Facility
M	M&E	material and equipment
	MAPEP	Mixed Analyte Performance Evaluation Program
	MARSAME	*Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual*

	MARSSIM	*Multi-Agency Radiation Survey and Site Investigation Manual*
	MBK	Mill Branch kilometer
	MCK	McCoy Branch kilometer
	MCL	maximum contaminant level
	MEI	maximally exposed individual
	MEK	Melton Branch kilometer
	MIK	Mitchell Branch kilometer
	MOA	memorandum of agreement
	MSRE	Molten Salt Reactor Experiment
	MT	meteorological tower
N	NAAQS	National Ambient Air Quality Standards
	NELAP	National Environmental Laboratory Accreditation Program
	NEPA	National Environmental Policy Act
	NESHAPs	National Emission Standards for Hazardous Air Pollutants
	NNSA	National Nuclear Security Administration
	NPDES	National Pollutant Discharge Elimination System
	NPO	NNSA Production Office
	NRC	US Nuclear Regulatory Commission
	NRHP	National Register of Historic Places
	NTRC	National Transportation Research Center
	NWSol	North Wind Solutions, LLC
O	ODS	ozone-depleting substance
	OLCF	Oak Ridge Leadership Computing Facility
	OREM	DOE Oak Ridge Office of Environmental Management
	ORETTC	Oak Ridge Enhanced Technology and Training Center
	ORGDP	Oak Ridge Gaseous Diffusion Plant
	ORISE	Oak Ridge Institute for Science and Education
	ORNL	Oak Ridge National Laboratory
	ORO	DOE Oak Ridge Office
	ORR	Oak Ridge Reservation
	ORSSAB	Oak Ridge Site Specific Advisory Board
	OST	Office of Secure Transportation
P	P2	pollution prevention
	PCB	polychlorinated biphenyl
	PCBADL	Polychlorinated Biphenyl Annual Document Log
	PCCR	phased construction completion report
	PCE	tetrachloroethene
	PFAS	per- and polyfluoroalkyl substances
	PFOA	perfluorooctanoic acid
	PFOS	perfluorooctane sulfonate
	PM_{10}	particulate matter with an aerodynamic diameter ≤ 10 µm

	$PM_{2.5}$	fine particulate matter with an aerodynamic diameter ≤ 2.5 µm
	PWTC	Process Waste Treatment Complex
Q	QA	quality assurance
	QC	quality control
	QMS	quality management system
R	R&D	research and development
	RA	remedial action
	Rad-NESHAPs	National Emission Standards for Hazardous Air Pollutants for
	RCRA	Resource Conservation and Recovery Act
	RMAL	Radiochemical Materials Analytical Laboratory
	ROD	record of decision
	RSI	Restoration Services, Inc.
S	SA	supplement analysis
	SARA	Superfund Amendments and Reauthorization Act
	SBMS	UT-Battelle Standards-Based Management System
	SC	DOE Office of Science
	SD	storm water outfall/storm drain
	SNS	Spallation Neutron Source
	SODAR	sonic detection and ranging
	SOF	sum of fractions
	SOP	state operating permit
	SPCC	spill prevention, control, and countermeasures
	SSP	site sustainability plan
	STP	sewage treatment plant
	SWEIS	sitewide environmental impact statement
	SWPP	storm water pollution prevention
	SWPPP	storm water pollution prevention plan
	SWSA	solid waste storage area
T	TCE	trichloroethene/trichloroethylene
	TDEC	Tennessee Department of Environment and Conservation
	TEMA	Tennessee Emergency Management Agency
	TMDL	total maximum daily load
	TMI	Tennessee Macroinvertebrate Index
	TRI	toxic chemical release inventory
	TRO	total residue oxidant
	TRU	transuranic
	TSCA	Toxic Substances Control Act
	TSS	total suspended solids
	TVA	Tennessee Valley Authority
	TWPC	Transuranic Waste Processing Center

	TWRA	Tennessee Wildlife Resources Agency
U	UPF	Uranium Processing Facility
	USDA	US Department of Agriculture
	UST	underground storage tank
	UT	University of Tennessee
	UT-Battelle	UT-Battelle, LLC
V	VOC	volatile organic compound
W	WBK	Walker Branch kilometer
	WCK	White Oak Creek kilometer
	WEPAR	West End Protected Area Reduction
	WOC	White Oak Creek
	WOD	White Oak Dam
	WQC	water quality criterion
	WQPP	water quality protection plan
	WRRP	Water Resources Restoration Program
Y	Y-12 or Y-12 Complex	Y-12 National Security Complex

Units of Measure and Conversion Factors*

Units of measure and their abbreviations			
acre	acre	micrometer	µm
becquerel	Bq	millicurie	mCi
British thermal unit	Btu	milligram	mg
centimeter	cm	milliliter	mL
curie	Ci	millimeter	mm
day	d	million	M
degrees Celsius	°C	million gallons per day	MGD
degrees Fahrenheit	°F	millirad	mrad
disintegrations per minute	dpm	millirem	mrem
foot	ft	milliroentgen	mR
gallon	gal	millisievert	mSv
gallons per minute	gal/min	minute	min
gram	g	nanogram	ng
gray	Gy	nephelometric turbidity unit	NTU
gross square feet	gsf	parts per billion	ppb
hectare	ha	parts per million	ppm
hour	h	parts per trillion	ppt
inch	in.	picocurie	pCi
joule	J	pound	lb
kilocurie	kCi	pound mass	lbm
kilogram	kg	pounds per square inch	psi
kilometer	km	pounds per square inch gauge	psig
kilowatt	kW	quart	qt
linear feet	LF	rad	rad
liter	L	roentgen	R
megajoule	MJ	roentgen equivalent man	rem
megawatt	MW	second	S
megawatt-hour	MWh	sievert	Sv
meter	m	standard unit (pH)	SU
metric tons	MT	ton, short (2,000 lb)	ton
microcurie	µCi	yard	yd
microgram	µg	year	yr

Quantitative prefixes			
exa	$\times 10^{18}$	atto	$\times 10^{-18}$
peta	$\times 10^{15}$	femto	$\times 10^{-15}$
tera	$\times 10^{12}$	pico	$\times 10^{-12}$
giga	$\times 10^{9}$	nano	$\times 10^{-9}$
mega	$\times 10^{6}$	micro	$\times 10^{-6}$
kilo	$\times 10^{3}$	milli	$\times 10^{-3}$
hecto	$\times 10^{2}$	center	$\times 10^{-2}$
deka	$\times 10^{1}$	decic	$\times 10^{-1}$

**Due to differing permit reporting requirements and instrument capabilities, various units of measurement are used in this report. This list of units of measure and conversion factors is intended to help readers make approximate conversions to other units as needed for specific calculations and comparisons.*

Unit conversions

Unit	Conversion	Equivalent	Unit	Conversion	Equivalent
Length					
in.	× 2.54	cm	cm	× 0.394	in.
ft	× 0.305	m	m	× 3.28	ft
mile	× 1.61	km	km	× 0.621	mile
Area					
acre	× 0.405	ha	ha	× 2.47	acre
ft^2	× 0.093	m^2	m^2	× 10.764	ft^2
$mile^2$	× 2.59	km^2	km^2	× 0.386	$mile^2$
Volume					
ft^3	× 0.028	m^3	m^3	× 35.31	ft^3
qt (US liquid)	× 0.946	L	L	× 1.057	qt (US liquid)
gal	× 3.7854118	L	L	× 0.264172051	gal
Concentration					
ppb	× 1	µg/kg	µg/kg	× 1	ppb
ppm	× 1	mg/kg	mg/kg	× 1	ppm
ppb	× 1	µg/L	µg/L	× 1	ppb
ppm	× 1	mg/L	mg/L	× 1	ppm
Weight					
lb	× 0.4536	kg	kg	× 2.205	lb
lbm	× 0.45356	kg	kg	× 2.2046226	lbm
ton, short	× 907.1847	kg	kg	× 0.00110231131	ton, short
Temperature					
°C	°F = (9/5)°C + 32	°F	°F	°C = (5/9) (F–32)	°C
Activity					
Bq	$\times 2.7 \times 10^{-11}$	Ci	Ci	$\times 3.7 \times 10^{10}$	Bq
Bq	× 27	pCi	pCi	× 0.037	Bq
mSv	× 100	mrem	mrem	× 0.01	mSv
Sv	× 100	rem	rem	× 0.01	Sv
nCi	× 1,000	pCi	pCi	× 0.001	nCi
mCi/km^2	× 1	nCi/m^2	nCi/m^2	× 1	mCi/km^2
dpm/L	$\times 0.45 \times 10^{9}$	$µCi/cm^3$	$µCi/cm^3$	$\times 2.22 \times 10^{9}$	dpm/L
pCi/L	$\times 10^{-9}$	µCi/mL	µCi/mL	$\times 10^{9}$	pCi/L
pCi/m^3	$\times 10^{12}$	$µCi/cm^3$	$µCi/cm^3$	$\times 10^{12}$	pCi/m^3

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In Memoriam

Photo courtesy of DOE

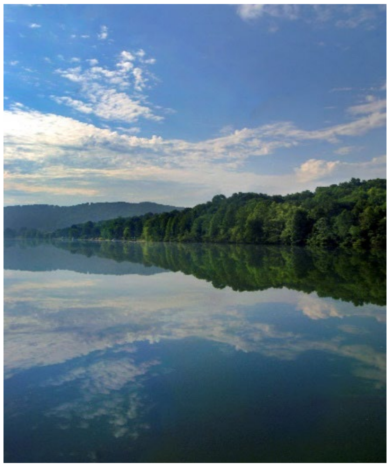
Lynn Freeny
1958 – 2021

Lynn Freeny grew up in East Tennessee, and was hired in 1992 as the third official DOE photographer for Oak Ridge. A familiar sight with his oversized camera bag slung over his shoulder, he documented newsworthy events such as visits from presidents and other dignitaries, groundbreaking and ribbon-cutting ceremonies, and important DOE milestones. He also captured tranquil scenes of wildlife and native plants, beautiful sunrises, and other everyday views of nature on the Oak Ridge Reservation; many have been included in the Oak Ridge Reservation Annual Site Environmental Reports over the years. Lynn used his passion for photography to tell the story of Oak Ridge through his expertly composed images. He not only chronicled events at Oak Ridge during his tenure, he was the acknowledged authority on the extensive collection of Manhattan Project photos taken by DOE's first Oak Ridge photographer, Ed Westcott. Lynn posted many of Westcott's images online, and often produced just the right photograph for an article, display, or document about Oak Ridge's impressive and unique history. As Ken Tarcza, manager of DOE's Office of Science Consolidated Service Center in Oak Ridge stated, "He was an artist as much as a photographer and captured so much more than an image when he pushed the shutter on a camera. Lynn's role in documenting both current and historic Oak Ridge activity cannot be understated. His passion for photography drove him to memorialize the broad, ongoing initiatives being undertaken by DOE in Oak Ridge, and his legacy will live on for years to come."

Photo courtesy of Suzy Peterson

Mark Peterson
1961 – 2020

Mark Peterson was born and raised in a small town near Chicago, and his lifelong love of all things aquatic began with the fishing trips he took with his dad on the great northern lakes. Early on, Mark decided to make understanding and protecting these ecosystems his life's work. After earning his Master's degree in Aquatic Ecology he moved to Oak Ridge and began his career with ORNL's Environmental Sciences Division, where he would remain for the rest of his life. He helped develop the Aquatic Ecology Laboratory into the world-class facility that it is today and helped guide its missions, both in research and in compliance and conservation. Although Mark was involved in DOE projects across the country, he is best known for his work here in Oak Ridge. Active in the field and in the lab, Mark mapped and documented aquatic resources such as wetlands all across the Oak Ridge Reservation. He was instrumental in the major upgrade of the Aquatic Ecology Lab. He worked with DOE and regulators such as TDEC and EPA to develop and manage the biological monitoring and abatement programs at the three main ORR sites, and he pioneered innovative remediation techniques to protect the environment while maximizing the return on the investment of resources. And, of course, when there were fish to be collected, Mark made every effort to be in on the action. Mark's love of nature and the great outdoors was evident throughout his career, and he was proud to devote his life to protecting and restoring natural resources for the use and enjoyment of all.



Located on the banks of the Clinch River, the Oak Ridge Reservation comprises three major facilities involved in every mission in the DOE portfolio. DOE is committed to enhancing environmental stewardship and managing the impacts its operations may have on the environment.

Executive Summary

Overview

The Oak Ridge Reservation (ORR), located in Roane and Anderson Counties in East Tennessee about 40 km (25 mi) west of Knoxville, is managed by the US Department of Energy (DOE). Today ORR is one of DOE's most complex sites. Established in the early 1940s as part of the Manhattan Project to enrich uranium and pioneer methods for producing and separating plutonium, ORR continued those activities until the mid-1980s. Today ORR comprises three major facilities with thousands of employees performing every mission in the DOE portfolio: energy research, environmental restoration, national security, nuclear fuel supply, reindustrialization, science education, basic and applied research in areas important to US security, and technology transfer. Scientists at the Oak Ridge National Laboratory (ORNL), DOE's largest science and energy laboratory, conduct leading-edge research in advanced materials, neutron scattering, nuclear programs (including isotope production), and high-performance computing. The Y-12 National Security Complex (Y-12 or Y-12 Complex) is vital to maintaining the safety, security, and effectiveness of the US nuclear weapons stockpile and reducing the global threat posed by nuclear proliferation and terrorism. The East Tennessee Technology Park (ETTP), a former uranium enrichment complex, is being transitioned to a clean, revitalized industrial park.

ORR is managed by three DOE Program Secretarial Offices and their management, operating, and support contractors. This calendar year 2020 Oak Ridge Reservation Annual Site Environmental Report (ASER) contains information furnished to the DOE ORR integrating contractor by other contractors including UT-Battelle, LLC; Consolidated Nuclear Security, LLC; UCOR, an Amentum-led partnership with Jacobs; North Wind Solutions, LLC; Oak Ridge Associated Universities; and Isotek Systems, LLC.

Chapter 3 of this report was prepared by UCOR, the lead environmental management contractor for ETTP. Chapter 4 was developed by Consolidated Nuclear Security, LLC, which manages and operates the Y-12 Complex. Chapter 5 was written by UT-Battelle, LLC, the ORNL managing contractor. These contractors are responsible for independently carrying out the various DOE missions at the three major ORR sites. They manage and implement environmental protection programs through environmental management systems that adhere to International Organization for Standardization Standard 14001, Environmental Management Systems. Chapters 3, 4, and 5 include detailed information on each contractor's environmental management systems, which interface with with DOE's signature integrated safety management system (ISMS) to provide unified strategies for managing resources. ISMS incorporates safety in all aspects of work and helps ensure safety at all DOE facilities. Safety, as defined in ISMS, encompasses protection of the public, the worker, and the environment and includes all safety, health, and environmental disciplines: radiation protection, fire protection, nuclear safety, environmental protection, waste management, and environmental management.

DOE operations on ORR have the potential to release various constituents to the environment via atmospheric, surface water, and groundwater pathways. Some of these constituents, such as particles from diesel engines, are common at many types of facilities while others, such as radionuclides, are unique to specialized research and production activities like those conducted on ORR. DOE is committed to enhancing environmental stewardship and managing the impacts its operations may have on the environment. To encourage the public to participate in matters related to ORR's environmental impact on the community, DOE solicits citizens' input on matters of significant public interest through multiple channels. DOE also offers access to information on all of its Oak Ridge environmental, safety, and health activities.

The ASER is prepared for DOE according to the requirements of DOE Order 231.1B, *Environment, Safety, and Health Reporting*. The ASER includes data on the environmental performance of each of the major DOE ORR contractors and describes significant accomplishments in pollution prevention and sustainability programs that reduce many types of waste and pollutant releases to the environment. DOE has published an annual environmental report with consolidated data on overall ORR performance and status since the mid-1970s. The ASER is a key component of DOE's effort to keep the public informed about environmental conditions across DOE and National Nuclear Security Administration sites.

Impacts

DOE ORR operations resulted in minimal impact to the public and the environment in 2020. Permitted discharges to air and water continued to be well below regulatory standards, and potential radiation doses to the public from activities on the reservation were much less than the 100 mrem standard established for DOE sites in DOE Order 458.1, *Radiation Protection of the Public and the Environment*.

The maximum radiation dose a hypothetical off-site individual could have received from DOE activities on ORR in 2020 was estimated to be 0.4 mrem from air pathways, 2 mrem from water pathways (drinking water, fish consumption, swimming, recreation, and other uses), and 0.07 mrem from consumption of wildlife harvested on ORR. This is about 3 percent of the DOE 100 mrem standard for all pathways and is significantly less than the 300 mrem annual average dose to people in the United States from natural or background radiation.

Environmental Monitoring

Each year extensive environmental monitoring is conducted across ORR. Site-specific environmental protection programs are implemented at ORNL, the Y-12 Complex, and ETTP. ORR-wide environmental surveillance programs, which include locations and media both on and off the reservation, are carried out to enhance and supplement data from site-specific efforts. In 2020 many thousands of samples and measurements of air, water, direct radiation, vegetation, fish, and wildlife were collected from across the reservation and analyzed for radioactive and nonradioactive contaminants. Sample media, locations, frequencies, and parameters were selected based on environmental regulations and standards, public and environmental exposure pathways, environmental permits, and measurement capabilities. Chapters 2 through 7 of this report summarize the environmental protection and surveillance programs on ORR. These extensive sampling and monitoring efforts demonstrate DOE's commitment to ensuring safety; protecting human health; complying with regulations, standards, DOE Orders, and "as low as reasonably achievable" principles; reducing the risks associated with past, present, and future operations; and improving cost-effectiveness.

Compliance with Environmental Regulations

Federal, state, and local government agencies including the US Environmental Protection Agency and the Tennessee Department of Environment and Conservation monitor ORR for compliance with applicable environmental regulations. These agencies issue permits, review compliance reports, participate in monitoring programs, and inspect facilities and operations. Compliance with environmental regulations and DOE Orders ensures ORR activities do not result in adverse impacts to the public or the environment.

Compliance in 2020 with applicable regulations for the three major ORR sites is summarized as follows:

- ETTP had no notices of environmental violations or penalties.
- Y-12 had no Clean Air Act permit violations or exceedances. Y-12 did have five National Pollutant Discharge Elimination System (NPDES) permit noncompliances out of approximately 2,600 samples analyzed for the program, resulting in a 99.8% compliance rate.
- ORNL facilities include those on the Oak Ridge campus as well as off-campus entities such as the National Transportation Research Center and the Carbon Fiber Technology Facility. In 2020 there were no Clean Air Act violations by UT-Battelle, LLC, the ORNL managing contractor, and no Clean Air Act violations or exceedances by the other contractors who conduct activities at ORNL (Isotek Systems, LLC; North Wind Solutions, LLC; and UCOR). ORNL had one violation of Tennessee's hazardous waste management regulations and one NPDES permit noncompliance, achieving a compliance rate of more than 99 percent.

Chapter 2 provides a more detailed summary of ORR environmental compliance during 2020. Chapters 3, 4, and 5 further discuss each site's compliance status for the year.

Environmental Management, Pollution Prevention, and Site Sustainability

Numerous environmental management, pollution prevention, and sustainability programs across ORR embody efforts to achieve enduring sustainability in facilities, operations, and organizational culture. These programs conserve water and energy, minimize waste, and promote energy-efficient buildings, sustainable landscaping, green transportation, and sustainable acquisition. In turn, these initiatives decrease the life cycle costs of programs and projects while also reducing risks to the environment. As described in Chapters 3, 4, and 5, ORR contractors achieved a high level of excellence in environmental management, pollution prevention, and sustainability programs in 2020.

Environmental Management

Since 1943 ORR has played key roles in America's defense and energy research. However, past waste disposal practices, operational and industrial practices, changing standards, and unintentional releases left some land and facilities contaminated with radioactive elements, mercury, asbestos, polychlorinated biphenyls, and industrial wastes. The DOE Environmental Management program is responsible for cleaning up these sites, and numerous cleanup projects are under way at the reservation's three main facilities.

ETTP completed major environmental remediation and facility demolition projects in 2020. The most visible demolition projects were large facilities previously used to test and develop enriched uranium technologies (the K-1200 Centrifuge Complex and the K-1600 Building), the abandoned K-1203 Sewage Treatment Plant, and the K-832 Cooling Water Basin. With major demolition projects complete in 2020, ETTP moved closer to achieving its three end-state goals: a multi-use industrial park, national historic preservation, and conservation and greenspace areas. DOE initiated the transfer of Access Portals 4 and 11, two roadways, the former K-1037 building site, and the former Toxic Substances Control Act Incinerator area for economic development opportunities. DOE also continued to support the proposed general aviation airport project. The K-25 History Center, which features exhibits, audio-visual displays, period artifacts, equipment replicas, and workers' oral histories, opened in February 2020. Finally, potential greenspace initiatives are planned through the transfer of land from DOE to the Tennessee Wildlife Resources Agency for areas less amenable to industrial redevelopment.

Y-12 achievements in 2020 included the recovery of an additional half ton of elemental mercury during the treatment of debris and grit from the Alpha 4 building's column exchange (COLEX) equipment. Construction of the Outfall 200 Mercury Treatment Facility continued, with contractors beginning excavations at the treatment plant site and at the Headworks site, and with installation and operation of a small treatment system to remove mercury from water during this project. Crews also poured concrete pads and began installing rebar for the walls of the treatment facility. Shoring walls and excavations will be completed at the Headworks site in fiscal year (FY) 2021. The entire facility will be capable of treating 3,000 gallons of water per minute and will include a 2-million-gallon storage tank to handle storm water peak flow conditions. Preparation for the demolition of the last two buildings in the Y-12 Biology Complex (9207 and 9210) took place throughout 2020, and demolition of Building 9210 commenced on November 16, 2020. Removal of the complex, which once included 11 buildings, will provide approximately 18 acres of land for reuse by Y-12.

ORNL achievements in 2020 included the characterization and deactivation of former reactors and isotope production facilities as well as remediation to support future brownfield redevelopment. Workers used a 175-ton crane to install a protective tent at Building 3026, the Radioisotope Development Lab, to protect nearby research facilities while the final two hot cells from the building are demolished. Characterization and deactivation also continued in former reactors and isotope production facilities, including Buildings 3005, 3010, 3042, 3009, 3010, 3010-A, 3080, 3083, and 3107, and in 11 other facilities in the Isotope Row area that supported and produced radioisotopes. Actions included asbestos abatement, removal of combustible materials, and isolation of electrical and mechanical utilities at the facilities. On June 3, 2020, ORNL received final approval for the phased construction completion report that details Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) environmental remediation activities at the 3500 Area of the Central Campus. This area is slated for brownfield reuse after final waste disposition was completed in September 2019.

The Environmental Management Waste Management Facility (EMWMF) received 12,271 waste shipments, totaling 129,038 cubic yards, from ORR cleanup projects in FY 2020. EMWMF operations also collected, analyzed, and disposed of approximately 4.3 million gallons of leachate treated by the Liquid and Gaseous Waste Operations facility.

In FY 2020, the Transuranic Waste Processing Center completed nine contact-handled transuranic shipments containing 378 drums to the Waste Isolation Pilot Plant in Carlsbad, New Mexico. To date, approximately 78 percent of the contact-handled transuranic waste and 63 percent of the remote-handled transuranic waste have been dispositioned at the Waste Isolation Pilot Plant. Construction began on the Sludge Processing Mock Test Facility, which will play a vital role in maturing technologies needed to begin processing Oak Ridge's 500,000-gallon inventory of transuranic waste.

In the fall of 2019, Isotek Systems, LLC began processing uranium-233 material inside glove boxes in Building 2026 to produce a solidified, low-level waste form acceptable for disposal.

Pollution Prevention and Sustainability

The three main ORR sites made significant strides in sustainability and pollution prevention in 2020, and highlights are summarized below.

Within the next 10 years, 83 excess facilities at Y-12 and another 55 National Nuclear Security Administration facilities are projected to be taken down. To date, Y-12 has demolished more than 2.8 million gross square feet of excess facilities. This progress is in line with meeting the DOE site sustainability plan reduction goal of 25 percent by fiscal year 2025. In 2020, Y-12 also achieved a 12 percent reduction in water use and a 10 percent reduction in energy intensity, and 46.7 percent of municipal and 46.9 percent of construction and demolition waste was diverted from landfills. More than 98.7 percent of eligible electronic acquisitions were registered through EPEAT, the Electronic Product Environmental Assessment Tool. Greenhouse gas emissions were reduced by 23 percent compared to the 2008 baseline.

ORNL implemented 24 new pollution prevention projects and ongoing reuse and recycle projects during 2020, eliminating more than 3 million kg of waste. With the addition of 100 new sustainable vehicles, approximately 90 percent of ORNL's 467-vehicle fleet is compliant with alternative fuel vehicle criteria. In 2020, one hundred percent of light-duty vehicles operated on alternative fuels, exceeding DOE fleet management goals. Total annual water use at ORNL has been reduced by 27.2 percent since FY 2007, although water consumption at ORNL is expected to rise to support additional high-performance computing and Spallation Neutron Source activities. Calculated energy use intensity for FY 2020 was 237,298 Btu per gross square foot, a cumulative reduction of 34.8 percent since FY 2003 and a reduction of 1.36 percent since FY 2019.

The ETTP decommissioning and demolition project was recognized for recycling 178,150 lb of scrap metal from deactivation work that met CERCLA qualification. This effort saved 203,499 kWh of energy, 17,400 gal of water, and 54 metric tons in greenhouse gas emissions while preserving valuable landfill space. ETTP decommissioning and demolition operations were also recognized for repurposing excavation spoils material from the ED-19 utility upgrade project as backfill at the K-832-H Basin, which avoided 730 cubic yards of waste, reduced 2.59 metric tons of greenhouse gas emissions, and saved over $70,000.

The Office of Environmental Management continued planning for capital asset projects that will further advance ORR cleanup objectives. These include the Outfall 200 Mercury Treatment Facility at Y-12, the new disposal facility that will accept debris from future cleanup at Y-12 and ORNL, and the sludge treatment facility at the Transuranic Waste Processing Center.

The Oak Ridge National Laboratory Operations and Cleanup Enterprise project was recognized for recharacterizing radioactively contaminated equipment as CERCLA-compliant waste in order to dispose of it locally, which avoided 59 metric tons of greenhouse gas emissions and saved the project $245,000 in container, shipping, and disposal fees.

Signs such as this were common in the city of Oak Ridge during the Manhattan Project era and for years afterward.

1

Introduction to the Oak Ridge Reservation

It was not shown on any maps. No visitors were allowed without special approval. US Army guards were posted at the entrances to the city, and all residents were required to wear badges at all times outside their homes. Thus Oak Ridge existed for seven years, from 1942 to 1949, as a truly secret city. Here and in supporting locations humankind made the leap from candlepower to nuclear power in a single generation. The engineering marvel that materialized in the Secret City changed the world, helped end World War II, and launched life-saving diagnostic tools such as magnetic resonance imaging and nuclear medicine. Today the former Secret City exists in two parts: the City of Oak Ridge and the Oak Ridge Reservation (ORR). ORR's mission continues to evolve as it adapts to meet the changing basic and applied research and national security needs of the United States.

ORR covers a little over 50 square miles of land in Anderson and Roane counties and is home to two major US Department of Energy (DOE) operating facilities: the Oak Ridge National Laboratory (ORNL) and the Y-12 National Security Complex (Y-12). Other ORR facilities include the East Tennessee Technology Park (ETTP), the site of a former gaseous diffusion plant that has undergone significant environmental cleanup and transitioned to a private sector business and industrial park; the Oak Ridge Institute for Science and Education (ORISE) South Campus, which includes training, laboratory, and support facilities; small government-owned, contractor-operated environmental cleanup entities; and the government-owned, government-operated Agent Operations Eastern Command (AOEC) of the National Nuclear Security Administration (NNSA) Office of Secure Transportation (OST). Some things have not changed; personnel seeking entrance to ORR must have proper credentials in accordance with current access security requirements.

Due to different permit reporting requirements and instrument capabilities, this report uses various units of measurement. The lists of units of measure and conversion factors on pages xxx and xxxi are included to help readers convert numeric values as needed for specific calculations and comparisons.

1.1. Background

The ORR Annual Site Environmental Report (ASER) is a summary of environmental data that characterizes environmental performance, lists environmental occurrences reported during the year, confirms compliance with environmental standards and requirements, and highlights significant environmental program activities. The ASER meets the requirements of DOE Order 231.1B, *Environment, Safety, and Health Reporting*, and its Attachment 2 (DOE 2012) regarding the preparation of an integrated annual site environmental report.

Summary results in this report are based on data collected before and continuing through 2020. Not all results of the environmental monitoring associated with ORR are reported here, and this is not intended to be a comprehensive monitoring report. Data collected for other site and regulatory purposes, such as environmental restoration and remedial investigation reports, waste management characterization sampling data, and environmental permit compliance data, are presented in other documents that have been prepared in accordance with applicable laws, regulations, policies, and guidance. These data are referenced herein as appropriate.

Environmental monitoring of ORR activities consists primarily of effluent monitoring and environmental surveillance. Effluent monitoring involves the collection and analysis of samples or measurements of liquid and gaseous effluents at the points of their release to the environment. These measurements allow quantification and official reporting of contaminant levels, assessment of public exposures to radiation (see Appendix E) and chemicals (see Appendix F), and demonstration of compliance with applicable standards and permit requirements. Environmental surveillance consists of direct measurement, collection, and analysis of samples taken from the site and its environs, exclusive of effluents. These surveillance activities provide information on contaminant concentrations in air, water, groundwater, soil, foods, biota, and other media. Other environmental surveillance data support environmental compliance and, when combined with data from effluent monitoring, also support chemical and radiation dose and exposure assessments of the potential effects of ORR operations, if any, on the local environment.

1.2. History of the Area around the Oak Ridge Reservation

Native Americans first inhabited the ORR area during the Woodland Period (c. 1000 BC to AD 1000). Descendants of these early dwellers, whose ancestors were Neolithic and Stone Age people, still lived in the East Tennessee region when European settlers arrived in the late 1700s. The Cherokee people were dominant in the area after wars with the Shawnee and Creek. Early European settlers of the area lived on farms or in four small communities named Elza, Robertsville, Wheat, and Scarborough; all but Elza were founded shortly after the Revolutionary War. About a thousand families inhabited the area in the early 1940s.

President Franklin D. Roosevelt received the famous Einstein-Szilard letter in 1939 informing him that German scientists were working on a nuclear weapon. In utmost secrecy, he formed the agencies leading up to the Manhattan Project. Then, on June 28, 1941, five months and nine days prior to the Japanese attack on Pearl Harbor, he signed Executive Order 8807 which funded the Manhattan Project. The super secret code name gave no indication of the classified activities it concealed. So named because its original headquarters were established in June 1942 in New York City's Manhattan district, in the summer of 1943 the project moved to Oak Ridge where construction of America's first full-scale gaseous diffusion plant was underway. Here scientists began using the gaseous diffusion process to enrich uranium using Graham's Law of Diffusion.

Graham's Law was formulated by Scottish physical chemist Thomas Graham in 1848. He found experimentally that the rate of diffusion of a gas is inversely proportional to the square root of its molecular weight. Thus, if the molecular weight of one gas is four times that of another, it will diffuse through a porous plug or escape through a small pinhole in a vessel at half the rate of the lighter gas. In other words, heavier gases diffuse more slowly. Graham's Law provides a basis for separating isotopes by diffusion—the method that played a crucial role in the development of the atomic bomb 100 years after Graham's discovery.

The area that became ORR was selected in 1942 for the Manhattan Project, in part, because the Clinch River provided abundant water and the terrain's linear and partitioned ridges offered separation and protection that, in the words of General Leslie Groves, "prevented them from blowing up like firecrackers on a string." Nearby Knoxville was a good source of labor, and the Tennessee Valley Authority could supply ample amounts of needed electricity. Families that had occupied homes and farms for generations received orders to vacate within just a few weeks. The federal government's acquisition of property under the right of eminent domain immediately affected more than three thousand individuals. According to the US Department of Agriculture's National Agricultural Statistics Service, the average farm real estate value in 1942 for the 48 contiguous states was $34 per acre. Some property owners were paid this amount for their land; others were paid less. Many felt they were poorly compensated, especially for their homes.

The site's wartime name was Clinton Engineering Works. Although it did not appear on any map, the workers' city on the reservation's northern edge, named Oak Ridge, quickly grew to a population of 75,000, becoming the fifth largest city in Tennessee. To the south of the residential area at the Y-12 Complex, an electromagnetic method separated uranium-235 from natural uranium. The K-25 gaseous diffusion plant was built on the reservation's western edge. Near the reservation's southwest corner, about 16 km (10 mi) from the Y-12 Complex, a third facility—known as X-10 or Clinton Laboratories—housed the experimental graphite reactor. X-10 served as a pilot scale facility for the larger plutonium production facilities built at Hanford, Washington.

Two years after World War II ended, Oak Ridge shifted to civilian control under the authority of the US Atomic Energy Commission. In 1959 the city was incorporated and the community adopted a city manager and city council form of government. The missions of the three major ORR installations have continued to evolve and operations have adapted to meet America's changing defense, energy, and research needs. Section 1.4 describes the current missions of these and several smaller ORR facilities and activities.

1.3. Location and Description

Situated in the Great Valley of East Tennessee between the Cumberland and Great Smoky Mountains, ORR borders the Clinch River (see Figures 1.1 and 1.2). The Cumberland Mountains are 16 km (10 mi) to the northwest and the Great Smoky Mountains are 51 km (31.6 mi) to the southeast. ORR encompasses a little over 13,000 hectares (32,259 acres) of mostly contiguous, federally owned land in Anderson and Roane Counties, and is under the management of DOE.

1.3.1. Population

As reported in *US Department of Energy Fiscal Year 2017 Economic Impact in Tennessee* (East Tennessee Economic Council 2017), ORR supported more than 34,000 members of the region's labor force. The US Census Vintage 2020 Population Estimate (which was released on April 22, 2021 and is based on the 2010 Census) for the Knoxville Metropolitan Statistical Area, which includes Oak Ridge, was 878,124. The combined US Census Vintage 2020 Population Estimate for the 10 counties surrounding ORR (Anderson, Blount, Campbell, Cumberland, Knox, Loudon, McMinn, Monroe, Morgan, and Roane) was 1,041,112. Knoxville, the nearest major city, is about 40 km (25 mi) to the east and had a population of 190,223, according to the US Census Vintage 2020 Population Estimate. Other municipalities within about 30 km (18.6 mi) of ORR include Oliver Springs, Clinton, Rocky Top, Lenoir City, Farragut, Kingston, and Harriman. Except for the city of Oak Ridge, the land within 8 km (5 mi) of ORR is semirural and is used primarily for residences, small farms, and cattle pasture. Fishing, hunting, boating, water skiing, and swimming are popular recreational activities.

Figure 1.1. Location of the Oak Ridge Reservation in Tennessee

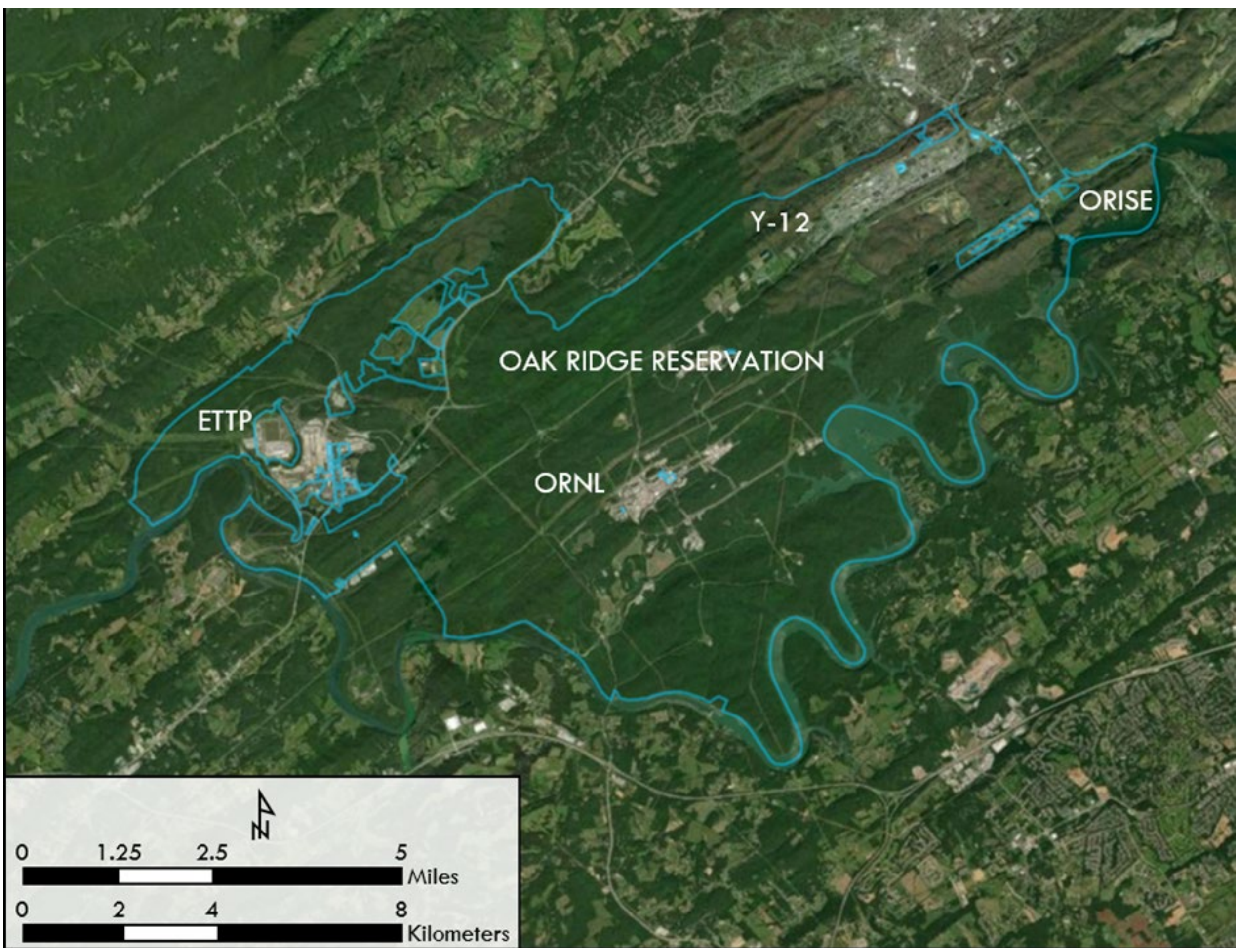


Figure 1.2. Map of the Oak Ridge Reservation

1.3.2. Climate

Although it features significant temperature changes between summer and winter, the climate of the Oak Ridge region qualifies as humid subtropical. The 30-year average temperature for 1991–2020 was 15.1°C (59.2°F). The average temperature for the Oak Ridge area in 2020 was 14.7°C (58.4°F). December temperatures were coldest in 2020, averaging -1.7°C (29.0°F). July was the warmest month, with average temperatures of 25.7°C (78.1°F). Monthly summaries of temperature averages, extremes, and 2020 values are provided in Appendix B, Table B.1.

Average annual precipitation in the Oak Ridge area for the 30-year period from 1991 to 2020 was 1,420.3 mm (55.90 in.), including about 12.7 cm (5.0 in.) of snowfall (NOAA 2011). Total precipitation during 2020 as measured at meteorological tower (MT)2 was 1,801.2 mm (70.89 in.), which is 21 percent above the 30-year average. Monthly summaries of precipitation averages, extremes, and 2020 values can also be found in Appendix B, Table B.1.

The average annual wind data recovery rates (a measure of acceptable data) across locations used for modeling during 2020 were greater than 99 percent for wind sensors at the ORNL sites (towers MT2, MT3, MT4, MT10, and MT12). All other (MT6, MT9, and MT11) instrument recoveries were above 88 percent for annual values.

In 2020 wind speeds at ORNL Tower D (MT2), measured at 15 m (49 ft) above ground level, averaged 1.4 meters per second (3.1 mph). This value was 2.4 meters per second (5.5 mph) for winds at 60 m (198 ft) above ground level. The local ridge-and-valley terrain reduces average wind speeds at valley bottoms, resulting in frequent periods of calm or near-calm conditions, particularly during clear early morning hours in weak synoptic weather environments. Wind direction frequencies with respect to precipitation hours for the ORR towers may be reviewed **here** under the heading 2020 Annual Precipitation Wind Roses–Oak Ridge Reservation.

Detailed information on the climate of the Oak Ridge area is available in *Oak Ridge Reservation Physical Characteristics and Natural Resources* (Parr and Hughes 2006) and in Appendix B of this report. An in-depth analysis of wind patterns for ORR conducted from 2009 to 2011 and documented in "Wind Regimes in Complex Terrain in the Great Valley of Eastern Tennessee" (Birdwell 2011) is available online **here**.

1.3.3. Regional Air Quality

The US Environmental Protection Agency (EPA) Office of Air Quality Planning and Standards set national ambient air quality standards (NAAQS) for key principal pollutants, also known as criteria pollutants. These key pollutants are sulfur dioxide, carbon monoxide, nitrogen dioxide, lead, ozone, particulate matter with an aerodynamic diameter less than or equal to 10 µm (PM_{10}), and fine particulate matter with an aerodynamic diameter less than or equal to 2.5 µm ($PM_{2.5}$). EPA evaluates NAAQS based on ambient, or outdoor, levels of the criteria pollutants. Areas that satisfy NAAQS are classified as attainment areas, and areas that exceed NAAQS for a particular pollutant are considered non-attainment areas for that pollutant.

ORR is located in Anderson and Roane Counties. As of August 30, 2017, EPA designated Anderson, Knox, Blount, and Roane Counties as attainment areas for the $PM_{2.5}$ air quality standard. The greater Knoxville and Oak Ridge area is a NAAQS attainment area for all other criteria pollutants for which EPA has made attainment designations.

1.3.4. Surface Water

The ORR area comprises a series of drainage basins or troughs containing numerous small streams that feed the Clinch River. Surface water on ORR drains into a series of tributaries, streams, or creeks in different watersheds. Each of these watersheds drains into the Clinch River, which in turn flows into the Tennessee River. The Tennessee Valley Authority declared 2020 the wettest year on record for the Tennessee Valley region with 70.36 inches of precipitation, surpassing a previous record of 67.01 inches set in

2018 (TVA 2021). With 66.47 inches of rainfall, 2019 was the third wettest year on record. This conclusion is based on more than 100 years of collected weather data.

The largest of the ORR drainage basins is Poplar Creek, which receives drainage from a 352 km^2 (136 mi^2) area including the northwestern sector of ORR. Flow is from northeast to southwest, roughly through the center of ETTP, and the creek discharges directly into the Clinch River.

East Fork Poplar Creek, which discharges into Poplar Creek east of ETTP, originates within the Y-12 Complex and flows northeast along the south side of the complex. Bear Creek also originates within the Y-12 Complex and flows southwest. Bear Creek is affected by storm water runoff, groundwater infiltration, and tributaries that drain former waste disposal sites in the Bear Creek Valley Burial Grounds Waste Management Area and the current Environmental Management Waste Management Facility (EMWMF).

Both the Bethel Valley and Melton Valley portions of ORNL are in the White Oak Creek drainage basin, which covers 16.5 km^2 (6.4 mi^2). The headwaters of White Oak Creek originate on Chestnut Ridge, north of ORNL and near the Spallation Neutron Source site. The creek flows west along the southern boundary of the developed area of the ORNL site, then flows southwest through a gap in Haw Ridge to the western portion of Melton Valley, forming a confluence with Melton Branch. The headwaters of Melton Branch originate in Melton Valley east of the High Flux Isotope Reactor complex, and the area of the drainage basin is about 3.8 km^2 (1.47 mi^2). The waters of White Oak Creek enter White Oak Lake, an impoundment formed by White Oak Dam. Water flowing over White Oak Dam enters the Clinch River after passing through the White Oak Creek embayment area.

1.3.5. Geological Setting

ORR is in the Tennessee portion of the Valley and Ridge Physiographic Province, which is part of the southern Appalachian fold-and-thrust belt. Thrust faulting, associated fracturing of the rock, and differential erosion rates created a series of parallel valleys and ridges that trend southwest to northeast.

Two geologic units on ORR, the Knox Group and the Maynardville Limestone of the Upper Conasauga Group, consist of dolostone and limestone, respectively, and make up the most significant water-bearing hydrostratigraphic units in the Valley and Ridge Province (Zurawski 1978) and on ORR. Composed of moderately soluble minerals, these bedrock formations are prone to dissolution as slightly acidic rainwater and percolating recharge water come in contact with the mineral surfaces. This dissolution increases fracture apertures and can, under some circumstances, form caverns and extensive solution conduit networks. This hydrostratigraphic unit is locally known as the Knox Aquifer. A combination of fractures and solution conduits in the aquifer control flow over substantial areas and large quantities of water may move long distances. Active groundwater flow can occur at substantial depths (91.5 to 122 m, or 300 to 400 ft) in the Knox Aquifer. The Knox Aquifer is the primary source of groundwater (base flow) for many streams, and most large springs on ORR receive discharge from the Knox Aquifer. Yields of some wells penetrating larger solution conduits exceed 3,785.4 liters per minute (1,000 gallons per minute). The high productivity of the Knox Aquifer results from the combination of its abundant and sometimes large solution conduit systems and frequently thick overburden soils that promote recharge and storage of groundwater.

The remaining geologic units on ORR (the Rome Formation, the Conasauga Group below the Maynardville Limestone, and the Chickamauga Group) are composed predominantly of shale, siltstones, and sandstones with a subordinate and locally variable amount of carbonate bedrock. These formations are primarily composed of insoluble minerals such as clays and quartz that were derived from ancient continental erosion. Groundwater occurs in and moves through fractures in these bedrock units. Groundwater availability in such settings depends on the abundance and interconnectedness of fractures and the connection of fractures to sources of recharge, such as alluvial soils along streams, which can provide some sustained infiltration. The shale and sandstone formations are the poorest aquifers in the Valley and Ridge Province (Zurawski 1978). Well yields are generally low in the Rome, Conasauga, and Chickamauga bedrock formations except in localized areas where carbonate beds may provide greater groundwater storage than adjacent clastic bedrock. Detailed information on ORR groundwater hydrology and flow is available in *Oak Ridge Reservation Physical Characteristics and Natural Resources* (Parr and Hughes 2006).

1.3.6. Natural, Cultural, and Historic Resources

ORR has an exceptional variety of natural, cultural, and historic resources. Ongoing efforts continue to focus on preserving the rich diversity of these resources.

1.3.6.1. Wetlands

Wetlands occur across ORR at low elevations, primarily in riparian zones of headwater streams and receiving streams and in the Clinch River embayments, as shown in Figure 1.3. Surveys of wetland resources presented in *Identification and Characterization of Wetlands in the Bear Creek Watershed* (Rosensteel and Trettin 1993), *Wetland Survey of the X-10 Bethel Valley and Melton Valley Groundwater Operable Units at Oak Ridge National Laboratory, Oak Ridge, Tennessee* (Rosensteel 1996), and *Wetland Survey of Selected Areas in the Oak Ridge Y-12 Plant Area of Responsibility, Oak Ridge, Tennessee* (Rosensteel 1997) serve as references to support wetland assessments for upcoming projects and activities. About 243 hectares (600 acres) of wetlands have been identified on ORR; most are classified as forested palustrine, scrub/shrub, and emergent wetlands. Wetlands identified to date range from several square meters at small seeps and springs to about 10 hectares (25 acres) at White Oak Lake. In 2017, wetlands were delineated in the Copper Ridge Borrow Area and 294 Power Line Area. The Tennessee Department of Environment and Conservation's wetland mitigation aquatic resource alteration permits, required by Section 401 of the Clean Water Act (CWA 1972), entail monitoring restored or created wetland mitigation sites for five years. Activities and conditions in and around ORNL wetlands are verified by site inspections when appropriate (see Chapter 5, Section 5.3.12).

In late 2019, Consolidated Nuclear Security, LLC proposed to develop and construct the Oak Ridge Enhanced Technology and Training Center (ORETTC) on 24 acres of DOE-owned land, part of an 81-acre parcel to be transferred to NNSA. Although the site was previously disturbed land, it contained considerable forest-type cover and growth. In July 2020, NNSA determined an environmental assessment (10 CFR 1021.321) was required to evaluate the proposed action. Due to the potential impact to 0.05 acres of wetland, NNSA prepared a Wetland Statement of Findings (in accordance with 10 CFR 1022) and determined no practicable alternative to the construction and operation of the ORETTC exists at the proposed site. In accordance with 10 CFR 1022 and Executive Order 11990 (EO 1977), NNSA identified, evaluated, minimized, and mitigated adverse wetlands impacts associated with the construction and operation of the ORETTC at the proposed site. NNSA approved the Final Environmental Assessment, Wetland Statement of Findings, and Finding of No Significant Impact (NNSA 2020) on November 4, 2020.

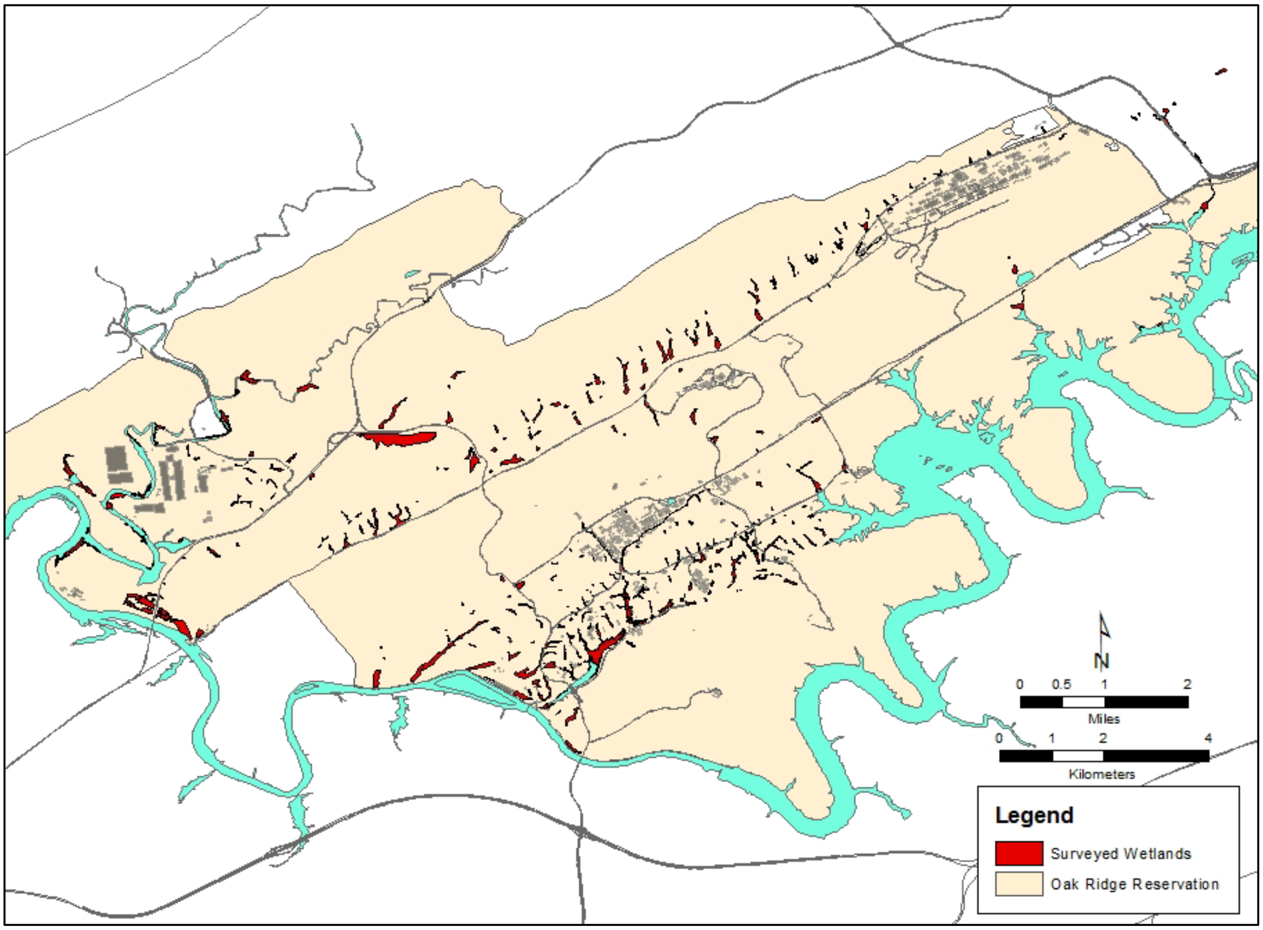


Figure 1.3. Location of Oak Ridge Reservation wetlands

1.3.6.2. Wildlife and Endangered Species

Animals listed as species of concern by state, federal, or international organizations and known to have occurred on the reservation (excluding the Clinch River bordering the reservation) are listed, along with their status, in Table 1.1. Some of these, such as hellbender, have been seen only once or a few times; others, including wood thrush, are comparatively common and widespread on ORR. As of July 2016, Tennessee had 93 species listed under the federal Endangered Species Act (ESA 1973), including 75 endangered and 18 threatened species. The complete Tennessee Threatened and Endangered List–New Rules is found **here.**

Birds, fish, reptiles and amphibians, and aquatic invertebrates are the most thoroughly surveyed animal groups on ORR. Nevertheless, the only federally listed animal species observed on ORR in recent years are mammals. Gray bats were seen over the Clinch River bordering ORR in 2003 and over a pond on ORR in 2004. Three gray bats were mist-netted outside a cave on ORR in 2006. Several gray bats and one Indiana bat were caught in mist nets bordering the Clinch River in June and July 2013. Northern long-eared bats, recently federally listed as threatened, are known to be present on ORR; their calls have been identified in various acoustic surveys of the reservation, and in 2013 their presence was confirmed when a number were captured in mist nets (McCracken et al. 2015).

Table 1.1. Animal species of special concern reported on the Oak Ridge Reservation[a]

Scientific name	Common name	Status[b]		
		Federal	State	PIF[c]
FISH				
Phoxinus tennesseensis	Tennessee dace		NM	
AMPHIBIANS AND REPTILES				
Crytobranchus alleganiensis	Hellbender		T	
Hemidactylium scutatum	Four-toed salamander		NM	
BIRDS				
Swans, Geese, and Ducks				
Branta canadensis	Canada goose	MCOB	NM	
Aix sponsa	Wood duck	MC		
Anas strepera	Gadwall	MC		
Anas americana	American wigeon	MC		
Anas rubripes	American black duck	MC		RC
Anas platyrhynchos	Mallard	MC		
Anas discors	Blue-winged teal	MC		
Anas crecca	Green-winged teal	MC		
Anas clypeata	Northern shovler	MC		
Anas acuta	Northern pintail	MC		
Aythya valisineria	Canvasback	MC		
Aythya americana	Redhead	MC		
Aythya collaris	Ring-necked duck	MC		
Aythya affinis	Lesser scaup	MC		
Grebes				
Podilymbus podiceps	Pie-billed grebe	MC		
Podiceps auritus	Horned grebe	MC		
Frigatebirds, Boobies, Cormorants				
Phalacrocorax auritus	Double-breasted cormorant	MCOB		
Bitterns and Herons				
Ixobrychus exilis	Least bittern		NM	
Egretta caerulea	Little blue heron		NM	
Nycticorax nycticorax	Black-crowned night heron		NM	
Butorides virescens	Green heron			CBSD
Mycteria americana	Wood stork	T		
Kites, Hawks, Eagles, and Allies				
Haliaeetus leucocephalus	Bald eagle	MC[d]		
Chordeiles minor	Common nighhawk			CBSD
Rails, Gallinules, and Coots				
Rallus limicola	Virginia rail	MC		
Porzana carolina	Sora	MC		

Table 1.1. Animal species of special concern reported on the Oak Ridge Reservation[a] (continued)

Scientific name	Common name	Status[b]		
		Federal	State	PIF[c]
Fulica americana	American coot	MC		
Actitus macularius	Spotted sandpiper	MC		
Tringa solitaria	Solitary sandpiper	MC		
Tringa flavipes	Lesser yellowlegs	MC		
Scolopax minor	American woodcock	MC		
Grouse, Turkey, and Quail				
Bonasa umbellus	Ruffed grouse			RC
Colinus virginianus	Northern bobwhite	MC		CBSD
Pigeons and Doves				
Zenaida macroura	Mourning dove	MC		
Cuckoos and Roadrunners				
Coccyzus americaus	Yellow-billed cuckoo			CBSD
Goatsuckers				
Caprimulgus carolinensis	Chuck-will's-widow			CBSD
Caprimulgus vociferus	Eastern whip-poor-will			RC
Chordeiles minor	Common nighthawk			CBSD
Swifts				
Chaetura pelagica	Chimney swift			RC
Kingfishers				
Megaceryle alcyon	Belted kingfisher			RC
Woodpeckers				
Melanerpes erythrocephalus	Red-headed woodpecker			RC
Colaptes auratus	Northern flicker			RC
Tyrant Flycatchers				
Contopus virens	Eastern wood-pewee			RC
Empidonax virescens	Acadian flycatcher			RC
Contopus cooperi	Olive-sided flycatcher			
Empidonax trailii	Willow flycatcher	MC		
Swallows				
Progne subis	Purple martin			RC
Hirundo rustica	Barn swallow			RC
Kinglets, Gnatcatchers, and Thrushes				
Hylocichla mustelina	Wood thrush		NM	RC
Shrikes				
Lanius ludovicianus	Loggerhead shrike		NM	
Wood Warblers				
Vermivora chrysoptera	Golden-winged warbler		T	RC
Setophaga cerulea	Cerulean warbler		NM	RC
Setophaga discolor	Prairie warbler			RC

Table 1.1. Animal species of special concern reported on the Oak Ridge Reservation[a] (continued)

Scientific name	Common name	Status[b]		
		Federal	State	PIF[c]
Mniotilta varia	Black-and-white warbler			RC
Protonotaria citrea	Prothonotary warbler			RC
Geothlypis formosa	Kentucky warbler			RC
Cardellina canadensis	Canada warbler			RC
Icteria virens	Yellow-breasted chat			RC
Tanagers				
Piranga rubra	Summer tanager			RC
Towhees, Sparrows, and Allies				
Pipilo erythrophthalmus	Eastern towhee			RC
Spizella pusilla	Field sparrow			RC
Ammodramus savannarum	Grasshopper sparrow			RC
Ammodramus henslowii	Henslow's sparrow		T	RC
Melospiza Georgiana	Swamp sparrow			RC
Finches and Allies				
Spinus tristis	American goldfinch			RC
MAMMALS				
Myotis grisescens	Gray bat	E	E	
Myotis lucifugus	Little brown bat		T	
Myotis sodalist	Indiana bat[e]	E	E	
Myotis septentrionalis	Northern long-eared bat	T		
Myotis leibii	Eastern small-footed bat		NM	
Perimyotis subflavus	Tri-colored bat		T	
Corynorhinus rafinesquii	Rafinesque's Big-eared bat		NM	
Sorex dispar	Long-tailed shrew		NM	

[a] *Land and surface waters of the Oak Ridge Reservation (ORR) exclusive of the Clinch River, which borders ORR.*
[b] *Status codes:*
E = endangered
FS = federal focal species
T = threatened
MC = of management concern
NM = in need of management
OB = overly abundant
RC = regional concern
CBSD = common bird in steep decline
[c] *Partners in Flight (PIF) is an international organization devoted to conserving bird populations in the Western Hemisphere.*
[d] *The bald eagle was federally delisted effective August 9, 2007.*
[e] *A single specimen was captured in a mist net bordering the Clinch River in June 2013.*

Birds recorded on ORR and its boundary waters include the 228 species documented by Roy et al. (2014) plus the cackling goose (*Branta hutchinsii*), purple gallinule (*Porphyrio martinicus*), American bittern (*Botaurus lentiginosus*) and federally threatened wood stork (*Mycteria Americana*) for a total of 232 species. Most of these species are protected under the Migratory Bird Treaty Act (MBTA 1918) and Executive Order 13186, *Responsibilities of Federal Agencies to Protect Migratory Birds* (EO 2001). DOE's updated memorandum of understanding on migratory birds with the US Fish and Wildlife Service (FWS) (DOE-FWS 2013) strengthens migratory bird conservation on ORR through enhanced collaboration between DOE and FWS.

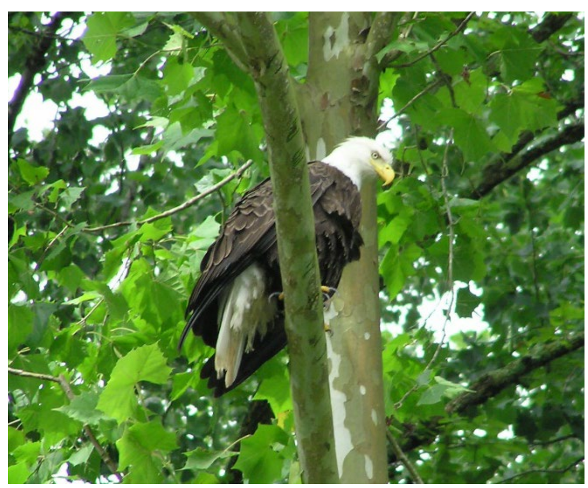
Breeding bird surveys conducted along varying numbers of up to 10 routes on ORR provide data for the Partners in Flight Program. Eight public nature walks scheduled to be held on ORR during 2020 were cancelled due to the COVID-19 pandemic. Topics included American woodcock (shown in Figure 1.4) and birds of prey, birds, frog calls, a reptiles and amphibians inventory, and history of ORR. In past years ORR has been nominated for the Presidential Migratory Bird Federal Stewardship Award. A technical manuscript, *Oak Ridge Reservation Bird Records and Population Trends* (Roy et al. 2014), documents known ORR bird records since 1950 and population trends for 32 species of birds.

Several state-listed bird species such as the golden-winged warbler, cerulean warbler, and little blue heron are uncommon migrants or visitors to the reservation. The cerulean warbler, listed by the state as in need of management, often appears during the breeding season on ORR but is currently listed as a potential breeding bird on the reservation (Roy et al. 2014) as its actual breeding status is still uncertain. The bald eagle (Figure 1.5), which was removed from the federal list of threatened and endangered species on August 9, 2007, is a year-round resident in Tennessee, though it can be difficult to find on the reservation from September through November. One bald eagle nest was confirmed on the reservation in 2020. This nest was first observed in 2011 and has remained active every year since. More than two dozen eaglets fledged in East Tennessee during 2017, according to bald eagle information published by the East Tennessee State University College of Arts and Sciences Biological Sciences department.

Other species such as the wood thrush and barn swallow are migrants and are known to nest on the reservation. The golden-winged warbler (*Vermivora chrysoptera*), listed by the state as threatened, was sighted once, in May 1998, on the reservation, as was the Lincoln's sparrow (*Melospiza lincolnii*) (no listed status) in May 2014. Barn owls were documented nesting on the reservation in 2019.

Source: Sarah Darling, ORNL

Figure 1.4. American woodcock fledgling on ORR



Source: Kelly Roy, ORNL

Figure 1.5. Bald eagle photographed on ORR

With many northern lakes freezing solid during the winter of 2013–2014, white-winged scoters (*Melanitta fusca*) and red-necked grebes (*Podiceps grisegena*) made rare appearances in East Tennessee in February and March of 2014, though they were recorded locally only on boundary waters of the reservation. Other uncommon birds for ORR recorded in recent years include several species associated with wetland habitats. The sora, least bittern, and Virginia rail were observed at the K1007 P1 pond at ETTP in 2013 and were likely attracted to high quality wildlife habitat established through recent restoration efforts. The sora, seen as recently as December 2016, is a fairly common migrant throughout Tennessee but is seldom seen on ORR. The least bittern, an uncommon migrant and summer resident in Tennessee, was documented calling on an acoustic recorder in 2018 at P-1 Pond on ETTP. The Virginia rail, most recently observed in October 2013, was previously known on ORR only through historic records from the early 1950s (Roy et al. 2014). FWS lists all three of these species as of management concern. The least bittern is also deemed in need of management by the State of Tennessee, as shown in Table 1.1. While collaborating on detection methodologies for secretive marsh birds, researchers from ORNL and Charles Sturt University in New South Wales, Australia, photographed a purple gallinule on a trail camera at the Heritage Center Greenway Powerhouse Trail in 2017 (Figure 1.6). This was the first documented appearance of a purple gallinule on ORR.

Figure 1.6. Purple gallinule caught on a trail surveillance camera at ETTP in 2017

One fish species, the spotfin chub (*Erimonax monachus*), which is listed as threatened by both the state and the federal government, has been sighted and collected in the city of Oak Ridge and may be present on ORR. The tangerine darter (*Percina aurantiaca*), a species listed by the state as in need of management, has also been recorded in close proximity to ORR. The lake sturgeon (*Acipenser fulvescens*), state-listed as endangered, is known to inhabit the adjacent Clinch River. The Tennessee dace, listed by the state as in need of management, appears in the Bear Creek watershed, tributaries to the lower East Fork watershed, and Ish Creek. The Tennessee dace also occurs in some sections of Grassy Creek upstream of Scientific Ecology Group, Inc. and International Technology Corporation at Clinch River kilometer 23, south of west Bear Creek Road near Grassy Creek sampling point 1.9.

1.3.6.3. Threatened and Endangered Plants

Four plant species known to be on ORR (spreading false foxglove, Appalachian bugbane, tall larkspur, and butternut) have been under review for federal listing and were previously listed under the C2 candidate designation. FWS now informally refers to these as special concern species.

The State of Tennessee lists 17 plant species occurring on ORR as endangered, threatened, or of special concern; these are included in Table 1.2. Appalachian bugbane is no longer listed by Tennessee and does not have official federal status; therefore, it does not appear in Table 1.2. An additional 10 threatened, endangered, or special concern species occur in the area and may be present on ORR, although currently unconfirmed. These are also included in Table 1.2. Other plant populations currently under study on ORR may be added to the table in future years.

The latest Tennessee Rare Plant List (TDEC 2016) was published in October 2016. The 2012 Tennessee Rare Plant List reduced the number of state-protected species on ORR by six, and the 2016 Tennessee Rare Plant List reduced this number by an additional two species: the Tennessee coneflower (*Echinacea tennesseensis*) and Egget's sunflower (*Helianthus eggertii*).

Table 1.2. Vascular plant species listed by state or federal agencies and sighted or reported on or near the Oak Ridge Reservation

Species	Common name	Habitat on ORR	Status code[a]
Currently known to be or previously reported on ORR			
Aureolaria patula	Spreading false foxglove	River bluff	FSC, S
Berberis canadensis	American barberry	Rocky bluff	S
Bolboschoenus fluviatilis	River bulrush	Wetland	S
Delphinium exaltatum	Tall larkspur	Barrens and woodlands	FSC, E
Diervilla lonicera	Northern bush-honeysuckle	Rocky river bluff	T
Draba ramosissima	Branching whitlow-grass	Limestone cliff	S
Elodea nuttallii	Nuttall waterweed	Pond, embayment	S
Eupatorium godfreyanum	Godfrey's thoroughwort	Dry woods edge	S
Fothergilla major	Mountain witch-alder	Woods	T
Helianthus occidentalis	Naked-stem sunflower	Barrens	S
Juglans cinerea	Butternut	Lake shore	FSC, T
Juncus brachycephalus	Small-head rush	Open wetland	S
Liparis loeselii	Fen orchid	Forested wetland	T
Panax quinquifolius	American ginseng	Rich woods	S, CE
Platanthera flava var. herbiola	Tuberculed rein-orchid	Forested wetland	T
Spiranthes lucida	Shining ladies'-tresses	Boggy wetland	T
Thuja occidentalis	Northern white cedar	Rocky river bluffs	S
Rare plants that occur near and could be present on ORR			
Agalinis auriculata	Earleaf false foxglove	Calcareous barren	FSC, E
Allium burdickii or A. tricoccom[b]	Ramps	Moist woods	S, CE
Lathyrus palustris	Marsh pea	Moist meadows	S
Liatris cylindracea	Slender blazing star	Calcareous barren	T
Lonicera dioica	Mountain honeysuckle	Rocky river bluff	S
Meehania cordata	Heartleaf meehania	Moist calcareous woods	T
Pedicularis lanceolata	Swamp lousewort	Calcareous wet meadow	S
Pseudognaphalium helleri	Heller's catfoot	Dry woodland edge	S
Pycnanthemum torrei	Torrey's mountain-mint	Calcareous barren edge	S
Solidago ptarmicoides	Prairie goldenrod	Calcareous barren	E

[a] *Status codes:*

CE = Status due to commercial exploitation
E = Endangered in Tennessee
FSC = Federal Special Concern; formerly designated as C2. See Federal Register, February 28, 1996.
S = Special concern in Tennessee
T = Threatened in Tennessee

[b] *Ramps have been reported near ORR, but there is not sufficient information to determine which of the two species is present or whether the occurrence may have been the result of planting. Both species of ramps have the same state status.*

Acronym: *ORR = Oak Ridge Reservation*

1.3.6.4. Historical and Cultural Resources

Efforts continue to preserve ORR's rich prehistoric and historic cultural resources. Compliance with the National Historic Preservation Act (NHPA 1966) is maintained in conjunction with National Environmental Policy Act (NEPA 1969) compliance. The scope of proposed actions is reviewed in accordance with the *Cultural Resource Management Plan, DOE Oak Ridge Reservation, Anderson and Roane Counties, Tennessee* (DOE 2001). ORR has several facilities that were eligible for inclusion on the National Register of Historic Places (NRHP), a National Park Service program to identify, evaluate, and protect historic and archeological resources in the US, as well as numerous facilities that were not eligible for NHRP inclusion. Artifacts of historical or cultural significance are identified prior to demolition and catalogued in a database to aid in historic interpretation. The reservation contains more than 44 known prehistoric sites (primarily archeological evidence of former structures), 254 historic pre-World War II structures, 32 cemeteries, and several historically significant structures from the Manhattan Project era.

The National Defense Authorization Act of 2015 (NDAA 2014), passed by Congress and signed into law on December 19, 2014, included provisions authorizing the Manhattan Project National Historical Park. An agreement by the Secretaries of Energy and Interior established the Manhattan Project National Historical Park on November 10, 2015 (DOE-DOI 2015). The Park includes facilities and lands in Los Alamos, New Mexico and Hanford, Washington, as well as Oak Ridge. On ORR, the National Park includes the X-10 Graphite Reactor, Buildings 9731 and 9204-3 at the Y-12 Complex, and the K-25 Building Site at ETTP.

The X-10 Graphite Reactor building has been a National Historic Landmark since 1966, and has been open for public access in various ways since that time. Enhancing access and improving the visitor experience are important DOE objectives as it moves forward in implementing the National Park.

Although Buildings 9731 and 9204-3 at the Y-12 Complex are eligible for listing on the NRHP, at present neither is available for regular public access. Occasional public access to both facilities last occurred on Nov. 12, 2015, when DOE facilitated public tours of both buildings to celebrate the establishment of the National Park. By developing the National Park, DOE aims to enhance safe access to these buildings while protecting the agency's mission capabilities.

DOE will fulfill the objective of enabling safe access to the former site of the K-25 Building. The National Park Service will aid in historic interpretation of the site, although the K-25 Building site is already undergoing extensive historic interpretation activities separate and independent from the National Park. DOE launched the K-25 Virtual Museum as part of the activities to establish the Park. The online exhibit, which details the history of the K-25 Gaseous Diffusion Plant through narrative and photographs, can be viewed **here**. The K-25 History Center held its grand opening on February 27, 2020. It was temporarily shuttered in 2020, however, due to the COVID-19 pandemic.

The Graphite Reactor is a National Historic Landmark, and six additional historic ORR properties are listed individually in the NRHP:

- Freels Bend Cabin
- New Bethel Baptist Church and Cemetery
- Oak Ridge Turnpike Checking Station
- George Jones Memorial Baptist Church and Cemetery
- Bear Creek (Scarboro) Road Checking Station
- Bethel Valley Road Checking Station

Although not yet included on the NRHP, an area known as the Wheat Community African Burial Grounds was dedicated in June 2000, and a memorial monument was erected.

A memorandum of agreement signed in 2012 between DOE Oak Ridge Office, the State Historic Preservation Officer, the Advisory Council on Historic Preservation, the City of Oak Ridge, and the East Tennessee Preservation Alliance ensures consistent interpretation of site historic properties at ETTP. The memorandum of agreement is being implemented through planning for a History Center that will highlight the historic aspects of ETTP and of the communities that were displaced during the construction of the site.

Three site-wide programmatic agreements among the DOE Oak Ridge Office, the State Historic Preservation Officer, and the Advisory Council on Historic Preservation concerning management of historical and cultural properties on ORR, at ORNL, and at Y-12 are being implemented since their respective approvals.

1.4. Oak Ridge Sites

ORR includes a number of sites critical to the mission of DOE. Eight of these sites are described in this section: ORNL, the Y-12 Complex, ETTP, EMWMF, the Oak Ridge National Environmental Research Park, ORISE, NNSA OST AOEC, and the Transuranic Waste Processing Center (TWPC).

UCOR is the lead DOE ORR cleanup contractor. The scope of UCOR activities includes characterization and cleanup of former production facilities, building pads, and impacted environmental media; management and maintenance of active ORR facilities; long-term management of inactive waste disposal sites; and water quality monitoring.

1.4.1. Oak Ridge National Laboratory

ORNL (shown in Figure 1.7) is managed for DOE by UT-Battelle, LLC, a partnership between the University of Tennessee and Battelle Memorial Institute. The largest science and energy national laboratory in the DOE system, ORNL conducts basic and applied research to deliver transformative solutions to compelling problems in energy and security. The laboratory is home to several of the world's top supercomputers and is a leading neutron science and nuclear energy research facility that includes the Spallation Neutron Source and the High Flux Isotope Reactor. ORNL hosts a DOE leadership computing facility, home of the Summit supercomputer; one of DOE's nanoscience centers, the Center for Nanophase Materials Sciences; one of DOE's energy research centers; and the Bio-Energy Science Center. UT-Battelle, LLC also manages the US ITER project (formerly the International Thermonuclear Experimental Reactor project) for DOE.

Formerly known as X-10, ORNL was established in 1943 to support the Manhattan Project. From an early focus on chemical technology and reactor development, ORNL's research and development portfolio broadened to include programs supporting DOE missions in scientific discovery and innovation, clean energy, and nuclear security. Today ORNL employs about 4,400 workers, and the laboratory's extensive capabilities in scientific discovery and innovation are applied to the delivery of mission outcomes for DOE and other sponsors.

During fiscal year (FY) 2020, DOE remained focused on disposing of a significant inventory of uranium-233 stored in Building 3019 at ORNL. This special nuclear material requires strict safeguards and security controls to protect against access. The objectives of the Uranium-233 Project are to address safeguards and security requirements, eliminate safety and nuclear criticality concerns, and safely dispose of the material. DOE has successfully resolved the concerns associated with the disposition of the Consolidated Edison Uranium Solidification Project material, which originated from a 1960s research and development test of thorium and uranium fuel at Consolidated Edison's Indian Point 1 Nuclear Plant in New York. Isotek Systems, LLC manages activities at the Building 3019 complex for DOE and is responsible for activities associated with processing, down-blending, and packaging the DOE inventory of uranium-233 stored in the complex.

UCOR continued to carry out characterization and deactivation of former reactors and isotope production facilities in 2020. One of the priority projects was to prepare the 3026 facility—the Radioisotope Development Lab—for demolition.

Figure 1.7. Aerial view of the Oak Ridge National Laboratory

Using a 175-ton crane, workers installed a tent to protect nearby research facilities while the final two hot cells are demolished. Characterization and deactivation also continued in former reactors and isotope production facilities, including Buildings 3005, 3010, 3042, 3009, 3010, 3010-A, 3080, 3083, and 3107, as well as 11 other facilities in the area known as Isotope Row that supported and produced radioisotopes. Deactivation actions included asbestos abatement, removal of combustible materials, and isolation of electrical and mechanical utilities at the facilities. Other UCOR activities include groundwater monitoring, transuranic waste storage, and operation of the liquid low-level and process waste systems and the off-gas collection and treatment system.

Demonstrating environmental excellence through high-level policies that clearly state expectations for continual improvement, pollution prevention, and compliance with regulations and other requirements is a priority at ORNL. Implementing an environmental management system (EMS) allows environmental impacts to be systematically measured, managed, and controlled. UT-Battelle's EMS is a fully integrated set of environmental management services for UT-Battelle activities and facilities. Services include pollution prevention, waste management, effluent management, regulatory review, reporting, permitting, and other environmental management programs.

Examples of environmental performance optimization during FY 2020 include the following:

- The calculated energy use intensity was 237,298 Btu/gross square foot, a cumulative reduction of 34.8 percent since FY 2003 and a reduction of 1.36 percent since FY 2019.
- The diversion rate for municipal solid waste at ORNL was 49 percent in FY 2020; the DOE sustainability goal remained at 50 percent. The diversion rate for construction and demolition materials and debris was 75 percent and exceeded the DOE target.

- UT-Battelle implemented 24 new pollution prevention projects and ongoing reuse/recycle projects at ORNL during 2020, eliminating more than 3 million kg of waste.
- ORNL is replacing less fuel-efficient vehicles with new alternative fuel vehicles. As a result, approximately 90 percent of ORNL's 467-vehicle fleet comply with the alternative fuel vehicle criteria. In 2020, 100 percent of light-duty vehicles operated on alternative fuels, exceeding DOE fleet management goals.

See Section 5.2.1.4 for additional detail on ORNL environmental sustainability performance data for FY 2020.

1.4.2. Y-12 National Security Complex

The Y-12 Complex (shown in Figure 1.8) was originally constructed as part of the World War II Manhattan Project and began operations in November 1943. The first site mission was the separation of uranium-235 from natural uranium by an electromagnetic separation process. At its peak in 1945, more than 22,000 workers were employed at the Y-12 site.

Today, as part of the NNSA Nuclear Security Enterprise, the Y-12 Complex is a leader in materials science and precision manufacturing. As the main storage facility for the nation's supply of enriched uranium, Y-12 serves as the nation's only source of enriched uranium nuclear weapons components and provides enriched uranium for the US Navy. The Y-12 Complex also supports efforts to reduce the risk of nuclear proliferation and performs complementary work for other government agencies.

Outfall 200 Mercury Treatment Facility

In December 2017, UCOR issued the *Construction Execution/Management Plan, Outfall 200 Mercury Treatment Facility at the Y-12 Nuclear Security Complex, Oak Ridge, Tennessee* (UCOR 2017). The Outfall 200 Mercury Treatment Facility is a vital piece of infrastructure that will open the door for demolition of Y-12's large, deteriorated, mercury-contaminated facilities and subsequent soil remediation by providing a mechanism to limit potential mercury releases into Upper East Fork Poplar Creek. The west end Y-12 storm drain system discharges to Upper East Fork Poplar Creek at Outfall 200, and mercury from historic operations is present at Outfall 200 where storm water enters Poplar Creek. In FY 2020, contractors began excavations at the treatment plant site and at the Headworks site. They installed and operated a small treatment system to remove mercury from water collected in the Headworks excavation site. Crews also poured the concrete pads and began installing rebar for the walls of the treatment plant. Completion of shoring walls and excavations at the Headworks site is planned for FY 2021, and the entire facility is slated to be operational in the mid-2020s.

The Mercury Treatment Facility is designed to treat up to 3,000 gallons of storm water per minute. It includes a 2-million-gallon storage tank to collect storm water during peak flow conditions of up to 40,000 gallons per minute. The stored water can then be treated after storm flow subsides using chemical precipitation, clarification, and media filtration, and treated water will be discharged back into Upper East Fork Poplar Creek.

Figure 1.8. Aerial view of the Y-12 National Security Complex

Y-12's environmental policy reflects a commitment to providing sound environmental stewardship practices through the implementation of its EMS. At the end of FY 2020, the Y-12 Complex had achieved five of nine established environmental targets driven by the EMS, and the remaining targets were carried into future years. Highlights include the following; further details and additional successes are presented in Chapter 4 of this report.

Clean Air

Y-12 upgraded software, training, and procedures to improve control of ozone-depleting substances that are managed on site.

Energy Efficiency

Y-12 completed phase one of a project to upgrade power lines to 13.8 kV service. Additional power line upgrade work will continue into 2021. Energy-saving improvements for water chillers, cooling towers, and heating, ventilating, and air conditioning systems were completed by the end of the 2020 calendar year.

Hazardous Materials

A project to disposition and ship legacy mixed waste per Site Treatment Plan milestones was completed in 2020, and FY 2020 priorities to disposition unneeded materials and chemicals in one facility were completed. Y-12 identified and prioritized aboveground and inactive tanks to address in future years.

Y-12 continues to strive to reduce impacts on the environment through increased use of environmentally friendly products and processes and reductions in waste and emissions. In FY 2020, the Y-12 Complex implemented 105 pollution prevention initiatives resulting in a reduction of more than 44.2 million lb of waste and projected cost efficiencies of more than $6.9 million. Also in 2020, Y-12 diverted 46.7 percent of municipal and 46.9 percent of construction and demolition waste from landfill disposal through reuse and recycle. In FY 2020, Y-12 diverted more than 2.4 million lb of municipal materials from landfill disposal through source reduction, reuse, and recycling. More than 41.2 million lb of construction and demolition materials were diverted from landfill disposal.

From FY 2003 through FY 2020, the Y-12 Complex achieved a 54.1 percent reduction in energy intensity. Specific initiatives that helped reduce energy consumption at the Y-12 Complex include the following:

- Completing a new, more-efficient Air Compressor Plant at the end of FY 2016
- Upgrading light fixtures with T-8 fluorescent lighting and light-emitting diodes across the entire site
- Replacing steam with natural gas in areas that do not require it for process purposes
- Upgrading chillers with new high-efficiency variable speed modes; retrofitting existing chillers with efficient controls; replacing constant-speed chilled water pumps with a variable-speed type; and replacing tower pumps, steam controls, and control valves
- Replacing cooling towers
- Adding energy meters to buildings that previously had none to better capture waste and to track savings
- Upgrading heating, venting, and air conditioning systems to be compatible with Metasys, allowing for remote adjustment of louvers, dampers, set points, and motor speeds

Sustainability goals and performance status for the Y-12 Complex are listed in Chapter 4, Table 4.1.

1.4.3. East Tennessee Technology Park

ETTP (see Figure 1.9), originally named K-25, is the site of the nation's first gaseous diffusion uranium enrichment plant. It was established as part of the World War II Manhattan Project. Additional uranium enrichment facilities K-29, K-31, and K-33 were built adjacent to K-25 during the Cold War, and these facilities formed a complex officially known as the Oak Ridge Gaseous Diffusion Plant. Uranium enrichment operations at the site ceased in 1986, and restoration and decontamination and decommissioning activities began soon after in preparation for ultimate conversion of the site to a private sector industrial park, to be called the Heritage Center. Reindustrialization of the site began in 1996, when it was renamed the East Tennessee Technology Park.

In 2020 the final major cleanup project was completed by UCOR when the 42,000-square-foot K-1600 building was demolished (UCOR 2020). The ultimate goal of the remediation work is to make parcels of land available for a general aviation airport, conservation areas, and private-sector development that can provide economic benefits for the region.

In addition to the K-1600 facility, other major environmental remediation and facility demolition projects were completed at ETTP during 2020. The site is divided into two cleanup regions: Zone 1, a 1,400-acre area outside the main plant area, and Zone 2, the 800-acre area that comprises the main plant area. In Zone 1, two vaults associated with the abandoned underground utility system at the Powerhouse were remediated, and steps were initiated to remediate an area that contains buried asbestos. In Zone 2, the removal of soil contaminated with technetium-99 was completed. The highest visibility demolition projects were also in Zone 2: large facilities previously used for the testing and development of enriched uranium technologies (the K-1200 Centrifuge Complex and the K-1600 Building), the abandoned K-1203 Sewage Treatment Plant, and the K-832 Cooling Water Basin.

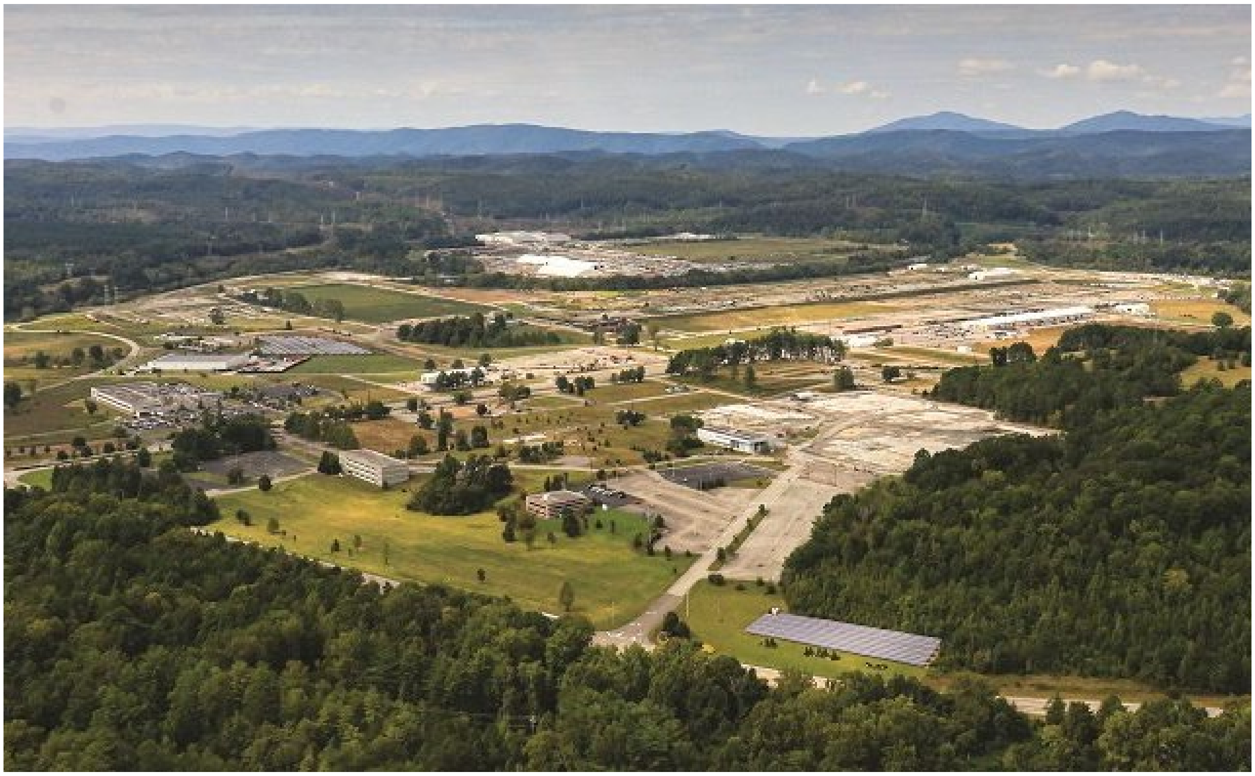


Figure 1.9. Aerial view of East Tennessee Technology Park

The UCOR EMS environmental sustainability principles incorporate the procurement of environmentally preferable products, recycling, and pollution prevention and waste minimization practices in work processes and activities. UCOR recycles much of its universal waste, municipal solid waste, and scrap metal, reuses large amounts of construction and demolition debris, and encourages the reduction of waste wherever possible. In 2020, more than 189 metric tons of greenhouse gas emissions, 910 metric tons of waste, 200,000 kWh of electricity, and 17,400 gal of water were saved as a result of projects implementing pollution prevention measures. For example, 175,080 lb (79.4 metric tons) of noncontaminated scrap metal contained in construction and demolition debris was recycled in FY 2020 in lieu of land disposal. In addition to lessening the impact on the environment, these pollution prevention measures saved more than $319,000. UCOR's pollution prevention and waste minimization practices at ETTP are detailed further in Section 3.2.1.

In 2020, DOE initiated transfer of Access Portals 4 and 11, two roadways, the former K-1037 building pad, and the former Toxic Substances Control Act Incinerator area. All transfers are in the review process and approval is pending. DOE also continued to support the proposed general aviation airport project. Management of the project was transferred to the City of Oak Ridge in 2020, and DOE continues to assist with land transfer requests to help bring this facility to fruition.

1.4.4. Environmental Management Waste Management Facility

The EMWMF (shown in Figure 1.10) is located in eastern Bear Creek Valley near the Y-12 Complex and is managed by UCOR. EMWMF was built for the disposal of waste resulting from Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA 1980) cleanup actions on ORR. The original design was for the construction, operation, and closure of a projected 1.3 million cubic meter (1.7 million cubic yard) disposal facility. The approved capacity was subsequently increased to 1.8 million cubic meters (2.4 million cubic yards) to maximize use of the footprint designated in a 1999 record of decision. The facility currently consists of six disposal cells.

Figure 1.10. Aerial view of the Environmental Management Waste Management Facility

EMWMF is an engineered landfill that accepts low-level, mixed low-level, and hazardous wastes from CERCLA cleanup activities on ORR that meet specific waste acceptance criteria developed in accordance with agreements with state and federal regulators. Waste types that qualify for disposal include soil, dried sludge and sediment, solidified waste, stabilized waste, building debris, scrap equipment, and secondary waste such as personal protective equipment, all of which must meet land disposal restrictions. In addition to the solid waste disposal facility, EMWMF operates a leachate collection system. In FY 2020 the facility collected, analyzed, and disposed of approximately 4.3 million gallons of leachate (UCOR 2020). The leachate is treated at the ORNL Liquids and Gaseous Treatment Facility, which is also operated by UCOR. ORR landfills disposed of 79,675 cubic yards of waste during 2020.

During FY 2020 the EMWMF received 12,271 waste shipments totaling 129,038 cubic yards from cleanup projects at ETTP, ORNL, and Y-12. However, EMWMF will reach its capacity before Oak Ridge Office of Environmental Management (OREM) completes its cleanup at Y-12 and ORNL. Planning continued throughout FY 2020 for a new facility, the Environmental Management Disposal Facility, which will provide the additional disposal capacity needed to complete the cleanup at Oak Ridge.

1.4.5. Oak Ridge National Environmental Research Park

DOE established the Oak Ridge National Environmental Research Park (see Figure 1.11) in 1980. Managed for DOE by UT-Battelle, LLC, the research park serves as an outdoor laboratory to evaluate the environmental consequences of energy use and development and strategies to mitigate those effects. Its large blocks of forest and diverse communities of vegetation offer unparalleled resources for ecosystem-level and large-scale research. Major national and international collaborative research initiatives use it to address issues such as multiple stress interactions, biodiversity, sustainable development, tropospheric air quality, global climate change, innovative power conductors, solar radiation monitoring, ecological recovery, and monitoring and remediation.

Field sites at the research park provide maintenance and support facilities that permit sophisticated and well-instrumented environmental experiments. These facilities include elaborate monitoring systems that enable users to precisely and accurately measure environmental factors for extended periods. Because the park is under the jurisdiction of the federal government, public access is restricted and therefore experimental sites and associated equipment are not disturbed. National recognition of the research park's value has led to its use in both regional- and continental-scale research projects. Research park sites offer opportunities for aquatic and terrestrial ecosystem analyses of topics such as biogeochemical cycling of pollutants resulting from energy production, landscape alterations, ecosystem restoration, wetland mitigation, and forest and wildlife management.

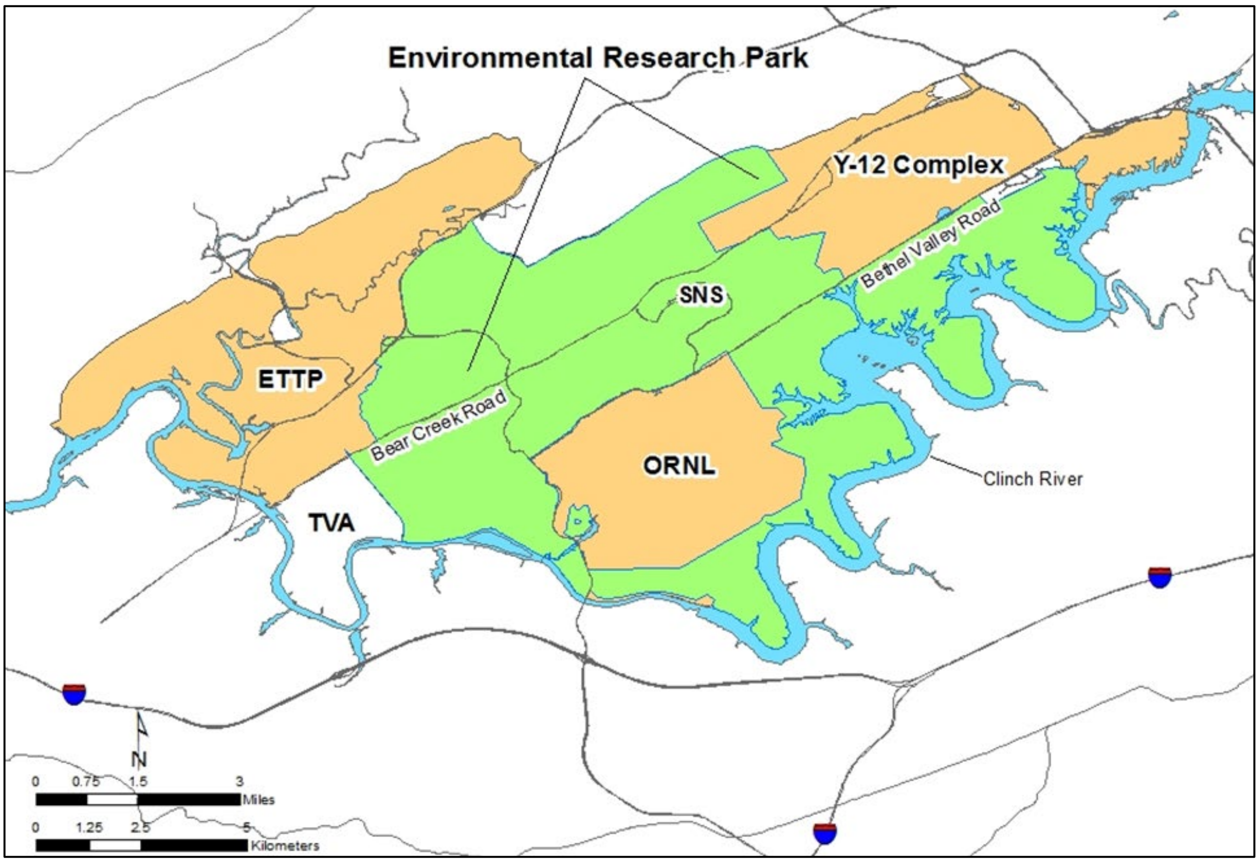


Figure 1.11. Location of the Oak Ridge National Environmental Research Park

1.4.6. Oak Ridge Institute for Science and Education

ORISE is managed for DOE by Oak Ridge Associated Universities. The ORISE mission is to develop people and solutions to strengthen our nation's competitive advantage in science. ORISE accomplishes its mission by recruiting and preparing the next generation of our nation's scientific workforce; promoting sound scientific and technical investment decisions through independent peer reviews; facilitating and preparing for the medical management of radiation incidents in the US and abroad; evaluating health outcomes in workers exposed to chemical and radiological hazards on the job; and ensuring public confidence in environmental cleanup through independent environmental assessments. ORISE creates opportunities for collaboration through partnerships with other DOE facilities, federal agencies, academia, and industry consistent with DOE objectives and the ORISE mission.

ORISE is located in an area on the southeastern border of ORR that was part of an agricultural experiment station owned by the federal government from the late 1940s to the mid-1980s and, until 1981, was operated by the University of Tennessee. The site houses offices, laboratories, and storage areas for ORISE program offices and support departments.

1.4.7. National Nuclear Security Administration Office of Secure Transportation, Agent Operations Eastern Command

Beginning in 1947, DOE and its predecessor agencies moved nuclear weapons, weapons components, special nuclear materials, and other important national security assets by commercial and government modes of transportation. In the late 1960s, worldwide terrorism and acts of violence prompted a review of procedures for safeguarding these materials. As a result, a comprehensive new series of regulations and equipment was developed to enhance the safety and security of these materials in transit. Modified and redesigned transport equipment was created to incorporate features that more effectively enhance self-protection and deny unauthorized access to the materials. Also during this time, the use of commercial transportation systems was abandoned and a totally federal operation was implemented. The organization responsible for this mission within DOE NNSA is the Office of Secure Transportation, or OST.

The NNSA OST AOEC Secure Transportation Center and Training Facility is located on ORR. Situated on about 723 ha (1,786 acres), it operates under a user permit agreement with DOE Oak Ridge Office. NNSA OST AOEC implements its assigned mission transportation operations, maintains applicable fleet and escort vehicles, and continues extensive training activities for its federal agents.

1.4.8. Transuranic Waste Processing Center

TWPC is located on an approximately 10.5-hectare (26-acre) tract of land in the Melton Valley area of ORNL about 120 feet west of the existing Melton Valley Storage Tanks. North Wind Solutions, LLC manages TWPC for DOE. TWPC's mission is to receive transuranic waste for processing, treatment, repackaging, and shipment to DOE's Waste Isolation Pilot Plant near Carlsbad, New Mexico.

Transuranic waste consists of materials and debris that are contaminated with elements that have a higher atomic mass and are listed after uranium on the periodic table. The majority of Oak Ridge's inventory of transuranic materials originated from previous research and isotope production missions at ORNL. Waste determined to be non-transuranic (e.g., low-level radioactive waste or mixed low-level waste) is shipped to the Nevada National Security Site or other approved facilities. TWPC has processed approximately 98 percent of the contact-handled transuranic waste and 98 percent of the remote-handled transuranic waste, and has also completed key regulatory milestones in the *Site Treatment Plan for Mixed Wastes on the US Department of Energy Oak Ridge Reservation* (TDEC 2020) on schedule.

Key progress for the project during FY 2020 included the following actions (UCOR 2020):

- Nine shipments containing 378 drums of contact-handled transuranic waste were sent to the Waste Isolation Pilot Plant.
- Construction began on the Sludge Processing Mock Test Facility, which will play a vital role in maturing technologies needed to begin processing Oak Ridge's 500,000-gallon inventory of transuranic sludge waste.

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Migratory birds known to nest on the Oak Ridge Reservation, such as this summer tanager, are covered by the Migratory Bird Treaty Act. DOE and its partners follow a wildlife management plan to protect migratory birds and their habitats.

2

Compliance Summary and Community Involvement

Activities conducted on ORR must conform to environmental standards established by federal and state statutes and regulations, DOE Orders, contract-based standards, and compliance and settlement agreements where applicable. The US Environmental Protection Agency (EPA) and the Tennessee Department of Environment and Conservation (TDEC) are the principal regulating agencies that issue permits, review compliance reports, participate in joint monitoring programs, inspect facilities and operations, and enforce compliance with applicable regulations.

The following sections summarize the major environmental statutes and their 2020 status for DOE operations on ORR. Note that the DOE Reindustrialization Program, typically in coordination with the Community Reuse Organization of East Tennessee, has leased several facilities at ETTP and the Oak Ridge Science and Technology Park to private entities over the past several years. This report does not discuss the compliance status of these lessee operations.

2.1. Laws and Regulations

Table 2.1, which begins on page 2-4, is a summary of the principal environmental standards applicable to DOE activities on ORR, their 2020 status, and the sections in this report that provide more detailed information.

2.2. External Oversight and Assessments

Table 2.2 (see page 2-9) lists the inspections of ORR environmental activities conducted by regulatory agencies for each of the major ORR sites (ETTP, Y-12, and ORNL) during 2020. This table does not include internal DOE or DOE contractor assessments, audits, or evaluations.

2.3. Reporting of Oak Ridge Reservation Spills and Releases

Substances defined as hazardous under the Comprehensive Environmental Response, Compensation, and Liablity Act (CERCLA) are considered to be harmful to human health and the environment. Because many are commonly used substances that are harmless in normal uses but can be dangerous when released, CERCLA establishes reportable quantities for hazardous substance releases.

Certain releases of oil must be reported if they "cause a film or sheen upon or discoloration of the surface of the water or adjoining shorelines or cause a sludge or emulsion to be deposited beneath the surface of the water or upon adjoining shorelines" (40 *Code of Federal Regulations* 110.3[b]). In May 2020, a hose on a mobile generator failed, leaking diesel to a storm drain inlet to Outfall 227 on White Oak Creek. The spill was contained with absorbent booms and was reported to TDEC due to the resulting sheen, which was visible for a short period of time.

Neither ETTP, Y-12, nor ORNL had any reportable releases of extremely hazardous substances, as defined by the Emergency Planning and Community Right-to-Know Act, in 2020. See Sections 3.3.11, 4.3.10, and 5.3.10 of this report for more information.

2.4. Notices of Violations and Penalties

ETTP had no notices of environmental violations or penalties in 2020. Y-12 had five permit noncompliances out of approximately 2,600 samples analyzed for National Pollutant Discharge Elimination System (NPDES) program requirements in 2020.

ORNL had one violation of Tennessee's hazardous waste management regulations during a TDEC inspection in 2020, which was immediately corrected. Compliance with the ORNL NPDES permit in 2020 was determined by approximately 1,800 laboratory analyses and field measurements. One NPDES permit noncompliance for an ORNL wastewater treatment facility was reported during 2020. A follow-up test seven days later indicated the effluent was back in compliance.

2.5. Community Involvement and Resources

Public activities were severely curtailed in 2020 due to COVID-19 and its applicable restrictions. In previous years, DOE and its contractors have provided or supported numerous community involvement activities on a range of subjects including ETTP historic interpretation efforts, Manhattan Project National Historical Park public meetings and public engagement efforts, Historic American Engineering Record activities, American Museum of Science and Energy community meetings hosted by the City of Oak Ridge, ETTP airport public meetings, public bus tours of ORR, public comment periods for draft environmental assessments, and Community Relations Council meetings. Public collaboration will resume when COVID-19 safety restrictions are lifted.

During 2020, organizations such as the Boys & Girls Club, Discover Life in America, Dolly Parton's Imagination Library, the Michael Dunn Center, the United Way, and many other local charities benefited from DOE and its contractors' involvement in the community.

2.5.1. Public Comments Solicited

To keep the public informed of comment periods and other matters related to cleanup activities on ORR, DOE publishes online notices at https://www.energy.gov/orem/services/community-engagement, conducts public meetings, and issues notices in local newspapers as appropriate. Information on environmental policy and DOE's commitment to providing sound environmental stewardship practices and keeping the public informed is available to the public through sponsored forums and public documents such as this report.

2.5.2. Oak Ridge Site Specific Advisory Board

The Oak Ridge Site Specific Advisory Board (ORSSAB) is a federally appointed citizens' panel that provides independent advice and recommendations to the DOE Oak Ridge Environmental Management Program. The board was formed in 1995 and is composed of up to 22 members chosen to reflect the diversity of genders, races, occupations, views, and interests of persons living near ORR. Members are appointed by DOE and serve on a voluntary basis without compensation.

Information on recommendations the board has made since its establishment, minutes of board and committee meetings, and other information are available on the ORSSAB website at http://www.energy.gov/ORSSAB. Videos of the first hour of recent board meetings are posted at https://www.energy.gov/orem/listings/oak-ridge-site-specific-advisory-board-meetings. Additional information may be obtained by calling 865-241-4583 or 865-241-4584.

2.5.3. DOE Information Center

The DOE Information Center, located at 1 Science.Gov Way, Oak Ridge, Tennessee, is a one-stop information facility that maintains a collection of more than 45,000 documents describing environmental activities in Oak Ridge. The center is open Monday through Friday from 8 a.m. to 5 p.m. and can be reached by phone at 865-241-4780, or toll-free at 1-800-382-6938 (option 6). An online catalog that can be used to search for DOE documents by author, title, date, and other fields is available at https://www.energy.gov/orem/services/community-engagement/doe-information-center.

2.5.4. Other Resources

- Agency for Toxic Substances and Disease Registry: 1-800-232-4636, http://www.atsdr.cdc.gov
- DOE main website: http://www.energy.gov
- DOE Oak Ridge Public Affairs Office: 865-576-0885
- EPA Region 4: 1-800-241-1754, http://www.epa.gov/region4
- TDEC, DOE Oversight Division: 865-481-0995, https://www.tn.gov/environment/program-areas/rem-remediation/rem-oak-ridge-reservation-clean-up.html
- ETTP: https://www.energy.gov/orem/cleanup-sites/east-tennessee-technology-park
- Y-12 National Security Complex: http://www.y12.doe.gov/
- ORNL: https://www.ornl.gov/

Table 2.1. Applicable environmental laws and regulations and 2020 status

Regulatory program description	2020 status	Report sections
The Clean Air Act and corollary State of Tennessee requirements regulate the release of air pollutants through permits and air quality limits. Emissions of airborne radionuclides are regulated by EPA via National Emission Standards for Hazardous Air Pollutants for radionuclides authorization. Greenhouse gas emissions inventory tracking and reporting are regulated by EPA and by DOE internal oversight.	In 2020 all activities on ORR were conducted in accordance with Clean Air Act requirements.	3.3.3 4.3.4 5.3.3
The Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) provides a regulatory framework for remediation of the release or threat of release of hazardous substances from past practices on ORR.	ORR was placed on the EPA National Priorities List in 1989. The ORR Federal Facility Agreement, initiated in 1992 between EPA, TDEC, and DOE, established the framework and schedule for developing, implementing, and monitoring remedial actions on ORR. The on-site CERCLA Environmental Management Waste Management Facility (EMWMF) is operated by UCOR for DOE. Located in Bear Creek Valley, EMWMF is used for disposal of waste resulting from CERCLA cleanup actions on ORR. EMWMF is an engineered landfill that accepts low-level radioactive, hazardous, asbestos, and polychlorinated biphenyl (PCB) wastes, and combinations of these wastes, in accordance with specific waste acceptance criteria under an agreement with state and federal regulators. No notices of violations were issued for CERCLA-related ORR actions during 2020.	3.3.8 4.3.8, 4.3.12, 4.6.3 5.3.8
The Clean Water Act seeks to protect and improve surface water quality by establishing surface water standards enabled by a system of permits. Wastewater discharges are regulated by National Pollutant Discharge Elimination System (NPDES) permits issued by TDEC.	Discharges to surface water at each of the three major ORR sites are governed by NPDES permits. In 2020, ETTP achieved a compliance rate of 100%, and the ORNL and Y-12 NPDES permit limit compliance rate for all discharge points was greater than 99%. ETTP had no permit noncompliances; ORNL had one nonnumeric permit noncompliance and Y-12 had five permit noncompliances. ORNL also had a release of diesel to White Oak Creek, which was immediately contained and reported to TDEC. See Appendix D for more information.	3.3.4 4.3.5 5.3.4
The Energy Independence and Security Act (EISA) Section 438 establishes requirements for federal agencies to reduce storm water runoff from development projects to protect water resources.	A variety of storm water management techniques, referred to as green infrastructure or low impact design practices, have been implemented on ORR to comply with EISA. The site sustainability plans and associated reporting provide data on sustainability projects and support EISA Section 438 compliance.	3.6.2 4.2.6.4 5.2.1.5

Table 2.1. Applicable environmental laws and regulations and 2020 status (continued)

Regulatory program description	2020 status	Report sections
The Emergency Planning and Community Right-to-Know Act (EPCRA), also referred to as the Superfund Amendments and Reauthorization Act Title III, requires reporting of emergency planning information, hazardous chemical inventories, and environmental releases of certain toxic chemicals to federal, state, and local authorities.	In 2020 DOE facilities on ORR were operated in accordance with emergency planning and reporting requirements. ETTP had no reportable releases of hazardous or extremely hazardous substances. Y-12 and ORNL had no reportable releases of extremely hazardous substances but ORNL exceeded the reporting threshold and reported on the otherwise use of nitric acid and the manufacture of nitrate compounds, as defined by the Emergency Planning and Community Right-to-Know Act, in 2020. Y-12 exceeded the 10,000-pound reporting threshold for Bromo-chloro, 5, 5-dimethyl hydantoin.	3.3.11 4.3.10 5.3.10
The National Environmental Policy Act (NEPA) requires consideration of how federal actions may impact the environment and an examination of alternatives to the actions. NEPA also requires that decisions include public input and involvement thorough scoping and review of NEPA documents.	During 2020, DOE planning and decision-making activities at ETTP, Y-12, and ORNL were conducted via site-level procedures that provide requirements for project reviews and NEPA compliance. In 2020, 37 NEPA reviews were completed at Y-12, five reviews were completed at ETTP, 127 reviews were completed by UT-Battelle, LLC at ORNL, and two reviews were completed by North Wind Solutions, LLC.	3.3.2 4.3.2 5.3.2
The National Historic Preservation Act provides protection for the nation's historic resources by establishing a comprehensive national historic preservation policy.	ORR has several facilities eligible for inclusion in the National Register of Historic Places. Proposed activities are reviewed to determine potential adverse effects on these properties, and methods to avoid or minimize harm are identified. During 2020, activities on ORR were conducted in compliance with National Historic Preservation Act requirements.	3.3.2 4.3.3 5.3.2
ORR Protection of Wetlands Programs are implemented to minimize the destruction, loss, or degradation of ORR wetlands and to preserve and enhance their beneficial value.	Surveys to determine the presence of wetlands are conducted as needed for projects or programs through NEPA and other reviews to facilitate compliance with TDEC and US Army Corps of Engineers wetlands protection requirements. Wetland protection on ORR is conducted in accordance with 10 *Code of Federal Regulations* 1022 and Executive Order (EO) 11990, *Protection of Wetlands*. No new wetlands were delineated at ETTP, Y-12, or ORNL in 2020.	1.3.6.1 5.3.12
The Resource Conservation and Recovery Act (RCRA) governs the generation, storage, handling, and disposal of hazardous wastes. RCRA also regulates underground storage tanks containing petroleum and hazardous substances, universal waste, and recyclable used oil.	Y-12, ORNL, and ETTP are defined as large-quantity generators of hazardous waste because each generates more than 1,000 kg of hazardous waste per month. Each site is also regulated as a handler of universal waste. In addition, several permits have been issued for hazardous waste management units on ORR. No notices of violation were issued for ETTP or Y-12 in 2020. At ORNL, one violation was identified and corrected when identified, returning the facility to compliance.	3.3.7 4.3.7 5.3.6

Table 2.1. Applicable environmental laws and regulations and 2020 status (continued)

Regulatory program description	2020 status	Report sections
The Safe Drinking Water Act establishes minimum drinking water standards and monitoring requirements.	The City of Oak Ridge supplies potable water to the facilities on ORR and is responsible for meeting all regulatory requirements for drinking water. Sampling results in 2020 for residual chlorine levels, bacterial constituents, disinfectant by-products, lead, and copper in ORR's water system were all within acceptable limits.	3.3.6 4.3.6 5.3.5
The Toxic Substances Control Act regulates the manufacture, use, and distribution of a number of toxic chemicals.	PCB waste generation, transportation, disposal, and storage at ORR are regulated under EPA identification numbers TN1890090003 and TN0890090004. ETTP operated two PCB waste storage areas in 2020 in RCRA-permitted facilities that meet the PCB regulations for long-term storage when PCB waste is being stored for longer than 30 days, which may be necessary for PCB radioactive waste. In 2020, UT-Battelle, LLC operated six PCB storage areas. Five were located at ORNL. The one PCB waste storage area located in the Y-12 Complex was operated by UT-Battelle, LLC. The ORR PCB Federal Facilities Compliance Agreement between EPA and DOE continues to provide a mechanism to address legacy PCB-use issues across ORR. The agreement specifically addresses the unauthorized use of PCBs, storage and disposal of PCB waste, PCB spill cleanup and decontamination, PCBs mixed with radioactive materials, PCB research and development, and ORR records and reporting requirements. EPA is updated annually on the status of DOE actions regarding management and disposition of legacy PCBs covered by the ORR PCB Federal Facilities Compliance Agreement.	3.3.10 4.3.9 5.3.9
The Bald and Golden Eagle Protection Act (16 US Code 668-668d) protects bald and golden eagles by prohibiting, except under certain specified conditions, the taking or possession of and commerce in such birds. The act imposes criminal and civil penalties for any such actions.	Bald eagles are known to frequent ORR year-round. The one active bald eagle nest on ORR is protected in accordance with this act. Eaglets have been successfully fledged from a Poplar Creek nesting location in the past.	1.3.6.2
The Endangered Species Act prohibits activities that would jeopardize the continued existence of an endangered or threatened species or cause adverse modification to a critical habitat.	ORR is host to several plant and animal species categorized as endangered, threatened, or of special concern, and these species are protected in accordance with this act.	1.3.6.2, 1.3.6.3
The Migratory Bird Treaty Act protects migratory birds by governing the taking, killing, possession, transportation, and importation of such birds, including their eggs, parts, and nests and any product, manufactured or not, from such items.	ORR hosts numerous migratory birds that are protected under this act.	1.3.6.2

Table 2.1. Applicable environmental laws and regulations and 2020 status (continued)

Regulatory program description	2020 status	Report sections
DOE Order 231.1B, *Environment, Safety, and Health Reporting,* ensures timely collection, reporting, analysis, and dissemination of information on environment, safety, and health issues.	The *2020 Oak Ridge Reservation Annual Site Environmental Report* summarizes ORR environmental activities during 2020 and characterizes environmental performance.	All chapters
DOE Order 435.1, Change 1, *Radioactive Waste Management,* is implemented to ensure that all DOE radioactive waste is managed in a manner that protects workers, public health and safety, and the environment.	Waste certification programs that are protective of workers, the public, and the environment have been implemented for all activities on ORR to ensure compliance with this DOE Order.	3.3 4.3.14, 4.8.2 5.3
DOE Order 436.1, *Department Sustainability,* provides requirements and responsibilities for managing sustainability within DOE to ensure the department carries out its missions in a sustainable manner that addresses national energy security and global environmental challenges and advances sustainable, efficient, and reliable energy for the future.	DOE contractors on ORR have developed site sustainability plans and have implemented environmental management systems that are incorporated with the contractors' integrated safety management systems to promote sound stewardship practices and ensure compliance with this DOE Order.	3.2 4.2 5.2
DOE Order 458.1, *Radiation Protection of the Public and the Environment,* issued in June 2011, canceled DOE Order 5400.5 and was established to protect members of the public and the environment from undue risk from radiation. This order established standards and requirements for operations of DOE and DOE contractors.	In 2020, DOE Order 458.1 was the primary contractual obligation for radiation protection programs for UT-Battelle, LLC and Consolidated Nuclear Security LLC, and for all UCOR work scope areas where existing CERCLA decision documents do not specifically identify DOE Order 5400.5 requirements. A dose assessment was performed to ensure that the total dose to members of the public from all DOE ORR pathways did not exceed the 100 mrem annual limit established by this order. The assessment estimated the maximum 2020 dose to a hypothetically exposed member of the public from all ORR potential exposure pathways combined would be about 3 mrem. Therefore, the 2020 maximum effective dose was about 3% of the 100 mrem annual limit given in DOE Order 458.1. Clearance of property from ORNL, ETTP, and the Y-12 Complex was conducted in accordance with approved procedures that comply with DOE Order 458.1. There were no unplanned radiological air emission releases from the three major ORR sites in 2020. No limits were exceeded in 2020.	Chapter 7

Table 2.1. Applicable environmental laws and regulations and 2020 status (continued)

Regulatory program description	2020 status	Report sections
DOE Order 5400.5, *Radiation Protection*, was established to protect members of the public and the environment against undue risk from radiation. This order established standards and requirements for operations of DOE and DOE contractors.	DOE Order 5400.5 is the primary environmental surveillance radiological applicable, relevant, and appropriate requirement for most CERCLA activities across ORR. It will remain in force until the individual CERCLA decision documents are reissued or revised to incorporate DOE Order 458.1. A dose assessment, performed to ensure the total dose to members of the public from all ORR pathways did not exceed the 100 mrem annual limit established by this order, estimated the maximum 2020 dose to a hypothetical exposed member of the public from all ORR potential exposure pathways combined would be about 3 mrem.	Chapter 7
Executive Order 13186, *Responsibilities of Federal Agencies to Protect Migratory Birds*, identifies the responsibilities of federal agencies to promote the conservation of migratory bird populations.	A memorandum of understanding entered into by DOE and the US Fish and Wildlife Service meets the requirements under Section 3 of EO 13186. ORR hosts numerous migratory birds that are present either seasonally or year-round. This memorandum, which was updated in September 2013, strengthens migratory bird conservation on ORR through enhanced collaboration between DOE and the US Fish and Wildlife Service.	1.3.6.2
Executive Order 13834, *Efficient Federal Operations*, directs federal agencies to manage their buildings, vehicles, and overall operations to optimize energy and environmental performance, reduce waste, and cut costs.	EO 13834, *Efficient Federal Operations*, superseded EO 13693. Progress toward meeting the requirements of the EO and achieving DOE sustainability goals is summarized in this report. ORNL, Y-12, and ETTP all have sustainability processes and management systems to comply with the EO and subsequent federal instructions for implementing the EO.	3.2.1 4.2.6.3 5.2.1.4

Acronyms:

CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
DOE = US Department of Energy
EISA = Energy Independence and Security Act
EMWMF = Environmental Management Waste Management Facility
EO = Executive Order
EPA = US Environmental Protection Agency
EPCRA = Emergency Planning and Community Right-to-Know Act
ETTP = East Tennessee Technology Park
NEPA = National Environmental Policy Act
NPDES = National Pollutant Discharge Elimination System
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
PCB = polychlorinated biphenyl
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation
Y-12 or Y-12 Complex = Y-12 National Security Complex

Table 2.2. Summary of regulatory environmental audits, evaluations, inspections, and assessments conducted at ORR, 2020

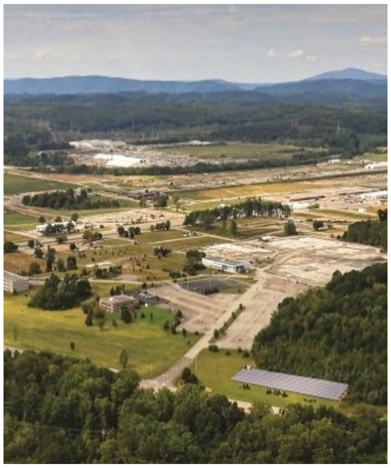
Date	Reviewer	Subject	Issues
		East Tennessee Technology Park	
January 6	TDEC	K-1600 Closure Inspection	0
February 5	TDEC	K-1200 RCRA Compliance Inspection	0
May 12	City of Oak Ridge	ETTP Sewage and Storm Drain Inspection	0
June 4	TDEC	K-1066-F and K-1066-G RCRA Closure Inspection	0
June 10	TDEC	ETTP CERCLA/NPDES Inspection	0
July 28	TDEC	ETTP NPDES Outfall Inspection	0
August 26	EPA/TDEC	RCRA Inspection of ETTP	0
November 19	TDEC	Air Inspection of removed generator sites	0
		Y-12 National Security Complex	
January 24	City of Oak Ridge	Semiannual Industrial Pretreatment Compliance Inspection	0
August 19	TDEC	Annual RCRA Hazardous Waste Compliance Inspection	0
July 29	TDEC	Annual Air Quality Compliance Inspection	0
October 2	City of Oak Ridge	Semiannual Industrial Pretreatment Compliance Inspection	0
		Oak Ridge National Laboratory (including UT-Battelle, LLC; UCOR; Isotek Systems, LLC; and North Wind Solutions, LLC activities)	
March 4	TDEC	Hazardous Waste Compliance Evaluation Inspection (ORNL Warehouse)	0
March 11–12	TDEC	Hazardous Waste Compliance Evaluation Inspection (including UT-Battelle, TWPC, and UCOR)	1
January 3	City of Oak Ridge	Carbon Fiber Technology Facility Wastewater Inspection	0
July 21	KCDAQM	National Transportation Research Center CAA Inspection	0
August 25	City of Oak Ridge	Carbon Fiber Technology Facility Wastewater Inspection	0
October 22	TDEC	Annual CAA Inspection for ORNL and Carbon Fiber Technology Facility	0

Acronyms:
CAA = Clean Air Act
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
EPA = US Environmental Protection Agency
ETTP = East Tennessee Technology Park
KCDAQM = Knox County Department of Air Quality Management
NPDES = National Pollutant Discharge Elimination System
ORNL = Oak Ridge National Laboratory
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation
TWPC = Transuranic Waste Processing Center

2.6. References

DOE 2020. *2020 Remediation Effectiveness Report for the US Department of Energy Oak Ridge Reservation, Oak Ridge, Tennessee, Data and Evaluations.* DOE/OR/01-2844&D1, US Department of Energy, Oak Ridge, Tennessee, March.

UCOR 2020. *2020 Cleanup Progress: Annual Report to the Oak Ridge Regional Community, Oak Ridge, Tennessee.* OREM-20-7603, UCOR, Oak Ridge, Tennessee.



The East Tennessee Technology Park has changed greatly in recent years as remediation projects have been completed.

3

East Tennessee Technology Park

ETTP was built during World War II as part of the Manhattan Project. Formerly known as the K-25 Site, its primary mission was to enrich uranium for use in atomic weapons. After the war, the mission changed to include the enrichment of uranium for nuclear reactor fuel elements and recycling of uranium recovered from spent fuel, and the name changed to the "Oak Ridge Gaseous Diffusion Plant" (ORGDP). In the 1980s, a reduction in demand for nuclear fuel resulted in the shutdown of the enrichment process and production. The emphasis of the mission then changed to environmental management and remediation operations. In 1996, the name changed to the "East Tennessee Technology Park."

Environmental management and remediation consist of waste management, the cleanup of outdoor storage and disposal areas, the demolition and cleanup of facilities, land restoration, environmental monitoring, and the proper disposal of waste generated from production operations. Beginning in the 1990s, reindustrialization (the conversion of underused government facilities for use by the private sector) became part of ETTP's mission. State and federally mandated effluent monitoring and environmental surveillance involve the collection and analysis of air, water, soil, sediment, and biota samples from ETTP and surrounding areas. Monitoring results are used to assess exposures to the public and the environment, evaluate the performance of treatment systems, and identify concerns within permitted standards for emissions and discharges. On November 10, 2015, DOE and the US Department of Interior signed a memorandum of agreement (MOA) establishing the Manhattan Project National Historical Park. The MOA defines agency roles and responsibilities in park administration and provisions for enhanced public access, management, interpretation, and historic preservation. The ORGDP footprint is included within the Manhattan Project National Historical Park. Details are available on the Manhattan Project National Historical Park page of the National Park Service website, **here**, and the K-25 Virtual Museum website details its history through narrative, interviews, and photographs, found **here**.

3.1. Description of Site and Operations

Construction of the K-25 Site (Figure 3.1) began in 1943 as part of the World War II Manhattan Project. The plant's original mission was the production of enriched uranium for nuclear weapons. Enrichment was initially carried out in the S-50 thermal diffusion process facility, which operated for one year, and the K-25 and K-27 gaseous diffusion process buildings. Later, the K-29, K-31, and K-33 buildings were built to increase the production capacity of the original facilities by raising the assay of the feed material entering K-27. Following the war years, the site became officially known as ORGDP.

After military production of highly enriched uranium was concluded in 1964, the two original process buildings were shut down. For the next 20 years, the plant's primary mission was the production of low enriched uranium fabricated into fuel elements for nuclear reactors throughout the world. Other missions during the latter part of this 20-year period included developing and testing the gas centrifuge method of uranium enrichment and laser isotope separation research and development.

By 1985, the demand for enriched uranium declined, and the gaseous diffusion cascades at ORGDP were placed in standby mode. That same year, the gas centrifuge program was canceled. The decision to permanently shut down the diffusion cascades was announced in late 1987 and actions necessary to implement that decision were initiated soon thereafter. Because of the termination of the original and primary missions, ORGDP was renamed the "Oak Ridge K-25 Site" in 1989. Figure 3.2 shows the ETTP site areas before the start of decontamination and decommissioning (D&D) activities. In 1996, the K-25 Site was renamed the "East Tennessee Technology Park" to reflect its new mission.

Figure 3.3 shows the ETTP areas designated for D&D activities through 2020. The ETTP mission is to reindustrialize and reuse site assets through leasing and/or transferring excess or underused land and facilities and by incorporating commercial industrial organizations as partners in the ongoing environmental restoration, D&D, and waste treatment and disposal. The site is undergoing environmental cleanup of its land, as well as D&D of most of its buildings. The cleanup approach makes land and various types of buildings (e.g., office, manufacturing) suitable for private industrial use and for title transfer to the Community Reuse Organization of East Tennessee (CROET) or other entities such as the City of Oak Ridge (COR). The long-term DOE goal for ETTP is to transfer as much of the site property as practicable out of DOE ownership and into CROET's control for the development of a commercial business and industrial park. The facilities may then be subleased or sold, with the goal of stimulating private industry and recruiting business to the area. These transfers also reduce maintenance costs for DOE, which frees up additional money for environmental cleanup. The reuse of key facilities through title transfer is part of the site's closure plan.

UCOR, the lead environmental management contractor for ETTP, supports DOE in the reindustrialization program as part of the continuing effort to transform ETTP into a private-sector industrial park. Unless otherwise noted, information about non-DOE entities located on the ETTP site is not provided in this document.

Figure 3.1. The K-25 Site in 1946

Figure 3.2. East Tennessee Technology Park since the start of decontamination and decommissioning activities in 1991

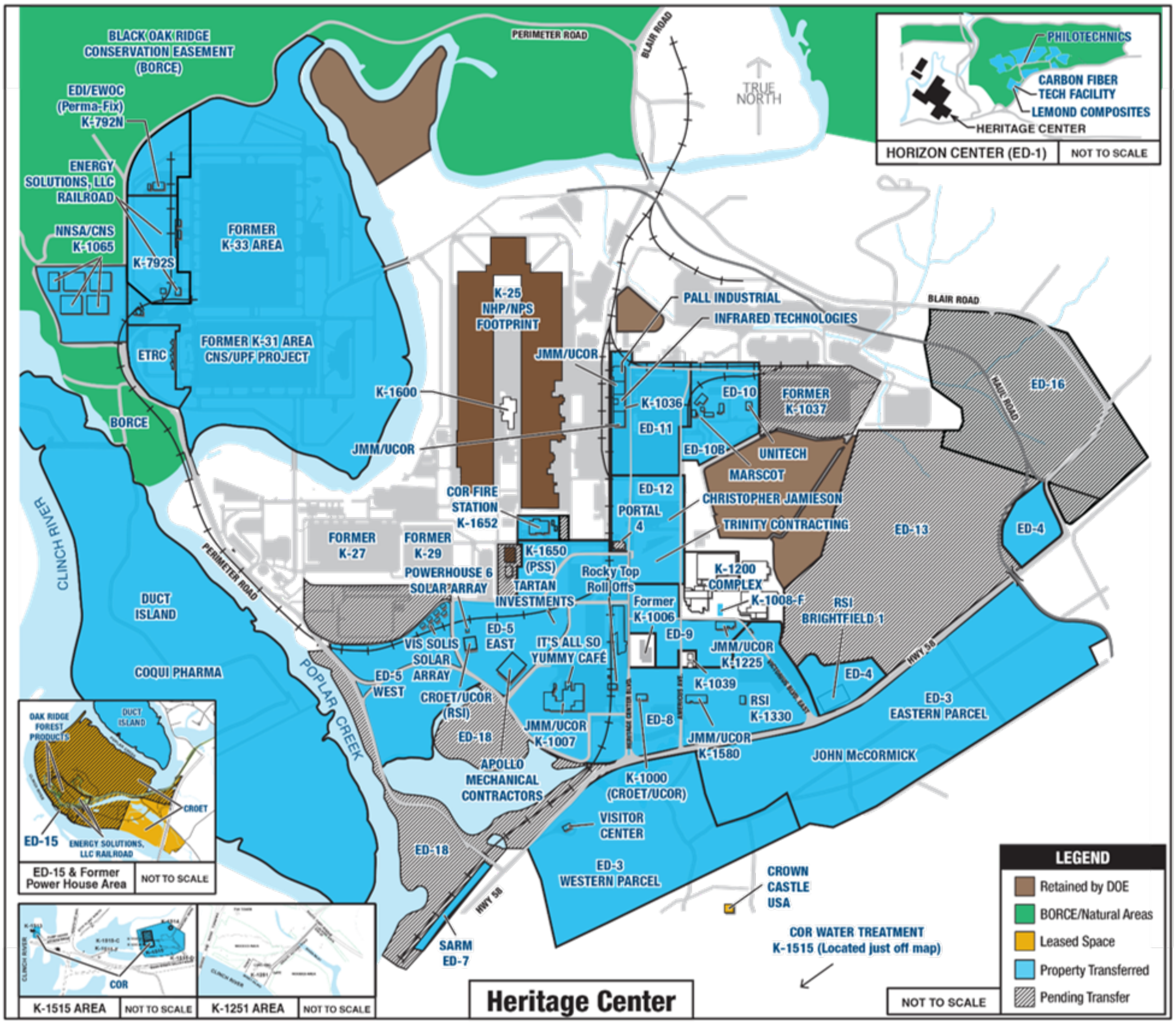


Figure 3.3. East Tennessee Technology Park in 2020, showing progress in reindustrialization

3.2. Environmental Management System

The UCOR Environmental Management System (EMS) is integrated with the UCOR Integrated Safety Management System (ISMS). UCOR's EMS is based on a graded approach for a closure and remediation contract and reflects the elements and framework contained in International Organization for Standardization (ISO) Standard 14001:2004, *Environmental management systems—Requirements with guidance for use* (ISO 2004). UCOR is committed to incorporating sound environmental management, protection, and sustainability practices in all work processes and activities that are part of the DOE Environmental Management (EM) program in Oak Ridge, Tennessee. UCOR's environmental policy states, in part, "Our commitment to protect and sustain human, natural, and cultural resources is inherent in our mission to complete environmental cleanup safely with reduced risks to the public, workers, and the environment." To achieve this, UCOR's environmental policy adheres to the following principles:

- **Leadership Commitment**—Integrate responsible environmental practices into project operations.

- **Environmental Compliance and Protection (EC&P)—**Comply with all environmental regulations and standards.
- **Sustainable Environmental Stewardship—**Minimize the effects of our operations on the environment through a combination of source reduction, recycling, and reuse; sound waste management practices; and pollution prevention (P2).
- **Partnership/Stakeholder Involvement—**Maintain partnerships through effective two-way communications with our customers and other stakeholders.

3.2.1. Sustainable Environmental Stewardship

UCOR incorporates environmental sustainability principles, the procurement of environmentally preferable products, recycling, and P2 and waste minimization practices in its work processes and activities. As an example, Figure 3.4 presents a selection of information on UCOR's 2020 P2 recycling activities related to solid waste reduction at ETTP. UCOR recycles much of its universal waste, municipal solid waste and scrap metal, reuses large amounts of construction and demolition debris, and encourages the reduction of waste wherever possible.

UCOR's exceptional electronics stewardship earned it an award in 2020 from the Global Electronics Council for its use of Electronic Product Environmental Assessment Tool (EPEAT) methods and leadership in sustainable electronics procurement. This is the sixth consecutive year that UCOR has won an EPEAT award and the second consecutive year it was achieved at the four-star level.

Additionally, UCOR internally recognized four projects for their P2 and waste minimization accomplishments in 2020, which are summarized below.

- The East Tennessee Technology Park Decommissioning and Demolition project was recognized for recycling 178,150 lb of scrap metal from deactivation work that met Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) qualification. This effort saved 203,499 kWh of energy, 17,400 gal of water and 54 metric tons (MT) in greenhouse gas emissions while saving valuable landfill space.
- The East Tennessee Technology Park Decommissioning and Demolition project was recognized for re-purposing excavation spoils material from the ED-19 utility upgrade project as backfill at the K-832-H Basin, which avoided 730 yd^3 of waste, reduced 2.59 MT in greenhouse gas emissions, and saved over $70,000.
- The Oak Ridge National Laboratory Operations and Cleanup Enterprise project was recognized for recharacterizing radioactively contaminated equipment as CERCLA in order to dispose of it locally, which avoided 59 MT of greenhouse gas emissions and saved the project $245,000 in container, shipping, and disposal fees.
- The Y-12 National Security Complex Biology and Excess Contaminated Facilities Decommissioning and Demolition project was recognized for realizing the opportunity to reduce the size of fluorescent light tubes through use of a bulb crusher. This resulted in more efficient shipping, which avoided 3.37 MT of greenhouse gas emissions and saved $3,911.

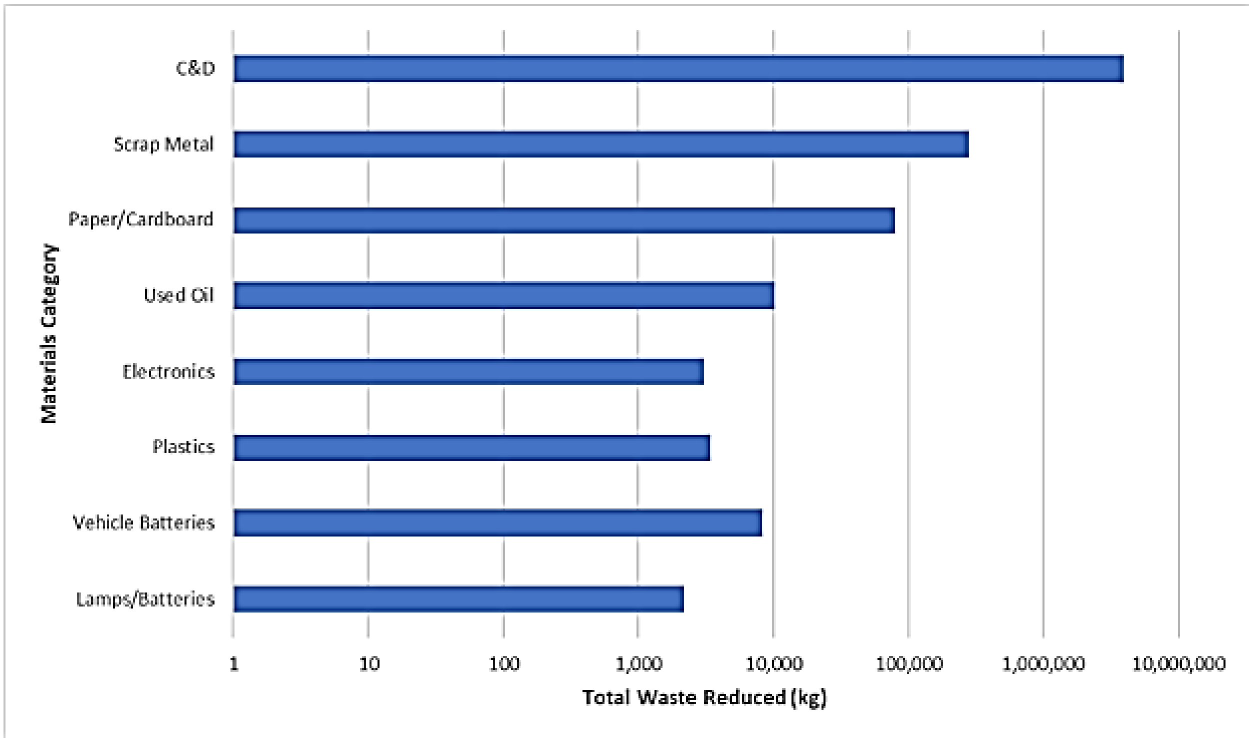


Figure 3.4. Pollution prevention recycling activities related to solid waste reduction at the East Tennessee Technology Park in calendar year 2020

Together, the projects represented sustainability accomplishments in resource conservation, waste diversion, waste reduction, and P2. These accomplishments were the result of teamwork, leveraging a number of work control and management tools to save landfill space, reduce the use of virgin material, mitigate hazards to the environment and workers, and increase work efficiencies. In 2020, more than 189 MT of greenhouse gas emissions, 910 MT of waste, 200,000 kWh of electricity, and 17,400 gal of water were saved as a result of implementation of P2 measures by the projects. In addition to lessening the impact on the environment, these P2 measures also saved more than $319,000.

In 2016, a significant improvement in the diversion of scrap metal was made, by petitioning and receiving agreement from EPA and the Tennessee Department of Environment and Conservation (TDEC) to apply an unprecedented CERCLA screening process that allows noncontaminated scrap metal from CERCLA areas, previously excluded from commercial recycling services, to be safely shipped to commercial scrap-metal dealers for recycle. Effectively, the screening process removes the noncontaminated scrap metal from regulation under CERCLA; therefore, any non-CERCLA commercial scrap-metal recyclers can receive the material for recycle. This agreement continues to be successfully employed, allowing approximately 175,080 lb (79.4 MT) of scrap metal to be recycled in fiscal year (FY) 2020 in lieu of land disposal and provides a path forward for additional waste diversion for the duration of the contract.

Some of the significant benefits of the scrap-metal recycling under this approval include:

- Provides funds from the recycling payments that are available to go back into the programs and support further actions in the Oak Ridge cleanup program.
- Conserves valuable landfill space. To date, the scrap metal recycled as a result of the screening process has saved approximately 788 yd^3 of valuable landfill space, which

translates into a considerable cost savings, which takes into consideration capital cost, landfill capacity, historical operating costs, packing, and transportation.

- Supports EPA, TDEC, and DOE programmatic environmental stewardship goals for waste diversion.

The CERCLA screening process will continue to be used as more demolition and cleanup are continued at ETTP, Oak Ridge National Laboratory (ORNL), and the Y-12 National Security Complex (Y-12).

In the area of alternative energy, Restoration Services, Inc. (RSI), in concert with UCOR, continued operations of ETTP's solar parks (Figure 3.5). Brightfield 1 is a 200-kW solar array located on a 0.405-ha (1-acre) tract purchased from CROET and built by RSI as part of UCOR's commitment to the revitalization of the former K-25 Site.

Figure 3.5. Oak Ridge Powerhouse Six Solar Farm

RSI self-financed the project using solar panels manufactured in Tennessee and partnering with other local small businesses for the installation. Power generated from Brightfield 1 is being sold to the Tennessee Valley Authority (TVA) through the City of Oak Ridge Electric Department using a TVA Generation Partners contract. The completed project was commissioned in April 2012 and is part of RSI's Brownfields to Brightfields initiative that works to develop restricted-use properties into solar farms. Brightfield 1 energy production in its first year was 110 percent more than projected, with no downtime due to maintenance issues. In calendar year (CY) 2020, Brightfield 1 produced 248,000 kWh of energy. During January 2020, Brightfield 1 continued a single downtime that had begun in December 2019 due to maintenance activities, with the seasonal timing resulting in only a negligible increase in the use of conventionally supplied power.

In addition, through the cooperative efforts of DOE, UCOR, RSI, Vis Solis, Inc., CROET, and COR, a second solar farm—the Powerhouse Six Solar Farm—was constructed on the west end of the park. It is a 1-MW solar farm that became operational in April 2015 and provides renewable energy, long-term lease income to CROET and bolsters development at ETTP. This project continues to provide numerous benefits to the environment and the community at large, which include the following:

- Generates enough clean energy to power more than 100 homes.
- Prevents pollution by removing the equivalent of 240 cars from the road annually (1,141 MT of CO_2).
- Provides brownfield reuse/redevelopment at ETTP.
- Supports COR renewable energy goals.
- Supports TVA renewable energy initiatives.
- Offers community economic development jobs and property tax income to COR.
- Demonstrates benefits of ETTP reindustrialization.
- Supports DOE renewable energy goals.
- Demonstrates collaborative success between DOE and a public utility for renewable energy development.

UCOR also continues to use environmentally sustainable products. Large quantity purchases are evaluated for less toxic alternatives. Other product purchases are first reviewed to determine if a recycled content material or biobased content alternatives are commercially available, and those alternatives are prioritized for purchase when feasible.

UCOR is one of the DOE contractors having responsibilities for land management of portions of the Oak Ridge Reservation (ORR). The Natural Resources Management Team for ORR, centered at ORNL, is partially funded by UCOR, and is responsible for the creation and implementation of an Invasive Plant Management Plan. At ETTP, these efforts have included:

- Exposure Unit (EU)-29 demonstration field invasive plant control
- Powerhouse Trail privet control
- Wheat Church Vista invasive plant control
- Black Oak Ridge Conservation Easement kudzu and invasive plant control
- Black Oak Ridge Conservation Easement greenway and trail invasive plant control

For additional information, please see Chapter 6.

3.2.2. Environmental Compliance

UCOR maintains various layers of oversight to ensure compliance with legal and other requirements. The methods of evaluation include independent assessments by outside parties, assessments conducted by functional or project organizations, and routine field walkdowns conducted by a variety of functional and project personnel. Assessments are prioritized and scheduled based on risk management principles and performed in accordance with procedures. Records are maintained for all formal assessments and audits. Issues identified in assessments are handled, as required, by ISO 14001:2004, Section 4.5.3, "Nonconformity, Corrective Action, and Preventive Action" (ISO 2004). For additional information see Section 3.4.

3.2.3. Environmental Aspects/Impacts

Using a graded approach appropriate for EMS includes an environmental policy that provides a unified strategy for the management, conservation, and protection of natural resources; the control and attenuation of risks; and the establishment and attainment of all environment, safety, and health (ES&H) goals. UCOR works continuously to improve its EMS to reduce impacts from activities and associated effects on the environment (i.e., environmental aspects) and to communicate and reinforce this policy to its internal and external stakeholders.

3.2.4. Environmental Performance Objectives and Targets

UCOR conserves and protects environmental resources by: (1) incorporating environmental protection and the elements of an enabling EMS into the daily conduct of business; (2) fostering a spirit of cooperation with federal, state, and local regulatory agencies; and (3) using appropriate waste management, treatment, storage, and disposal methods.

UCOR has established a set of core, company-level EMS objectives that remain relatively unchanged from year to year. These objectives are generally applicable to all operations and activities throughout UCOR's work scope. The core environmental objectives are based on compliance with applicable legal requirements and sustainable environmental practices contained in DOE Order 436.1, *Departmental Sustainability* (DOE 2011a), and include the following:

- Comply with all environmental regulations, permits, and regulatory agreements.
- Reduce or eliminate the acquisition, use, storage, generation, and/or release of toxic, hazardous, and radioactive materials; waste; and greenhouse gas emissions through acquisition of environmentally preferable products, conduct of operations, removal and safe disposition, and WMin and sustainable practices.

- Reduce degradation and depletion of environmental resources and potential impact on climate change through post-consumer material recycling, energy, fuel, and water conservation efforts, use or promotion of renewable energy, and transfer for reuse valuable real estate assets.
- Reduce the environmental impact on surface water and groundwater resources.
- Reduce the environmental impact associated with project and facility activities.

The EMS objectives and targets reduce the environmental impact of UCOR activities and accomplish the DOE sustainability goals. Each year, ETTP reports its performance in the DOE Sustainability Dashboard, which collects data such as energy and water usage, greenhouse gas generation, sustainable buildings, facility metering, waste diversion, renewable energy, sustainable acquisitions, and electronic stewardship.

The Office of Management and Budget's Environmental Stewardship Scorecard is used to track and measure site-level EMS performance. During FY 2020, UCOR received a "green" for EMS performance, indicating full implementation of EMS requirements.

3.2.5. Implementation and Operation

UCOR protects the safety and health of workers and the public by identifying, analyzing, and mitigating aspects, hazards, and impacts from ETTP operations, and by implementing sound work practices. All UCOR employees and subcontractors are held responsible for complying with all ES&H requirements during all work activities and are expected to correct noncompliant conditions immediately. UCOR's internal assessments also provide a measure of how well EMS attributes are integrated into work activities through ISMS. UCOR has embodied its program for the environmental compliance and the protection of natural resources in a companywide environmental management and protection policy. The policy is UCOR's fundamental commitment to incorporating sound environmental management practices in all work processes and activities.

3.2.6. Pollution Prevention/Waste Minimization/Release of Property

UCOR's work control process requires that all waste-generating activities be evaluated for source reduction and that product substitution be used to produce less toxic waste, when possible. The reuse or recycling of building debris and other generated wastes is evaluated in all cases.

The ETTP EMS program fosters P2 at every level of its operations, from routine office recycling of paper, cardboard and plastics, to unique reuse and recycling at the project-field level. UCOR's P2 program is successful because it is tightly bound to its work control process. Thus, many original applications of material reuse and recycling have resulted, many of which have been captured through its internal P2 awards program. Each year, the projects that are recognized in the P2 internal awards program are often the source of UCOR's national-level awards nominations (e.g., DOE Headquarters annual award program).

DOE Order 458.1, *Radiation Protection of the Public and Environment* (DOE 2011), requires that a process be in place to ensure that radiologically contaminated materials are not released to the public or the environment, except in compliance with permit effluent requirements or other agreements with regulatory agencies. Materials and equipment may be released to the public through an approved pollution prevention/recycling program or through property sales (procedure PROC-PR-2032, *Disposition of Personal Property*, governs the process of releasing personal property), and real property may be transferred to the public through CROET.

Materials and equipment that are to be recycled or reused may follow one of two paths. If process knowledge is sufficient to establish that the materials and equipment have never been in contaminated areas (for example, empty beverage cans from a specified break area or an office building) then the materials may be released for recycling or reuse. Materials and equipment from areas that have, or in the past have had, radiologic areas must be examined by trained radiologic control technicians and the results documented before the materials and equipment may be released. Materials and equipment that fail to meet the free release criteria are either decontaminated to the point that they meet the free release criteria, or are properly disposed of at an appropriate disposal facility. The release of property from radiologic areas is governed by procedure PROC-RP-4516, *Radioactive Contamination Control and Monitoring* (Table 3.1). In addition to the types and quantities of recycled materials and equipment shown in Figure 3.4 above, 187,083 kg of office furniture, office supplies, electronics, electrical equipment, and building materials were released to the public through property sales.

Real property to be transferred must meet the release criteria established by DOE Order 458.1 and the appropriate Record of Decision. DOE ensures that these requirements are met through independent verification by a third party. Currently, this verification is performed by Oak Ridge Associated Universities (ORAU) through a direct contract with DOE. The direct contract with DOE ensures that the evaluation is performed independently of UCOR, DOE's cleanup contractor. ORAU reviews historic data, facility use history, verification strategies, methodologies, techniques, and equipment. When ORAU deems it appropriate, additional sampling and/or radiological surveys are conducted. Results of the evaluation and verification are summarized in a report to DOE that is then submitted to DOE Headquarters for approval as part of the transfer package. Section 3.8 contains a summary of the real property releases to the public.

Table 3.1. Surface contamination values and DOE Order 458.1 authorized limits for surface activity

Radionuclide	Removable	Total (Fixed + Removable)
Natural Uranium, ^{235}U, ^{238}U, and associated decay products	1,000	5,000
Transuranics, ^{226}Ra,^{228}Ra,^{230}Th,^{228}Th,^{231}Pa,^{227}Ac,^{125}I,^{129}I	20	100/500
Natural Th, ^{232}Th,^{90}Sr,^{223}Ra,^{224}Ra,^{232}U,^{126}I,^{131}I,^{133}I	200	1,000
Beta-gamma emitters except ^{90}Sr and others noted above	1,000	5,000
Tritium and Special Tritium Compounds	10,000	

Note: *Limits are shown in dpm/100 cm^2.*

3.2.7. Competence, Training, and Awareness

The UCOR training program and qualification process ensures that needed skills for the workforce are identified and developed and documents knowledge, experience, abilities, and competencies of the workforce for key positions requiring qualification. Completion and documentation of training, including required reading, are managed by the Local Education Administration Requirements Network, or LEARN.

3.2.8. Communication

UCOR communicates externally regarding environmental aspects through the UCOR public website, found **here**, which includes a link to its environmental policy statement in *Environmental Management and Protection* POL-UCOR-007, and a list of environmental aspects.

A number of other documents and reports that address environmental aspects and cleanup progress are also published and made available to the public (e.g., the Annual Site Environmental Report [ASER] [DOE 2020, DOE/ORO-2512] and the annual cleanup progress report [UCOR 2021a, *2020 Cleanup Progress—Annual Report to the Oak Ridge Regional Community,* OREM-20-7603]).

UCOR participates in a number of public meetings related to environmental activities at the site (e.g., Oak Ridge Site Specific Advisory Board [ORSSAB] meetings, which include community stakeholders, public permit reviews, and public CERCLA decision document reviews). Written communications from external parties are tracked using the weekly Open Action Report.

3.2.9. Benefits and Successes of Environmental Management System Implementation

An EMS program provides many benefits to an organization's success. Based upon the simplified model of Plan-Do-Act-Check, it provides a framework by which work incorporates mitigation of environmental hazards into its work control and planning. This translates into many returns to the organization. UCOR uses EMS objectives and targets, an internal P2 recognition program, environmentally preferable purchasing, work control processes, and a recycle program to meet sustainability and environmental stewardship goals and requirements. The approach is outlined in UCOR's *Pollution Prevention and Waste Minimization Program Plan for the East Tennessee Technology Park, Oak Ridge, Tennessee* (UCOR 2021b, UCOR-4127/R9). The EMS program is audited by a third party triennially as for conformance to the ISO 14001:2004 standard (ISO 2004) as required by DOE Order 436.1, *Departmental Sustainability, Attachment1 Contractor Requirements Document* (DOE 2011a), with the most recent having been conducted in 2018. The results of the audit were zero findings, three observations, and four proficiencies.

3.2.10. Management Review

A formal review/presentation with UCOR senior management is conducted once per year that addresses the ISO 14001:2004 (ISO 2004) required elements, including focus areas for the upcoming year. At least two of the senior managers are present for management reviews. The environmental policy is also reviewed during the annual EMS management review and revised as necessary. Also, periodic reports are submitted to senior management on the status of EMS calendar year company level objectives and targets.

3.3. Compliance Programs and Status

During 2020, ETTP operations were conducted in compliance with contractual and regulatory environmental requirements. There were no National Pollutant Discharge Elimination System (NPDES) permit noncompliances and no Clean Air Act (CAA) noncompliances in 2020. Figure 3.6 shows the trend of NPDES compliance at ETTP since 2012. The following sections provide more detail on each compliance program and the environmental remediation-related activities in 2020.

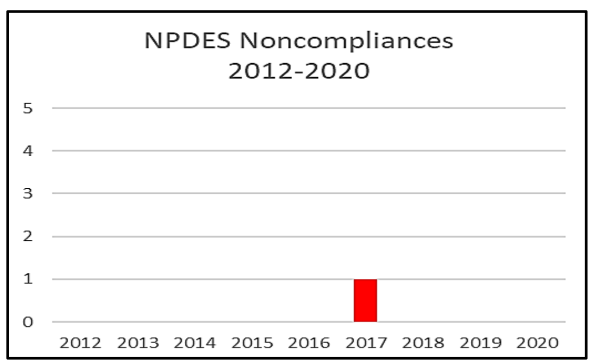


Figure 3.6. East Tennessee Technology Park National Pollutant Discharge Elimination System permit noncompliances since 2012

3.3.1. Environmental Permits Compliance Status

Table 3.2 contains a list of environmental permits that were in effect at ETTP in 2020. ETTP received no notices of environmental violations or penalties in 2020.

Table 3.3 presents a summary of environmental audits and oversight visits conducted at ETTP in 2020.

3.3.2. National Environmental Policy Act/National Historic Preservation Act

The National Environmental Policy Act (NEPA) provides a means to evaluate the potential environmental impact of proposed federal activities and to examine alternatives to those actions. ETTP maintains compliance with NEPA through the use of site-level procedures and program descriptions that establish effective and responsive communications with program managers and project engineers to ensure NEPA is a key consideration in the formative stages of project planning. Many of the current operations at ETTP are conducted under CERCLA. NEPA reviews are part of the CERCLA planning process to ensure that NEPA values are incorporated into CERCLA projects and documentation. NEPA reviews identify new or changing environmental aspects associated with proposed activities.

During 2020, ETTP continued to operate under site-level, site-specific procedures that provide requirements for project reviews and NEPA compliance. These procedures call for a review of each proposed project, activity, or facility to determine the potential for impacts on the environment. To streamline the NEPA review and documentation process, DOE Oak Ridge Office has approved generic categorical exclusion determinations that cover certain proposed activities (i.e., maintenance activities, facility upgrades, personnel safety enhancements). A categorical exclusion is one of a category of actions defined in 40 *Code of Federal Regulations* (CFR) Part 1508.4 (EPA 1978) that does not individually or cumulatively have a significant effect on the human environment and for which neither an environmental assessment nor an environmental impact statement is normally required. UCOR activities on ORR are in full compliance with NEPA requirements, and procedures for implementing NEPA requirements have been fully developed and implemented. At ETTP, a checklist incorporating NEPA and EMS requirements has been developed as an aid for project planners. For routine, recurring activities, DOE generic categorical exclusion determinations are used. During 2020, five review reports were generated to document UCOR activities such as construction of small support buildings, storage yards, and access road improvements.

Compliance with the National Historic Preservation Act at ETTP is achieved and maintained in conjunction with NEPA compliance. The scope of proposed actions is reviewed in accordance with the ORR Cultural Resource Management Plan (Souza et al. 2001). At ETTP, there were 135 facilities eligible for inclusion on the National Register of Historic Places, a US National Park Service program to identify, evaluate, and protect historic and archeological resources in the United States, as well as numerous facilities that were not eligible for inclusion on the National Register of Historic Places. To date, more than 800 facilities have been demolished. Artifacts of historical and/or cultural significance are identified before demolition and are catalogued in a database to aid in the historic interpretation of ETTP.

On December 14, 2014, Congress authorized the establishment of the Manhattan Project National Historical Park to commemorate the history of the Manhattan Project (DOI 2015). It will comprise the three major sites: Los Alamos, New Mexico; Oak Ridge, Tennessee; and Hanford, Washington, which were dedicated to accomplishing the Manhattan Project mission.

Table 3.2. East Tennessee Technology Park environmental permits, 2020

Regulatory driver	Permit title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
CAA	State permit to operate an air contaminant source—internal combustion engine–powered emergency generators and fire water pump replaced by PBR when NOA received from TDEC	069346P, NOA Number R74133	03-03-2015 Amended 11-22-2016 NOA issued 7-19-2018	10-01-2024, none for NOA NOA terminated in 2020	DOE	UCOR	UCOR
CWA	NPDES permit for storm water discharges	TN0002950	02-01-2015	03-31-2020 Remains in effect	DOE	UCOR	UCOR
CWA	SOP—waste transportation project; Blair Road and Portal 6 sewage pump and haul permit	SOP-05068	07-01-2014	02-28-2019 Remains in effect	TFE	TFE	TFE
CWA	SOP—ETTP holding tank/haul system for domestic wastewater	SOP-99033	07-01-2015	06-30-2020 Not renewed	UCOR	UCOR	UCOR
RCRA	ETTP container storage and treatment units	TNHW-165	09-15-2015	[b]09-15-2020	DOE	UCOR	UCOR
RCRA	Hazardous waste corrective action document (encompasses entire ORR)	TNHW-164	09-15-2015	09-15-2025	DOE	DOE/All[a]	DOE/All[a]

[a] *DOE and ORR contractors that are co-operators of hazardous waste permits.*
[b] *This permit was terminated by TDEC at the request of UCOR. All hazardous waste treatment and storage units were certified/verified closed by TDEC.*

Acronyms:
CAA = Clean Air Act
CWA = Clean Water Act
DOE = US Department of Energy
ETTP = East Tennessee Technology Park
ID = identification (number)
NOA = Notice of Authorization
NPDES = National Pollutant Discharge Elimination System
ORR = Oak Ridge Reservation
PBR = Permit-by-Rule
RCRA = Resource Conservation and Recovery Act of 1976
SOP = state operating permit
TDEC = Tennessee Department of Environment and Conservation
TFE = Technical and Field Engineering, Inc.
UCOR = UCOR, an Amentum-led partnership with Jacobs

Table 3.3. Regulatory oversight, assessments, inspections, and site visits at East Tennessee Technology Park, 2020

Date	Reviewer	Subject	Issues
January 6	TDEC	K-1600 Closure Inspection	0
February 5	TDEC	K-1200 RCRA Compliance Inspection	0
May 12	COR	ETTP Sewage and Storm Drain Inspection	0
June 4	TDEC	K-1066-F and –G RCRA Closure Inspection	0
June 10	TDEC	ETTP CERCLA/NPDES Inspection	0
July 28	TDEC	ETTP NPDES Outfall Inspection	0
August 26	EPA/TDEC	RCRA Inspection of ETTP	0
November 19	TDEC	Air Inspection of removed generator sites	0

Acronyms:
COR = City of Oak Ridge
EPA = US Environmental Protection Agency
ETTP = East Tennessee Technology Park
NPDES = National Pollutant Discharge Elimination System
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation

Consultation for the development of a MOA for D&D of the K-25 and K-27 buildings started in 2001; the document, approved in 2003, required a third-party analysis of the preservation and interpretive strategies for those two buildings. In 2005, DOE, the Tennessee State Historic Preservation Office, and the Advisory Council on Historic Preservation entered into an MOA that included the retention of the north end tower (also known as the north wing and the north end) of the K-25 Building and Portal 4 (K-1028-45), among other features, as the "best and most cost-effective mitigation to permanently commemorate, interpret, and preserve the significance" of ETTP. After another series of consultation meetings from 2009 through 2011, a final mitigation plan was developed by DOE that permitted demolition of the entire K-25 Building and called for, among other mitigation measures, the designation of a commemorative area around the building's perimeter from which future surface development would largely be restricted; the retention, if possible, of the entire concrete slab or the demarcation of the building's footprint; the construction of a viewing tower and structure for equipment display; and the development of a history center within the ETTP Fire Station #4. A final MOA was signed in August 2012, finalizing the aspects set forth in the mitigation plan. A Professional Design Team and Museum Professional were selected in 2014. The museum design was completed in 2017, construction began in 2018, and the K-25 History Center opened to the public on February 27, 2020. The K-25 History Center closed in April 2020 due to the COVID-19 pandemic.

The Memorandum of Agreement between the United States Department of the Interior and the United States Department of Energy for the Manhattan Project National Historical Park was signed by Department of the Interior and DOE on November 10, 2015 (DOE 2015), creating the new Manhattan Project National Historical Park. The K-25 Virtual Museum website, found **here**, was launched in conjunction with the signing of the MOA.

The Historic American Engineering Record (HAER) documentation is being prepared for the K-25 Building. The documentation will be transmitted to the National Park Service upon completion.

3.3.3. Clean Air Act Compliance Status

The CAA, passed in 1970 and amended in 1977 and 1990, forms the basis for the national air pollution control effort. This legislation establishes comprehensive federal and state regulations to limit air emissions and includes five major regulatory programs: the National Ambient Air Quality Standards (NAAQS), State Implementation Plans (SIPs), New Source

Performance Standards (NSPSs), Prevention of Significant Deterioration permitting programs, and National Emission Standards for Hazardous Air Pollutants (NESHAPs). Airborne discharges from DOE Oak Ridge facilities, both radioactive and nonradioactive, are subject to regulation by EPA and the TDEC Division of Air Pollution Control.

Full compliance with CAA regulations and permit conditions was demonstrated in 2020. The ETTP ambient air-monitoring program, permitted source operations tracking, and record keeping provided documentation fully supporting a 100 percent compliance rate.

3.3.4. Clean Water Act Compliance Status

The objective of the Clean Water Act is to restore, maintain, and protect the integrity of the nation's waters. This act serves as the basis for comprehensive federal and state programs to protect the waters from pollutants (see Appendix C for water reference standards). One of the strategies developed to achieve the goals of the Clean Water Act was EPA establishment of limits on specific pollutants allowed to be discharged in US waters by municipal sewage treatment plants and industrial facilities. EPA established the NPDES permitting program to regulate compliance with pollutant limitations. The program was designed to protect surface waters by limiting effluent discharges into streams, reservoirs, wetlands, and other surface waters. EPA has delegated authority for implementation and enforcement of the NPDES program to the state of Tennessee. In 2020, ETTP discharged storm water to the waters of the state of Tennessee under the individual NPDES permit TN0002950, which regulates storm water discharges.

In 2020, sewage discharges from routine breakrooms, restrooms, and change house showers were discharged to the COR Rarity Ridge Wastewater Treatment Plant collection network and sewage holding tanks under permits SOP-05068 and SOP-99033. SOP-99033 was allowed to expire on June 30, 2020.

3.3.5. National Pollutant Discharge Elimination System Permit Noncompliances

In 2020, compliance with ETTP NPDES storm water permit TN0002950 was determined by more than 150 laboratory analyses, field measurements, and flow estimates. The NPDES permit compliance rate for all discharge points for 2020 was 100 percent. There were no permit noncompliances in 2020.

3.3.6. Safe Drinking Water Act Compliance Status

Since October 1, 2014, all water at the ETTP site is supplied by the COR drinking water plant, located north of the Y-12 Complex in Oak Ridge, Tennessee. ETTP operations are in full compliance with this act.

3.3.7. Resource Conservation and Recovery Act Compliance Status

ETTP is regulated as a large-quantity generator of hazardous waste because the facility generates more than 1,000 kg of hazardous waste per month. At the end of 2020, ETTP had two generator accumulation areas for hazardous or mixed waste.

In addition, ETTP was permitted to store and treat hazardous and mixed waste under the Resource Conservation and Recovery Act (RCRA) Part B Permit TNHW-165. However, in 2020 the last of the permitted storage and treatment units were officially closed by UCOR and verified/certified that the units were closed according to the permit Closure Plan by TDEC and the permit was terminated on September 29, 2020.

TNHW-164 is the hazardous waste corrective action document, which covers ORR areas of concern and solid waste management units.

In CY 2020, ETTP prepared and submitted to the TDEC Division of Solid Waste Management the CY 2019 annual report of hazardous waste activities. This report identifies the type and amount of hazardous waste that was generated, shipped off site, or is currently in storage. In 2020, ETTP was in full compliance with this act.

3.3.8. Comprehensive Environmental Response, Compensation, and Liability Act Compliance Status

CERCLA, also known as "Superfund," was passed in 1980 and was amended in 1986 by the Superfund Amendments and Reauthorization Act (SARA). Under CERCLA, a site is investigated and remediated if it poses significant risk to health or the environment. The EPA National Priorities List is a comprehensive list of sites and facilities that have been found to pose a sufficient threat to human health and/or the environment to warrant cleanup under CERCLA. ORR is on the National Priorities List and numerous CERCLA decision documents are approved for ETTP site cleanup actions for both facility demolitions and soil remediation. In 2020, ETTP was in full compliance with this Act.

3.3.9. East Tennessee Technology Park RCRA-CERCLA Coordination

The *Federal Facility Agreement for the Oak Ridge Reservation* (DOE 2018b, DOE/OR-1014) is intended to coordinate the corrective action processes of RCRA required under the *Hazardous and Solid Waste Amendments* permit with CERCLA response actions.

3.3.10. Toxic Substances Control Act Compliance Status—Polychlorinated Biphenyls

On April 3, 1990, DOE notified EPA headquarters (as required by 40 CFR Part 761.205, *Polychlorinated Biphenyls (PCBs) Manufacturing, Processing, Distribution in Commerce, and Use Prohibitions* [EPA 1979]) that ETTP is a generator with on-site storage, a transporter, and an approved disposer of polychlorinated biphenyl (PCB) wastes.

TN0890090004. In 2020, ETTP operated two PCB waste storage areas in RCRA-permitted storage buildings. These facilities were operated under 40 CFR Part 761.65(b)(2)(iii) (EPA 1979), which allows PCB storage permitted by the state authorized under Section 3006 of RCRA to manage hazardous waste in containers, and spills of PCBs are cleaned up in accordance with Subpart G of this part. ETTP operated one long-term PCB waste storage area on site where nonradioactive PCB waste was stored in a facility that was not a RCRA-permitted storage facility. At this time, no PCB-contaminated electrical equipment is in service at ETTP.

Because of the age of many ETTP facilities and the varied uses for PCBs in gaskets, grease, building materials, and equipment, DOE self-disclosed unauthorized use of PCBs to EPA in the late 1980s. As a result, DOE Oak Ridge Office and EPA Region 4 consummated a major compliance agreement known as the *Oak Ridge Reservation Polychlorinated Biphenyl Federal Facilities Compliance Agreement* (DOE 2018c, ORR-PCB-FFCA), which became effective December 16, 1996, and was last revised on October 8, 2018, to Revision 6.

ORR-PCB-FFCA specifically addresses the unauthorized use of PCBs in ventilation ducts and gaskets, lubricants, hydraulic systems, heat transfer systems, and other unauthorized uses; storage for disposal; disposal; cleanup and/or decontamination of PCBs and PCB items, including PCBs mixed with radioactive materials; and ORR records and reporting requirements. A major focus of the agreement is the disposal of PCB waste. As a result of that agreement, DOE and UCOR continue to notify EPA when additional unauthorized uses of PCBs, such as in paint, adhesives, electrical wiring, or floor tile, are identified at ETTP. This notification process is routinely incorporated into the CERCLA documentation for demolition and remedial actions (RAs).

The ETTP site prepares a PCB Annual Document Log (PCBADL) per 40 CFR Part 761.180(a) (EPA 1979). The written PCBADL is prepared by July 1 of each year and covers the previous calendar year. The PCBADL documents such things as container inventory, shipments, and PCB spills at the facility. Authorized representatives of EPA may inspect the PCBADL at the facility where they are maintained during normal business hours. The PCBADL must be maintained on site for a minimum of three years. In 2020, ETTP was in full compliance with this Act.

3.3.11. Emergency Planning and Community Right-to-Know Act Compliance Status

The Emergency Planning and Community Right-to-Know Act (EPCRA) that is also identified as Title III of SARA requires that facilities report inventory that exceed threshold planning quantities and releases of hazardous and toxic chemicals. The reports are submitted electronically and are available online for the local emergency planning committee, the state emergency response commission, and the local fire department. ETTP complied with these requirements in 2020 through the submittal of required reports as applicable under EPCRA Sections 302, 311, 312, and 313. ETTP had no reportable releases of hazardous substances or extremely hazardous substances, as defined by EPCRA, in 2020.

3.3.11.1. Chemical Inventories (EPCRA Section 312)

Inventories, locations, and associated hazards of hazardous and extremely hazardous chemicals were submitted in an annual report to state and local emergency responders, as required by EPCRA Section 312. Of the ORR chemicals identified for 2020, 11 chemicals were located at ETTP. These chemicals were lead metal (including large, lead-acid batteries), diesel fuel, unleaded gasoline, sulfuric acid (including large, lead-acid batteries), Chemical Specialties, Inc. Ultrapoles, Sakrete™ Type S or N mortar mix, arsenic pentoxide (the active ingredient in CCA Type C pressure-treated wood), Flexterra FGM erosion control agent, crystalline silica, New Pig absorbents, and various lubricating oils (including motor, lubricants, distillates, hydraulic and gear oils).

3.3.11.2. Toxic Chemical Release Reporting (EPCRA Section 313)

EPCRA Section 313 requires facilities to complete and submit a toxic chemical release inventory (TRI) form (Form R) annually. Form R must be submitted for each TRI chemical that is manufactured, processed, or otherwise used in quantities above the applicable threshold quantity. The reports address releases of certain toxic chemicals to air, water, land, and waste management, recycling, and P2 activities. Threshold determinations and reports for each of the ORR facilities are made separately. Operations involving TRI chemicals were compared with regulatory thresholds to determine which chemicals exceeded the reporting thresholds based on amounts manufactured, processed, or otherwise used at each facility. After threshold determinations were made, releases and off-site transfers were calculated for each chemical that exceeded the threshold quantity. In 2020, there were no chemicals that met the reporting requirements.

3.4. Quality Assurance Program

Integrated Assessment and Oversight Program

Quality assurance (QA) program implementation and procedural and subcontract compliance are verified through the UCOR integrated assessment and oversight program. The program identifies the processes for planning, conducting, and coordinating assessment and oversight of UCOR activities, including both self-performed and subcontracted activities, resulting in an integrated assessment and oversight process. The program is composed of three key elements: (1) external assessments conducted by organizations external to UCOR, (2) independent assessments conducted by teams composed of UCOR personnel who are not directly involved with the project/function being assessed, and (3) management assessments and surveillances conducted as self-assessments and surveillances by the organization or on behalf of the organization manager.

Self-assessments are performed by the organization/function with primary responsibility for the work, process, or system being assessed. Organizations and functions within the company plan and schedule self-assessments. Self-assessments encompass both formal and informal assessments. The formal self-assessments include management assessments and surveillances, and subcontractor oversight. Informal self-assessments include weekly inspections and routine walkthroughs conducted by subcontractor coordinators, ES&H and QA representatives, quality engineers, and line managers.

Conditions adverse to quality identified from internal and external assessments are documented, causal analyses are performed, and corrective actions are developed and tracked to closure. Analyses are conducted periodically to identify trends for management action. Senior management evaluates data from those processes to identify opportunities for improvement.

3.5. Air Quality Program

The state of Tennessee has been delegated authority by EPA to convey the clean air requirements that are applicable to ETTP operations. New projects are governed by construction and operating permit regulatory requirements. The owner or operator of air pollutant emitting sources is responsible for ensuring full compliance with any issued permit or other generally applicable CAA requirement. During 2020, ETTP DOE EM operations were under UCOR responsibility for regulatory compliance.

3.5.1. Construction and Operating Permits

UCOR ETTP operations are subject to CAA regulations and permitting under TDEC Air Pollution Control rules that are specific to stationary fossil-fueled reciprocating internal combustion engines for emergency use. TDEC originally issued an operating permit (069346P) covering six stationary emergency reciprocating internal combustion engine (e-RICE) units on March 3, 2015. An amended permit was issued on November 22, 2016, that removed one permanently shut-down unit. The last operating permit was amended on November 22, 2016, and covered four stationary e-RICE generators and one stationary e-RICE firewater booster pump. Three generators have diesel-fueled engines, one generator has a natural gas-fueled engine, and the firewater booster pump engine is diesel fueled. On July 19, 2018, TDEC provided a Notice of Authorization (NOA) to UCOR for coverage under Permit-by-Rule (PBR) for all of the ETTP stationary e-RICE. During 2020 all generators and the firewater booster pump were either removed from the ETTP site or transferred to new owners; UCOR then surrendered its PBR authorization.

Although the PBR subsumed the previous operating permit for the ETTP stationary e-RICE generators and firewater booster pump, the compliance requirements remained essentially the same. Compliance for all units is demonstrated by following specified maintenance schedules, limiting hours of operations for non-emergencies to 100 hours per year, and record keeping. Regulations exempt any operating hours of these units during nonscheduled (emergency) power outages.

All other ETTP operations that emit low levels of air pollutants have been classified as insignificant under TDEC rules. Any planned stationary sources that may emit air pollutants are evaluated and compared against applicable pollutant emission limits to document this classification and pursue permitting if required under TDEC regulations.

3.5.1.1. Generally Applicable Permit Requirements

ETTP is subject to a number of generally applicable requirements that involve management and control. Asbestos, ozone-depleting substances (ODSs), and fugitive particulate emissions are specific examples.

Control of Asbestos

ETTP's asbestos management program ensures all activities involving demolitions and all other actions involving asbestos-containing materials (ACM) are fully compliant with 40 CFR Part 61, Subpart M, *National Emission Standards for Hazardous Air Pollutants*, "National Emission Standard for Asbestos." This includes using approved engineering controls and work practices, inspections, and monitoring for proper removal and waste disposal of ACM. Most demolition and ACM abatement activities at ETTP are governed under CERCLA. Under this act, notifications of asbestos demolition or renovations, as specified in 40 CFR Part 61.145(b), are incorporated into CERCLA document regulatory notifications.

Non-CERCLA planned demolition or renovation activities were individually reviewed for applicability of the TDEC notification requirements of the rule. During 2020, four Notifications of Demolition and/or Asbestos Renovation (NDARs) were submitted to TDEC for non-CERCLA ETTP activities. The NDAR for non-CERCLA facilities K-1039 and K-1039-1 was considered a non-regulated asbestos demolition. These two facilities had asphalt roofs that were considered Presumed Asbestos Containing Material (PACM) Category I Non-Friable. All other facilities were non-asbestos demolitions. There were no Regulated Asbestos Containing Material (RACM) demolitions during 2020.

The rule also requires an annual notification for all nonscheduled, minor asbestos renovations if the accumulated total amount of regulated or potentially regulated asbestos exceeds stipulated thresholds. For 2020, the total ETTP projected nonscheduled amounts were below thresholds that would require the submittal of an annual notification to TDEC. No releases of reportable quantities of ACM occurred at ETTP during 2020.

Stratospheric Ozone Protection

The management of ODSs at ETTP is subject to regulations in 40 CFR Part 82, Subpart F, Recycling and Emissions Reduction; these regulations require preparation of documentation to establish that actions necessary to reduce emissions of Class I and Class II refrigerants to the lowest achievable level have been observed during maintenance activities at ETTP. The applicable actions include, but may not be limited to, the service, maintenance, repair, and disposal of appliances containing Class I and Class II refrigerants, such as motor vehicle air conditioners. In addition, the regulations apply to refrigerant reclamation activities, appliance owners, manufacturers of appliances, and recycling and recovery equipment. Figure 3.7 illustrates the historical on-site ODS inventory at ETTP. During 2020 the ODS inventory was reduced to zero.

3.5.1.2. Fugitive Particulate Emissions

ETTP has been the location of major building demolition activities, soil remediation activities, and waste debris transportation with the potential for the release of fugitive dust. All planned and ongoing activities include the use of dust control measures to minimize the release of visible fugitive dust beyond the project perimeter. This includes the use of specialized demolition equipment and water misters. Gravel roads in and around ETTP that are under DOE control are wetted with water, as needed, to minimize airborne dusts caused by vehicle traffic.

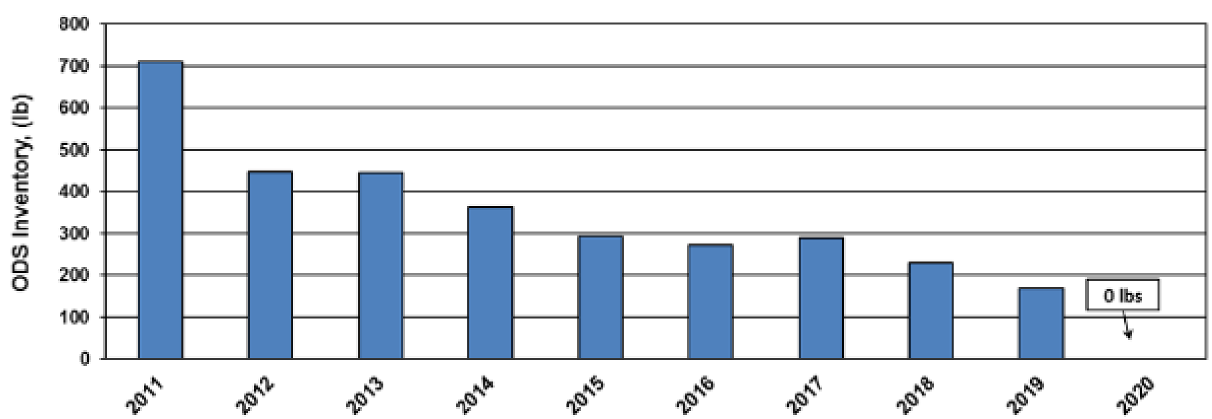


Figure 3.7. East Tennessee Technology Park total on-site ozone-depleting substances inventory, 10-year history

3.5.1.3. Radionuclide National Emission Standards for Hazardous Air Pollutants

Radionuclide airborne emissions from ETTP are regulated under 40 CFR Part 61, *National Emission Standards for Hazardous Air Pollutants (Rad-NESHAP)*. Characterization of the impact on public health of radionuclides released to the atmosphere from ETTP operations was accomplished by conservatively estimating the dose to the maximally exposed member of the public. The dose calculations were performed using the Clean Air Assessment Package (CAP-88) computer codes, which were developed under EPA sponsorship for use in demonstrating compliance with the 10 mrem/year effective dose National Emission Standards for Hazardous Air Pollutants for radionuclides (Rad-NESHAP) emission standard for the entire DOE ORR. Source emissions used to calculate the dose are determined using EPA-approved methods that can range from continuous sampling systems to conservative estimations based on process and waste characteristics. Continuous sampling systems are required for radionuclide-emitting sources that have a potential dose impact of not less than 0.1 mrem per year to any member of the public. The only ETTP Rad-NESHAP source that operated during 2020—the K-1407 Chromium Water Treatment System (CWTS) Volatile Organic Compound (VOC) Air Stripper is considered minor based on emissions evaluations using EPA-approved calculation methods. A minor Rad-NESHAP source is defined as having a potential dose impact on the public that is less than 0.1 mrem/year. Compliance is demonstrated using data collected by the ETTP ambient air monitoring program.

Quarterly radiochemical analyses are performed on composited samples collected at all ETTP ambient air sampling stations. The selected isotopes of interest were ^{234}uranium (^{234}U), ^{235}uranium (^{235}U), and ^{238}uranium (^{238}U), with the ^{99}technetium (^{99}Tc) inorganic analysis results included as a dose contributor. The concentration for each of the nuclides and the total dose at each monitoring station are presented in Table 3.4 for the 2020 reporting period. No radionuclides analyzed for at ETTP ambient air locations were detected; therefore, no doses could be calculated from these results.

Table 3.4. Radionuclides in ambient air at East Tennessee Technology Park, January 2020 through December 2020

Station	Concentration (μCi/mL)			
	^{99}Tc	^{234}U	^{235}U	^{238}U
K2[a]	ND[b]	ND	ND	ND
K11[c]	ND	ND	ND	ND
K12[c]	ND	ND	ND	ND

[a] *K2 result represents a residential exposure.*
[b] *ND = not detectable.*
[c] *K11 and K12 represent an on-site business exposure equivalent to half of a yearly exposure at this location.*

Stations K11 and K12 are near on-site businesses; therefore, the estimated doses based upon residential exposures were divided by two to account for occupational exposures following approved procedures. This conservatively assumes that the on-site member of the public is at his or her workstation for half of the year. Based upon the reduced activities at ETTP that could generate air emissions, and the long term low trends at K2, the K2 air monitor was taken out of service at the end of 2020.

3.5.1.4. Quality Assurance

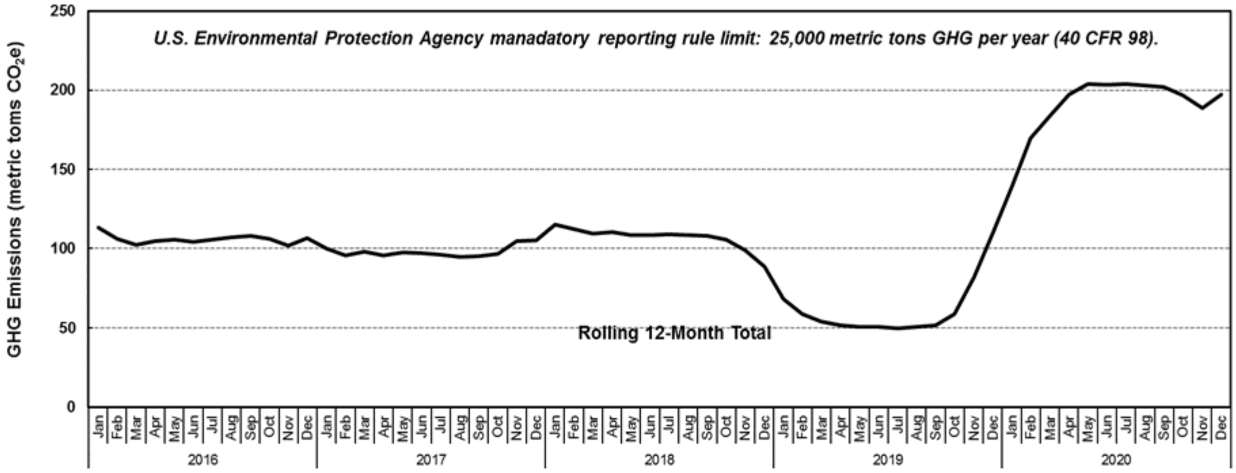
QA activities for the Rad-NESHAP program are documented in the Quality Assurance Program Plan for Compliance with Radionuclide National Emission Standards for Hazardous Air Pollutants, East Tennessee Technology Park, Oak Ridge Tennessee (UCOR 2018, UCOR-4257/R2). The plan satisfies the QA requirements in 40 CFR Part 61, Method 114, for ensuring that the radionuclide air emission measurements from ETTP are representative of known levels of precision and accuracy and that administrative controls (ACs) are in place to ensure prompt response when emission measurements indicate an increase over normal radionuclide emissions. The requirements are also referenced in TDEC regulation 1200-3-11-.08, Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities. The plan ensures the quality of ETTP radionuclide emission measurement data from continuous samplers and minor radionuclide release points. Only EPA preapproved methods are referenced through the Compliance Plan National Emission Standards for Hazardous Air Pollutants for Airborne Radionuclides on the Oak Ridge Reservation, Oak Ridge, Tennessee (DOE/ORO/2196).

3.5.1.5. Greenhouse Gas Emissions

The EPA rule for mandatory reporting of Greenhouse Gases (GHGs) (also referred to as the "Greenhouse Gas Reporting Program") was enacted October 30, 2009, under 40 CFR Part 98. According to the rule in general, the stationary source emissions threshold for reporting is 25,000 MT of CO_2 equivalent (CO_2e) or more of GHGs per year. The rule defines GHGs as:

- Carbon dioxide (CO_2)
- Methane (CH_4)
- Nitrous oxide (N_2O)
- Hydrofluorocarbons
- Perfluorocarbons
- Sulfur hexafluoride (SF_6)

A 2020 review was performed of ETTP processes and equipment categorically identified under 40 CFR Part 98.2 whose emissions must be included as part of a facility annual GHG report, starting with the CY 2010 reporting period. Based on total GHG emissions from all ETTP stationary sources during 2020, ETTP did not exceed the annual threshold limit and therefore was not subject to mandatory annual reporting under the GHG rule during this performance period. The total GHG emissions for any continuous 12 month period beginning with CY 2008 have not exceeded 12,390 MT CO_2e of GHGs. The most significant decrease in stationary source emissions was due to the permanent shutdown of the TSCA Incinerator in 2009. The remaining sources are predominantly small comfort heating systems, hot water systems, and power generators. Figure 3.8 shows the 5-year trend up through 2020 of ETTP total GHG stationary emissions. For CY 2020, GHG emissions totaled 197 MT CO_2e, which is 0.8 percent of the 25,000 MT CO_2e per year threshold for reporting.



Note:
Shown in carbon dioxide equivalent (CO_2e)
Acronyms:
CFR = Code of Federal Regulations
GHG = greenhouse gas

Figure 3.8. East Tennessee Technology Park stationary source greenhouse gas emissions tracking history

The increase from the previous year resulted from the leasing of several large bays in Building K-1036; these bays are heated with natural gas.

Executive Order (EO) 13514, *Federal Leadership in Environmental, Energy, and Economic Performance*, was published in the Federal Register on October 8, 2009. The purpose of this order was to establish policies for federal facilities that will increase energy efficiency; measure, report, and reduce GHG emissions from direct and indirect activities; conserve and protect water resources through efficiency, reuse, and storm water management; eliminate waste; recycle; and prevent pollution at all such facilities. While the order deals with a number of environmental media, only its applicability to GHG is considered here. The EO defines three distinct scopes for purposes of reporting:

1. Scope 1 is essentially direct GHG emissions from sources that are owned or controlled by a federal agency.
2. Scope 2 encompasses GHG emissions resulting from the generation of electricity, heat, or steam purchased by a federal agency.
3. Scope 3 involves GHG emissions from sources not owned or directly controlled by a federal agency, but related to agency activities, such as vendor supply chains, delivery services, and employee business travel and commuting.

One goal of this order was to establish a FY 2020 Scope 1 and Scope 2 reduction target of 28 percent, as compared to the 2008 baseline year.

EO 13693, *Planning for Federal Sustainability in the Next Decade,* was published in the Federal Register on March 25, 2015. This order superseded EO 13514 and established a new Scope 1 and Scope 2 federal-wide total reduction target of 40 percent by 2025, as compared to the 2008 baseline year. For reporting purposes, GHG emission data are compared to both goals.

EO 13834, *Efficient Federal Operations*, was published in the Federal Register on May 22, 2018. This order superseded EO 13693. It requires continued tracking and reporting of GHG emissions, but no specific federal-wide total reduction target.

The information reported here includes GHG emissions from the industrial landfills at Y-12 that are managed and operated by UCOR. The landfills are not part of the contiguous ETTP site; however, DOE requested that UCOR, as the operator, include landfill GHG emissions with ETTP reporting in the Consolidated Energy Data Report. To be consistent with reporting this information, the landfill emissions are also included with ETTP ASER data. Figure 3.9 shows the trend toward meeting both the original EO 13514 Scope 1 and 2 GHG emissions reduction target of 28 percent by FY 2020 and the EO 13693 Scope 1 and 2 GHG emissions reduction target of 40 percent by FY 2025.

Scope 1 and 2 GHG emissions for FY 2020, including the landfills, totaled 18,476 MT CO_2e, which is a 70 percent reduction from emissions in the FY 2008 baseline year.

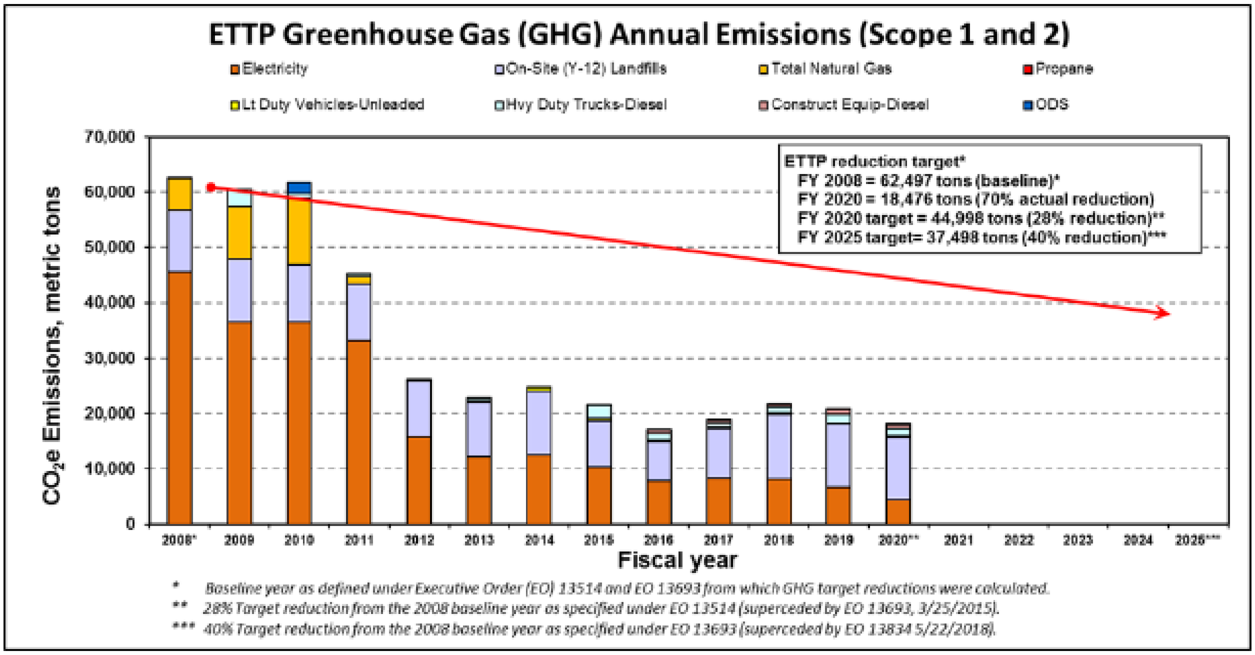
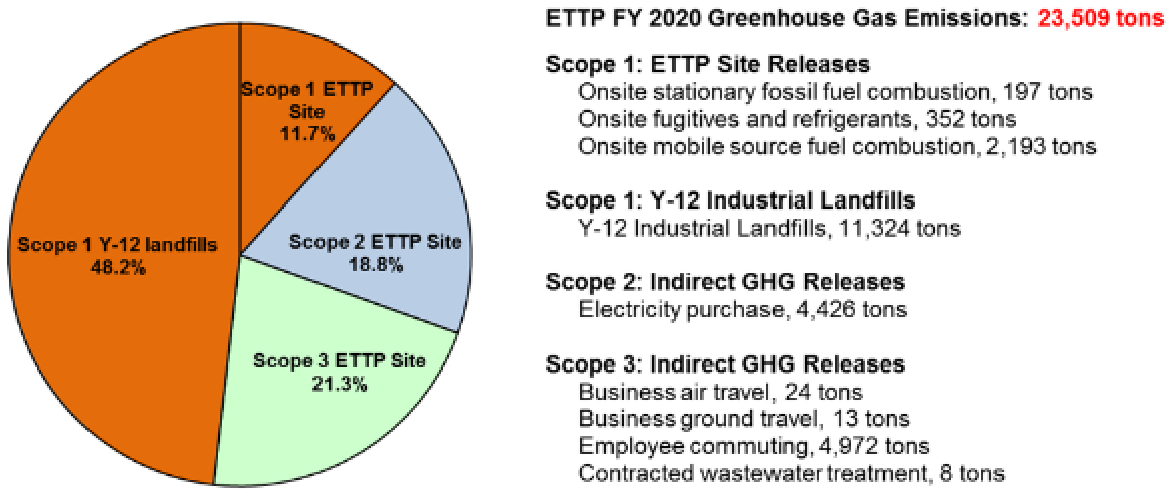


Figure 3.9. East Tennessee Technology Park greenhouse gas annual emissions (Scopes 1 and 2, including industrial landfills at Y-12)

Figure 3.10 shows the relative distribution and amounts of all ETTP FY 2020 GHG emissions for Scopes 1, 2, and 3 including the industrial landfills at Y-12. Total GHG emissions remain well below the levels first reported in the 2008 baseline year as demolition and remediation efforts continue at ETTP. Many of the early reductions were due to lower on-site combustion of fuels (stationary and mobile sources), lower consumption of electricity, and a smaller workforce. The total amount of GHG emissions for Scopes 1, 2, and 3, including landfills at Y-12, for FY 2020 was 23,509 MT CO_2e.



Acronyms:
ETTP = East Tennessee Technology Park
GHG = greenhouse gas
SF_6 = sulfur (hexafluoride)
Y-12 = Y-12 National Security Complex

Figure 3.10. Fiscal year 2020 East Tennessee Technology Park greenhouse gas emissions by scope

3.5.1.6. Source-Specific Criteria Pollutants

ETTP operations included one functioning minor stationary source, the CWTS, with a potential to emit any form of criteria air pollutant. This unit is equipped with an air stripper to remove VOCs from the effluent stream. All process data records and the calculated potential maximum VOC emission rates for the CWTS air stripper were below levels that would require permitting. The calculated VOC annual emissions during 2020 for CWTS were only 0.006 ton/year as compared to an emission limit of 5 tons/year. The annual potential emissions for this facility would be well below the 5 ton/year limit assuming it operated at the maximum hourly emission rate continuously for the entire year.

Federal regulations amended in January 2013 require TDEC permitting for existing and new stationary reciprocating internal combustion engine-powered emergency generators and firewater booster pumps. Permitting actions do not apply to e-RICE covered under CERCLA projects. However, specific maintenance and recordkeeping requirements specified in the federal regulations are applicable to CERCLA projects operating e-RICE.

The 2020 operations included four e-RICE powered emergency generators (K-1007, K-1039, K-1095, and K-1652), and one e-RICE powered firewater booster pump (K-1310-RW). TDEC issued a NOA to UCOR on July 19, 2018, for e-RICE at ETTP to operate under the PBR provisions of Rule 1200-03-09-.07 for stationary emergency internal combustion engines. This authorization (number R74133) subsumed the previous operating permit.

During 2020 the emergency generators at K-1007, K-1039, and K-1095 were all removed from the ETTP site. The emergency generator at K-1652 was transferred to the City of Oak Ridge. The K-1310-RW firewater booster pump was transferred to Consolidated Nuclear Security, LLC. The PBR authorization for UCOR was then surrendered.

Regulations limit e-RICE nonemergency and maintenance operations to 100 h of operations per 12-month rolling total (i.e., 100 h of running the engines for testing and maintenance purposes per year). Additionally, nonemergency operations are limited to 50 h of the 100-h annual limit. PBR provisions also require performing scheduled maintenance and recordkeeping. These requirements were met in CY 2020.

ETTP operations released airborne pollutants from a variety of minor pollutant-emitting sources, such as vents, and fugitive and diffuse activities. The emissions from all stacks and vents are evaluated following approved methods to establish their low emissions potential. This is done to verify and document their minor source permit exempt status under all applicable state and federal regulations.

3.5.1.7. Hazardous Air Pollutants (Nonradionuclide)

Unplanned releases of hazardous air pollutants are regulated through the risk management planning regulations under 40 CFR Part 68. To ensure compliance, periodic inventory reviews of ETTP operations were performed that used monthly data obtained through the EPCRA Section 311 reporting program. This program applies to any facility at which a hazardous chemical is present in an amount exceeding a specified threshold. A comparison of the EPCRA 311 monthly Hazardous Materials Inventory System (HMIS) chemical inventories at ETTP with the risk management plan threshold quantities listed in 40 CFR Part 68.130 was conducted. This is an ongoing action that documents the potential applicability for maintaining and distributing a risk management plan and ensuring threshold quantities are not exceeded.

ETTP personnel have determined that there are no processes or facilities containing inventories of chemicals in quantities exceeding thresholds specified in rules pursuant to CAA, Title III, Section 112(r),"Prevention of Accidental Releases." Therefore, activities at ETTP are not subject to the rule. Procedures are in place and implemented to continually review new processes, process changes, or activities with the rule thresholds.

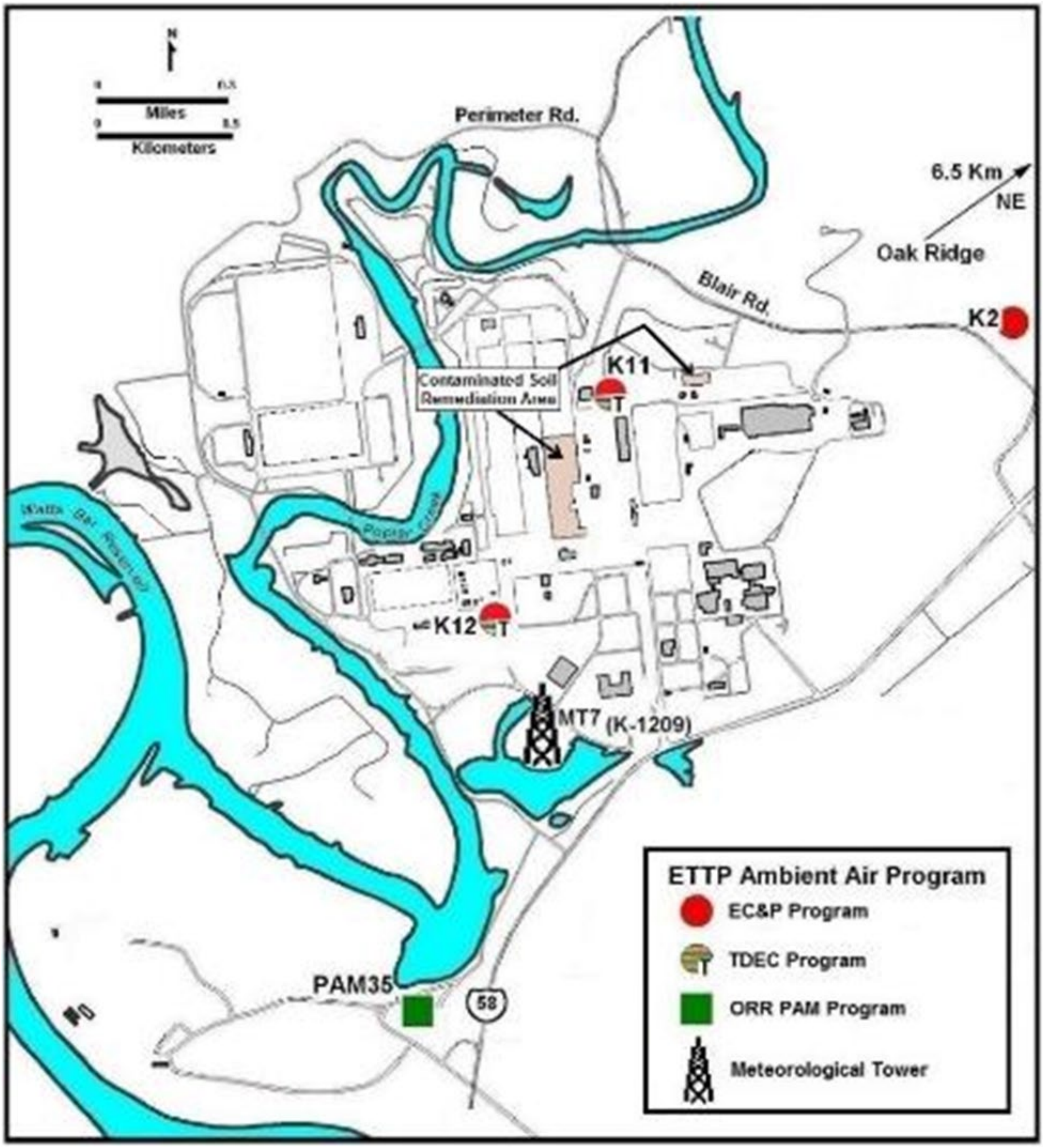
3.5.2. Ambient Air

Compliance of fugitive and diffuse sources is demonstrated based on environmental measurements. The ETTP Ambient Air Quality Monitoring Program is designed to provide environmental measurements to accomplish the following:

- Tracking of long-term trends of airborne concentration levels of selected air contaminant species.
- Measurement of the highest concentrations of the selected air contaminant species that occur in the vicinity of ETTP operations.
- Evaluation of the potential impact on air contaminant emissions from ETTP operations on ambient air quality.

The three sampling programs in the ETTP area are designated as the EC&P program, TDEC program, and the ORR perimeter air monitoring program. Figure 3.11 shows an example of a typical EC&P program air monitoring station.Figure 3.12 shows the locations of all ambient air sampling stations in and around ETTP that were active during the 2020 reporting period.

Figure 3.11. East Tennessee Technology Park ambient air monitoring station



Acronyms:
ETTP = East Tennessee Technology Park
MT = meteorological tower
ORR = Oak Ridge Reservation
PAM = perimeter air monitoring
TDEC = Tennessee Department of Environment and Conservation

Figure 3.12. East Tennessee Technology Park ambient air monitoring station locations

The EC&P program consisted of three sampling locations throughout 2020. All projects are operating similar high-volume sampling systems. The EC&P, TDEC, and perimeter air monitoring samplers operate continuously with exposed filters collected weekly. The radiological monitoring results for samples collected at the one ETTP area perimeter air monitoring station are the responsibility of UT-Battelle, LLC. TDEC is responsible for the data collected from their samplers. UT-Battelle, LLC and TDEC results are not included with the EC&P data presented in this section. However, results from the other programs are requested periodically for comparison.

The analytical parameters were chosen with regard to existing and proposed regulations and with respect to activities at ETTP. The principle reason for EC&P program stations is to demonstrate that radiological emissions from the demolition of ETTP gaseous diffusion buildings, supporting structures, and associated remediation activities are in compliance with the annual dose limit to the most exposed members of the public that are either on site (on ORR) or off site. K11 and K12 were key sampling locations regarding the potential dose impact on the most exposed member of the public at an on-site business location during the demolition of the K-1600 Complex, K-1004-J Lab Complex, K-1200 Centrifuge Complex, and K-832 Basin, as well as slab removals, small structures demolition, and the excavation and removal of ^{99}Tc-contaminated soil from the Building K-25 footprint.

Changes of emissions from ETTP will warrant periodic reevaluation of the parameters being sampled. Ongoing ETTP reindustrialization efforts will also introduce new locations for members of the public that may require adding or relocating monitoring site locations. To ensure understanding of the potential impacts on the public and to establish any required emissions monitoring and emissions controls, a survey of all on-site tenants is reviewed every 6 months through a request for the most recent ETTP reindustrialization map.

All EC&P program stations collected continuous samples for radiological analyses during 2020. These analyses of samples from the EC&P stations test for the isotopes ^{234}U, ^{235}U, ^{238}U, and ^{99}Tc.

Station K2 is in the prevailing topography of influenced downwind directions that are for identifying the impact to off-site members of the public. As previously noted, the K2 air monitor was taken out of service at the end of 2020. Stations K11 and K12 are located to provide a conservative measurement of the impact to on-site members of the public.

3.6. Water Quality Program

The vast majority of the radionuclide measurements in surface water at ETTP are less than 1% of the allowable standards.

Water quality is monitored via multiple programs at ETTP. Stormwater monitoring is conducted through the NPDES Program (Section 3.6.1) and the SWPPP Program (Section 3.6.2). Surface water monitoring is conducted through the Environmental Monitoring Program (Section 3.6.3). Ground water monitoring is conducted through the Water Resources Protection Program (Section 3.6.4).

3.6.1. National Pollutant Discharge Elimination System Permit Monitoring

NPDES monitoring is conducted to demonstrate compliance with the ETTP NPDES Permit. The latest ETTP NPDES permit became effective on April 1, 2015 and expired on March 31, 2020. The permit renewal application was submitted to TDEC on September 18, 2019. The expired permit will continue in effect until a new permit is issued by the State of Tennessee. Under the ETTP NPDES Permit, 27 representative outfalls are monitored annually for oil and grease, total suspended solids (TSS), pH, and flow (Figure 3.13). Outfall 170 is also monitored quarterly for total chromium and hexavalent chromium. There were no permit noncompliances in 2020.

Figure 3.13. Storm water outfall monitoring

3.6.2. Storm Water Pollution Prevention Program

In addition to the NPDES permit required monitoring, storm water is also monitored for a variety of substances, including radionuclides, metals, and organic compounds. Routine SWPPP monitoring is conducted at various locations that vary from year to year depending on activities going on within the drainage basins and historical monitoring results. SWPPP monitoring includes radiological monitoring, D&D and remedial action monitoring, CERCLA PCCR monitoring, legacy contamination monitoring, and investigative monitoring.

Investigative monitoring is triggered by elevated analytical results, CERLCA requirements, and changes in site conditions. Investigative samples were collected from the Powerhouse Area Outfalls and the Outfall 690 Network in 2020. Storm water sampling results were reviewed and evaluated to provide feedback for the next round of investigative sampling, generate suggested modifications and improvements to storm water runoff controls, and provide input for CERCLA project cleanup decisions.

3.6.2.1. Radiologic Monitoring of Storm Water

Radiological monitoring of storm water discharges is performed to determine compliance with applicable dose standards. Selected outfalls are sampled for gross alpha and gross beta radioactivity, as well as specific radionuclides. Analytical results are used to estimate the total discharge of each radionuclide from ETTP via the storm water discharge system. No reference standards were exceeded at outfalls monitored in CY 2020. Table 3.5 contains the total calculated discharge of radionuclides from storm water outfalls in CY 2020. Overall, 2020 saw a decrease in the discharge of radionuclides relative to the discharges of 2019.

Table 3.5. Radionuclides released to off-site waters from the East Tennnessee Technology Park storm water system in 2020

Isotope	^{234}U	^{235}U	^{238}U	^{99}Tc
Activity level (Ci)	0.018	0.0017	0.014	0.064

3.6.2.2. Storm Water Monitoring Associated with D&D Activities

Stormwater monitoring is performed before, during, and after demolition to evaluate the effectiveness of remedial actions. Storm water samples are collected prior to the initiation of D&D activities in order to determine baseline conditions. Storm water samples are also collected at potentially affected outfalls and storm water catch basins after remedial activities have been undertaken and after they have been completed to help gauge the potential effectiveness of the remediation.

3.6.2.3. Technetium-99 Monitoring of Storm Water Associated with D&D Activities

Outfall 190 is sampled quarterly for ^{99}Tc. During sampling conducted in CY 2020, ^{99}Tc was not detected in samples collected at Outfall 190. Based on this data, it does not appear that ^{99}Tc-contaminated groundwater from the K-25 Building D&D project is discharging to Mitchell Branch via storm water Outfall 190.

Outfall 490 drains the area that was once occupied by the ^{99}Tc operations area in the K-25 Building. Consequently, ^{99}Tc samples are collected in conjunction with routine storm water runoff samples collected at Outfall 490. Results from this monitoring effort in 2020 showed that ^{99}Tc concentrations in discharges from Outfall 490 were approximately 0.3% of the Derived Concentration Standards Sum of Fractions values.

The maximum ^{99}Tc measurement at K-1700 during the last decade, obtained in February 2014, was 258 pCi/L, which is well below the ^{99}Tc derived concentration standard value of 44,000 pCi/L and the drinking water maximum contaminant level (MCL) of 900 pCi/L. The cumulative radionuclide (^{99}Tc and uranium isotopes) measurements at the Mitchell Branch exit weir K-1700 location are calculated to be in the range of 1%-2% of the Derived Concentration Standards Sum of Fractions values.

3.6.2.4. D&D of the K-1203 Sewage Treatment Plant

Post-demolition sampling was undertaken in January and February 2020 at Outfall 05A-2.

Water samples were collected from behind the gravel berm that is located in front of the Outfall 05A-2 piping system inlet. Analytical results that exceeded reference standards are shown in Table 3.6.

Table 3.6. Analytical results exceeding reference standards from the Outfall 05A-2 sampling effort, February 6, 2020

Reference standards[a]	Copper 9 µg/L (CCC)	Lead 2.5 µg/L (CCC)
Outfall 05A-2 behind berm - unfiltered	12.4	11.7
Outfall 05A-2 behind berm - filtered	11.3	10.9

[a] *Reference standards sources are defined as follows:*
CCCTDEC Rule 0400-40-03-.03(3)(g), Criterion Continuous Concentration
REC OOTDEC Rule 0400-40-03-.03(4)(j), Organisms Only Criteria

Routine quarterly SWPPP samples were collected at Outfall 05A-2 on March 3, 2020, May 19, 2020, August 13, 2020, and October 29, 2020. The March 3, 2020, sample was collected using an automatic sampler. This may have led to elevated copper, mercury, and lead results in the sample due to sediments being suctioned up by the sampler. The May 19, August 13, and October 29, 2020 samples were collected by manual grab. Analytical results exceeding reference standards are shown in Table 3.7. Based on the results from these SWPP Program samples, previous guidance concerning collection of samples at Outfall 05A-2 was revised. It was determined that all future samples from this location be collected by the grab sampling technique if possible to avoid any sediment being included in the sample. In addition, collection of filtered samples may be performed to further reduce the effect of sediment on analytical results.

Table 3.7. Analytical results exceeding reference standards from quarterly SWPPP monitoring at Outfall 05A-2, March 3, 2020, May 19, 2020, August 13, 2020, and October 29, 2020

Location	Date Sampled	Copper Reference standard 9 µg/L (CCC) 13 µg/L (CMC)	Lead Reference standard 2.5 µg/L (CCC)	Mercury Reference standard 51 ng/L (REC OO) 51 ng/L (REC WO)
Outfall 05A-2	3/3/20	20.5	18.7	54
Outfall 05A-2	5/19/20	---	4.7	---
Outfall 05A-2	8/13/20	9.2	7.28	---
Outfall 05A-2	10/29/20	14.4	11.8	---

Reference standards sources are defined as follows:
CCC *TDEC Rule 0400-40-03-.03(3)(g), Criterion Continuous Concentration*
CMC *TDEC Rule 0400-40-03-.03(3)(g), Criterion Maximum Concentration*
REC OO *TDEC Rule 0400-40-03-.03(4)(j), Organisms Only Criteria*
REC WO *TDEC Rule 0400-40-03-.03(4)(j), Water & Organisms Criteria*

3.6.2.5. D&D of Buildings K-131/K-631

A small amount of flow still discharges from Outfall 382 on occasion despite the upper portion of the outfall's piping system having been plugged. The source of the flow is believed to be groundwater that infiltrates the piping system below the final plugged area of the Outfall 382 piping system. Samples of the discharge from Outfall 382 were collected on February 10, 2020 to determine if the outfall continued to discharge contaminants at levels above reference standards despite the drainage system being plugged. Analytical data from this sampling event are shown in Table 3.8.

Additional investigation into potential sources of lead, copper, and thallium in the ongoing discharge from Outfall 382 may be conducted as part of future ETTP SWPP Program sampling activities.

Table 3.8. Analytical results exceeding reference standards from Outfall 382 monitoring, February 10, 2020

Reference standards[a]	Copper Reference standard 9 µg/L (CCC) 13 µg/L (CMC)	Lead Reference standard 2.5 µg/L (CCC)	Thallium Reference standard 0.47 µg/L (REC OO) 0.24 µg/L (REC WO)
Outfall 382	24.1	37.1	0.586

[a] *Reference standards sources are defined as follows:*
CCC *TDEC Rule 0400-40-03-.03(3)(g), Criterion Continuous Concentration*
CMC *TDEC Rule 0400-40-03-.03(3)(g), Criterion Maximum Concentration*
REC OO *TDEC Rule 0400-40-03-.03(4)(j), Organisms Only Criteria*
REC WO *TDEC Rule 0400-40-03-.03(4)(j), Water & Organisms Criteria*

3.6.2.6. Monitoring Conducted in the Exposure Unit 19 Area

Storm Water Outfall 362 receives storm water runoff from the EU-19 area. Remedial actions for the EU-19 area began in summer of CY 2019. Samples collected from Outfall 362 on July 17, 2019, indicated the presence of metals, mercury, and PCBs at levels exceeding reference standards, as well as elevated levels of several radiological contaminants.

On February 11, 2020, a follow-up sample of the total flow at Outfall 362 was collected. Table 3.9 shows the parameters in this sample that exceeded reference standards.

Table 3.9. Analytical results exceeding reference standards from samples collected at Outfall 362, February 11, 2020

Location	Gross alpha Reference standard[a] 15 pCi/L (DWS)	Gross beta Reference standard[a] 50 pCi/L (DWS)	PCB-1254 Reference standard[a] 0.00064 μg/L (REC OO and REC WO)
Outfall 362	349	75.6	0.0811 J

[a] Reference standards for radionuclides equal Derived Concentration Standard (DCS) for ingested water (DOE-STD-1196-2011, Derived Concentration Technical Standard). Derived Concentration Guide (DCG) values for ingested water (DOE Order 5400.5 Chg. 2, Radiation Protection of the Public and the Environment, Chap. III) are also listed because they remain in effect for certain CERCLA activities. Reference standards for gross alpha and gross beta measurements correspond to national primary drinking water standards (40 CFR Part 141, National Primary Drinking Water Regulations, Subparts B and G).

Reference standards sources are defined as follows:

REC OO   TDEC Rule 0400-40-03-.03(4)(j), Organisms Only Criteria

REC WO   TDEC Rule 0400-40-03-.03(4)(j), Water & Organisms Criteria

Each of the analytical results from samples collected at Outfall 362 that exceeded reference standards is believed to have been a result of legacy operations conducted at K-1410 and associated facilities. The remedial actions will eliminate the sources discharging through Outfall 362 and then remove the outfall piping itself, after which the outfall will be removed from the ETTP NPDES permit.

Soil removal activities in the Outfall 350 drainage network were ongoing during the fourth quarter of CY 2020. Samples were collected on October 29, 2020, and on November 12, 2020, as part of these removal actions. None of the analytical results for any of the radiological samples collected on these occasions exceeded reference standards. It is believed that any radiologically contaminated soil was removed as part of the remedial actions conducted in the Outfall 350 drainage network.

3.6.2.7. D&D of the J-Labs Complex and Building K-1023

Monitoring was performed during the demolition of the J-Labs Complex and Building K-1023. None of the analytical results from sampling events conducted during D&D activities exceeded reference standards. Sampling was also performed on February 6, 2020, after D&D activities had been completed. None of the analytical results from this sampling event exceeded reference standards.

3.6.2.8. D&D of the K-1210/K-1220 Complex

Demolition activities began at the K-1210/K-1220 Complex (Figure 3.14) in March 2020. A pre-demolition sample was collected at Outfall 100 on February 6, 2020, to establish baseline conditions. None of the analytical results from this sampling event exceeded reference standards. Samples were also collected on May 28, 2020, during demolition activities. None of the analytical results from this sampling event exceeded reference standards. A final monitoring event was conducted on September 14, 2020, at the conclusion of the demolition, when waste handling and any potential post-demolition mitigation actions were assessed (Figure 3.15). The analytical result for PCB-1248 (0.0497 µg/L) exceeded the reference standard for PCBs. However, it is not believed that the D&D activities performed at the K-1210/K-1220 Complex were responsible for this result, since Outfall 100 has had elevated levels of PCBs as part of past monitoring efforts, and no PCBs had been detected during other sampling activities conducted in association with the K-1210/K-1220 Complex.

Figure 3.14. K-1200 Complex before decontamination and demolition

Figure 3.15. K-1200 Complex after decontamination and demolition

3.6.2.9. Monitoring of Outfalls Designated in the CERCLA Phased Construction Completion Reports

Samples were collected from storm water outfalls that are required to be monitored as part of the Phased Construction Completion Reports (PCCRs). The outfalls that were selected to be sampled included those specified in the PCCRs that are not NPDES permit representative outfalls as well as NPDES permit representative outfalls where the last available analytical data was collected at least three years prior. Analytical results for the indicated parameters are shown in Table 3.10.

Table 3.10. Analytical results for monitoring of storm water runoff from building slabs

Parameter	Reference standard[a]	Outfall 170	Outfall 294	Outfall 362	Outfall 490
Alpha activity (pCi/L)[a]	15 (DWS)	11.2	6.06	**190**	Not sampled
Beta activity (pCi/L)[a]	50 (DWS)	14.5	6.74	**51.9**	Not sampled
^{99}Tc (pCi/L)	44,000 (DCS) 100,000 (DCG)	2.23 U	0.914 U	Not sampled	115
$^{233/234}$U (pCi/L)	680 (DCS) 500 (DCG)	2.2	2.9	71.5	1.06
$^{235/236}$U (pCi/L)	720 (DCS) 600 (DCG)	0.178 U	0.19 U	6.29	0.104 U
^{238}U (pCi/L)	750 DCS 600 (DCG)	0.807	2.324	72.6	0.374

***Note: Bold** indicates reference standard exceeded.*

[a] Reference standards for radionuclides equal Derived Concentration Standard (DCS) for ingested water (DOE-STD-1196-2011, Derived Concentration Technical Standard). Derived Concentration Guide (DCG) values for ingested water (DOE Order 5400.5 Chg. 2, Radiation Protection of the Public and the Environment, Chap. III) are also listed because they remain in effect for certain CERCLA activities. Reference standards for gross alpha and gross beta measurements correspond to national primary drinking water standards (40 CFR Part 141, National Primary Drinking Water Regulations, Subparts B and G).

3.6.2.10. Legacy Mercury Investigation Monitoring

Mercury levels that exceed the AWQC of 51 nanograms per liter (ng/L) have been identified in the Mitchell Branch watershed, as well as in a number of storm water outfalls, surface water locations, and groundwater monitoring wells at ETTP. In addition, knowledge of known historical mercury processes at the facility has increased substantially. These factors have led to an ongoing facility investigation to more precisely detect and quantify the extent of any mercury contamination that may exist. Table 3.11 contains analytical data from mercury sampling performed at Outfalls 180, 190, and 05A during 2020.

Figures 3.16 and 3.17 indicate results from the quarterly monitoring performed at Outfalls 180 and 190, respectively, as well as other SWPP Program sampling that was conducted at the outfall during the period covered by these graphs. Because the discharges from Outfalls 180 and 190 occasionally contain mercury at levels above the reference standard, these outfalls are thought to be the major contributors of mercury to Mitchell Branch as well. Mitchell Branch mercury levels are monitored routinely at the K-1700 Weir as part of the ETTP Environmental Monitoring Program. Figure 3.18 shows mercury levels at the K-1700 Weir from CY 2010 through CY 2020 were well below the reference standards for the past three years. For additional information on monitoring along Mitchell Branch, see Section 3.6.4.

Storm water Outfall 05A once drained portions of the former K-1203 Sewage Treatment Plant that discharged into the K-1203-10 sump. The D&D of the K-1203 Sewage Treatment Plant was completed in 2019. Figure 3.19 shows mercury concentrations at storm water Outfall 05A-2 since the remediation was completed.

Table 3.11. Quarterly NPDES/SWPP Program mercury monitoring results, calendar year 2020

Sampling location	1st Quarter CY 2020 (ng/L)	2nd Quarter CY 2020 (ng/L)	3rd Quarter CY 2020 (ng/L)	4th Quarter CY 2020 (ng/L)
Outfall 180	38.5	**382**	**96.7**	27.4
Outfall 190	15.7	17.2	11.4	12.8
Outfall 05A-2	**54**	28.8	17.4	39.1

Notes:

1. *Results in* ***bold*** *exceed the reference standard for mercury (51 ng/L REC OO and REC WO).*
   REC OOTDEC Rule 0400-40-03-.03(4)(j), Organisms Only Criteria
   REC WOTDEC Rule 0400-40-03-.03(4)(j), Water & Organisms Criteria
2. *No mercury sample was collected at Outfall 05A-2 due to remedial activities being conducted in the outfall watershed.*

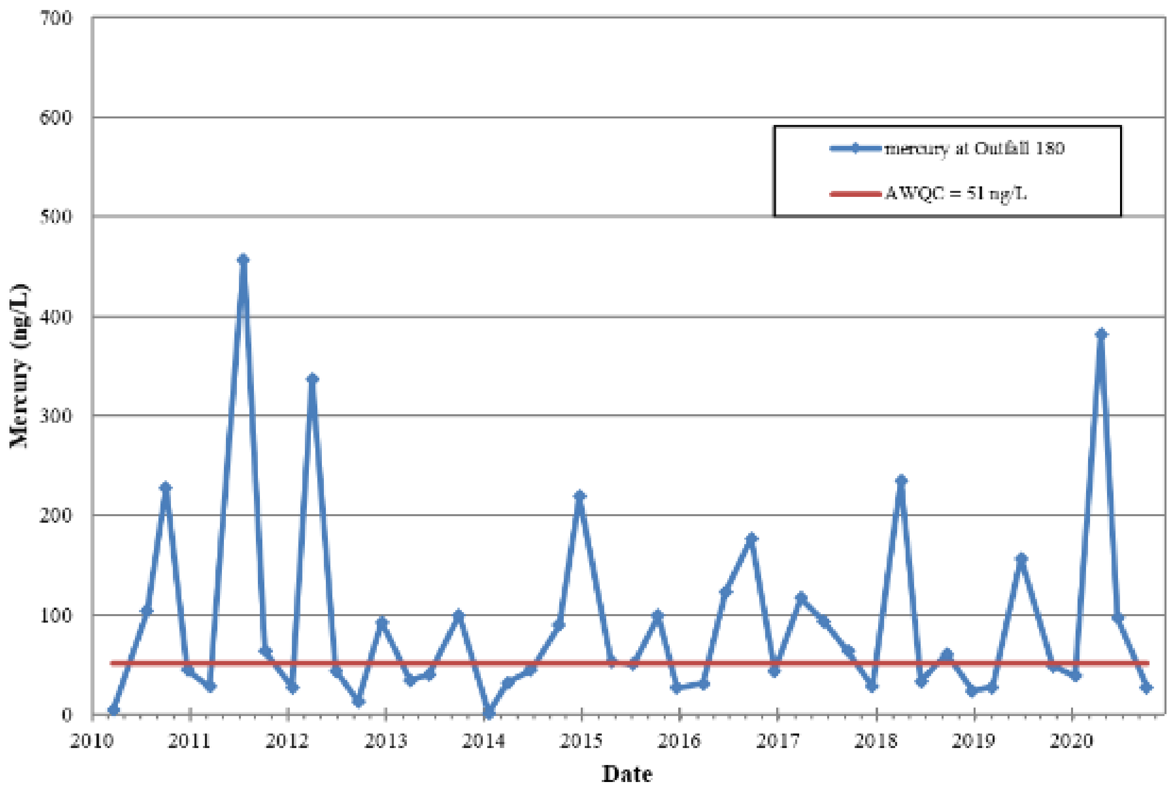


Figure 3.16. Mercury concentrations at Outfall 180

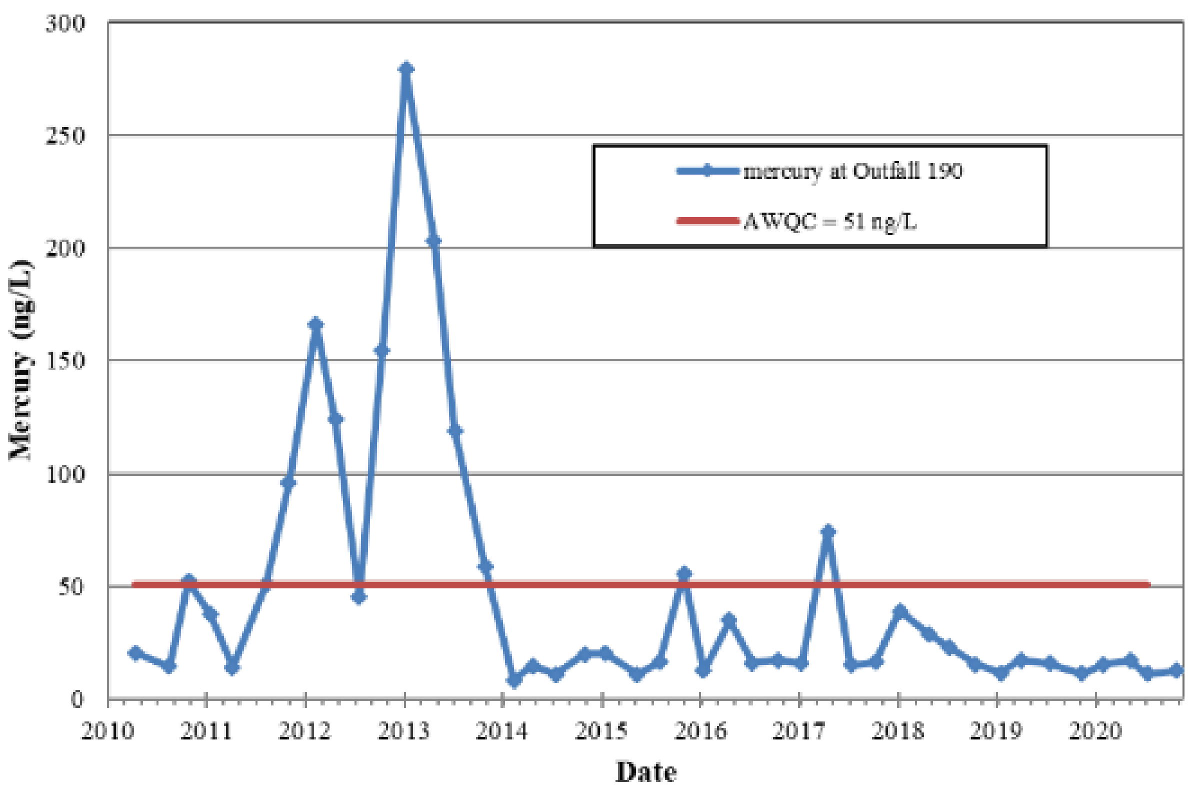


Figure 3.17. Mercury concentrations at Outfall 190

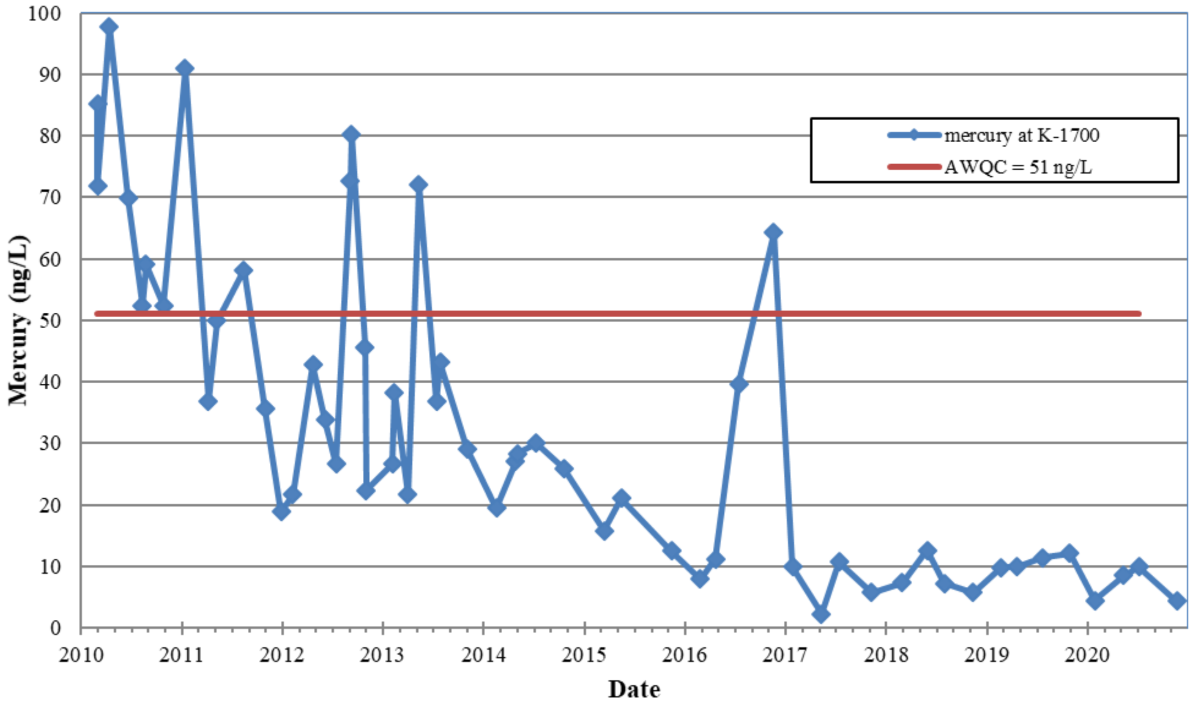


Figure 3.18. Mercury concentrations at the K-1700 Weir

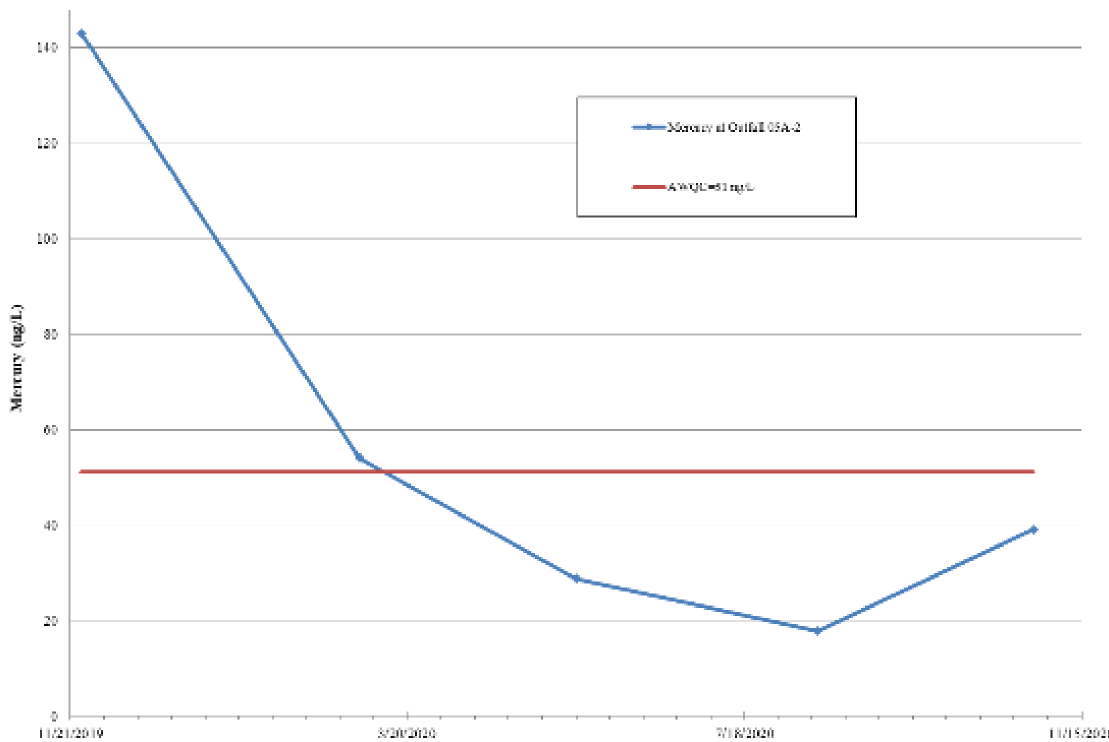


Figure 3.19. Mercury concentrations at Outfall 05A-2

Non-representative outfalls that were grouped with the representative outfalls where mercury has been identified and have not been sampled in several years were selected to be sampled as part of the 2020 SWPP Program. Analytical results from this sampling effort are shown in Table 3.12, with results in bold indicating exceedance of the reference standard.

Table 3.12. Analytical results from mercury sampling at selected storm water outfalls

Location	Mercury Reference standard 51 ng/L (REC OO) 50 ng/L (REC WO)
Outfall 195	7.63
Outfall 200	9.62
Outfall 240	22.2
Outfall 382	**68.4**
Outfall 850	21.9

REC OO TDEC Rule 0400-40-03-.03(4)(j), Organisms Only Criteria
REC WO TDEC Rule 0400-40-03-.03(4)(j), Water & Organisms Criteria

3.6.2.11. Investigation of Powerhouse Area Outfalls

Additional monitoring of selected Powerhouse outfalls was performed as part of the FY 2020 SWPP Program sampling and analysis plan. Analytical results that exceeded reference standards for this sampling effort are shown in Table 3.13.

Monitoring of mercury performed in CY 2020 confirmed that mercury is present in several locations in the Outfall 780 drainage network at levels exceeding reference standards.

Parameters that exceeded reference standard levels from follow-up sampling efforts at Outfall 780 are indicated in Table 3.14. Historic results are also included for purposes of comparison.

The mercury, PCBs, and radiological analytes are likely to be legacy contaminants that remain from past Powerhouse operations that were conducted in the drainage area of Outfall 780.

Table 3.13. Analytical results exceeding reference standards from samples collected at Powerhouse storm water outfalls

Reference Standards[a]	Gross alpha	Thallium	Mercury	PCB-1248	PCB-1254	PCB-1260	Lead
	15 pCi/L (DWS)	0.24 µg/L (REC WO)	0.51 ng/L (REC WO)	0.00064 µg/L (REC OO)	0.00064 µg/L (REC OO)	0.00064 µg/L (REC OO)	2.5 µg/L (CCC)
Outfall 830	15.4	0.273	72.8		0.0844 J	0.137	
Outfall 870							17
Outfall 890			123	0.0664	0.0632		

Reference standards sources are defined as follows:
CCC TDEC Rule 0400-40-03-.03(3)(g), Criterion Continuous Concentration
REC OO TDEC Rule 0400-40-03-.03(4)(j), Organisms Only Criteria
REC WO TDEC Rule 0400-40-03-.03(4)(j), Water & Organisms Criteria
Reference standards for radionuclides equal Derived Concentration Standard (DCS) for ingested water (DOE-STD-1196-2011, Derived Concentration Technical Standard). Derived Concentration Guide (DCG) values for ingested water (DOE Order 5400.5 Chg. 2, Radiation Protection of the Public and the Environment, Chap. III) are also listed because they remain in effect for certain CERCLA activities. Reference standards for gross alpha and gross beta measurements correspond to the national primary drinking water standard (40 CFR Part 141, National Primary Drinking Water Regulations, Subparts B and G).

Table 3.14. Results exceeding reference standards for the Outfall 780 monitoring effort

Sampling location	Mercury (ng/L)	PCB-1254 (µg/L)	PCB-1260 (µg/L)
Reference Standards	51.0	0.00064	0.00064
Outfall 780 (March 2018 results)	691.0	below detection	0.626
Outfall 780 (March 2019 results)	no discharge	no discharge	no discharge
Outfall 780 (October 2020 results)	no discharge	no discharge	no discharge
Outfall 780 D2 (March 2019 results)	66.7	0.0452	0.041
Outfall 780 D2 (October 2020 results)	Within standard	0.0871	0.21
Outfall 780 D3 (March 2019 results)	102.0	0.0408	0.0342
Outfall 780 D3 (October 2020 results)	105.0	below detection	below detection

3.6.2.12. PCB Monitoring at ETTP Storm Water Outfalls

Outfalls where PCBs have been identified and have not been sampled in several years were selected to be sampled as part of the FY 2020 SWPP Program sampling program. Analytical results from samples collected as part of this sampling effort are shown in Table 3.15. The presence of PCB-1260 in the storm water runoff from Outfall 292 may be related to legacy operations conducted in portions of the K-1064 peninsula area.

Table 3.15. Analytical results from fiscal year 2020 SWPP Program PCB sampling

Location	Parameter[a]	Reference Standard[b] 0.00064 µg/L (REC OO)
Outfall 148	Individual PCBs	No detectable PCBs
Outfall 156	Individual PCBs	No detectable PCBs
Outfall 240	Individual PCBs	No detectable PCBs
Outfall 250	Individual PCBs	No detectable PCBs
Outfall 292	Individual PCBs	PCB-1260 – 0.188 µg/L
Outfall 340	Individual PCBs	Outfall plugged
Outfall 360	Individual PCBs	No detectable PCBs
Outfall 390	Individual PCBs	No detectable PCBs
Outfall 410	Individual PCBs	No detectable PCBs
Outfall 420	Individual PCBs	No detectable PCBs
Outfall 570	Individual PCBs	No detectable PCBs
Outfall 610	Individual PCBs	No detectable PCBs
Outfall 760	Individual PCBs	No detectable PCBs
Outfall 810	Individual PCBs	No detectable PCBs
Outfall 900	Individual PCBs	No detectable PCBs

[a] PCB analysis includes PCB-1016, -1221, -1232, -1242, -1248, -1254, -1260, -1262, and -1268.
[b] Reference standards sources are defined as follows:
REC OOTDEC Rule 0400-40-03-.03(4)(j), Organisms Only Criteria

3.6.2.13. Storm Water Monitoring in the Outfall 690 Drainage Network

PCBs have been identified at Outfall 690 as part of previous sampling efforts. It was speculated that the source of the PCBs at Outfall 690 was likely the K-897-A oil/water separator. In order to better identify potential sources of PCBs in the Outfall 690 drainage network additional PCB samples were collected on December 14, 2020. Analytical results from this sampling effort are shown in Table 3.16 that show PCBs were detected in the storm drain network upstream from, and below stream of, the oil/waterseparator.

Table 3.16. Analytical results from Outfall 690 network sampling, December 14, 2020

Location	Parameter[a]	Reference Standard – 0.00064 ug/L (REC OO)[b]
Catch Basin 1027	Individual PCBs	PCB-1254 – 0.0512 ug/L
Catch Basin 1028	Individual PCBs	No detectable PCBs
Catch Basin 1032	Individual PCBs	No detectable PCBs
Catch Basin 1B020	Individual PCBs	PCB-1254 – 0.0346 ug/L
Catch Basin 1B024	Individual PCBs	No detectable PCBs
Catch Basin 1B025	Individual PCBs	PCB-1254 – 0.142 ug/L PCB-1260 – 0.0806 ug/L PCB-1268 – 0.0369 ug/L
Outfall 690 Headwall	Individual PCBs	PCB-1254 – 0.0365 ug/L
Outfall 690	Individual PCBs	No detectable PCBs

[a] PCB analysis includes PCB-1016, -1221, -1232, -1242, -1248, -1254, -1260, -1262, and -1268.
[b]Reference standards sources are defined as follows: REC OO: TDEC Rule 0400-40-03-.03(4)(j), Organisms Only Criteria
***Acronym:** PCB = polychlorinated biphenyl*

3.6.2.14. Chromium Water Treatment System and Plume Monitoring

The Chromium Water Treatment System (CWTS) (Figure 3.20) was constructed to intercept a plume of contaminated groundwater before it enters Mitchell Branch.

The CWTS consists of interceptor wells, pumps, holding tanks, a treatment system, and an air stripper. Effluent is discharged through the pipeline that originally carried effluent from the Central Neutralization Facility (which was previously demolished). In CY 2020, monitoring was conducted at monitoring well 289 (TP-289), the chromium collection system wells, Outfall 170, and Mitchell Branch kilometer (MIK) 0.79. Figures 3.21 and 3.22 show the results for the analyses for total chromium and hexavalent chromium, respectively.

The analytical data indicate that both total and hexavalent chromium levels may fluctuate slightly at TP-289 and the collection wells but are relatively consistent but slow decline over the long term. Figures 3.21 and 3.22 also show the continuing low level results over a long period for total chromium and hexavalent chromium at Outfall 170 and MIK 0.79. These results demonstrate the continuing positive impact of the collection well system to minimize the release of chromium into Mitchell Branch.

Figure 3.20. The Chromium Water Treatment System

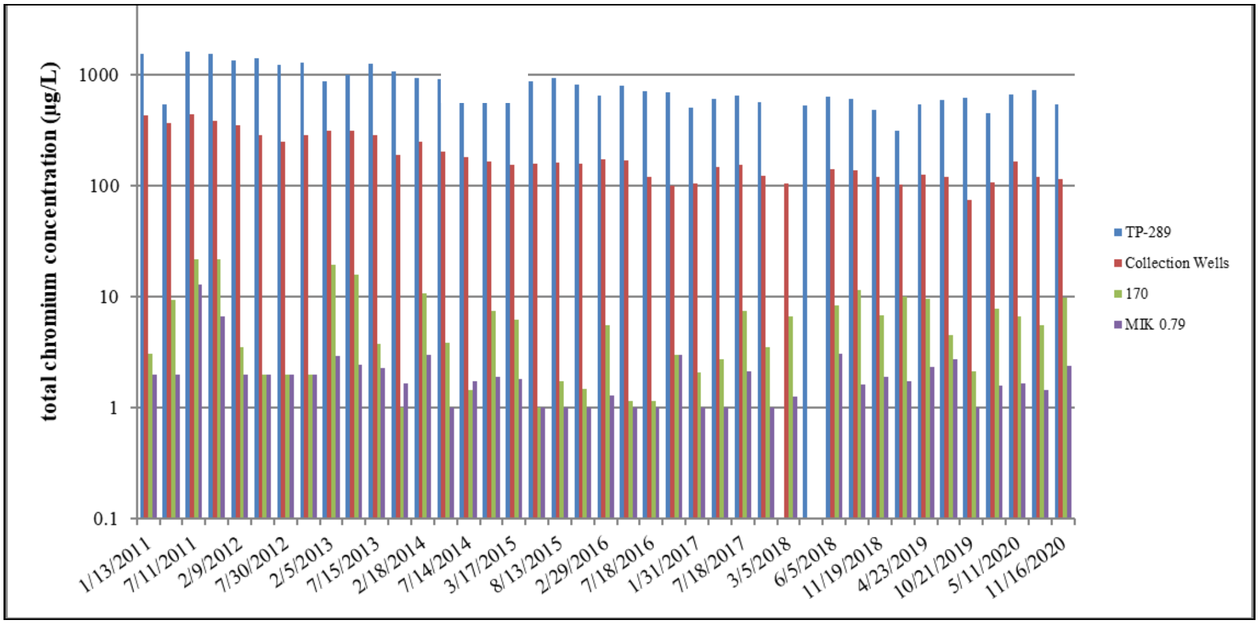


Figure 3.21. Total chromium sample results for the chromium collection system

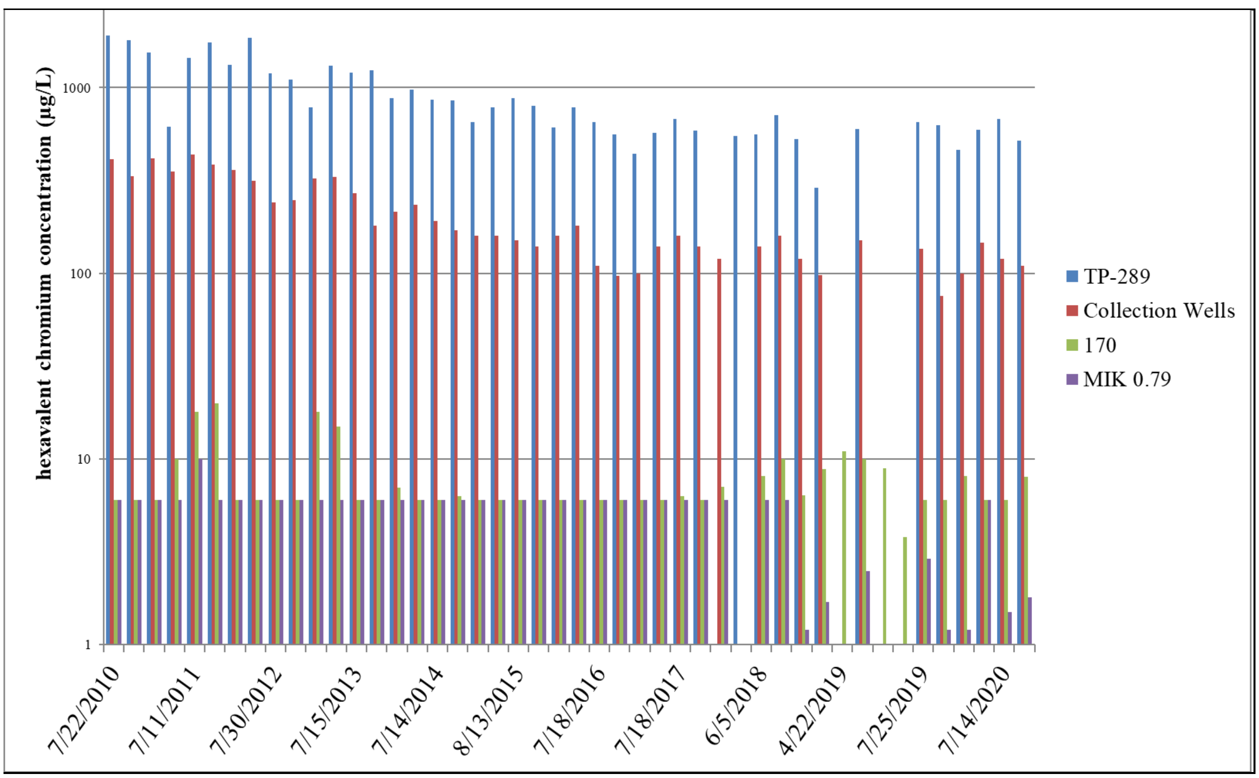
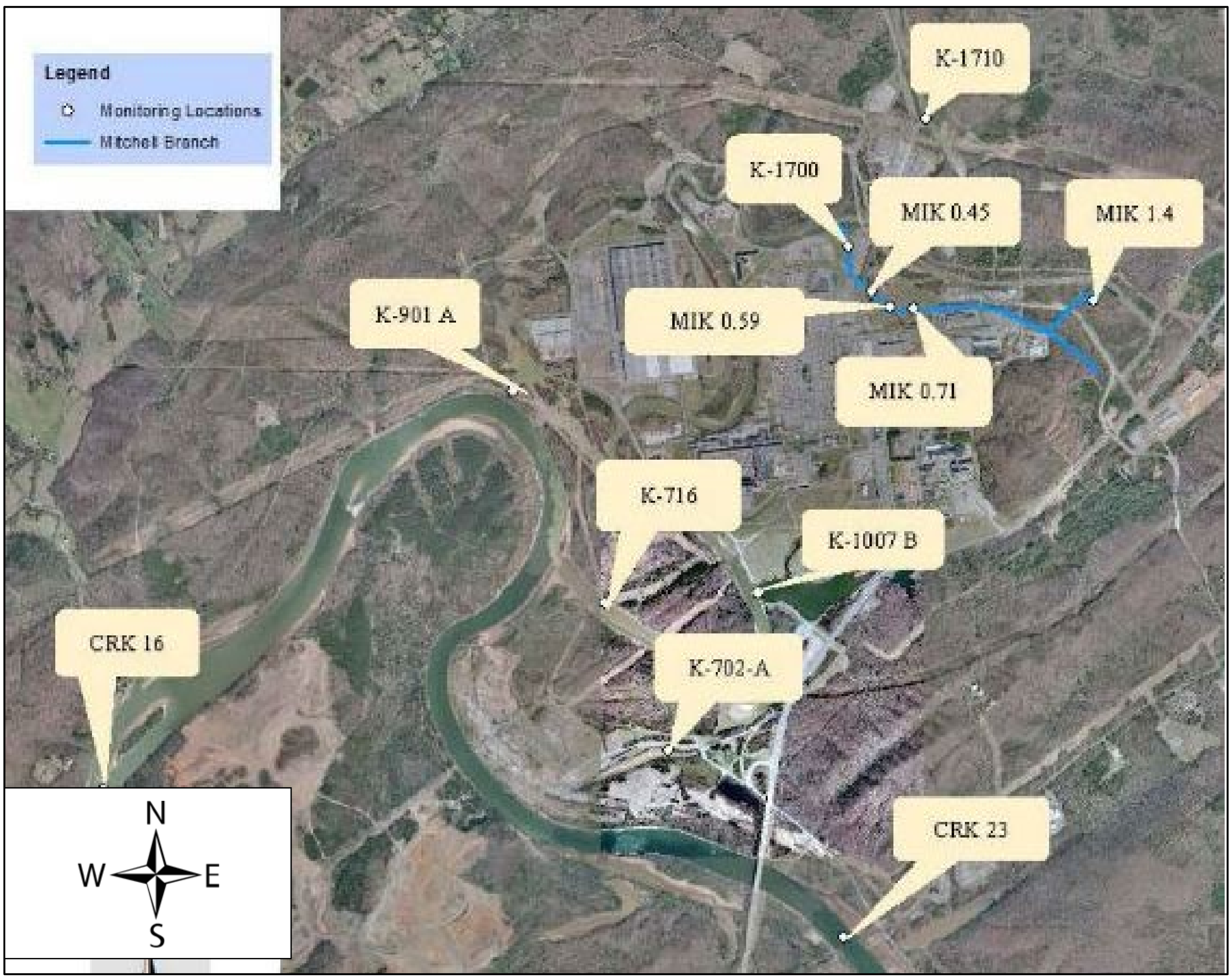


Figure 3.22. Hexavalent chromium sample results for the chromium collection system

3.6.3. Surface Water Monitoring

During 2020, the ETTP EMP personnel conducted environmental surveillance activities at 12 surface water locations (Figures 3.23 and 3.24) to monitor surface water conditions at watershed exit pathway locations (K-1700, K-1007-B, and K-901-A) or ambient stream conditions (Clinch River kilometers [CRKs] 16 and 23; K-1710; K-716; the K-702-A slough; and MIKs 0.45, 0.59, 0.71, and 1.4). Monitoring locations K-1700 and MIKs 0.45, 0.59, 0.71, and 1.4 were sampled quarterly; and monitoring locations CRKs 16 and 23, K-716, K-1007-B, K-901-A, and the K-702-A slough were sampled semiannually.

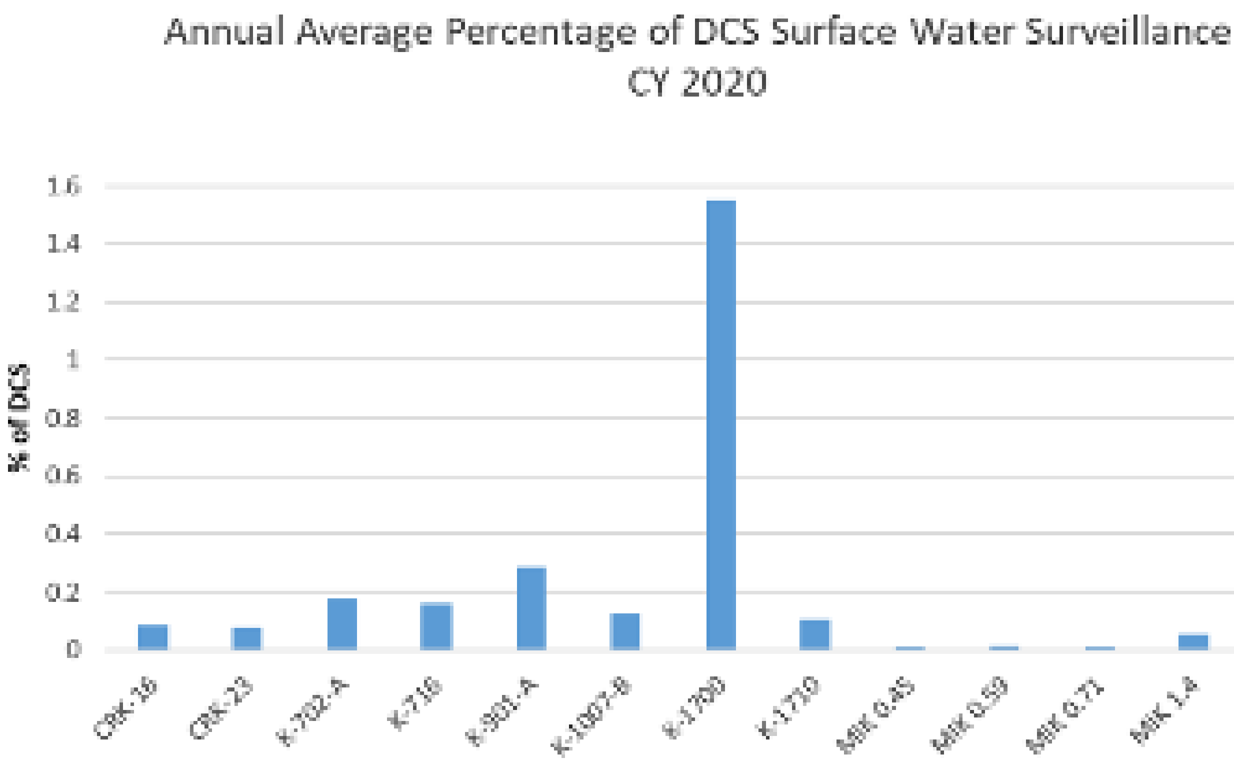
Figure 3.23. Surface water surveillance monitoring



Acronyms:
CRK = Clinch River kilometer *MIK = Mitchell Branch kilometer*

Figure 3.24. East Tennessee Technology Park Environmental Monitoring Program surface water monitoring locations

Results of radiological monitoring were compared with the DCS values in DOE Standard 1196 (DOE 2011b). Radiological data are reported as fractions of DCSs for reported radionuclides, and the fractions for all of the isotopes are added together to produce the sum of fractions (SOF) and averaged to produce a rolling 12-month average. The average SOF is recalculated whenever new data become available. If the average SOF for a location exceeds the DCS requirement of remaining below 1.0 (100 percent) for the year, a formal source investigation is required. Sources exceeding DCS requirements would need an analysis of the best available technology to reduce the SOF of the radionuclide concentrations to less than 1.0 (100 percent). In 2020, the monitoring results yielded SOF values of less than 0.01 (1 percent of the allowable DCS) at all surface water surveillance locations at ETTP, with the exception of monitoring location K-1700 (Figure 3.25). At K-1700, the annual average SOF was 0.0155 (1.55 percent). At MIKs 0.45, 0.59, and 0.71, quarterly monitoring is conducted for ^{99}Tc only.



Acronyms: *CRK = Clinch River kilometer   DCS = derived concentration standard   MIK = Mitchell Branch kilometer*

Figure 3.25. Annual average percentage of derived concentration standards at surface water monitoring locations, 2020

The vast majority of the results from monitoring of surface water at ETTP are well within the Ambient Water Quality Criteria. The most common exceedance, low dissolved oxygen levels, is a result of natural conditions (high biological activity during periods of low flow).

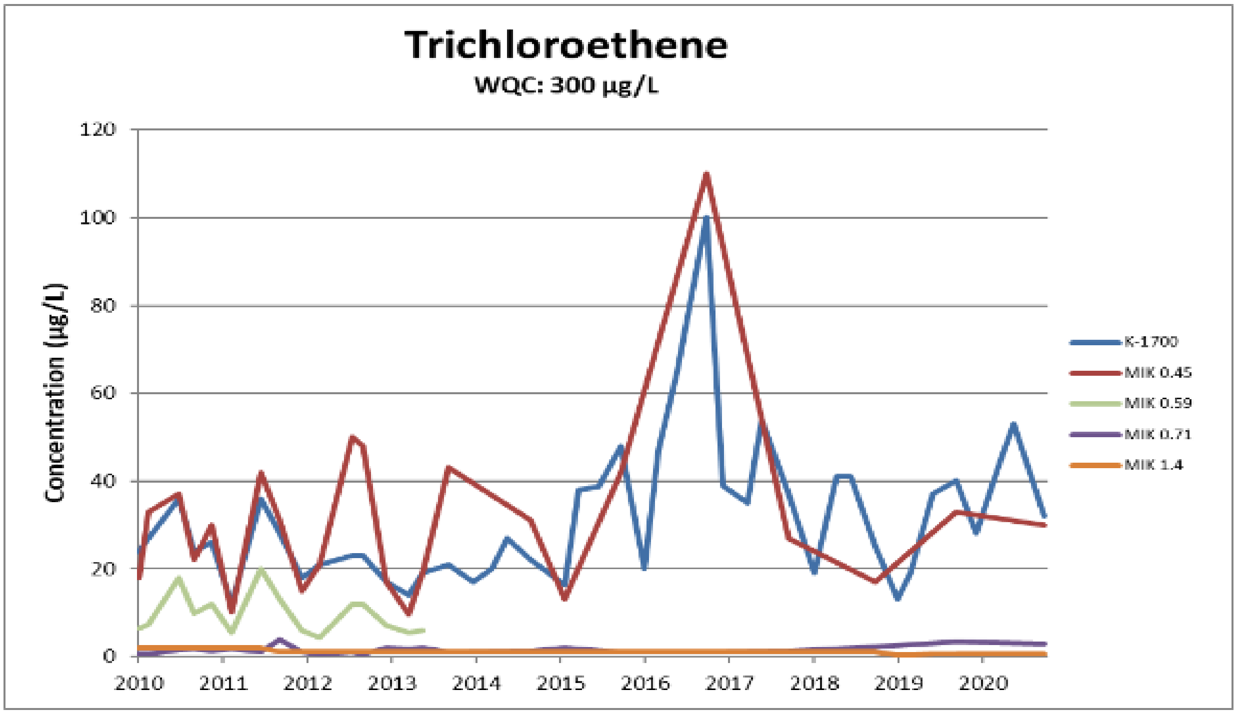
Depending on the monitoring location, water samples may be analyzed for pH, selected metals, and VOCs. In 2020, 1553 analytical results and 156 field readings were collected under the EMP. The vast majority of these results were well within the appropriate AWQC. There were two exceptions in 2020. During the third quarter, there were two failures to meet the minimum level of dissolved oxygen (5.0 mg/L). Dissolved oxygen levels were measured at 3.9 mg/L at K-1007-B, and at 4.7 mg/L at K-1700. These readings were collected at a time of elevated temperatures and very low flow due to the drought conditions, which favor high biological activity and the resulting depletion of dissolved oxygen. In the fourth quarter monitoring, all results met the AWQC.

Figure 3.26 illustrates the concentrations of TCE (trichloroethene) from the Mitchell Branch monitoring locations. Although VOCs are routinely detected at K-1700 and MIK 0.45, they are rarely detected at other surface water surveillance locations across ETTP. In the samples collected on November 22, 2016, results for several VOCs, including TCE and cis-1,2-dichloroethene, at several of the Mitchell Branch monitoring locations were reported at levels significantly higher than seen in recent monitoring. It should be noted that the November 22, 2016, sample date was at the end of an extended dry weather period that began in August 2016.

It should be noted that even at the increased levels, the results are still well within the AWQC. Concentrations of TCE and total 1,2-DCE are below the AWQCs for recreation, organisms only (300 µg/L for TCE and 10,000 µg/L for trans-1,2-DCE), which are appropriate standards for Mitchell Branch. In addition, vinyl chloride has sometimes been detected in Mitchell Branch water. VOCs have been detected in groundwater in the vicinity of Mitchell Branch and in building sumps discharging into storm water outfalls that discharge into the stream; these compounds have generally not been detected in storm water during the monitoring of network discharges. It appears that the primary source of these compounds is contaminated groundwater.

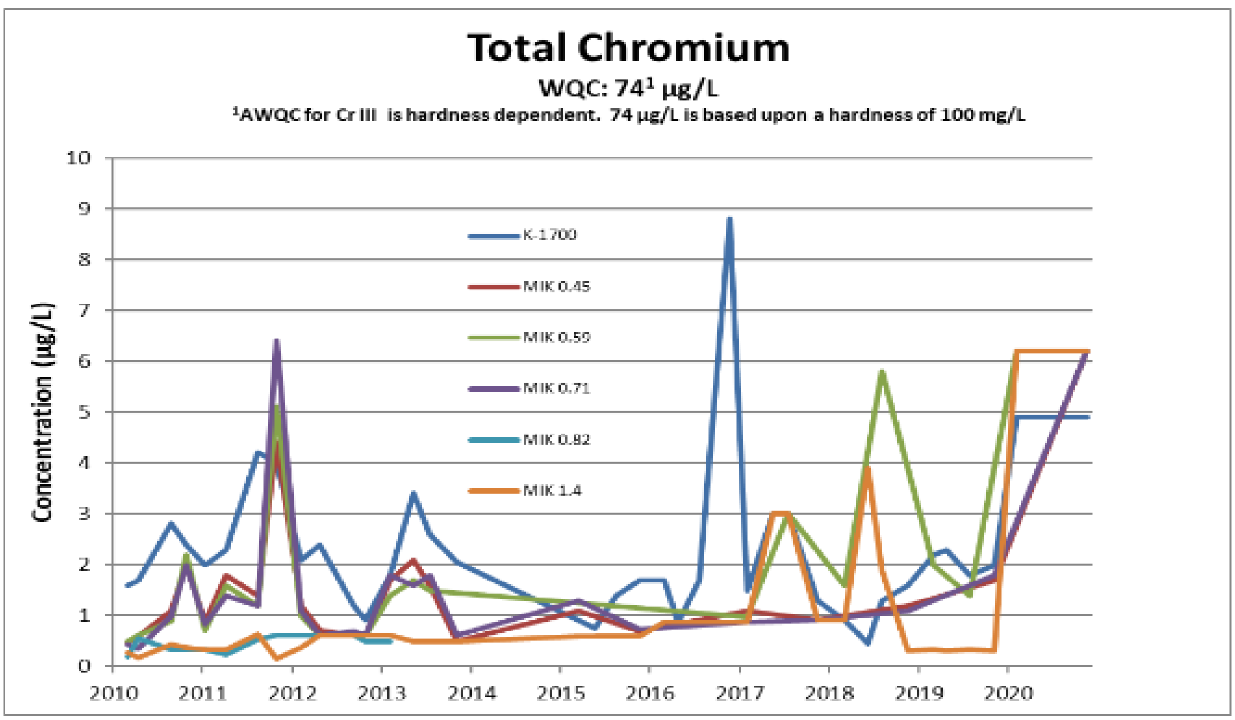
Since CWTS was installed, chromium levels in Mitchell Branch have dropped dramatically, with levels of total chromium being routinely measured at less than 6 µg/L (Figure 3.27). In 2020, hexavalent chromium levels in Mitchell Branch were all below the sample quantitation limit.

The completed Zone 1 actions through FY 2021 do not specify post-RA collection and analysis of environmental monitoring data. However, at the request of EPA, DOE agreed to conduct preliminary surface water screening for the presence of the emerging contaminant per- and polyfluoroalkyl substances (PFAS) compounds at exit pathway points in all ORR watersheds. DOE conducted reconnaissance sampling for PFAS compounds in surface water at four surface water monitoring locations, (K-901-A, K-1007-B, K-1700, and MIK 0.39). Table 3.17 includes results of the reconnaissance sampling and analysis. Individual concentrations at K-1007-P1 weir, K-901A weir, and the K-1700 weir were all less than the 40 ng/L screening level (sl), and the combined concentrations of PFOS+PFOA for these locations were less than the 70 ng/L recommended preliminary remediation goal (PRG). The duplicate sample collected at MIK 0.39 contained PFOS at 40 ng/L (equal to the sl) and PFOA at 30.2 ng/L which yielded a total PFAS concentration of 70.2 ng/L, slightly greater than the recommended PRG (70 ng/L). Historic fire training activities at the former K-1435 building near Mitchell Branch are the presumed source of PFAS detected in Mitchell Branch.



Acronym: *MIK = Mitchell Branch kilometer*

Figure 3.26. Trichloroethene concentrations in Mitchell Branch



Note:

The AWQC for Cr(III), which is hardness-dependent, is 74 µg/L, based on a hardness of 100 mg/L. The AWQC for Cr(IV) is 11 µg/L.

Acronyms: *AWQC = ambient water quality criterion MIK = Mitchell Branch kilometer*

Figure 3.27. Total chromium concentrations in Mitchell Branch

Table 3.17. East Tennessee Technology Park Site PFAS (PFOA/PFOS) surface water reconnaissance results

Location	Chemical Name	Result (ng/L)[a,b]	Combined PFAS Total (ng/L)[b]
K-1007 P1-Weir, Zone 1	PFOS	10.1	19.6
	PFOA	9.52	
K-901A Weir, Zone 1	PFOS	1.13 J	1.9
	PFOA	0.725 U	
K-1700 Weir, Zone 2	PFOS	29 J	51.1
	PFOA	22.1 J	
MIK 0.39, Zone 2	PFOS	40 J	**70.2**
	PFOA	30.2 J	
	PFOS	37.4	63.7
	PFOA	26.3	

[a] Individual results were screened against the recommended groundwater SL based on a target Hazard Quotient of 0.1 for PFOA or PFOS individually, which is currently 40 ng/L.
[b] Individual and combined results were screened against the PFOA and PFOS Lifetime Drinking Water Health Advisories of 70 ng/L as the recommended PRG for groundwater that is a current or potential source of drinking water.
***Bold** = values that exceed the SL or PRG.*
HQ = Hazard quotient.
PFOA = Perfluorooctanoic acid.
PFOS = Perfluorooctane sulfonate
PRG = Preliminary remediation goal.
SL = Screening level.

3.6.4. Groundwater Monitoring at ETTP

ETTP was divided into two zones to complete the primary source RA work. Zone 1 comprises 1,290 acres outside the ETTP Main Plant Area, and Zone 2 comprises 806 acres of the ETTP Main Plant Area. Actions under the two Records of Decision (RODs) have been on-going to characterize and address soil, buried waste, and subsurface structures for the protection of human health and to limit further contamination of groundwater through source reduction or removal (*Record of Decision for Interim Actions in Zone 1, East Tennessee Technology Park, Oak Ridge, Tennessee* [Zone 1 Interim ROD; DOE/OR/01-1997&D2] and *Record of Decision for Soil, Buried Waste, and Subsurface Structure Actions in Zone 2, East Tennessee Technology Park, Oak Ridge, Tennessee* [Zone 2 ROD; DOE/OR/01-2161&D2]). The cleanup of the remaining environmental media at ETTP, e.g., groundwater, surface water/sediment, and remaining ecological receptors will be addressed under future CERCLA decision documents, and these projects were started. Concurrent with these remedial actions, demolition of buildings at ETTP has been performed via the *Policy on Decommissioning Department of Energy Facilities Under CERCLA* (EPA and DOE 1995) and DOE's Removal Action authority.

Planning continued in FY 2020 for the ETTP Main Plant Area and K-31/K-33 groundwater RODs. The *K-31/K-33 Area Groundwater Remedial Site Evaluation Report for the East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE/OR/01-2765&D2; RSE) was submitted to EPA and TDEC in May 2019. In June 2020, DOE requested a 253-day extension to address D1 regulatory comments.

The data screen and trend assignments show that contaminant concentration trends are highly variable across the site as numerous remediation activities are underway.

- VOC concentrations in wells monitored downgradient of K-1070-C/D show that a broad area is affected by releases from the past disposal of liquid VOCs at G-Pit. While evaluations for data collected within the most recent five years indicate stable, indeterminate, or decreasing concentrations in wells monitored in the area, very high VOC concentrations affect wells DPT-K1070-5 and DPT-K1070-6. The persistent, very high concentrations of these VOCs suggest an ongoing contaminant source release.

- In the K-31/K-33 Area, chromium continues to be measured at levels near the MCL. During FY 2020, antimony slightly exceeded the MCL screening concentration (0.006 mg/L) in a filtered sample from well BRW-066). Maximum chromium results in unfiltered and field-filtered samples from BRW-030 were just slightly above the 0.1 mg/L MCL. Nickel is present in groundwater samples from one well (UNW-043) at concentrations greater than the Tennessee MCL of 0.1 mg/L.
- At the K-27/K-29 area groundwater contamination migrates toward Poplar Creek in both north and south directions from the area facilities. In the northern area chromium continues to exceed the MCL at well UNW-028, TCE continues to exceed the MCL screening level (0.005 mg/L) at wells BRW-041 (increasing trend), UNP-007 (stable trend) and at wells UNW-028 and UNW-29 (no significant trend), and uranium exceeds the MCL screening concentration (0.030 mg/L) in filtered and unfiltered samples form well UNP-007. In the southern area, carbon tetrachloride was equal to the MCL screening concentration (0.005 mg/L) in well UNW-088 having exhibited an increasing trend over 10 years but no trend during the past five years. Chromium exceeded its MCL screening concentration (0.1 mg/L) in unfiltered samples from wells UNW-036 and UNW-087 and in the filtered sample from well UNW-087. Nickel exceeded its MCL screening concentration (0.1 mg/L) in the unfiltered sample from well UNW-036. TCE continues to exceed the MCL screening concentration (0.005 mg/L) in wells BRW-069, UNW-036, UNW-037, UNW-085, UNW-087, and UNW-088. Most of the TCE trends in the K-27/K-29 southern area are no significant trend or decreasing with exception of an increasing trend determination for well UNW-037.
- At PC-0 spring, TCE was detected in samples collected in December 2019 and February 2020, but TCE was not detected in samples collected during March and September 2020. The maximum TCE result from PC-0 spring was 1.7 µg/L in February 2020. No TCE transformation products (1,2-DCE or VC) were detected in PC-0 spring samples during FY 2020. At spring 10-895, TCE was detected in samples collected in all four fiscal quarters of 2020. The maximum measured TCE concentration at spring 10-895 was 3.7 µg/L in May 2020. Cis-1,2-DCE was detected at 0.58 J µg/L in September 2020.
- In the K-770 Area, alpha activity concentrations at UNW-015 decreased to a level less than the 15 pCi/L MCL.
- At wells near the K-1007-P1 Holding Pond, alpha activity was detected at a concentration less than the 15 pCi/L MCL in wells BRW-084 and UNW-108. TCE was detected in the March 2020 sample from well BRW-084 at 0.002 mg/L, which is slightly less than the 0.005 mg/L MCL.
- Monitoring results from wells in the K-1407-B/C Ponds Area are generally consistent with results from previous years and show several fold concentration fluctuations in seasonal and longer term periods. The detection of VOCs at concentrations well above 1,000 µg/L and the steady concentrations over recent years suggest the presence of dense non-aqueous phase liquid (DNAPL) in the vicinity of well UNW-003.

The principal groundwater contaminants at ETTP are chlorinated VOCs (primarily trichloroethene [TCE] and its degradation products such as 1,2-dichloroethene and vinyl chloride) and ^{99}Tc. Despite the fact that ETTP is a former gaseous diffusion plant used for uranium enrichment, the occurrence of elevated uranium concentrations in groundwater is relatively uncommon at the site. The reason for this is that the uranium enrichment process used gaseous uranium hexafluoride (UF^6) which was contained inside process equipment and depleted UF^6 was returned to storage cylinders where it returned to solid form upon cooling. The Water Resources Restoration Program (WRRP) analyzes total uranium in samples from 53 wells, two springs, and one surface water location. During FY 2019, the uranium MCL, 30 µg/L, was exceeded in samples from two wells located north of the K-27 Building footprint. One of these uranium MCL exceedances was a result of well BRW-016 having been flooded by water associated with local decontamination and decommissioning activities. The well has subsequently been re-developed to clean up the well casing and remove groundwater within capture zone. The second well (UNP-007) has exhibited uranium MCL exceedances since 2017. During FY 2020, alpha activity and uranium concentrations in these two wells continued to decrease. Chromium and nickel (and less frequently lead) are the most common metal contaminants in groundwater and they are relatively widespread at ETTP as well as elsewhere on the Oak Ridge Reservation. Chromium was used in the hexavalent form in the recirculating cooling water and fire protection water systems to prevent corrosion of pipes. Leaks of pipes that circulated the corrosion inhibiting additives were common and in some cases were of quite large volume. In the Mitchell Branch plume area near the former K-1420 facility, hexavalent chromium in groundwater is collected and treated prior to discharge to protect the water quality in Mitchell Branch and maintain instream chromium concentrations compliant with the 0.011 mg/L ambient water quality criteria. (For more information, see Section 3.6.3.12 above) The origin of nickel as a groundwater contaminant is not readily tied to site processes that would have created releases of soluble nickel to the subsurface. Lead was widely used at the DOE facilities as shielding material and for other typical industrial purposes. Lead materials were sometimes stored outdoors, in the open, and some was disposed in waste burial areas either as material shielding or as waste.

Chromium, nickel, and lead are widespread in ORR soils. The ORR background soils report indicates that for Knox and Chickamauga group soils the chromium concentrations are in the range of about 40-50 mg/kg at 95th percentile of the median. Nickel concentrations in Knox and Chickamauga group soils are in the ranges of about 10–30 mg/kg in the Knox and about 25-45 mg/kg in the Chickamauga group soils. Lead concentrations in soils are typically somewhat higher than the chromium and nickel levels. Chromium and nickel are also constituents of the stainless steel that comprises many of the monitoring well casings and screens. There is literature documentation that microbial induced corrosion can cause elevated chromium and nickel in groundwater monitoring wells at levels that can exceed the water quality criterion. In many instances, metals contamination detected in ETTP groundwater monitoring is particle associated material as demonstrated by either much lower, or non-detect concentrations measured in field-filtered sample aliquots than in the unfiltered aliquots. These factors lead to uncertainty in the interpretation of chromium and nickel (and other metals) data from groundwater monitoring because of multiple potential sources of metals—especially when data indicate that the metals are particle associated in the samples.

DOE has compiled the analytical data for groundwater contaminants in wells included in the routine WRRP monitoring program at ETTP to evaluate contaminant concentrations with respect to U.S. Environmental Protection Agency's National Primary Drinking Water Regulations MCLs and maximum contaminant level derived concentrations (MCL-DCs) and to determine if statistically significant trends are occurring. Data are compared to MCLs or MCL-DC for radionuclides. Data were compartmentalized into a maximum time period of 10 years for longer duration trend evaluation and a secondary time period of five years to evaluate more recent trends. Trend evaluations were made using the annual maximum concentration values over the

10-year period. The reason for the additional trend evaluation is to determine if the frequently observed seasonal concentration fluctuations mask trends that appear to be present based on visual examination of contaminant history graphs.

Former Buildings K-27 and K-29 were gaseous diffusion uranium enrichment process buildings. A number of process support facilities, including wastewater treatment, were located to the north of building K-27 and south of Poplar Creek. Groundwater contamination in the K-27/K-29 Area includes alpha activity, metals (including uranium), and VOCs. Contaminant concentration trends are quite mixed with some increasing, some decreasing, and many for which no trend can be confidently assigned.

The central plant area of ETTP includes the majority of the former gaseous diffusion process and support facilities. Figure 3.28 shows groundwater plume evaluation areas and several VOC plume areas. TCE is the principal chlorinated solvent that comprises the VOC plume sources although lesser amounts of tetrachloroethene, 1,1,1 trichloroethane, and Freon-113 are present in selected areas. TCE-rich dense non-aqueous phase liquid (DNAPL) has been confirmed to be present beneath the former K-1401 facility where parts cleaning using vapor degreasing facilities occurred. DNAPL is suspected to be present in the central portion of the K-1070-C/D plume area based on liquid waste disposal records for the "G-Pit" site. On the basis of continuing high concentration TCE signatures in groundwater, DNAPL is also suspected to be present at the K-1070-C/D South/K-1200 Area, the K 1035 site, and near Mitchell Branch related to the K-1407-A neutralization pit and/or the K-1407-B Pond. The Zone 2 remedial action (RA) program has identified a significant source of TCE beneath the center of the K-25 Building where a soil RA will be required consistent with the *Record of Decision for Soil, Buried Waste, and Subsurface Structure Actions in Zone 2, East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE/OR/01-2161&D2). No monitoring wells exist in that area to allow ongoing groundwater sampling and thus no groundwater trend evaluations are possible in that area. The ^{99}Tc contamination beneath the K-25 Building East Wing is being remediated by excavation and much of the ^{99}Tc plume shown on figures is based on groundwater grab samples obtained from exploratory soil sample borings installed through the course of the ^{99}Tc RA project over the past several years. Since these samples were obtained from uncased borings with no wells, there will not be further sampling of the locations to allow trend evaluation. Groundwater investigations in support of a groundwater feasibility study for the central plant area included installation of wells that provide the possibility of future monitoring at selected locations.

Five plume evaluation areas have been established within the central plant area. For information concerning conditions at the K-1401 site, readers are referred to the *Design Characterization Completion Report for the Sitewide Groundwater Treatability Study at the East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE 2018d, DOE/OR/01-2768&D1), which includes the detailed characterization of the confirmed DNAPL source area.

The ETTP Northwest Quadrant includes former K-1070-A Burial Ground, the K-31/K-33 Area, K-1064, and the K-901-A Holding Pond. The K-1070-A Burial Ground was remediated by excavation of buried waste materials in the early 2000's and a TCE-dominated groundwater plume remains. At the K 1064 site, various waste handling and material storage activities occurred during the gaseous diffusion process operations and low concentration residual groundwater contaminants include arsenic and TCE. The K-31 and K-33 buildings were gaseous diffusion process buildings that have undergone decontamination and decommissioning. The principal groundwater contaminants at K-31/K-33 are metals that have mostly decreased in concentration to levels less than their MCLs. At the K-901 groundwater exit pathway, the only groundwater contaminant that has been present at greater than 80% of its MCL within the past decade is alpha activity which has decreased in concentration to levels less than 50% of the MCL or non-detectable levels.

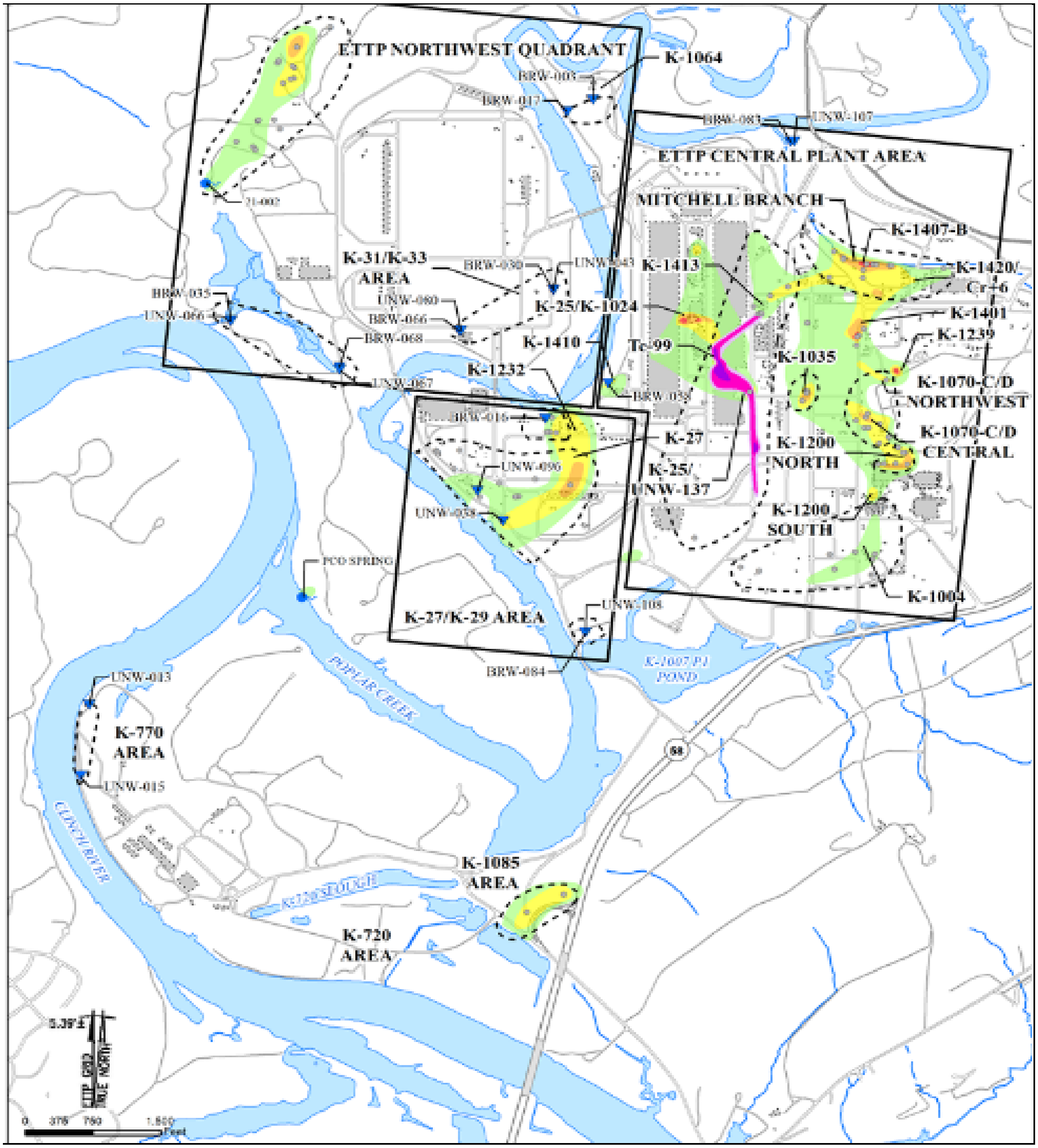


Figure 3.28. East Tennessee Technology Park volatile organic compound and ^{99}Tc plumes

The K-770 Area is the site of the former electrical generating powerhouse that provided the first electrical power for the gaseous diffusion plant in 1944. A portion of the northern K-770 Area was used for the storage of radioactively contaminated scrap metal for many years. Radiological materials associated with that scrap metal caused contamination of the underlying soil and groundwater. The scrap metal was removed and disposed and a RA was conducted to remove contaminated soil. Groundwater contamination is indicated by alpha activity which has decreased in concentration over time to levels below the 15 pCi/L MCL.

Across ETTP, contaminant conditions in the groundwater exit pathway areas are generally stable and similar to conditions in recent years. For additional information, see the 2020 Remediation Effectiveness Report for the U.S. Department of Energy, Oak Ridge Site, Oak Ridge Tennessee (DOE 2020).

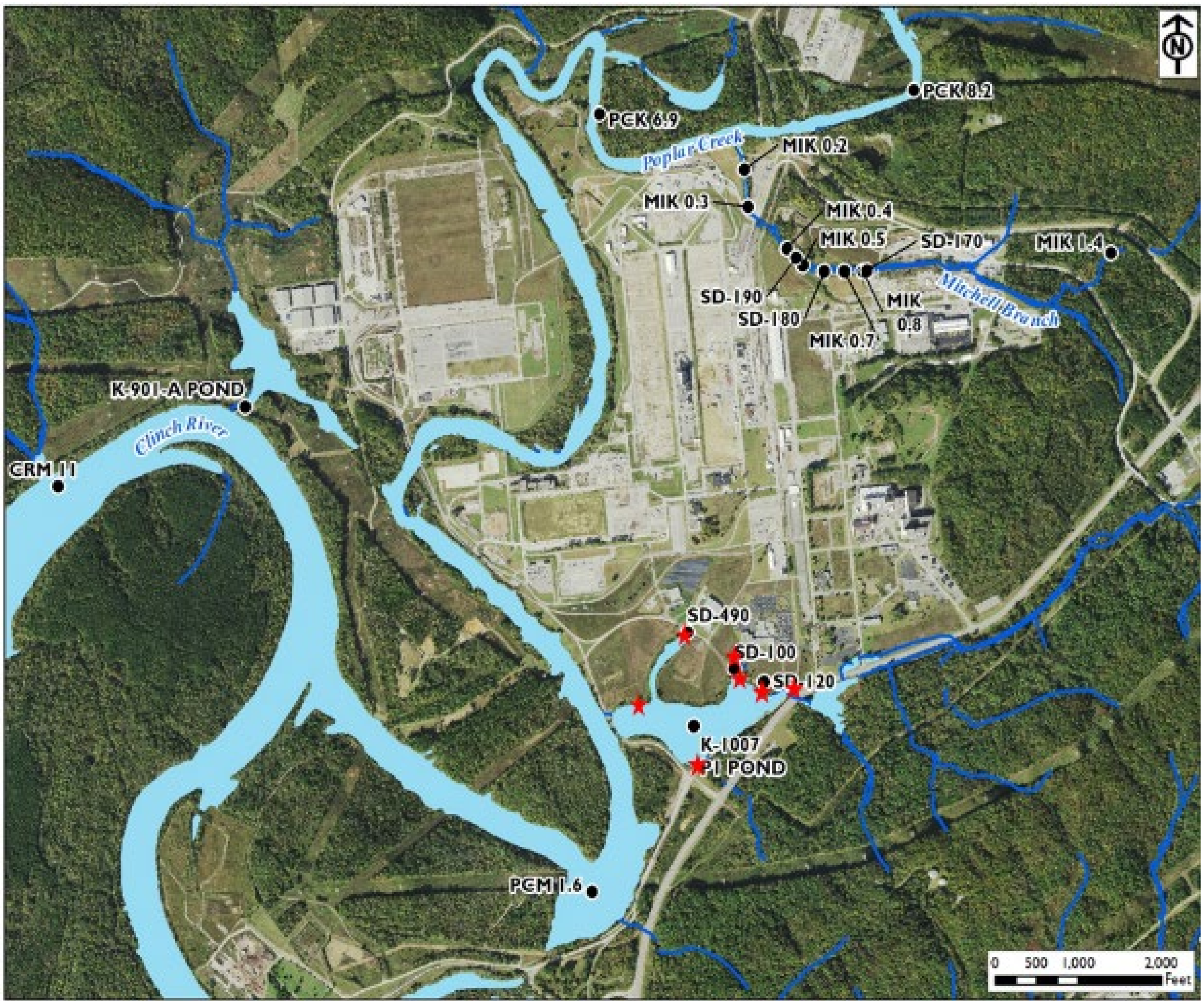
3.7. Biological Monitoring

The ETTP BMAP consists of two tasks designed to evaluate the effects of ETTP legacy operations on the local environment, identify areas where abatement measures would be most effective, and test the efficacy of the measures. The results from this program will support future CERCLA cleanup actions. These tasks are: (1) bioaccumulation studies, and (2) instream monitoring of biological communities. Figure 3.29 shows the major water bodies at ETTP and Figure 3.30 shows the BMAP monitoring locations along Mitchell Branch.

3.7.1. Task 1: Bioaccumulation Monitoring

Bioaccumulation monitoring for the ETTP BMAP has focused on evaluating the impact of PCB discharges into the environment because of historical operations at the ETTP complex. It was previously assumed that mercury (Hg) flux into Poplar Creek and the Clinch River originated largely from Y-12 Complex discharges into East Fork Poplar Creek (EFPC). However, more recently monitoring has shown that water in ETTP storm drains and biota from lower Mitchell Branch have elevated mercury concentrations. Mercury bioaccumulation monitoring is routinely conducted in the watersheds adjacent to ETTP by the Y-12 and ORNL BMAPs, both on and off ORR. The available Hg bioaccumulation monitoring data will be presented in the following subsections with long-term trends in PCB contamination in resident fish and caged clams from ETTP waters. Recent tabular results were provided in the FY 2020 ETTP BMAP Report.

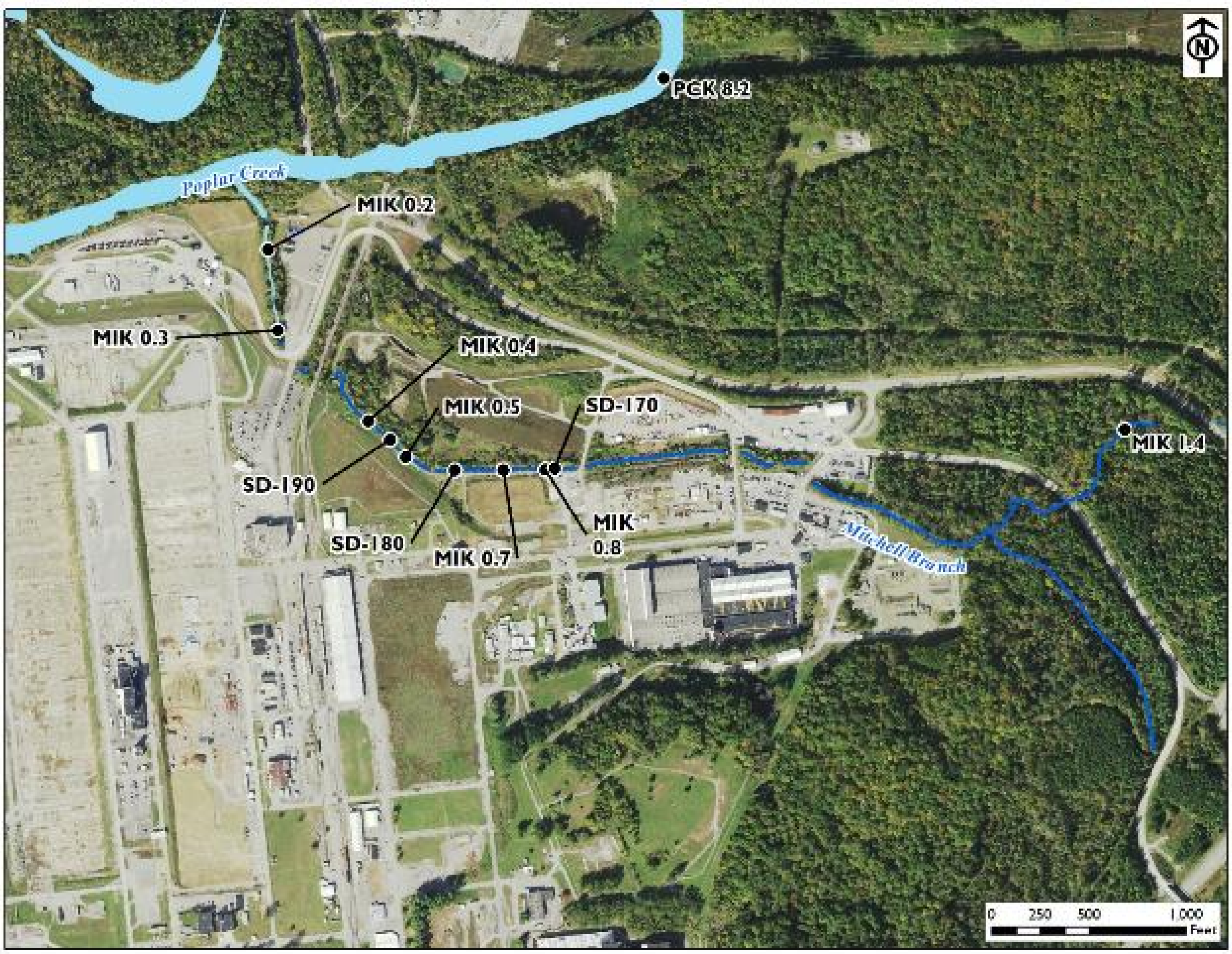
Because the consumption of contaminated fish represents the largest dose of Hg and many other bioaccumulative contaminants to humans, fish fillet concentrations are relevant to assessing human health risks, whereas whole body fish are relevant to assessing ecological risks. Largemouth bass (*Micropterus salmoides*) and various sunfish species are used to monitor Hg and PCB fillet concentrations, and gizzard shad (*Dorosoma cepedianum*) and bluegill (*Lepomis macrochirus*) are used to monitor whole body concentrations at various locations over time. Largemouth bass are larger, upper trophic level predatory fish and are, therefore, susceptible to Hg and PCB bioaccumulation. Fillet concentrations in these fish represent the near maximum potential dose to humans, if eaten. Largemouth bass tend to live in larger, deeper pools of water and are collected in the ponds at ETTP (K-1007-P1 Pond, K-901-A Pond, and K-720 Slough) as well as in off-site river and reservoir locations. Sunfish are short-lived and have small home ranges, so fillet Hg and PCB concentrations in these fish are representative of exposure at the site of collection. These fish are used in long-term studies to monitor changes in bioaccumulation at a given site over time. Collections of sunfish are restricted to sizes large enough to be taken by sport anglers (generally 50–150 g total weight) to minimize effects of covariance between size and contaminant concentrations, as well as for spatial and temporal comparability. The target sunfish species for bioaccumulation studies in Mitchell Branch and other ORR stream sites is redbreast sunfish (*Lepomis auritus*), but where these fish are not present, other species with similar feeding habits (e.g., bluegill sunfish [*Lepomis macrochirus*]) are collected.



Note:
1. *Red stars indicate clam sampling locations in and around the K-1007-P1 Pond in 2020.*
Acronyms:
CRM = Clinch River mile
PCK = Poplar Creek kilometer
MIK = Mitchell Branch kilometer
SD = storm drain

Figure 3.29. Water bodies at the East Tennessee Technology Park

For bioaccumulative contaminants such as Hg and PCBs, US fish bioaccumulation data have become important measures of compliance for both the Clean Water Act and CERCLA. For Hg, the EPA National Recommended Water Quality Criterion for Hg in fish (0.3 µg/g) is used as the trigger point for fish consumption advisories in Tennessee, the target concentration for NPDES permit compliance, and the threshold for impairment designations that require a Total Maximum Daily Load (TMDL) assessment. In addition to fish Hg limits, the State of Tennessee continues to use the statewide AWQC for Hg of 51 ng/L in water, based on organisms only, and 50 ng/L for recreation-water and organisms (TDEC 2013). Regulatory guidance and human health risk levels have varied more widely for PCBs, depending on the regulatory program and the assumptions used in the risk analysis. The Tennessee water quality criteria for individual Aroclors and total PCBs are both 0.00064 µg/L under the recreation designated use classification and are the target for PCB-focused TMDLs, including for local reservoirs (Melton Hill, Watts Bar, and Fort Loudon) (TDEC 2010a, 2010b, 2010c). However, most conventional PCB water analyses have detection limits much higher than the PCB AWQC. Therefore, in Tennessee and in many other states, assessments of impairment for water body segments, as well as public fishing advisories for PCBs, are based on fish tissue concentrations. Historically, the US Food and Drug Administration (FDA) threshold limit of 2 µg/g in fish fillet was used for PCB advisories; then for many years in Tennessee, an approximate range of 0.8 to 1 µg/g was used, depending on the data available and factors such as the fish species and size. The remediation goal for fish fillet at the ETTP K-1007-P1 Pond is 1 µg/g. Most recently, the water quality criterion that has been used by TDEC to calculate the fish tissue concentration triggering a determination of impairment and a TMDL, and this concentration is 0.02 µg/g in fish fillet (TDEC 2010a, 2010b, 2010c). The fish PCB concentrations at and near ETTP are well above this most conservative concentration.



Acronyms:
BMAP = Biological Monitoring and Abatement Program
MIK = Mitchell Branch kilometer
SD = storm drain/storm water outfall

Figure 3.30. Major storm water outfalls and biological monitoring locations on Mitchell Branch

In addition to monitoring for human health and ecological risks as well as long-term trends, bioaccumulation monitoring also includes investigations of sources of contamination to ETTP waterways. Caged Asiatic clams (*Corbicula fluminea*) are used as bioindicators of contaminant sources in Mitchell Branch and other sites around ETTP. These clams are collected from an uncontaminated reference site (Little Sewee Creek in Meigs County, Tennessee) and are divided into groups of 10 clams of equal mass. In 2020, clams were placed in baskets to be deployed at strategic locations around ETTP (i.e., in and around storm drains) for a 4-week exposure period (May 4–June 1, 2020). Two clam baskets were placed at each site with 10 clams in each basket.

Because these animals are sedentary filter feeders, they accumulate contaminants that are present in the water and in suspended particles at a given site. They are useful indicators of the bioavailable (and therefore potentially toxic) portion of contaminants that enter the environment at a given location, and they provide spatial resolution of contamination on a finer scale than is possible with fish bioaccumulation studies. Caged clams have been used for more than 25 years to evaluate the importance of storm drains and other inputs of PCBs into the waterways around ETTP and for the past 10 years to monitor total mercury (Hg_T) and methylmercury (MeHg) inputs to Mitchell Branch. Whereas most of the Hg in the environment is inorganic mercury (Hg^{2+}), a small fraction of Hg^{2+} is converted to the more toxic and bioaccumulative MeHg. Because MeHg biomagnifies in aquatic systems, increasing in concentration as it moves up through the food chain, more than 90 percent of the Hg in upper trophic level fish is MeHg. Clams, which feed on periphyton and detritus at the base of the food chain, have a much smaller proportion of MeHg in their tissues but are still good indicators of MeHg hotspots and sources. The soft tissues of the clams from each cage were homogenized, and aliquots were taken for PCB and Hg analysis.

To assess spatial and temporal variability in exposure to PCBs following remediation activities, water samples have been collected for analysis of aqueous PCBs and total suspended solids (TSS) from the outfall of K-1007-P1 and an uncontaminated reference site (upper First Creek, ORNL). Samples from K-1007-P1 are collected four times each year (March/April, June, July, and August).

3.7.1.1. Mitchell Branch

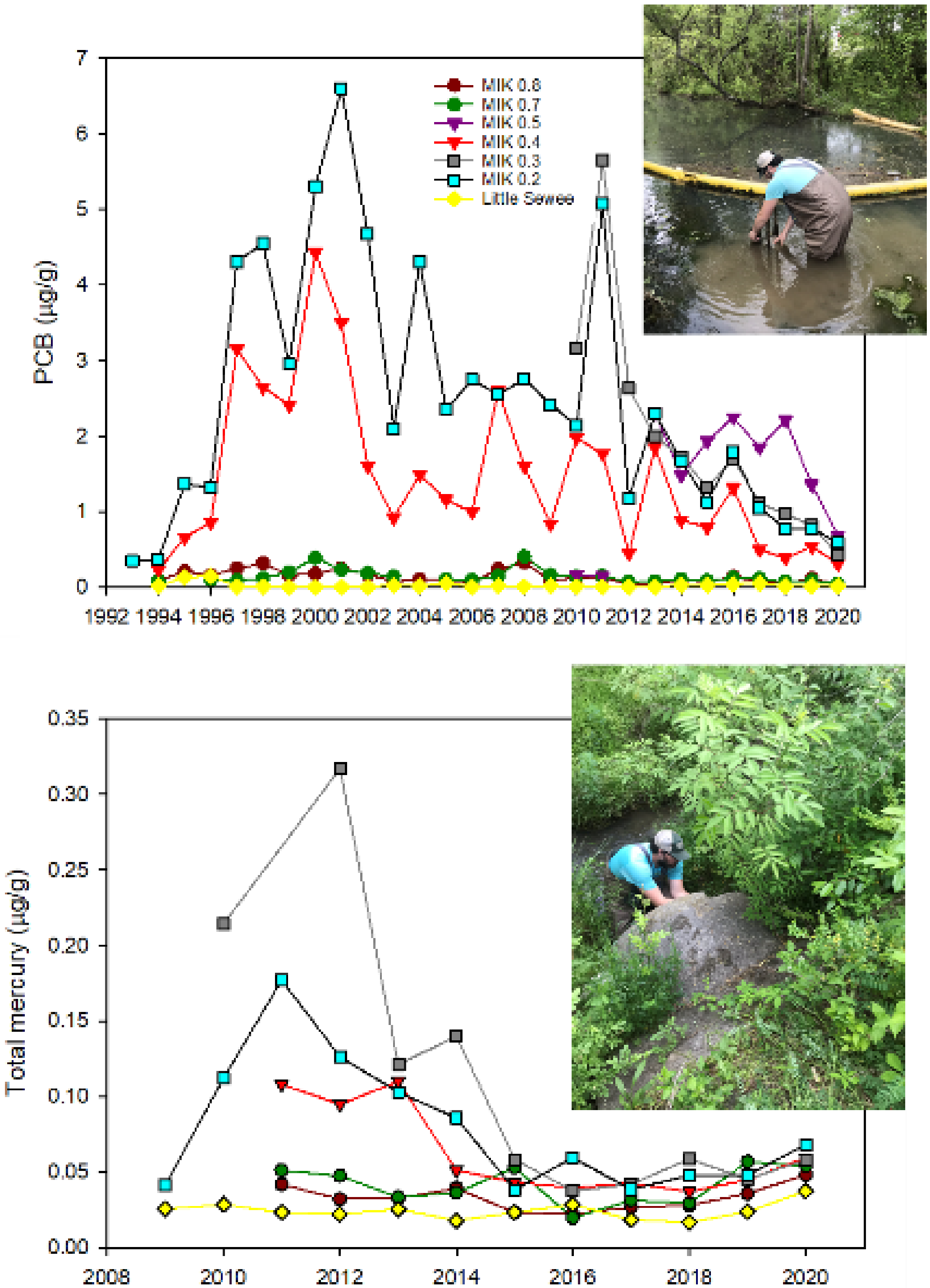
Figure 3.31 shows long-term monitoring results in caged clams deployed at various sites in Mitchell Branch. The lower portion of this stream (MIK 0.5, SD 190, MIK 0.2) has historically been a “hot spot” for both Hg and PCB contamination, and in 2020 PCB concentrations continued to be elevated (~1–2 µg/g) with respect to other Mitchell Branch and reference sites with concentrations remaining comparable to those seen in recent years. Although there is considerable interannual variability, PCB concentrations in clams placed in lower Mitchell Branch appear to be generally trending downward since peak years in 2000-2001. While there was a slight bump up in PCB concentrations at Mitchell Branch sites in 2016, concentrations since then have dropped back down, continuing the overall decreasing trend. PCB concentrations in the upper portion of Mitchell Branch were similar to previous years’ concentrations and were slightly elevated (0.04 µg/g) with respect to the reference site (0.02 µg/g).

Surface water monitoring conducted by various programs (e.g., ETTP Compliance, WRRP) has shown that aqueous Hg concentrations in Mitchell Branch may fluctuate significantly, with concentrations occasionally exceeding the AWQC. This level of variability is typical of stream systems because aqueous Hg concentrations can change with various environmental factors (e.g., flow, suspended solids, etc.) as well as with sample collection methods. Variation in aqueous Hg concentrations is not uncommon and illustrates that aqueous concentrations in a grab sample taken on a certain day reflect a snapshot of the conditions during that sampling period. In addition, the relationship between aqueous Hg concentrations and MeHg concentrations is not a straightforward one, leading to further complexities with respect to Hg bioaccumulation. Although monitoring aqueous concentrations is still indicative of gauging the relative importance of different Hg sources to a given watershed, bioaccumulation data are informative in that they reflect an integrative measure of the bioavailable portion of Hg exposure at a given site. Monitoring eHg concentrations in clams is illustrative in that they highlight the complexity of Hg bioaccumulation—whereas Hg_T concentrations in clams varied greatly between sites, MeHg concentrations in Mitchell Branch were elevated with respect to the reference site but did not vary as much as total Hg between sites or between years.

Mercury concentrations in clams deployed in Mitchell Branch in 2020 were slightly higher than concentrations seen in 2019 (Figure 3.32). In 2020, concentrations throughout Mitchell Branch were only slightly higher than at the reference site, which also experienced a slight increase in Hg concentrations. Within the Mitchell Branch system, the highest Hg concentrations were again seen in clams deployed at SD180 (0.12 μg/g). Mercury concentrations in clams deployed at the K-1007-P1 and K-901-A Ponds were again comparable to reference site concentrations. Clams deployed at two oil skimmers (K-897-A and K-897-J) had Hg concentrations similar to those of the reference site. Unlike in fish tissue, MeHg in the soft tissues of clams generally made up a small proportion of HgT (Figure 3.32). Although MeHg concentrations in clams remained low in 2020, they were either comparable to or slightly higher than concentrations in 2019.

Figure 3.33 shows long-term monitoring results in redbreast sunfish (*Lepomis auritus*) at MIK 0.2. Average PCB concentrations in fish collected at MIK 0.2 in 2020 (1.49 ± 0.25 μg/g) were higher than those seen in 2019 (0.74 ± 0.08 μg/g) but remained comparable to concentrations seen at this site in recent years (Figure 3.32). Although there is not a regulatory limit for PCBs in fish, the level most often used in practice to issue fish consumption advisories in the State of Tennessee, as previously stated, is 1 μg/g. In 2020, the mean PCB concentration in sunfish fillets collected from MIK 0.2 was above this limit. While the observed fish tissue concentrations in Mitchell Branch are lower than they have historically been, they are still two to three orders of magnitude higher than concentrations seen in the same species at the Hinds Creek reference site in Anderson County.

Total mercury has been monitored more sporadically in redbreast sunfish fillets at MIK 0.2. Figure 3.33 shows long-term trends in HgT concentrations (μg/g) in these fish. A rapid increase in fillet HgT concentrations was observed in the early 1990s and generally remained elevated, with mean concentrations exceeding the AWQC (0.3 μg/g) in most years. Similar to the PCB concentrations in fish from this site, HgT concentrations at MIK 0.2 have been oscillating around the EPA's recommended AWQC for the past several years. Mean mercury concentrations in redbreast at this site remained just above the mercury tissue criterion, averaging 0.31 + 0.004 μg/g in 2020.

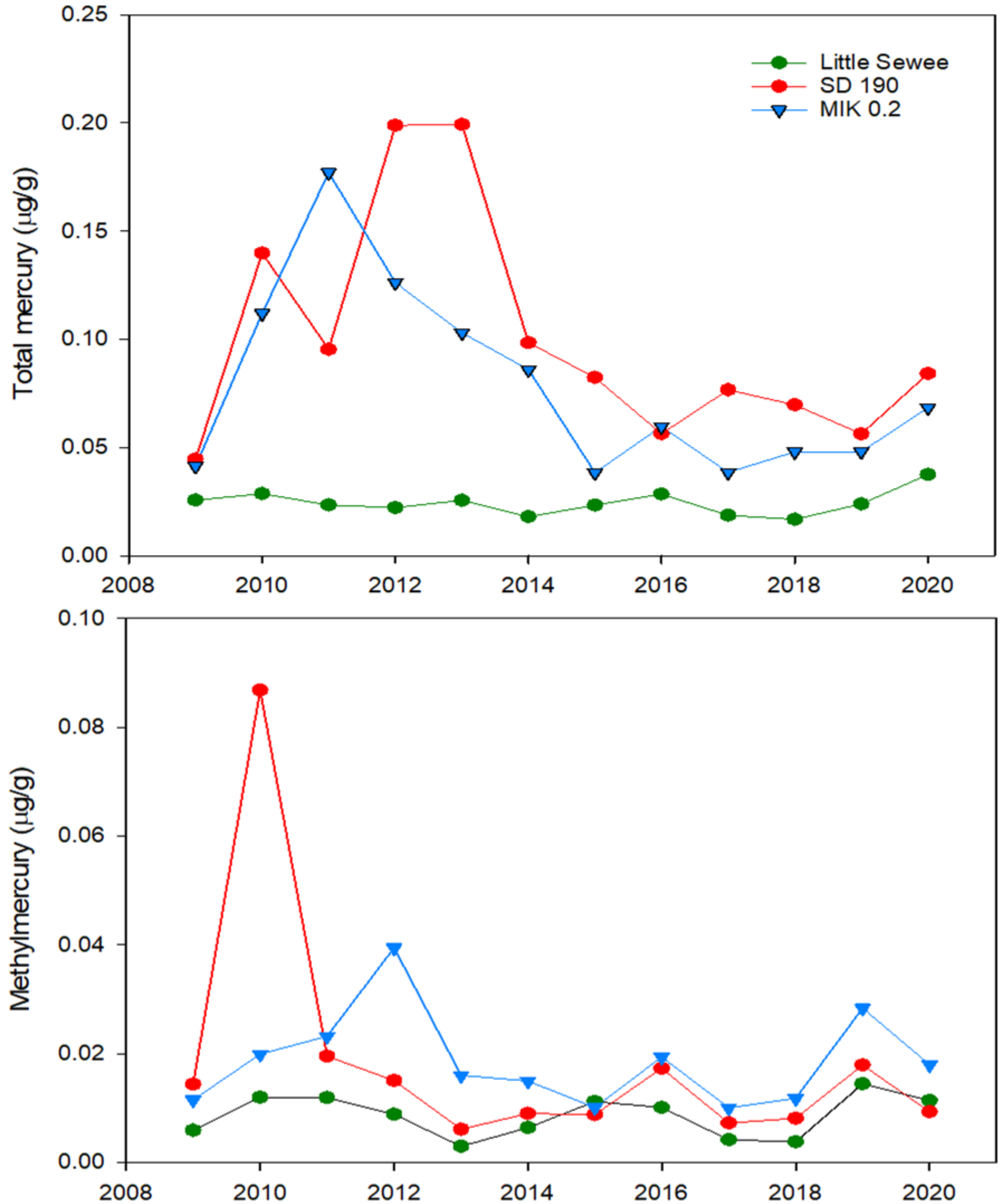


Notes:

1. *N = 2 composites of 10 clams each per year.*
2. *Shown in yellow are data for clams collected from the reference site, Little Sewee Creek (Meigs County, Tennessee).*
3. *Total PCBs is defined as the sum of Aroclors 1248, 1254, and 1260.*

Acronyms: *MIK = Mitchell Branch kilometer   PCB = polychlorinated biphenyl*

Figure 3.31. Mean total PCB (Top: µg/g, wet wt; 1993–2020) and mercury (Bottom: µg/g wet wt; 2009–2020) concentrations in the soft tissues of caged Asiatic clams deployed in Mitchell Branch

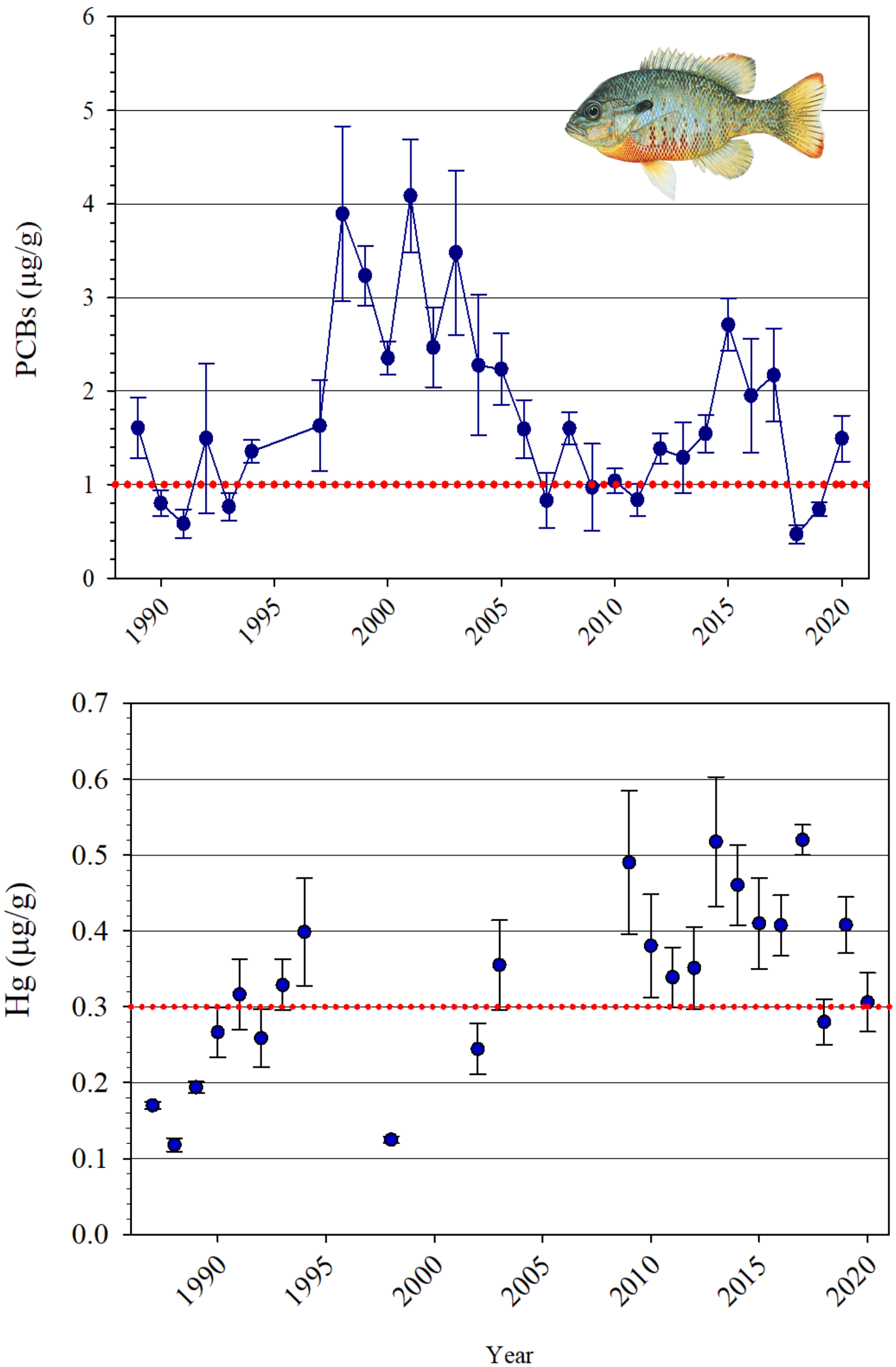


Notes:

1. *N = 2 composites of 10 clams each per year.*
2. *Shown in yellow are data for clams collected from the reference site, Little Sewee Creek (Sweetwater, Tennessee*
3. *Black bars denote MeHg concentrations, where the total height of bars (color and black band) represents HgT concentration.*

Acronyms and abbreviations: *HgT = total mercury MIK = Mitchell Branch kilometer SD = storm drain MeHg = methylmercury PCB = polychlorinated biphenyl*

Figure 3.32. Total (top panel) and methylmercury (bottom panel) concentrations in the soft tissues of caged Asiatic clams deployed in Mitchell Branch (µg/g wet wt; 2009–2020)



Notes:

1. *1989–2020 N = 6 fish per year.*
2. *Shown in red is the fish advisory level for PCBs (1 µg/g) and mercury concentration (0.3 µg/g).*

Acronyms and abbreviations:

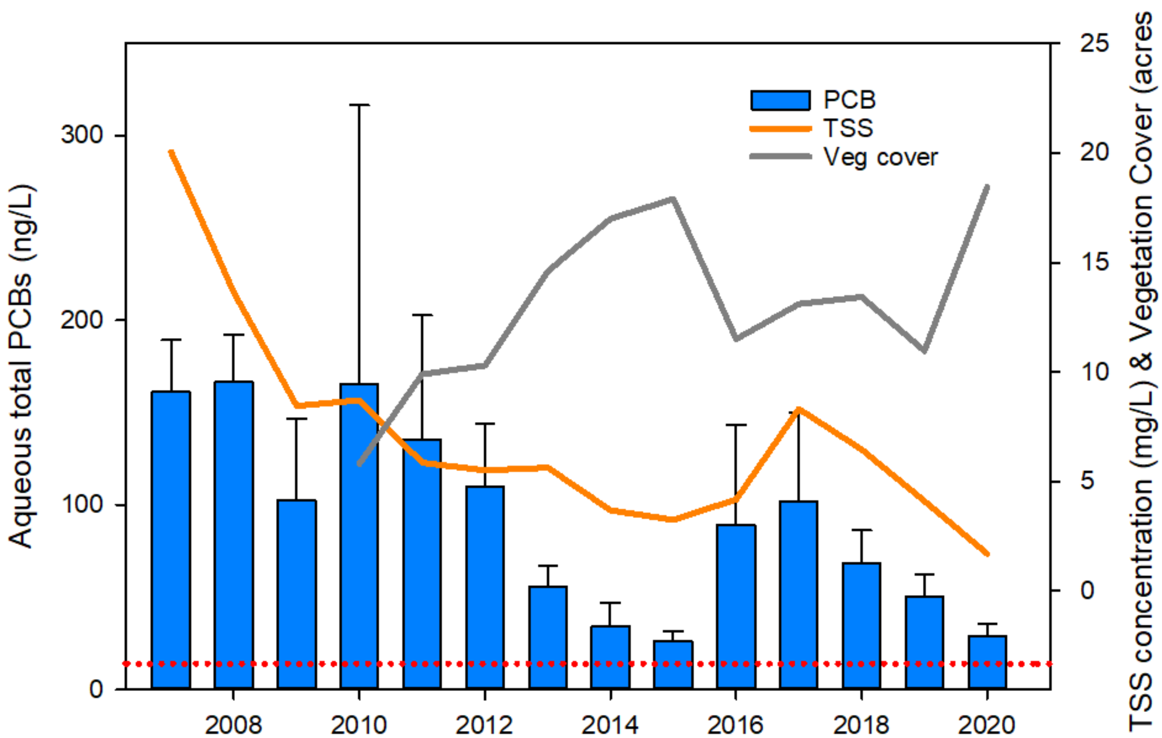
Hg = mercury   MIK = Mitchell Branch kilometer   MeHg = methylmercury   PCB = polychlorinated biphenyl

Figure 3.33. Mean PCB (top panel) and mercury (bottom panel) concentrations (µg/g, wet wt) in redbreast sunfish fillets in Mitchell Branch (MIK 0.2)

3.7.1.2. 1007-P1 Pond

Over the past decade, mean aqueous PCB concentrations in the K-1007-P1 Pond have fluctuated significantly but have generally been lower than concentrations seen before 2009 remediation activities (e.g., 29 ng/L in 2020 compared with 161 ng/L in 2007; Figure 3.34). Concentrations in 2020 were slightly lower than they have been for the past 3 years, and were comparable to the lowest recorded average PCB concentration since remediation (26 ng/L in 2015). As hydrophobic contaminants, PCBs tend to be particle associated and are positively correlated with total suspended solids (TSS). The fluctuations in PCB and TSS concentrations in water in the K-1007-P1 Pond could be related to fluctuations in aquatic plant coverage which can affect sediment stability. The aqueous PCB concentrations measured in the K-1007-P1 Pond are above concentrations seen at the First Creek reference site (< 0.3 ng/L) and are above the State of Tennessee water quality criterion for the protection of fish and wildlife (14 ng/L) (TDEC 2019).

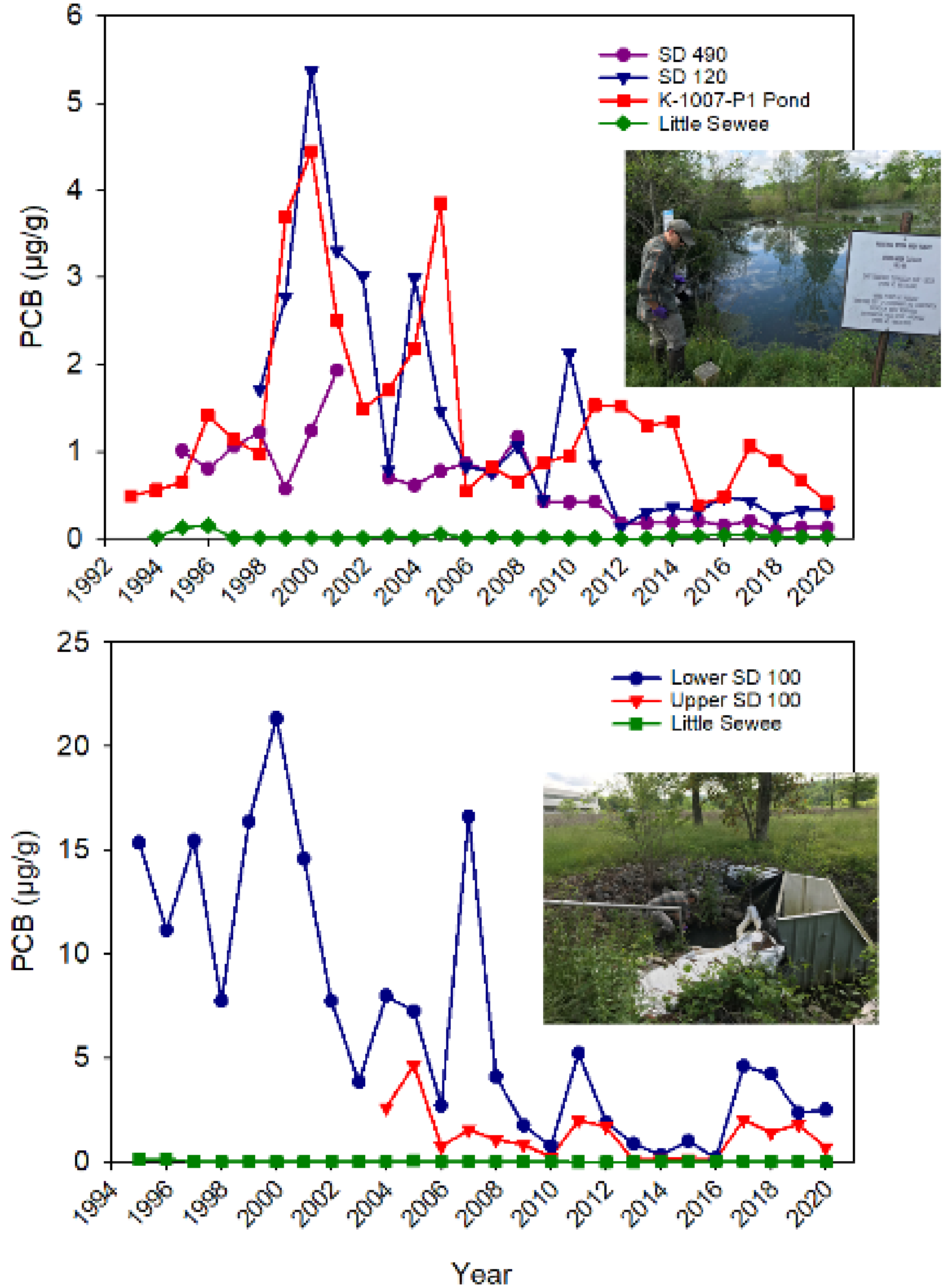
PCB concentrations in clams placed at lower and upper SD-100 locations have fluctuated significantly since remediation actions in 2009, and were on an overall decreasing trajectory until the significant increases seen in 2017 and 2018 (Figure 3.35). Concentrations in clams deployed in lower SD-100 in 2020 were similar to those in 2019, but concentrations in clams deployed in upper SD-100 decreased slightly compared with those seen in 2017 to 2019, and remained elevated with respect to the reference site. PCB concentrations in clams placed at the K-1007-P1 outfall were also higher since the increase in 2017, but have been steadily falling since then and in 2020 were comparable to concentrations seen just after remediation actions in this pond (Figure 3.36).



Notes:
1. *Means for PCBs in water and TSS are based on results across all collections made each year.*
2. *Note that mean concentrations of PCBs in water from First Creek were <0.3 ng/L in all years.*

Acronyms: *PCB = polychlorinated biphenyl ITSS = total suspended solids*

Figure 3.34. Mean aqueous total PCB concentrations, total suspended solids, and vegetation cover in the K-1007-P1 Pond, 2007–2020

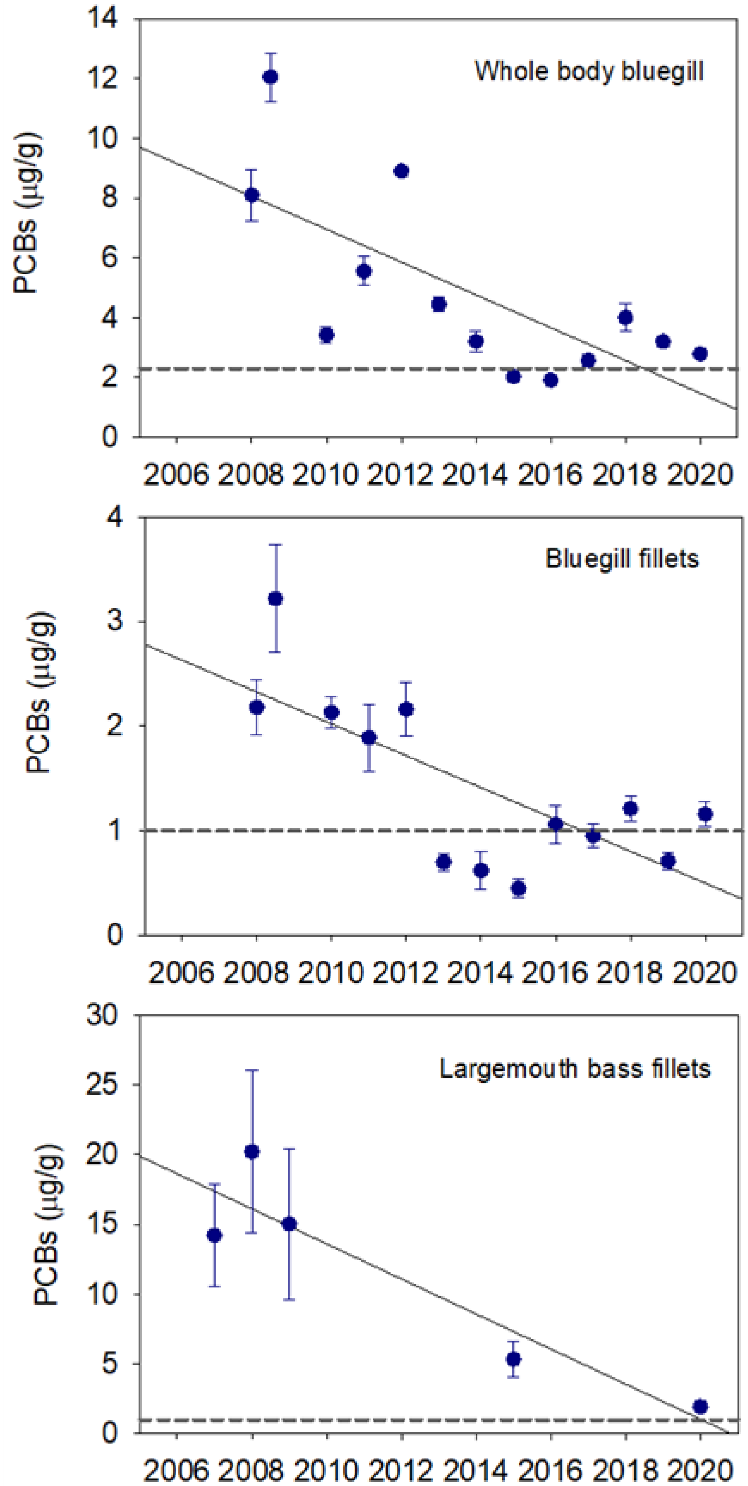


Notes:

1. *N = 2 clam composite samples per site/year.*
2. *Total PCBs defined as the sum of Aroclors 1248, 1254, and 1260.*
3. *Photos: Upper graph shows a clam basket in a storm drain, and Little Sewee Creek; lower graph photo shows placement of clam cages in Upper SD-100 (upper photo) and Lower SD-100 locations.*

Acronyms: *PCB = polychlorinated biphenyl   ISD = storm drain*

Figure 3.35. Mean total PCB concentrations (µg/g, wet wt) in caged clams placed at K-1007-P1 outfalls compared with reference stream clams (Little Sewee Creek), 1993–2020



Notes:

1. *For largemouth bass, N = 6 fish per site/year. For bluegill sunfish, N = 20 for fillets and N = 6 composites of 10 whole body fish.*
2. *The target for fillet (1 µg/g) and whole body concentrations (2.3 µg/g) is shown with the gray dotted lines.*

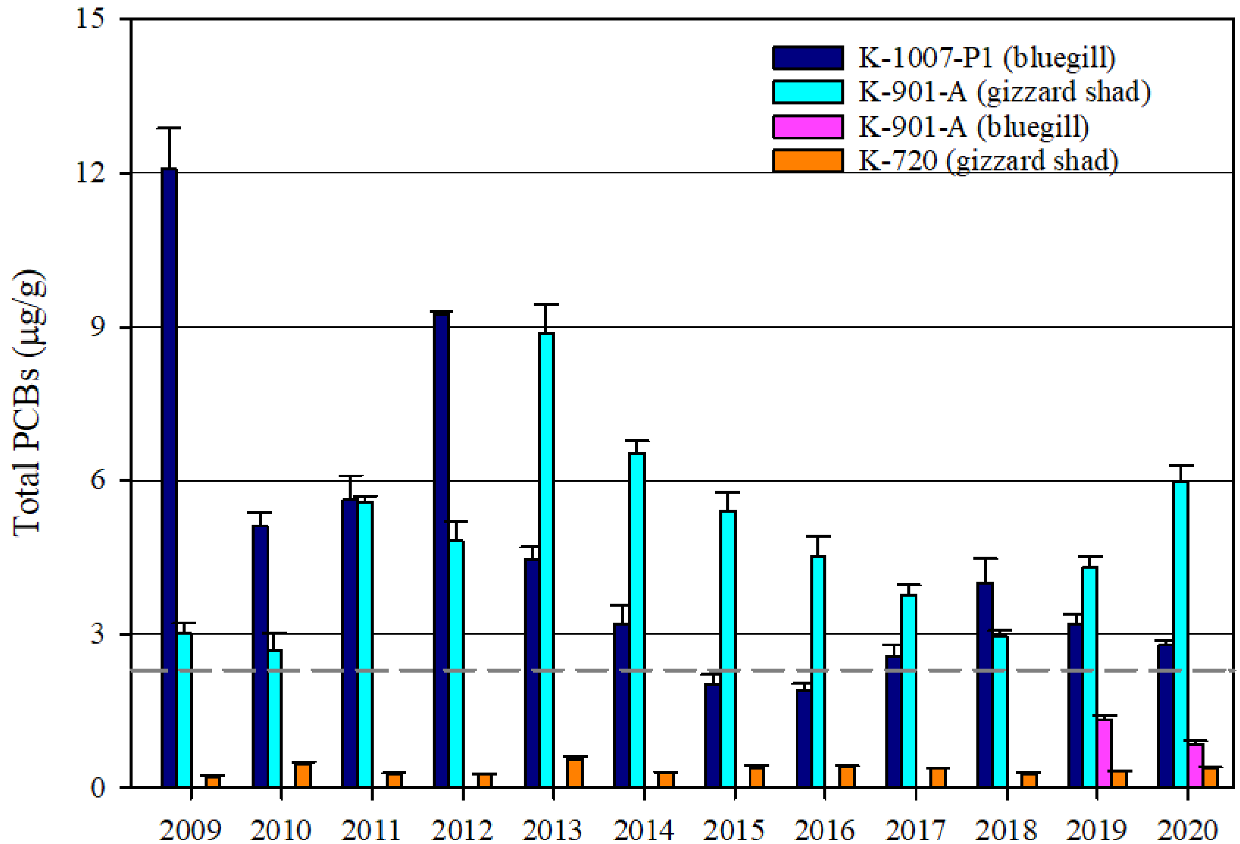
Acronym: *PCB = polychlorinated biphenyl*

Figure 3.36. Mean PCB concentrations (µg/g, wet wt) in fish from the K-1007-P1 Pond, 2007–2020

Similar trends have been observed in fish tissue PCB concentrations in the K-1007-P1 Pond (Figure 3.37). Since 2009, the target species for bioaccumulation monitoring in the K-1007-P1 Pond has been bluegill sunfish (*Lepomis macrochirus*). As in previous years, fillets from 20 individual bluegill and 6 whole body composites (10 bluegill per composite) from the K-1007-P1 Pond were analyzed for PCBs in 2020 to assess the ecological and human health risks associated with PCB contamination in this pond. In addition, fillets from 6 largemouth bass collected from this pond were analyzed for PCBs.

Average PCB concentrations in fish fillets and whole-body composites have decreased significantly over the past 10 years since remediation activities, with significant fluctuations. Concentrations were lowest in the 2013-2015 time period but have slightly increased over the past three years. The mean concentration in whole body composites of bluegill collected from the K-1007-P1 Holding Pond was lower in 2020 (2.79 µg/g) than in 2019 (3.20 µg/g), remaining above the target concentration for whole body fish in this pond (2.3 µg/g) (Table 3.18, Figures 3.39 and 3.40). Although fillet concentrations had dropped below the remediation target of 1 µg/g, averaging 0.71 µg/g in FY 2019, concentrations increased to 1.16 µg/g in FY 2020, slightly exceeding the target concentration. Mean PCB concentrations in largemouth bass fillets were 1.91 µg/g, which—while slightly above the target fillet concentration of 1 µg/g for this pond—is significantly lower than concentrations seen in this species 5 years ago (5.33 µg/g) and is an order of magnitude lower than concentrations seen prior to remediation actions (20.2 µg/g in 2008).

The interannual fluctuations in PCB concentrations could be due to water quality changes that have taken place in this pond, (e.g., higher TSS, PCB inputs, fluctuations in vegetation cover; Figures 3.30 and 3.33). The observed fluctuations in PCB concentrations seen in biota suggest that this system is still in transition and that as the fish and plant communities stabilize, further decreases in PCB bioaccumulation may become apparent.



Notes:
1. *Total PCBs are defined as the sum of Aroclors 1248, 1254, and 1260.*
2. *The dotted line signifies the target PCB concentration of 2.3 µg/g in whole body fish.*

Acronym:
PCB = polychlorinated biphenyl

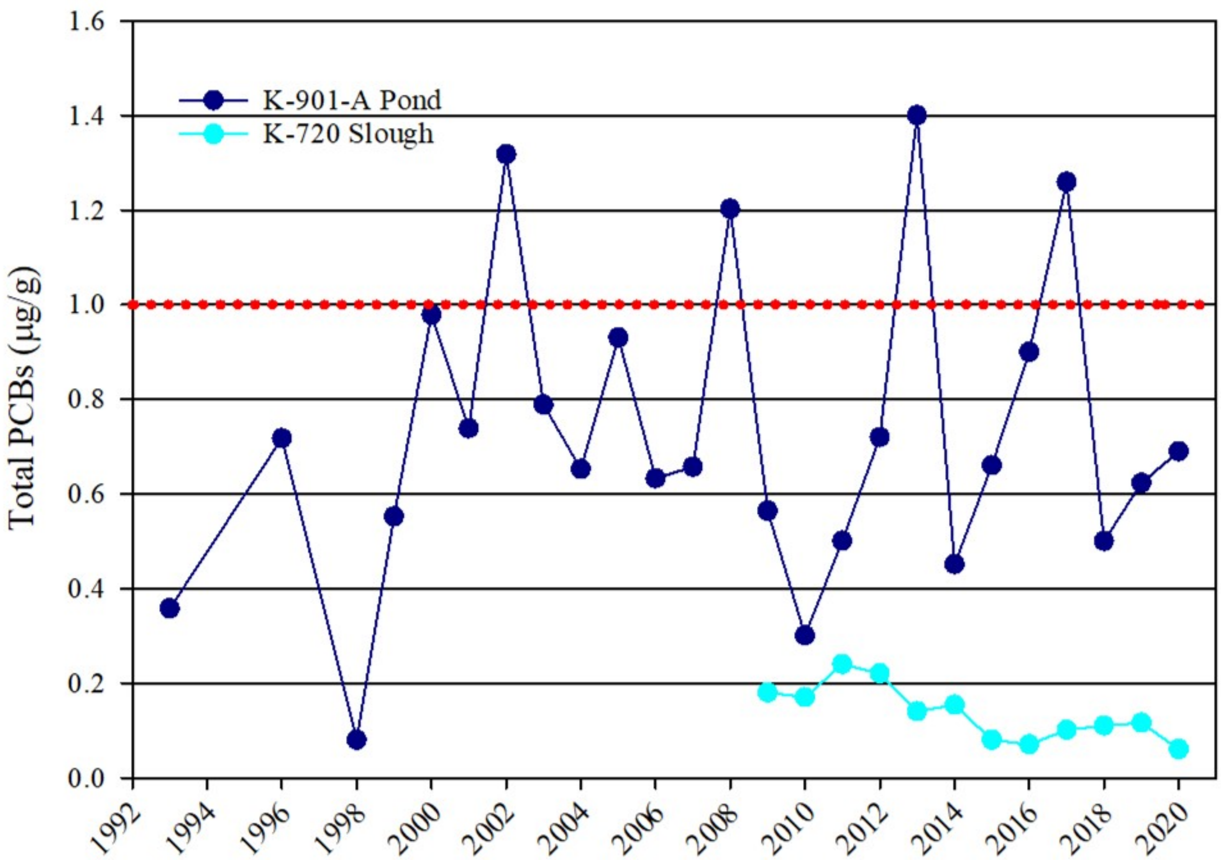
Figure 3.37. Mean (+1 standard error) total PCB concentrations (µg/g, wet wt) in whole body fish from K1007-P1 Pond, K-901-A Holding Pond, and K-720 Slough, 2009–2020

3.7.1.3. K-901-A Pond

The target fish species for analysis of PCBs in the K-901-A Holding Pond and K-720 Slough were gizzard shad (*Dorosoma cepedianum*) and largemouth bass (*Micropterus salmoides*). It was not possible to collect the target number of 20 bass from each body of water, so common carp (*Cyprinus carpio*) also were collected to provide a combined total of 20 fish. Carp were selected as a surrogate species for bass because they are widely distributed, are present at both locations, and have been used historically in other monitoring efforts on ORR for contaminant analyses.

At the K-901-A Holding Pond, PCB concentrations in largemouth bass were comparable (0.69 µg/g) to concentrations seen in 2019 (0.62 µg/g) and were below the target concentration set for the K-1007-P1 Pond of 1 µg/g total PCBs (Figure 3.38). Mean PCB concentrations in carp collected from the K-901-A Holding Pond were above the target concentration of 1 µg/g in fillets in 2020 (3.77 µg/g) and were higher than concentrations measured in 2019 (1.22 µg/g). Carp are not the target species in this pond and are generally undesirable fish to have in a pond affected by PCBs because they tend to stir up sediments, which exposes them and other organisms to elevated PCB concentrations.

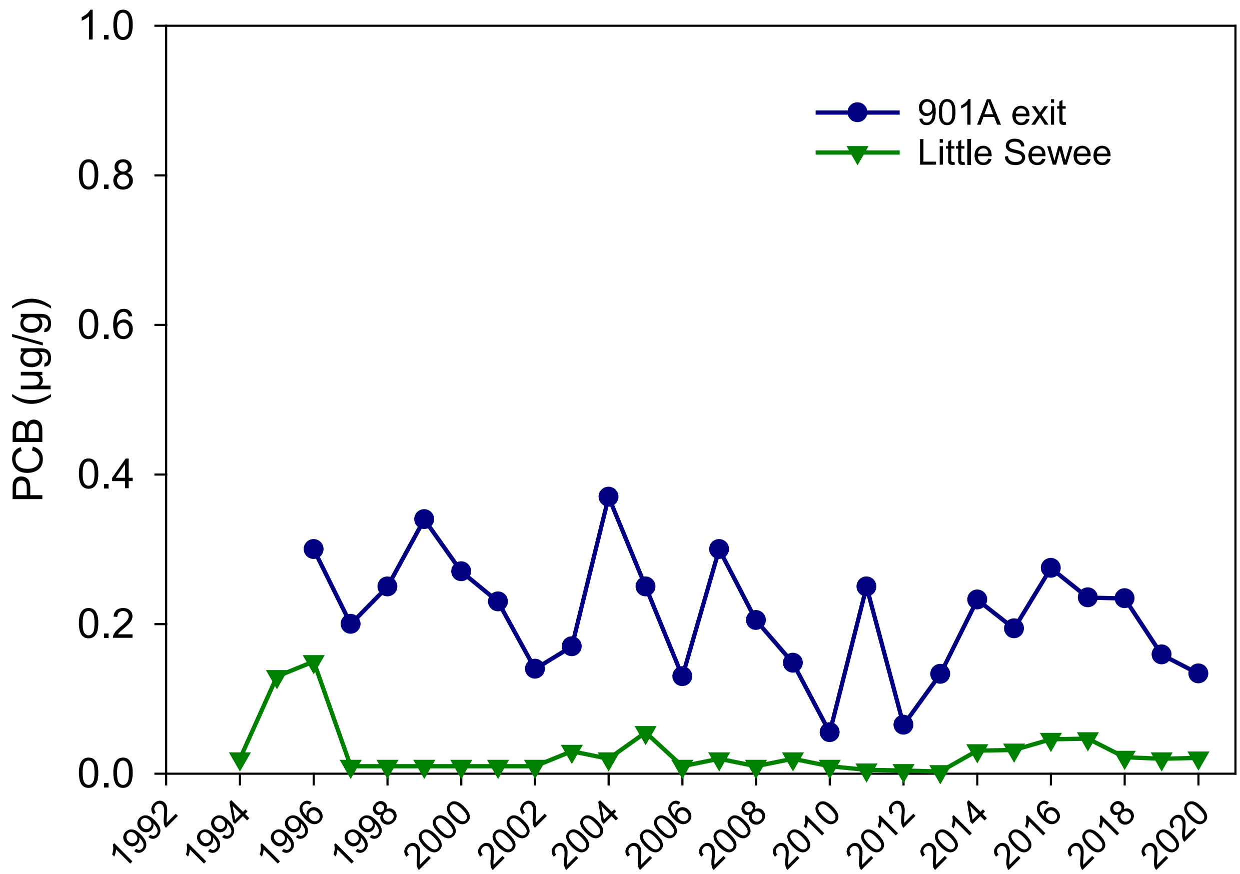
However, when a full collection of largemouth bass cannot be collected, carp are collected to complete the collection. Whole body gizzard shad from the K-901-A Holding Pond, collected as a measure of potential ecological risk to terrestrial wildlife, were substantially higher in concentration (5.99 µg/g) than the fillets of bass and carp, and were higher than the concentrations seen in this species in the past three years, remaining above the target concentration set for the K-1007-P1 Holding Pond for whole body fish (2.3 µg/g) (Figure 3.40). However, mean PCB concentrations in whole-body bluegill (0.84 µg/g) were lower than concentrations in this same species collected from the K-1007-P1 Pond, were below the target concentration for whole-body fish in the K-1007-P1 Pond (2.3 µg/g), and were lower than those observed in 2019 (1.33 µg/g) (Figure 3.37). PCB concentrations in clams deployed in the K-901-A Pond were lower than those deployed in the K-1007-P1 Pond and were similar in 2020 (0.13 µg/g) to concentrations seen in 2019 (Figure 3.39).



Notes:
1. *Mean PCBs (± 1 SE) in largemouth bass fillets, 1993-2020 (µg/g).*
2. *N = 6 fish per year, when possible.*
3. *The dotted red line shows the advisory level for PCBs in fish fillets (1 µg/g).*

Acronyms:
PCB = polychlorinated biphenyl
SE = standard error

Figure 3.38. Mean total PCB concentrations in largemouth bass from the K-901-A Pond and the K-720 Slough



Notes:

1. *Total PCBs defined as the sum of Aroclors 1248, 1254, and 1260.*
2. *N = 2 composites of 10 clams each per year.*
3. *Shown in green are data for clams collected from the reference site, Little Sewee Creek (Sweetwater, Tennessee).*

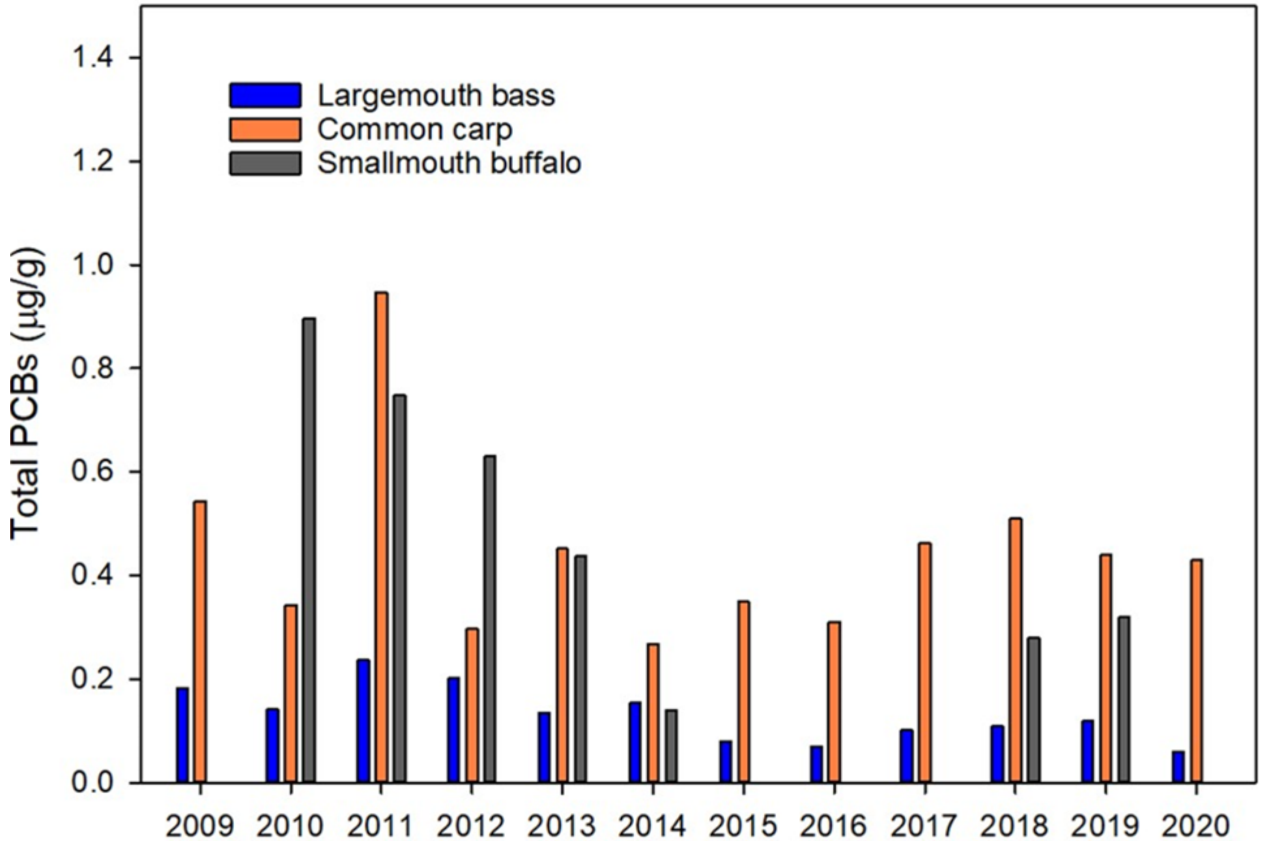
Acronym:

PCB = polychlorinated biphenyl

Figure 3.39. Mean total PCB (µg/g, wet wt; 1993–2020) concentrations in the soft tissues of caged Asiatic clams deployed in the K-901-A Pond for a 4-week period

3.7.1.4. K-720 Slough

Routine bioaccumulation monitoring in the K-720 Slough began in 2009 (Figure 3.40). Although the target species for fish fillet monitoring in this slough is largemouth bass, as in the K-901-A Pond it has been difficult to collect a full sample of 20 fish of this species; to complete the collection, common carp also are collected for a total of 20 fish. Figure 3.40 shows the temporal trends in fish fillet concentrations in the slough. In 2020, PCB concentrations in both fish species monitored were below the state advisory limit of 1 µg/g. In all cases PCB levels in fish collected from the K-720 Slough were significantly lower than in the K-901-A Holding Pond for the same species (Table 3.18). PCB concentrations in largemouth bass collected from the K-720 Slough were significantly lower than those in the other monitored ponds, averaging 0.06 µg/g in 2020. Concentrations in carp collected from the slough were higher than concentrations in bass, averaging 0.43 µg/g. Total PCBs in whole body gizzard shad from the K-720 Slough were similar to those seen in recent years and were lower than those seen in whole body fish collected from the other monitored ponds, averaging 0.39 µg/g in 2020.



Notes:

1. *Total PCBs defined as the sum of Aroclors 1248, 1254, and 1260.*
2. *The target sample was 20 largemouth bass, but because these fish are not abundant in the slough, carp and smallmouth buffalo were collected to complete the sample size of 20 fish.*

Acronym:

PCB = polychlorinated biphenyl

Figure 3.40. Mean total PCB (µg/g, wet wt; 2009–2020) concentrations in the fillets of largemouth bass, common carp, and smallmouth buffalo collected from the K-720 Slough

Table 3.18. Average concentrations of total PCBs in fillets and whole-body composites of fish collected in 2020 near the East Tennessee Technology Park

Site	Species	Sample type	Sample size (n)	Total PCBs (mean ± SE)	Range of PCB values	No. > target (PCBs)/n
K-1007-P1 Pond	Bluegill	Fillets	20	1.17 ± 0.12	0.43–2.91	12/20
		Whole-body composites	6	2.79 ± 0.10	2.47–3.1	6/6
	Largemouth bass	Fillets	6	1.91 ± 0.42	0.98–3.42	5/6
K-901-A Pond	Largemouth bass	Fillets	16	0.69 ± 0.21	0.22–3.67	2/16
	Common carp	Fillets	4	3.77 ± 0.78	1.94–5.46	4/4
	Bluegill	Fillets	20	0.78 ± 0.13	0.04–2.06	5/20
		Whole-body composites	6	0.84 ± 0.08	0.60–1.14	0/6
	Gizzard shad	Whole-body composites	6	5.99 ± 0.30	5.37–7.21	6/6
K-720 Slough	Largemouth bass	Fillets	13	0.06 ± 0.00	0.04–0.10	0/13
	Common carp	Fillets	7	0.43 ± 0.12	0.07–0.88	0/7
	Gizzard shad	Whole-body composites	6	0.39 ± 0.02	0.33–0.45	0/6
CRM 11.0	Bluegill	Whole-body composites	6	0.10 ± 0.02	0.06–0.21	0/6
	Gizzard shad	Whole-body composites	6	0.19 ± 0.06	0.01–0.31	0/6
PCM 1.0	Bluegill	Whole-body composites	6	0.20 ± 0.06	0.11–0.48	0/6
	Gizzard shad	Whole-body composites	6	0.36 ± 0.10	0.23–0.57	0/6

Notes:

1. *Average concentrations = µg/g, wet wt*
2. *Total PCBs = Aroclors 1248, 1254, and 1260*
3. *Values are mean concentrations (µg/g) ± 1 SE.*
4. *Each whole body composite sample is composed of 10 individual fish.*
5. *Also shown are the ranges of values observed for PCBs and the number of fish whose fillet PCB concentrations exceeded 1 µg/g out of the total number of fish (or composites) sampled (n). (1 µg/g total PCBs in fish fillets and 2.3 µg/g in whole-body composites).*

Acronyms and abbreviations:

CRM = Clinch River mile
PCB = polychlorinated biphenyl
SE = standard error
No. = number
PCM = Poplar Creek mile

3.7.2. Task 2: Instream Benthic Macroinvertebrate Communities

Benthic macroinvertebrate communities in Mitchell Branch are sampled using ORNL and TDEC protocols (Figures 3.41 and 3.42). Evaluation of long-term trends of macroinvertebrate communities in the stream make it possible to document the effectiveness of pollution abatement activities or remediation efforts as well as to assess the potential consequences of unanticipated events as sitewide remediation continues (e.g., chromium release into Mitchell Branch).

Figure 3.41. Collecting an invertebrate sample using Oak Ridge National Laboratory Biological Monitoring and Abatement Program protocols

3.7.2.1. Benthic Macroinvertebrates

The major objectives of the benthic macroinvertebrate task are: (1) to help assess the ecological condition of Mitchell Branch, and (2) to evaluate changes in stream ecology associated with changes in facilities operations and RAs within the Mitchell Branch watershed. To meet these objectives, the condition of the benthic macroinvertebrate community of Mitchell Branch has been monitored routinely since late 1986. This summary includes results of samples collected each April from 1987 to 2020 following ORNL BMAP quantitative sampling protocols and samples collected annually (August/September) with TDEC semi-quantitative sampling protocols for estimating the Tennessee Macroinvertebrate Biotic Index and the Habitat Index (TDEC 2011; TDEC 2017). TDEC protocol guidance was updated in August 2017 and the most recent 2017 guidance was used for all invertebrate and habitat surveys. For both sets of protocols, four sites were assessed in Mitchell Branch—MIKs 0.4, 0.7, 0.8, and 1.4. MIK 1.4 serves as the primary reference site, but narrative Biotic Index results for TDEC protocols are based on reference conditions established by TDEC from a suite of reference sites in the same ecoregion as Mitchell Branch. Finally, also included in this summary is a comparison between the macroinvertebrate community structure at the four Mitchell Branch sites and five other reference sites on ORR. Most of these reference sites—spanning a range of stream sizes both smaller and larger than Mitchell Branch (based on watershed area)—have been monitored using ORNL protocols since the mid-1980s for other biological monitoring projects on ORR (ORNL BMAP and WRRP/Bear Creek Biological Monitoring Program) (Table 3.19). This summary provides information on how invertebrate community structure at Mitchell Branch sites, including MIK 1.4, compares with the community structure of a range of relatively unaffected reference sites on ORR.

Figure 3.42. Sampling for benthic macroinvertebrates with TDEC protocols

Table 3.19. Stream sites included in the comparison between Mitchell Branch and other reference sites on the Oak Ridge Reservation

Site	Location		Watershed area (km^2)	Program
	Latitude (N)	Longitude (W)		
Mitchell Branch				
MIK 0.4	35.93859	84.39040	1.554	ETTP BMAP
MIK 0.7	35.93786	84.38792	1.347	ETTP BMAP
MIK 0.8	35.93786	84.38682	1.269	ETTP BMAP
MIK 1.4 (reference)	35.93790	84.37662	0.311	ETTP BMAP
Other ORR reference sites				
First Creek (FCK 0.8)	35.92670	84.32355	0.596	ORNL BMAP
Fifth Creek (FFK 1.0)	35.93228	84.31746	0.596	ORNL BMAP
Gum Hollow Branch (GHK 2.9)	35.96385	84.31594	0.777	Bear Creek BMP/WRRP
Walker Branch (WBK 1.0)	35.95805	84.27953	1.010	ORNL BMAP
White Oak Creek (WCK 6.8)	35.94106	84.30145	2.072	ORNL BMAP

Acronyms:
BMAP = Biological Monitoring and Abatement Program
BMP = Biological Monitoring Program
ETTP = East Tennessee Technology Park
MIK = Mitchell Branch kilometer
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
WRRP = Water Resources Restoration Program

3.7.2.2. Mitchell Branch–ORNL and TDEC Protocols

Total taxa richness (i.e., the total number of taxa per sample) and Ephemeroptera, Plecoptera, and Trichoptera (EPT) taxa richness (i.e., the total number of pollution-intolerant EPT taxa [mayflies, stoneflies, and caddisflies] per sample) measured using ORNL protocols has varied over the measurement period (1986–2020) in all Mitchell Branch sites (Figure 3.43). Both total taxa richness and EPT taxa richness increased in MIKs 0.4, 0.7, and 0.8 from 1987 to the late 1990s, and then reached fairly consistent values, albeit with considerable year to year variation (Figure 3.43). Total taxa richness and EPT taxa richness have been fairly consistent throughout the measurement period in the reference site, MIK 1.4, though values have been lower in three of the past four years (Figure 3.44). In April 2020, total taxa richness and EPT taxa richness were highest at MIK 0.7 and MIK 0.8 and lowest in MIK 0.4 (Figure 3.43). As previously seen in 2019, EPT taxa richness patterns among sites in 2020 again differed from the pattern observed in 2018 and in 2010–2016, where EPT taxa richness was highest upstream at MIK 1.4 and lowest downstream at MIK 0.4 (Figure 3.43).

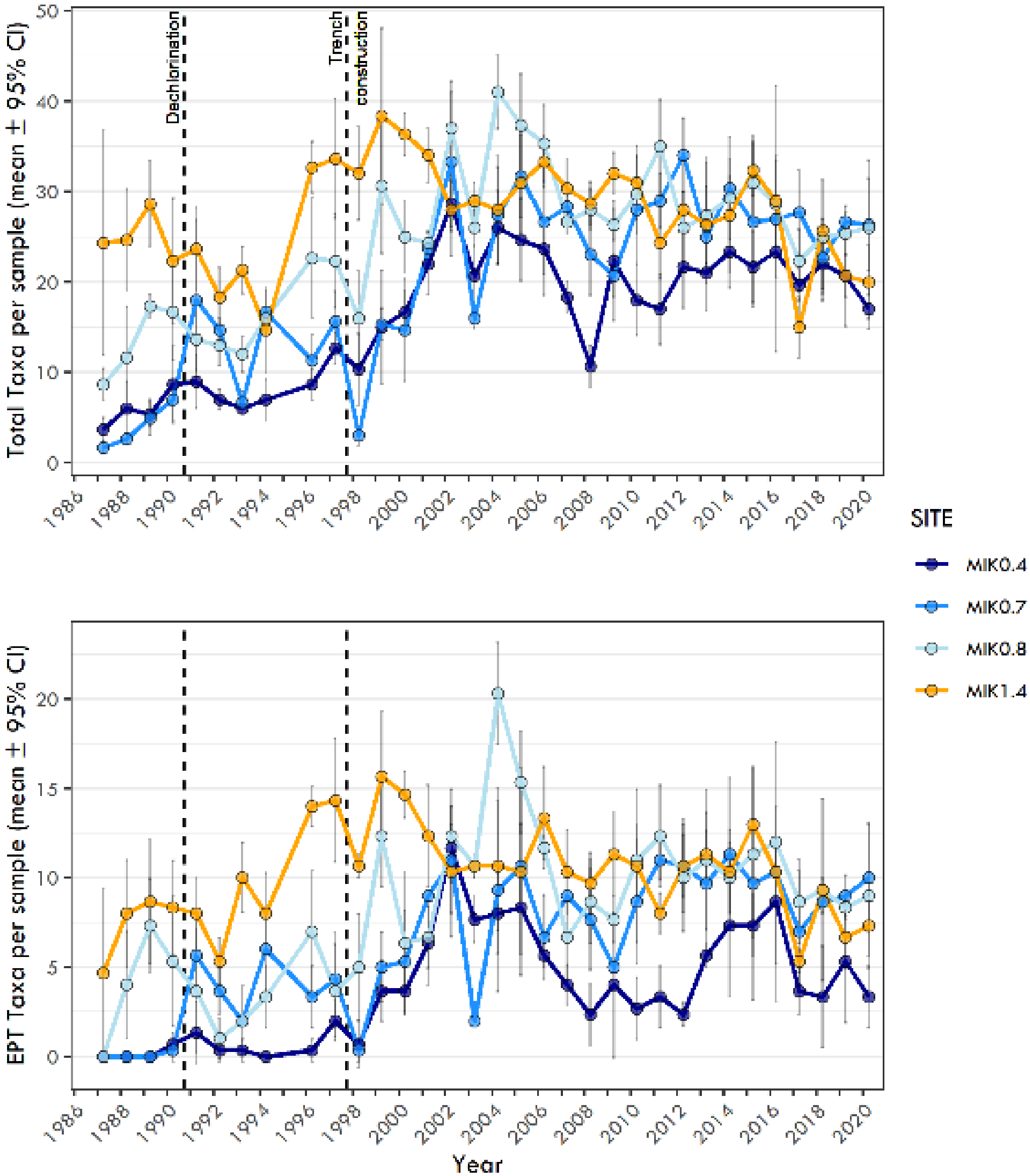
The percent density of the pollution-intolerant taxa (higher values are indicative of good condition) was highest at MIK 1.4, the reference site, and lowest at MIK 0.4 in April 2020, which is a pattern that has been observed in most years since monitoring began in 1987 (Figure 3.44). In most years, the percent density of pollution-tolerant taxa (lower values are indicative of good conditions) was lowest at the reference site, MIK 1.4. However, in April 2019 and 2020, the percent density of pollution-tolerant taxa was higher at MIK 1.4 than MIK 0.8 but still lower than at MIK

0.4 and MIK 0.7 (Figure 3.44). In 2020, the percent of pollution-tolerant taxa at MIK 1.4 decreased from 2019, which was one of the highest values seen since monitoring began and only surpassed in 1988 and 1992 (Figure 3.44). Continued monitoring will determine if these higher values at MIK 1.4 persist or rather reflect interannual variability.

Based on TDEC 2017 protocols, scores for the Tennessee Macroinvertebrate Biotic Index (TMI) in 2020 rated the invertebrate community as passing biocriteria guidelines at MIK 1.4 while TMI scores at MIK 0.4, MIK 0.7, and MIK 0.8 fell below these guidelines (Figure 3.45). TMI scores in 2020 remained stable (MIK 0.8) or declined (MIK 1.4, MIK 0.7, MIK 0.4) compared to 2019 scores (Figure 3.45). In 2020, MIK 1.4 scores decreased for percentage of EPT taxa and percentage of nutrient-tolerant taxa, but increased for percentage of clingers (Table 3.20). Both MIK 0.8 and MIK 0.7 received low scores for EPT taxa richness and percentage of EPT taxa while MIK 0.7 also received low scores for total taxa richness (Table 3.20). MIK 0.4 received low scores for total taxa richness, EPT taxa richness, and percentage EPT, but received the highest scores possible for all other invertebrate metrics except the percentage of nutrient-tolerant taxa (Table 3.20).

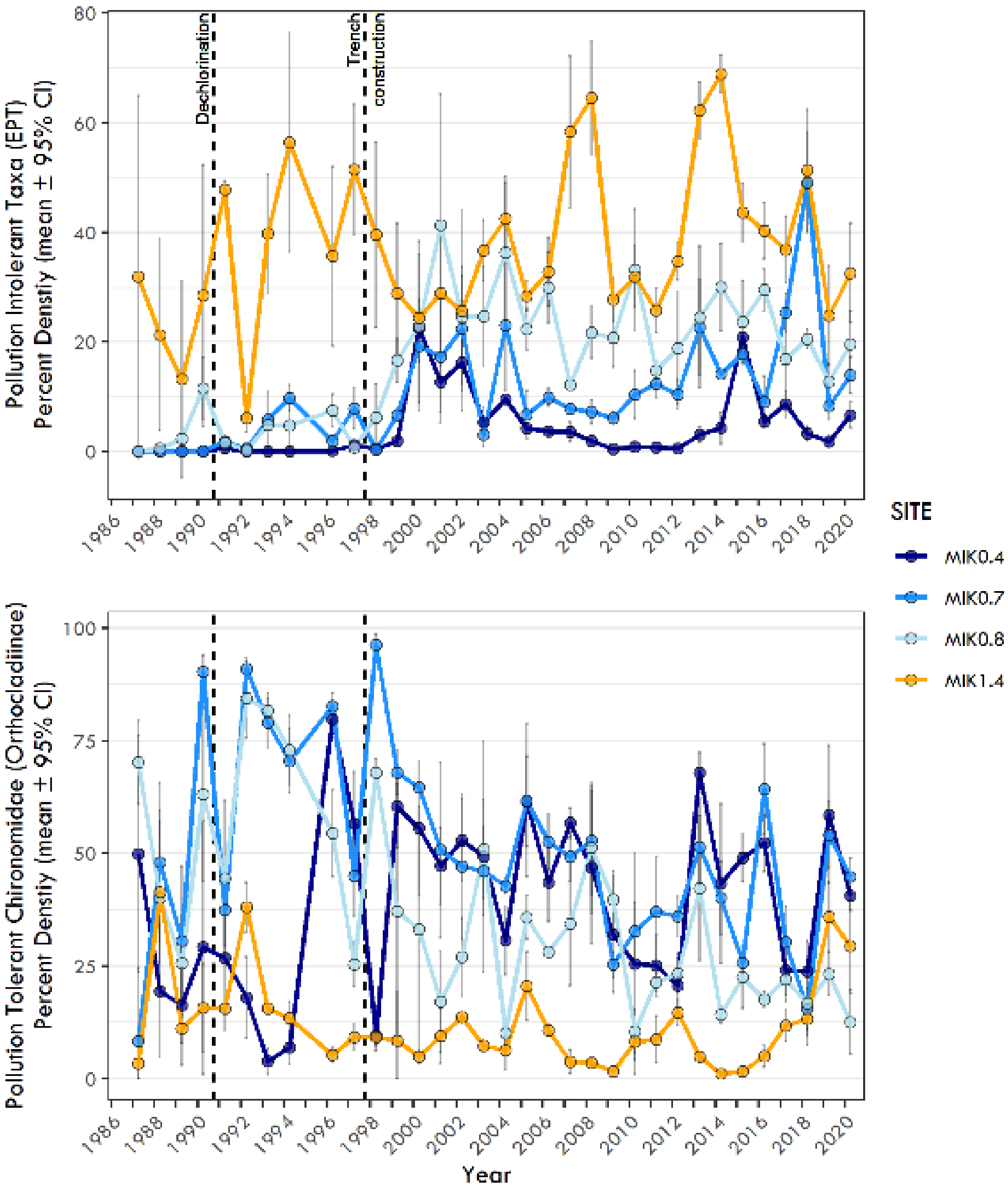
Since sampling using TDEC protocols began in 2008 in Mitchell Branch, TMI scores at have almost always rated the invertebrate community at MIK 1.4 as passing biocriteria guidelines, MIK 0.4 as falling below biocriteria guidelines, and MIK 0.7 and MIK 0.8 as oscillating between passing and falling below biocriteria guidelines (Figure 3.45). TDEC protocol states that TMI scores should only be calculated for samples with 160–240 invertebrates identified to genus (TDEC 2017). In August 2020, only 138, 111, and 78 individuals were collected from MIK 1.4, MIK 0.7, and MIK 0.4 respectively, so results from these sites should be interpreted with caution.

Based on TDEC stream habitat protocols, habitat quality was above the ecoregion 67f guideline at all sites within Mitchell Branch (Figure 3.45). Habitat scores increased at all sites from 2018 to 2020. In general, improvements from the previous three years were primarily seen in epifaunal substrate/available cover, channel flow, sediment deposition, embeddedness, and vegetative protection. However, poor substrate quality (dominance of gravel instead of cobble) and unstable, highly erodible banks continued to be an issue at multiple sites. Habitat conditions related to riffle stability (i.e., frequency of reoxygenation zones) improved at all sites except MIK 0.4.



Note:
1. Samples were not collected in April 1995.
Acronyms:
EPT = Ephemeroptera, Plecoptera, and Trichoptera MIK = Mitchell Branch kilometer CI = confidence interval

Figure 3.43. Mean (± 95% confidence interval) total taxonomic richness (top) and richness of the pollution-intolerant taxa per sample (bottom) for Mitchell Branch sites, April 1987–2020



Notes:

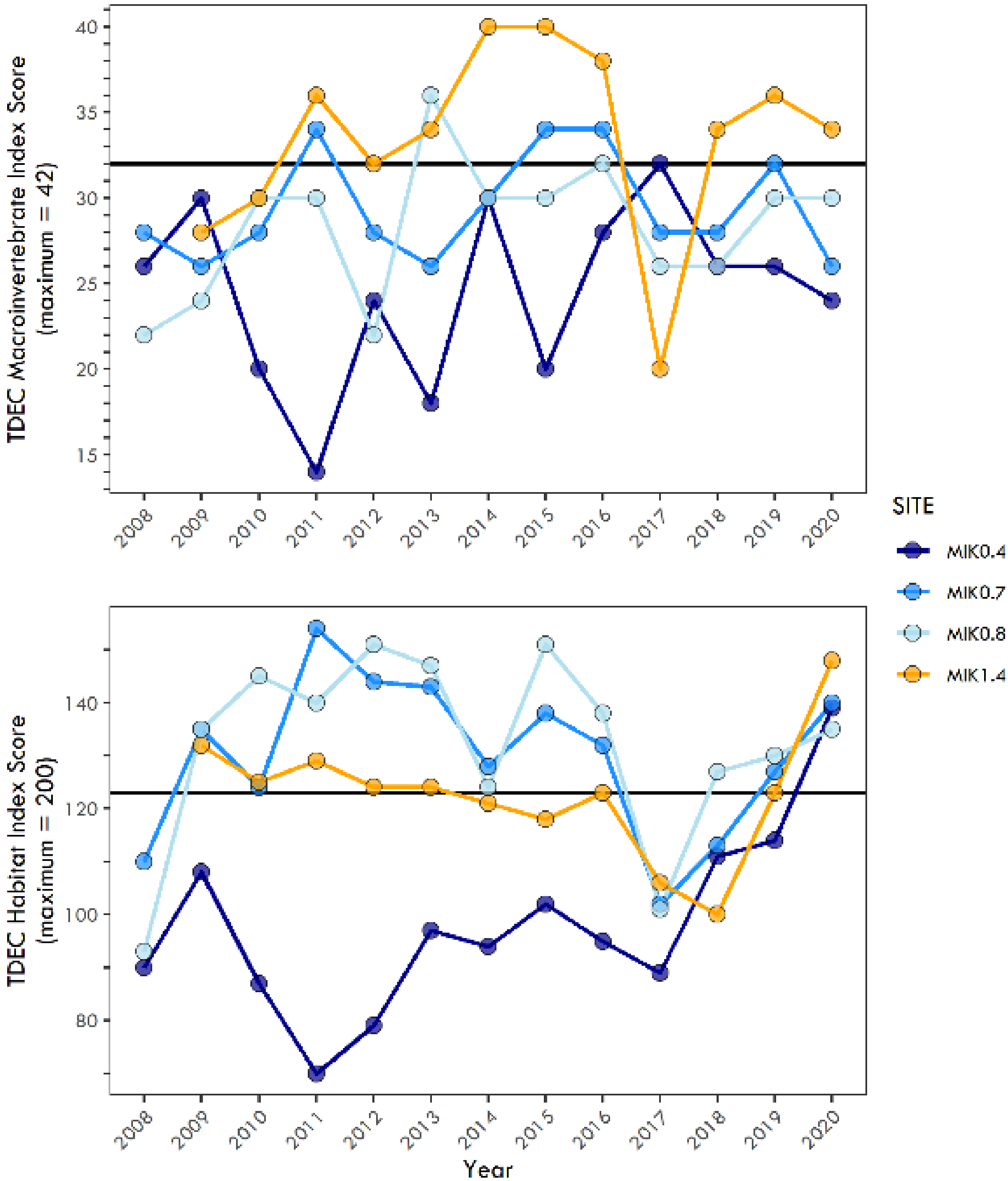
1. *Pollution intolerant taxa = stoneflies, mayflies, and caddisflies.*
2. *Percentages were based on total densities for each site.*
3. *Samples were not collected in April 1995.*

Acronyms:

MIK = Mitchell Branch kilometer CI = confidence interval

EPT = Ephemeroptera, Plecoptera, and Trichoptera (pollution-intolerant tax)

Figure 3.44. Mean percent density of pollution-intolerant taxa and of the pollution-tolerant Orthocladiinae midge larvae (Chironomidae) at Mitchell Branch sites, April 1987–2020



Notes:

1. *Mitchell Branch site MIK 1.4 was not sampled with TDEC protocols in 2008.*
2. *The horizontal line on each graph shows the rating threshold for each index; TDEC macroinvertebrate index threshold is 32; TDEC habitat index threshold for ecoregion 67f is 123. Values above the thresholds are indicative of passing biocriteria or habitat guidelines.*
3. *TDEC 2017 guidance used for all years.*

Figure 3.45. Temporal trends in the TDEC Macroinvertebrate Index (top) and Stream Habitat Index (bottom) scores for four Mitchell Branch sites, August 2008–2020

Table 3.20. Tennessee Macroinvertebrate Index metric values and scores and index score for Mitchell Branch, August 19, 2020 [a,b,c]

Site	Metric values							Metric scores							TMI[d,e]
	Taxa rich	EPT rich	%EPT	%OC	NCBI	%Cling	%TN Nuttol	Taxa rich	EPT rich	%EPT	%OC	NCBI	%Cling	%TN Nuttol	
MIK 0.4	11	2	1.3	7.7	3.7	83.3	32.1	2	0	0	6	6	6	4	24
MIK 0.7	18	5	20.7	11.7	5.3	63.1	38.7	2	2	2	6	4	6	4	26
MIK 0.8	20	6	26.8	5.7	4.6	85.2	45.9	4	2	2	6	6	6	4	30
MIK 1.4	28	8	36.2	12.3	4.5	56.5	41.3	4	4	4	6	6	6	4	34 [**pass**]

[a] *TMI metric calculations and scoring and index calculations are based on Tennessee Department of Environment and Conservation (TDEC) protocols for ecoregion 67f: TDEC 2017, Quality System Standard Operating Procedures for Macroinvertebrate Stream Surveys, TDEC Division of Water Pollution Control, Nashville, Tennessee. Available* ***here****.*

[b] *Taxa rich = Taxa richness; EPT rich = Ephemeroptera, Plecoptera, and Trichoptera (mayflies, stoneflies, and caddisflies) taxa richness; %EPT = EPT abundance excluding Cheumatopsyche spp.; %OC = percent abundance of oligochaetes (worms) and chironomids (nonbiting midges); NCBI = North Carolina Biotic Index; %Cling = percent abundance of taxa that build fixed retreats or otherwise attach to substrate surfaces in flowing water excluding Cheumatopsyche spp; %TN Nuttol. = percent abundance of nutrient-tolerant organisms.*

[c] *MIK = Mitchell Branch kilometer.*

[d] *TMI = Tennessee Macroinvertebrate Index score. TMI is the total index score and higher index scores indicate higher quality conditions. A score of ≥ 32 is considered to pass biocriteria guidelines.*

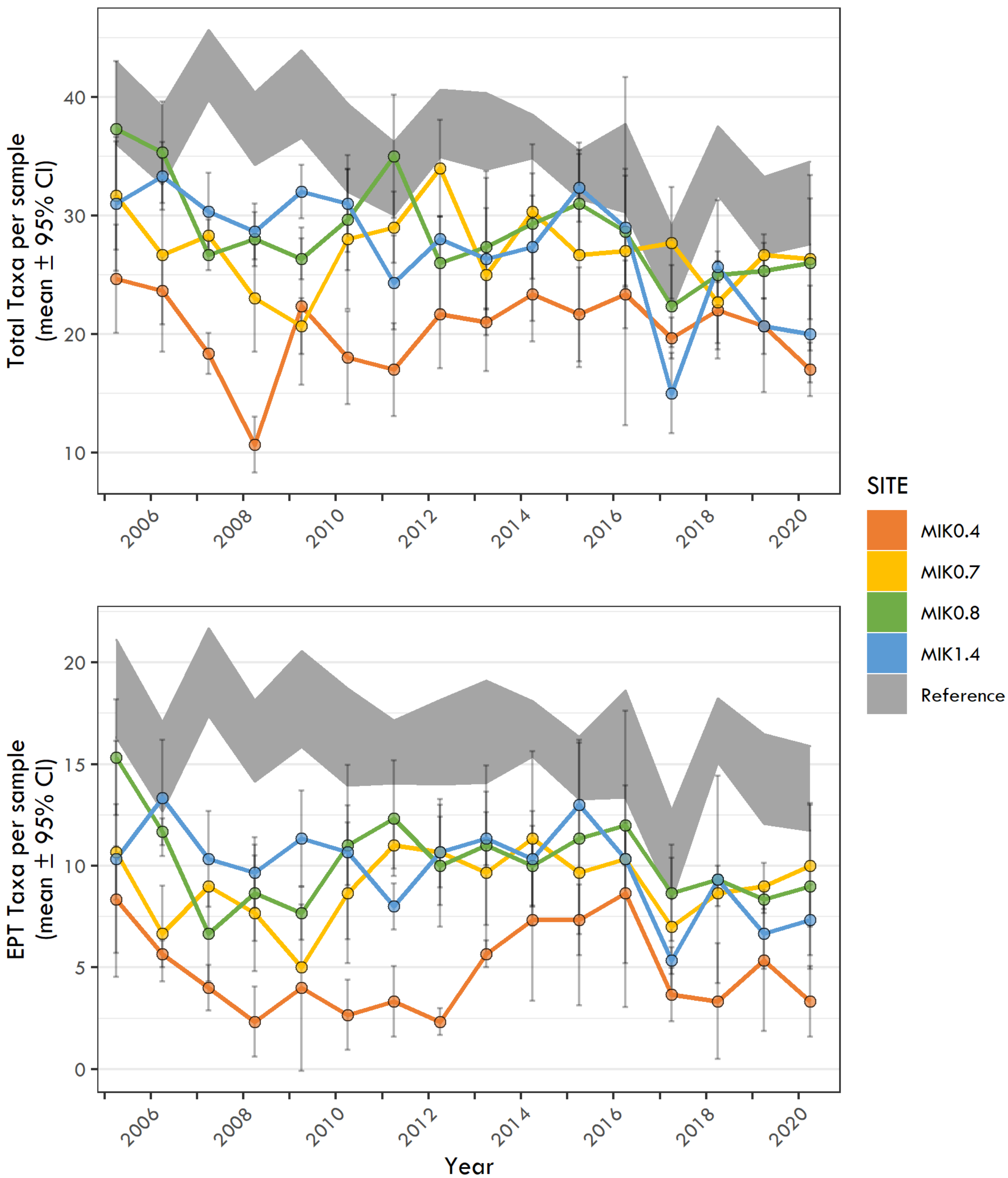
[e] *TDEC protocol states that TMI scores should only be calculated for samples with 160–240 invertebrates identified to genus (TDEC 2017). In August 2020, only 78, 111, and 138 individuals were collected from MIK 0.4, MIK 0.7, and MIK 1.4, respectively, so results from these sites should be interpreted with caution.*

3.7.2.3. Comparison between Mitchell Branch and Other Reference Sites on ORR

Here the benthic macroinvertebrate communities in Mitchell Branch are compared to ORR reference streams over a 15-year period since 2005. Mean values for total taxa richness and taxa richness of pollution-intolerant (EPT) taxa for Mitchell Branch are shown in Figure 3.46, and percent density of the pollution-intolerant and pollution-tolerant taxa are shown in Figure 3.47. Also shown in Figures 3.46 and 3.47 is the 95% confidence interval for the five reference sites on ORR, First Creek kilometer 0.8, Fifth Creek kilometer 1.0, White Oak Creek kilometer 6.8, Walker Branch kilometer 1.0, and Gum Hollow Branch kilometer 2.9, in gray shading.

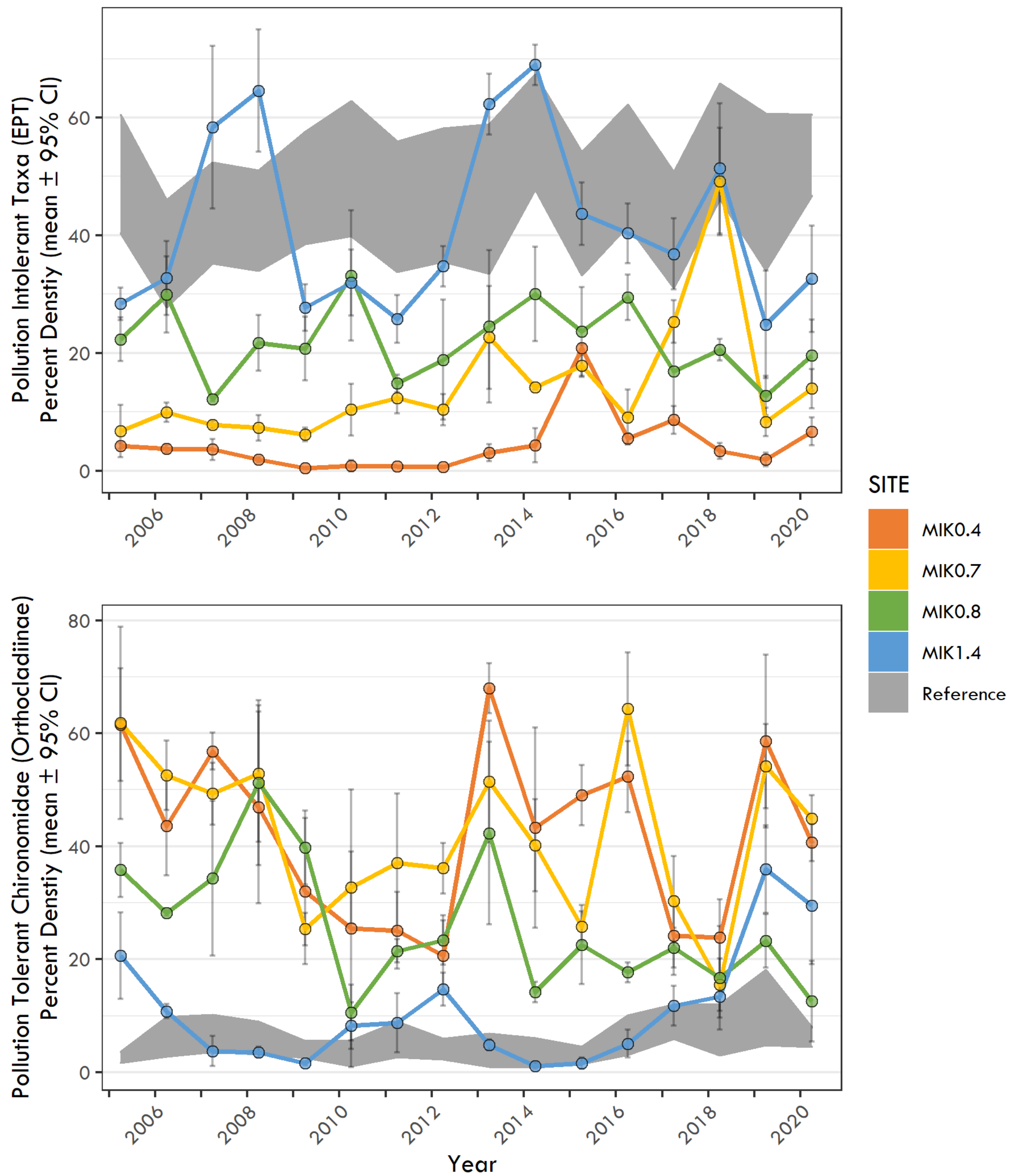
In 2020, total taxa richness and taxa richness of pollution-intolerant (EPT) taxa at Mitchell Branch sites, including MIK 1.4, were less than both the 95% confidence interval for the five reference sites (Figure 3.46). This trend was observed since these comparisons began in 2005, with some exceptions (e.g., 2011, 2017). In contrast to richness metrics, the mean percent densities of pollution-intolerant and pollution-tolerant taxa at MIK 1.4 were rarely outside of the 95% confidence interval for the reference sites (Figure 3.47). As noted above, the percent density of pollution-tolerant taxa at MIK 1.4 decreased in 2020 from one of the highest values measured (in 2019) since monitoring began; however, higher values were also observed at some of the reference sites (Figure 3.47). Since 2005, the mean percent density of pollution-intolerant taxa at MIK 0.8 and MIK 0.7 have fluctuated but have largely remained below the reference 95% confidence interval, while the percent density of pollution-tolerant taxa was higher than the reference 95% confidence interval. MIK 0.4 has largely remained well outside the 95% confidence intervals for reference sites in every year (Figure 3.47).

These results from the comparison of Mitchell Branch sites with the reference sites, combined with the long-term results for all Mitchell Branch sites discussed above, suggest that from the standpoint of reference sites, MIK 1.4 falls near the lower distribution of expected reference conditions on ORR. Factors potentially contributing to frequent excursions of invertebrate community metrics outside of the 95% confidence interval surrounding other reference sites include the somewhat smaller size of MIK 1.4 compared with the other reference sites (based on watershed area, Table 3.20), which may limit the range of invertebrate species that can colonize and thrive at the site, and habitat characteristics that have typically contributed to the lower quality habitat at the site, such as low flow and poor substrate quality (Figures 3.44 and 3.45). These results also support the contention that sites downstream of MIK 1.4 continue to exhibit evidence of mild to moderate degradation.



Note:
The gray shading on each graph shows the 95% confidence interval of values at five additional reference stream sites on ORR from 2005 to 2020.
Acronyms:
CI = confidence interval
EPT = Ephemeroptera, Plecoptera, and Trichoptera
MIK = Mitchell Branch kilometer
MIK 1.4 = reference site
ORR = Oak Ridge Reservation

Figure 3.46. Mean total taxonomic richness (top) and pollution-intolerant taxa per sample (bottom) for the benthic macroinvertebrate community at Mitchell Branch and reference sites, April 2005–2020



Notes:

1. *Pollution intolerant taxa, i.e., stoneflies, mayflies, and caddisflies or Ephemeroptera, Plecoptera, and Trichoptera taxa (top).*
2. *Polution tolerant Orthocladiinae midge larvae (bottom).*
3. *Percentages were based on total densities for each site.*
4. *The gray shading on each graph shows the 95% confidence interval for values at five additional reference sites on ORR from 2005 to 2020.*

Acronyms:

CI = confidence interval MIK 1.4 = reference site EPT = Ephemeroptera, Plecoptera, and Trichoptera
ORR = Oak Ridge Reservation MIK = Mitchell Branch kilometer

Figure 3.47. Mean percent density of pollution-intolerant taxa (top) and pollution-tolerant Chironomidae (bottom) in Mitchell Branch, with reference site mean values, April 2005–2020

3.7.3. Task 3: Fish Community

Fish population and community studies are used to evaluate the biotic integrity (or general ecological health) of Mitchell Branch. The fish community is sampled quantitatively at two sites in Mitchell Branch, MIK 0.4 (downstream of SD 190) and MIK 0.7 (downstream of SD 170) and at local reference streams each spring.

Historically, the fish community in Mitchell Branch was most severely affected in the late 1980s and early 1990s. After some recovery in the mid-1990s, Mitchell Branch was affected negatively again in 1998 in association with a remedial activity that replaced a large section of stream bottom with a liner and interlocking rock substrate (Figure 3.48). In recent years, this reach of stream appears to be developing more natural habitat, including a more robust riparian plant community and some instream riffle/pool sequences as substrate is slowly beginning to accumulate throughout the reach. This has added to the complexity of the habitat available for fishes to colonize. Since 2000, the fish community has had relatively stable species diversity but rather large variations in fish density and biomass (Figure 3.49), which are often reflective of unstable, impaired streams. Streams that experience high density and biomass of tolerant fish species are often indicative of either high nutrient influences on a fish community (i.e., more algal growth means more food at the base of the food chain) or poor instream habitat—and often a combination of both. Of the two sites sampled for fish community, MIK 0.7 has experienced the greatest fluctuations in these community parameters. This is likely due to the modified stream channel and riparian areas and poor instream habitat associated with the remediation work in this reach. Similar conditions are seen in other area streams on ORR, including sections of EFPC where tolerant species dominate the concrete- and bedrock-lined channel, which supports little riparian protection. In addition, extremely low precipitation amounts which often occur in the summer result in very low flows in many area streams. Small first and second order streams without springs or groundwater influence are most severely affected by these conditions. This may partially explain the decreased density and biomass numbers observed in some years and the apparent return of higher values in following years.

Figure 3.48. Construction of lined section of Mitchell Branch, MIK 0.7, in 1998

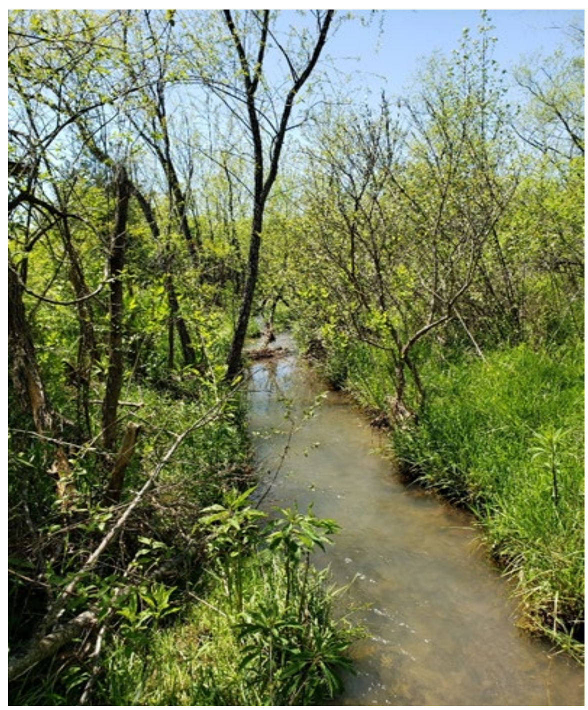
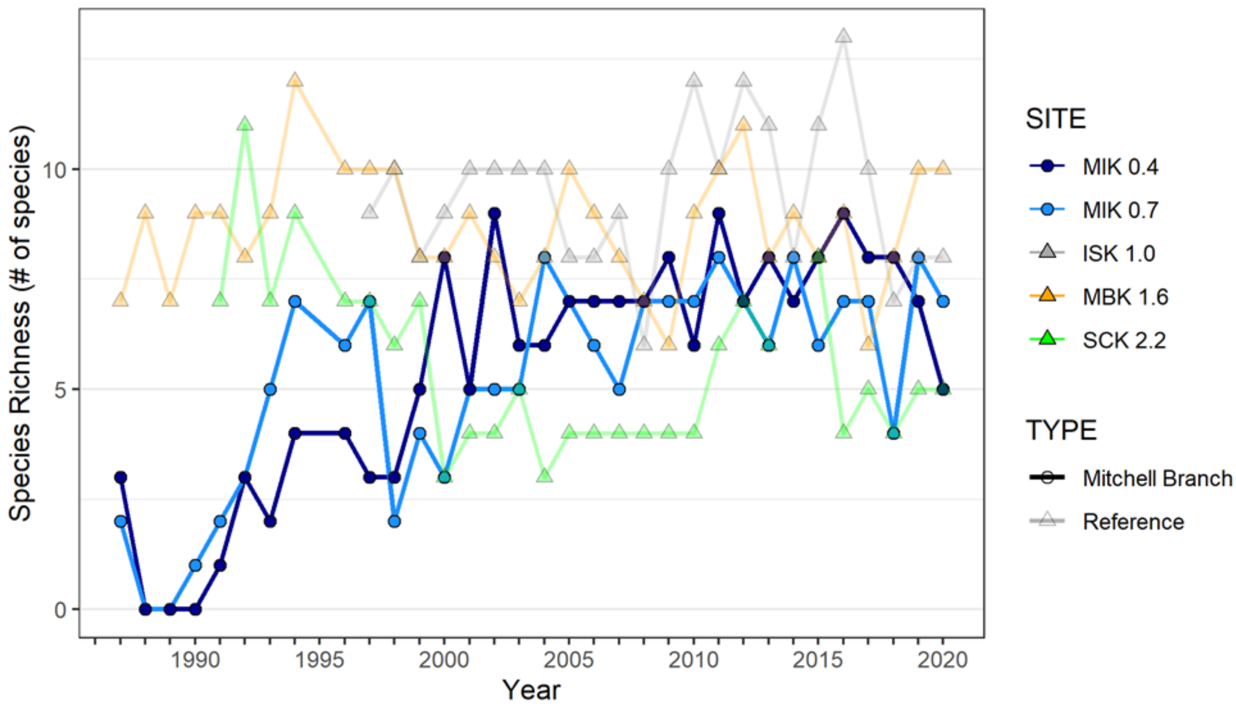


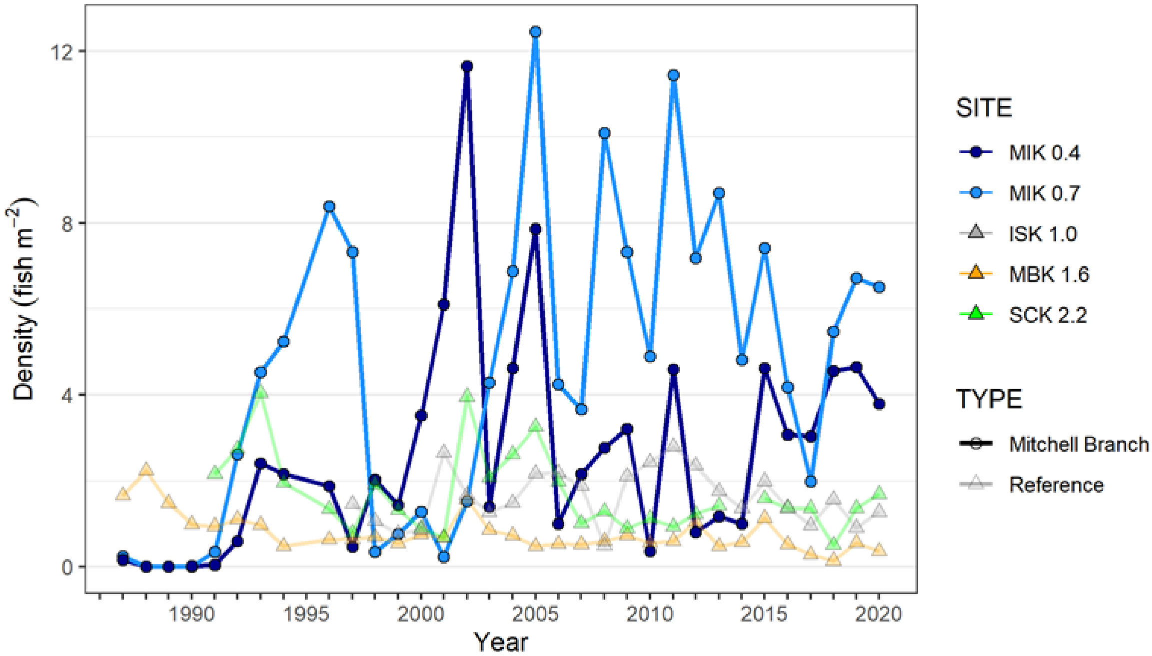
Figure 3.49. More recent habitat conditions at Mitchell Branch in 2020

At both MIK 0.4 and MIK 0.7, the 2020 sample of fish community parameters indicated continued variation. Species richness (number of species) at both sites experienced a slight decrease from 2019 values (Figure 3.50). Both sites have species richness comparable with similar sized reference streams. Density (number of fish) at both sites still remains well above reference conditions (Figure 3.51). Biomass (weight) also remains above elevated at both sites however, MIK 0.4 is approaching reference values in recent samples (Figure 3.52). Both the lower Mitchell Branch site and the upper site had reduced diversity and density of sensitive fish species in 2020. Overall the last five years, there has been a slight uptick in sensitive species diversity and density at both sampled sites in Mitchell Branch which can be attributed to the presence of fish such as banded sculpin (*Cottus carolinae*), which appear to be a resident species in Mitchell Branch, and also occasional occurrences of other more sensitive fish. In 2019-2020 a new species were observed in the upper site. Snubnose darter (*Etheostoma simoterum*) were collected both years, and represents a unique sensitive species in this reach of stream. They have been observed at the very mouth of the system in past samples.



Acronyms:
ISK = Ish Creek
MBK = Mill Branch kilometer
MIK = Mitchell Branch kilometer
SCK = Scarboro Creek

Figure 3.50. Species richness for the fish communities at sites in Mitchell Branch and in reference streams Mill Branch, Scarboro Creek, and Ish Creek, 1987–2020

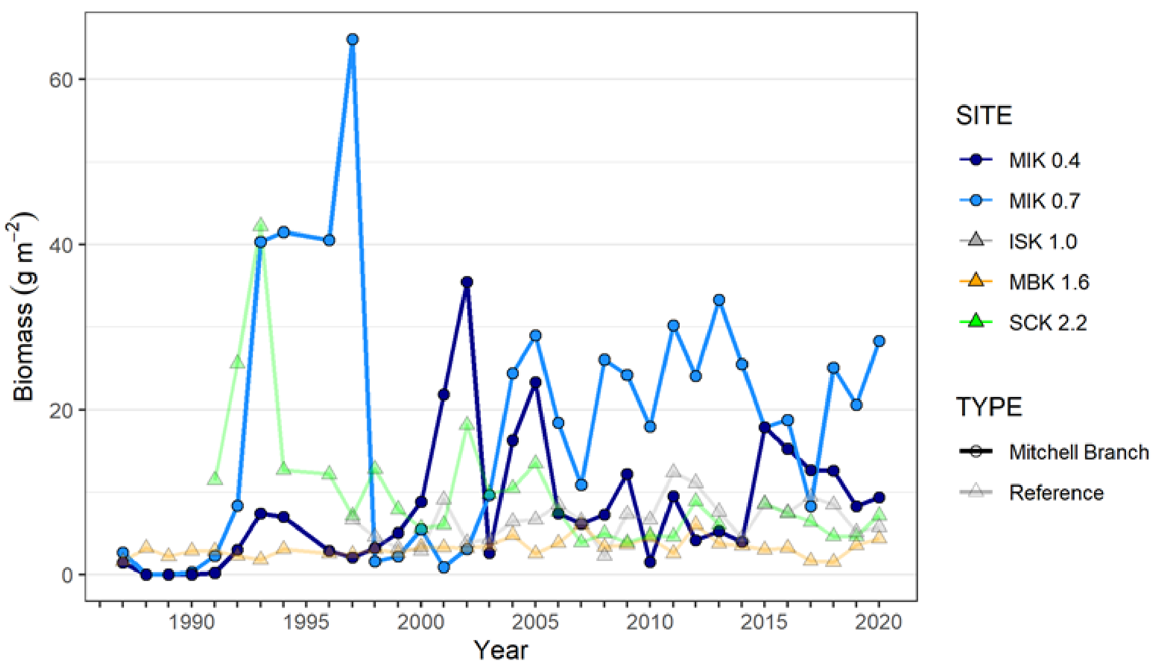


Acronyms:

ISK = Ish Creek | *MIK = Mitchell Branch kilometer*

MBK = Mill Branch kilometer | *SCK = Scarboro Creek*

Figure 3.51. Density for the fish communities at sites in Mitchell Branch and in reference streams Mill Branch, Scarboro Creek, and Ish Creek, 1987–2020



Acronyms:

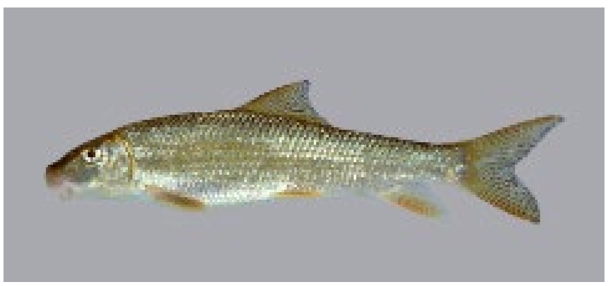
ISK = Ish Creek | *MIK = Mitchell Branch kilometer*

MBK = Mill Branch kilometer | *SCK = Scarboro Creek*

Figure 3.52. Biomass for the fish communities at sites in Mitchell Branch and in reference streams Mill Branch, Scarboro Creek, and Ish Creek, 1987–2020

In general, the Mitchell Branch fish communities at MIK 0.4 and MIK 0.7 continue to lack diverse resident species that are sensitive to stress or that have specialized feeding or reproductive requirements, such as darters or suckers that occur consistently at higher frequencies in the reference streams. Like the benthic communities, fish community monitoring provides an integrated response to *all* of the various water chemistry and habitat influences in a stream. Identifying the major stressor influences on the community (i.e., causal analysis) would require additional investigatory strategies coupled with the monitoring data.

During routine bioaccumulation sampling, several species of fish are collected regularly at MIK 0.2 that are almost never observed in the Mitchell Branch fish community monitoring activities at the upstream sites. These included four pollution-sensitive species: snubnose darter, greenside darter (*Etheostoma blennioides*), black redhorse (*Moxostoma duquesnei*), and northern hogsucker (*Hypentelium nigricans*) (Figure 3.53). Future monitoring will help determine if these species are becoming established farther upstream in Mitchell Branch or are merely seasonal migrants to the stream's lower section, which is easily accessible from the much larger Poplar Creek.



Black redhorse *(Moxostoma duquesnei)*

Snubnose darter *(Etheostoma simoterum)*

Northern hogsucker *(Hypentelium nigricans)*

Greenside darter *(Etheostoma blennioides)*

Photos: Chris Bryant

Figure 3.53. Sensitive fish species observed in lower Mitchell Branch

K-1007-P1 Pond Fish Community

The fish communities in the K-1007-P1 pond are assessed annually. This sampling is conducted to evaluate the effectiveness of remediation efforts implemented in 2009 and is aimed at reducing the PCBs available for transfer out of the pond via natural routes (i.e., trophic transfer). The RAs included capping contaminated sediment with fill dirt, planting native aquatic vegetation to stabilize sediment, and removing potentially contaminated fish from the pond. Fish initially were removed from the pond using a piscicide (Rotenone), and uncontaminated native fish were stocked in the pond with the goal of establishing a sunfish-dominated community. Sunfish have a shorter lifespan than many other species of fish, especially higher trophic level fish, and they have a prey source that is generally varied but consistently lower on the aquatic food chain compared with species such as largemouth bass, thus reducing the likelihood that contaminants would biomagnify within the system.

Despite efforts to remove all unwanted fish from the pond, an unexpected breach in the weir separating the K-1007-P1 pond from the adjacent Poplar Creek in May 2010 allowed numerous fish to enter the pond during high waters. These unwanted fish constituted several species that were unfavorable to the pond action—including: (1) nonnative species and (2) species with life history traits that undermined the remediation efforts, such as being long-lived and having feeding habits that disturb potentially contaminated sediments. Continued work to remove these unwanted fish has been productive, and only limited numbers of the most long-lived species, such as common carp (*Cyprinus carpio*) and smallmouth buffalo (*Ictiobus bubalus*), are encountered in annual monitoring.

Two additional species that returned to the pond after the weir breach were gizzard shad (*Dorosoma cepedianum*) and largemouth bass (*Micropterus salmoides*). Gizzard shad feed on phytoplankton and zooplankton in natural environments such as larger reservoirs, but in smaller ponds such as P1, they often turn to feeding on algal growth at the surface of the pond sediment, which can disturb soils and potentially resuspend contaminants in the pond substrate. Largemouth bass tend to be a long-lived species and are a top predator in aquatic environments, making them particularly susceptible to bioaccumulation. They also are a game fish highly prized by many anglers as well as a common table fare. These two species also have been targeted for removal during continued remediation efforts and fish surveys.

Overall, the K-1007-P1 Pond fish community surveys conducted in January 202019 revealed the presence of 24 species of fish. An observation of particular importance from previous surveys is the abundance of sunfish species (bluegill, redear sunfish, and warmouth), which constitute approximately 70 percent of the total fish population (Figure 3.54). Bluegill, the most prevalent of these species, were historically the dominant sunfish species in the pond, and they are the desired bioindicator fish species to have in the remediated pond. Although largemouth bass continue to persist in the pond, their abundance remains relatively low. Despite removal efforts, their presence is likely to continue, given the habitat conditions currently in the pond (i.e., abundant prey sources and open water). Gizzard shad continue to be present in the pond and are suspected of reproducing; they constituted a much larger portion of the fish population in 2020 than in previous years. Their abundance has had some minor fluctuations each year but in general has remained relatively low compared with earlier years until 2020. The increased abundance of gizzard shad observed in 2020 likely reflects periodic increased fecundity, as has been observed for shad in other aquatic systems in Tennessee.

3.8. Environmental Management and Waste Management Activities

Remediation actiivites were underway across the ETTP in 2020. Wastes were generated during these operations, and were handled in accordance with the applicable regulations.

3.8.1. Waste Management Activities

Restoration of the environment, D&D of facilities, and management of legacy wastes constitute the major operations at ETTP. In 2020, all of the major D&D work at ETTP was completed. However, several smaller projects, and the finishing touches of the cleanup activities, remain to be completed.

CWTS is a small water treatment unit for chromium-contaminated groundwater that sits within the existing Central Neutralization Facility footprint. CWTS came online in late 2012 and handles purge water from groundwater monitoring, as well as the chromium collection system water. Effluent from CWTS discharges into the Clinch River through an existing Central Neutralization Facility discharge line. Section 3.6.2.14 provides a more detailed discussion of CWTS operations.

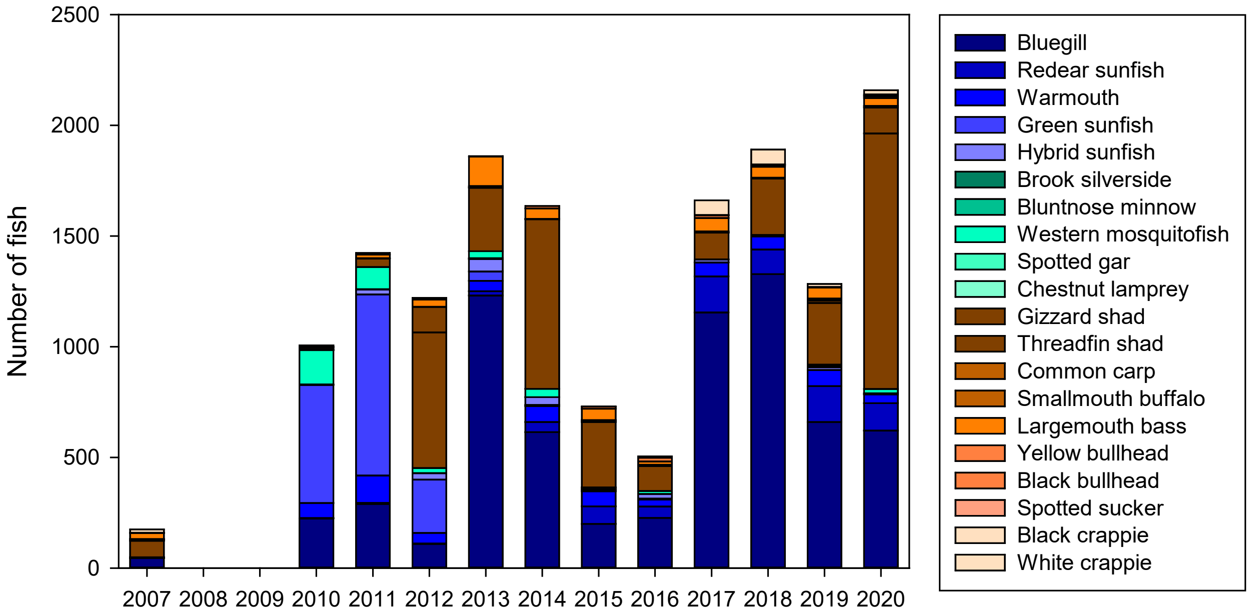


Figure 3.54. Changes in the K-1007-P1 Pond fish community from 2007 to 2020

3.8.2. Environmental Remediation Activities

During 2020, the final major cleanup project was completed. The ultimate goal of the remediation work is to make parcels of land available for a general aviation airport, conservation areas, and private-sector development that can economically benefit the region. Highlights of this effort are given below. For details, please see the *2020 Cleanup Progress—Annual Report to the Oak Ridge Regional Community* (UCOR 2021a, OREM-20-7603).

3.8.2.1. Soil Remediation

UCOR's soil remediation efforts at ETTP are helping to prepare the site for future commercial industrial use. The site is divided into two cleanup regions: Zone 1, a 1,400-acre area outside the main plant area, and Zone 2, the 800-acre area that comprises the main plant area. The areas in these zones are divided into EUs that vary in size. Remediation efforts are designed to protect groundwater, wildlife, and the future workforce. Remediation activities include removal of facilities, excavation of soil, and land use covenants. In fiscal year 2020, planning began on a project to eliminate risk to wildlife in the Zone 1 area. In addition, two vaults associated with the abandoned underground utility system at the Powerhouse were remediated, and steps were initiated to address an area that contains buried asbestos. In the Zone 2 area, the removal of soil contaminated with ^{99}Tc was completed. Also in Zone 2, the abandoned K-1203 Sewage Treatment Plant and the K-832 Cooling Water Basin were remediated, leaving a grassy field at the site.

3.8.2.2. K-1200 Centrifuge Project Demolition Completed

The K-1200 Centrifuge Complex was a large complex of facilities that were designed to develop and test technologies associated with the use of centrifuges for uranium enrichment. In 2020, the last of these facilities were demolished. See also Section 3.6.2.8.

3.8.2.3. Building K-1600 Demolition Completed

Building K-1600 was the last remaining major structure within the footprint of the K-25 Building. It had been used to test new enrichment technologies.

3.8.2.4. Smaller Facilities Demolition Completed

The demolition of several smaller facilities was completed in 2020. The K-1039 telecommunications facilities were demolished, as were the K-1095 Paint Shop, the K-1006 support facility, and the Segmentation Shop. The Segmentation Shop had been used to process waste piping, contaminated equipment, and other items that required size reduction and recyclable materials.

3.8.2.5. Commemoration of the K-25 Site

National historic preservation initiatives at ETTP continued in 2020. The K-25 History Center (Figure 3.55) is located on the second floor of the COR-owned Fire Station #4 at ETTP. The K-25 History Center opened in February, 2020. Visitors to the K-25 History Center will be invited to explore the rich history of this Manhattan Project site. This facility features exhibits, audio-visual displays, period artifacts, equipment replicas, and workers' oral histories, placing K-25 in its proper historical context in World War II and the Cold War.

Figure 3.55. Exhibit at the K-25 History Center

3.8.3. Reindustrialization

With major demolition projects complete in 2020, ETTP moved closer to achieving the three end state goals of a multi-use industrial park, national historic preservation, and conservation/greenspace areas.

Multi-Use Industrial Park

In 2020, DOE initiated transfer of Access Portals 4 and 11, two roadways, the former K-1037 pad and the former Toxic Substances Control Act Incinerator (TSCAI) area. Portal 4 and one block sections of both 9th and 10th Streets were requested by the Community Reuse Organization of East Tennessee (CROET) and comprise 0.84 acres of land. Portal 11 (0.52 acres) was requested by the City of Oak Ridge as a complement to their existing Fire Station. The K-1037 pad and TSCAI area (27.9 acres) were requested by CROET for economic development opportunities. All transfers are in the review process and pending approval. DOE also continued to support the proposed general aviation airport project. Management of the project was transferred to the City in CY2020 and it was determined that a different alignment and additional acreage would be needed. DOE assisted the City with the transfer requests for approximately 65 acres, adding to the 170 acres previously requested for transfer.

Additionally, DOE completed an Environmental Assessment to support potential development at the Horizon Center, including land use changes.

Conservation/Greenspace

DOE continued to work with the Tennessee Wildlife Resources Agency on greenspace initiatives and waterway access to enhance public recreation opportunities at ETTP. The team also supported the development of the *Natural Asset Guidebook* which was published in early 2020 by the Legacy Parks Foundation. The Guidebook describes how to maximize the area's natural assets and provide connectivity throughout the greater Oak Ridge community and the surrounding region.

To date, DOE has transferred a total of 1,280 acres. The continued transfer of parcels, as more of the site cleanup is completed, provides the best opportunities to date for industrial and commercial development of ETTP.

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Y-12 is a one-of-a-kind manufacturing complex that plays an important role in United States national security. Through life extension program activities, Y-12 produces refurbished, replaced, and upgraded weapons components to modernize the enduring stockpile.

4

The Y-12 National Security Complex

Y-12, a premier manufacturing facility operated by Consolidated Nuclear Security, LLC (CNS) for the National Nuclear Security Administration (NNSA), plays a vital role in the DOE Nuclear Security Enterprise. Drawing on more than 75 years of manufacturing excellence, Y-12 helps ensure a safe and reliable United States nuclear weapons deterrent.

Y-12's primary mission includes processing, retrieving, and storing nuclear materials; dismantling nuclear weapons; providing fuels to the nation's naval reactors; and complementarily working for other government and private-sector entities.

Today's environment requires Y-12 to have a new level of flexibility and versatility. Therefore, while continuing its key role, Y-12 has evolved to become the resource that the nation looks to for support in protecting America's future by developing innovative solutions in manufacturing technologies, prototyping, safeguards and security, technical computing, and environmental stewardship.

4.1. Description of Site and Operations

4.1.1. Mission

Charged with maintaining the safety, security, and effectiveness of the United States' nuclear weapons stockpile, Y-12 is a one-of-a-kind manufacturing facility that plays an important role in United States national security. Y-12's core mission is to ensure a safe, secure, and reliable United States nuclear deterrent, which is essential to national security. Every weapon in the United States nuclear stockpile has components manufactured, maintained, or ultimately dismantled by Y-12. Through life extension program activities, Y-12 produces refurbished, replaced, and/or upgraded weapons components to modernize the enduring stockpile. As the nation reduces the size of its arsenal, Y-12 has a central role in decommissioning weapons systems and providing weapons material for nonexplosive, peaceful uses.

Y-12 expertly secures highly enriched uranium, stores it with the highest security, and makes material available for nonweapons uses (e.g., in research reactors that produce cancer-fighting medical isotopes and in commercial power reactors). Y-12 also processes highly enriched uranium from weapons removed from the nation's nuclear weapons stockpile for use by the Naval Reactors Program to fuel nuclear-powered submarines and aircraft carriers.

Located within the city limits of Oak Ridge, Tennessee, the Y-12 site covers more than 328 ha (810 acres) in the Bear Creek Valley, stretching 4.0 km (2.5 mi) in length down the valley and nearly 2.4 km (1.5 mi) in width across it. Additional NNSA-related facilities are located offsite from Y-12 and include the Central Training Facility, Alternate Emergency Operations Center (K-1650), Uranium Processing Facility (UPF) project laydown storage and offices, Y-12 Material Acquisition and Control Facilities (K-1065), Commerce Park Office Complex, and Union Valley Sample Preparation Facility.

4.1.2. Modernization

Y-12 directly supports four of the five NNSA Centers of Excellence, including uranium, lithium, weapons assembly and disassembly, and safe and secure storage of strategic materials. The Y-12 strategic vision is driven by the overarching objectives that, by 2040, Y-12 will be capable of reliably fabricating any component, building any weapon, and qualifying any system on any day; and executing a digital transformation strategy that enables smart, real-time, data-driven operations. Today, Y-12 is not well suited to deliver this type of responsive capability. Following the end of the Cold War, operations were scaled-back, and many once-reliable processes have since atrophied.

The ability to deliver a nuclear weapon without reusing components from legacy weapons and relying heavily on aging infrastructure does not exist. Additionally, Y-12 faces a unique need to reestablish capabilities and two material streams—binary and special materials associated with the canned subassembly (CSA) and Radiation Case mission. A key component to reestablishing these capabilities is accelerated planning and execution of site infrastructure improvements to include:

- new production facilities
- new capability and operational support facilities
- capability bridging, until new facilities are in place

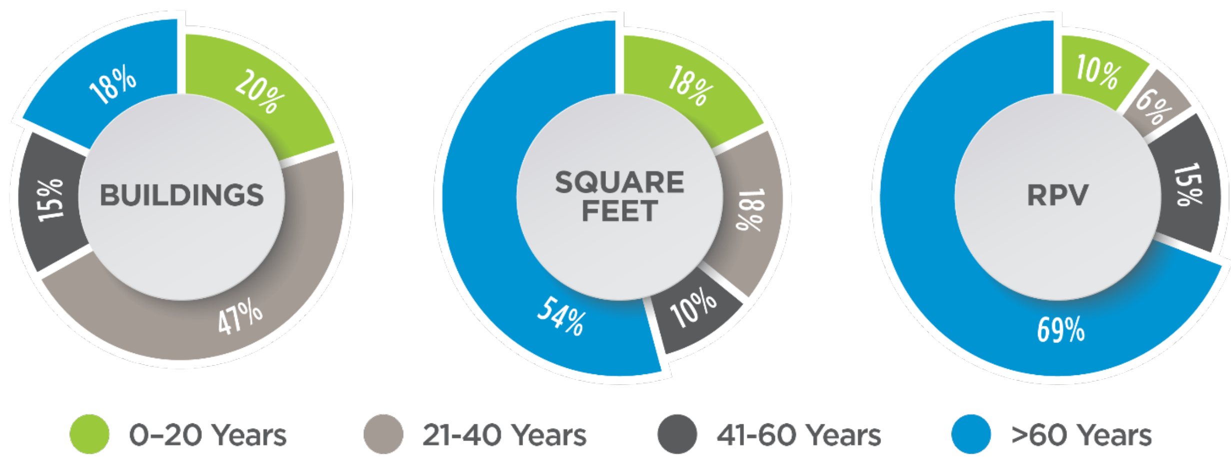
Planning for the future site is designed to ensure that Y-12 will continue to provide the infrastructure needed to support the primary capabilities and materials missions with new facilities and associated technologies. In addition to new and revitalized facilities, the security posture will be strengthened by a reduced Protected Area footprint and revitalized security infrastructure and systems. The envisioned future Y-12 site includes the following elements:

- Major supply chains, including uranium (enriched uranium [EU], depleted uranium [DU], and low enriched uranium) and lithium, are reestablished and/or transformed.
- The UPF, Lithium Processing Facility (LPF), EU Manufacturing Center, Assembly and Disassembly Center, and DU Manufacturing Center are constructed.
- The security posture through recapitalized and transformed footprint and security systems is sustained and improved.
- Approximately 2.8 million gross square feet of excess facilities are demolished and legacy environmental threats are remediated.
- Become an active participant in the Manhattan Project National Historic Park, which accommodates public tours for Y-12 historic facilities.

- Become an active participant in the Manhattan Project National Historic Park, which accommodates public tours for Y-12 historic facilities.

More than 50 percent of the Y-12 footprint is over 60 yr. old (Figure 4.1). To address this situation, Y-12 has been consolidating operations, modernizing facilities and infrastructure, and reducing the legacy footprint for more than one decade. These actions are consistent with and supportive of NNSA enterprise transformation planning. Through continued infrastructure projects, new construction, and the disposition of excess facilities, Y-12 will continue to strive toward becoming a more responsive, sustainable enterprise.

Replacement and revitalization are key elements of the modernization strategy at Y-12. A significant number of facilities at Y-12 are at or beyond design life. Currently, planned construction activities include the UPF, Emergency Operations Center, Fire Station, and West End Protected Area Reduction (WEPAR), and soon the LPF.



Acronym: *RPV = replacement plant value*

Figure 4.1. Age of facilities at Y-12

4.1.3. Production Operations

Y-12's core manufacturing and processing operations are housed in decades-old buildings near or past the end of their expected life spans. An integral part of Y-12's transformation, the UPF is one of two facilities at Y-12 whose joint mission will be to store and process EU in one much smaller, centralized area.

The major production capabilities and associated facilities at Y-12 include the following:

- **EU:** Buildings 9212, 9215 and the UPF (2025)
- **DU:** Buildings 9215, 9201-05N, 9201-05W, 9996, and 9998
- **Lithium:** Buildings 9204-02 and 9202
- **General manufacturing and fabricating:** Building 9201-01
- **Assembly and disassembly:** Building 9204-02E
- **Special materials:** Building 9225-03
- **Storage:** Buildings 9720-82, 9720-05, 9720-32, 9720-33, 9720-59, and 9811-01

The following major construction activities comprise the long-range vision for replacing key production operations from aging oversized facilities:

- Building 9212 functions are to be replaced by the UPF in 2025, with some Building 9212 processes relocated to Buildings 9215 and 9204-2E.

- Building 9215 EU functions are to be replaced by the EU Manufacturing Center by 2042.
- Building 9204-02E functions are to be replaced by the Assembly and Disassembly Center by 2045.
- Building 9204-02 lithium functions are to be replaced by the LPF by 2031.
- DU and fabricating and manufacturing functions from the Building 9215 Complex, Building 9201-05N, Building 9201-05W, and Building 9201-01 are to be replaced by the DU Manufacturing Capability (DUMC) by 2045.

4.1.4. Support Facilities

Operations support infrastructure plays an integral role in ensuring Y-12 mission-critical work is successfully completed. The primary missions of operations support infrastructure are to protect vital national security assets and people and enable site missions. These organizations and facilities provide the resources and infrastructure that directly support mission-critical production operations. Operations support facilities include the following categories of assets:

- Security
- Emergency Services
- Development
- Analytical Chemistry
- General Storage and Warehousing
- Cybersecurity and Information Technology
- Global Security and Strategic Partnerships
- Waste Management
- Sustainability and Stewardship

The following major construction activities comprise the long-range vision for replacing key operations support facilities:

- Replace the Emergency Operations Center and Fire Station by 2023.
- Relocate development functions from Buildings 9202 and 9203, initially by the off-site acquisition at 103 Palladium Way in 2021, followed by the Applied Technologies Laboratory by 2035.
- Implement the WEPAR project and a new Entry Control Facility by 2023.
- Implement the Security Infrastructure Revitalization Program to replace the legacy Perimeter Intrusion Detection and Assessment System and secondary systems.
- Explore new construction for replacement facilities to support Analytical Chemistry operations.
- Construct a new Strategic Partnership Program training campus as the Oak Ridge Enhanced Technology and Training Center (ORETTC), including the Emergency Response Training Facility and the Simulated Nuclear and Radiological Activities Facility.
- Construct a new Maintenance complex to replace the 78-year-old 9201-03 and other aging maintenance facilities.
- Construct a new Waste Management Complex to replace the aging West End Treatment Facilities.
- Implement a digital transformation and cyber security strategy.
- Refurbish existing facilities to accommodate a Protected Area Security facility and construct a new Security Complex to enable growing requirements.

4.1.5. Excess Facility Disposition

Currently, 83 excess facilities at Y-12 and another 55 NNSA facilities are projected to be excessed within the next 10 yr. The major excess process-contaminated facilities, including Building 9201-05 (Alpha 5), Building 9204-04 (Beta 4), and Building 9206, will be transitioned to Environmental Management (EM) for disposition. The smaller, process-contaminated, ancillary facilities associated with Buildings 9201-05, 9204-04, and 9206; Building 9212-associated facilities; and Building 9401-03 (Steam Plant) Complex facilities are currently planned to be dispositioned by NNSA.

Process-contaminated facilities contain radiological and/or chemical contamination resulting from mission operations during the Manhattan Project or Cold War eras. Excess process-contaminated facilities are expected to be sufficiently managed until facility conditions meet criteria for transition to EM. Excess, non-process-contaminated facilities are generally expected to be demolished by NNSA; however, some excess, non-process-contaminated facilities may be demolished by EM depending on their complexity and/or proximity to process-contaminated facilities. Construction of the Mercury Treatment Facility and the Environmental Management Disposal Facility is required before any mercury-contaminated facilities can be demolished. Surveillance and maintenance activities, along with utility reroutes, unneeded material cleanout, and fluid and oil disposition, are ongoing while the Mercury Treatment Facility and Environmental Management Disposal Facility are being constructed.

4.2. Environmental Management System

As part of CNS's commitment to environmentally responsible operations, Y-12 has implemented an Environmental Management System (EMS) based on requirements of the globally recognized International Organization of Standardization (ISO) 14001:2004 standard to plan, implement, control, and continually improve environmental performance at Y-12 (ISO 2004).

DOE Order 436.1, Departmental Sustainability (DOE 2011a), provides requirements and responsibilities for managing sustainability within DOE in accordance with applicable Executive Orders (EOs). DOE Order 436.1 further requires implementation of an EMS that is either registered to the requirements of ISO 14001:2004 by an accredited ISO 14001 registrar or self-declared to be in conformance to the standard in accordance with instructions issued by the Office of the Federal Environmental Executive, a chartered task force under the White House Council on Environmental Quality. Y-12 has maintained an EMS with self-declared conformance to ISO 14001:2004 since 2006. The ISO 14001 standard was revised by the international organization in 2015. The Y-12 EMS continues to satisfy DOE requirements while incorporating ISO 14001 revisions that continually improve the EMS. The EMS requirements taken from DOE Order 436.1 have been incorporated into the Environmental Protection functional area of Y-12's Contractor Assurance System.

4.2.1. Integrating with Integrated Safety Management System

Y-12's Integrated Safety Management System (ISMS) is the basis for planning and implementing environment, safety, and health (ES&H) programs and systems that provide the necessary structure for any work activity that could affect the public, a worker, or the environment. At Y-12, the elements of the ISO 14001 EMS are incorporated in and are consistent with the ISMS to achieve environmental compliance, pollution prevention, waste minimization, resource conservation, and sustainability. Both the ISMS and EMS are based on an internationally recognized cycle of continual improvement, commonly known as the plan-do-check-act cycle, as depicted in Figure 4.2, which shows the relationship between the ISMS and the integrated EMS.

4.2.2. Policy

Y-12's environmental policy and commitment to providing sound environmental stewardship practices through the implementation of an EMS have been defined, are endorsed by top management, and have been made available to the public via company-sponsored forums and public documents such as this one. Y-12's ES&H policy is presented in Figure 4.3.

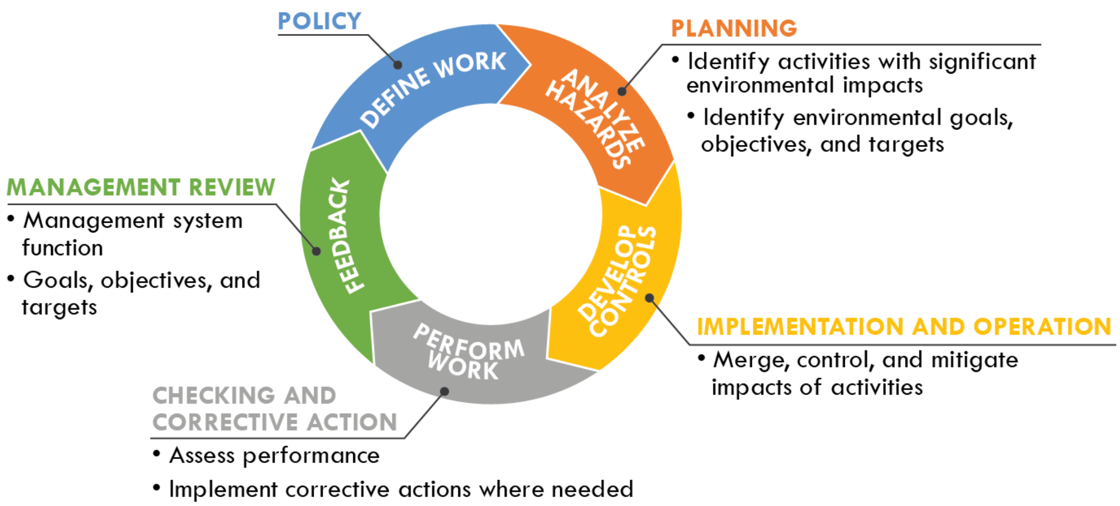


Figure 4.2. The Environmental Management System plan-do-check-act cycle of continual improvement

Y12 ENVIRONMENT, SAFETY, AND HEALTH POLICY STATEMENT

As we work to achieve the Y-12 mission and our vision of a modernized Y-12 Complex, we will do so by ensuring the safety and health of every worker, the public, and the environment. Every employee, contractor, and visitor is expected to take personal responsibility for their actions.

- Environmental Policy Statement: We protect the environment, prevent pollution, comply with applicable requirements, and continually improve our environment.
- Safety and Health Policy Statement: The safety and health of our workers and the protection of public health and safety are paramount in all that we do. We maintain a safe work place, and plan and conduct our work to ensure hazard prevention and control methods are in place and effective.

In support of these policies, we are committed to:

- Integrating Environment, Safety and Health into our business processes
- Continuously improving our processes and systems
- Directly, openly, and truthfully communicating this policy and our ES&H performance
- Striving to minimize the impact of our operations on the environment in a safe, compliant, and cost-effective manner using sustainable practices
- Incorporating sustainable design principles into the design and construction of facility upgrades, new facilities, and infrastructure considering life-cycle costs and savings
- Incorporating the use of engineering controls to reduce or eliminate hazards whenever possible into the design and construction of facility upgrades, new facilities, and infrastructure
- Striving to provide a clean and efficient workplace free of occupational injuries and illnesses (Target Zero)
- Fostering and maintaining a work environment of mutual respect and teamwork that encourages free and open expression of ES&H concerns

Acronym:
ES&H = environment, safety, and health

Figure 4.3. Y-12's environment, safety, and health policy

In addition to Y-12's ES&H policy, CNS has issued an environmental policy that is a significant component of the CNS ISMS and contributes to sustaining the Pantex and Y-12 imperatives of safe and secure operations. The Y-12 ES&H policy and the CNS environmental policy are communicated to and are incorporated into mandatory training for every employee and subcontractor. The policies are available for viewing on both Y-12's external and internal websites. Y-12 personnel are made aware of the commitments stated in the policies and how the commitments relate to Y-12 work activities.

4.2.3. Planning

The following sections describe planning activities conducted as part of the Y-12 EMS.

4.2.3.1. Y-12 Environmental Aspects

Environmental aspects may be thought of as potential environmental hazards associated with a facility operation, maintenance job, or work activity. The environmental aspects and their impacts (potential effects on the environment) are evaluated to ensure that the significant aspects of Y-12 activities that are identified continue to reflect stakeholder concerns and changes in regulatory requirements. The EMS provides the system to ensure that environmental aspects are systematically identified, monitored, and controlled to mitigate or eliminate potential impacts to the environment.

The analysis identified the following as significant environmental aspects in 2020:

- Storm water (runoff from roofs and outdoor storage areas)
- Surface water (process water and dike emissions to creek)
- Wastewater (sanitary sewer and process water treated and disposed)
- Radiological waste
- Excess facilities and unneeded materials and chemicals
- Aging infrastructure and equipment
- Legacy contamination and disturbance

4.2.3.2. Legal and Other Requirements

To implement the compliance commitments of the ES&H policy and to meet legal requirements, systems are in place to review changes in federal, state, or local environmental regulations and to communicate those changes to affected staff. The environmental compliance status is documented each year in this report (see Section 4.3).

4.2.3.3. Objectives, Targets, and Environmental Action Plans

CNS responds to change and pursues sustainability initiatives at Y-12 by establishing and maintaining environmental objectives, targets (goals), and action plans. Goals and commitments are established annually considering Y-12's significant environmental aspects. They are consistent with Y-12's mission, budget guidance, ES&H work scope, and DOE sustainability goals. Targets and action plans are established for broad objectives to pursue improvement in environmental performance in five areas—clean air; energy efficiency; hazardous materials; stewardship of land and water resources; and waste reduction, recycling, and buying green. Highlights of the 2020 environmental targets achieved at Y-12 are presented in Section 4.2.6.1.

4.2.3.4. Programs

NNSA has developed and funded several important programs to integrate environmental stewardship into all facets of Y-12 missions. The programs also address the requirements in DOE Orders for protecting various environmental media, reducing pollution, conserving resources, and helping to promote compliance with all applicable environmental regulatory requirements and permits.

Environmental Compliance

Y-12's Environmental Compliance Department (ECD) provides environmental technical support services and oversees Y-12 line organizations to ensure that site operations are conducted in a manner that is protective of workers, the public, and the environment; in compliance with applicable standards, DOE Orders, environmental laws, and regulations; and consistent with CNS environmental policy and Y-12 site procedures. ECD serves as Y-12's interpretive authority for environmental compliance requirements and as the primary point of contact between Y-12 and external environmental compliance regulatory agencies such as the City of Oak Ridge, the Tennessee Department of Environment and Conservation (TDEC), and EPA. ECD administers compliance programs aligned with the major environmental legislation that affects Y-12 activities. Compliance status and results of monitoring and measurements conducted for these compliance programs are presented in this document.

ECD also maintains and ensures implementation of Y-12's EMS and spearheads initiatives to proactively address environmental concerns, to continually improve environmental performance, and to exceed compliance requirements.

Waste Management

The Y-12 Waste Management Program supports the full life cycle of all waste streams within Y-12. While ensuring compliance with federal and state regulations, DOE Orders, waste acceptance criteria, and Y-12 procedures and policies, the Waste Management Program provides services for day-to-day solid and liquid waste operations, including collection and transport, storage, on-site treatment operations, and shipment to off-site treatment and disposal. The program also provides technical support to Y-12 operations for waste planning, characterizing, packaging, tracking, reporting, and managing waste treatment and disposal subcontracts.

Sustainability and Stewardship

The Sustainability and Stewardship Program has two major missions. The first is to establish and maintain companywide programs and services to support sustainable material management operations. These sustainable operations include pollution prevention and recycling programs, excess materials programs, the PrYde Program, generator services programs, sanitary waste and landfill coordination, and destruction and recycle facility operations. Y-12 has implemented continuous improvement activities, such as an Items Available for Reuse section on the Property Accountability Tracking System website and a central telephone number (574-JUNK), to provide employees easy access to information and assistance related to the proper methods for disposing of excess materials.

The second mission is stewardship practices, the programs that manage legacy issues and assist in preventing development of new problematic issues. Stewardship programs include Clean Sweep, Unneeded Materials and Chemicals, and Targeted Excess Materials. The Clean Sweep Program provides turnkey services to material generators, including segregation, staging, and pickup of materials for excess, recycle, and disposal. Sustain areas have been established across the site to improve housekeeping through efficient material disposition. Customers place unneeded items into the transition portion of each Sustain area and Clean Sweep Program personnel take care of the rest. Additionally, at Y-12, unneeded materials are not automatically assumed to be wastes requiring disposal. Y-12 uses a systematic disposition evaluation process. The first step in the disposition process is to determine if the items can be reused at Y-12. Items that cannot be used at Y-12 are evaluated for use at other DOE facilities or government agencies. Items are then evaluated for potential sale; recycle; or, as a last resort, disposal as waste.

Combining these programs under a single umbrella improves overall compliance with EOs, DOE Orders, federal and state regulations, and NNSA expectations, and eliminates duplication of efforts while providing an overall improved appearance at Y-12.

Additionally, implementing these programs directly supports EMS objectives and targets to disposition Unneeded Materials and Chemicals, continually improves recycle programs by adding new recycle streams as applicable, improves sustainable acquisition (i.e., promotes the purchase of products made with recycled content and bio-based products), meets sustainable design requirements, and adheres to pollution prevention reporting requirements.

Energy Management

The mission of Y-12's Energy Management Program is to incorporate energy-efficient technologies sitewide and to position Y-12 to meet NNSA energy requirement needs and reduction requirements set forth by DOE. The program identifies improvements in energy efficiency in facilities, coordinates energy-related efforts across the site, is involved with the continual Energy Savings and Performance Contracts (ESPCs), and promotes employee awareness of energy conservation programs and opportunities.

4.2.4. Implementing and Operating

The following sections describe activities conducted as part of the Y-12 EMS to establish, implement, and maintain good environmental practices and procedures.

4.2.4.1. Roles, Responsibility, and Authority

Safe, secure, efficient, and environmentally responsible operation of Y-12 requires the commitment of all personnel. All personnel share the responsibility for successful day-to-day accomplishment of work and the environmentally responsible operation of Y-12.

Environmental and Waste Management technical support personnel assist line organizations with identifying and carrying out their environmental responsibilities. Additionally, the Environmental Officer Program facilitates communication of environmental regulatory requirements and promotes EMS as a tool to drive continual environmental improvement at Y-12. Environmental Officers coordinate their organizations' efforts to maintain environmental regulatory compliance and promote other proactive improvement activities.

4.2.4.2. Communication and Community Involvement

Y-12 is committed to keeping the community informed on operations, environmental concerns, safety, and emergency preparedness. The Community Relations Council, composed of more than 20 members from a cross-section of the community, including environmental advocates, neighborhood residents, Y-12 retirees, and business and government leaders, facilitates communication between Y-12 and the community. The council provides feedback to Y-12 regarding its operations and ways to enhance community and public communications. Additionally, an Introduce a Girl to Engineering event was held at Y-12's New Hope Center on February 20, 2020. Community outreach activities were limited in 2020 due to the COVID-19 pandemic.

Local charities receive donations from funds raised by Y-12 employee aluminum beverage can recycling efforts. Since the program began in 1994, more than $92,000 raised by the collection of aluminum beverage cans has been donated to various local charities.

Y-12 continues to promote sustainable behaviors for environmental improvements at the site and within the community. A United Way Coat and Toiletries Drive is conducted annually to provide coats and other needed items for the Volunteer Ministry Center for the Homeless. These activities reflect Y-12 employees' commitment to reduce landfill waste and to support community outreach.

4.2.4.3. Emergency Preparedness and Response

Local, state, and federal emergency response organizations are fully involved in Y-12's emergency drill and exercise program. The annual drill and exercise schedule is coordinated with all organizations to ensure maximum possible participation. At a minimum, the Tennessee Emergency Management Agency (TEMA) Operations Office and the DOE Headquarters Watch Office participate in all Y-12 emergency response exercises.

Exercises, performance drills, and training drills were conducted at Y-12 during fiscal year (FY) 2020. The drills and exercises focused on topics such as responding to a security condition change, criticality incident, and natural disaster with a radiological fire and release. Building evacuation and accountability drills were also conducted.

4.2.5. Checking

The following sections describe activities conducted as part of the Y-12 EMS to review, assess, and monitor Y-12 operations to maintain environmentally safe and compliant practices and continually improve environmental performance.

4.2.5.1. Monitoring and Measuring

Y-12 maintains procedures to monitor overall environmental performance and to monitor and measure key characteristics of its operations and activities that can have a significant environmental impact. Environmental effluent and surveillance monitoring programs are well established, and results of 2020 program activities are described throughout this chapter. Progress in achieving environmental goals is reported as a monthly metric on Performance Track, the senior management web portal that consolidates and maintains Y-12 site-level performance. Progress is reviewed in periodic meetings with senior management and the NNSA Production Office (NPO).

4.2.5.2. Environmental Management System Assessments

To periodically verify that EMS is operating as intended, assessments are conducted as part of the Y-12 internal assessment program. The assessments are designed to ensure that nonconformities with ISO 14001 are identified and addressed.

The Environmental Assessment (EA) Program comprises several types of assessments, each type serving a distinct but complementary purpose. Assessments range from informal observations of specific activities to rigorous audits of site-level programs.

To self-declare conformance to ISO 14001 in accordance with instructions issued by the Federal Environmental Executive and to adhere to DOE Order 436.1 (DOE 2011a) requirements, EMS must be audited at least every 3 years by a qualified party outside of the control or scope of EMS. To fulfill this requirement, a four-person audit team from The University of Tennessee Center for Industrial Services evaluated Y-12's EMS during June 2018. The Y-12 EMS was found to fully conform, and no issues were identified. The next external verification audit is scheduled for summer 2021.

4.2.6. Performing

This section discusses EMS objectives, targets, other plans, initiatives, and successes that work together to accomplish DOE goals and reduce environmental impacts. Y-12 used a number of DOE reporting systems, including the following, to report performance:

- The Federal Automotive Statistical Tool, which collects fleet inventory and fuel use.
- The DOE Sustainability Dashboard, which collects data on metering requirements, water use, renewable energy generation and purchases, greenhouse gas (GHG) generation, and sustainable buildings. Pollution prevention waste reduction and recycling data, sustainable acquisition product purchases, electronic stewardship, and best practices data are also collected in this Dashboard system.

The DOE Office of Health, Safety, and Security Annual Environmental Progress Reports on implementing EMS requirements and sustainability goals driven by EOs and the Office of Management and Budget's Environmental Stewardship Scorecard gave Y-12 an EMS scorecard rating for FY 2020 of green, indicating full implementation of EMS requirements.

4.2.6.1. Environmental Management System Objectives and Targets

At the end of FY 2020, Y-12 had achieved five of nine targets that had been established; the remaining targets were carried into future years. Highlights include the following, with additional details and successes presented in other sections of this report:

- **Clean air:** Y-12 upgraded software, training, and procedures to improve control of ozone-depleting substances that are managed onsite.
- **Energy efficiency:** Y-12 completed phase one of a project to upgrade power lines to 13.8kV service. Additional power line upgrade work will continue into 2021. Progress on several energy-saving improvements for water chillers; heating, ventilating, and air conditioning systems; and cooling towers was made and completed by the end of the 2020 calendar year (CY).
- **Hazardous materials:** A project to disposition and ship legacy mixed waste according to the Site Treatment Plan continued in 2020. The FY 2020 milestone was completed. FY 2020 priorities to disposition unneeded materials and chemicals in one facility were completed. Y-12 identified and prioritized aboveground and inactive tanks to address in future years.

4.2.6.2. Sustainability and Stewardship

Numerous efforts, including increased use of environmentally friendly products and processes and reductions in waste and emissions, at Y-12 have reduced its impact on the environment. During the past few years, these efforts have been recognized by our customers, our community, and other stakeholders (see Section 4.2.7). Pollution prevention efforts at Y-12 have not only benefited the environment but have also resulted in cost efficiencies (Figure 4.4).

In FY 2020, Y-12 implemented 105 pollution prevention initiatives (Figure 4.5), with a reduction of more than 44.2 million lbs. of waste and projected cost efficiencies of more than $6.9 million. The completed projects include the activities described below.

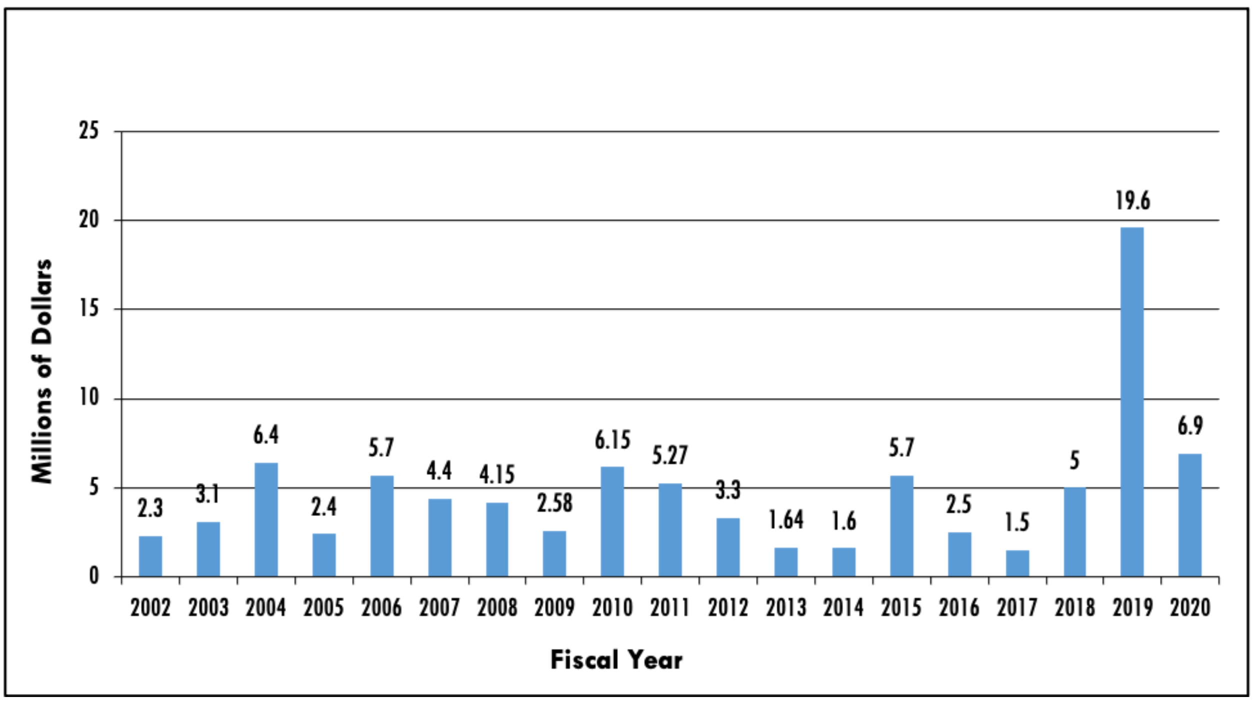


Figure 4.4. Cost efficiencies from Y-12 pollution prevention activities

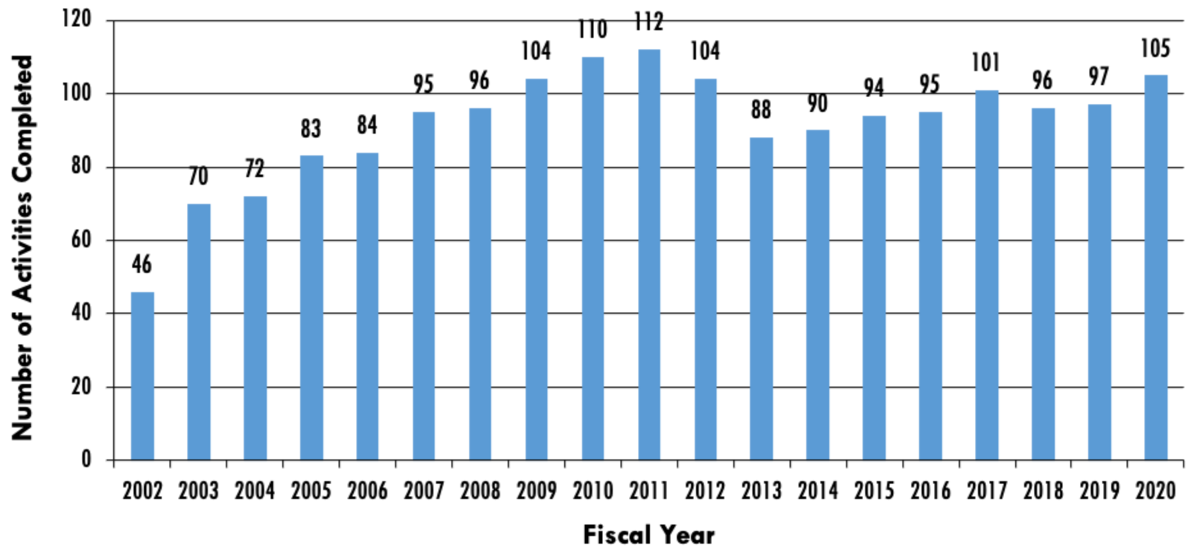


Figure 4.5. Y-12 pollution prevention initiatives

Pollution Prevention and Source Reduction

Across Y-12, sustainable initiatives have been embraced to reduce the impact of pollution on the environment and to increase operational efficiency. Many of Y-12's sustainable initiatives have pollution prevention benefits or targets eliminating the source of pollution, including the 2020 activities highlighted in this section.

Sustainable Acquisition—Environmentally Preferable Purchasing

Sustainable products, including recycled-content materials, are procured for use across Y-12. In 2020, Y-12 procured recycled-content materials valued at more than $10.2 million for use at the site.

Solid Waste Reduction

At Y-12, unneeded materials are not automatically assumed to be wastes requiring disposal. Y-12 uses a systematic disposition evaluation process. The first step in the disposition process is to determine if the items can be reused at Y-12. Items that cannot be reused at Y-12 are evaluated for use at other DOE facilities or government agencies. Items are then evaluated for potential sale; recycle; or, as a last resort, disposal as waste. Tennessee does not have a waste-to-energy facility for nonhazardous solid municipal or construction and demolition waste.

In 2020, Y-12 diverted 46.7 percent of municipal and 46.9 percent of construction and demolition waste from landfill disposal through reuse and recycle. Y-12 diverted more than 2.4 million lbs. of municipal materials from landfill disposal through source reduction, reuse, and recycling in FY 2020. More than 41.2 million lbs. of construction and demolition materials were diverted from landfill disposal in FY 2020.

Hazardous Chemical Minimization

Generator Services Group provides a material disposition management service for generators at Y-12, which includes the technical support aspect to assist generators with determining whether the materials can be recycled, excessed, or reused rather than determining all materials received must be declared as a waste. Generator Services Group can be used by any department or generator at Y-12. During FY 2020, Generator Services Group personnel, rather than declaring materials as waste, reused or disseminated to other Y-12 organizations for reuse, various excess materials and chemicals. In FY 2020, Utilities Management retro-filled 20 transformers with a bio-based transformer fluid, which has a lower flammability rating than the previously used transformer fluid. The transformer retro-fill project not only supported site sustainable acquisition methods, but also recycled 16,770 gal of transformer fluid. The Infrastructure Paint Shop developed a list of standard paint colors for routine applications to reduce the generation of unneeded paint from custom color requests.

Recycling

Y-12 has a well-established recycling program and continues to identify new material streams and expand the types of materials that can be recycled by finding new markets and outlets for the materials. As shown in Figure 4.6, more than 3.87 million lbs. of materials were diverted from landfills and into viable recycle processes during 2020. Currently, recycled materials range from office-related materials to operations-related materials, such as scrap metal, tires, and batteries. Y-12 adds at least one new recycle stream to the Recycle Program each year to continue to increase the waste diversion rate. The Recycle Program was expanded in FY 2020 to include painted pallets to broaden waste diversion efforts.

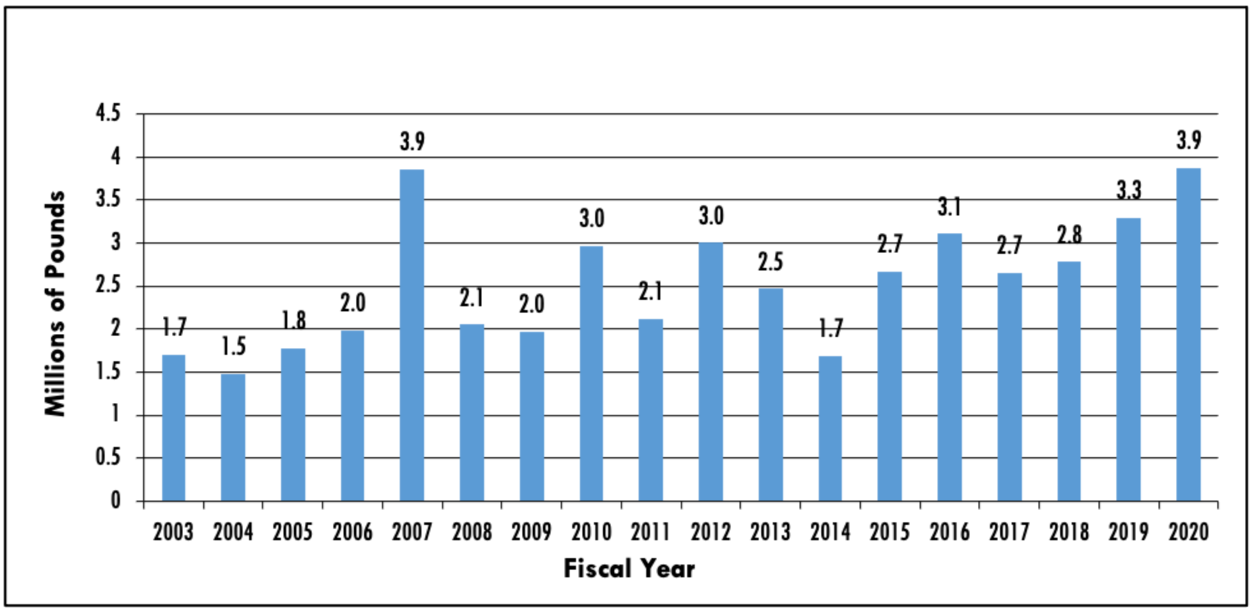
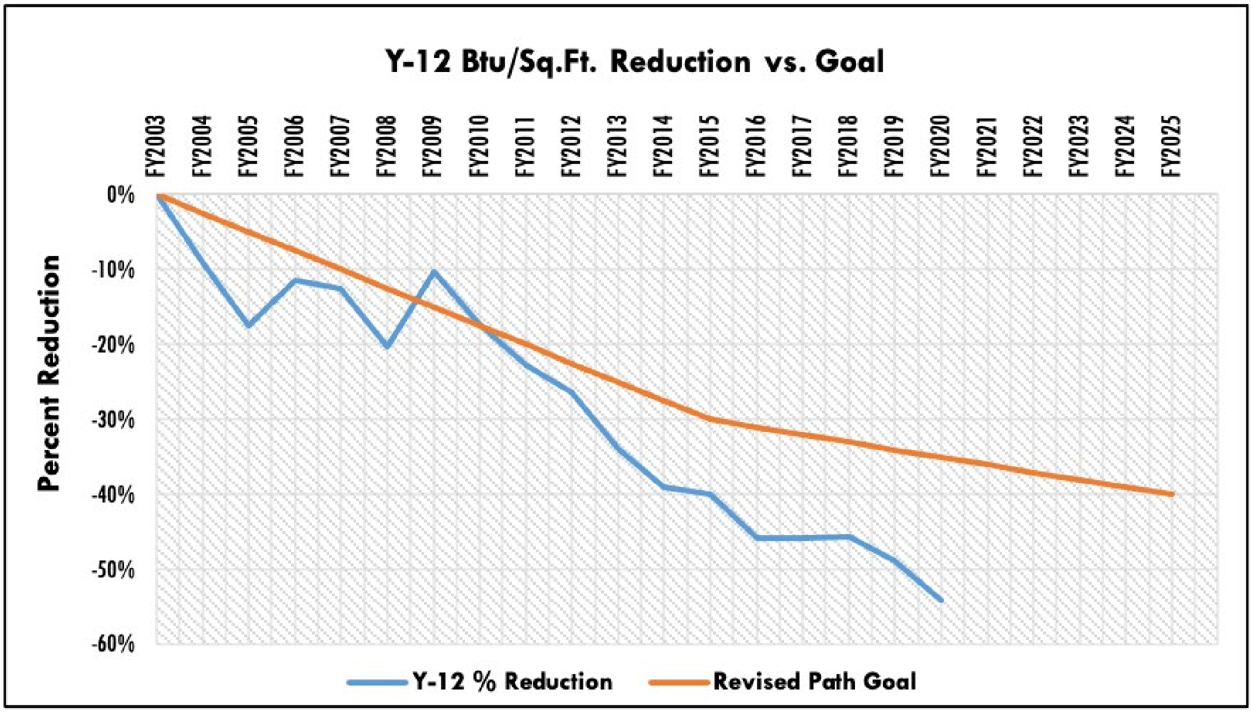


Figure 4.6. Y-12 recycling results

4.2.6.3. Energy Management

The mission of Y-12's Energy Management Program is to incorporate energy-efficient technologies sitewide and to position Y-12 to meet NNSA energy requirement needs and reduction requirements set forth by DOE. The program identifies improvements in energy efficiency in facilities, coordinates energy-related efforts across the site, and promotes employee awareness of energy conservation programs and opportunities.

Y-12 statuses Energy Management goals in accordance with Executive Order 13834, Efficient Federal Operations (Executive Order 2018), and DOE Sustainability Performance Office Guidance. The FY 2019-established goal was a 30-percent energy intensity reduction by FY 2015 from a FY 2003 baseline and a 1-percent reduction each year thereafter. Y-12 had a 39.9-percent reduction by FY 2015 (see Figure 4.7 below), with an additional 14.1-percent reduction in the FY 2015 to FY 2020 timeframe, for a total reduction of 54.09 percent (Figure 4.7).



Acronym:
FY = fiscal year

Figure 4.7. Y-12 energy intensity chart with baseline

Significant reductions have been noted with ESPCs implementation at Y-12. Specific ESPC initiatives that aided in reducing energy consumption at Y-12 include:

- Completing a new, more-efficient Air Compressor Plant at the end of FY 2016.
- Upgrading light fixtures with T-8 fluorescent lighting and light-emitting diode across the entire site.
- Replacing steam with natural gas in areas that do not require it for process purposes.
- Upgrading chillers with new, high-efficiency, variable-speed modes; retrofitting existing chillers with efficient controls; replacing constant-speed chilled water pumps with a variable-speed type; and replacing tower pumps, steam controls, and control valves.
- Replacing Cooling Towers.

- Adding energy meters to buildings that previously had none to better capture waste and to track savings.
- Upgrading heating, venting, and air conditioning systems to be compatible with Metasys, allowing for remote adjustment of louvers, dampers, set points, and motor speeds.

4.2.6.4. Dashboard Reporting and the Y-12 Complex Site Sustainability Plan

DOE is required to meet sustainability goals mandated by statute and related EOs, including goals for GHG emissions, energy and water use, fleet optimization, green buildings, and renewable energy. In 2020, the Sustainability Performance Office used the web-based DOE Sustainability Dashboard to collect DOE site-level sustainability data and to consolidate these data sets on behalf of the Department. The Sustainability Dashboard focuses on specific sustainability goals, and Site Sustainability Plans are completed within the Dashboard. These goals are established by the DOE Sustainability Performance Office and are found in Table 4.1, along with the current Y-12 performance ratings.

Table 4.1. Fiscal year 2020 sustainability goals and performance

DOE goal	Current performance status
Energy management	
Zero percent energy intensity (Btu per gross ft2) reduction in goal-subject buildings by FY 2015 from a FY 2003 baseline and 1.0% YOY thereafter	**Goal Met:** Y-12 achieved a 39% energy intensity reduction in FY 2015 from a FY 2003 baseline. For FY 2020, Y-12 achieved a 10% reduction from FY 2019, which exceeds the targeted 1% reduction.
Energy Independence and Security Act Section 432 continuous (4-yr cycle) energy and water evaluations.	**Goal Met:** Y-12 conducts Energy and Independence and Security Act evaluations on a continuous 4-yr cycle.
Meter all individual buildings for electricity, natural gas, steam, and water, where cost-effective and appropriate.	**Goal Not Met:** Y-12 meters all utilities; however, not all appropriate buildings are currently metered.
Water management	
Twenty percent potable water intensity (gal per gross ft2) reduction by FY 2015 from a FY 2007 baseline and 0.5% YOY thereafter.	**Goal Met:** Y-12 achieved a 62% energy intensity reduction in FY 2015 from a FY 2007 baseline. For FY 2020, Y-12 achieved a 12% reduction from FY 2019, which exceeds the targeted 0.5% reduction.
Nonpotable freshwater consumption (gal) reduction of industrial, landscaping, and agricultural water. YOY reduction; no set target.	**Goal Not Applicable:** Y-12 does not use industrial, landscaping, and agricultural water.
Waste management	
Reduce at least 50% of nonhazardous solid waste, excluding construction and demolition debris, sent to treatment and disposal facilities.	**Goal Not Met:** 46.7% (1,088 metric tons of construction debris and 2,329 metric tons of demolition debris) of nonhazardous waste diverted from the landfill.

Table 4.1. Fiscal year 2020 sustainability goals and performance (continued)

DOE goal	Current performance status
Reduce construction and demolition materials and debris sent to treatment and disposal facilities. YOY reduction; no set target.	**Goal Met:** 46.9% (18,700 metric tons of construction debris and 39,884 metric tons of demolition debris) of materials were diverted from the landfill in FY 2020 in comparison to 38.6% diverted in FY 2019. Increased Office of Environmental Management construction and demolition activities resulted in a large volume of construction and demolition debris that was not suitable for reuse and recycle.
Fleet management	
Twenty percent reduction in annual petroleum consumption by FY 2015 relative to a FY 2005 baseline and 2.0% YOY thereafter.	While Y-12 met this goal prior to FY 2015, and the 2.0% YOY thereafter, the addition of 34 vehicles to the Y-12 fleet inventory in FY 2020 increased fuel consumption accordingly (8.7%). The UPF project vehicle inventory additions alone in FY 2020 acquired 264,651 mi, and that project is set to continue for the next 5 yr.
Ten percent increase in annual alternative fuel consumption by FY 2015 relative to a FY 2005 baseline; maintain 10% increase thereafter.	**Not Applicable:** Alternative fuel is not available in the vicinity of Y-12, and an Energy Policy Act 701 waiver has been granted exempting Y-12 from this requirement. However, once a new fueling station is constructed and in service onsite, E-85 will be used in all alternative fuel-capable vehicles.
Seventy-five percent of light-duty vehicle acquisitions must consist of alternative fuel vehicles.	**Metric achieved:** Any future acquisitions of light-duty vehicles will include alternative fuel vehicles.
Clean and renewable energy	
Renewable electric energy is required to account for not less than 7.5% of a total agency electric consumption by FY 2013 and each year thereafter.	**Goal Met:** The FY 2019 anticipated amount was 7.5%. Y-12 receives renewable energy credits from Pantex under the shared contract structure. This allows both sites to meet this goal.
Continue to increase nonelectric thermal usage. YOY increase; no set target but an indicator in the Office of Management and Budget scorecard.	Y-12 will continue to update buildings from steam to natural gas. This increases natural gas efficiencies and decreases steam loss.
Acquisition and procurement	
Promote sustainable acquisition and procurement to the maximum extent practicable, ensuring bio-preferred and bio-based provisions and clauses are included in all applicable contracts.	**Goal Met:** All contracts issued after October 1, 2013, contain the sustainable acquisition requirements.
Measures, funding, and training	
Site set annual targets for sustainability investment with appropriated funds and/or financed contracts for implementation.	**Goal Met:** Y-12 has supported performance contracts issued by NNSA. These contracts have been instrumental in achieving energy, water, building modernization, and infrastructure goals at Y-12.

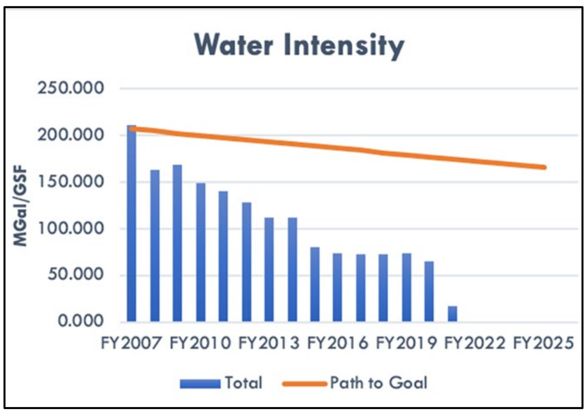
Table 4.1. Fiscal year 2020 sustainability goals and performance (continued)

DOE goal	Current performance status
Electronic stewardship	
End of life: 100% of used electronics are reused or recycled using environmentally sound disposition options each year.	**Goal Met:** Y-12's electronics recycling vendor maintained R2 certification; therefore, all FY 2020 shipments were made to a R2-certified recycler. Electronics that were not recycled were those that could not be radiologically cleared for release. Therefore, 100% of eligible electronics were recycled to a R2-certified recycler.
Data center efficiency: Establish a power usage effectiveness target for new and existing data centers; discuss efforts to meet targets.	**Goal Not Met:** Y-12 data centers are not currently metered; current power usage effectiveness is estimated to be <2.4.
Organizational resilience	
Discuss overall integration of climate resilience in emergency response, workforce, and operations procedures and protocols.	**Goal Met:** The Y-12 Severe Event Emergency Response Plan addresses severe natural phenomena events, extended loss of power events, and events that result in loss of mutual aid. The site is monitoring the increased number of events as related to grand solar minimum of activity.
Multiple categories	
YOY Scope 1 and Scope 2 GHG emissions reduction from a FY 2008 baseline.	**Goal Met:** Site Scope 1 and Scope 2 GHG emissions have been reduced by 23% from a 2008 baseline. Contributing energy-reduction efforts can be attributed to major initiatives involving infrastructure improvements completed through ESPC projects.
YOY Scope 3 GHG emissions reduction from a FY 2008 baseline.	**Goal Met:** Site Scope 3 emissions decreased by 9.8% from FY 2019 (32,704 MtCO2e) to FY 2020 (29,491 MtCO2e). Overall, Scope 3 emissions have decreased by 7.5% since the FY 2008 baseline (31,894.5 MtCO2e). The reduction in Scope 3 emissions in FY 2020 is primarily due to a severe reduction in business travel due to the COVID-19 pandemic.

Acronyms:
DOE = US Department of Energy
ESPC = Energy Savings and Performance Contracts
FY = fiscal year
GHG = greenhouse gas
MtCO2e = metric tons of carbon dioxide equivalent
NNSA = National Nuclear Security Administration
UPF = Uranium Processing Facility
Y-12 = Y-12 National Security Complex
YOY = year over year

4.2.6.5. Water Conservation

The current DOE water intensity goal is a 20-percent reduction from a FY 2007 baseline by FY 2015 and year-to-year reductions of 0.5 percent thereafter. As seen in Figure 4.8, Y-12 surpassed the initial FY 2015 goal with a 62-percent reduction. In FY 2020, Y-12's water intensity rating was 64.97 gal/ft^2, which is a 12-percent decrease from 2019 and a 69-percent reduction from FY 2007. However, Y-12 is currently meeting the year-to-year reduction goal and is seeing considerable savings when compared to the 2007 baseline. This year's decrease can be largely attributed to the large amount of individuals who teleworked throughout the majority of FY 2020, thus using no on-site potable water for activities. To date, according to the Site President and Chief Executive Officer, 20 percent of the workforce remains at home teleworking, thus this trend is expected to affect FY 2021 numbers as well.



Acronyms:
FY = fiscal year
GSF = gross square feet
Mgal = millions of gallons

Figure 4.8. Water intensity reduction with baseline

All potable water consumed at Y-12 originates from Melton Hill Lake as raw water and is pumped across the ridge to the City of Oak Ridge water treatment plant, which is located within the Y-12 boundary. Y-12 purchases potable water from the city for all domestic and industrial applications. Actions that have contributed to overall reduction in potable water use include:

- Repairing and improving steam traps
- Installing, repairing, and rerouting condensate returns
- Replacing once-through air handling units
- Installing low-flow fixtures
- Replacing chillers
- Replacing cooling towers
- Replacing steam with natural gas in buildings
- Ceasing concrete batch plant activities in support of the UPF project

Most potable water is not metered at the point of use at Y-12, but an evaluation based on known data, facility usage, and other factors provides an estimated assessment of the usage by type. Cooling towers, production facilities, and maintenance-related activities comprise the largest consumers on the Y-12 site. Through ESPC and utility efficiency improvement initiatives, the site is seeing significant improvement in water consumption. Since FY 2020, Y-12 has been aggressively pursuing a metering strategy to capture potable water usage on the building-level and, to date, has added 10 potable water meters on various buildings across the site.

4.2.6.6. Fleet Management

The Y-12 site is currently undergoing a massive construction phase, including the UPF project along with the new Mercury Treatment Facility and multiple other construction projects. The Y-12 fleet inventory tasked with supporting these projects, along with the normal day-to-day processes at the plant, is comprised of a total of 624 vehicles, which includes 125 agency-owned units, 485 leased from the General Services Administration, and 14 commercially leased Special Purpose vehicles during FY 2020. The inventory consists of sedans; light-duty trucks, vans, and sport utility vehicles; medium-duty trucks, vans, and sport utility vehicles; and heavy-duty trucks. During FY 2020, Y-12 exchanged 14 older General Services Administration-leased vehicles with new units. The new replacements

(General Services Administration-leased and agency-owned) were all ordered with alternative fuel capabilities when available, and these new vehicles all have better fuel consumption and GHG emission figures than the older vehicles that were replaced.

The Y-12 vehicle fleet achieved a 99.35-percent vehicle utilization rate for FY 2020 compared to 99 percent the previous year, and the four vehicles that did not meet that goal are being reassigned to maximize vehicle utilization at the site. Fuel (diesel and gasoline) consumption at Y-12 was reduced by 8.7 percent compared with 4.7 percent for FY 2019.

Currently, Y-12 does not have an on-site fuel station and does not use alternative fuel, based on a FY 2019 DOE-approved Energy Policy Act 701 waiver, because alternative fuel is not available near the site. Y-12 continues to implement an interim refueling process using mobile tanker trucks to perform vehicle and equipment fueling operations until a new fuel center is constructed at the site. The mobile tanker trucks only have capacity to provide diesel and unleaded gasoline.

4.2.6.7. Electronic Stewardship

Y-12 has implemented a variety of electronic stewardship activities, including virtualizing servers, creating virtual desktop infrastructure, procuring energy-efficient computing equipment, reusing and recycling computing equipment, replacing aging computing equipment with more energy-efficient equipment, and reconfiguring data centers to achieve more energy-efficient operations. Approximately 98.7 percent of desktop computers, laptops, monitors, and thin clients purchased or leased during FY 2020 were registered Electronic Product Environmental Assessment Tool products. Y-12's standard desktop configuration specifies the procurement of Electronic Product Environmental Assessment Tool-registered and Energy Star-qualified products.

4.2.6.8. Greenhouse Gases

Compared to the FY 2008 baseline, Y-12 Scope 1 and Scope 2 GHG emissions have been reduced. Emission reductions can be attributed primarily to decreased Scope 1 (on-site fuel burning) emissions from more-efficient steam generation and decreased Scope 2 (purchased electricity) emissions from energy efficiency projects.

Purchased electricity is by far the biggest contributor to Y-12's GHG footprint. Energy-reduction efforts include major initiatives involving production facilities and utility infrastructure completed through ESPC projects.

4.2.6.9. Storm Water Management and the Energy Independence and Security Act of 2007

The Energy Independence and Security Act of 2007, Section 438 requires federal agencies to reduce storm water runoff from development and redevelopment projects to protect water resources. Y-12 complies with these requirements using a variety of storm water management practices, often referred to as green infrastructure or low-impact development practices. During the last few years, several green infrastructure initiatives have been implemented to reduce the size and number of impervious surfaces through the use of sustainable vegetative practices and porous pavements. No project actions contributed to the overall prevention of storm water runoff during CY 2020.

4.2.7. Awarding and Recognizing

Since November 2000, the commitment to environmentally responsible operations at Y-12 has been recognized, with more than 153 external environmental awards from local, state, and national agencies. The awards received in 2020 are summarized below.

4.2.7.1. Electronic Product Environmental Assessment Tool Award

In FY 2020, Y-12 received an Electronic Product Environmental Assessment Tool Purchaser 5 Star Level Award for Excellence in Green Procurement of Electronics in recognition of Y-12's procurement of sustainable information technology products. Y-12 was recognized by the Green Electronics Council at the 5 Star Level for purchasing Electronic Product Environmental Assessment Tool electronics in the following categories during FY 2019: computers and displays (including desktops, notebooks, workstations, integrated systems, and tablets), imaging equipment (copiers, scanners, and multifunction devices), televisions, mobile phones, and servers.

4.2.7.2. DOE Sustainability and National Nuclear Security Administration Excellence Awards

Y-12 received the following 2020 DOE Sustainability Awards:

- The Sustainability Lifetime Achievement Award was presented to NPO's Jim Donnelly for using his comprehensive oversight position in NPO to green Y-12 by challenging Y-12 to meet and exceed sustainability goals and supporting innovative sustainable implementation.
- The Innovative Approach to Sustainability Award was presented to Y-12 and the UPF Pervious Paving Team for expanding parking capacity in a sustainable manner to meet the needs of the growing site population.

Y-12 also received an NNSA Office of Safety, Infrastructure, and Operations (NA-50) Excellence Award for exceptional accomplishment during 2019 for the Building 9720-58 (Y-12 Recycle Center) Fire System Conversion Project Team.

4.3. Compliance Status

During 2020, Y-12 operations were conducted to comply with contractual and regulatory environmental requirements. Table 4.2 presents a summary of environmental audits conducted at Y-12 in 2020. The following discussions summarize the major environmental programs and activities carried out at Y-12 and provide an overview of the compliance status for the year.

4.3.1. Environmental Permits

Table 4.3 lists environmental permits in force at Y-12 during 2020. More-detailed information can be found in the following sections.

Table 4.2. Summary of external regulatory audits and reviews, 2020

Date	Reviewer	Subject	Issues
01/24	City of Oak Ridge	Semiannual Industrial Pretreatment Compliance Inspection	0
08/19	TDEC	Annual RCRA Hazardous Waste Compliance Inspection	0
07/29	TDEC	Annual Air Quality Compliance Inspection	0
10/02	City of Oak Ridge	Semiannual Industrial Pretreatment Compliance Inspection	0

Acronyms:
RCRA = Resource Conservation and Recovery Act
TDEC = Tennessee Department of Environment and Conservation

Table 4.3. Y-12 environmental permits, calendar year 2020

Regulatory driver	Title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
CAA	Title V Major Source Operating Permit	571832	12/1/17	11/30/22	DOE	DOE	CNS
CWA	Industrial and Commercial User Wastewater Discharge (Sanitary Sewer) Permit	1-91	07/01/17	03/31/21	DOE	DOE	CNS
CWA	NPDES Permit	TN0002968	10/31/11	11/30/16[a]	DOE	DOE	CNS
CWA	UPF 401 Water Quality Certification/Aquatic Resource Alteration Permit Access/Haul Road	NRS10.083	06/10/10	Upon Notice of Termination	DOE	DOE	CNS
CWA	UPF Department of Army Section 404 CWA Permit	2010-00366	09/02/10	Upon Notice of Termination	DOE	DOE	CNS
CWA	UPF General Storm Water Permit Y-12 (41.7 ha/103 acres)	TNR 134022	10/27/11	Upon Notice of Termination	DOE	CNS	CNS
CWA	UPF NPDES General Permit for Construction Storm Water	TNR135568	08/06/18	Upon Notice of Termination	DOE	BNI	BNI
CWA	Central Training Facility Berm Reinvestment Project NPDES Construction General Permit	TNR 135924	10/01/19	Upon Notice of Termination	DOE	DOE	CNS
CWA	Y-12 Outfall 014 Repair Aquatic Resource Alteration Permit	NR1903.116	06/21/19	04/12/21	DOE	DOE	CNS
CWA	Central Training Facility Berm Aquatic Resource Alteration Permit	NR1903.096	05/15/19	04/06/21	DOE	DOE	CNS
CWA	Bear Creek Road Power Installation	TNR 136037	02/19/20	Upon Notice of Termination	DOE	DOE	CNS
CWA	No Discharge Portal 20 Pump and Haul Permit	SOP-17014	07/08/17	07/01/22	DOE	DOE	CNS
CWA	No Discharge Portal 23 Pump and Haul Permit	SOP-17015	07/08/17	07/01/22	DOE	DOE	CNS
CWA	No Discharge Portal 19 Pump and Haul Permit	SOP-13031	06/26/18	06/30/23	DOE	DOE	CNS

Table 4.3. Y-12 environmental permits, calendar year 2020 (continued)

Regulatory driver	Title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
CWA	No Discharge Environmental Management Waste Management Facility Pump and Haul Permit	SOP-01043	09/01/17	08/31/22	DOE	UCOR	UCOR
RCRA	Hazardous Waste Transporter Permit	TN3890090001	12/16/19	01/31/21	DOE	DOE	CNS
RCRA	Hazardous Waste Corrective Action Permit	TNHW-164	09/15/15	09/15/25	DOE	DOE, NNSA, and all ORR co-operators of hazardous waste permits	UCOR
RCRA	Hazardous Waste Container Storage Units	TNHW-122	08/31/05	08/31/15[a]	DOE	DOE/CNS	CNS/ LATS co-operator
RCRA	Hazardous Waste Container Storage and Treatment Units	TNHW-127	10/06/05	10/06/15[a]	DOE	DOE/CNS	CNS co-operator
Solid Waste	Industrial Landfill IV (operating, Class II)	IDL-01-000-0075	Permitted in 1988—most recent modification approved 12/18/18	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Industrial Landfill V (operating, Class II)	IDL-01-000-0083	Initial permit, most recent modification approved 12/18/18	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Construction and Demolition Landfill (overfilled, Class IV subject to CERCLA ROD)	DML-01-000-0012	Initial permit 01/15/86	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Construction and Demolition Landfill VI (postclosure care and maintenance)	DML-01-000-0036	Permit terminated by TDEC 03/15/07	N/A	DOE	DOE/UCOR	UCOR
Solid Waste	Construction and Demolition Landfill VII (operating, Class IV)	DML-01-000-0045	Initial permit, most recent modification approved 11/16/18	N/A	DOE	DOE/UCOR	UCOR

Table 4.3. Y-12 environmental permits, calendar year 2020 (continued)

Regulatory driver	Title/description	Permit number	Issue date	Expiration date	Owner	Operator	Responsible contractor
Solid Waste	Centralized Industrial Landfill II (postclosure care and maintenance)	IDL-01-000-0189	Most recent modification approved 05/08/92	N/A	DOE	DOE/UCOR	UCOR
SDWA	Underground Injection Control Class V Injection Well Permit	Permit by Rule, TDEC Rule 0400-45-06	03/12/02	None	DOE	DOE	CNS

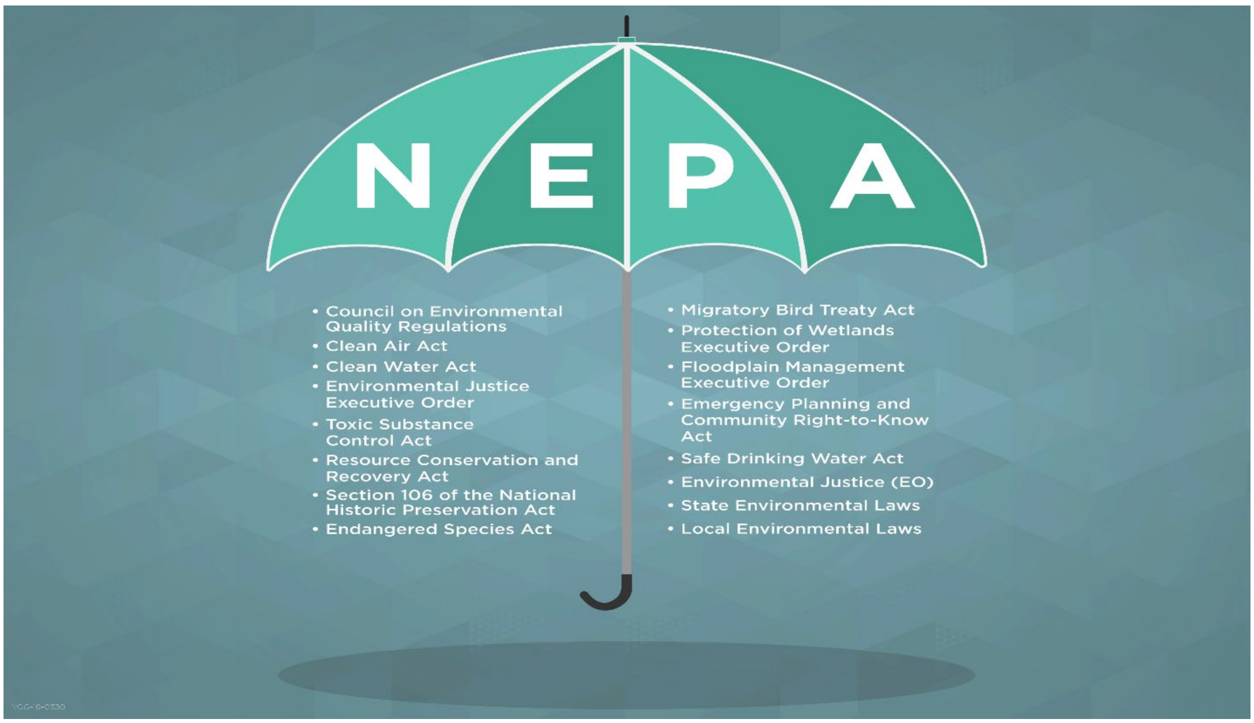
[a] Continue to operate in compliance pending TDEC action on renewal and reissuance.

Acronyms:

BNI = Bechtel National Inc.
CAA = Clean Air Act
CERCLA = Comprehensive Environmental Response, Compensation, and Liability Act
CNS = Consolidated Nuclear Security, LLC
CWA = Clean Water Act
DOE = U.S Department of Energy
LATS = LATA-Atkins Technical Services, LLC
N/A = not applicable
NNSA = National Nuclear Security Administration
NPDES = National Pollutant Discharge Elimination System
ORR = Oak Ridge Reservation
RCRA = Resource Conservation and Recovery Act
ROD = Record of Decision
SDWA = Safe Drinking Water Act
TDEC = Tennessee Department of Environment and Conservation
UCOR = URS | CH2M Oak Ridge LL
UPF = Uranium Processing Facility
Y-12 = Y-12 National Security Complex

4.3.2. National Environmental Policy Act and National Historic Preservation Act

As federal agencies, DOE and NNSA comply with National Environmental Policy Act (NEPA) requirements (procedural provisions, 40 Code of Federal Regulations [CFR] 1500 through 1508), as outlined in DOE's NEPA Implementing Procedures (10 CFR 1021). NNSA's commitment to NEPA is performed by thoroughly evaluating the potential impacts of proposed federal actions that affect the quality of the environment at Y-12. NNSA ensures that reasonable alternatives for implementing such actions have been considered in the decision-making process and that such decisions are documented in accordance with DOE and NNSA and the Council on Environmental Quality regulations. Such a prescribed evaluation process ensures that the proper level of environmental review (called a NEPA review), while considering other statutory requirements (NEPA is often referred to as the umbrella law; see Figure 4.9), is performed before an irreversible commitment of resources is made.



Acronym:
NEPA = National Environmental Policy Act

Figure 4.9. National Environmental Policy Act—an umbrella law

In March 2011, the Final *Site-Wide Environmental Impact Statement for the Y-12 National Security Complex* (DOE 2011b) was issued. The Site-Wide Environmental Impact Statement (SWEIS) analyzed potential environmental impacts of ongoing and future operations (missions) and activities at Y-12, including alternatives to changes in site infrastructure (including the UPF) and levels of operation. The SWEIS and the Notice of Availability were published on March 4, 2011 (DOE-EIS-0387). NNSA issued a Record of Decision (ROD) in July 2011 (EIS-0387 ROD) (DOE 2011c). Since the ROD, NNSA has updated the strategy and design approach for the UPF. NNSA would use a hybrid approach of upgrading existing Y-12 facilities and building multiple UPF facilities, which was consistent with recommendations from a project peer review of the UPF, *Final Report of the Committee to Recommend Alternatives to the Uranium Processing*

Facility Plan in Meeting the Nation's Enriched Uranium Strategy (ORNL 2014). The updated UPF strategy was addressed in detail in a Supplement Analysis (SA) for the Final SWEIS (DOE 2016a; EIS-0387-SA-01), and NNSA amended the ROD (DOE 2016b, 81 Federal Register 45138) on July 22, 2017.

In July 2017, the Oak Ridge Environmental Peace Alliance, Nuclear Watch New Mexico, and Natural Resources Defense Council and four individual plaintiffs filed a federal lawsuit asserting that NNSA had violated NEPA by failing to prepare a supplemental SWEIS. Among other things, the plaintiffs argued that NNSA should prepare a supplemental SWEIS due to significant new information that became known after the publication of the 2011 SWEIS. More specifically, plaintiffs asserted that the seismic risk in East Tennessee had increased, as evidenced by seismic hazard maps published in 2014 by the US Geological Survey.

In August 2018, NNSA prepared another SA to the Y-12 SWEIS (DOE/EIS-0387-SA-03) (NNSA 2018), which evaluated the environmental impacts of continuing site operations against the existing Y-12 SWEIS to determine if significant changes or new information warranted a supplemental or new SWEIS. In the 2018 SA, NNSA determined Y-12 continuing operations were not significantly different from those evaluated in the 2011 SWEIS.

On September 24, 2019, a Memorandum Opinion and Order was issued by the US District Court for the Eastern District of Tennessee as a result of the July 2017 federal lawsuit (USDC 2019). The Court ruled that NNSA is not required to prepare a new or supplemental SWEIS due to the decision to construct a smaller-scale UPF project and continue some EU operations in the Extended Life Program facilities. However, the Court also ruled that "new information revealed since the 2011 SWEIS requires further analysis," and consistent with that ruling, the Court vacated the 2016 SA, the 2016 Amended ROD (AROD), and the 2018 SA. Further, the Court ordered that NNSA "shall conduct further NEPA analysis—including at a minimum, a supplemental analysis—that includes an unbounded accident analysis of earthquake consequences at the Y-12 site, performed using updated seismic hazard analyses that incorporated the 2014 US Geological Survey map." The Court also ruled that 69 categorical exclusion determinations were in violation of NEPA and ordered "the relevant exclusions should be prepared in a manner consistent with the letter of the relevant DOE regulations." Consistent with the Court Order, NNSA has appropriately revised those categorical exclusion determinations for projects that were still ongoing at the time of the Court's Order.

On October 4, 2019, NNSA amended its July 2011 ROD for the Y-12 SWEIS to reflect its decision to continue to implement, on an interim basis, the hybrid approach previously approved in the vacated 2016 AROD. As the Court previously ruled in its Order, that hybrid approach, which combined elements of the two alternatives previously analyzed in the Y-12 SWEIS, was adequately analyzed within the range of alternatives considered in the Y-12 SWEIS. The 2019 AROD enables NNSA to conduct the required additional NEPA documentation, while continuing to implement safety improvements previously approved in the 2016 AROD, pending completion of the additional analysis ordered by the Court. Pursuant to the Court's Order, NNSA published the Draft *Supplemental Analysis for the Site Wide Environmental Impact Statement for the Y-12 National Security Complex, Earthquake Accident Analysis* (NNSA 2020) for public comment on April 9, 2020. The purpose of the SA was to determine whether the earthquake consequences constitute a substantial change that is relevant to environmental concerns, or if significant new circumstances or information relevant to environmental concerns and bearing on continued operations at Y-12 exist compared to the analysis in the 2011 SWEIS. The Draft SA was made available for public review and comment, and 142 comments were received. The Final SA was issued on July 15, 2020, and NNSA determined the potential impacts associated with an earthquake accident at Y-12 would not be significantly different than the impacts presented in the Y-12 SWEIS. Based on the results of this Final SA, NNSA determined: (1) the earthquake consequences and risks do not constitute a substantial change, (2) no significant new circumstances or information relevant to environmental concerns exist, and (3) no additional NEPA documentation is required at this time. On September 22, 2020, NNSA issued an AROD which reflected its decision to continue to implement its approach for meeting enriched uranium requirements, by upgrading existing enriched uranium processing buildings and constructing a new UPF. All other defense mission activities and non-defense mission activities conducted at Y-12 under the alternative selected for implementation in the 2011 ROD would continue to be implemented.

During 2020, 38 proposed actions at Y-12 were categorically excluded—4 categorical exclusion determinations approved by the NNSA NEPA Compliance Officer (Table 4.4), and 34 such actions (internal NEPA reviews) that were reviewed against and consistent with Y/TS-2312, *National Environmental Policy Act General Categorical Exclusion*, Appendix B to Subpart D of Part 1021 (B&W Y-12 2012a). The majority of the proposed actions involved infrastructure upgrades, facilities and equipment modernization, enduring facilities sustainment, bridging strategies for facilities identified with an out-year replacement, and the deactivation and demolition of facilities deemed excess to Y-12's needs. As many facilities have, or are, approaching the end of design life, substantial investment is required to ensure they remain viable for the near future. NEPA reviews and evaluation were conducted for the following projects:

- Upgrades to laboratory rooms in Building 9995
- Elevator upgrades (several buildings)
- Building mitigation actions
- Building renovations for increased office space, where available
- Security upgrade projects in prelude to WEPAR
- Decoupling of utilities and buildings from Building 9212
- Off-site housing of technologies at the Test and Demonstration Facility

Table 4.4. National Nuclear Security Administration-approved categorical exclusions

Date issued	Title
08/18/20	NEPA 4914, Demolition of Building 9404-18
06/11/20	NEPA 4909, Test and Demonstration Facility
05/27/20	CX-ORR-24-001, Property Transfer of SSP-2A to NNSA

Acronyms:
NEPA = National Environmental Policy Act
NNSA = National Nuclear Security Administration
SSP = self-sufficiency parcel

The following projects continued for FY 2020 also were reviewed:

- WEPAR project (including utility reroutes and disconnects)
- LPF (see below)
- Bridging and sustainment of current lithium-production capabilities in Building 9204-02
- Energy Savings Performance Contract, Phase III, Mod 4 projects under the Cooling and Heating Asset Management Program (environmental systems and control upgrades)
- Excess Facility Disposition Program (deactivation and demolition of excess facilities and structures)

Table 4.4 lists the 2020 categorically excluded determination forms approved by NPO and posted on the public website.

In late 2019, CNS proposed to develop and construct an ORETTC on the DOE ORR property. The ORETTC was envisioned as a state-of-the-art center with highly specialized industrial training facilities and equipment with national-level emergency response experts. Such nuclear emergency response training currently occurs in bifurcated facilities at Y-12, across the National Security Enterprise, and in non-NNSA facilities across the country. The lack of a dedicated, centralized training facility reduces training effectiveness and efficiency. The ORETTC would act as the Center of Excellence for advanced emergency response training, high-consequence operations, and processes that would challenge critical thinking and problem solving for key state, regional, national, and global collaborators. On average, about 200 to 250 personnel would be trained daily, with a maximum capacity of 500 personnel. The proposed ORETTC (Figure 4.10) would consist of: (1) a Simulated Nuclear and Radiological Activities Facility and a Technical Rescue Training Area, consisting of a Live Burn Fire Tower and Rubble Pit to be developed by NNSA at the proposed site; and (2) an Emergency Response Training Facility funded by the State of Tennessee and developed by the Roane County Industrial Board.

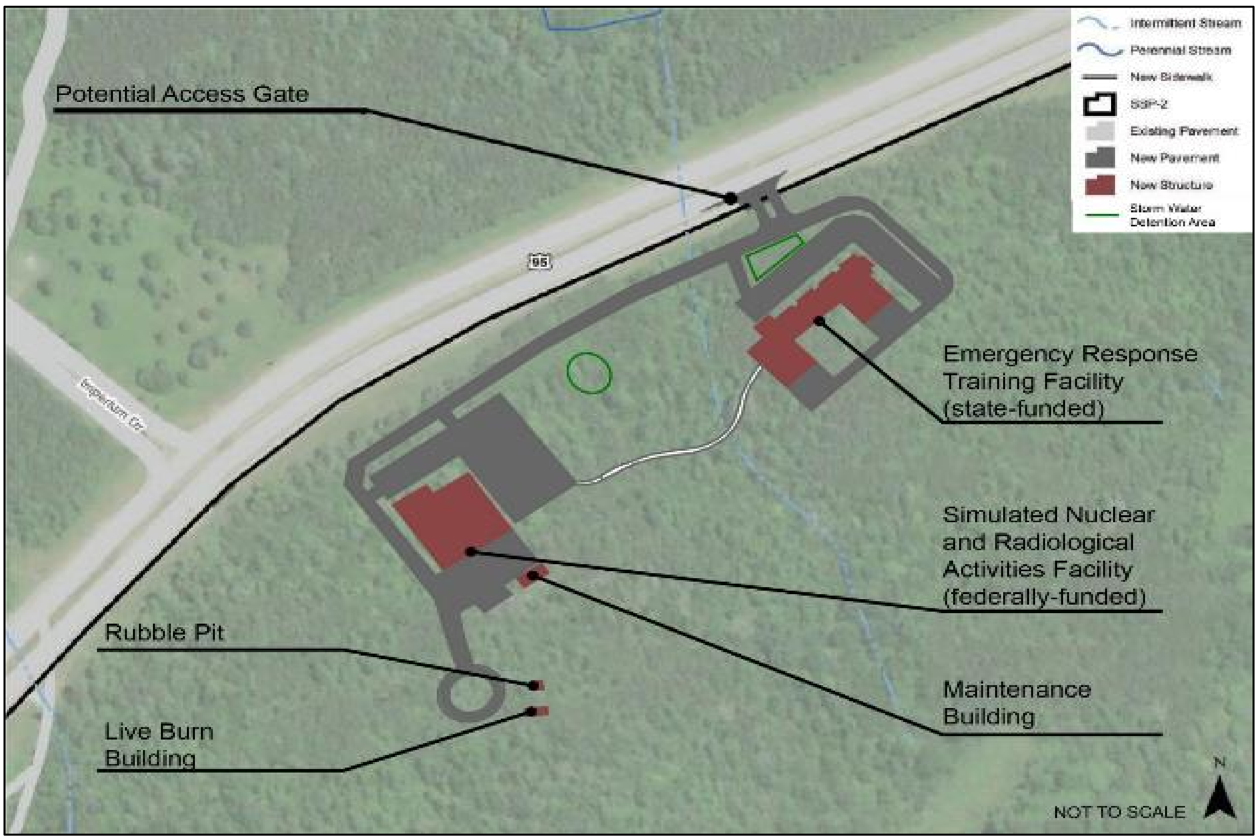
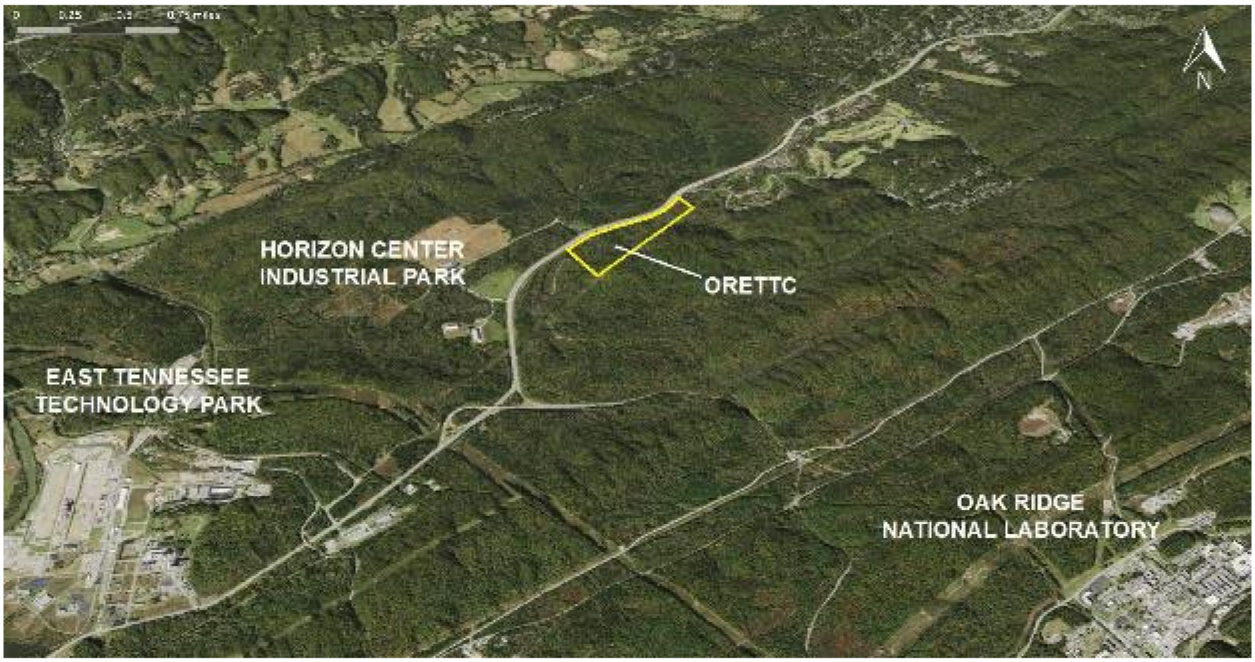


Figure 4.10. Conceptual layout of Oak Ridge Enhanced Technology and Training Center facilities at the proposed site

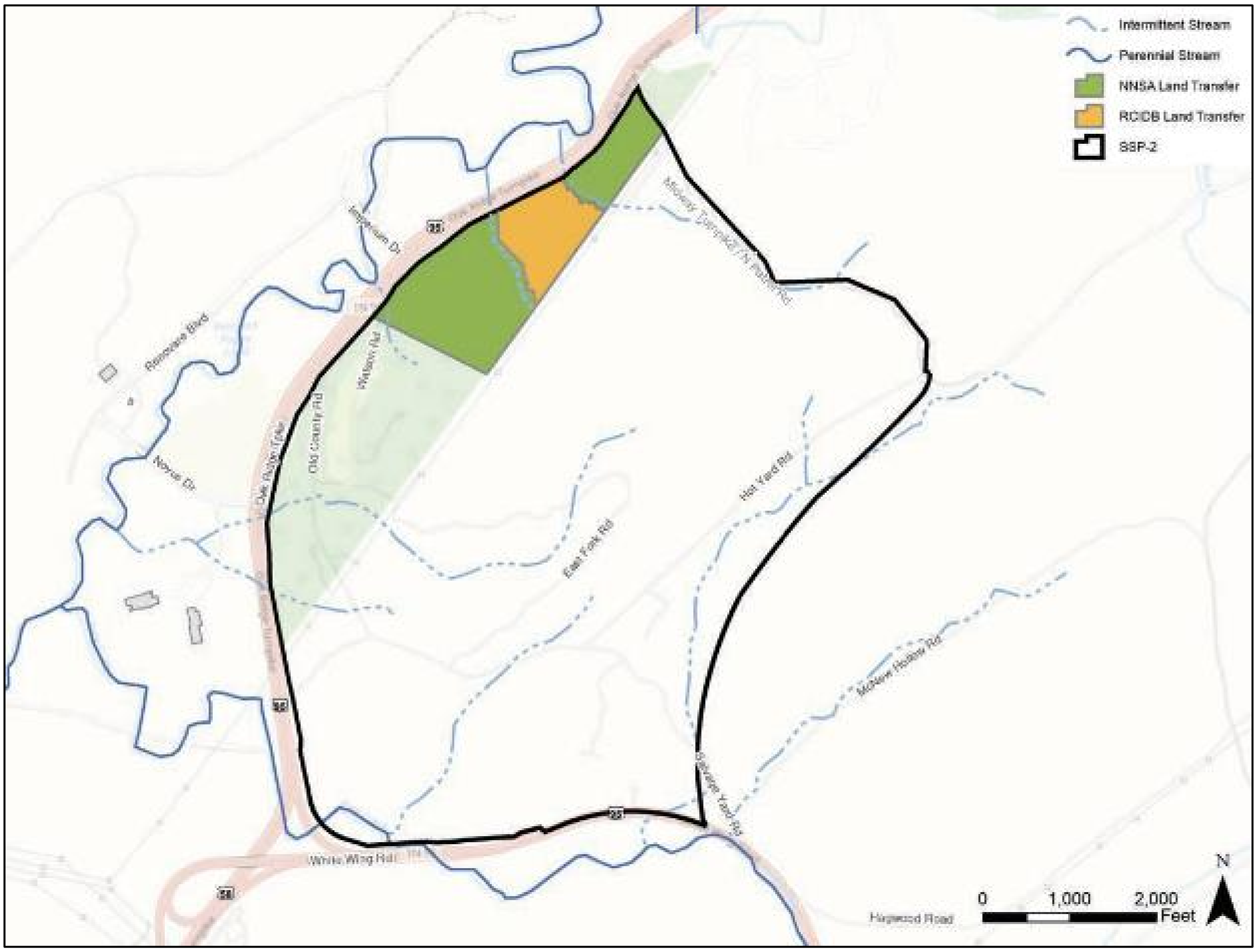
In July 2020, NNSA determined an EA (10 CFR 1021.321) was required to evaluate the proposed action—to construct and operate the ORETTC on 24 acres of DOE ORR forested land of an 81-acre parcel to be transferred to NNSA (previously disturbed land, but with considerable forest-type cover and growth). The 81-acre parcel (Figures 4.11 and 4.12) was identified as the best candidate during a site selection process and is contained in a 950-acre tract of land, identified as Self-sufficiency Parcel 2 (SSP-2). Self-sufficiency Parcel 2 required no further investigation under Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) Section 120(h) (DOE/OR/01-2568&D2). The 81-acre parcel was designated as Self-sufficiency Parcel 2A and is bounded on the northwest by the Oak Ridge Turnpike and State Route 95, on the northeast by Midway Turnpike, south across the Oak Ridge Turnpike from the Horizon Center, and about 6 mi west of Y-12. The environment assessment would evaluate an alternative (and potential environmental impacts) for the construction of the training center on 24.1 acres of the 81 acres (Figure 4.13). Of these 24.1 acres, approximately 7.7 acres would remain permanently disturbed by the facility footprint, parking lots, and the access road. The other 16.4 acres would be temporarily disturbed (i.e., surfaces would remain pervious) to grade the land and provide greenspace around the ORETTC to enhance the campus feel.



Acronym:
ORETTC = Oak Ridge Enhanced Technology and Training Center

Figure 4.11. Proposed location of the Oak Ridge Enhanced Technology and Training Center

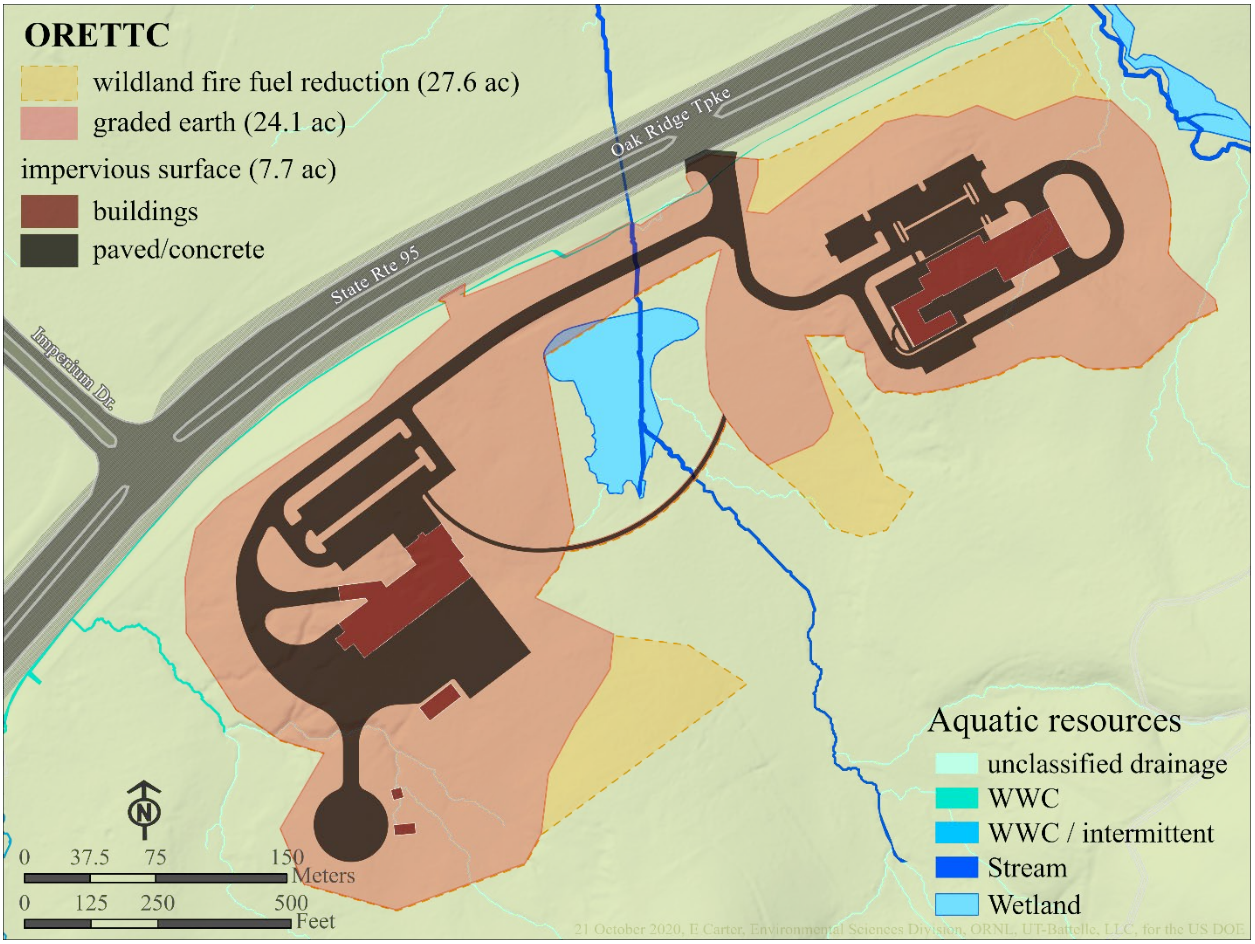
A Draft EA was published in August 2020 and eight comments were received from the public. In response to public comments, NNSA reevaluated the potential use of ETTP as a site alternative for the ORETTC and added its analysis to the Final EA. At the proposed site, the ORETTC would not be located within a 100- or 500-yr floodplain, but could potentially impact approximately 0.05 acres of wetlands. In accordance with 10 CFR 1022, NNSA prepared a Wetland Statement of Findings and determined no practicable alternative to the construction and operation of the ORETTC exists at the proposed site. In accordance with 10 CFR 1022 and Executive Order 11990, NNSA identified, evaluated, minimized, and mitigated adverse wetlands impacts associated with the construction and operation of the ORETTC at the proposed site. NNSA approved the Final EA (DOE 2020a), Wetlands Finding Statement (DOE 2020b), and Finding of No Significant Impact (DOE 2020c) on November 4, 2020.



Acronyms:
NNSA = National Nuclear Security Administration
RCCB = Roane County Industrial Board

Figure 4.12. Proposed Oak Ridge Enhanced Technology and Training Center location and land transfers

The EA document for the replacement facility for manufacturing and production capability for lithium components began in July 2020. NNSA's proposed action was to construct and operate a new LPF that would provide administrative and manufacturing space for production of lithium components. The new facility would replace Building 9204-2 and ensure Y-12 maintains the required lithium production capabilities, reduces annual operating costs, and increases processing efficiencies—using safer, more-modern, more-agile, and more-responsive processes. Y-12 is the only source of secondaries, cases, lithium components, and other nuclear weapon components for the NNSA nuclear security mission. Lithium is an essential element for refurbishing and modernizing the nuclear weapons stockpile. The EA would analyze potential environmental impacts associated with constructing and operating the LPF to process and supply the lithium material and components that are needed to support the National Security Enterprise.



Note:
Showing the Simulated Nuclear and Radiological Activities Facility and Emergency Response Training Facility buildings
Acronyms:
ORETTC = Oak Ridge Enhanced Technology and Training Center
WWC = wet weather conveyance

Figure 4.13. Artist rendering of proposed Oak Ridge Enhanced Technology and Training Center

The proposed LPF location is within the current footprint of the Biology Complex (Figures 4.14 and 4.15) on the east end of Y-12. DOE Office of Environmental Management (OREM) has committed to demolishing several of the Biology Complex buildings (currently in progress), removing slabs and/or footings, and remediating any contaminated soil. DOE OREM will need to gain regulatory concurrence that no further action will be required to address soil contamination (within the defined construction footprint) for NNSA to proceed.

The LPF would be designed and constructed to meet the high-hazard classification for occupancy described in Section 307 of the International Building Code. The LPF is anticipated to be a nonnuclear, hazardous material facility. For a nonnuclear facility, the International Building Code establishes minimum requirements to safeguard public safety and safety to life and property from fire and other hazards, and provides building classification based on the purpose(s) for which they are used. The two primary functions of the LPF are: (1) recovery and purification, and (2) processing.

Note:
Demolition is currently in process.

Figure 4.14. Biology Complex on the east side of Y-12

The constructed facility (see artist rendering in Figure 4.16) would consist of a reinforced concrete and steel structure, approximately 135,000 ft^2 in size, and made up of eight independent wings. To an outside observer, the eight wings would be adjoining such that the LPF would appear as a single structure. The majority of the LPF would be 10 to 20 ft. high, although portions of the facility with high bays would be approximately 50 ft. high. Operations would be expected to begin in about 2030. The operational workforce at the LPF is estimated to be 70 persons.

The Draft EA was approved and published in December 2020 and received seven public comments. The Final EA included noted responses to comments received, including those from TEMA. Subsequent actions related to this EA will be described in future reports.

In January 2020, CNS proposed to relocate the majority of the Y-12 Development Organization and their work to an off-site facility at the Horizon Center Industrial Park. This bridging strategy would house NNSA's research and development work for the next 15 yr. The Organization is currently housed in Buildings 9202 and 9203, which are greater than 70 yr. old, heavily contaminated, and have failing structural, electrical, ventilation, cooling water, and climate controls. To execute their mission, Y-12

Development requires facilities that safely and efficiently house the necessary research equipment and instrumentation, provide modern laboratory facilities to attract and retain top scientists and engineers, and are adaptable to a changing mission.

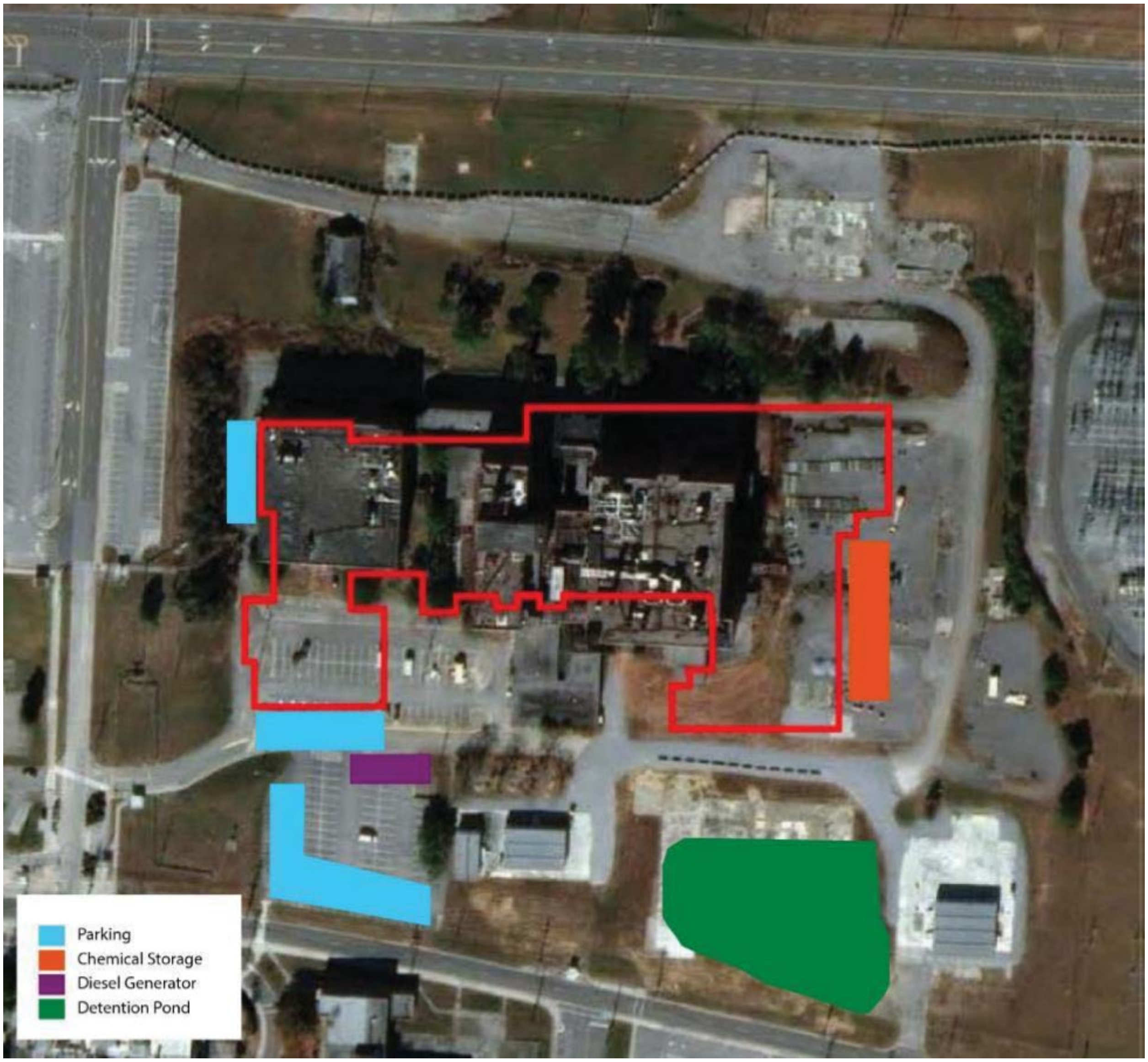


Figure 4.15. Lithium Processing Facility construction footprint

Figure 4.16. Artist rendering of the Lithium Processing Facility

In October 2020, NNSA determined an EA (10 CFR 1021.321) was required to evaluate the proposed action—to acquire the existing facility at 103 Palladium Way, Horizon Center Industrial Park (about 10 mi from Y-12, Figures 4.17 and 4.18), and the surrounding 21 acres, and to transition and house the current and future mission of Y-12 Development for the next 15, or more, years. The facility is located on a secure and fenced campus with approximately 73,000 ft^2 of high-tech interior space. The facility would be modified for Y-12 Development's needs, including installing multiple chemical hoods; modifying exhaust ductwork; installing or modifying utilities; constructing partitions between radiological and nonradiological areas; upgrading sensors and security; and upgrading, as necessary, cyber connectivity. The facility would be a nonnuclear facility. Nuclear materials to be stored and used at this facility would include DU, low enriched uranium, small quantities of highly enriched uranium (<400 g), lithium, and other special materials in laboratory quantities.

Acronyms:
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
Y-12 = Y-12 National Security Complex

Figure 4.17. Horizon Center Industrial Park

Acronym:
ORNL = Oak Ridge National Laboratory

Figure 4.18. 103 Palladium Way facility and surrounding 21 acres

There would be no change to the constructed footprint, exterior wall structure, or outside appearance of the building. Because only internal modifications of the existing facility would be required, no land disturbance would occur. Y-12 Development would relocate some 50 laboratories, including laboratory instrumentation, prototype and demonstration models, metallurgy machining equipment, foundry equipment, and various other laboratory equipment. Operations would be expected to begin in about 2025 and the facility would house Y-12 Development operations for at least 15 yr. The operational workforce is estimated to be 70 to 100 persons.

Subsequent actions related to this EA will be described in future reports.

4.3.3. National Historic Preservation Act

In accordance with the National Historic Preservation Act of 1966, NNSA is committed to identifying, preserving, enhancing, and protecting its cultural resources. The prescribed evaluation process ensures that the proper level of environmental review is performed before an irreversible commitment of resources is made. Compliance activities in 2020 included completing Section 106 reviews of ongoing and new projects, collecting and storing historic artifacts, and maintaining the Y-12 History Center.

In CY 2020, 37 proposed projects were evaluated to determine whether any historic properties eligible for inclusion in the National Register of Historic Places would be adversely impacted. The Infrastructure Disposition Program proposed project to demolish Buildings 9201-5 and 9204-4 was determined to have adverse effects on historic properties eligible for listing in the National Register of Historic Places. In accordance with the *Programmatic Agreement Among the Department of Energy, Oak Ridge Operations Office, the National Nuclear Security Administration, the Tennessee State Historic Preservation Office, and the Advisory Council on Historic Preservation Concerning the Management of Historical and*

Cultural Properties at the Y-12 National Security Complex (PA), required Section 106 recordation, interpretation, and documentation information is being prepared and will be submitted to the State Historical Preservation Office (SHPO) for concurrence to demolish these two major process facilities. Also in accordance with the PA, required Section 106 documentation for the proposed Modification and Reuse of Building 9731 project was submitted to the State Historical Preservation Office for review. In consultation with the SHPO, it was determined that the proposed Modification and Reuse of Building 9731 project would not adversely affect a property being recommended as a National Historic Landmark and is eligible for listing in the National Register of Historic Places.

The Y-12 Oral History Program continues efforts to identify leads to conduct oral interviews and to document the knowledge and experience of those who worked at Y-12 during World War II and the Cold War era. The interviews also provide information on day-to-day operations of Y-12, use and operation of significant components and machinery, and how technological innovations occurred over time. Some of the information collected from past interviews is available in various media, including digital versatile discs shown in the Y-12 History Center.

The Y-12 History Center, located in the New Hope Center, features many historical photographs and artifacts, a history library, and a video-viewing area. More interactive and video-based exhibits are planned for the future. The public may visit the Y-12 History Center Monday through Thursday from 8:00 a.m. to 5:00 p.m. and on Fridays by special request. A selection of materials, including brochures, books, pamphlets, postcards, and fact sheets, is available free to the public. The display area highlighting current and future missions of Y-12 is also available in the New Hope Center for the public.

- Due to COVID-19 and applicable restrictions, there have been very little to no public activities at Y-12. The Secret City Festival scheduled for June 2020 that promoted the history of the Manhattan Project by providing information to visitors regarding the history of Y-12 and directions for them to visit the Y-12 History Center for a more in-depth tour was cancelled.
- Y-12 was unable to partner with the American Museum of Science and Energy to provide guided public tours of the Y-12 History Center from March through November. Other outreach activities to local and visiting schools, agencies, and organizations, including tours and presentations on the rich and significant history of Y-12 and Oak Ridge, were also discontinued.

4.3.4. Clean Air Act Compliance Status

Permits issued by the State of Tennessee are the primary vehicle used to impose clean air requirements that are applicable to Y-12. New projects are governed by construction permits and modifications to the Title V operating air permit, and eventually the requirements are incorporated into the site wide Title V operating permit. Y-12 is currently governed by Title V Major Source Operating Permit 571832.

The permit requires recordkeeping and annual and semiannual reports. More than 2,000 data points are obtained and reported each year. All reporting requirements were met during CY 2020, and there were no permit violations or exceedances during the reporting period.

Ambient air monitoring, while not specifically required by any permit condition, is conducted at Y-12 to satisfy DOE Order 458.1, Radiation Protection of the Public and the Environment (DOE 2011d), requirements as a best management practice and/or to provide evidence of sufficient programmatic control of certain emissions. Ambient air monitoring conducted specifically for Y-12 (i.e., mercury monitoring) is supplemented by additional monitoring conducted for ORR and by both on- and off-site monitoring conducted by TDEC.

Section 4.4 provides detailed information on 2020 activities conducted at Y-12 in support of the Clean Air Act (CAA).

4.3.5. Clean Water Act Compliance Status

During 2020, Y-12 continued its excellent record for compliance with the National Pollutant Discharge Elimination System (NPDES) water discharge permit. Data obtained as part of the NPDES program are provided in a monthly report to TDEC. The percentage of compliance with permit discharge limits for 2020 was 99.8 percent.

Approximately 2,600 data points were obtained from sampling required by the NPDES permit, and five noncompliances were reported. Y-12's NPDES permit in effect during 2020 (TN0002968) was issued on October 31, 2011, and became effective on December 1, 2011. A modification was effective in May 2014. It expired on November 30, 2016.

An application for a new permit was prepared and submitted to TDEC in May 2016. The currently expired NPDES permit continues in effect until the new permit is issued by the State of Tennessee.

4.3.6. Safe Drinking Water Act Compliance Status

The City of Oak Ridge supplies potable water to Y-12 and meets all federal, state, and local standards for drinking water. The water treatment plant, located north of Y-12, is operated by the City of Oak Ridge. Y-12 potable water distribution is operated by a state-certified distribution system operator. The distribution system is regulated by TDEC as a public water system, with public water distribution system identification number 0001068.

Tennessee Regulations for Public Water Systems and Drinking Water Quality, Chapter 0400-45-01 (TDEC 2019), sets limits for biological contaminants, chemical activities, and chemical contaminants. Sampling for total coliform, chlorine residuals, lead, copper, and disinfectant byproducts is conducted by Y-12's ECD, with oversite by a state-certified operator.

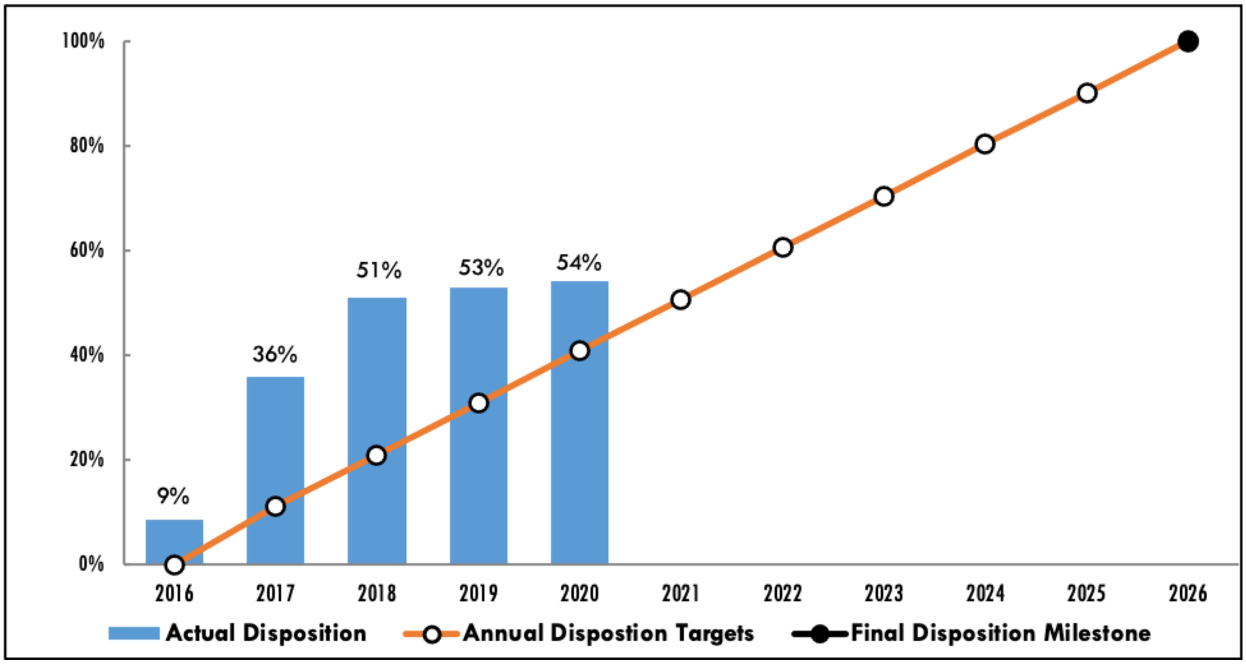
Y-12's potable water distribution system was last reviewed by TDEC in 2018 and received a sanitary survey score of 100 out of a possible 100 points and, thus, retained its approved status as a public water system in good standing with TDEC. The next sanitary survey is scheduled for 2021. All total coliform samples collected during 2020 were analyzed by the State of Tennessee laboratory, and all results were negative. Analytical results for disinfectant byproducts (total trihalomethanes and haloacetic acids) for Y-12's water distribution system were within allowable TDEC and Safe Drinking Water Act limits for the yearly average. Y-12's potable water system is currently sampled triennially for lead and copper. The system sampling was last completed in 2020. These results were below TDEC and Safe Drinking Water Act limits and met established requirements.

4.3.7. Resource Conservation and Recovery Act Compliance Status

The Resource Conservation and Recovery Act (RCRA) regulates hazardous wastes that, if mismanaged, could present risks to human health or the environment. The regulations are designed to ensure that hazardous wastes are managed from the point of generation to final disposal. In Tennessee, EPA delegates the RCRA program to TDEC, but EPA retains an oversight role. Y-12 is considered a large-quantity generator because it may generate more than 1,000 kg of hazardous waste in a month and because it has RCRA permits to store hazardous wastes for up to 1 yr. before shipping offsite to licensed treatment and disposal facilities. Y-12 also has a number of satellite accumulation areas and 90-d waste storage areas.

Mixed wastes are materials that are both hazardous (under RCRA guidelines) and radioactive. The Federal Facility Compliance Act requires that DOE work with local regulators to develop a Site Treatment Plan to manage mixed waste. Development of the plan has two purposes: to identify available treatment technologies and disposal facilities (federal or commercial) that can manage mixed waste produced at federal facilities, and to develop a schedule for treating and disposing of the waste streams.

The ORR Site Treatment Plan is updated annually and submitted to TDEC for review. The current plan (TDEC 2020) documents the mixed-waste inventory and describes efforts undertaken to seek new commercial treatment and disposal outlets for various waste streams. NNSA has developed a disposition schedule for the mixed waste in storage and will continue to maintain and update the plan, as a reporting mechanism, as progress is made. Y-12 has developed disposition milestones to address its remaining inventory of legacy mixed waste. Disposition milestones for the final inventory are FYs 2016 through 2026 (see Figure 4.19). In FY 2020, Y-12 staff dispositioned 54 percent of the legacy mixed waste inventory listed in the ORR Site Treatment Plan.



Note:
As part of the Oak Ridge Reservation Site Treatment Plan.

Figure 4.19. Path to eliminate Y-12's legacy mixed waste inventory by fiscal year

The quantity of hazardous and mixed wastes generated by Y-12 decreased in 2020 (Figure 4.20). Y-12 currently reports waste on 74 active waste streams. Y-12 is a state-permitted treatment, storage, and disposal facility. Under its permits, Y-12 received 5,258 kg of hazardous and mixed waste from offsite in 2020.

In addition, 174,660 kg of hazardous and mixed waste was shipped to DOE-owned and commercial treatment, storage, and disposal facilities. More than 9 million kg of hazardous and mixed wastewater was treated at on-site wastewater treatment facilities.

4.3.7.1. Resource Conservation and Recovery Act Underground Storage Tanks

TDEC regulates active petroleum underground storage tanks (USTs). Existing underground storage tank systems that remain in service must comply with performance requirements described in TDEC underground storage tank regulations (TN 0400-18-01).

The last two petroleum USTs at the East End Fuel Station were closed and removed in August 2012. No petroleum USTs remain at Y-12.

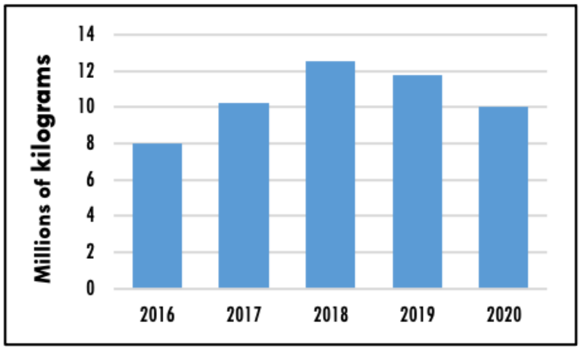


Figure 4.20. Hazardous waste generation, 2016–2020

4.3.7.2. Resource Conservation and Recovery Act Subtitle D Solid Waste

The ORR landfills operated by the DOE EM Program are located within the Y-12 boundary. The facilities include two Class II, operating, industrial solid waste disposal landfills and one operating, Class IV, construction demolition landfill. The facilities are permitted by TDEC and accept solid waste from DOE operations on ORR. In addition, one Class IV facility (Spoil Area 1) is overfilled by 8,945 m^3 and has been the subject of a CERCLA remedial investigation and feasibility study. A CERCLA ROD for Spoil Area 1 was signed in 1997 (DOE 1997a). One Class II facility (Landfill II) has been closed and is subject to postclosure care and maintenance. Associated TDEC permit numbers are noted in Table 4.3. Additional information about the operation of these landfills is addressed in Section 4.8.2.

4.3.8. Resource Conservation and Recovery Act–Comprehensive Environmental Response, Compensation, and Liability Act Coordination

The intent of the ORR Federal Facility Agreement (DOE 2017) is to coordinate the corrective action processes of RCRA required under the Hazardous Waste Corrective Action document (formerly known as the Hazardous and Solid Waste Amendments permit) with CERCLA response actions.

During CY 2015, ORR Corrective Action TNHW-164 was renewed for the 10-yr period from September 15, 2015, through September 15, 2025. As required in TNHW-164, the annual update of solid waste management units and areas of concern was submitted to TDEC in January 2020 as an update of the previous CY 2019 activities.

4.3.9. Toxic Substances Control Act Compliance Status

Storage, handling, and use of polychlorinated biphenyls (PCBs) are regulated under the Toxic Substances Control Act (TSCA). Capacitors manufactured before 1970 believed to be oil-filled are handled as though they contain PCBs, even when that cannot be verified from manufacturer records. Certain equipment containing PCBs and PCB waste containers must be inventoried and labeled. The inventory is updated by July 1 of each year and was last submitted on June 25, 2020.

Given the widespread historical uses of PCBs at Y-12 and fissionable material requirements that must be met, EPA and DOE negotiated an agreement to assist ORR facilities in becoming compliant with TSCA regulations. This agreement, the ORR PCB Federal Facility Compliance Agreement, which became effective in 1996, provides a forum within which to address PCB compliance issues that are unique to these facilities. Y-12 operations involving TSCA-regulated materials were conducted in accordance with TSCA regulations and the ORR PCB Federal Facility Compliance Agreement.

The removal of legacy PCB waste, some of which had been stored since 1997, in accordance with the terms of the ORR PCB Federal Facility Compliance Agreement, was completed in 2011.

4.3.10. Emergency Planning and Community Right-to-Know Act Compliance Status

The Emergency Planning and Community Right-to-Know Act requires that facilities report inventories (i.e., Tier II Report sent to state and local emergency responders) and releases (i.e., toxic release inventory report submitted to state and federal environmental agencies) of certain chemicals that exceed specified thresholds. Y-12 submitted reports for reporting year 2020 in accordance with requirements under Emergency

Planning and Community Right-to-Know Act Sections 302, 303, 311, 312, and 313.

Y-12 had no unplanned release of a hazardous substance that required notification of the regulatory agencies (see Section 4.3.11 for more information). During a routine review of chemical inventories, Bromo-chloro, 5, 5-dimethyl hydantoin, CAS No. 32718-18-6, contained in Spectrus OX103, exceeded the 10,000-pound reporting threshold. A notification was sent to TEMA and local emergency responders on November 25, 2020. Inventories, locations, and associated hazards of over-threshold hazardous and extremely hazardous chemicals were submitted to TEMA and local emergency responders in the annual Tier II Report required by Section 312. Data submittal was through the E-Plan web-based reporting system, as requested by TEMA. Some local emergency responders also accepted data through the E-Plan system, but others require that electronic copies of the Tier II Reports be submitted via email. Y-12 reported 43 chemicals that were over Section 312 inventory thresholds in 2020.

Y-12 operations are evaluated annually to determine the applicability for submittal of a toxic release inventory report to TEMA and EPA in accordance with Emergency Planning and Community Right-to-Know Act Section 313 requirements. The amounts of certain chemicals manufactured, processed, or otherwise used are calculated to identify those that exceed reporting thresholds. After threshold determinations are made, releases and off-site transfers are calculated for each chemical that exceeds a threshold. Submittal of the data to TEMA and EPA is made through the Toxics Release Inventory-Made Easy (abbreviated as TRI-ME) web-based reporting system operated by EPA. Total 2020 reportable toxic releases to air, water, and land and waste transferred off-site for treatment, disposal, and recycling were 32,820 kg (72,354 lb.). Table 4.5 lists the reported chemicals for Y-12 for-2019 and 2020 and summarizes releases and off-site waste transfers for those chemicals.

4.3.11. Spill Prevention, Control, and Countermeasures

Clean Water Act, Section 311, regulates the discharge of oils or petroleum products to waters of the United States and requires spill prevention, control, and countermeasure (SPCC) plans be developed and implemented to minimize the potential for oil discharges. The major requirements for SPCC plans are contained in Title 40 CFR Part 112. These regulations require that SPCC plans be reviewed, evaluated, and amended at least once every 5 yr. or earlier if significant changes occur. The SPCC rule includes requirements for oil spill prevention, preparedness, and response to prevent oil discharges to navigable waters and adjoining shorelines. The rule requires specific facilities to prepare, amend, and implement SPCC plans.

Table 4.5. Emergency Planning and Community Right-to-Know Act Section 313 toxic chemical release and off-site transfer summary for Y-12, 2019–2020

Chemical	Year	Quantity[a] (lb)[b]
Chromium	2019	11,361
	2020	9,913
Cobalt	2019	862
	2020	964
Copper	2019	4,030
	2020	4,035
Lead compounds	2019	46,346
	2020	26,698
Manganese	2019	6,052
	2020	9,255
Mercury	2019	10,435
	2020	1,055
Methanol	2019	25,945
	2020	11,585
Nickel	2019	9,349
	2020	8,849

[a] Represents total releases to air, land, and water and includes off-site transfers. Also includes quantities released to the environment as a result of remedial actions, catastrophic events, or onetime events not associated with production processes.

[b] 1 lb = 0.4536kg.

The *Spill Prevention, Control, and Countermeasure Plan for the U.S. Department of Energy Y-12 National Security Complex* (CNS 2020a) was revised in September 2020 to update general Y-12 changing site infrastructure. This plan presents the SPCC requirements to be implemented by Y-12 to prevent spills of oil and the countermeasures to be invoked should a spill occur. In general, the first response of an individual discovering a spill is to call the Y-12 Plant Shift Superintendent. Spill response materials and equipment are stored near tanks and drum storage areas and other strategic areas of Y-12 to facilitate spill response. All Y-12 personnel and subcontractors are required to have initial spill and emergency response training before they can work on the site.

4.3.12. Unplanned Releases

Y-12 has procedures for notifying off-site authorities of categorized events at Y-12. Off-site notifications are required for specified events according to federal statutes, DOE Orders, and the Tennessee Oversight Agreement. As an example, any observable oil sheen on East Fork Poplar Creek (EFPC) and any release impacting surface water must be reported to the EPA National Response Center in addition to other reporting requirements. Spills of CERCLA reportable quantity limits must be reported to the EPA National Response Center, DOE, TEMA, and the Anderson County Local Emergency Planning Committee.

In addition, Y-12's Occurrence Reporting Program provides timely notification to the DOE community of Y-12 events and site conditions that could adversely affect public or worker health and safety, the environment, national security, DOE safeguards and security interests, DOE facilities' function, or DOE's reputation.

Y-12 occurrences are categorized and reported through the Occurrence Reporting and Processing System, which provides NNSA and the DOE community with a readily accessible database of information about occurrences at DOE facilities, causes of those occurrences, and corrective actions to prevent recurrence of the events. DOE analyzes aggregate occurrence information for generic implications and operational improvements.

There were no reportable releases to the environment in 2020. During 2020, there were no unplanned radiological air emission releases for Y-12.

4.3.13. Audits and Oversight

A number of federal, state, and local agencies oversee Y-12 activities. In 2020, Y-12 was inspected by federal, state, or local regulators on four occasions. Table 4.2 summarizes the results, and additional details follow.

As part of the City of Oak Ridge's pretreatment program, city personnel collect samples from the Y-12 monitoring station to conduct compliance monitoring, as required by the pretreatment regulations. City personnel also conduct compliance inspections twice yearly. No issues were identified in 2020.

Personnel from the TDEC Division of Solid Waste Management conducted a RCRA hazardous waste compliance inspection of Y-12 on August 19, 2020. The inspections covered waste storage areas and records reviews. No issues were identified.

Personnel from the TDEC Division of Air Pollution Control conducted an air quality inspection July 29, 2020. The inspection covered 13 air emission sources, including some emergency generators, and inspections of the facilities. Title V air permit records were also reviewed. No issues were identified.

In July 2019, as the result of a self-identified issue, shipments to the Nevada National Security Site were suspended due to incomplete characterization of weapons material and weapons-related material. Consequently, investigations, a series of improvement activities, and layers of self-critical audits have been conducted. Process improvements in handling, characterizing, and certifying waste are underway prior to resuming shipments to the Nevada National Security Site. Real-time radiography imaging is planned as a final check of waste, weapons material, and weapons-related material.

4.3.14. Radiological Release of Property

Clearance of property from Y-12 is conducted in accordance with approved procedures that comply with DOE Order 458.1, Radiation Protection of the Public and the Environment (DOE 2011e). Property consists of real property (i.e., land and structures), personal property, and material and equipment (M&E). At Y-12, three paths for releasing property to the public exist based on the potential for radiological contamination:

- Survey and release property potentially contaminated on the surface (using preapproved authorized limits for releasing property).
- Evaluate materials with a potential to be contaminated in volume (volumetric contamination).
- Evaluate using process knowledge (surface and volumetric). These three release paths are discussed in the following sections.

Table 4.6 summarizes some examples of the quantities of property released in 2020. During FY 2020, Y-12 recycled more than 3.88 million lb. of materials offsite for reuse, including computers, electronic office equipment, used oil, scrap metal, tires, batteries, lamps, and pallets.

Table 4.6. Summary of materials released, 2020

Category	Amount released
Real property (land and structures)	None
Computer equipment recycle:	61,131 lb
–Computers	
–Monitors	
–Printers	
–Mainframes	
Recycling examples:	
–Used oils	5,387 gal
–Used tires	9,880 lb
–Scrap metal	1,616,650 lb
–Lead acid batteries	59,952 lb
Public and negotiated sales:[a]	
–Brass	11,119 lb
–Miscellaneous furniture	15,178 lb
–Vehicles	132,740 lb
–Miscellaneous equipment	
External transfers[b]	99,001 lb

[a] *Sales during fiscal year 2020.*
[b] *Vehicles, miscellaneous equipment, and materials transferred to various federal, state, and local agencies for reuse during fiscal year 2020.*

4.3.14.1. Property Potentially Contaminated on the Surface

Property that is potentially contaminated on the surface is subject to a complete survey, unless it can be released based on process knowledge or via a survey plan that provides survey instructions, along with technical justification (process knowledge) for the survey plan based on the *Multi-Agency Radiation Survey and Site Investigation Manual* (NRC 2000) and the *Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual* (NRC 2009). The surface contamination limits used at Y-12 to determine whether M&E are suitable for release to the public are provided in Table 4.7.

Y-12 uses an administrative limit for average and maximum activity of 240 dpm/100 cm^2 for radionuclides in Group 3 and 2,400 dpm/100 cm^2 for radionuclides in Group 4 (see Table 4.7). Y-12 also uses an administrative limit for removable activity of 240 dpm/100 cm^2 for radionuclides in Group 3 (see Table 4.7). The use of the more-restrictive administrative limits ensures that M&E do not enter into commerce exceeding the definition of contamination for high-toxicity alpha emitters and for beta and gamma emitters, respectively, found in 49 CFR 173, Shippers—General Requirements for Shipments and Packagings.

Table 4.7. DOE Order 458.1 preapproved authorized limits[a,b]

Radionuclide[c]	Average[d,e]	Maximum[d,e]	Removable[f]
Group 1—Transuranics, ^{125}I, ^{129}I, ^{227}Ac, ^{226}Ra, ^{228}Ra, ^{228}Th, ^{230}Th, ^{231}Pa	100	300	20
Group 2—Th-natural, ^{90}Sr, ^{126}I, ^{131}I, ^{133}I, ^{223}Ra, ^{224}Ra, ^{232}U, ^{232}Th	1,000	3,000	200
Group 3—U-Natural, ^{235}U, ^{238}U, associated decay products, alpha emitters	5,000	15,000	1,000
Group 4—Beta-gamma emitters (radionuclides with decay modes other than alpha emission or spontaneous fission), except ^{90}Sr and others noted above[g]	5,000	15,000	1,000
Tritium (applicable to surface and subsurface)[h]	N/A	N/A	10,000

[a] The values in this table (except for tritium) apply to radioactive material deposited on but not incorporated into the interior or matrix of the property. No generic concentration guidelines have been approved for release of material that has been contaminated in depth, such as activated material or smelted contaminated metals (e.g., radioactivity per unit volume or per unit mass). Authorized limits for residual radioactive material in volume must be approved separately.

[b] As used in this table, disintegrations per minute means the rate of emission by radioactive material, as determined by counts per minute measured by an appropriate detector for background, efficiency, and geometric factors associated with the instrumentation.

[c] Where surface contamination by both alpha- and beta-gamma-emitting radionuclides exists, the limits established for alpha- and beta-gamma-emitting radionuclides should apply independently.

[d] Measurements of average contamination should not be averaged over an area of more than 1 m^2. Where scanning surveys are not sufficient to detect levels in the table, static counting must be used to measure surface activity. Representative sampling (static counts on the areas) may be used to demonstrate by analyses of the static counting data. The maximum contamination level applies to an area of not more than 100 cm^2.

[e] The average and maximum dose rates associated with surface contamination resulting from beta-gamma emitters should not exceed 0.2 mrad/h and 1.0 mrad/h, respectively, at 1 cm.

[f] The amount of removable material per 100 cm^2 of surface area should be determined by wiping an area of that size with dry filter or soft absorbent paper, applying moderate pressure, and measuring the amount of radioactive material on the wiping with an appropriate instrument of known efficiency. When removable contamination of objects on surfaces of less than 100 cm^2 is determined, the activity per unit area should be based on the actual area, and the entire surface should be wiped. Wiping techniques to measure removable contamination levels are unnecessary if direct scan surveys indicate the total residual surface contamination levels are within the limits for removable contamination.

[g] This category of radionuclides includes mixed fission products, including ^{90}Sr that is present in them. It does not apply to ^{90}Sr that has been separated from other fission products or mixtures where ^{90}Sr has been enriched.

[h] Measurement should be conducted by a standard smear measurement but using a damp swipe or material that will readily absorb tritium, such as polystyrene foam. Property recently exposed or decontaminated should have measurements (smears) at regular time intervals to prevent a buildup of contamination over time. Because tritium typically penetrates material it contacts, the surface guidelines in Group 4 do not apply to tritium. Measurements demonstrating compliance of the removable fraction of tritium on surfaces with this guideline are acceptable to ensure nonremovable fractions and residual tritium in mass will not cause exposures that exceed DOE dose limits and constraints.

Acronyms:

DOE = US Department of Energy

N/A = not applicable

4.3.14.2. Property Potentially Contaminated in Volume (Volumetric Contamination)

Materials, such as activated materials, smelted-contaminated metals, liquids, and powders, are subject to volumetric contamination (e.g., radioactivity per unit volume or per unit mass) and are treated separately from surface-contaminated objects. Materials that may be subject to volumetric contamination are evaluated for release by one of the following three methods:

- **Unopened, sealed containers:** Material is still in an original commercial manufacturer's sealed, unopened container. A seal can be a visible manufacturer's seal (i.e., lock tabs, heat shrink) or a manufacturer's seal that cannot be seen (e.g., unbroken fluorescent bulbs, sealed capacitors), as long as the container remains unopened once received from the manufacturer.

- **Process knowledge:** If contamination being able to enter a system is unlikely, then process knowledge is documented and used as the basis for release. Often, this is accompanied by confirmatory surveys.
- **Analytical:** The material is sampled, and analytical results are evaluated against measurement-method critical levels or background levels from materials that have not been impacted by Y-12 activities. If results meet defined criteria, then they are documented and the material is released. Alternatively, if volumetric authorized limits exist (per DOE Order 458.1) for a specified material stream, then the analytical results are evaluated and compared with the authorized limits for potential release (NPO 2018, 2019a, 2019b).

4.3.14.3. Process Knowledge

Process knowledge is used to release property from Y-12 without monitoring or analytical data and to implement a graded approach (less than 100 percent monitoring) for monitoring of some M&E (Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual Classes II and III) (NRC 2009). A conservative approach (nearly 100 percent monitoring) is used to release older M&E for which a complete and accurate history is difficult to compile and verify (Multi-Agency Radiation Survey and Assessment of Materials and Equipment Manual Class I). The process knowledge evaluation processes are described in Y-12 procedures.

The following M&E are released without monitoring based on process knowledge; this does not preclude conducting verification monitoring, for example, before sale:

- All M&E from buildings evaluated and designated as radiologically nonimpacted.
- Pallets generated from administrative buildings.
- Pallets that are returned to shipping during the same delivery trip.
- Lamps from administrative buildings.
- Drinking water filters.
- M&E approved for release by radiological engineering technical review.
- Portable restrooms used in nonradiological areas.
- Documents, mail, diskettes, compact disks, and other office media.
- Personal M&E.
- Paper, plastic products, water bottles, aluminum beverage cans, and toner cartridges.
- Office trash, house-keeping materials, and associated waste.
- Breakroom, cafeteria, and medical wastes.
- Medical and bioassay samples generated in nonradiological areas.
- Subcontractor, vendor, and privately owned vehicles, tools, and equipment used in nonradiological areas.
- M&E that are administratively released.
- M&E that were delivered to stores in error and that have not been distributed to other Y-12 locations.
- New computer equipment distributed from the Central Computing Facility.
- Subcontractor, vendor, and privately owned vehicles, tools, and equipment that have not been used in contaminated areas or for excavation activities.
- New cardboard.
- Consumer glass containers.

4.4. Air Quality Program

Sections of Y-12's Title V Permit 571832 contain requirements that are generally applicable to most industrial sites. Examples include requirements associated with control of asbestos, stratospheric ozone-depleting chemicals, and fugitive emissions, and general administration of the permit. The Title V permit also contains specific requirements directly applicable to individual sources of air emissions at Y-12. Major requirements in that section include the Radiological National Emission Standards for Hazardous Air Pollutants (NESHAPs) (40 CFR 61) and numerous ones associated with emissions of criteria pollutants and other, nonradiological hazardous air pollutants. In addition, a number of sources that are exempt from permitting requirements under state rules but subject to listing on the Title V Permit application are documented, and information about them is available upon request from the Y-12 Clean Air Program.

4.4.1. Construction and Operating Permits

The following Title V permitting actions were submitted and approved in 2020:

- Operational flexibility requests to add a new band saw and ventilation hood to M-Wing Machining Operations, Emission Source Y-9215-A (3), and to add a new Lithium Crystallizer (new bird bath) to the Building 9204-2 Wet Chemistry area.
- Minor permit modification to add the Electrorefining Processing Operation (Electrorefining project) to the Title V operating air permit, and to add Uranium-Thorium Activity to Special Processing Hood 78 Operation in Building 9212.
- Insignificant activity request to add a stationary, emergency-use, internal combustion engine fire water pump to the Title V operating air permit.
- Insignificant activity and exemption were completed for the welding operation for Buildings 9830-16 and 9423, and for the decontaminating, sorting, segmenting, and packaging operation in Building 9423.

Demonstrating compliance with air permits conditions is a significant effort at Y-12. Key elements of maintaining compliance are maintenance and operation of control devices, monitoring, record keeping, and reporting. High-efficiency particulate air filters and scrubbers are control devices used at Y-12. High-efficiency particulate air filters are found throughout the complex, and in-place testing of high-efficiency particulate air filters to verify the integrity of the filters is routinely performed. Scrubbers are operated and maintained in accordance with source-specific procedures. Monitoring tasks consist of continuous stack sampling, one-time stack sampling, and operation of control devices. Examples of continuous stack sampling are the radiological stack monitoring systems on numerous sources throughout Y-12.

The Y-12 sitewide permit requires annual and semiannual reports. One report is the overall Annual ORR Radiological NESHAPs Report, which includes specific information regarding Y-12 radiological emissions; another is an Annual Title V Compliance Certification Report, which indicates compliance status with all conditions of the permit. A third is a Title V Semiannual Report, which covers a 6-month period for some specific emission sources and consists of monitoring and record-keeping requirements for the sources. Another annual report is the Boiler Maximum Available Control Technology Report for the Y-12 Steam Plant, which requires the boilers to be tuned-up on an annual basis. Table 4.8 details the actual emissions versus allowable emissions for the Y-12 steam plant.

Table 4.8. Actual versus allowable air emissions from the Y-12 steam plant, 2020

Emissions (tons/yr)[a]			
Pollutant	**Actual**	**Allowable**	**Percentage of allowable**
Particulate	3.02	41.0	7.4
Sulfur dioxide	0.24	39.0	0.6
Nitrogen oxides[b]	12.69	81.0	15.7
VOCs[b]	2.17	9.4	23.1
Carbon monoxide[b]	33.22	139.0	23.9

Note:
The emissions are based on fuel usage data for January through December 2020. The VOC emissions include VOC hazard air pollutant emissions.
[a] 1 ton = 907.2 kg.
[b] When no applicable standard or enforceable permit condition exists for a pollutant, the allowable emissions are based on the maximum actual emissions calculation, as defined in Tennessee Department of Environment and Conservation Rule 1200-3-26-.02(2)(d)3 (maximum design capacity for 8,760 h/yr). Both actual and allowable emissions were calculated based on the latest US Environmental Protection Agency compilation of air pollutant emission factors (EPA 1995, 1998).
Acronyms:
VOC = volatile organic compound
Y-12 = Y-12 National Security Complex

4.4.1.1. Generally Applicable Permit Requirements

Y-12, like many industrial sites, has a number of generally applicable requirements, such as those pertaining to managing and controlling asbestos, ozone-depleting substances, and fugitive particulate emissions.

Asbestos Control

Y-12, like many industrial sites, has a number of general requirements applicable to removing and disposing of asbestos-containing materials, including monitoring, notifying TDEC of demolitions and renovations, and prescribed work practices for abating and disposing of asbestos materials. There was no reportable release of asbestos in 2020. There were five notifications of management and control. Asbestos, ozone-depleting substances, and fugitive particulate emissions are notable examples.

Stratospheric Ozone Protection

As required by the CAA Title VI Amendments of 1990 and in accordance with 40 CFR Part 82, actions have been implemented to comply with the prohibition against intentionally releasing ozone-depleting substances during maintenance activities performed on refrigeration equipment. During 2017, EPA enacted major revisions to the stratospheric ozone rules to include regulating non-ozone-depleting substance substitutes as part of 40 CFR 82 Subpart F. These revisions were effective January 1, 2018, for disposal of small appliances and January 1, 2019, for the leak rate provisions for large appliances. There were no appliances on Y-12 that leaked refrigerant in 2020 triggering this reporting.

Fugitive Particulate Emissions

As modernization reduction efforts increase at Y-12, the need also increases for good work practices and controls to minimize fugitive dust emissions from construction and demolition activities. Y-12 personnel continue to use a mature project-planning process to review, recommend, and implement appropriate work practices and controls to minimize fugitive dust emissions. Precautions used to prevent particulate matter from becoming airborne include the following:

- Using, where possible, water or chemicals to control dust when demolishing existing buildings or structures, performing construction operations, grading roads, or clearing land.
- Applying asphalt, water, or suitable chemicals on dirt roads, material stockpiles, and other surfaces that can create airborne dusts.
- Installing and using hoods, fans, and fabric filters to enclose and vent dusty materials.

4.4.1.2. National Emission Standards for Hazardous Air Pollutants for Radionuclides

The release of radiological contaminants, primarily uranium, into the atmosphere at Y-12 occurs almost exclusively as a result of plant production, maintenance, and waste management activities. The major radionuclide emissions contributing to the dose from Y-12 are ^{234}U, ^{235}U, ^{236}U, and ^{238}U, which are emitted as particulates (Figure 4.21). The particle size and solubility class of the emissions are determined based on review of the operations and processes served by the exhaust systems to determine the quantity of uranium handled in the operation or process, the physical form of the uranium, and the nature of the operation or process. The four categories of processes or operations that are considered when calculating the total uranium emissions are:

- Those that exhaust through monitored stacks.
- Unmonitored processes for which calculations are performed per Appendix D of 40 CFR 61.
- Processes or operations exhausting through laboratory hoods, also involving 40 CFR 61 Appendix D calculations.
- Emissions from room ventilation exhausts (calculated using radiological control monitoring data from the work area).

Continuous sampling systems are used to monitor emissions from a number of process exhaust stacks at Y-12. In addition, a probe-cleaning program is in place, and the results from the probe cleaning at each source are incorporated into the respective emission point source terms. In 2020, 24 process exhaust stacks were continuously monitored, 23 of which were major sources; the remaining 1 stack was a minor source and its contribution to Y-12's air emissions was conservatively accounted for using Appendix D calculations, as noted below. The sampling systems on the stacks have been approved by EPA Region 4.

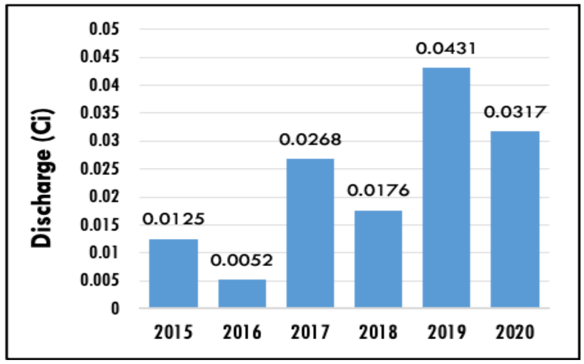


Figure 4.21. Total curies of uranium discharged from Y-12 to the atmosphere, 2015–2020

During 2020, unmonitored uranium emissions at Y-12 occurred from 43 points associated with on-site unmonitored processes and laboratories operated by CNS. Emission estimates for the processes and laboratory stacks were made using inventory data with emission factors provided in 40 CFR Part 61, Appendix D. The Y-12 source term includes an estimate of these emissions.

Y-12's Analytical Chemistry Organization operates out of two main laboratories. One is located onsite in Building 9995; the other is located in a leased facility on Union Valley Road, about 0.3 mi east of Y-12, and is not within the ORR boundary. In 2020, there were no radionuclide emission points (or sources) in the off-site laboratory facility.

Additionally, estimates from room ventilation systems are considered using radiological control data on airborne radioactivity concentrations in the work areas. Where applicable, exhausts from any area where the monthly concentration average exceeds 10 percent of the derived air concentration, as defined in the ORR Radionuclide Compliance Plan (DOE 2020d), are included in the annual source term. Annual average concentrations and design ventilation rates are used to arrive at the annual emission estimate for those areas. Five emission points from room ventilation exhausts were identified in 2020, where emissions exceeded 10 percent of the derived air concentration. Two of these emission points fed to monitored stacks, and any radionuclide emissions were accounted for as noted for monitored emission points. The remaining three emission points were the result of cleanup activities only (no mechanical or chemical processes) and are considered fugitive emissions. Therefore, they are not included in the total overall source term for Y-12.

Y-12 Title V (Major Source) Operating Permits contain a sitewide, streamlined alternate emission limit for EU and DU process emission units. A limit of 907 kg/yr. of particulate was set for the sources for the purposes of paying fees. The compliance method requires the annual actual mass emission particulate emissions to be generated using the same monitoring methods required for Radiological NESHAPs compliance. An estimated 0.0317 Ci (32.0 kg) of uranium was released into the atmosphere in 2020 as a result of Y-12 process and operational activities.

The calculated radiation dose to the maximally exposed off-site individual from airborne radiological release points at Y-12 during 2020 was 0.4 mrem. This dose is well below the NESHAP standard of 10 mrem and is less than 0.12 percent of the roughly 300 mrem that the average individual receives from natural sources of radiation. See Chapter 7 for an explanation of how the airborne radionuclide dose was determined.

Lastly, the UPF is presently being designed and constructed. This facility is intended to house some of the processes that are currently in existing production buildings. The UPF project was issued a Construction Air Permit (967550P) in March 2014. With concurrence from TDEC Air Division, the UPF was included in the 2018 update of Y-12's Title V Operating Permit 571832. The UPF Construction Air Permit was incorporated into the Y-12 Title V air permit on February 18, 2019. The Title V air permit expires on November 30, 2022. The UPF project will be maintained on inactive status until operational readiness and startup.

4.4.1.3. Quality Assurance

Quality assurance (QA) activities for the Radiological NESHAPs Program are documented in the *Y-12 National Security Complex Quality Assurance Project Plan for National Emission Standards for Hazardous Air Pollutants for Radionuclide Emission Measurements* (CNS 2020b). The plan satisfies the QA requirements in 40 CFR Part 61, Method 114, for ensuring that radionuclide air emission measurements from Y-12 are representative to known levels of precision and accuracy and that administrative controls are in place to ensure prompt response when emission measurements indicate an increase over normal radionuclide emissions. The requirements are also referenced in TDEC Regulation 1200-3-11-08 (TDEC 2015). The plan ensures the quality of Y-12 radionuclide emission measurements data from the continuous samplers and minor radionuclide release points. It specifies the procedures for managing activities affecting data quality. QA objectives for completeness, sensitivity, accuracy, and precision are discussed. Major programmatic elements addressed in the QA plan are the sampling and monitoring program, emissions characterization, analytical program, and minor source emission estimates.

4.4.1.4. Source-Specific Criteria Pollutants

Proper maintenance and operation of a number of control devices (e.g., high-efficiency particulate air filters and scrubbers) are key to controlling emissions of criteria pollutants. The primary source of criteria pollutants at Y-12 is the steam plant, where only natural gas and Number 2 fuel oil are permitted to be burned. Information regarding actual versus allowable emissions from the steam plant is provided in Table 4.8.

Particulate emissions from point sources result from many operations throughout Y-12. Demonstration of compliance is achieved via several activities, including monitoring the operations of control devices, limiting process input materials, and using certified readers to conduct emission evaluations of visible stacks.

Use of solvent 140/142 and methanol throughout Y-12 and use of acetonitrile at a single source are primary sources of volatile organic compound (VOC) emissions. Material mass balances and engineering calculations are used to determine annual emissions. The calculated amounts of solvent 140/142 and methanol emitted for CY 2020 are 500.73 lb. (0.25 tons) and 1,705 lb. (5.63 tons), respectively. The highest calculated amount of acetonitrile and isopropyl alcohol (VOCs) emitted to the atmosphere during any period of 12 consecutive months in CY 2020 was 2.447 tons, which was less than the permitted value of 9 tons/yr.

4.4.1.5. Mandatory Reporting of Greenhouse Gas Emissions under 40 Code of Federal Regulations 98

Title 40 of CFR Part 98, *Mandatory Reporting of Greenhouse Gases* (EPA 2010), establishes mandatory GHG reporting requirements for owners and operators of certain facilities that directly emit GHGs and for certain fossil fuel suppliers and industrial GHG suppliers. The purpose of the rule is to collect accurate and timely data on GHG emissions that can be used to inform future policy decisions.

The mandatory reporting of GHGs rule requires reporting of annual emissions of carbon dioxide, methane, nitrous oxide, sulfur hexafluoride, hydrofluorocarbons, perfluorochemicals, and other fluorinated gases (e.g., nitrogen trifluoride and hydrofluorinated ethers). These gases are often expressed in metric tons of carbon dioxide equivalent (CO_2e).

Y-12 is subject only to the Subpart A general provisions and reporting from stationary fuel combustion sources covered in 40 CFR 98, Subpart C, General Stationary Fuel Combustion (EPA 2010). Currently, the rule does not require control of GHGs; rather, it requires only that sources emitting above the 25,000-CO_2e threshold level monitor and report emissions.

The Y-12 steam plant is subject to this rule. The steam plant consists of four boilers. The maximum heat input capacity of each boiler shall not exceed 99 million Btu/h. Natural gas is the primary fuel source for the boilers; Number 2 fuel oil is a backup fuel source. Other limited, stationary combustion sources are metal-forming operations and production furnaces that use natural gas. In Building 9212, a gas-fired furnace used for drying wet residues and burning solids in a recovery process has a maximum heat input of 700,000 Btu/h. In Building 9215, 10 natural gas torches, each at 300 standard ft^3/h, are used to preheat tooling associated with a forging and forming press. In Building 9204-2, natural gas is used to heat two electrolytic cells. The maximum rated heat input to the burners on each cell is 550,000 Btu/h.

All of the combustion units burning natural gas are served through the fuel supply and distribution system and are reported as combined emissions consistent with the provisions of 40 CFR 98.36(c)(3). The Tier 1 Calculation Method was used to calculate GHGs from Y-12. The amount of natural gas supplied to the site, along with the fuel use logs, provides basic information required for calculating GHG emissions.

The emissions report is submitted electronically in a format specified by the EPA Administrator. Each report is signed by a designated representative of the owner or operator, certifying under penalty of law that the report has been prepared in accordance with the requirements of the rule. The total amount of GHGs, subject to the mandatory reporting rule, emitted from Y-12 is shown in Table 4.9. The decrease in emissions from 2010 to 2017 is associated with the fact that coal is no longer burned since the natural gas-fired steam plant came on line. The slight increase in CO_2e emissions was because fuel oil was burned for a few days in December 2018.

Table 4.9. Greenhouse gas emissions from Y-12 stationary fuel combustion sources

Year	GHG emissions (metric tons CO2e)
2010	97,610
2011	70,187
2012	63,177
2013	61,650
2014	58,509
2015	51,706
2016	50,671
2017	50,292
2018	51,010
2019	45,971
2020	46,126

Acronyms:
CO_2e = CO_2 equivalent
GHG = greenhouse gas
Y-12 = Y-12 National Security Complex

4.4.1.6. Hazardous Air Pollutants (Nonradiological)

Beryllium emissions from machine shops are regulated under a state-issued permit and are subject to a limit of 10 g/24 h. Compliance is demonstrated through a one-time stack test and through monitoring of control device operations. Hydrogen fluoride is used at one emission source, and emissions are controlled through the use of scrubber systems. The beryllium control devices and the scrubber systems were monitored during 2020 and were found to be operating properly.

Methanol is released as fugitive emissions (e.g., pump and valve leaks) as part of the brine and methanol system. Methanol is subject to state air permit requirements; however, due to the nature of its release (fugitive emissions only), no specific emission limits or mandated controls exist. Mercury is a significant legacy contaminant at Y-12, and cleanup is being addressed by OREM. Like methanol emissions, mercury air emissions from legacy sources are fugitive in nature and, therefore, are not subject to specific air emission limits or controls. On-site monitoring of mercury is conducted and is discussed in Section 4.4.2.1.

In 2007, EPA vacated a proposed Maximum Achievable Control Technology standard that was intended to minimize hazardous air pollutant emissions. At that time, a case-by-case Maximum Achievable Control Technology review was conducted as part of the construction-permitting process for the Y-12 replacement steam plant. The new natural gas-fired steam plant came online on April 20, 2010, and coal is no longer combusted. Specific conditions aimed at minimizing hazardous air pollutant emissions from the new steam plant were incorporated into the operating permit issued on January 9, 2012 (see Section 4.4.1). In addition, the boiler Maximum Achievable Control Technology standard was revised and reissued on January 31, 2013. TDEC issued a minor modification to the Title V air permit on October 29, 2014, which included the new boiler Maximum Achievable Control Technology requirements. The new requirements (work practice standards) include conducting annual tune-ups and a one-time energy assessment of the boilers to meet these requirements.

No numeric emission-limit requirements exist for the steam plant. The new rule requires that a one-time energy assessment for the steam plant must be completed on or after January 1, 2008. The new rule requires that tune-ups for the boilers must be completed 13 months from the previous tune-ups. To comply with that requirement, an energy assessment for the Y-12 steam plant, performed by a qualified energy assessor, was completed in July 2013. The tune-ups for boilers were completed on January 28 and 29, 2020.

Unplanned releases of hazardous air pollutants are regulated through risk management planning regulations. Y-12 personnel have determined no processes or facilities contain inventories of chemicals in quantities exceeding thresholds specified in rules pursuant to CAA, Title III, Section112(r), *Accidental Release Prevention/Risk Management Plan Rule* (EPA 1990). Therefore, Y-12 is not subject to that rule. Procedures are in place to continually review new processes and/or process changes against the rule thresholds.

EPA has created multiple national air pollution regulations to reduce air emissions from reciprocating internal combustion engines. Two types of federal air standards are applicable to reciprocating internal combustion engines—new source performance standards (Title 40 CFR Part 60, Subpart IIII), and NESHAPs (EPA 2013; Title 40 CFR Part 63, Subpart DDDDD). The compression ignition engines and generators located at Y-12 are subject to these rules. EPA is concerned how reciprocating internal combustion engines are used and the emissions generated from these engines in the form of both hazardous air pollutants and criteria pollutants.

All previous stationary, emergency engines and generators were listed in Y-12's Title V air permit application as insignificant activities. However, on January 16, 2013, EPA finalized revisions to standards to reduce air pollution from stationary engines that generate electricity and power equipment at sites of major sources of hazardous air pollutants. Regardless of engine size, the rules apply to any existing, new, or reconstructed stationary reciprocating internal combustion engine located at a major source of hazardous air pollutant emissions.

To comply with the rules, Y-12 prepared a significant permit modification to its Title V (Major Source) Operating Air Permit to add numerous stationary, emergency-use engines and generators located throughout Y-12. The permit application was submitted to TDEC on May 6, 2013, for review and approval. TDEC downgraded the significant modification to a minor modification per EPA's review and request. In a prior, updated permit application for renewal of Y-12's Title V (Major Source) Operating Air Permit dated March 9, 2011, Y-12 staff identified Title 40 CFR, Part 60, Subpart IIII, and Standards of Performance for Stationary Compression Ignition Internal Combustion Engines, as requirements applicable to the stationary, emergency-use engines located at Y-12. TDEC issued Y-12 a minor permit modification to the Title V air permit on March 3, 2014, for the emergency engines and generators. Compliance for the engines and generators is determined through monthly records of the operation of the engines and generators that are recorded through a nonresettable hour meter on each engine and generator. Documentation of how many hours are spent for emergency operation, maintenance checks and readiness testing, and nonemergency operation must be maintained. Each engine and generator must use only diesel fuel with low sulfur content (15 parts per million) and acetane index of 40.

Since the above rules were adopted into Tennessee Air Pollution Control Regulations 0400 30, Chapters 38 and 39, the emergency engines and generators can be considered an insignificant activity if the potential to emit is below the significance thresholds (less than 5 tons/yr of each criteria pollutant and less than 1,000 lb/yr of any hazardous air pollutant evaluated at a 500-h/yr limit). There was also a change to Chapter 9 of Tennessee Air Pollution Control Regulations that allows for stationary engines to be eligible to be considered insignificant activities. Condition D14 of the Title V Operating Air Permit 571832 was amended to incorporate new language specifying stationary reciprocating internal combustion engines are eligible to be considered insignificant activities that must comply with any underlying applicable rules associated with a stationary internal combustion engine.

The emergency engines and generators are used to provide power for critical systems in the event of electrical power failures and outages at Y-12. The engines and generators operate exclusively as emergency engines and generators. Based upon historical usage of the emergency engines, generators, and fire water pumps, and EPA's 500-h default assumption (maximum hour usage), calculations verify and confirm that potential emissions from each stationary, emergency, internal combustion engine less than 645 hp qualifies, or should be reclassified as an insignificant activity, because the potential to emit is well below the significance thresholds of less than 5 tons/yr of each regulated air pollutant that is not a hazardous air pollutant, and less than 1,000 lb/yr of any hazardous air pollutant, in accordance with Tennessee Air Pollution Control Regulations 1200-03-09-.04(5)(a)4(i). Approximately 95 percent of Y-12's stationary, emergency engines, generators, and fire water pumps are considered and/or reclassified as an insignificant activity in accordance with Tennessee Air Pollution Control Regulations Rule 1200-03-09-.04(5)(a)4. (i). These engines are listed in Y-12's Title V air permit.

4.4.2. Ambient Air

To understand the complete picture of ambient air monitoring in and around Y-12, data from on- and off-site monitoring conducted specifically for Y-12, DOE Reservation-wide monitoring, and on- and off-site monitoring conducted by EPA and TDEC personnel must be considered.

No federal regulations, state regulations, or DOE Orders require ambient air monitoring within the Y-12 boundary; however, on-site ambient air monitoring for mercury and radionuclides is conducted as a best management practice. With the reduction of plant operations and improved emission and administrative controls, levels of measured pollutants have decreased significantly during the past several years. In addition, major processes that result in EU and DU emissions are equipped with stack samplers that have been reviewed and approved by EPA to meet requirements of the NESHAPs regulations.

4.4.2.1. Mercury

The Y-12 Ambient Air Monitoring Program for mercury was established in 1986 as a best management practice. The objectives of the program have been to maintain a database of mercury concentrations in ambient air, to track long-term spatial and temporal trends in ambient mercury vapor, and to demonstrate protection of the environment and human health from releases of mercury to the atmosphere at Y-12. Originally, four monitoring stations were operated at Y-12. The two atmospheric mercury monitoring stations currently operating at Y-12—ambient air monitoring stations (AAS) AAS2 and AAS8—are located near the east and west boundaries of Y-12, respectively (Figure 4.22). Since their establishment in 1986, AAS2 and AAS8 have monitored mercury in ambient air continuously, except for short intervals of downtime because of electrical or equipment outages. In addition to the monitoring stations located at Y-12, two additional monitoring sites were operated—a reference site (rain gauge 2) was operated on Chestnut Ridge in the Walker Branch Watershed for a 20-month period in 1988 and 1989 to establish a reference concentration, and a site was operated at New Hope Pond for a 25-month period from August 1987 to September 1989.

To determine mercury concentrations in ambient air, airborne mercury vapor is collected by pulling ambient air through a sampling train consisting of a Teflon filter and an iodinated-charcoal sampling trap. A flow-limiting orifice upstream of the sampling trap restricts airflow through the sampling train to approximately 1 L/min. Actual flows are measured biweekly with a calibrated Gilmont flowmeter in conjunction with the biweekly changeout of the sampling trap. The charcoal in each trap is analyzed for total mercury using cold vapor atomic fluorescence spectrometry after acid digestion. The average concentration of mercury vapor in ambient air for each 14-d sampling period is then calculated by dividing the total mercury per trap by the volume of air pulled through the trap during the corresponding 14-d sampling period.

As reported previously, average mercury concentration at the ambient air monitoring sites has declined significantly since the late 1980s. Recent, average, annual concentrations at the two boundary stations are comparable to concentrations measured in 1988 and 1989 at the Chestnut Ridge reference site (Table 4.10). Average mercury concentration at the AAS2 site for 2020 is 0.0030 μg/m^3 (N = 27), comparable to averages measured since 2003. After an increase in average concentration at AAS8 for the period 2005 through 2007, thought to be possibly due to increased decontamination and decommissioning work on the west end, the average concentration at AAS8 for 2020 was 0.0032 μg/m^3 (N = 27), similar to levels reported for 2008 and the early 2000s.

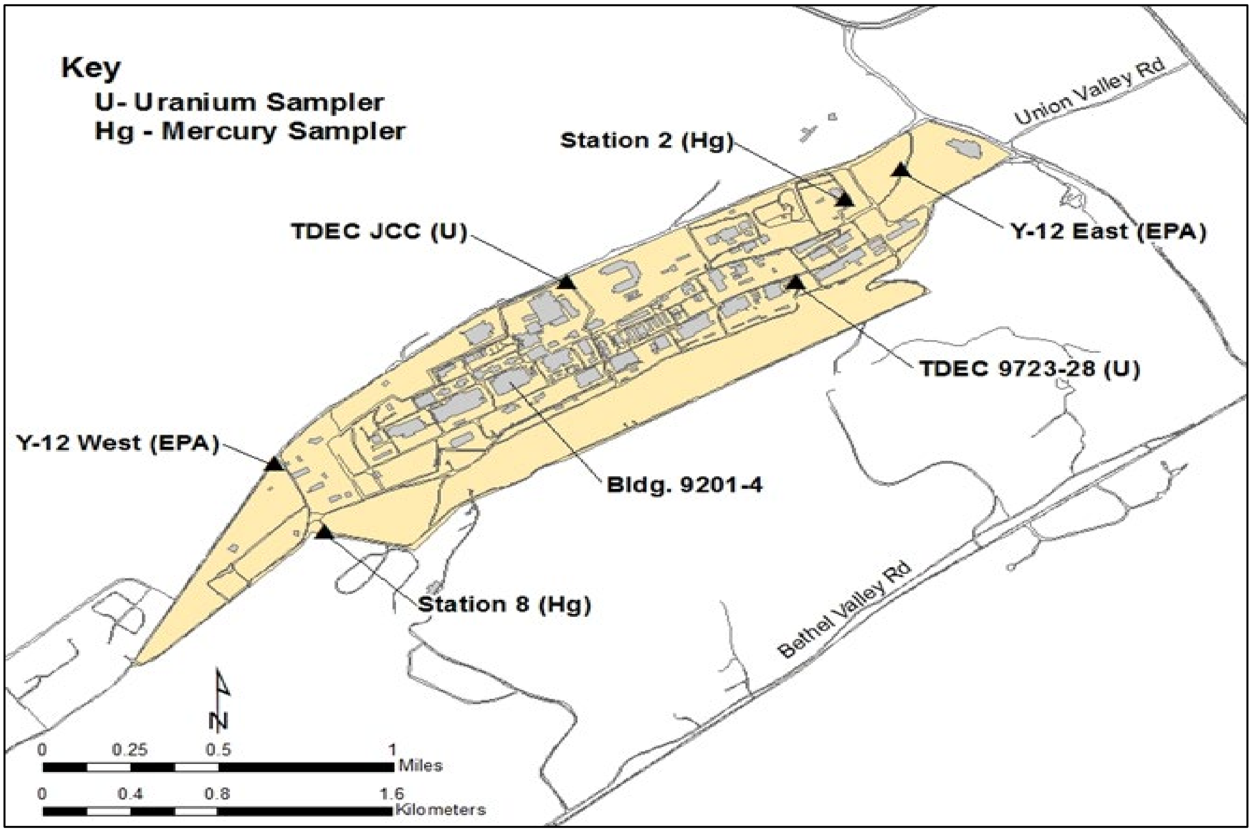


Figure 4.22. Locations of ambient air monitoring stations at Y-12

Acronyms:
Bldg. = building
EPA = US Environmental Protection Agency (sampler)
TDEC = Tennessee Department of Environment and Conservation
JCC = Jack Case Center
Y-12 = Y-12 National Security Complex

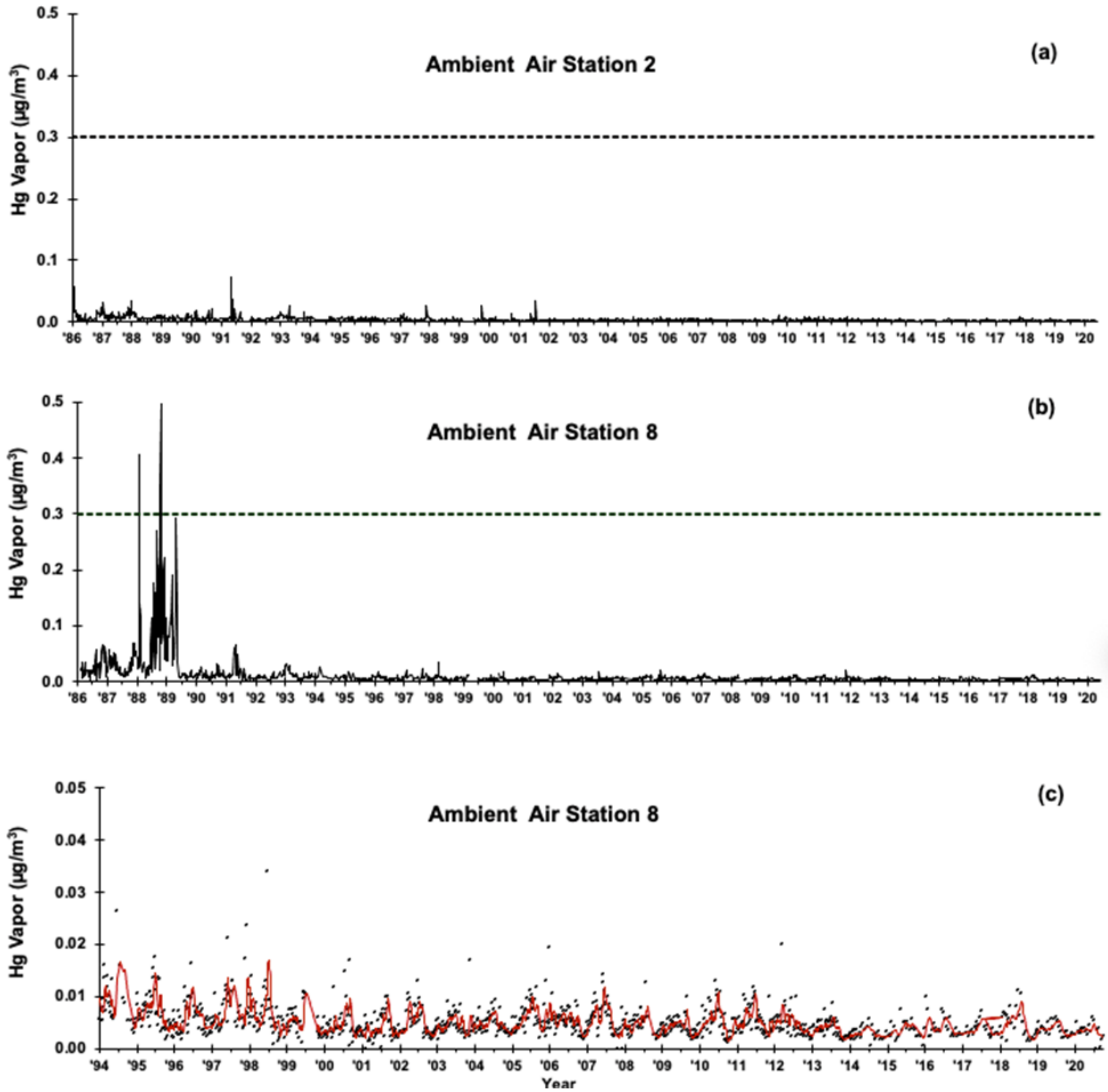
Table 4.10 summarizes the 2020 mercury results, with results from the 1986 through 1988 period included for comparison. Figure 4.23 illustrates temporal trends in mercury concentration for the two active mercury monitoring sites for the period since the inception of the program in 1986 through 2020 (parts [a] and [b]) and seasonal trends at AAS8 from 1994 through 2020 (part [c]). The dashed line superimposed on the plots in Figure 4.23 (parts [a] and [b]) is the EPA reference concentration of 0.3 μg/m3 for chronic inhalation exposure. The large increase in mercury concentration at AAS8 observed in the late 1980s (part [b]) is thought to be related to disturbances of mercury-contaminated soils and sediments during the Perimeter Intrusion Detection Assessment System installation and storm drain restoration projects under way at that time. In Figure 4.23 (part [c]), a monthly moving average has been superimposed over the AAS8 data to highlight seasonal trends in mercury at AAS8 from January 1994 through 2020.

Table 4.10. Data summary for Y-12's Ambient Air Monitoring Program for mercury, calendar year 2020

	Mercury vapor concentration (μg/m^3)			
AAS	**2020 Minimum**	**2020 Maximum**	**2020 Average**	**1986–1988[a] Average**
AAS2 (east end of Y-12)	0.0014	0.0048	0.0030	0.010
AAS8 (west end of Y-12)	0.0018	0.0059	0.0032	0.033
Reference site, rain gauge 2 (1988[b])	N/A	N/A	N/A	0.006
Reference site, rain gauge 2 (1989[c])	N/A	N/A	N/A	0.005

[a] *Period in late 1980s with elevated ambient air mercury levels; shown for comparison.*
[b] *Data for period from February 9 through December 31, 1988.*
[c] *Data for period from January 1 through October 31, 1989.*
Acronyms:
AAS = ambient air monitoring station
N/A = not available
Y-12 = Y-12 National Security Complex

In conclusion, 2020 average mercury concentrations at the two mercury-monitoring sites were comparable to reference levels measured for the Chestnut Ridge reference site in 1988 and 1989. More importantly, measured concentrations continue to be well below current environmental and occupational health standards for inhalation exposure to mercury vapor (i.e., the National Institute for Occupational Safety and Health-recommended exposure limit of 50 μg/m^3 as a time-weighted average for up to a 10-h workday and 40-h workweek, the American Conference of Governmental Industrial Hygienists workplace threshold limit value of 25 μg/m^3 as a time-weighted average for a normal 8-h workday and 40-h workweek, and the current EPA reference concentration of 0.3 μg/m^3 for elemental mercury for a continuous inhalation exposure to the human population without appreciable risk of harmful effects during a lifetime).



Notes:

(a) and (b): July 1986 to December 2020.

(a) and (b): The dashed line superimposed on the plots is the US Environmental Protection Agency reference concentration of 0.3 µg/m³ for chronic inhalation exposure.

(b): The large increase in mercury concentration at AAS8 observed in the late 1980s is thought to be related to disturbances of mercury-contaminated soils and sediments during the Perimeter Intrusion Detection Assessment System installation and storm drain restoration projects under way at that time.

(c): January 1994 to December 2020.

(c): A monthly moving average has been superimposed over the AAS8 data to highlight seasonal trends in mercury at AAS8 from January 1994 through 2020.

Acronym:

Hg = mercury

Figure 4.23. Temporal trends in mercury vapor concentration for boundary monitoring stations at Y-12

4.4.2.2. Quality Control

A number of QA and quality control (QC) steps are taken to ensure data quality for Y-12 mercury in the Ambient Air Monitoring Program.

An hour meter records the actual operating hours between sample changes. This allows for correction of total flow in the event of power outages during the weekly sampling interval.

The Gilmont correlated flowmeter, used for measuring flows through the sampling train, is purchased annually or, if not new, shipped back to the manufacturer annually for calibration in accordance with standards set by the National Institute of Standards and Technology.

A minimum of 5 percent of the samples in each batch submitted to the analytical laboratory are blank samples. The blank sample traps are submitted blind to verify trap blank values and to serve as a field blank for diffusion of mercury vapor into used sample traps during storage before analysis.

To verify the absence of mercury breakthrough, 5 to 10 percent of the field samples have the front (upstream) and back segments of the charcoal sample trap analyzed separately. The absence of mercury above blank values on the back segment confirms the absence of breakthrough.

Chain-of-custody forms track the transfer of sample traps from the field technicians all the way to the analytical laboratory.

A field performance evaluation is conducted annually by the project manager to ensure proper procedures are followed by the sampling technicians. The only issue noted during observation was the hour meter used to indicate the number of hours that the pump ran during the sampling period had malfunctioned. The meter was removed from service and replaced before the next sampling trap was started. The evaluation was conducted on December 8, 2020.

Analytical QA and QC requirements include the following:

- Using prescreened and/or laboratory-purified reagents.
- Analyzing at least two method blanks per batch.
- Analyzing standard reference materials.
- Analyzing laboratory duplicates (1 per 10 samples; any laboratory duplicates differing by more than 10 percent at 5 or more times the detection limit are to be rerun [third duplicate] to resolve the discrepancy).
- Archiving all primary laboratory records for at least 1 yr.

4.4.2.3. Ambient Air Monitoring Complementary to Y-12 Ambient Air Monitoring

Ambient air monitoring is conducted at multiple locations near ORR to measure radiological and other selected parameters directly in the ambient air. These monitors are operated in accordance with DOE Orders. Their locations were selected so that areas of potentially high exposure to the public are monitored continuously for parameters of concern. This monitoring provides direct measurement of airborne concentrations of radionuclides and other hazardous air pollutants, allows facility personnel to determine the relative level of contaminants at the monitoring locations during an emergency, verifies that the contributions of fugitive and diffuse sources are insignificant, and serves as a check on dose-modeling calculations. As part of the ORR network, an AAS located in the Scarboro Community of Oak Ridge (Station 46) measures off-site impacts of Y-12 operations. This station is located near the theoretical area of maximum public pollutant concentrations, as calculated by air-quality modeling. ORR network stations are also located at the east end of Y-12 (Station 40) and just south of the Country Club Estates neighborhood (Station 37).

In addition to the monitoring described above, the State of Tennessee (TDEC) and EPA perform ambient air monitoring to characterize the region in general and to characterize and monitor DOE operations locally. Specific to Y-12 operations, two uranium, ambient air, high-volume samplers provide isotopic uranium monitoring capability (Figure 4.22) within the Y-12 boundary that are used by TDEC personnel in their environmental monitoring program. These are located on the east side of the Jack Case Center and on the south side of the Building 9723-28 change house. EPA performs ambient air monitoring on the east end of the plant near the intersection of Scarboro Road and Bear Creek Road and on the west end of the plant near the intersection of Bear Creek Road and Old Bear Creek Road.

In addition, TDEC DOE Oversight Division air quality monitoring includes several other types of monitoring on ORR:

- RADNet—air
- Fugitive radioactive—air emission
- Ambient VOC—air
- Perimeter—air
- Gamma radiation—real-time
- Ambient gamma radiation—using external dosimetry
- Program-specific—associated with infrastructure-reduction activities

Results of these activities are summarized in annual status reports, which are issued by TDEC DOE Oversight Division.

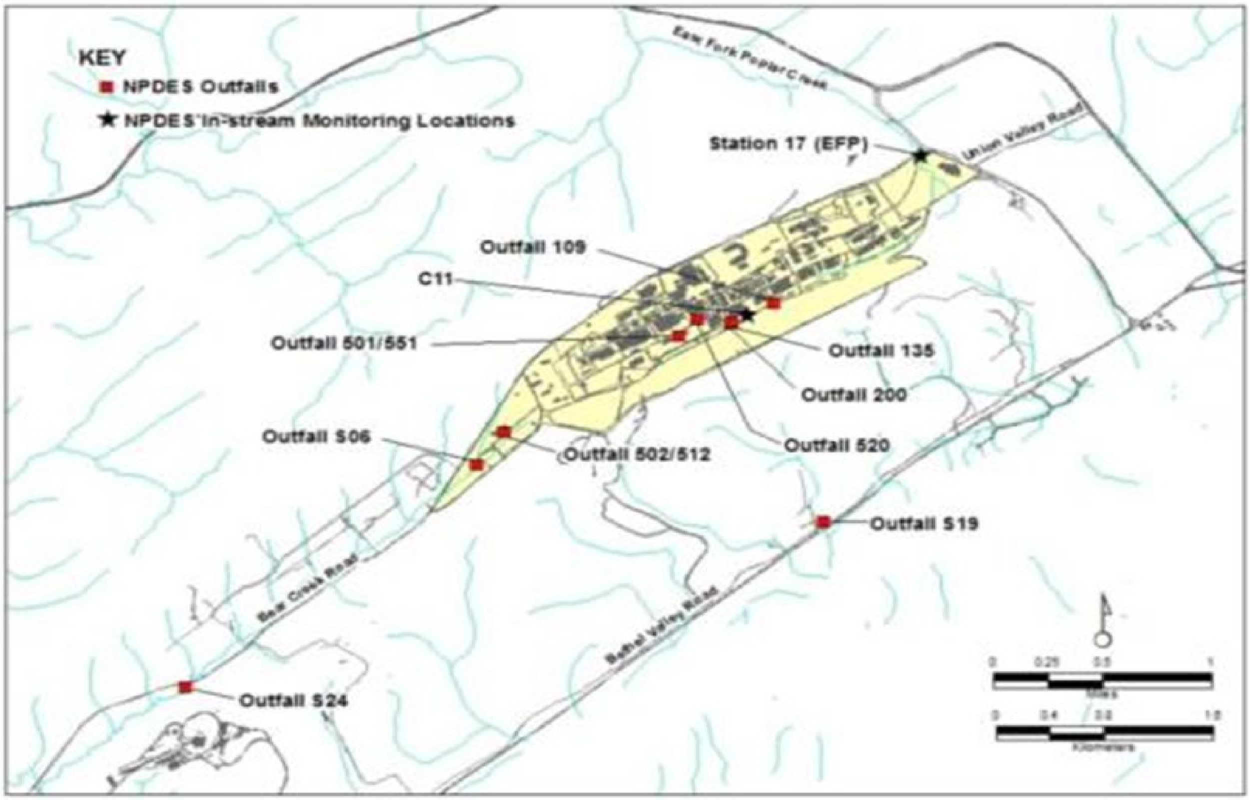
The State of Tennessee also operates a number of regional monitors to assess ambient concentrations of criteria pollutants, such as sulfur dioxide, particulate (various forms), and ozone, for comparison against ambient standards. The results are summarized and available through EPA and state reporting mechanisms.

4.5. Water Quality Program

4.5.1. National Pollutant Discharge Elimination System Permit and Compliance Monitoring

The current Y-12 NPDES permit (TN0002968) requires sampling, analysis, and reporting for about 56 outfalls. Major outfalls are depicted in Figure 4.24. The number is subject to change as outfalls are eliminated or consolidated or if permitted discharges are added. Currently, Y-12 has outfalls and monitoring points in the following water drainage areas: EFPC, Bear Creek, and several tributaries on the south side of Chestnut Ridge, all of which eventually drain to the Clinch River.

Discharges to surface water allowed under the permit include storm drainage; cooling water; cooling tower blowdown; steam condensate; and treated process wastewaters, including effluents from wastewater treatment facilities. Groundwater inflow into sumps in building basements and infiltration to the storm drain system are also permitted for discharge to the creek. The monitoring data collected by sampling and analyzing permitted discharges are compared with NPDES limits where applicable for each parameter. Some parameters, defined as monitor only, have no specified limits.



Acronyms:
EFP = East Fork Poplar
NPDES = National Pollutant Discharge Elimination System

Figure 4.24. Major Y-12 National Pollutant Discharge Elimination System outfalls and monitoring locations

The water quality of surface streams near Y-12 is affected by current and legacy operations. Discharges from Y-12 processes flow into EFPC before the water exits Y-12. EFPC eventually flows through the City of Oak Ridge to Poplar Creek and into Clinch River. Bear Creek water quality is affected by area source runoff and groundwater discharges. The NPDES permit requires regular monitoring and storm water characterization in Bear Creek and several of its tributaries.

Requirements of the NPDES permit for 2020 were satisfied, and monitoring of outfalls and instream locations indicated excellent compliance. Data obtained as part of the NPDES program, along with other events and observations, are provided in a monthly discharge monitoring report to TDEC. The percentage of compliance with permit discharge limits for 2020 was 99.8 percent (see Table 4.11).

Table 4.11. National Pollutant Discharge Elimination System compliance monitoring requirements and record for Y-12, January–December 2020

Discharge point	Effluent parameter	Daily average (lb)	Daily maximum (lb)	Monthly average (mg/L)	Daily maximum (mg/L)	Percentage of compliance	Number of samples
Outfall 501 (Central Pollution Control)							
	pH, standard units			[a]	9.0	[b]	0
	Total suspended solids			31.0	40.0	[b]	0
	Total toxic organic				2.13	[b]	0
	Hexane extractables			10	15	[b]	0
	Cadmium	0.16	0.4	0.07	0.15	[b]	0
	Chromium	1.0	1.7	0.5	1.0	[b]	0
	Copper	1.2	2.0	0.5	1.0	[b]	0
	Lead	0.26	0.4	0.1	0.2	[b]	0
	Nickel	1.4	2.4	2.38	3.98	[b]	0
	Nitrate/Nitrite				100	[b]	0
	Silver	0.14	0.26	0.05	0.05	[b]	0
	Zinc	0.9	1.6	1.48	2.0	[b]	0
	Cyanide	0.4	0.72	0.65	1.2	[b]	0
	PCB				0.001	[b]	0
Outfall 502 (West End Treatment Facility)							
	pH, standard units			[a]	9.0	100	3
	Total suspended solids		31		40	100	3
	Total toxic organic				2.13	67	3
	Hexane extractables			10	15	100	3
	Cadmium		0.4		0.15	100	3
	Chromium		1.7		1.0	100	3
	Copper		2.0		1.0	100	3
	Lead		0.4		0.2	100	3
	Nickel		2.4		3.98	100	3
	Nitrate/Nitrite				100	100	3
	Silver		0.26		0.05	100	3
	Zinc		0.9		1.48	100	3
	Cyanide		0.72		1.20	100	3
	PCB				0.001	67	3
Outfall 512 (Groundwater Treatment Facility)							
	pH, standard units			[a]	9.0	92	11
	PCB				0.001	100	1
Outfall 520							
	pH, standard units			[a]	9.0	[b]	0
Outfall 200 (North/South pipes)							
	pH, standard units			[a]	9.0	100	53
	Hexane extractables			10	15	100	13
	Cadmium			0.001	0.023	100	16

Table 4.11. National Pollutant Discharge Elimination System compliance monitoring requirements and record for Y-12, January–December 2020 (continued)

Discharge point	Effluent parameter	Daily average (lb)	Daily maximum (lb)	Monthly average (mg/L)	Daily maximum (mg/L)	Percentage of compliance	Number of samples
	IC_{25} *Ceriodaphnia*			37% Minimum		100	1
	IC_{25} *Pimephales*			37% Minimum		100	1
	Total residual chlorine			0.024	0.042	100	12
Outfall 551							
	pH, standard units			[a]	9.0	100	52
	Mercury			0.002	0.004	100	52
Outfall C11							
	pH, standard units			[a]	9.0	100	14
Outfall 135							
	pH, standard units			[a]	9.0	100	13
	IC_{25} *Ceriodaphnia*			9% Minimum		100	1
	IC_{25} *Pimephales*			9% Minimum		100	1
Outfall 109							
	pH, standard units			[a]	9.0	100	5
	Total residual chlorine			0.010	0.017	100	4
Outfall S19							
	pH, standard units			[a]	9.0	100	2
Outfall S06							
	pH, standard units			[a]	9.0	100	3
Outfall S24							
	pH, standard units			[a]	9.0	100	2
Outfall EFP							
	pH, standard units			[a]	9.0	100	14
Category I outfalls							
	pH, standard units			[a]	9.0	100	63
Category II outfalls							
	pH, standard units			[a]	9.0	100	21
	Total residual chlorine				0.5	100	16
Category III outfalls							
	pH, standard units			[a]	9.0	100	9
	Total residual chlorine			[a]	0.5	100	6

[a] Not applicable.
[b] No discharge.
Acronyms:
IC_{25} = 25-percent inhibition concentration
PCB = polychlorinated biphenyl
Y-12 = Y-12 National Security Complex

4.5.2. Radiological Monitoring Plan and Results

A radiological monitoring plan is in place at Y-12 to address compliance with DOE Orders and is provided to TDEC as a matter of comity under NPDES Permit TN0002968. Y-12 submits results from the radiological monitoring plan quarterly as an addendum to the NPDES Discharge Monitoring Report. There were no discharge limits set by the NPDES permit for radionuclides; the requirement is to monitor and report. The radiological monitoring plan was developed based on an analysis of operational history, expected chemical and physical relationships, and historical monitoring results. Under the existing plan, effluent monitoring is conducted at three types of locations: treatment facilities, other point-source and area-source discharges, and instream locations. Operational history and past monitoring results provide a basis for parameters routinely monitored under the plan (Table 4.12). The *Radiological Monitoring Plan for the Oak Ridge Y-12 National Security Complex: Surface Water* (B&W Y-12 2012b) was revised and reissued in January 2012. It was again revised and issued in October 2020. The revised plan was implemented on November 1, 2020. This revision added outfall 109 and roof runoff from production areas.

Table 4.12. Radiological parameters monitored at Y-12, 2020

Parameters	Specific isotopes	Rationale for monitoring
Uranium isotopes	^{238}U, ^{235}U, ^{234}U, total U, weight % ^{235}U	These parameters reflect the major activity, uranium processing, throughout the history of Y-12 and are the dominant detectable radiological parameters in surface water.
Fission and activation products	^{90}Sr, ^{99}Tc, ^{137}Cs	These parameters reflect a minor activity at Y-12, processing recycled uranium from reactor fuel elements from the early 1960s to the late 1980s, and will continue to be monitored as tracers for beta and gamma radionuclides, although their concentrations in surface water are low.
	^{3}H	Tritium is not expected to be high in fuel elements, because tritium is produced primarily as an activation product in reactor coolants. Tritium is highly mobile and is detected in groundwater samples associated with the S-3 Site.
Transuranium isotopes	^{241}Am, ^{237}Np, ^{238}Pu, $^{239/240}Pu$	These parameters are related to recycle uranium processing. Monitoring has continued because of their half-lives and presence in groundwater.
Other isotopes of interest	^{232}Th, ^{230}Th, ^{228}Th, ^{226}Ra, ^{228}Ra	These parameters reflect historical thorium processing and natural radionuclides necessary to characterize background radioisotopes.

Acronym:
Y-12 = Y-12 National Security Complex

Radiological monitoring during storm water events is accomplished as part of the storm water monitoring program. Uranium is monitored at three major EFPC storm water outfalls, two instream monitoring locations, and an outfall on Bear Creek. In addition, the monthly 7-d composite sample for radiological parameters taken at Station 17 on EFPC likely includes rain events.

Radiological monitoring plan locations sampled in 2020 are noted on Figure 4.25. Table 4.13 identifies the monitored locations, the frequency of monitoring, and the sum of the percentages of the derived concentration standards for radionuclides measured in 2020. Radiological data were well below the allowable derived concentration standards, with the exception of the Stack 47 storm runoff.

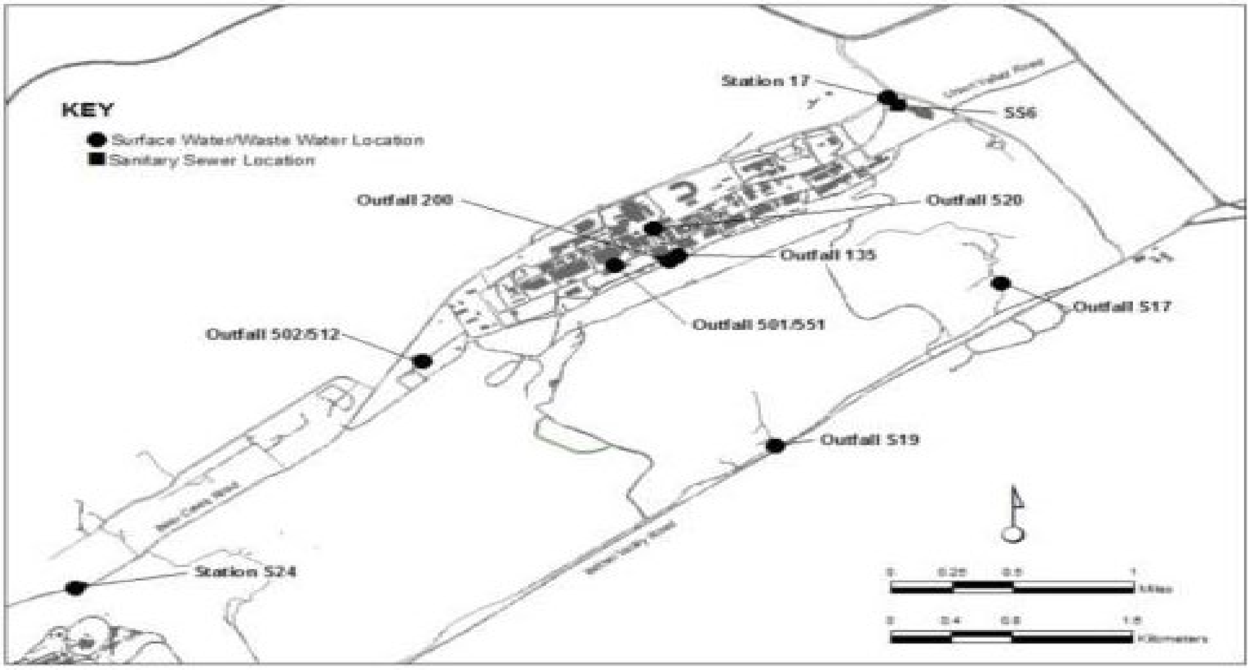


Figure 4.25. Surface water and sanitary sewer radiological sampling locations at Y-12

Table 4.13. Summary of Y-12's radiological monitoring plan sample requirements and 2020 results

Location	**Sample frequency**	**Sample type**	**Sum of derived concentration standards percentages**
Y-12 wastewater treatment facilities			
Central Pollution Control Facility	1/batch	Composite during batch operation	No flow
West End Treatment Facility	1/batch	24-h composite	2.8
Groundwater Treatment Facility	4/yr	24-h composite	3.2
Steam Condensate	1/yr	Grab	No flow
Central Mercury Treatment Facility	4/yr	24-h composite	0.26
Other Y-12 point- and area-source discharges			
Outfall 109	4/yr	24 h composite	0.48
Outfall 135	4/yr	24-h composite	0.58
Kerr Hollow Quarry	1/yr	24-h composite	0.41
Rogers Quarry	1/yr	24-h composite	0.30
Y-12 instream locations			
Outfall S24	1/yr	7-d composite	4.5
East Fork Poplar Creek, complex exit (east)	1/month	7-d composite	1.1
North/south pipes	1/month	24-h composite	3.8
Y-12 Sanitary Sewer			
East End Sanitary Sewer Monitoring Station	Production Facility Roofs	7-d composite roofs	16
Stack 47	4/yr	Grab during rain	53

Acronym:
Y-12 = Y-12 National Security Complex

In 2020, the total mass of uranium and associated curies released from Y-12 at the easternmost monitoring station, Station 17 on upper EFPC, was 173 kg or 0.082 Ci (Table 4.14).

Table 4.14. Uranium release from Y-12 to the off-site environment as liquid effluent, 2014–2020

Year	Quantity released	
	Ci[a]	kg
Station 17		
2014	0.061	90
2015	0.068	116
2016	0.045	88
2017	0.080	154
2018	0.084	205
2019	0.079	203
2020	0.082	173

[a] 1 Ci = 3.7E+10 Bq.
Acronym:
Y-12 = Y-12 National Security Complex

Figure 4.26 illustrates a 6-yr trend of these releases. The total release is calculated by multiplying the average concentration (g/L) by the average flow (million gal/d). Converting units and multiplying by 365 d/yr yields the calculated discharge.

Y-12 is permitted to discharge domestic wastewater to the City of Oak Ridge's publicly owned treatment works. Radiological monitoring of the sanitary sewer system discharge is conducted and reported to the City of Oak Ridge, although no city-established radiological limits exist. Alpha and beta levels are measured weekly, and subsequent uranium analyses are performed if the alpha or beta levels are above prescribed levels. Potential sources of radionuclides discharging to the sanitary sewer have been identified in previous studies at Y-12 as part of an initiative to meet goals to keep levels as low as reasonably achievable. Results of radiological monitoring were reported to the City of Oak Ridge in 2019 quarterly monitoring reports.

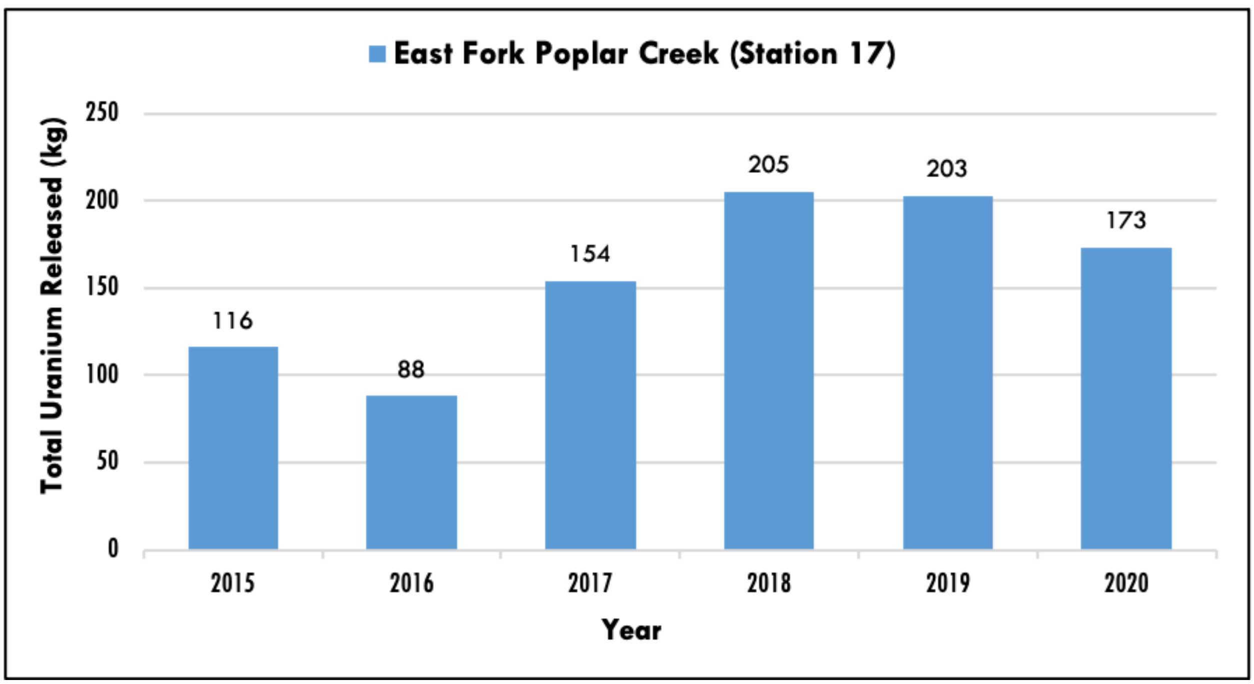


Figure 4.26. Six-year trend of Y-12 uranium releases to East Fork Poplar Creek

4.5.3. Storm Water Pollution Prevention

The Storm Water Pollution Prevention Plan at Y-12 is designed to minimize the discharge of pollutants in storm water runoff. The plan identifies areas that can reasonably be expected to contribute contaminants to surface water bodies via storm water runoff and describes the development and implementation of storm water management controls to reduce or eliminate the discharge of such pollutants. This plan requires characterizing storm water by sampling during storm events, implementing measures to reduce storm water pollution, facility inspections, and employee training.

Y-12's Storm Water Pollution Prevention Plan underwent a significant rewrite in September 2012 in response to issuance of a modified NPDES permit in November 2011. Significant changes included eliminating two instream monitoring locations (C05 and C08) and removing the requirement to perform instream base-load sediment sampling. Other requirements remained the same, with the exception of the lowering of a few benchmark values for certain sector outfalls. The NPDES permit defines the primary function of Y-12 to be a fabricated metal products industry. However, it also requires that storm water monitoring be conducted for three additional sectors: scrap and waste recycling activities; landfill and land-application activities; and discharges associated with treatment, storage, and disposal facilities as they are defined in the Tennessee Storm Water Multi Sector General Permit for Industrial Activities (TNR050000). Each sector has prescribed benchmark values, and some have defined sector mean values. The rationale portion of the NPDES permit for Y-12 states "These benchmark values were developed by the EPA and the State of Tennessee and are based on data submitted by similar industries for the development of the multisector general storm water permit. The benchmark concentrations are target values and should not be construed to represent permit limits."

Storm water sampling was conducted in 2018 during rain events that occurred on September 24, October 10, and October 24. Results were published in the *Annual Storm Water Report for the Y-12 National Security Complex* (CNS 2020c), which was submitted to TDEC Division of Water Pollution Control in January 2021. Consistent with permit requirements, storm water monitoring is performed each year for sector outfalls, three major outfalls that drain large areas of Y-12, and two instream monitoring locations on EFPC (Figure 4.27).

A significant change from 2013 to 2014 was the elimination of flow augmentation in EFPC. This discharge of raw water into EFPC was discontinued on April 30, 2014; thus, raw water is no longer required to be sampled. The discontinuation of flow augmentation has reduced the flow in EFPC by a significant amount (about 3.3 million gal/d, or about 60 percent).

An area of concern continues to be the concentration of mercury being measured in the discharge from Outfall 014. Since the first unexpected elevated result in 2013 (7.12 µg/L), this sector outfall has been on an annual monitoring schedule; however, no monitoring was conducted in 2018 or 2019 due to the degraded condition of the outfall piping and the inability to gather reliable flow rate data. However, the maintenance work on Outfall 014 was completed and sampling was resumed in 2020. Data collected to date are presented in Table 4.15.

Sampling conducted in 2020 revealed aluminum concentrations above the benchmark for Outfall 016. The exact cause of the aluminum results being above the benchmark for Outfall 016 is unknown. At Outfall S30, the copper value is slightly above the benchmark value, but well below the sector median value. The cause of the elevated copper result is unknown. At Outfall S06, the magnesium concentration exceeds both the benchmark and sector median values and the cadmium concentration is slightly above the benchmark value, but well below the sector median value. The geology of this portion of the Tennessee valley typically results in abnormally high levels of magnesium, and the cause of the elevated cadmium result is unknown.

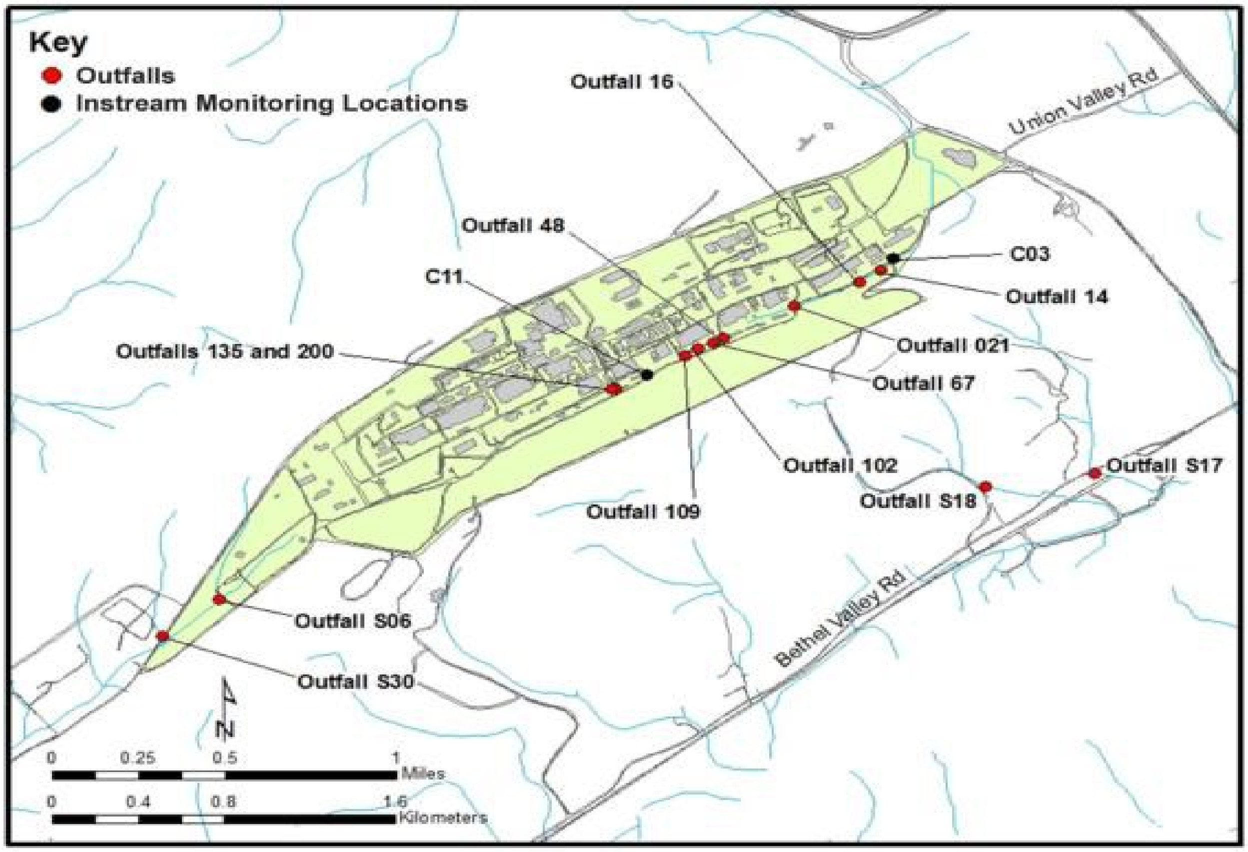


Figure 4.27. Y-12 storm water monitoring locations, East Fork Poplar Creek

Table 4.15. Mercury concentrations at Outfall 014

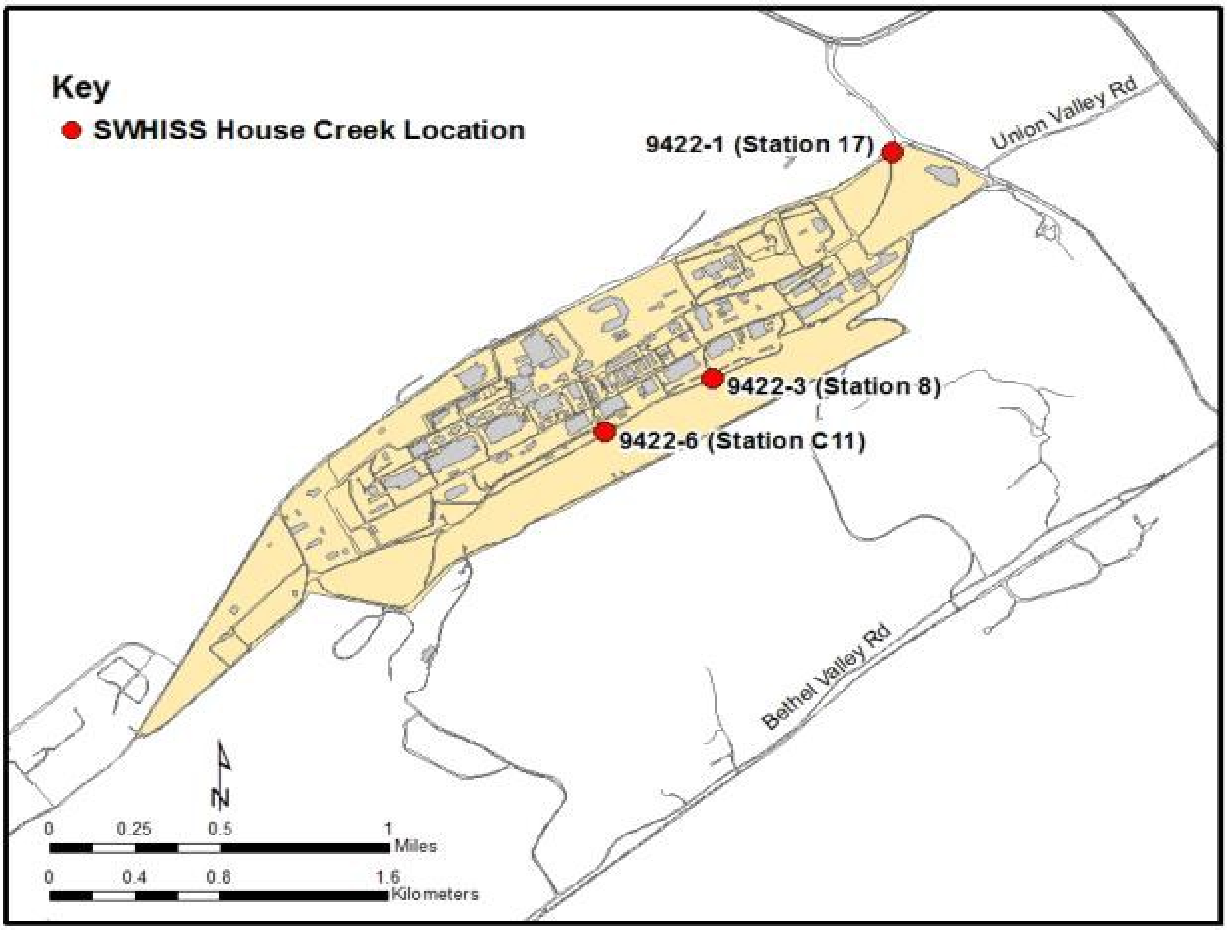
CY	2013	2014	2015	2016	2017	2018	2019	2020
Mercury concentration (µg/L)	7.12	0.892	9.11	0.49	0.237	N/A	N/A	1.66

Acronyms:
CY = calendar year
N/A = not available

4.5.4. Y-12 Ambient Surface Water Quality

To monitor key indicators of water quality, a network of real-time monitors located at three instream locations along upper EFPC is used. The Surface Water Hydrological Information Support System is available for real-time water quality measurements, such as pH, temperature, dissolved oxygen, conductivity, and chlorine. The locations are shown in Figure 4.28. The primary function of the Surface Water Hydrological Information Support System is to indicate potential adverse conditions that could be causing an impact on water quality in upper EFPC. It is operated as a best management practice.

Additional sampling of springs and tributaries is conducted in accordance with Y-12's Groundwater Protection Program to monitor trends throughout the three hydrogeologic regimes (see Section 4.6).



Acronyms:
SWHISS = Surface Water Hydrological Information Support System

Figure 4.28. Surface Water Hydrological Information Support System monitoring locations

4.5.5. Industrial Wastewater Discharge Permit

Industrial and Commercial User Wastewater Discharge Permit 1-91 defines requirements for the discharge of wastewaters to the sanitary sewer system as well as prohibitions for certain types of wastewaters. It prescribes requirements for monitoring certain parameters at the East End Sanitary Sewer Monitoring Station. The permit sets limits for most parameters. Samples for gross alpha, gross beta, and uranium are taken in a weekly 24-h composite sample. The sample is analyzed for uranium if the alpha or beta values exceed certain levels. Other parameters (including metals, oil and grease, solids, and biological oxygen demand) are monitored on a monthly basis. Organic parameters are monitored once per quarter. Results of compliance sampling are reported quarterly. Flow is measured continuously at the monitoring station.

As part of the City of Oak Ridge's pretreatment program, city personnel use the east end monitoring station (also known as SS6, see Figure 4.26) to conduct compliance monitoring as required by the pretreatment regulations. City personnel also conduct twice-yearly compliance inspections.

Monitoring results from 2020 are contained in Table 4.16. There were 10 exceedances of permit limits in 2020—5 exceedances of the cyanide limit; four exceedances of the 2,100-gal/min instantaneous flow limit; and one exceedance of the average daily flow limit.

Table 4.16. Y-12 discharge point SS6

Effluent parameter	Number of samples	Average value	Daily maximum (gal/min)[a]	Monthly average (effluent limit)[a]	Number of limit exceedances
Max flow rate (gal/min)	Continuous	N/A	2,100	N/A	4
Flow (average kgpd) January through March	91	612	N/A	500[b]	1
Flow (average kgpd) April through June	91	304	N/A	500[b]	0
Flow (average kgpd) July through September	92	264	N/A	500[b]	0
Flow (average kgpd) October through December	92	367	N/A	500[b]	0
pH (standard units)	92	N/A	N/A	9 and 6[c]	0
Biochemical oxygen demand	13	< 57	N/A	200	0
Kjeldhal nitrogen	14	19.6	N/A	45	0
Phenols—total recoverable	15	<0.059	N/A	0.15	0
Oil and grease	14	<7.2	N/A	25	0
Suspended solids	14	96.4	N/A	200	0
Cyanide	86	<0.0060	N/A	0.005	5
Arsenic	14	<0.002	N/A	0.010	0
Cadmium	14	<0.0004	N/A	0.0033	0
Chromium, hexavalent	13	0.005U	N/A	0.053	0
Copper	14	0.039	N/A	0.14	0
Iron	14	0.791	N/A	10	0
Lead	14	<0.002	N/A	0.049	0
Mercury	26	0.0012[d]	N/A	0.035[d]	0
Nickel	14	<0.004	N/A	0.021	0
Silver	14	<0.004	N/A	0.05	0
Zinc	14	0.122	N/A	0.35	0
Molybdenum	14	0.0459	N/A	0.05[e]	N/A
Selenium	14	<0.004	N/A	0.01[e]	N/A
Toluene	4	0.005U	N/A	0.005[e]	N/A
Ammonia	4	15.525	N/A	0.10[e]	N/A
Methanol	4	1.0U	N/A	1.0[e]	N/A
Benzene	4	0.005U	N/A	0.005[e]	N/A
1,1,1-Trichloroethane	4	0.005U	N/A	0.005[e]	N/A
Ethylbenzene	4	0.005U	N/A	0.005[e]	N/A
Carbon tetrachloride	4	0.005U	N/A	0.005[e]	N/A
Chloroform	4	0.003UJ	N/A	0.005[e]	N/A
Tetrachloroethene	4	0.004J	N/A	0.005[e]	N/A
Trichloroethene	4	0.005U	N/A	0.005[e]	N/A
trans-1,2-Dichloroethene	4	0.005U	N/A	0.005[e]	N/A
Methylene chloride	4	0.005U	N/A	0.005[e]	N/A

[a] *Industrial and commercial users wastewater permit limits.*
[b] *Average daily flow allowed in gal/d.*
[c] *Maximum and minimum value.*
[d] *Units are lb/d.*
[e] *This parameter does not have a permit limit. This value is the required detection limit. All units are mg/L unless noted otherwise.*

Acronyms: *kgpd = thousand gallons per day* *N/A = not applicable* *Y-12 = Y-12 National Security Complex*

4.5.6. Quality Assurance and Quality Control

The Environmental Monitoring Management Information System is used to manage surface water monitoring data at Y-12. It uses standard sample definitions to ensure that samples are taken at the correct location at a specified frequency using the correct sampling protocol.

Field sampling QA encompasses many practices that minimize error and evaluate sampling performance. Some key quality practices include the following:

- Using standard operating procedures for sample collection and analysis.
- Using chain-of-custody and sample identification, customized chain-of-custody documents, and sample labels provided by the Environmental Monitoring Management Information System.
- Standardizing, calibrating, and verifying instruments.
- Training sample technicians.
- Preserving, handling, and decontaminating samples.
- Using QC samples (i.e., field and trip blanks, duplicates, and equipment rinses).

Surface water data are entered directly by the analytical laboratory into the Laboratory Information Management System on the day of approval. The Environmental Monitoring Management Information System routinely accesses the Laboratory Information Management System electronically to capture pertinent data. Generally, the system will store data in the form of concentrations.

A number of electronic data management tools enable automatic flagging of data points and allow for monitoring and trending of data over time. Field information on all routine samples taken for surface water monitoring is entered in the Environmental Monitoring Management Information System, which also retrieves data nightly from the analytical laboratory. The system then performs numerous checks on the data, including comparisons of the individual results against any applicable screening criteria, regulatory thresholds, compliance limits, best management practices, or other water quality indicators, and produces required reports.

The NPDES permit for Y-12 (TN0002968, Part III, Section E) contains chronic toxicity testing requirements. These requirements specify that chronic toxicity testing (a 3-Brood *Ceriodaphnia dubia* survival and reproduction test and a 7-d fathead minnow larval survival and growth test) is required annually at Outfalls 135 and 200 to determine whether the effluent is contributing chronic toxicity to the receiving water. According to permit requirements, chronic toxicity testing is to be performed using 100 percent effluent and the dilution series shown in Table 4.17.

Table 4.17. Serial dilutions for whole effluent toxicity testing, as a percent of effluent

Outfall 200	**Control**	**0.25 x Permit limit**	**0.50 x Permit limit**	**Permit limit**	**(100+Permit limit)/2**	**100% Effluent**
	0	9.3	18	37	74	100
Outfall 135	**Control**	**0.25 x Permit limit**	**0.50 x Permit limit**	**Permit limit**	**2 x Permit limit**	**4 x Permit limit**
	0	2.3	4.5	9	18	36

Note:
The effluent water is diluted with control laboratory water.

Table 4.18 summarizes the results of the 2020 outfall biomonitoring tests in terms of the 25-percent inhibition concentration (IC_{25}), which is the concentration (i.e., a percentage of full-strength effluent diluted with laboratory control water) of each outfall effluent that causes a 25-percent reduction in the survival or reproduction of water fleas (*Ceriodaphnia dubia*) or the survival or growth of fathead minnow (*Pimephales promelas*) larvae (with respect to these same endpoints for these animals measured in control laboratory water). The lower the value of the IC_{25}, the more toxic the effluent. According to the NPDES permit, toxicity is demonstrated if the IC_{25} is less than or equal to the permit limit (9-percent whole effluent for Outfall 135 and 37-percent whole effluent for Outfall 200).

Table 4.18. Y-12 biomonitoring program summary information for Outfalls 200 and 135, 2020[a]

Water collection dates	Outfall	Test type	Test organism	End point	Metric	IC_{25}[b] (%)
07/22/20–07/28/20	135	Chronic	Fathead minnow (*Pimephales promelas*)	Survival Growth	IC_{25} IC_{25}	>36% >36%
			Water fleas (*Ceriodaphnia dubia*)	Survival Reproduction	IC_{25} IC_{25}	>36% >36%
07/22/20–07/28/20	200	Chronic	Water fleas (*Ceriodaphnia dubia*)	Survival Reproduction	IC_{25} IC_{25}	>100% >100%
			Fathead minnow (*Pimephales promelas*)	Survival Growth	IC_{25} IC_{25}	>100% >100%

[a] *IC_{25} is summarized for the discharge monitoring locations, Outfalls 200 and 135.*

[b] *IC_{25} as a percentage of full-strength effluent from Outfalls 200 and 135 diluted with laboratory control water. IC_{25} is the concentration that causes a 25-percent reduction in water fleas (Ceriodaphnia dubia) survival or reproduction or fathead minnow (Pimephales promelas) survival or growth; 36 percent is the highest concentration of Outfall 135 tested.*

Acronyms:

IC_{25} = 25-percent inhibition concentration

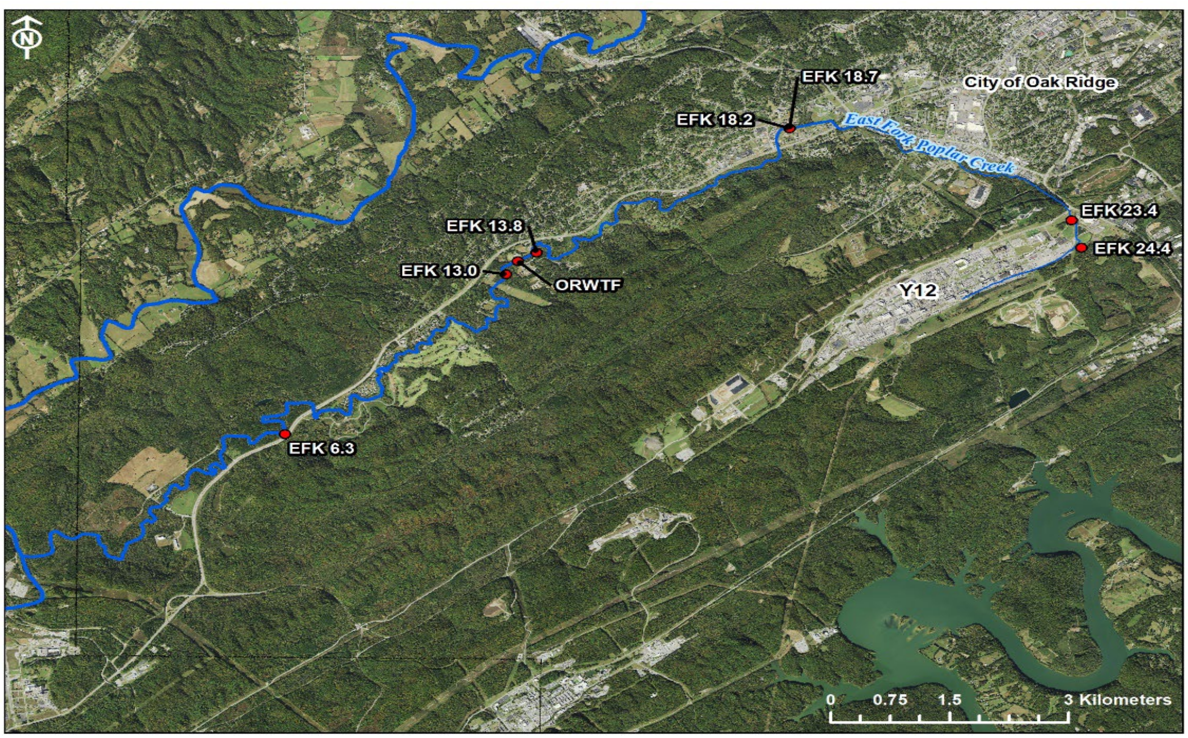
Y-12 = Y-12 National Security Complex

Annual NPDES permit testing was conducted in July 2020 with effluent from Outfalls 200 and 135. Effluent from Outfall 135 did not reduce fathead minnow (*Pimephales promelas*) survival or growth or water fleas' (*Ceriodaphnia dubia*) survival or reproduction by 25 percent or more at any of the tested concentrations. For both species, the IC_{25} for survival, growth, or reproduction was greater than 36 percent (the highest concentration of this effluent that was tested) (Table 4.18). Effluent from Outfall 200 did not reduce fathead minnow (*Pimephales promelas*) survival or growth or water fleas' (*Ceriodaphnia dubia*) survival or reproduction by 25 percent or more at any of the tested concentrations. For both species, the IC_{25} for survival, growth, or reproduction was greater than 100 percent (Table 4.18).

4.5.7. Biological Monitoring and Abatement Program

The NPDES permit issued for Y-12 mandates a Biological Monitoring and Abatement Program, with the objective of demonstrating that the effluent limitations established for the facility protect the classified uses of the receiving stream—EFPC. The 2020 Biological Monitoring and Abatement Program sampling efforts reported in this chapter follow the NPDES-required Y-12 Biological Monitoring and Abatement Program Plan (Peterson et al. 2013). Y-12's Biological Monitoring and Abatement Program, which has been monitoring the ecological health of EFPC since 1985, currently consists of three major tasks that reflect complementary approaches to evaluating the effects of Y-12 discharges on the aquatic integrity of EFPC: bioaccumulation monitoring, benthic macroinvertebrate community monitoring, and fish community monitoring. Data collected on contaminant bioaccumulation and the composition and abundance of communities of aquatic organisms directly evaluate the effectiveness of abatement and remedial measures in improving ecological conditions in the stream.

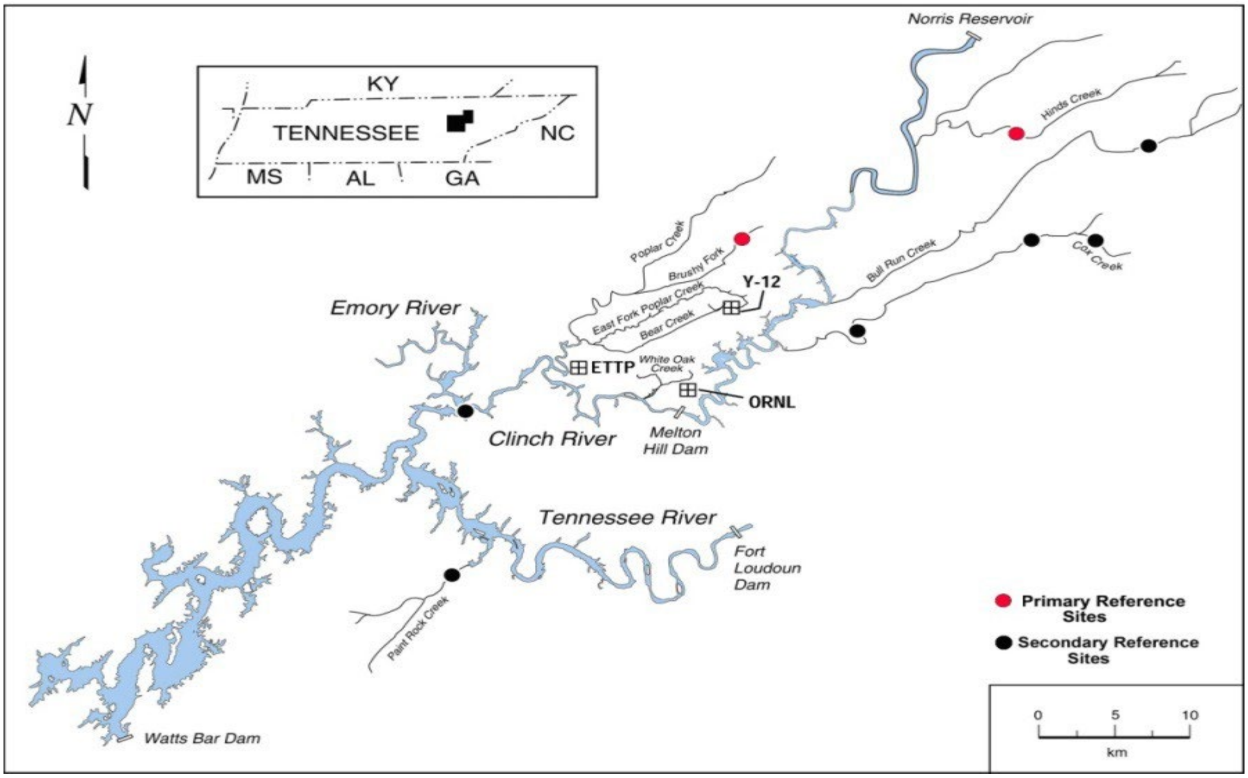
Monitoring is currently being conducted at seven primary EFPC sites (Figures 4.29 and 4.30), although sites may be excluded or added depending on the specific objectives of the various tasks. The primary sampling sites include Upper EFPC at EFPC kilometers (EFKs) 24.4 and 23.4, located upstream and downstream of Lake Reality, respectively; EFKs 18.7 and 18.2, located off-ORR and below an area of intensive commercial and light industrial development, respectively; EFKs 13.8 and 13.0, located upstream and downstream of the Oak Ridge Wastewater Treatment Facility, respectively; and EFK 6.3, located about 1.4 km downstream of the ORR boundary (Figure 4.29). Brushy Fork at Brushy Fork kilometer 7.6 is used as a reference stream in two Biological Monitoring and Abatement Program tasks (fish and macroinvertebrate community tasks). Hinds Creek at Hinds Creek kilometer 20.6 is also used as a reference for the macroinvertebrate community monitoring task.



Acronyms:
EFK = East Fork Poplar Creek kilometer
ORWTP = Oak Ridge Wastewater Treatment Plant
Y-12 = Y-12 National Security Complex

Figure 4.29. Biological monitoring sites locations on East Fork Poplar Creek relative to Y-12

ORNL-DWG-95M-7421R



Acronyms:
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
Y-12 = Y-12 National Security Complex

Figure 4.30. Biological monitoring reference sites locations relative to Y-12

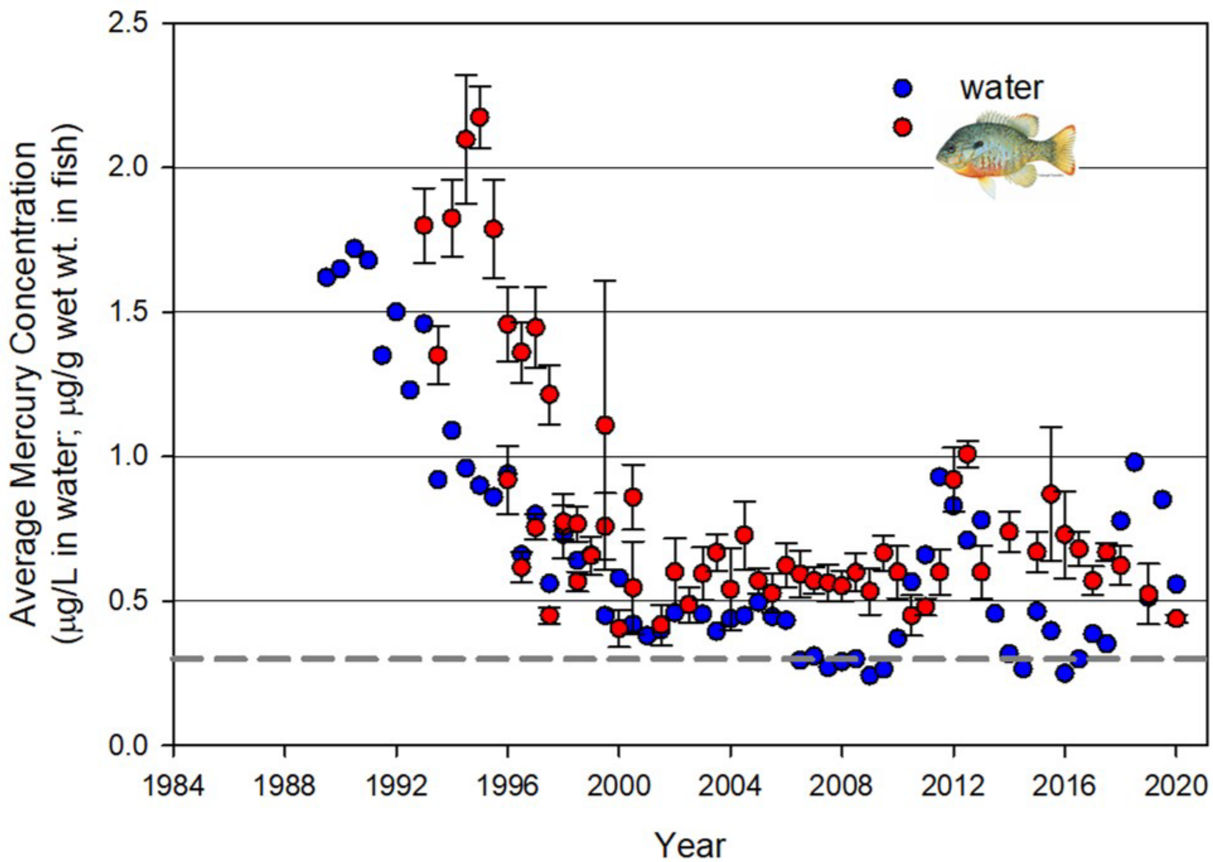
Generally, the number of invertebrate and fish species in EFPC has increased over the last three decades (primarily in the upstream sites), demonstrating that the overall ecological health of the stream continues to improve. However, the pace of improvement in Upper EFPC near Y-12 has slowed in recent years, and fish and invertebrate communities continue to have fewer species than the corresponding communities in reference streams.

4.5.7.1. Bioaccumulation Studies

Historically, mercury and PCB levels in fish from EFPC have been elevated relative to fish in uncontaminated reference streams. Fish in EFPC are monitored regularly for mercury and PCBs to assess spatial and temporal trends in bioaccumulation associated with ongoing remedial activities and Y-12 operations.

As part of this monitoring effort, redbreast sunfish (*Lepomis auritus*) and rock bass (*Ambloplites rupestris*) are collected twice a year from five sites throughout the length of EFPC and are analyzed for tissue concentrations of mercury (twice yearly) and PCBs (annually) (Figure 4.31). Mercury concentrations remained higher in fish from EFPC in 2020 than in fish from reference streams. Elevated mercury concentrations in fish from the upper reach of EFPC indicate that Y-12 remains a continuing source of mercury to fish in the stream.

Figure 4.31 shows temporal trends for mercury concentrations in water collected from EFK 23.4 (Station 17) and in fish collected just upstream of this monitoring station at EFK 24.4. Water-borne mercury concentrations in the upper reach of EFPC have decreased substantially over the years in response to various remedial actions, first over the 1990s time period and then again in response to the Big Springs Treatment System in 2006. Although mercury concentrations in fish over time have not decreased commensurate with mercury levels in water in the lower sections of EFPC, mercury concentrations in fish at the uppermost sampling site (EFK 24.4) decreased steadily in the 1990s, consistent with decreased concentrations in water (Figure 4.31). Significant fluctuations in aqueous mercury concentrations (thought to be the result of storm drain relining and cleanout) have been seen at EFK 23.4 since 2009. In July 2018, aqueous mercury concentrations spiked as a result of a one-time flux of mercury that occurred during construction and demolition activities at the west end of Y-12. The elevated mercury concentrations were associated with toxicity and a fish kill (Mathews et al. 2019). Aqueous mercury concentrations at Station 17 remained elevated in 2019 but have decreased in 2020. Mercury concentrations in fish collected at EFK 24.4 did not increase in response to this most-recent increase in aqueous concentrations, and actually decreased from 0.52 mg/g in 2019 to 0.44 mg/g in 2020, but remained above the EPA-recommended ambient water quality criterion for mercury (0.3 µg/g mercury as methylmercury in fish fillet).



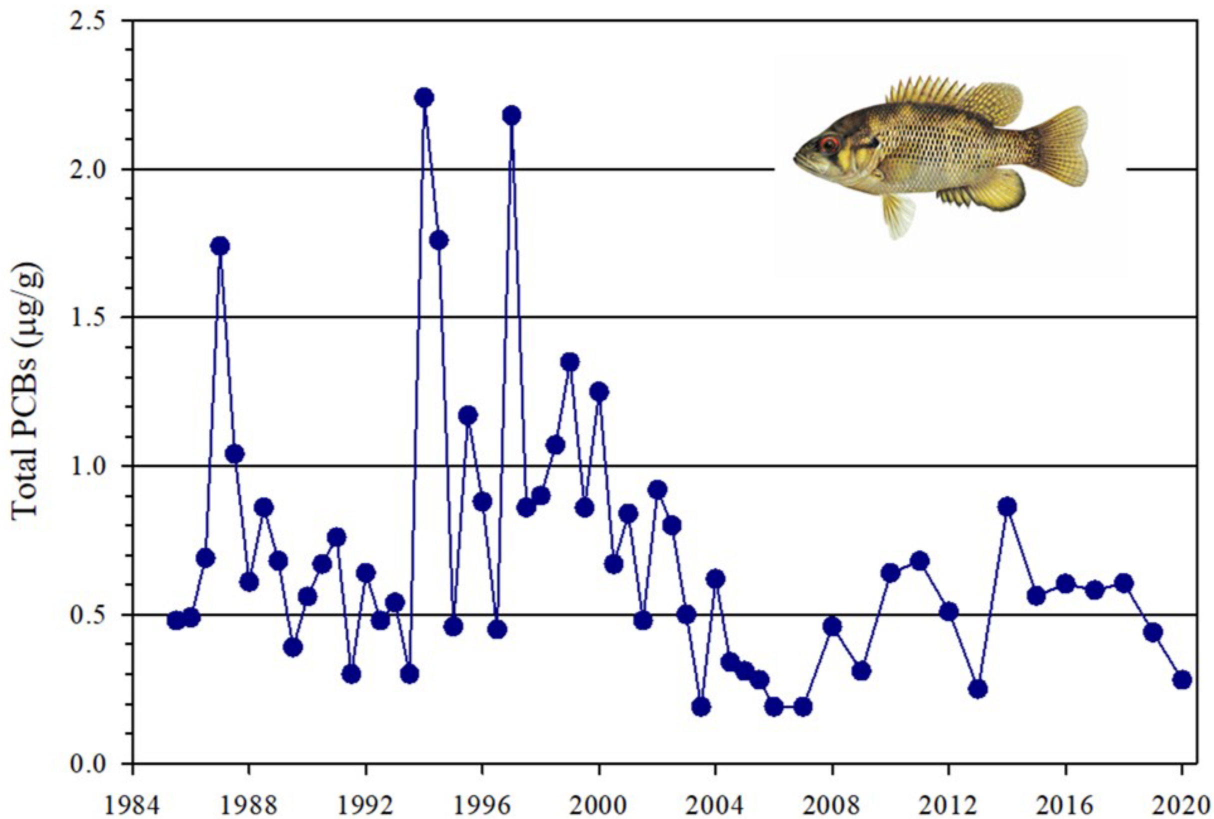
Notes:

1. *Dashed grey line represents the ambient water quality criterion for methylmercury in fish fillets (0.3 µg/g).*
2. *Water: at East Fork Poplar Creek kilometer 23.4.*
3. *Fish: at East Fork Poplar Creek kilometer 24.4.*

Figure 4.31. Semiannual average mercury concentration in muscle fillets of redbreast sunfish and water from East Fork Poplar Creek, fiscal year 2020

The relationship between aqueous total mercury concentrations and fish tissue concentrations is complex. Aqueous mercury concentrations vary by orders of magnitude throughout the various watersheds across ORR, but fish tissue concentrations tend not to vary greatly (twofold to threefold). Multiple ongoing investigations are being conducted to better understand mercury bioaccumulation dynamics in EFPC and to better predict how remedial changes may impact mercury concentrations in fish in the future.

The mean total PCB concentration in sunfish fillets at EFK 23.4 was 0.28 µg/g in FY 2020, slightly lower than concentrations seen in FY 2019 (0.44 µg/g) (Figure 4.32). Regulatory guidance and human health risk levels have varied widely for PCBs, depending on the regulatory program and the assumptions used in the risk analysis. The Tennessee water quality criterion for both individual aroclors and total PCBs is 0.00064 µg/L under the recreation designated-use classification and is the target for PCB focused total maximum daily loads, including for local reservoirs (Melton Hill, Watts Bar, and Fort Loudoun; TDEC 2010a, 2010b, 2010c).



Note:
At East Fork Poplar Creek kilometer 23.4.
Acronym:
PCB = polychlorinated biphenyl

Figure 4.32. Annual mean concentrations of polychlorinated biphenyls in rock bass muscle fillets, fiscal year 2020

In the state of Tennessee, assessments of impairment for water body segments, as well as public fishing advisories, are based on fish tissue concentrations. Historically, the US Food and Drug Administration threshold limit of 2-µg/g PCBs in fish fillets was used for advisories, and then for many years, an approximate range of 0.8 to 1 µg/g was used, depending on the data available and factors such as the fish species and size. The remediation goal for fish fillets at the ETTP K-1007-P1 Pond on ORR is 1-µg/g PCBs. Most recently, the water quality criterion has been used to calculate the fish tissue concentration triggering impairment and a total maximum daily load (TDEC 2007). This concentration is 0.02-µg/g PCBs in fish fillets (TDEC 2010a, 2010b, 2010c). The mean fish PCB concentration in Upper EFPC, 0.60 µg/g in fish fillets, is well above this concentration.

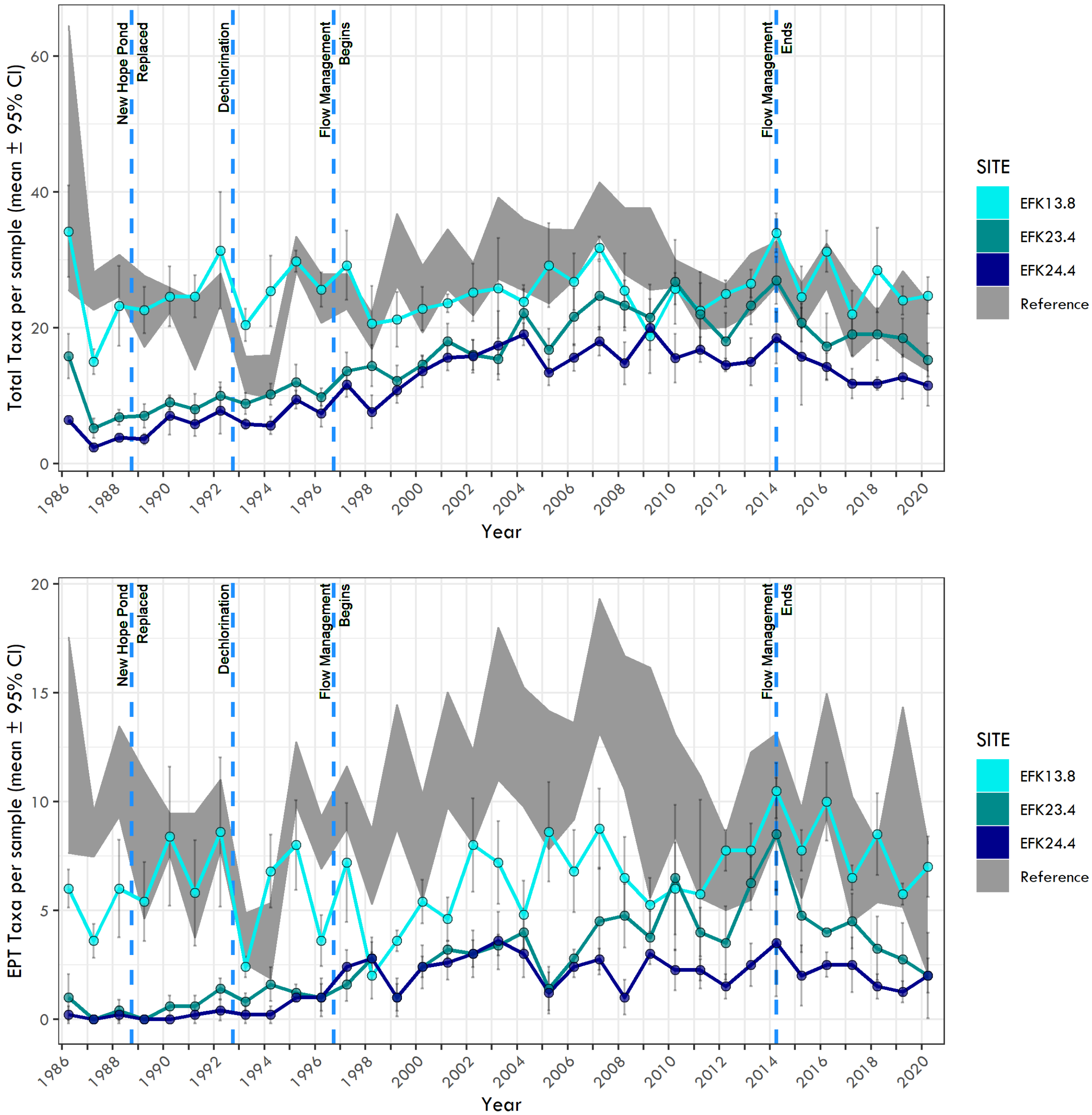
4.5.7.2. Benthic Invertebrate Surveys

Monitoring the benthic macroinvertebrate community continued in the spring of 2020 at three sites in EFPC and at two reference streams (Brushy Fork and Hinds Creek). There have been long-term changes in the macroinvertebrate community at EFPC sites since monitoring began in 1986 (Figure 4.33).

Total taxa richness (number of taxa and sample) increased at EFK 24.4 from 1986 until the mid-2000s, and then remained steady for approximately 14 yr (Figure 4.33). After flow management ended in 2014, total taxa richness decreased at EFK 24.4 and has remained at these lower values since that time. Total taxa richness at EFK 23.4 steadily increased since monitoring began, and values also decreased after flow management ceased (Figure 4.33). Total taxa richness at EFK 13.8 and the reference sites has been fairly consistent over the entire monitoring period, except for lower total taxa richness values during the first two monitoring years at EFK 13.8 (Figure 4.33). Total taxa richness at EFK 24.4 has consistently been lower than at the reference sites throughout the monitoring period, while total taxa richness at EFK 13.8 has fallen within the 95-percent confidence interval of reference site values, especially in the past decade (Figure 4.33). Total taxa richness at EFK 23.4 was lower than the 95-percent confidence interval of the reference sites from 1986 to 2009, but since then, richness has mostly been within the 95-percent confidence interval of the reference sites (Figure 4.33).

Temporal patterns in the number of pollution-intolerant taxa (Ephemeroptera, Plecoptera, and Tricoptera [EPT] taxa richness) were similar to those observed for total taxa richness (Figure 4.33). EPT taxa richness at EFK 24.4 was very low (less than 1 EPT taxa and sample) from 1986 until 1994 (Figure 4.33). EPT taxa richness then increased slightly (greater than 1 but less than 5 taxa and sample) until 2014. EPT taxa richness has been slightly lower since 2014 (Figure 4.33). EPT richness at EFK 23.4 steadily increased since 1986, but decreased after flow management ended (Figure 4.33). EPT taxa richness at EFKs 24.4 and 23.4 has typically been lower than the 95-percent confidence interval of EPT taxa richness at reference streams, indicative of degraded conditions. The number of pollution-intolerant taxa at EFK 13.8 has remained within the reference site confidence limits since 2012 (Figure 4.33).

The implications of ending flow management in 2014 on invertebrate communities in EFPC are still uncertain. After flow augmentation ceased, EPT taxa richness at EFK 23.4 has consistently declined (Figure 4.33). EPT taxa richness at EFK 24.4 has also shown a slight decrease since flow augmentation ended (Figure 4.33). The effects of ending flow augmentation on Lower EFPC (EFK 13.8) do not seem as evident, which makes intuitive sense as flow augmentation contributed a smaller percentage of total discharge at downstream sites. The long-term effects on the invertebrate community of ending flow management in EFPC will become more evident as conditions stabilize and additional data become available.



Notes:

1. *Top: total taxonomic richness (mean number of taxa per sample plus 95 percent confidence interval).*
2. *Bottom:* taxonomic richness of the pollution-intolerant taxa, Ephemeroptera, Plecoptera, and Tricoptera (mean number of *Ephemeroptera, Plecoptera, and Tricoptera taxa per sample plus 95 percent confidence interval). April, 1986–2020.*
3. *The timing of various activities within the watershed is shown in vertical blue lines.*
4. *Reference streams are Brushy Fork and Hinds Creek.*

Acronyms:

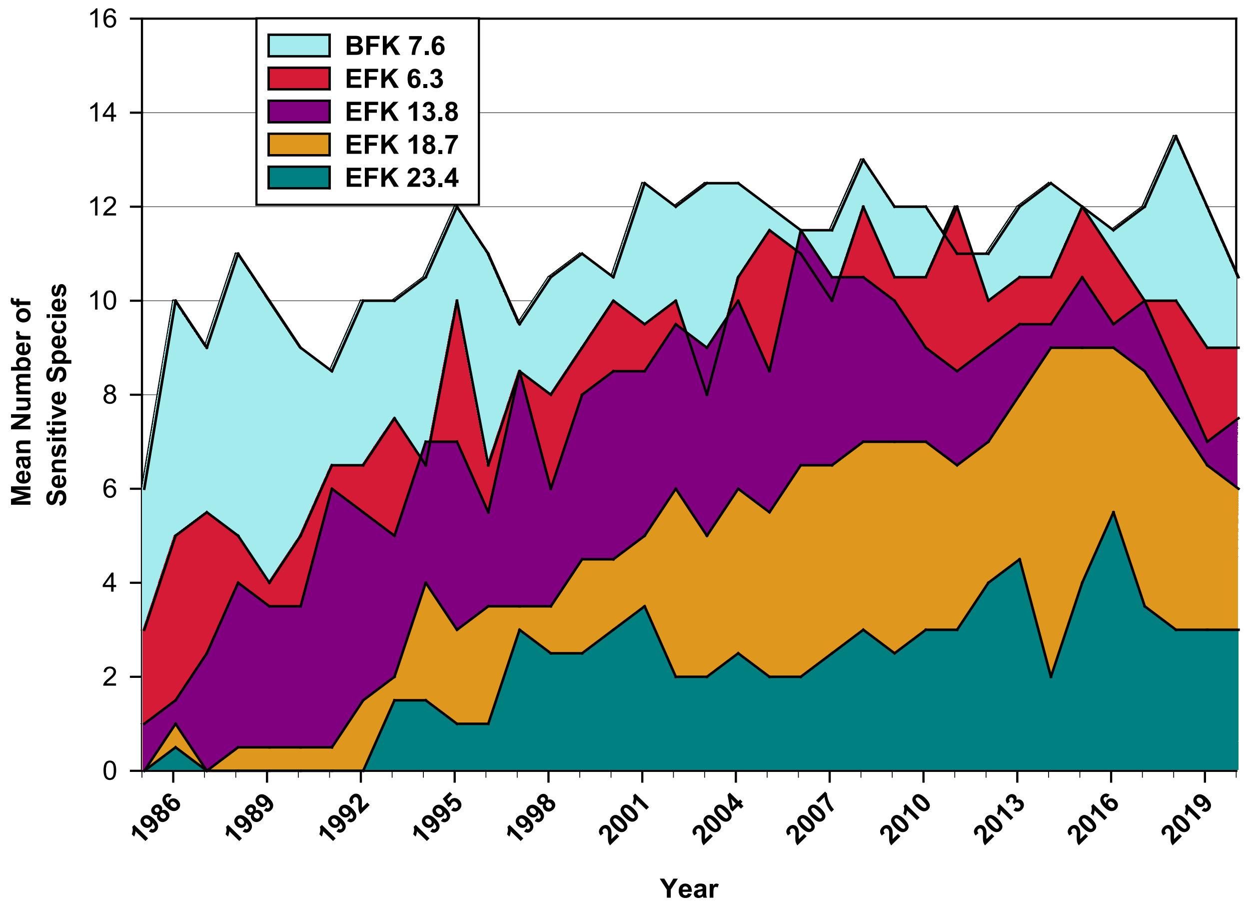
EFK = East Fork Poplar Creek kilometer

EPT = Ephemeroptera, Plecoptera, and Tricoptera

Figure 4.33. Benthic macroinvertebrate communities in three sites along East Fork Poplar Creek and the 95 percent confidence interval for two nearby reference streams

4.5.7.3. Fish Community Monitoring

Fish communities were monitored in the spring and fall of 2020 at five sites along EFPC and at a comparable local reference stream (Brushy Fork). In the past three decades, overall species richness, density, biomass, and number of pollution-sensitive fish species improved at all sampling locations below Lake Reality. Some seasonal conditions, such as flooding and drought, can cause minor fluctuations in values but rarely cause long-term impacts on larger systems such as EFPC. However, some species of fish are considered sensitive, require very specific habitat conditions to survive, and can only tolerate a narrow range of environmental disturbance. The mean number of sensitive species at four sites in EFPC and the reference stream is shown in Figure 4.34, dramatically highlighting major improvements in the fish community in the middle to lower sections (EFKs 6.3 and 13.8) of the stream. However, the EFPC fish community continues to lag behind the reference stream community (Brushy Fork kilometer 7.6) in the most important metrics of fish diversity and community structure, especially at the monitoring sites closest to Y-12 (EFKs 23.4 and 24.4).



Notes:

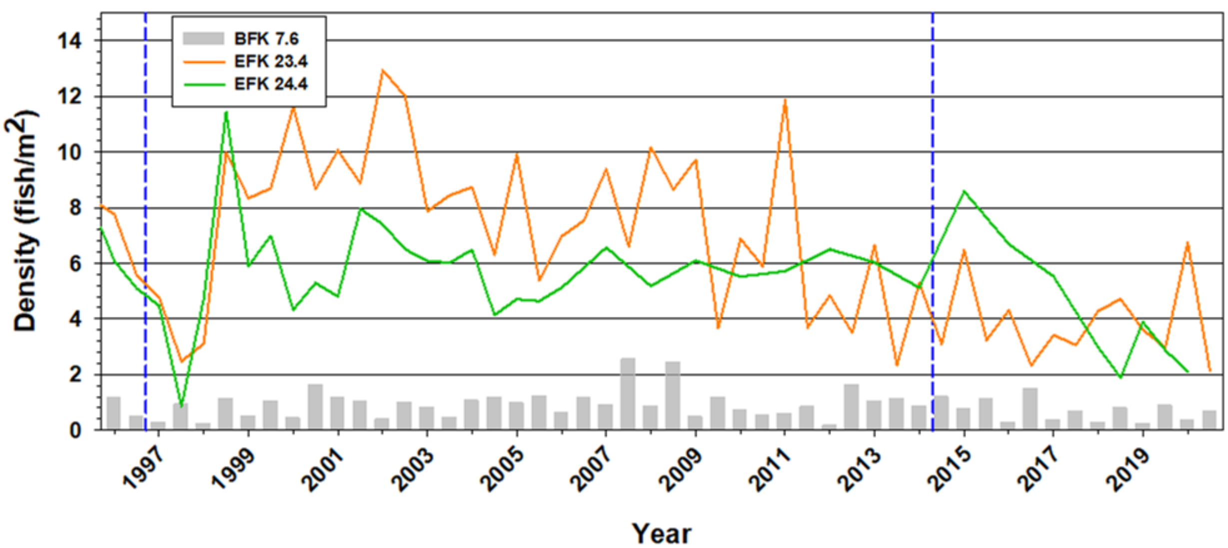
1. *Mean sensitive species richness refers to the number of species.*
2. *Showing years 1985–2020.*
3. *Reference site is Brushy Fork.*

Acronyms:

BFK = Brushy Fork kilometer
EFK = East Fork Poplar Creek kilometer

Figure 4.34. Comparison of mean sensitive species richness collected each year from four sites in East Fork Poplar Creek and a reference site

Fish communities in Upper EFPC in 2020 continued to fluctuate in density. Reduced stream flows associated with the termination of flow augmentation from Melton Hill in April 2014 and occasional unexpected fish kills are likely factors driving the decrease in fish densities in these upper sites (Figure 4.35). Despite this, fish diversity remained relatively consistent. Very high densities are not always a positive indicator of fish health, and the most abundant species within these sites continue to be those that are considered tolerant. Continued monitoring will provide additional insight into these variabilities.



Notes:

1. *The interval of time between the dashed lines represents the period of flow management in East Fork Poplar Creek.*
2. *Fish density refers to the number of fish per m^2.*
3. *Reference site is Brushy Fork.*

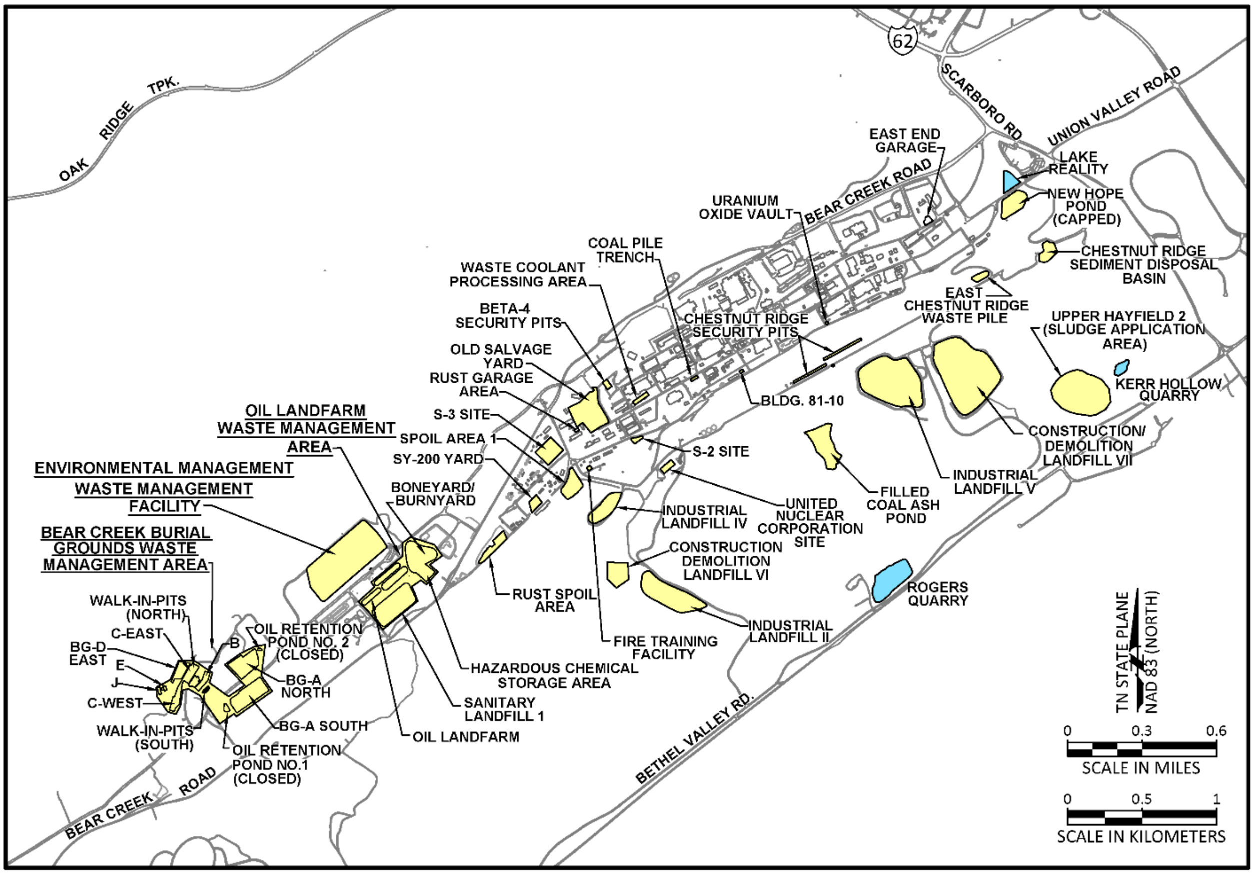
Acronyms:

BFK = Brushy Fork kilometer
EFK = East Fork Poplar Creek kilometer

Figure 4.35. Fish density for two sites in Upper East Fork Poplar Creek and a reference site, 1996–2020

4.6. Groundwater at the Y-12 National Security Complex

Groundwater is monitored to comply with federal, state, and local requirements and to determine the environmental impact from legacy and current operations. There are approximately 160 known or potential sources of contamination identified in the Federal Facility Agreement for Y-12 (DOE 2021a). Groundwater monitoring provides information on the nature and extent of contamination, which is used to identify actions needed to protect the worker, public, and environment. Figure 4.36 depicts major source areas where groundwater is monitored.



Acronyms:
Bldg. = building
Rd = road

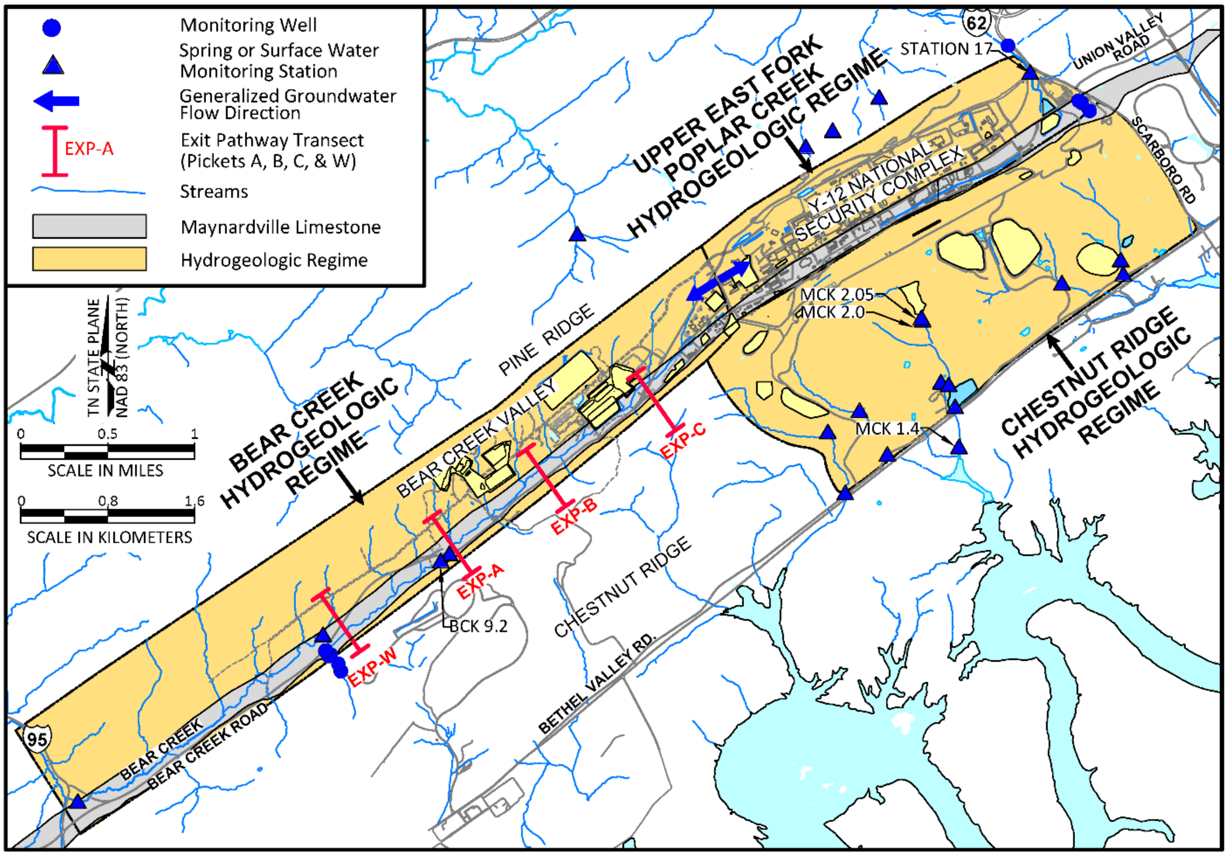
Figure 4.36. Known or potential contaminant source areas where groundwater is monitored at the Y-12 National Security Complex

4.6.1. Hydrogeologic Setting

Y-12 is divided into three hydrogeologic regimes—Bear Creek, Upper EFPC, and Chestnut Ridge (Figure 4.37). Most of the Bear Creek and Upper EFPC regimes are underlain by shale, siltstone, and sandstone bedrock, which act as an aquitard. An aquitard can contain water but does not readily yield that water to pumping wells. However, the southern portion of the Bear Creek and Upper EFPC regimes is underlain by the Maynardville Limestone, which is part of the Knox aquifer. (An aquifer more readily yields water to pumping wells.) The Chestnut Ridge regime is almost entirely underlain by the Knox aquifer.

In general, groundwater flow in the water table interval follows the topography; therefore, it flows off areas of higher elevation into the valleys and then flows parallel to the valley, along geologic strike (Figure 4.38). Shallow flow in the Bear Creek and Upper EFPC regimes diverges from a topographic and groundwater divide located near the western end of Y-12. In the Chestnut Ridge regime, a groundwater divide nearly coincides with the crest of the ridge. On Chestnut Ridge, shallow groundwater flow tends to be toward either flank of the ridge, with discharge primarily to surface streams and springs in Bethel Valley to the south and Bear Creek Valley to the north.

In Bear Creek Valley, groundwater in the intermediate and deep intervals moves through fractures in the aquitard, converging on and then moving through fractures and solution conduits in the Maynardville Limestone (Figure 4.37). Karst development in the Maynardville Limestone has a significant impact on groundwater flow paths in the water table and intermediate intervals. Groundwater flow rates in Bear Creek Valley vary; they are slow within the deep interval of the fractured non-carbonate rock (less than 10 ft/yr) but can be quite rapid within solution conduits in the Maynardville Limestone (10 to 5,000 ft/d).

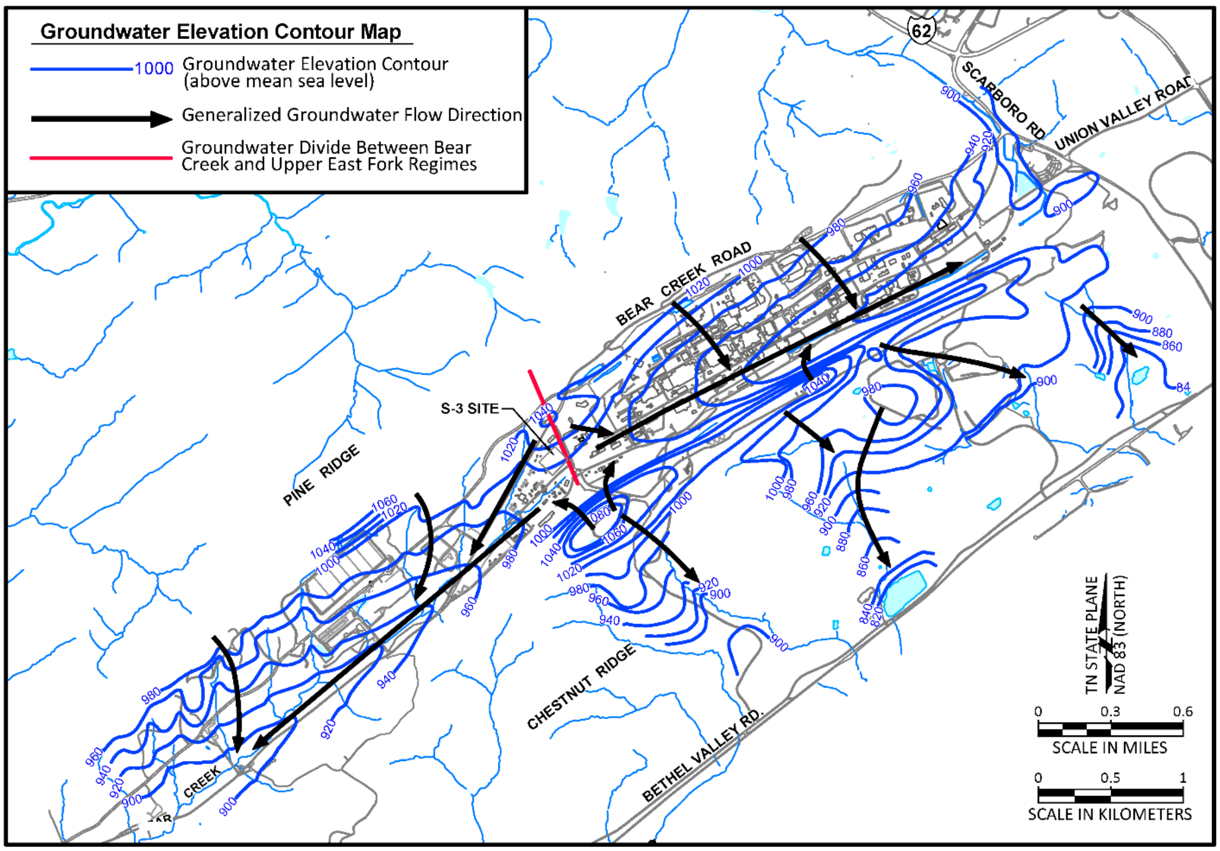


Acronyms:
MCK = McCoy Branch kilometer

Figure 4.37. Hydrogeologic regimes, flow directions, perimeter/exit pathway locations, and position of Maynardville Limestone at the Y-12 National Security Complex

Contaminants are transported, along with flowing groundwater, through the pore spaces, fractures, or solution conduits of the hydrogeologic system. Strike-parallel transport of some contaminants can even occur within the aquitard units for significant distances, where they discharge to surface water tributaries or underground utility and storm water distribution systems in Y-12's industrial area. For example, elevated levels of nitrate (a contaminant from legacy waste disposals) within the fractured bedrock of the aquitard are known to extend east and west from the S-2 and S-3 sites for thousands of feet. Extensive VOC contamination from multiple sources is observed in both the Bear Creek and Upper EFPC regimes, and to a lesser extent in the Chestnut Ridge regime. VOCs (e.g., petroleum products, coolants, and solvents) in groundwater within the fractured bedrock of the aquitard units can remain close to source areas because they tend to adsorb to the bedrock matrix, diffuse into pore spaces within the matrix, and degrade before migrating to exit pathways, where more rapid transport occurs for longer distances.

Groundwater flow in the Chestnut Ridge regime is through fractures and solution conduits in the Knox Group aquifer. Discharge points for intermediate and deep flow are not well known. However, following the crest of the Chestnut Ridge, water table elevations decrease from west to east, demonstrating an overall easterly trend in groundwater flow.



***Acronym:** Rd = road*

Figure 4.38. Groundwater elevation contours and flow directions at the Y-12 National Security Complex

4.6.2. Well Installation and Plugging and Abandonment Activities

No wells were installed, and no wells were plugged and abandoned in CY 2020.

4.6.3. Calendar Year 2020 Groundwater Monitoring

Groundwater monitoring in CY 2020 was performed as part of Y-12's Groundwater Protection Program, DOE EM programs such as the Water Resources Restoration Program, and other projects. Compliance requirements were met by monitoring 185 wells and 51 surface water locations and springs (Table 4.19). (Locations sampled for research projects [not compliance requirements] are not included in the totals.) Specific wells of interest based on CY 2020 data are called out later in this section. However, Figure 4.37 shows the locations of perimeter/exit pathway stations that are routinely monitored.

Water quality results of groundwater monitoring activities in CY 2020 are presented in the *Calendar Year 2020 Groundwater Monitoring Report* (CNS 2021). The groundwater sampling technicians shown in Figure 4.39 are taking water quality samples from a Westbay (multiport) well at the eastern end of Y-12 in Bear Creek Valley.

Table 4.19. Summary of groundwater monitoring at the Y-12 National Security Complex, 2020

Purpose for which monitoring was performed	Restoration[a]	Waste management[b]	Surveillance[c]	Other[d]	Total
Number of active wells	59	33	93	36	221
Number of other monitoring stations (e.g., springs, seeps, and surface water)	31	6	14	3	74
Number of samples taken[e]	201	120	107	10	438
Number of analyses performed	10,515	6,152	8,455	110	25,232
Percentage of analyses that are non-detects	70.3	85.3	83.4	8.8	78
Ranges of results for positive detections, VOCs (µg/L)[f]					
Chloroethenes	0.36–2,900	3.83–9.72	1–48,000	NA	
Chloroethanes	0.35–230	5.09–75.9	2–1,400	NA	
Chloromethanes	0.33–1,200	ND	2–5,100	NA	
Petroleum hydrocarbons	0.35–5,100	ND	2–1,700	NA	
Uranium (mg/L)	0.0001–0.53	0.0001–0.0161	0.00053–0.178	NA	
Nitrates (mg/L)	0.0056–4,100	0.514–1.16	0.0638–8,650	0.2–36,000	
Ranges of results for positive detections, radiological parameters (pCi/L)[g]					
Gross-alpha activity	1.96–244	1.77–4.98	4.7–76	NA	
Gross-beta activity	2.54–6,620	2.89–10.1	8.2–9,300	NA	

[a] *Monitoring to comply with Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requirements.*
[b] *Solid waste landfill detection monitoring and CERCLA landfill detection monitoring.*
[c] *US Department of Energy (DOE) Order surveillance monitoring.*
[d] *Research-related groundwater monitoring associated with activities of the DOE Oak Ridge Field Research Center and Ecosystems and Networks Integrated with Genes and Molecular Assemblies.*
[e] *The number of unfiltered samples, excluding duplicates, determined for unique location/date combinations.*
[f] *These ranges reflect concentrations of individual contaminants (not summed VOC concentrations):*
Chloroethenes—includes tetrachloroethene; trichloroethene; 1,2-dichloroethene (cis- and trans-); 1,1-dichloroethene; and vinyl chloride.
Chloroethanes—includes 1,1,1-trichloroethane; 1,2-dichloroethane; and 1,1-dichloroethane.
Chloromethanes—includes carbon tetrachloride, chloroform, and methylene chloride.
Petroleum hydrocarbon—includes benzene, toluene, ethylbenzene, and xylene.
[g] *pCi = 3.7×10^{-2} Bq*

Acronyms:
NA = not analyzed
ND = not detected
VOC = volatile organic compound

Figure 4.39. Groundwater monitoring well sampling at the Y-12 National Security Complex

Monitoring efforts performed specifically for CERCLA baseline and remediation evaluation are published in the FYs 2020 and 2021 Water Resources Restoration Program Sampling and Analysis Plans (UCOR 2019a, 2020a, respectively) and the Annual CERCLA Remediation Effectiveness Reports (DOE 2020e, 2021b).

4.6.4. Y-12 National Security Complex Groundwater Quality

Historical monitoring shows that four primary contaminants adversely affect groundwater quality at Y-12—nitrate, VOCs, metals, and radionuclides. Of those, VOCs are the most widespread. Uranium and ^{99}Tc are the radionuclides of greatest concern. Trace metals (e.g., arsenic, barium, cadmium, chromium, and mercury), the least extensive groundwater contaminants, generally occur close to source areas because of their high adsorption characteristics. Data show that plumes from multiple-source units have mixed with one another and that contaminants are not always easily associated with a single source.

4.6.4.1. Upper East Fork Poplar Creek Hydrogeologic Regime

Among the three hydrogeologic regimes, the Upper EFPC regime contains most of the known and potential sources of contamination. (Summary descriptions of waste management sites shown on Figure 4.36 were provided in previous-year ASERs—e.g., for CY17 and before—and are not repeated this year.) Contaminants from the S-3 site (nitrate and ^{99}Tc) and VOCs from multiple source areas are observed in groundwater in the western portion of the Upper EFPC regime; whereas, groundwater in the eastern portion of the regime is predominantly contaminated with VOCs.

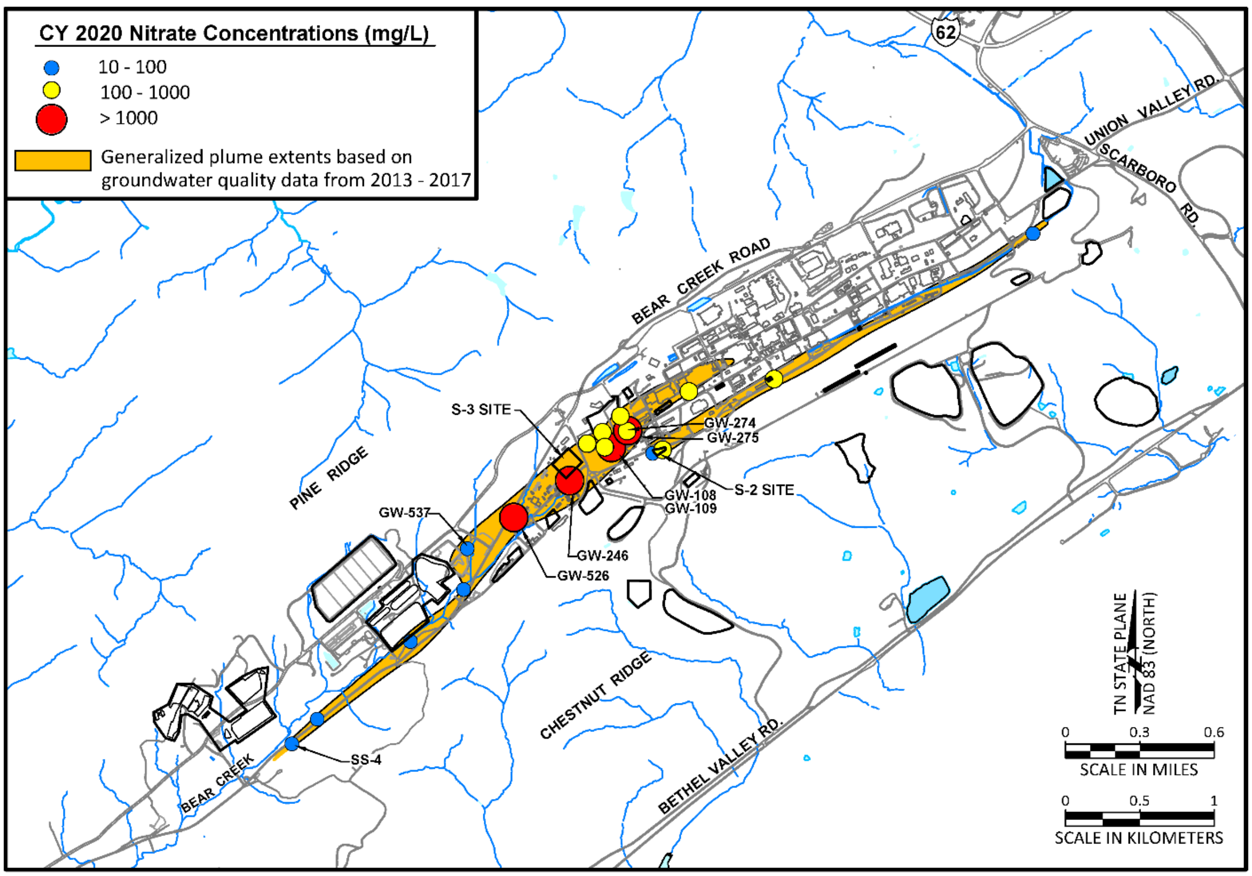
Plume Delineation

Sources of contaminants monitored during CY 2020 include the S-2 site, Fire Training Facility, S-3 site, Waste Coolant Processing Facility, former petroleum USTs, New Hope Pond, Old Salvage Yard, and process/production buildings throughout Y-12. The S-3 site is near the hydrologic divide that separates the Upper EFPC regime from the Bear Creek regime, and has contributed groundwater contamination to both regimes. Contaminant plumes in both regimes (shown in orange shading on Figures 4.40 through 4.43) are elongated as a result of preferential transport of contaminants parallel to strike (parallel to the valley axis) in both the Knox aquifer and the fractured bedrock of the aquitard.

The plumes depicted (orange shading) reflect the average concentrations and radioactivity in groundwater between CYs 2013 and 2017. The circular icons presented on the plume maps (Figures 4.41 through 4.43) represent CY 2020 monitoring results for the Upper EFPC regime (discussed in this section), the Bear Creek regime (discussed in Section 4.6.4.2), and the Chestnut Ridge regime (discussed in Section 4.6.4.3).

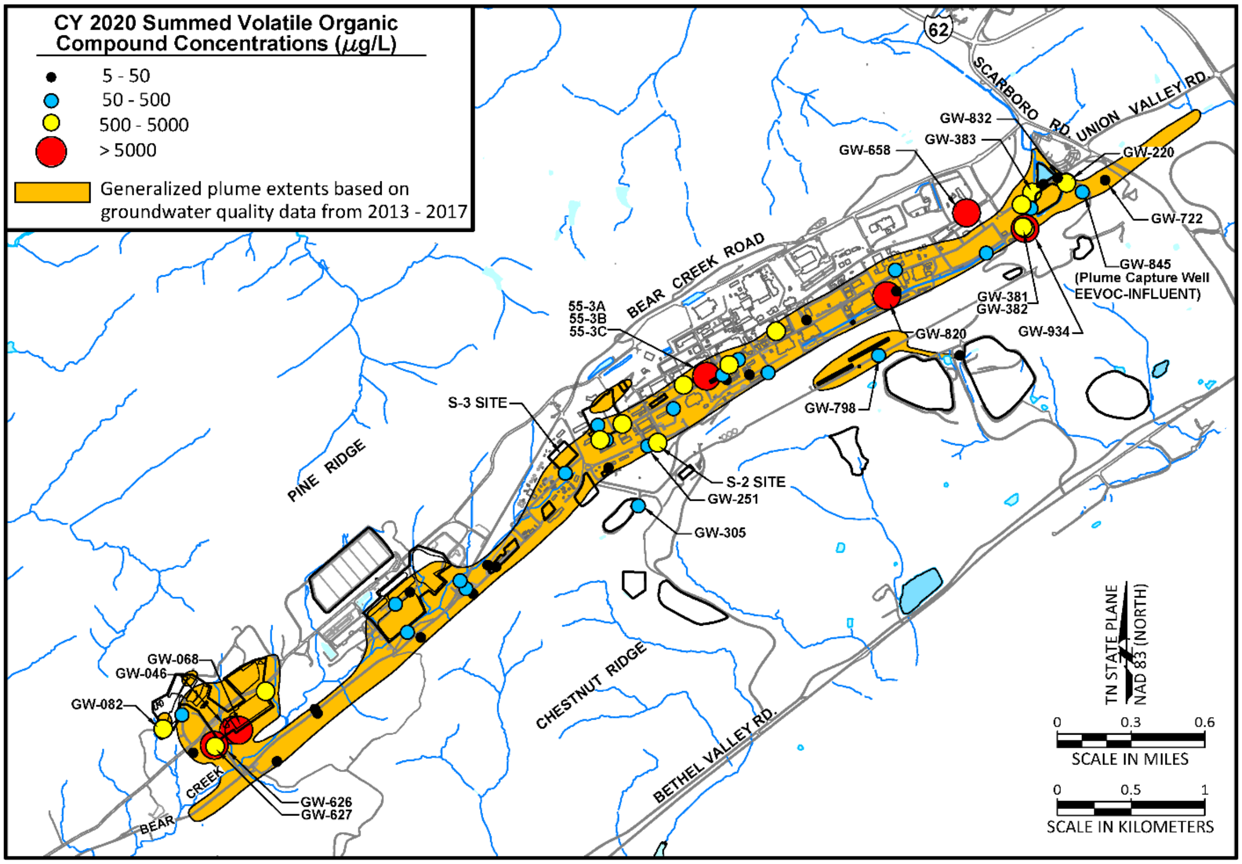
Nitrate

Nitrate is highly soluble and moves easily with groundwater. In the central and western portions of Upper EFPC, nitrate concentrations exceed the 10-mg/L drinking water standard. (A list of the national drinking water standards is presented in Appendix C.) The two primary sources of nitrate contamination are the S-2 and S-3 sites. In CY 2020, there was a maximum nitrate concentration of 8,650 mg/L in well GW-109. This well is located east of the S-3 site and is screened in the intermediate bedrock interval about 34 m (112 ft) below ground surface (Figure 4.40).



Acronyms:
CY = calendar year
Rd = road

Figure 4.40. Nitrate in groundwater at the Y-12 National Security Complex, 2020



Acronyms:
CY = calendar year
EEVOC = East End Volatile Organic Compound
Rd = road

Figure 4.41. Summed volatile organic compounds in groundwater at the Y-12 National Security Complex, 2020

The next highest nitrate concentration was found in well GW-275 at 8,220 mg/L. The complex nature of the subsurface in Bear Creek Valley is represented by the fact that, over the last two decades, GW-275 (screened at about 60 ft bgs) has shown an increasing trend (approximately 7,000 to approximately 9,000 mg/L), while the nearby shallower well (GW-274, screened at 31 ft below ground surface) has a decreasing trend, including nitrate, at 412 mg/L in CY 2020 compared to 5,410 mg/L in CY 2010.

Trace Metals

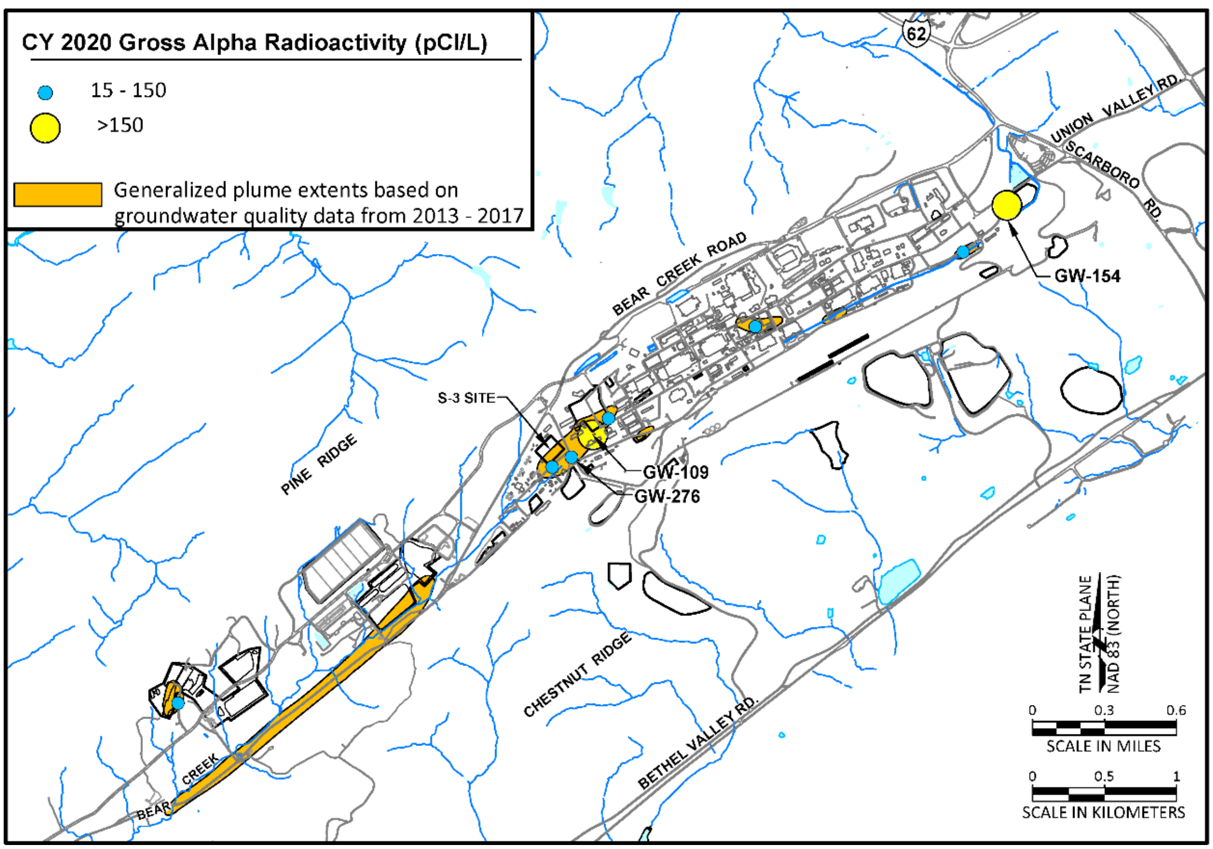
In CY 2020, barium, cadmium, chromium, copper, nickel, thallium, and uranium exceeded primary drinking water standards in groundwater in the Upper EFPC regime. Uranium was found predominately downgradient of the S-2, S-3, and New Hope Pond sites. Trace metal concentrations above standards occur adjacent to source areas because of their low solubility and high adsorption to the clay-rich soils and bedrock.

VOCs

VOCs, the most widespread contaminants in the Upper EFPC regime, consist of chlorinated and petroleum hydrocarbons. In CY 2020, the highest summed concentration of dissolved chlorinated hydrocarbons (56,045 µg/L) was again at well 55-3B in the western portion of Y-12, adjacent to currently inactive manufacturing facilities. The highest dissolved concentration of petroleum hydrocarbons was again at well GW-658 (12,500 µg/L) at the closed East End Garage.

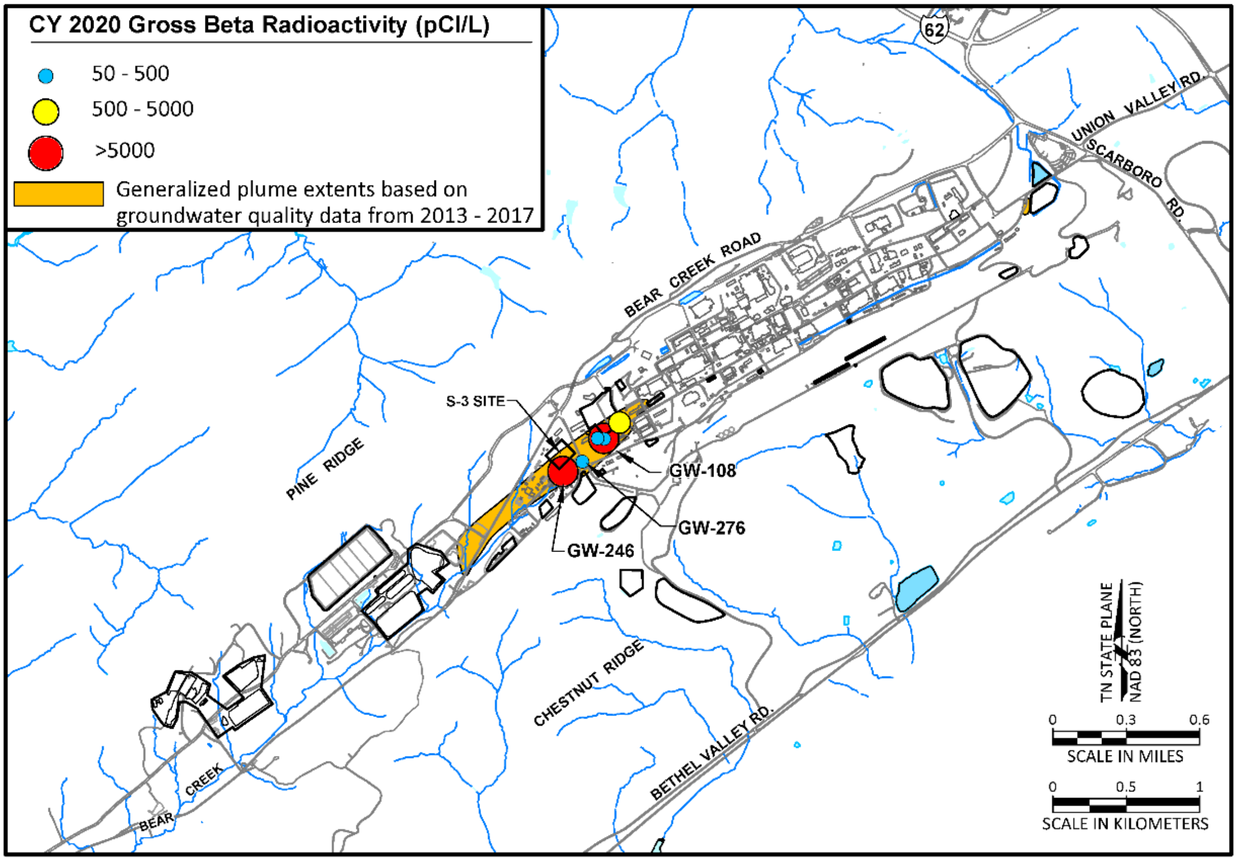
Most monitoring results are consistent with data from previous years because a dissolved plume of legacy VOCs in the bedrock zone extends eastward from the S-3 site over the entire length of the regime (Figure 4.41). Additional sources are the Waste Coolant Processing Facility, fuel facilities (Rust Garage and East End Garage), and other waste disposal and production areas. Chloroethene compounds (tetrachloroethene [PCE], trichloroethene [TCE], dichloroethene [DCE], and vinyl chloride) tend to dominate the VOC plume in the western and central portions of Y-12. However, PCE is almost ubiquitous throughout, indicating many source areas. Chloromethane compounds (carbon tetrachloride, chloroform, and methylene chloride) are the predominant VOCs in the eastern portion of Y-12.

Variability in concentration trends of chlorinated and petroleum VOCs is seen within the Upper EFPC regime. While data from most monitoring wells have remained relatively constant since the late 1980s/early 1990s, some wells show encouraging trends in recovery from legacy contamination. As shown in Figure 4.44, GW-383 (the shallow well) has remained constant for summed VOCs for 30 years, but nearby GW-382 (screened at 250 ft below ground surface) has shown a decrease in summed VOCs for most of that same time. These decreasing and stable trends west of New Hope Pond are indicators that contaminants are attenuating due to: (1) dilution by uncontaminated groundwater, (2) dispersion through a network of fractures and conduits, (3) degradation by chemical or biological means, and/or (4) adsorption by surrounding bedrock and soil media. However, in addition to the factors mentioned above, in CY 2000, plume capture well GW-845 began pumping operations to capture the East End VOC plume, mitigating migration off the ORR into Union Valley (see additional information in the Exit Pathway and Perimeter Monitoring section).



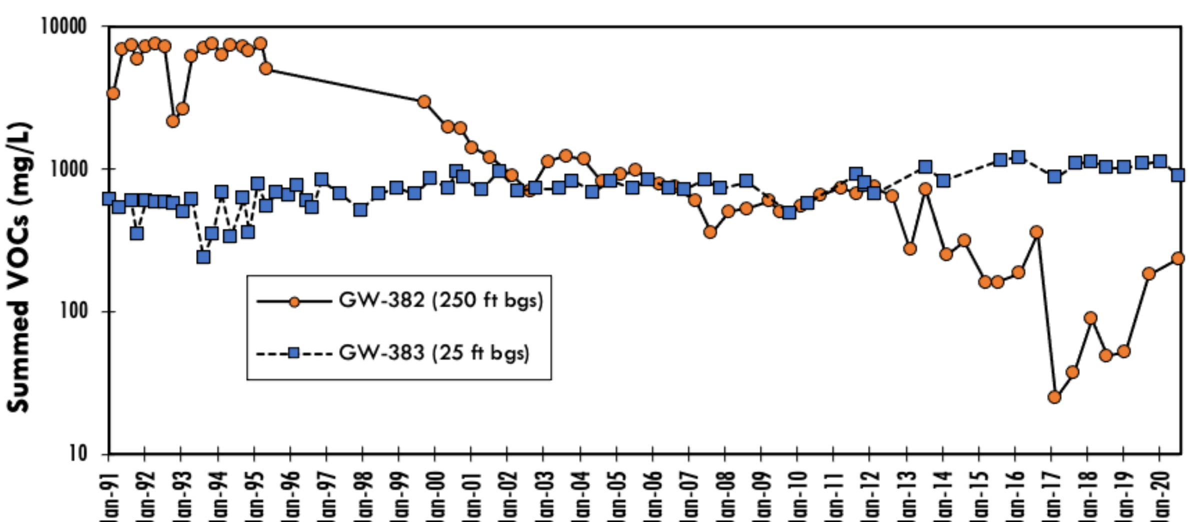
Acronyms: *CY = calendar year* *Rd = road*

Figure 4.42. Gross-alpha activity in groundwater at the Y-12 National Security Complex, 2020



Acronyms:
CY = calendar year *Rd = road*

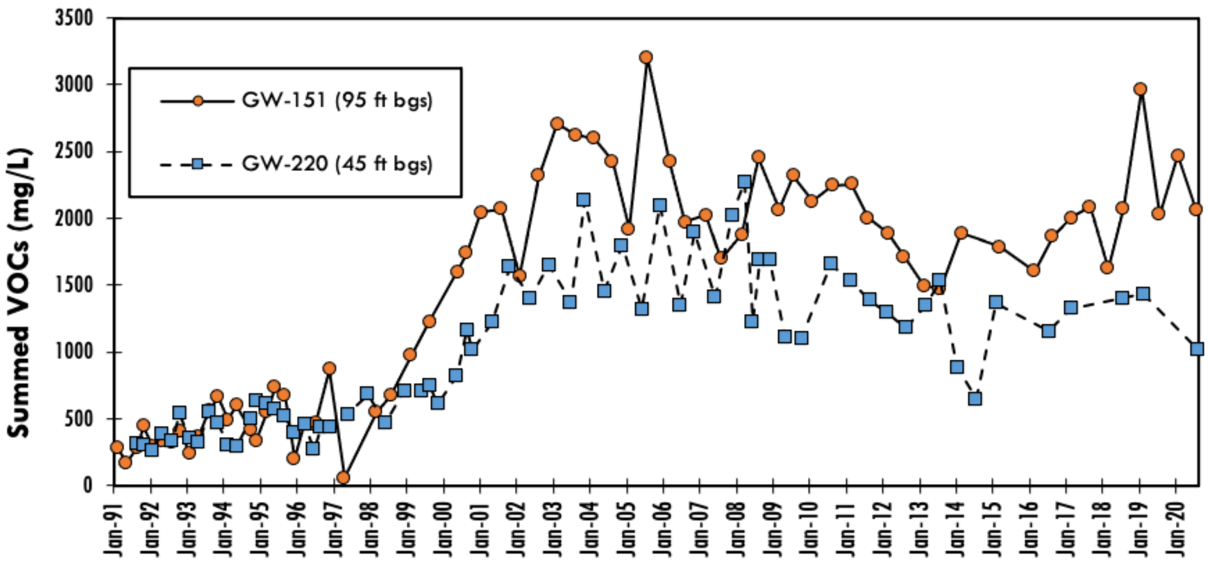
Figure 4.43. Gross-beta activity in groundwater at the Y-12 National Security Complex, 2020



Acronyms:
bgs = below ground surface *VOC = volatile organic compound*

Figure 4.44. Summed volatile organic compounds for GW-382 and GW-383 in the East Fork regime

Alternatively, increasing trends have been observed in wells associated with the Rust Garage, Old Salvage Yard, and S-3 site; some legacy sources at production/process facilities in central areas; and even the East End VOC plume (see Figure 4.45). These trends near the East End VOC plume show that contaminants in wells located perpendicular to strike across lithologic units from the plume capture system installed in GW-845 may be mobilized by the system. However, no downgradient detection of these compounds is apparent; therefore, migration is limited.



Acronyms:
bgs = below ground surface
VOC = volatile organic compound

Figure 4.45. Summed volatile organic compounds for GW-151 and GW-220 in the East Fork regime

Radionuclides

The primary alpha-emitting radionuclides found in the Upper EFPC regime during CY 2020 are isotopes of uranium. Exceedances of the drinking water standard for gross alpha (15 pCi/L) have been observed near the S-3 site, Old Salvage Yard, and other western source areas; in the central areas near production facilities and the Uranium Oxide Vault; and also in the east end near the former oil skimmer basin at the former inlet to New Hope Pond, which was capped in 1988. In CY 2020, the maximum occurrence of gross-alpha activity in groundwater in the Upper EFPC regime was 244 pCi/L, again at well GW-154 near the former oil skimmer basin.

The primary beta-emitting radionuclides observed in the Upper EFPC regime are ^{99}Tc and isotopes of uranium. Elevated gross-beta activity in groundwater shows a pattern similar to that observed for gross-alpha activity.

Technetium-99 is the primary contaminant exceeding the gross-beta screening level of 50 pCi/L; the source is the S-3 site. The highest gross-beta activity in groundwater was observed during CY 2020 from well GW-108 (9,300 pCi/L), similar to previous activity measured in CY 2018.

Exit Pathway and Perimeter Monitoring

In the Upper EFPC regime, VOCs have been observed at depths of up to 500 ft below ground surface. The deep fractures and solution channels in the Maynardville Limestone (the primary exit pathway) appear to be well connected and facilitate contaminant migration into Union Valley offsite to the east of Y-12.

Due to off-site migration of contaminants, a plume capture system (the East End VOC Treatment System) was constructed in and around well GW-845 (shown on Figure 4.41) and began continuous operation in October 2000. Groundwater is continuously pumped from the Maynardville Limestone at about 95 L/min (25 gal/min), passes through a treatment system to remove the VOCs, and then discharges to Upper EFPC. The effectiveness of this system is reported annually in Remediation Effectiveness Reports published by DOE EM (DOE 2020e, 2021b).

As explained previously for GW-382 and GW-383, monitoring wells near the plume capture system continue to show an encouraging response. Another example is observed in the Westbay system installed in well GW-722. This multiport well, located downgradient from the East End VOC Treatment System, allows sampling of several vertically discrete zones within the Maynardville Limestone. Monitoring results from well GW-722 indicate reductions in VOCs due to the plume capture system, derived from summed VOC levels above 1,000 µg/L before the treatment system was installed to below 50 µg/L in both CYs 2019 and 2020.

Five zones in well GW-722 were sampled in CY 2020, with all zones showing summed VOCs greater than 5 µg/L. Four zones exceeded the drinking water standard for carbon tetrachloride, with the highest concentration (20 µg/L) measured at both zones 722-17 and 722-20. One zone (722-20) exceeded the drinking water standard for PCE at 5.9 µg/L. Zone 722-20 is located 333 ft below ground surface, and 722-22 is located 313 ft below ground surface.

In addition to the deep system in the eastern portion of the Upper EFPC regime, VOCs have also been observed in shallow groundwater where it flows north-northeast (mimicking the flow of the creek) east of the New Hope Pond site and Lake Reality. In this area, GW-832 has been installed in a distribution channel underdrain associated with former New Hope Pond. During CY 2020, the observed concentrations of VOCs at the New Hope Pond distribution channel underdrain remained low (25 µg/L).

Upper EFPC flows north exiting Y-12 through a gap in Pine Ridge. As mentioned previously, shallow groundwater mimics the creek and also moves through this exit pathway. One well in this pathway gap was monitored in CY 2020, and no groundwater contaminants were observed above primary drinking water standards.

Perimeter sampling locations continue to be monitored north and northwest of Y-12 to evaluate possible contaminant transport, even though those locations are considered unlikely contaminant exit pathways. One of the stations monitored is a tributary that drains the north slope of Pine Ridge and discharges into the adjacent Scarboro Community. One location monitors an upper reach of Mill Branch, which discharges into the residential areas along Wiltshire Drive. The remaining location monitors Gum Hollow Branch as it flows adjacent to the Country Club Estates community. There were no indications that contaminants were being discharged from the ORR into those communities.

Union Valley Monitoring

Groundwater monitoring data obtained in the early 1990s provided the first indication that VOCs were being transported off the ORR through the deep Maynardville Limestone exit pathway. The Upper EFPC remedial investigation (DOE 1998) discussed the nature and extent of VOC contamination in Union Valley.

In CY 2020, monitoring of locations in Union Valley continued, showing overall decreasing or low-concentration stable trends. Vinyl chloride at 1.7 µg/L (below the maximum contaminant level of 2 mg/L) was detected at monitoring well GW-230, located east of Illinois Avenue in the University of Tennessee Arboretum (off the map and approximately 3,500 ft east of the ORR boundary). A groundwater flow divide west of well GW-230, coincident with Scarboro Creek, Illinois Avenue, and a gap in Chestnut Ridge, probably restricts transport of VOCs from the ORR further east (MMES 1995). This would indicate that the VOCs observed in the well are from a source other than Y-12.

Under the terms of an Interim ROD, administrative controls (i.e., restrictions on potential future groundwater use) have been established and maintained. Additionally, the previously discussed plume capture system (well GW-845) was installed to mitigate the migration of groundwater contaminated with VOCs into Union Valley (DOE 1997b).

In July 2006, the Agency for Toxic Substances and Diseases Registry—the principal federal public health agency charged with evaluating the human health effects of exposure to hazardous substances in the environment—published a report in which groundwater contamination across the ORR was evaluated (ATSDR 2006). In the report, it was acknowledged that groundwater contamination exists throughout the ORR, but the authors concluded there is no public health hazard from exposure to contaminated groundwater originating on the ORR. At that time, the Y-12 East End VOC groundwater contaminant plume was acknowledged as the only confirmed, off-site, contaminant plume migrating across the ORR boundary. The report recognized that institutional and administrative controls established in the ROD do not provide for reduction in toxicity, mobility, or volume of contaminants of concern, but it concluded the controls are protective of public health to the extent that they limit or prevent community exposure to contaminated groundwater in Union Valley.

4.6.4.2. Bear Creek Hydrogeologic Regime

Located west of Y-12 in Bear Creek Valley, the Bear Creek regime is bounded to the north by Pine Ridge and to the south by Chestnut Ridge. The regime encompasses the portion of Bear Creek Valley extending from the west end of Y-12 to State Highway 95. Descriptions of waste management sites in the Bear Creek regime and shown on Figure 4.36 were provided in previous year ASERs (e.g., in CY 2017 and previous) and are not repeated this year.

Plume Delineation

The primary contaminants in the Bear Creek regime are nitrate, trace metals, VOCs, and radionuclides. The S-3 site is a source of all four contaminants. The Bear Creek Burial Grounds and Oil Landfarm waste management areas are sources of uranium, other trace metals, and VOCs. Chlorinated hydrocarbons and PCBs have been observed in groundwater as deep as 82 m (270 ft) below the Bear Creek Burial Grounds (MMES 1990).

Contaminant plume boundaries are constrained by the bedrock formations (particularly the Nolichucky Shale) that underlie the waste disposal areas in the Bear Creek regime. This fractured aquitard unit is north of and adjacent to the exit pathway unit, the Maynardville Limestone (an aquifer). The elongated shape of the plumes in the Bear Creek regime is the result of preferential transport of the contaminants parallel to strike (parallel to the valley axis).

The plumes in the Bear Creek regime (shown by orange shading on Figures 4.40 through 4.43) represent the average concentrations and radioactivity between CYs 2013 and 2017. The circular icons presented on the figures represent CY 2020 monitoring results.

Nitrate

CY 2020 data indicate nitrate in groundwater continues to exceed the drinking water standard (10 mg/L) in an area that extends west from the S-3 site. The highest nitrate concentration (2,070 mg/L) was observed at well GW-246 adjacent to the S-3 site at a depth of 19 m (62.5 ft) below ground surface. Historically, elevated concentrations of nitrate (>1,000 mg/L) have been detected at greater depths (>700 ft below ground surface) near the S-3 site. In CY 2020, a concentration exceeding the drinking water standard was detected in groundwater as far as 2,438 m (8,000 ft) west of the S-3 site, from spring location SS-4 (13 mg/L). However, encouraging trends in both nitrate and gross-beta contamination are evident in the aquitard (the Nolichucky Formation) approximately 910 m (2,985 ft) west of the S-3 site (see Figure 4.46).

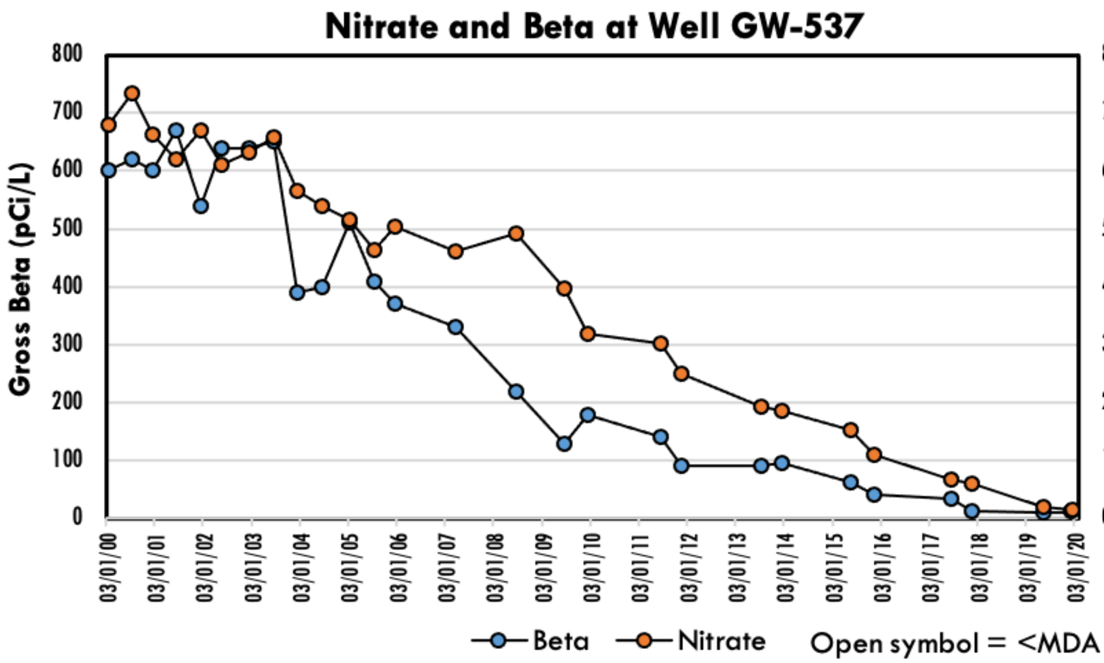


Figure 4.46. Nitrate and gross-beta trends for GW-537 in the Bear Creek regime

Trace Metals

During CY 2020, barium, cadmium, and uranium were identified as trace metal contaminants in the Bear Creek regime that exceeded primary drinking water standards. Elevated concentrations of many of the trace metals were observed at shallow depths near the S-3 site. Disposal of acidic liquid wastes at the S-3 site reduced the pH of the groundwater, which allows the metals to remain in solution longer and migrate further from the source area. In other areas of the Bear Creek regime, where natural geochemical conditions prevail, the trace metals may occur sporadically and in close association with source areas because conditions are typically not favorable for dissolution and migration.

The most prevalent trace metal contaminant is uranium. There has been a decrease in uranium in Bear Creek since 1990 (Table 4.20); however, uranium concentrations in the upper reaches of Bear Creek have been stable, indicating that this contaminant still presents an impact in surface water and groundwater.

VOCs

VOCs are widespread in groundwater in the Bear Creek regime. The primary compounds are PCE; TCE; cis-1,2-DCE; vinyl chloride; and 1,1-dichoroethane. In most areas, they are dissolved in groundwater and can occur in bedrock at depths up to 92 m (300 ft) below ground surface. VOCs that occur in groundwater of the fractured bedrock aquitard units are found within about 305 m (1,000 ft) laterally of source areas.

The highest concentration observed in CY 2020 occurred in the Nolichucky Shale aquitard at the Bear Creek Burial Ground waste management area, with a maximum summed VOC concentration of 6,062 µg/L in well GW-068 (Figure 4.41); cis-1,2-DCE at 3,100 µg/L and 1,1-dichloroethane at 1,400 µg/L comprised most of the summed total.

Increasing trends of VOCs have been seen in GW-627 downgradient of the Bear Creek Burial Ground waste management area (Figure 4.47). An increasing trend, but widely varying since CY 2010, is observed in GW-082 downgradient of the Bear Creek Burial Grounds (Figure 4.48).

Table 4.20. Nitrate and uranium concentrations in Bear Creek

Bear Creek Monitoring station (distance from S-3 site)	Contaminant	Average concentration[a] (mg/L) 1990–1999	2000–2009	2010–2019	2020
BCK[b]: 11.84–11.97	Nitrate	91.9	75.2	43.4	18.7
(approximately 0.5 mi downstream)	Uranium	1.61	0.124	0.183	0.129
BCK: 09.20–09.47	Nitrate	12.4	11.3	4.8	2.6
(approximately 2 mi downstream)	Uranium	0.096	0.115	0.061	0.053
BCK: 04.55	Nitrate	3.8	2.5	0.96	1.29
(approximately 5 mi downstream)	Uranium	0.033	0.028	0.018	0.018

[a] *Excludes results that do not meet data quality objectives.*
[b] *Measured upstream from the confluence with East Fork Poplar Creek.*
Acronym:
BCK = Bear Creek kilometer

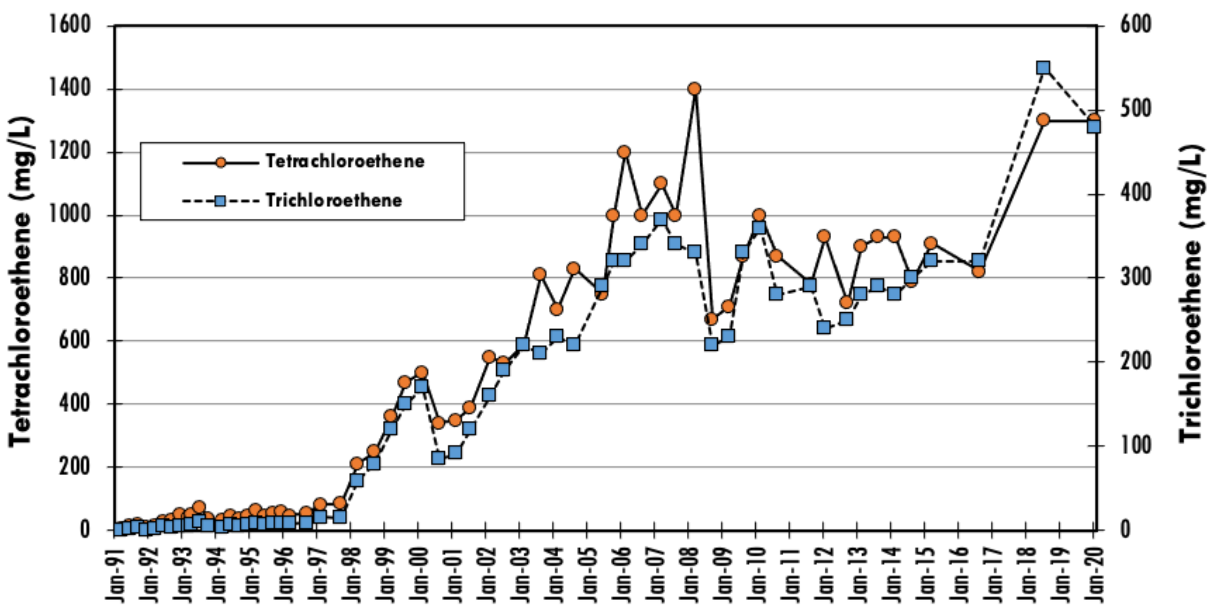


Figure 4.47. Volatile organic compounds in GW-627 at the Bear Creek Burial Ground waste management area

Radionuclides

As in the EFPC regime, the primary radionuclides identified in the Bear Creek regime are isotopes of uranium and ^{99}Tc. The extent of radionuclides in groundwater in the Bear Creek regime during CY 2020 was based primarily on measurements of gross-alpha and gross-beta activity. If the gross-alpha activity in a well exceeded 15 pCi/L (the drinking water standard for gross-alpha activity), then one (or more) of the alpha-emitting radionuclides (e.g., uranium) is assumed to be present and, at certain monitoring locations, is evaluated isotopically. A similar rationale is used for gross-beta activity that exceeds 50 pCi/L. Technetium-99, a more volatile radionuclide, is qualitatively screened by gross-beta activity analysis.

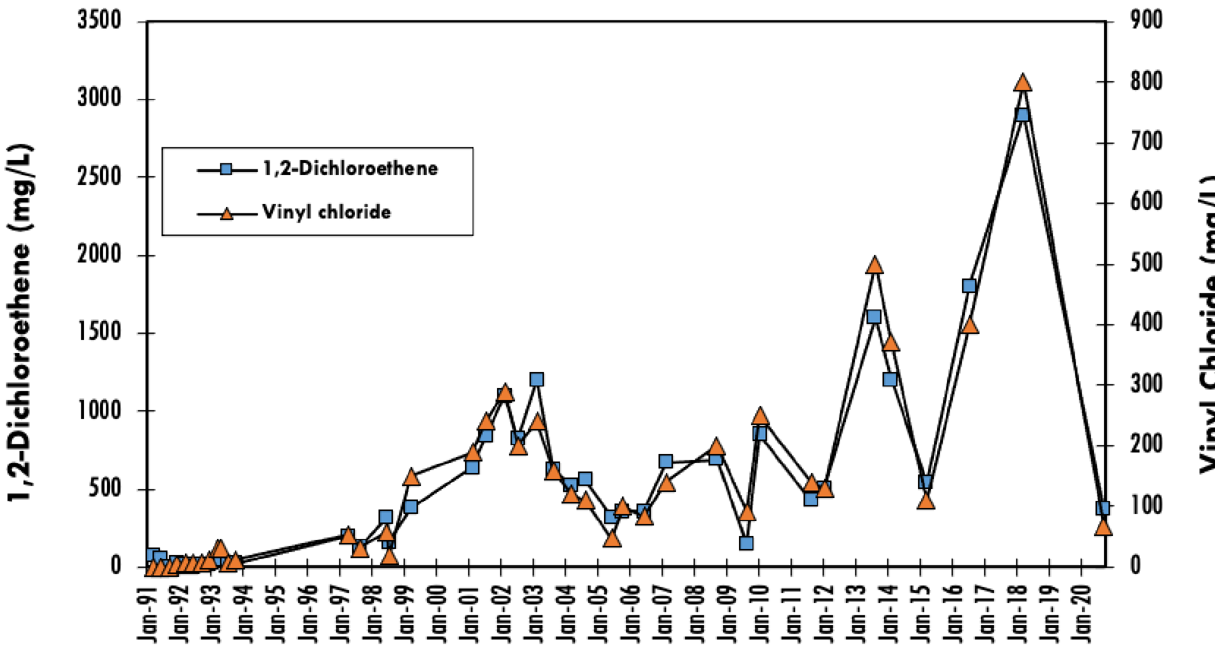


Figure 4.48. Volatile organic compounds in GW-082 at the Bear Creek Burial Grounds

Groundwater in the Bear Creek regime with elevated gross-alpha activity occurs near the S-3 site and the Oil Landfarm waste management area. In the bedrock interval, gross-alpha activity has exceeded 15 pCi/L in groundwater in the fractured bedrock of the aquitard units only near source areas (Figure 4.42).

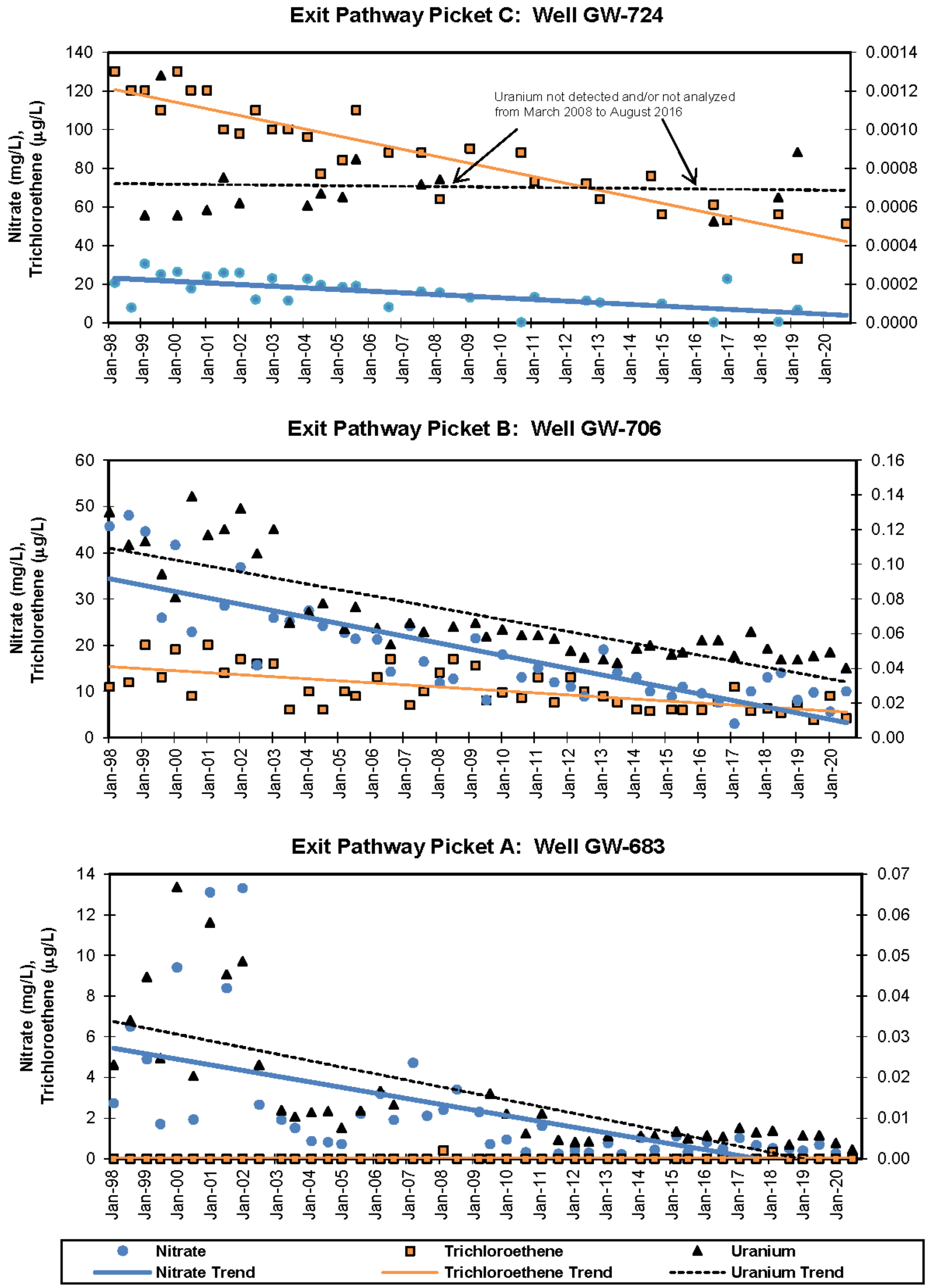
In CY 2020, the highest gross-alpha activity observed in a monitoring well in the Bear Creek regime (102 pCi/L) was in GW-276 (Figure 4.43).

In CY 2020, the highest gross-beta activity in groundwater in the Bear Creek regime was observed at well GW-246 (9,300 pCi/L) adjacent to the S-3 site. The next highest gross-beta activity was measured at 84.2 pCi/L in GW-276, also downgradient of the S-3 site. Figure 4.46 shows the decreasing trend for gross-beta at GW-537 in the aquitard of the Bear Creek regime.

Exit Pathway and Perimeter Monitoring

Bear Creek, which flows over the Maynardville Limestone (the primary exit pathway for groundwater) in much of the Bear Creek regime, is the principal exit pathway for surface water. Studies have shown the surface water in Bear Creek, the springs along the valley floor, and the groundwater in the Maynardville Limestone are hydraulically connected. Surveys have been performed identifying gaining (groundwater discharging into surface waters) and losing (surface water discharging into a groundwater system) reaches of Bear Creek. The western exit pathway monitoring well transect (Picket W) serves as the perimeter designation for the Bear Creek regime (Figure 4.37).

Exit pathway monitoring consists of continued monitoring at four well transects (pickets) and selected springs and surface water stations. Data obtained during CY 2020 indicate groundwater is contaminated above drinking water standards in the Maynardville Limestone between Pickets A and C. With the exception of uranium at Picket C (GW-724), which has shown in increase in concentration, trends continue to be generally stable to decreasing (Figure 4.49).



Note: Only nitrate and uranium results above the detection limit are plotted; non-detected trichloroethene results are plotted at zero.

Figure 4.49. Concentrations of selected contaminants in exit pathway monitoring wells in the Bear Creek hydrogeologic regime

In CY 2020, GW-713 in exit pathway transect W (Figure 4.37) showed a trace concentration (0.62 µg/L) of TCE (below drinking water standards), thus indicating migration of contaminants potentially thousands of feet from likely sources areas to the east (e.g., Boneyard/ Burnyard, the S-3 site, or Spoil Area 1).

Surface water samples collected in CY 2020 indicate water in Bear Creek contains many of the same compounds found in the groundwater. Uranium concentrations exceeding the drinking water standard have been observed in surface water west of the Burial Grounds as far as Picket W. The concentrations in the creek generally decrease with distance downstream of the waste disposal sites (Table 4.20).

4.6.4.3. Chestnut Ridge Hydrogeologic Regime

The Chestnut Ridge hydrogeologic regime is flanked to the north by Bear Creek Valley and to the south by Bethel Valley Road (Figure 4.37). The regime encompasses the portion of Chestnut Ridge extending from Scarboro Road, east of the complex, to Dunaway Branch, located just west of Industrial Landfill II. Descriptions of waste management sites in the Chestnut Ridge regime and shown on Figure 4.36 were provided in previous year ASERs (i.e., CY 2017 and previous) and are not repeated this year.

The Chestnut Ridge Security Pits area is the primary source of groundwater contamination in the regime. Contamination from the security pits is distinct and does not mingle with plumes from other sources.

Plume Delineation

The extent of the VOC plume at the Chestnut Ridge Security Pits is reasonably well defined in the water table and shallow bedrock zones. With two exceptions, mentioned in the next paragraph, historical monitoring indicates the VOC plume from the Chestnut Ridge Security Pits has shown minimal migration in any direction (<305 m [<1,000 ft]).

Data obtained during CY 2020 indicate the western lateral extent of the VOCs plume at the site has not changed significantly. VOC contaminants at a well about 458 m (1,500 ft) southeast and downgradient of the Chestnut Ridge Security Pits (well GW-798 at 30.57-µg/L summed total VOCs; Figure 4.41) continue to show some migration of the eastern plume has occurred. Additionally, previously performed dye tracer test results and the intermittent detection of trace concentrations of VOCs (similar to those found in wells adjacent to the Chestnut Ridge Security Pits) at a natural spring about 2,745 m (9,000 ft) to the east and along geologic strike may suggest that Chestnut Ridge Security Pits contaminants have migrated further than the monitoring well network indicates. However, as in CY 2019, no VOCs were detected at this spring in CY 2020.

The Chestnut Ridge Security Pits plume in the Chestnut Ridge regime (shown by orange shading on Figure 4.41) represents the average VOC concentrations between CYs 2013 and 2017. The circular icons presented on the figure represent CY 2020 monitoring results.

Nitrate

As in CYs 2018 and 2019, nitrate concentrations were below the drinking water standard at all monitoring stations in the Chestnut Ridge regime in CY 2020.

Trace Metals

Concentrations of arsenic above drinking water standards have been observed in two surface water monitoring locations downstream from the Filled Coal Ash Pond, which is monitored under a CERCLA ROD (DOE 1996). Under the ROD, migration of contaminated effluent from the Filled Coal Ash Pond is reduced by a constructed wetland area. In recent years, it became apparent the wetland efficiency was decreasing, in part, because of erosion channels forming around the wetland. During CY 2019, a maintenance activity was conducted at the site to improve the aquatic habitat for plant growth and to increase retention time for water within the wetland (DOE 2020e). The elevated arsenic levels were detected both upgradient (McCoy Branch kilometer [MCK] 2.05) and downgradient (MCK 2.0) of this wetland area (Figure 4.37). In CY 2020, the passive wetland treatment area reduced dissolved arsenic by about 64 percent and total arsenic by 77 percent. A surface water monitoring location (MCK 1.4) about 1,021 m (3,900 ft) downstream from the Filled Coal Ash Pond was also sampled during CY 2020; arsenic was detected below drinking water standards at 0.0026 mg/L in January and 0.0023 mg/L in August. These results are below the drinking water standard of 0.010 mg/L and are an order of magnitude below the MCK 2.0 and MCK 2.05 locations.

VOCs

Concentrations of VOCs in groundwater at the Chestnut Ridge Security Pits have decreased since 1988. However, stable to increasing trends in VOCs from well GW-798 (Figure 4.41) have been developing since CY 2000. The maximum summed VOC concentration observed at well GW-798 during CY 2020 was 30.57 µg/L, down from 65.66 µg/L in CY 2019. The VOCs detected in well GW 798 continue to be characteristic of the Chestnut Ridge Security Pits.

At Industrial Landfill IV, VOCs have been observed in the groundwater since 1992. Well GW-305, located immediately to the southeast of the facility (Figure 4.41), continues to exhibit increasing trends of summed VOCs, with the CY 2020 concentration at 84.17 µg/L being the highest sum in the Chestnut Ridge regime in CY 2020. Because samples from this well previously exceeded the drinking water standard for 1,1-DCE (7 µg/L), quarterly monitoring was initiated in CY 2015 to further evaluate the trend. In CY 2019, one sample at 8.15 µg/L for 1,1-DCE exceeded the drinking water standard. Quarterly sampling ended at this well in July 2019. In CY 2020, GW-305 was sampled in January and July with results for 1,1-DCE of 7.21 µg/L and 7.14 µg/L, respectively; less than the previous year, but still above the drinking water standard.

Radionuclides

In CY 2020, no gross-alpha or gross-beta activity above the drinking water standards of 15 and 50 pCi/L, respectively, was observed in the Chestnut Ridge hydrogeologic regime.

Exit Pathway and Perimeter Monitoring

Contaminant and groundwater flow paths in the karst bedrock underlying the Chestnut Ridge regime have not been well characterized. Tracer studies have been conducted that show groundwater from Chestnut Ridge discharging into Scarboro Creek and other tributaries that feed into Melton Hill Lake. However, no springs or surface streams that represent discharge points for groundwater have been conclusively correlated to a waste management unit or operation at Y-12 that is a known or potential groundwater contaminant source. Springs along Scarboro Creek are monitored for water quality, and trace concentrations of VOCs are intermittently detected. The detected VOCs are suspected to originate from the Chestnut Ridge Security Pits; however, this has not been confirmed. In CY 2020, six springs were sampled with no detected concentrations of VOCs.

Monitoring natural groundwater exit pathways is a basic monitoring strategy in a karst regime, such as that of Chestnut Ridge. Perimeter springs and surface water tributaries were monitored to determine whether contaminants are exiting the downgradient (southern) side of the regime. Six springs and four surface water monitoring locations were sampled during CY 2020. No contaminants at any of these monitoring stations were detected at levels above primary drinking water standards.

Exit pathway monitoring stations sampled in CY 2020 show that gross-alpha activity in the Maynardville Limestone and the surface waters of Bear Creek was undetectable at SS-5 for the first time since CY 2005. This location is over 3,353 m (11,000 ft) west of the S-3 site, and in the recent past, has shown activities of 31 pCi/L in CY 2017, 19 pCi/L in CY 2018, and 17 pCi/L in CY 2019, continuing with the decreasing trend in CY 2020.

PFAS

In CY 2020, the Water Resources Restoration Program (UCOR, OREM) performed reconnaissance sampling for per- and polyfluoroalkyl substances (PFAS) at two surface water locations—Station 17 and BCK 9.2—at Y-12, located on the eastern and western perimeters, respectively (see Figure 4.37). The samples were analyzed by drinking water method EPA 537.1 for perfluorooctane sulfonate (PFOS) and perfluorooctanoic acid (PFOA). The results are shown in Table 4.21 and are below the EPA health advisory level of 70 ng/L.

Table 4.21. PFAS concentrations

Location	PFOS (ng/L)	PFOA (ng/L)
Station 17	2.44	1.51 *J
BCK 9.2	10.1	12.1

**J = Data qualifier indicating quantity is estimated.*

Acronyms:

BCK = Bear Creek kilometer

PFAS = per- and polyfluoroalkyl substances

PFOA = perfluorooctanoic acid

PFOS = perfluorooctane sulfonate

The following actions and activities were conducted at Y-12 during CY 2020 to address these emerging contaminants of concern:

- Current and historic uses of 172 PFAS or PFAS-related substances are being tracked using the Y-12 Hazardous Material Information System, and they will be reported in the Emergency Planning and Community Right-to-Know Act Toxics Release Inventory Report beginning in CY 2021.
- One waste storage building (9720-09) has an aqueous film-forming foam (AFFF) fire suppression system. These AFFFs are common sources of PFAS contamination in soils, groundwater, and surface waters.
    - There were no releases of AFFF from this facility during CY 2020.
    - Y-12 personnel began planning to drain and replace the AFFF from this system. The replacement AFFF contains short-chain C-6 fluorochemicals manufactured using a telomer-based process. The telomer process produces no PFOS, and these C-6 chains do not break down to yield PFOA. This new product meets the goals of the EPA 2010/2015 PFOA Stewardship Program.
- Y-12 has a fire department and fire training facility onsite. The Y-12 Fire Department has one firetruck with a foam induction system for using AFFF. The AFFF used likely contains PFAS.
    - There were no releases of AFFF to the environment by the Y-12 Fire Department during CY 2020.
    - The Y-12 Fire Department is actively seeking a fluorine-free alternative to the AFFF currently in use.
- No production-related activities, equipment, or processes are known to have generated or released PFAS to the environment. However, a number of products/chemicals containing PFAS have been used in small quantities, primarily in the Analytical Chemistry Organization laboratories and in the Development Organization Facilities.

4.7. Quality Assurance Program

Y-12's QA Program establishes a quality policy and requirements for the overall QA Program for the Y-12 site. Management requirement E-SD-0002, *Quality Assurance Program Description*, details the methods used to carry out work processes safely and securely and in accordance with established procedures (CNS 2019). It also describes mechanisms in place to seek continuous improvements by identifying and correcting findings and preventing recurrences.

Many factors can potentially affect the results of environmental data-collection activities, including sampling personnel, methods, and procedures; field conditions; sample handling, preservation, and transport; personnel training; analytical methods; data reporting; and record keeping. QA programs are designed to minimize these sources of variability and to control all phases of the monitoring process.

Field sampling QA encompasses many practices that minimize error and evaluate sampling performance. Some key quality practices include the following:

- Using work control processes and standard operating procedures for sample collection and analysis.
- Using chain-of-custody and sample identification procedures.
- Standardizing, calibrating, and verifying instruments.
- Training sample technicians and laboratory analysts.
- Preserving, handling, and decontaminating samples.
- Using QC samples, such as field and trip blanks, duplicates, and equipment rinses.

Y-12's Environmental Sampling Services are responsible for field sampling activities, sample preservation and handling, chain-of-custody, and transport field QC samples in accordance with Y-12 Environmental Compliance's internal procedures. Environmental Sampling Services developed a Standards and Calibration Program that conforms to ISO/International Electrotechnical Commission 17025, *General Requirements for the Competence of Testing and Calibration Laboratories* (ISO 2005, 2017), and provides a process for uniform standardization, calibration, and verification of measurement and test equipment. The Standards and Calibration Program ensures measurements are made using appropriate, documented methods; traceable standards; appropriate measurement and test equipment of known accuracy; trained personnel; and technical best practices.

Analytical results may be affected by a large number of factors inherent to the measurement process. Laboratories that support Y-12 environmental monitoring programs use internal QA/QC programs to ensure the early detection of problems that may arise from contamination, inadequate calibrations, calculation errors, or improper procedure performance. Internal laboratory QA/QC programs include routine calibrations of counting instruments; yield determinations; include frequent use of check sources and background counts, replicate and spiked sample analyses, and matrix and reagent blanks; and include maintenance of control charts to indicate analytical deficiencies. These activities are supported by the use of standard materials or reference materials (e.g., materials of known composition that are used in the calibration of instruments, methods standardization, spike additions for recovery tests, and other practices). Certified standards traceable to National Institute of Standards and Technology, DOE sources, or EPA are used (when available) for such work.

Y-12's Analytical Chemistry Organization QA Manual describes QA Program elements that are based on Y-12's QA Program; customer-specific requirements; certification program requirements; ISO/International Electrotechnical Commission 17025, *General Requirements for Competence of Testing and Calibration Laboratories* (ISO 2005, 2017); federal, state, and local regulations; and waste acceptance criteria. As a government-owned, contractor-operated laboratory that performs work for DOE, the Analytical Chemistry Organization laboratory operates in accordance with DOE Order 414.1D, Quality Assurance (DOE 2011e).

Other internal practices used to ensure laboratory results are representative of actual conditions include training and managing staff; maintaining adequacy of the laboratory environment; safety; controlling the storage, integrity, and identity of samples; record keeping; maintaining and calibrating instruments; and using technically validated and properly documented methods.

Y-12's Analytical Chemistry Organization participated in both Mixed Analyte Performance Evaluation Program studies conducted in 2020 for water, soil, and air filter matrices for metals, organics, and radionuclides. The overall acceptability rating from both studies was greater than 97 percent.

Verification and validation of environmental data are performed as components of the data-collection process, which includes planning, sampling, analyzing, and performing data review. Some level of verification and validation of field and analytical data collected for environmental monitoring and restoration programs is necessary to ensure that data conform to applicable regulatory and contractual requirements. Validation of field and analytical data is a technical review performed to compare data with established quality criteria to ensure that data are adequate for the intended use. The extent of project data verification and validation activities is based on project-specific requirements.

For routine environmental effluent monitoring and surveillance monitoring, data-verification activities may include processes of checking whether data have been accurately transcribed and recorded, appropriate procedures have been followed, electronic and hard-copy data show one-to-one correspondence, and data are consistent with expected trends. Typically, routine data-verification actions alone are sufficient to document the validity and accuracy of environmental reports. For restoration projects, routine verification activities are more contractually oriented and include checks for data completeness, consistency, and compliance with a predetermined standard or contract.

Certain projects may require a more-thorough technical validation of the data, as mandated by the project's data quality objectives. Sampling and analyses conducted as part of a remedial investigation to support the CERCLA process may generate data that are needed to evaluate risk to human health and the environment, to document that no further remediation is necessary, or to support a multimillion-dollar construction activity and treatment alternative. In these cases, the data quality objectives of the project may mandate a thorough technical evaluation of the data against rigorous predetermined criteria. The validation process may result in the identification of data that do not meet predetermined QC criteria or in the ultimate rejection of data for their intended use. Typical criteria evaluated in the validation of contract laboratory program data include the percentage of surrogate recoveries, spike recoveries, method blanks, instrument tuning, instrument calibration, continuing calibration verifications, internal standard response, comparison of duplicate samples, and sample holding times.

4.8. Environmental Management and Waste Management Activities

ORR has played key roles in our nation's defense and energy research. However, past waste disposal practices and unintentional releases have left portions of the land and facilities contaminated and in need of environmental cleanup. The contaminated areas of the reservation are on EPA's National Priorities List, which includes sites across the nation that require cleanup under CERCLA. These areas on the ORR have been clearly defined, and DOE OREM is working to clean and restore them under a partnership with the EPA and TDEC. The *2020 Cleanup Progress Annual Report to the Oak Ridge Regional Community* (UCOR 2020b) provides detailed information on DOE OREM's 2020 cleanup activities.

4.8.1. Environmental Management

At Y-12, DOE OREM is working to address excess and contaminated facilities, remove mercury soil and groundwater contamination, and enable modernization that allows NNSA to continue its crucial national security and nuclear non-proliferation responsibilities.

Mercury Technology Development Activities

Mercury remediation is OREM's highest priority at Y-12 due to large historical losses of the element in buildings, soils, and surface waters in previous decades. Mercury contamination in the environment poses significant technical and regulatory challenges and can benefit from development of new tools and approaches that might be more effective, reduce costs, and accelerate cleanup schedules.

OREM is making significant investments into the development of new remediation technologies to help address the complex mercury challenge in Oak Ridge. In the near-term, mercury technology development activities will support the successful completion of the demolition of Y-12's mercury-contaminated facilities and soils remediation, waste disposition, and reduction of mercury-related ecological risks in EFPC.

In 2020, COVID-19 restrictions led to reduced access to laboratory and field facilities, but work on the major mercury technology tasks (i.e., studying water chemistry, soil and sediment, and ecological manipulation) continued. A work-from-home plan allowed scientists to continue data analysis while essential personnel kept laboratory and fieldwork running. A larger emphasis was placed on quantitative modeling to simulate various remediation- and technology-development scenarios and better inform future remedial decision-making. With a better understanding of mercury transport processes in the watershed system, specific technologies and strategies can be assessed and implemented to aid future cleanup.

In spring FY 2020, construction was completed on a major addition to ORNL's Aquatic Ecology Laboratory. This new infrastructure allows scientists to bring water from EFPC and run it through the laboratory to test remediation technologies. This upgrade provides real-world settings to test technologies to ensure greater effectiveness when they are implemented in the field.

In the downstream environment, field characterization and research undertaken during the 2015 to 2021 time period will support an evaluation of potential remediation alternatives for the creek in the mid-2020s. As a new task added to the project, algae and bacteria, which are abundant in stream systems, have been recognized to play an important role in mercury methylation and bioaccumulation. In FY 2021, major efforts will be involved in mapping these areas to determine the role and impact they play in the ecosystem related to mercury methylation and bioaccumulation.

Studies have been conducted to evaluate alternative treatment chemicals on mercury flux, the effect of sorbents on mercury and methylmercury concentrations in the presence of dissolved organic matter, and the use of mussels as a tool for reducing mercury in the water column. ORNL scientists have prepared a report titled *Mercury Remediation Technology Development for Lower East Fork Poplar Creek—FY 2020 Update* (ORNL 2020). This report describes, in detail, each of the study areas and findings from studies performed in FY 2020.

Mercury Removed from COLEX

At the Alpha-4 building, an additional half ton of mercury was recovered during the treatment of debris and grit from the building's Column Exchange (COLEX) equipment in FY 2020. Combined with the mercury previously removed from the West and East COLEX equipment, more than 5.1 tons of mercury have been removed.

The four-story, 500,000-ft^2 Alpha-4 building was used for uranium separation from 1944 to 1945. Workers finished installing the COLEX equipment in 1955 for lithium separation, a process that required large amounts of mercury. A significant amount of the element was lost into the equipment, buildings, and surrounding soils, and its cleanup is one of OREM's top priorities. The COLEX project successfully prevented a large release of mercury into the environment from deteriorating, rusted equipment that was exposed to the elements.

Biology Complex Demolition

OREM is preparing to remove the remaining buildings in Y-12's Biology Complex, which are listed as high-risk, excess, contaminated facilities. The 350,000-ft^2 area poses asbestos hazards as well as structural deterioration risks. Demolition of these facilities is part of an effort to eliminate excess contaminated facilities throughout the DOE Complex. Asbestos abatement and material removal continued in FY 2020. Originally constructed in the 1940s to recover uranium from process streams, the complex later housed ORNL's Biology Research Division, which among other things, made strides in understanding genetics and the effects of radiation. The facilities once housed more individuals with doctorates than anywhere in the world.

The complex originally consisted of 11 buildings, until OREM demolished 4 of them in 2010 as part of the American Recovery and Reinvestment Act of 2009. Buildings 9743-2 and 9770-2 were demolished in FY 2018, when mobilization started for the demolition of the remaining buildings. The completion of this project will clear land for important, future, national security missions.

Mercury Treatment Facility Construction

The Outfall 200 Mercury Treatment Facility is a vital piece of infrastructure that will open the door for demolition of Y-12's large, deteriorated, mercury-contaminated facilities and subsequent soil remediation by providing a mechanism to limit potential mercury releases into Upper EFPC. When operational, the facility will be able to treat 3,000 gal of water per minute and help Oak Ridge meet regulatory limits in compliance with EPA and state of Tennessee requirements.

In FY 2020, contractors began excavations at the Treatment Plant site and at the Headworks site, and they installed and operated a small treatment system to remove mercury from water collected in the Headworks excavation site. Additionally, crews poured the concrete pads and began installing rebar for the walls of the treatment plant. Shoring walls and excavations will be completed at the Headworks site in FY 2021, and the entire facility is slated to be operational in the mid-2020s.

4.8.2. Waste Management

Waste management is performed at multiple locations on the ORR for both solid and liquid wastes, including landfills and water treatment facilities.

4.8.2.1. Comprehensive Environmental Response, Compensation, and Liability Act Waste Disposal

Most of the waste generated during FY 2020 cleanup activities in Oak Ridge went to disposal facilities on the ORR. The Environmental Management Waste Management Facility received 12,271 waste shipments, totaling 129,038 yd^3, from cleanup projects at ETTP, ORNL, and Y-12. This engineered landfill consists of six disposal cells that only accept low-level radioactive and hazardous waste meeting specific criteria. These wastes include soil, dried sludge and sediment, building debris, and personal protective equipment.

4.8.2.2. Solid Waste Disposal

DOE operates and maintains solid waste disposal facilities called the ORR Landfills. In FY 2020, these three active landfills received 6,334 waste shipments, totaling 79,675 yd^3 of waste.

4.8.2.3. Wastewater Treatment

NNSA at Y-12 treats wastewater generated from both production and environmental cleanup activities. Safe and compliant treatment of more than 121 million gal of wastewater and groundwater was provided at various facilities during CY 2020:

- The West End Treatment Facility and the Central Pollution Control Facility at Y-12 processed approximately 780,000 gal of wastewater, primarily in support of NNSA operational activities.

- The Big Springs Water Treatment System treated more than 103 million gal of mercury-contaminated groundwater. The East End VOC Treatment System treated 13 million gal of VOC-contaminated groundwater.
- The Liquid Storage Facility and Groundwater Treatment Facility treated more than 3 million gal of leachate from burial grounds and well purge waters from remediation areas.
- The Central Mercury Treatment System treated approximately 2.0 million gal of mercury-contaminated sump waters from the Alpha-4 building.

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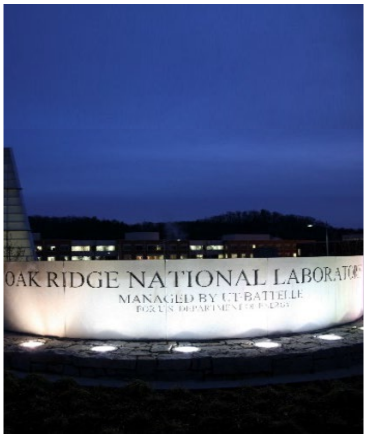


DOE's Oak Ridge National Laboratory is the nation's largest multiprogram science and technology laboratory. ORNL's mission has grown and expanded through the years, and now it is at the forefront of supercomputing, advanced manufacturing, materials research, neutron science, clean energy, and national security.

5

Oak Ridge National Laboratory

ORNL is a thriving multiprogram research campus with world-leading facilities and a talented and diverse workforce of innovators and problem solvers. Researchers use these unique facilities along with sophisticated tools and signature strengths in neutron science, high-performance computing, advanced materials, nuclear science and engineering, and isotopes to benefit science and society, making it possible to meet the following goals:

- Advance understanding, design, and use of new materials and chemical processes
- Reveal unmatched insights through computing and data
- Ensure safe, clean nuclear power and secure nuclear materials
- Produce rare isotopes for medicine, industry, security, research, and space exploration
- Increase and exploit understanding of biological and environmental systems, from genes to ecosystems

Nine world-class facilities that support ORNL's research and development activities are also available to users from universities, industry, and other institutions:

- Building Technologies Research and Integration Center
- Carbon Fiber Technology Facility
- Center for Nanophase Materials Sciences
- Center for Structural Molecular Biology
- High Flux Isotope Reactor
- Manufacturing Demonstration Facility
- National Transportation Research Center
- Oak Ridge Leadership Computing Facility
- Spallation Neutron Source

ORNL is managed by UT-Battelle LLC, a partnership between the University of Tennessee and Battelle Memorial Institute. Other DOE contractors conducting activities at ORNL in 2020 included North Wind Solutions, LLC; UCOR; and Isotek Systems, LLC (Isotek).

In 2020, the coronavirus disease (COVID-19) introduced unique challenges and opportunities at ORNL. To maximize social distancing, roughly two-thirds of ORNL's staff began working remotely, necessitating abrupt and dramatic changes in the conduct of work both on and off the ORNL site. On-site, procedures to prevent COVID-19 exposure and infection were quickly developed to protect staff members with jobs that cannot be performed remotely. The relocation of a majority of employees to remote workplaces in a short period of time created ergonomic concerns and presented challenges for the UT-Battelle Information Technology Services Division as the demand for connection clients for remote workers grew substantially and rapidly.

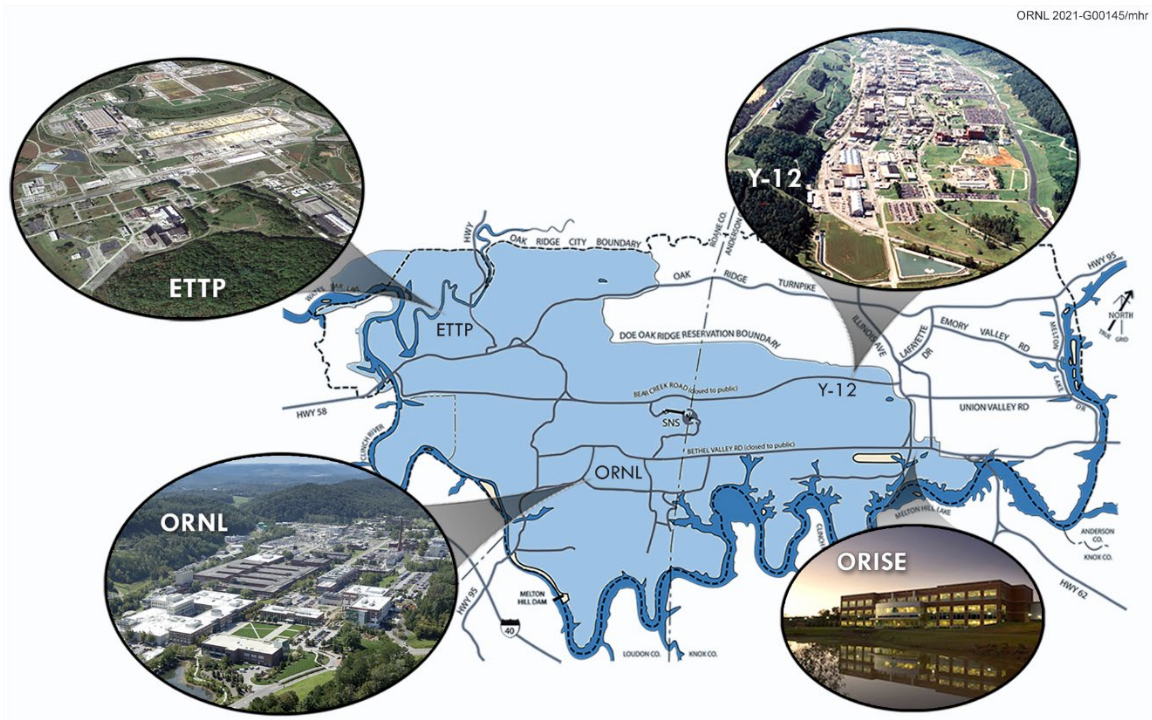
At the same time, ORNL researchers rapidly shifted their efforts and resources toward joining the fight to identify solutions to the pandemic. Remote rapid access to ORNL's cutting-edge facilities was made available to scientists from other government facilities, medical institutions, industry, and academia to allow collaborative exploration of effective COVID-19 preventative measures, tests, and treatments.

In the midst of these unexpected and unprecedented changes, UT-Battelle continued to meet commitments to provide a safe and healthy workplace, protect the public and the environment, and meet regulatory requirements and commitments. All required state and federal environmental monitoring, sampling, and reporting tasks were completed in 2020. No 2020 environmental compliance issues resulted from changes in ORNL operations and procedures as a result of COVID-19.

5.1. Description of Site, Missions, and Operations

ORNL, which is managed for DOE by UT-Battelle, LLC, a partnership of the University of Tennessee and Battelle Memorial Institute, lies in the southwest corner of ORR (Figure 5.1) and includes facilities in two valleys (Bethel and Melton) and on Chestnut Ridge. ORNL was established in 1943 as part of the secret Manhattan Project to pioneer a method for producing and separating plutonium. During the 1950s and 1960s, and with the creation of DOE in the 1970s, ORNL became an international center for the study of nuclear energy and related research in the physical and life sciences. By the turn of the century, the laboratory supported the nation with a peacetime science and technology mission that was just as important as, but very different from, the work carried out in the days of the Manhattan Project.

In March 2007, Isotek assumed responsibility for the Building 3019 Complex at ORNL, where the national repository of ^{233}U has been kept since 1962. In 2010, an Analysis of Alternatives was conducted to evaluate methods available for ^{233}U disposition, and in 2011, the recommendations in the *Final Draft ^{233}U Alternatives Analysis Phase I Report* (DOE 2011b) were endorsed. The Phase I recommendations included (1) transfer of Zero-Power Reactor plate canisters to the National Nuclear Security Administration and disposal of Consolidated Edison Uranium Solidification Project material canisters and (2) completing a Phase II alternatives analysis for processing the remaining 50 percent of the inventory. The transfer of the reactor plate canisters was completed in 2012. Disposal of the material canisters began in 2015 and was completed in 2017. UT-Battelle provides air and water quality monitoring support for the Building 3019 complex; results are included in the UT-Battelle air and water monitoring discussions in this chapter.



Acronyms:
ETTP = East Tennessee Technology Park *ORISE = Oak Ridge Institute for Science and Education*
ORNL = Oak Ridge National Laboratory *Y-12 = Y-12 National Security Complex*

Figure 5.1. Location of ORNL within ORR and its relationship to other local DOE facilities

Responsibility for Building 2026 was transferred from UT-Battelle to Isotek in May 2017. Isotek began processing ^{233}U material inside glove boxes in Building 2026 in the fall of 2019. The processing of the ^{233}U material produces a solidified, low-level radioactive waste (LLW) form that is acceptable for disposal. Additionally, Isotek is extracting ^{229}Th from the material and is transferring it to a customer for use as source material for medical isotope production.

UCOR is the DOE ORR cleanup contractor. The scope of UCOR activities at ORNL includes long-term surveillance, maintenance, and management of inactive waste disposal sites, structures, and buildings. Characterization and deactivation of former reactors and isotope production facilities continued in 2020. One of the priority projects was to prepare the 3026 facility—the Radioisotope Development Lab—for demolition. Using a 175 ton crane, workers installed a protective tent to keep nearby research facilities protected while the final two hot cells are being demolished. Characterization and deactivation also continued in former reactors and isotope production facilities, including Buildings 3005, 3010, 3042, 3009, 3010, 3010-A, 3080, 3083, 3107 and 11 facilities in the area that supported and produced radioisotopes ("Isotope Row"). Actions included asbestos abatement, removal of combustible materials, and isolation of electrical and mechanical utilities at the facilities.
Other activities include groundwater monitoring, transuranic (TRU) waste storage, and operation of the wastewater treatment facility and the waste-processing facility for liquid LLW.

As of December 11, 2015, North Wind Solutions, LLC, (NWSol) has been the prime contractor for the Transuranic Waste Processing Center (TWPC), which is located on the western boundary of ORNL on about 26 acres of land adjacent to the Melton Valley Storage Tanks along State Route 95. TWPC's mission is to receive, process, treat, and repackage TRU wastes for shipment to designated facilities for final disposal. TWPC consists of the waste-processing facility, the personnel building, and numerous support buildings and storage areas. TWPC began processing supernatant liquid from the Melton Valley Storage Tanks in 2002, contact-handled debris waste in December 2005, and remotely handled debris waste in May 2008. Based on the definition of TRU waste, some waste being managed as TRU is later determined to be LLW or mixed LLW. UT-Battelle provides water quality monitoring for operations at the TWPC, and results are included in water monitoring discussions in this chapter. Air monitoring data from TWPC are provided to UT-Battelle for inclusion in the ORR National Emission Standards for Hazardous Air Pollutants for Radionuclides (Rad-NESHAPs) annual report and is incorporated into air monitoring discussions in this chapter.

UT-Battelle manages several facilities located off the main ORNL campus for DOE. The Hardin Valley Campus (HVC) is home to the National Transportation Research Center (NTRC) (see website **here**) and the Manufacturing Demonstration Facility (see website **here**). The HVC is located on a 6 acre site owned by Pellissippi Investors, LLC, and is leased to UT-Battelle and the University of Tennessee. Approximately 152 industry partners work on the HVC to shape America's mobility future. NTRC is DOE's only user facility dedicated to transportation and serves as the gateway to UT-Battelle's comprehensive capabilities for transportation research and development (R&D). Research focuses on fuels and lubricants, engines, emissions, electric drive technologies, lightweight and power-train materials, vehicle systems integration, energy storage and fuel cell technologies, vehicle cyber security, and intelligent transportation systems.

The Manufacturing Demonstration Facility focuses on advanced manufacturing research, including the development of carbon fiber composites and additive manufacturing involving polymers, metal wires, and metal powders. The facility hosts the Institute for Advanced Composites Manufacturing Innovation lab space and an outreach program for local high school students.

The Carbon Fiber Technology Facility (CFTF), a leased 42,000 ft^2 innovative technology facility located in the Horizon Center Business Park, offers a flexible, highly instrumented carbon fiber line for demonstrating the scalability of advanced carbon fiber technology and for producing market-development volumes of prototypical carbon fibers (Figure 5.2). The CFTF is the world's most capable open-access facility for the scale-up of emerging carbon fiber technology. The cost of carbon fiber material remains relatively high, prohibiting widespread adoption of carbon fiber–containing composite materials in the automotive manufacturing industry, which requires lower commodity pricing. The lower-cost carbon fiber produced at ORNL meets the performance criteria prescribed by some automotive manufacturers for carbon fiber materials for use in high-volume vehicle applications.

UT-Battelle also manages several buildings and trailers located at Y-12 and in the city of Oak Ridge.

Photo by Carlos Jones. Approved for public release.

Figure 5.2. Carbon Fiber Technology Facility

5.2. Environmental Management Systems

Demonstration of environmental excellence through high-level policies that clearly state expectations for continual improvement, pollution prevention, and compliance with regulations and other requirements is a priority at ORNL. In accordance with DOE Order 436.1, *Departmental Sustainability* (DOE 2011), UT-Battelle, NWSol, UCOR, and Isotek have implemented environmental management systems (EMSs), modeled after International Organization for Standardization (ISO) 1400: 2015, to measure, manage, and control environmental impacts (ISO 2015). An EMS is a continuing cycle of planning, implementing, evaluating, and improving processes and actions undertaken to achieve environmental goals.

5.2.1. UT-Battelle Environmental Management System

UT-Battelle's EMS is designed to fully comply with all applicable requirements and to continually improve ORNL's environmental performance. Until August 2018, UT-Battelle was registered to the ISO 14001:2015 standard and had maintained ISO 14001 registration since 2004. In FY 2018 a management decision was made to transition from registration to a declaration of conformance to ISO 14001:2015. Because of that decision, the external registration audits have been discontinued.

UT-Battelle's EMS is a fully integrated set of environmental management services for UT-Battelle activities and facilities. Services include pollution prevention, waste management, effluent management, regulatory review, reporting, permitting, and other environmental management programs. Through the UT-Battelle Standards-Based Management System (SBMS), the EMS establishes environmental policy and translates environmental laws, applicable DOE orders, and other requirements into laboratory-wide documents (procedures and guidelines). Through environmental protection officers, environmental compliance representatives, and waste services representatives, the UT-Battelle EMS assists the line organizations in complying with environmental requirements.

5.2.1.1. Integration with the Integrated Safety Management System

The objective of the UT-Battelle Integrated Safety Management System (ISMS) is to systematically integrate environment, safety, and health (ES&H) requirements and controls into all work activities and to ensure protection of the workers, the environment, and the public. The UT-Battelle EMS and the ISMS are integrated to provide a unified strategy for the management of resources, the control and attenuation of risks, and the establishment and achievement of the organization's ES&H goals. Guided by the ISMS and EMS, UT-Battelle strives for continual improvement through "plan-do-check-act" cycles. Under the ISMS, the term "safety" also encompasses ES&H, including pollution prevention, waste minimization, and resource conservation. Therefore, the guiding principles and core functions in the ISMS apply both to the protection of the environment and to safety. The UT-Battelle EMS is consistent with the ISMS and includes all the elements in the ISO 14001:2015 standard.

5.2.1.2. UT-Battelle Environmental Policy for ORNL

UT-Battelle's Environmental Policy for ORNL, which can be found on the ORNL website **here**, clearly states expectations and includes commitments to continual improvement, pollution prevention, and compliance with regulations and other requirements.

5.2.1.3. Environmental Management System Planning

ISO 14001 planning clause requires organizations to identify the environmental aspects and impacts of their operations, products, and services; identify applicable regulations and requirements; establish objectives; implement plans to achieve the objectives; and identify and control risks and opportunities.

UT-Battelle environmental aspects

Environmental aspects are elements of an organization's activities, products, or services that can interact with the environment. Environmental aspects associated with UT-Battelle activities, products, and services have been identified at both the line organization level and the laboratory level. Activities that are relative to any of the aspects are carefully controlled to minimize or eliminate impacts to the environment. Nine significant environmental aspects (listed on the

ORNL website **here**) have been identified as potentially having significant environmental impacts.

UT-Battelle legal and other requirements

Legal and other requirements that apply to the environmental aspects identified by UT-Battelle include federal, state, and local laws and regulations; environmental permits; applicable DOE orders; UT-Battelle contract clauses; waste acceptance criteria; and voluntary requirements such as ISO 14001:2015. UT Battelle has established procedures to ensure that all applicable requirements are reviewed and that changes and updates are communicated to staff and are incorporated into work-planning activities. UT Battelle's environmental compliance status is discussed in Section 5.3.

UT-Battelle objectives

To improve environmental performance, UT-Battelle establishes objectives for monitoring progress for appropriate functions and activities. Laboratory-level environmental objectives are documented in the annual Site Sustainability Plan. Line organization objectives are developed annually, entered into a commitment tracking system, and tracked to completion. In all cases, the objectives are consistent with the UT-Battelle environmental policy for ORNL (found on the ORNL website **here**), are supportive of the laboratory mission, and where practical, are measurable.

UT-Battelle programs

UT-Battelle has established an organizational structure to ensure that environmental stewardship practices are integrated into all facets of its missions at ORNL. Programs led by experts in environmental protection and compliance, energy and resource conservation, pollution prevention, and waste management ensure that laboratory activities are conducted in accordance with the environmental policy (see Section 5.2.1.2). Information on UT-Battelle's 2020 compliance status, activities, and accomplishments is presented in Section 5.3.

Environmental protection and waste management staff provide critical support services in the following areas:

- Waste management
- Solid and hazardous waste compliance
- National Environmental Policy Act (NEPA 1969) compliance
- Air quality compliance
- Water quality compliance
- US Department of Agriculture (USDA) compliance
- Transportation safety
- Environmental sampling and data evaluation
- Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA 1980) interface

Subject matter experts at UT-Battelle provide expertise in waste management, transportation, and disposition support services to research, operations, and support divisions:

- Pollution prevention staff manage recycling programs and work with staff to reduce waste generation and to promote sustainable acquisition.
- Radiological engineering staff provide radiological characterization support to generators and waste service representatives, develop tools to help ensure compliance with facility safety and transportation, and provide packaging support.
- Waste acceptance and disposition staff review and approve waste characterization methods, accept waste from generator areas into Transportation and Waste Management Division storage areas, review waste disposal paperwork to ensure compliance with the disposal facility's waste acceptance criteria, certify waste packages, and coordinate off-site disposition of UT-Battelle's newly generated waste.

- Waste service representatives provide technical support to waste generators to properly manage waste by assisting in identifying, characterizing, packaging, and certifying wastes for disposal;
- The waste-handling team performs waste-packing operations and conducts inspections of waste items, areas, and containers.
- The transportation management team ensures that both the on-site and off-site packaging and transportation activities are performed in an efficient and compliant manner.
- The hazardous material spill response team is the first line of response to hazardous materials spills at ORNL and controls and contains spills until the situation is stabilized.

5.2.1.4. Site Sustainability

As required by DOE Order 436.1, Department Sustainability (DOE 2011), The Oak Ridge National Laboratory FY 2021 Site Sustainability Plan (SSP), an internal document that includes FY 2020 performance data, was completed in December 2020 in compliance with annual DOE guidance.

To attain the federal sustainability goals outlined in the SSP, sites operated by DOE are expected to contribute toward all targets and to identify strengths that can be adapted as agencywide best practices. To meet the SSP goals at ORNL, UT-Battelle identifies opportunities for continuous improvements in operational and business processes and implements practices to maximize the return on investment in modernizing facilities and equipment.

ORNL Facilities Management Division (FMD) is tasked with the management of distinctive research facilities and extraordinary scientific equipment. The commissioning dates of the systems range from the 1940s to 2020. As such, many facilities require a customized methodology to enhance sustainability; a boilerplate approach would not be sufficient to operate efficiently and deliver the desired results. FMD's Energy Efficiency and Sustainability Program (EESP) is tasked with the daily management of the energy- and water-saving projects that are the key to results in operational savings and sustainable practices.

The Sustainable ORNL website is actively managed and is available for employee and public view **here**. Sustainable ORNL promotes systemwide best practices, management commitment, and employee engagement that will help lead ORNL into a future of efficient, sustainable operations.

Sustainable ORNL awards

Awards and recognition for sustainability efforts at ORNL received in FY 2020 are listed below. Information about ORNL awards can be found at the on the Sustainable ORNL website **here**, on the *R&D Magazine* website **here**, and on the Federal Laboratory Consortium website **here**.

- US DOE awards
  - Sustainability Champion: Amy Albaugh, of FMD's EESP, for initiatives to foster behavioral change at ORNL that advanced the progress in meeting sustainability goals such as those pertaining to energy and water in Executive Order 13834 (EO 2018)
  - Sustainability Program/Project: ORNL Water Use Reduction, Facility and Research Cooperation
  - Strategic Partnerships for Sustainability: ORNL Arboretum in Partnership with the University of Tennessee and the State of Tennessee
- *R&D Magazine* R&D 100 Awards
  - Biomacromolecule Engineering by Soft Chain Coupling
  - Cobalt-Free Li-ion Battery Cathode Material developed by ORNL and Sparkz
- Federal Laboratory Consortium 2021 Excellence in Technology Transfer National Technology Transfer Awards

  - Impactful Technology Transfer of Revolutionary Large-Scale, Energy-Efficient 3D-Printer by ORNL and Magnum Venus Products
  - Building Sustainability with Cobalt-Free Battery Technologies
- Recognition for sustainable transportation and commuting by community partners
  - 2020 Best Workplace for Commuters, National Standard of Excellence, February 2020
  - Knoxville Area Smart Trips 2019 Top Employer, February 2020

Sustainable ORNL Notable Achievements

To promote regional outreach and involvement, the Oak Ridge National Laboratory Annual Sustainability Report is published annually by the Sustainable ORNL program and distributed electronically to ORNL staff and associates as well as the surrounding communities (city/county governments and educational institutions). Reports for ORNL are archived on the ORNL website **here**. The purpose of the reports is to share the positive benefits that can be experienced by all entities that commit to sustainable practices, energy conservation, and the reduction of long-term risks due to carbon emissions. The 2020 ORNL report (ORNL 2020) can be viewed and downloaded from the ORNL website **here**.

DOE 50001 Ready. In FY 2020 FMD's EESP was successful in the attainment of DOE's 50001 Ready recertification. The 50001 Ready program recognizes facilities and organizations that attest to the implementation of an ISO 50001–based energy management system. DOE launched the 50001 Ready Program in 2017, and ORNL is the third federal location and the second national laboratory to receive the certification. The program, which is described on the DOE website **here,** is a self-guided, self-paced approach for organizations to realize improvements in energy management that does not require external audits or certifications. To obtain certification, organizations are responsible for completing all 25 tasks in the 50001 Ready Navigator online tool **here** and for measuring and improving energy performance over time.

The program recognizes organizations that demonstrate outstanding energy management standards and best practices in their facilities. The certification covers more than 3 million ft^2 in 65 buildings at ORNL that are equipped with advanced metering. ORNL's advanced metering system aids in the reporting of quality energy data and supports the monitoring of facility energy performance toward the goal of savings in utility use and operations cost. The EESP led the certification effort, but contributions and support from many other divisions were necessary for achievement of the project goals.

The Sustainable ORNL website "News" page **here** provides more information about the certification and a link to DOE's announcement. The effort is described in "Oak Ridge National Laboratory—50001 Ready Facility," a case study on the DOE Better Buildings website **here**.

Summary of performance data for energy, water, and waste

Executive Order 13834 (EO 2018) directs federal agencies to manage their buildings, vehicles, and overall operations to optimize energy and environmental performance, reduce waste, and cut costs. ORNL collects data and publishes the results in the Annual Sustainability Report to document its compliance with Executive Order 13834 and other applicable guidance. In FY 2020 the annual SSP guidance and ORNL's submittal were updated to include modifications made to executive orders and applicable federal statutes (ORNL 2020).

Energy use intensity. Based on FY 2020 data, energy use in the buildings category at ORNL was 1,024 billion Btu, not including ORNL's excluded facilities as defined by the Energy Policy Act of 1992 (EPACT 1992). "Energy use intensity," given in British thermal units per square foot, is the metric used at ORNL to monitor energy use. Based on 4,314,051 ft^2 of energy-consuming buildings, trailers, and other structures and facilities identified in the Facilities Information Management System (DOE 2020), the FY 2020 calculated energy use intensity was 237,298 Btu/ft^2, a cumulative reduction of 34.8 percent since FY 2003 and a reduction of 1.36 percent since FY 2019 (Figure 5.3).

Efforts to maintain steady progress toward energy use intensity reductions at ORNL focus on sustainable, energy-efficient design in construction projects, smart repurposing of existing facilities, and continuous improvements in facility and utility operations. Modernization continues at ORNL as old, energy-inefficient buildings are demolished to make way for the construction of high-performance buildings. Improvements in utilities services have reduced the costs of energy, fuel, water, and maintenance and have increased reliability in the delivery of steam, chilled water, and potable water.

ORNL 2021-G00152/mhr

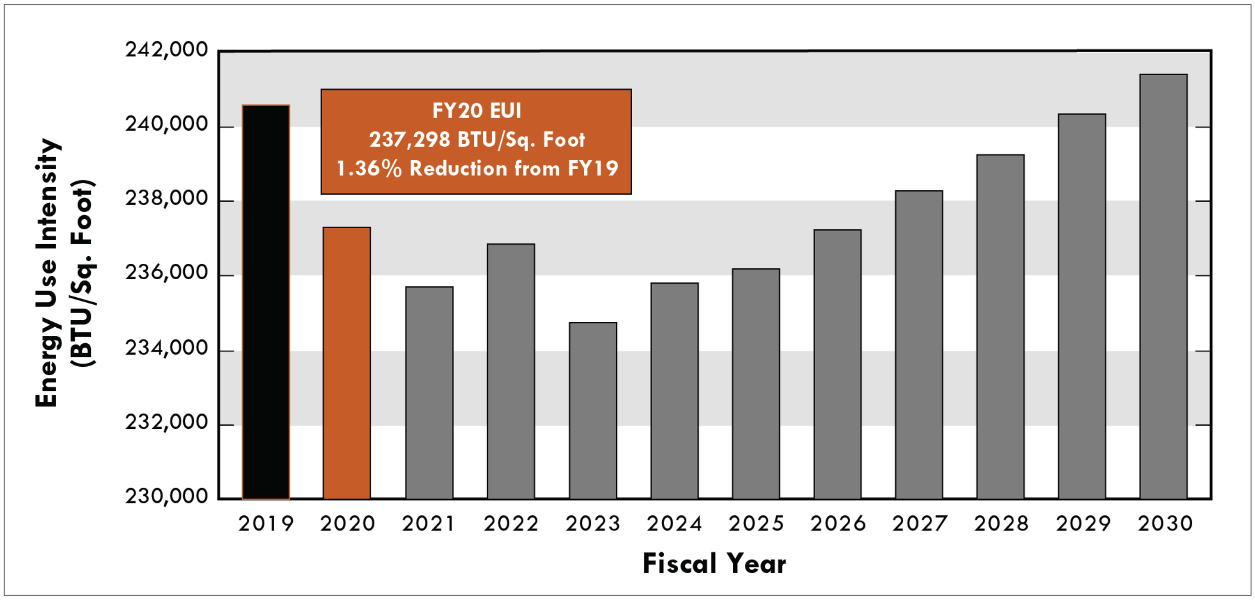


Figure 5.3. Recent, current (FY 2020), and projected energy use intensity at ORNL

Energy use intensity reduction in existing ORNL facilities is data-driven, and efforts are made to quantify and bring awareness to building energy performance so that operations staff can make informed decisions. FMD pursues approaches to energy consumption awareness using data visualization and reporting. Building data analytics, including fault detection and diagnostics, are also being added to ORNL's energy conservation tools. In FY 2020, FMD purchased a license for a new fault detection and diagnostics system after prior pilots of multiple systems. EESP elected the system after learning about it from other national laboratories during a peer discussion meeting. A graded approach is planned to introduce the new platform while staff are learning to utilize the tool to its full potential. The establishment of the standards-driven DOE 50001 Ready program will allow FMD and the EESP staff to concentrate limited resources on the most significant energy users to better influence return on investments.

Implementation of improvements in utility services to realize reduced costs for energy, fuel, water, and maintenance and improvements in the delivery of potable and chilled water and steam continued across ORNL in 2020. The Utilities Division is currently conducting a comprehensive utility study that encompasses all major utility systems throughout the campus. This study focuses on improved operations, resiliency, and efficiency.

Water use intensity. ORNL procures potable water from the City of Oak Ridge for domestic use (handwashing, flushing), cooling (cooling towers, chillers), heating (steam generation, hot water generation), laboratories, and special research processes. "Water use intensity," given in kilogallons per square foot, is the metric used at ORNL to monitor water consumption.

Even before the baseline target year of 2007, numerous strategies to reduce water consumption were in place. Strategies include repairing leaks, replacing old lines in the site water distribution system, and eliminating once-through-cooling where possible. FY 2020 water consumption increased 25.3 percent from FY 2019, primarily due to HFIR's return to normal operations from a year-long maintenance outage. In addition, the high-performance computing operations of ORNL's Summit supercomputer increased in FY 2020, resulting in more water utilization for the cooling tower. An increase in research activities at the Spallation Neutron Source (SNS) also added to the consumption of cooling tower water. Even though water use increased from FY 2019 to FY 2020, total annual water use at ORNL has been reduced by 27.2 percent since FY 2007 (see Figure 5.4). Water consumption at ORNL is expected to rise to support additional high-performance computing and SNS activities. A 41 percent increase is anticipated by FY 2030. Mitigation factors (such as the comprehensive study being carried out by the Utilities Division to reduce costs for energy, fuel, water, and maintenance) will continue to be deployed; however, the increase in laboratory mission growth will require the continued increase in water resources.

Waste diversion. The diversion rate for municipal solid waste at ORNL was 49 percent in FY 2020; the DOE sustainability goal remained at 50 percent. The diversion rate for construction and demolition materials and debris was 75 percent and exceeded the DOE target.

Pollution prevention. Source reduction efforts at ORNL include increases in the use of acceptable nontoxic or less-toxic alternative chemicals and processes while minimizing the acquisition of hazardous chemicals and materials through material substitution, operational assessments, and inventory management. In cases where the complete elimination of a particular hazardous material is not possible, a combination of actions is pursued, including controls to limit use, procurement alternatives, and recycling processes to mitigate the environmental impact. UT-Battelle implemented 24 new pollution prevention projects and ongoing reuse/recycle projects at ORNL during 2020, eliminating more than 3 million kg of waste. Researchers implement traditional recycling options and create processes for others through R&D when a need is identified. For instance, in 2020 ORNL researchers and a commercial partner recognized the need for and invented a process to extract and recover more than 97 percent of the rare earth elements from scrapped magnets in electronics at purities exceeding 99.5 percent. (Figure 5.5).

Efforts to continue to reduce and divert the amount of material going to the landfill include the development of contract language requiring construction contractors to recycle as much construction debris as possible. Internally, the extensive use of training, awareness, presentations, and outreach encourage source reduction and recycling by all associates.

Electronic stewardship. Environmentally sound disposition (reuse or recycle) of all used electronics is accomplished at ORNL by implementation of the property management and environmental management policies and procedures documented in SBMS. Options include transfer to other DOE contractors, nonprofit organizations, and qualified educational institutions. Traditional electronic equipment is recycled through an off-site certified recycler. These efforts continue to close the recycling loop for electronics.

Sustainable vehicle fleet. ORNL recently transitioned to a General Services Administration leased fleet. This change in vehicle management enables ORNL to replace older, less fuel-efficient vehicles in its fleet with new alternative-fuel vehicles at a faster rate. Orders for 305 new vehicles were placed in FY 2020, and is better aligned to comply with DOE guidance concerning sustainable fleet management practices. To date, approximately 100 new vehicles have been received at ORNL. With these additions, approximately 90 percent of ORNL's 467 vehicle fleet is compliant with the alternative-fuel vehicle criteria. In 2020,100 percent of light-duty vehicles operated on alternative fuels, exceeding DOE fleet management goals.

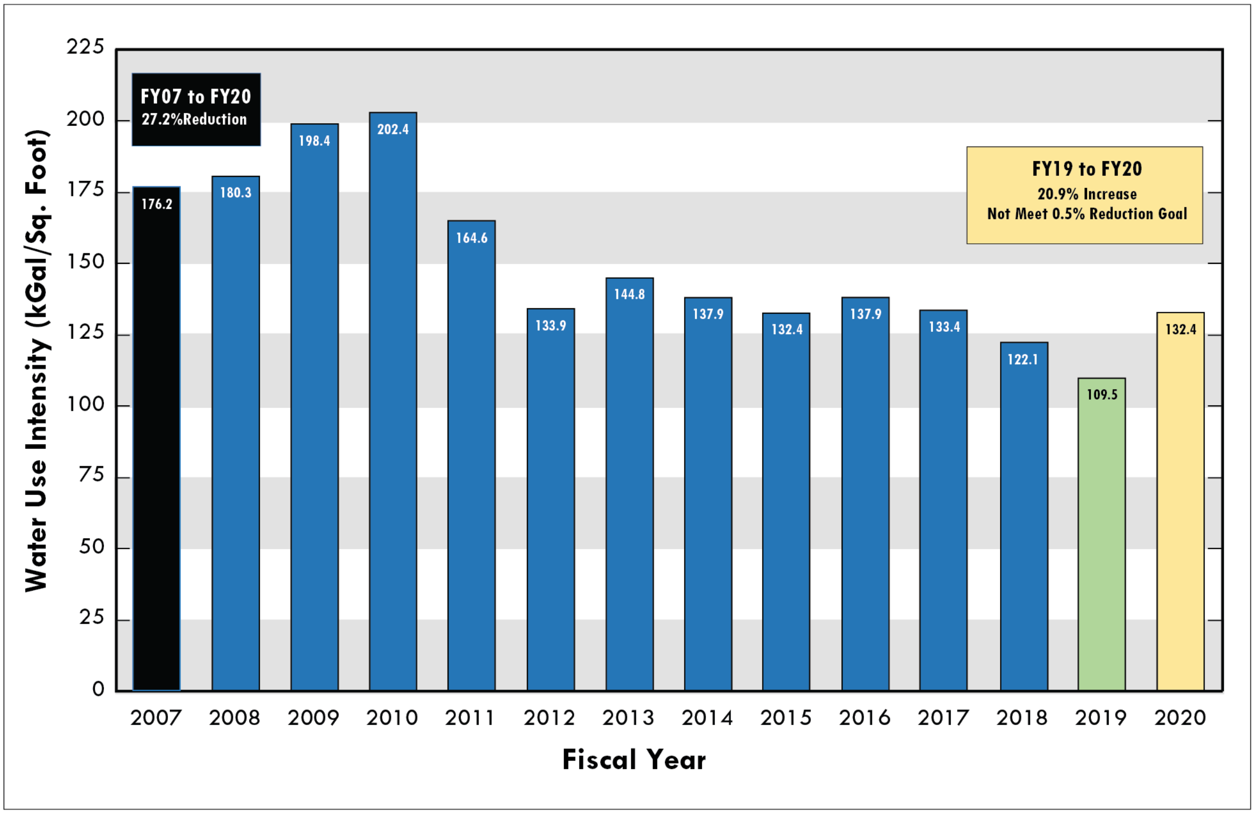


Figure 5.4. Historical and current (FY 2020) water use intensity at ORNL

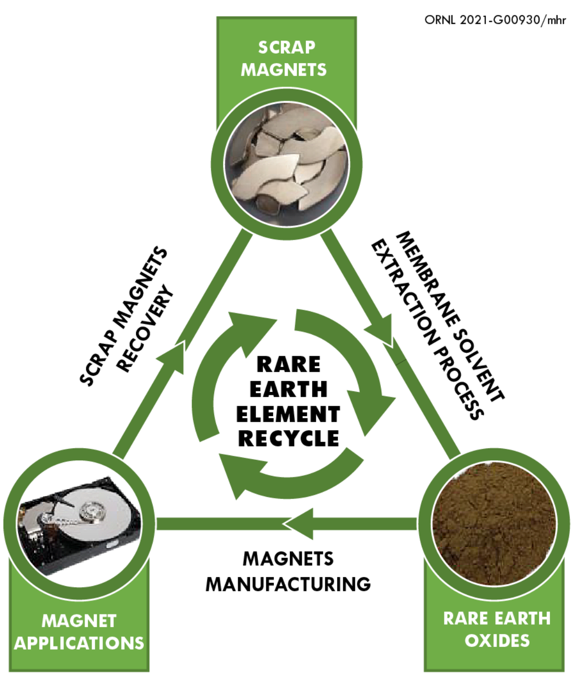


Figure 5.5. The rare earth recycling process at ORNL

High-performance sustainable buildings: Guiding principles. In FY 2020, on-site High Performance Sustainable Buildings (HPSBs) at ORNL included 22 buildings that are certified, either by being grandfathered through Leadership in Energy and Environmental Design (LEED) certification or by having attained 100 percent compliance with the HPSB guiding principles (EO 2007, DOE 2020a). This meets the current DOE SSP target.

One of the ways in which ORNL achieved success in meeting the guiding principles was through our long association with the LEED certification program. Although LEED certification has been a focus for ORNL in the past, ORNL is shifting focus to the HPSB guiding principles certification. This year, ORNL added two new buildings and 20,000 ft^2 of a third building to the list of HPSB-compliant buildings per the grandfathering provisions established in the 2016 Guiding Principles Guidance (CEQ 2016). LEED program information is available at the US Green Building Council website **here**.

Candidate buildings will be identified by Sustainable ORNL based on existing building space use, existing metering infrastructure, and known energy conservation opportunities. Action plans for establishing building-specific guiding principles will be developed and executed. Laboratory-wide standards will be used when feasible to fulfill applicable policies and procedures found in the guiding principles across multiple facilities. As experience with the guiding principles grows, the focus of ORNL's efforts remains on certifying office buildings for which the guidance is clearly applicable while establishing a path for future certification in larger, more complex facilities such as laboratories and mixed-use buildings. Information about DOE's HPSB directives can be found **here**.

5.2.1.5. Storm Water Management and the Energy Independence and Security Act of 2007

Section 438 of the Energy Independence and Security Act of 2007 stipulates the following:

> The sponsor of any development or redevelopment project involving a Federal facility with a footprint that exceeds 5,000 square feet shall use site planning, design, construction, and maintenance strategies for the property to maintain or restore, to the maximum extent technically feasible, the predevelopment hydrology of the property with regard to the temperature, rate, volume, and duration of flow (EISA 2007).

For the purposes of this provision, "development or redevelopment" is defined as follows:

> any action that results in the alteration of the landscape during construction of buildings or other infrastructure such as parking lots, roads, etc. (e.g., grading, removal of vegetation, soil compaction) such that the changes affect runoff volumes, rates, temperature, and duration of flow. Examples of projects that would fall under 'redevelopment' include structures or other infrastructure that are being reconstructed or replaced and the landscape is altered. Typical patching or resurfacing of parking lots or other travel areas would not fall under this requirement (EISA 2007).

In 2020, ORNL's approach to addressing EISA-438 requirements for storm water management was revised. Due to the type of soils (low permeability) and karst geology, conditions exist at ORNL that would allow claiming "technical infeasibility," as described in technical guidance from EPA (EPA 2009b). Clay soils have low infiltrative capacities, and the introduction of more water to the subsurface in a karst geology can accelerate the formation of sinkholes. As a result of these two geological conditions at ORNL, the use of subsurface infiltration to address EISA-438 is not being pursued. Instead, mitigation strategies (e.g., for streams and their associated buffer zones, installation of water quality systems and devices to improve water quality, and strategies that would allow for additional evapotranspiration) are being pursued. Implementing this revised approach to EISA-438 compliance, as opposed to claiming "technical infeasibility" demonstrates ORNL's commitment to environmental stewardship.

When possible, this environmental stewardship approach is implemented on an "area" basis at ORNL. Addressing EISA-438 on an area basis, instead of a project by project basis, allows for the following:

- Storm water runoff from adjacent areas can be diverted around developed areas to keep water quality high.
- Water quality structures/devices can be installed to handle runoff from developed areas, therefore reducing the number of water quality structures/devices to be installed and maintained.
- Individual projects are not burdened with the costs associated with addressing EISA-438 requirements.

If projects are located in existing contaminated areas or where an area approach is not feasible, technical infeasibility is claimed to prevent potential movement of contamination within soil or groundwater. In 2020, one of several water quality improvements for the 7000 area of ORNL was completed. Two water quality structures that aid in removal of sediments and floatables from storm water runoff from approximately two-thirds of the 7000 area were installed. Remaining water quality improvements will be completed in 2021 and will be summarized in the 2021 ASER.

5.2.1.6. Emergency Preparedness and Response

The UT-Battelle Emergency Management Program supplies the resources and capabilities to provide emergency preparedness services and, in the event of an accident, emergency response services. Emergency preparedness personnel perform hazard surveys and hazard assessments to identify potential emergency situations. Procedures and plans have been developed to prepare for and respond to a wide variety of potential emergency situations. Training is provided to ensure appropriate response and performance during emergency events. Frequent exercises and drills are scheduled to ensure the effective performance of the procedures and plans. An environmental subject matter expert is a member of the emergency response team and participates in drills and exercises to ensure that environmental requirements are met and that environmental impacts from an event and the response are mitigated.

5.2.1.7. Environmental Management System Performance Evaluation

ISO 14001 includes requirements to monitor, measure, analyze, and regularly evaluate the performance of the EMS. EMS performance evaluations ensure that goals and objectives are being met and that opportunities to continually improve are identified.

Monitoring and measurement

UT-Battelle has developed monitoring and measurement processes for each operation or activity that can have a significant adverse effect on the environment. SBMS includes requirements for management system owners to establish performance objectives and indicators, conduct performance assessments to collect data and monitor progress, and evaluate the data to identify strengths and weaknesses in performance and areas for improvement.

UT-Battelle Environmental Management System assessments

UT-Battelle uses several methods to evaluate compliance with legal and other environmental requirements. Most of the compliance evaluation activities are implemented through the EMS or participation in line-organization assessment activities. If a nonconformance were identified, the ORNL issues-management process requires that any regulatory or management system nonconformance be reviewed for cause and that corrective and/or preventive actions be developed. These actions would then be implemented and tracked to completion.

Environmental assessments that cover legal and other requirements are performed periodically. Additionally, management system owners are required to assess management system performance and to address issues identified from customer feedback, staff suggestions, and other assessment activities.

UT-Battelle also uses the results from numerous external compliance inspections conducted by regulators to verify compliance with requirements. In addition to regulatory compliance assessments, an internal EMS assessment is performed annually to ensure that the UT-Battelle EMS continues to conform to ISO requirements. An independent internal audit conducted in 2020 verified that the EMS conforms to ISO 14001:2015. In addition to verifying conformance, these management system assessments also identify continual improvement opportunities.

5.2.2. Environmental Management System for the Transuranic Waste Processing Center

NWSol has been the prime contractor for the TWPC since 2015. The National Sanitation Foundation, International Strategic Registrations, Ltd. registered NWSol's EMS for activities at the TWPC to the ISO 14001:2015 standard (ISO 2015) in May 2017. The EMS is integrated with ISMS to provide a unified strategy for the management of resources, the control and reduction of risks, and the establishment and achievement of the organization's ES&H goals. The EMS and ISMS are incorporated into the *Integrated Safety Management System Description* (BJC 2009), and a "plan-do-check-act" cycle is used for continual improvement in both. National Sanitation Foundation, International Strategic Registrations, Ltd. conducted a recertification audit in April. No nonconformances or issues were identified, and several significant practices were noted.

The NWSol EMS for the TWPC incorporates applicable environmental laws, DOE orders, and other requirements (i.e., DOE directives and federal, state, and local laws) according to internal NWSol documentation that describes how the various requirements are incorporated into subject area documents (procedures and guidelines). The EMS assists NWSol line organizations in identifying and addressing environmental issues.

Environmental aspects are elements of an organization's activities, products, or services that can interact with the environment. NWSol has identified environmental aspects associated with TWPC activities, products, and services at both the project and activity level and has identified waste management activities, air emissions, storm water contamination, pollution prevention, habitat alteration, and energy consumption as potentially having significant environmental impacts. Activities that are relative to any of those environmental aspects are carefully controlled to minimize or eliminate impacts to the environment. NWSol has established and implemented objectives and measurable performance indicators for the targets associated with the identified significant impacts.

The pollution prevention programs at TWPC involve waste reduction efforts and implementation of sustainable practices that reduce the environmental impacts of the activities conducted at TWPC. The TWPC EMS establishes annual goals and targets to reduce the impact of TWPC's environmental aspects.

NWSol has a well-established recycling program at TWPC and continues to identify new material-recycling streams and to expand the types of materials included in the program. Currently, recycle streams at TWPC range from office materials such as paper, aluminum cans, plastic drinking bottles, foam beverage cups, alkaline batteries, and toner cartridges to operations-oriented materials such as cardboard, lamps, circuit boards, used oil, and batteries. The "single stream" recycling program established by NWSol allows the mixing of multiple types of recyclables and thus increases the amount of recyclable items and improves compliance.

"Environmentally preferable purchasing" is a term used to describe an organization's policy to reduce packaging and to purchase products made with recycled material or biobased materials and other environmentally friendly products. NWSol ensures that environmentally preferable products are purchased by incorporating the "green" procurement requirements in NWSol procurement procedures.

NWSol uses several methods to evaluate compliance with legal and other requirements. Most of these compliance evaluation activities are implemented by internal and external environmental and management assessment activities and by routine reporting and reviews. NWSol also uses the results from numerous external compliance inspections conducted by regulators and contractors to verify compliance with requirements.

5.2.3. Environmental Management System for Isotek

Isotek has developed and implemented an EMS for the U-233 Disposition Project that reflects the elements and framework found in the ISO14001:2004 standard (ISO 2004) and satisfies the applicable requirements of DOE Order 450.1A, *Environmental Protection Program* (DOE 2008). The scope of the Isotek EMS is to achieve and demonstrate environmental excellence by identifying, assessing, and controlling the impact of Isotek activities and facilities on the environment. The EMS is designed to ensure compliance with environmental laws, regulations, and other applicable requirements and to improve effectiveness and efficiency, reduce costs, and earn and retain regulator and community trust. The Isotek EMS and ISMS are fully integrated.

Project procedures provide a systematic approach to integrating environmental considerations into all aspects of Isotek's activities at ORNL. The Isotek EMS includes a procedure for identifying environmental aspects associated with the U-233 Disposition Project and for determining whether those aspects can have significant environmental impacts. Isotek has identified radiological air emissions as the only environmental aspect of its operations that has potentially significant environmental impacts and has developed an environmental management plan with measurable objectives and targets to address that aspect. Isotek reviews environmental aspects, potential impacts, objectives, targets, and its environmental management plan at least annually and updates them as necessary.

The U-233 Disposition Project has a well-established recycling program that is implemented at all Isotek-managed facilities and includes Buildings 3017, 3019 Complex, 2026, and 3137 at ORNL and two off-site administrative offices in Oak Ridge. The materials currently recycled by Isotek include paper, cardboard, aluminum cans, plastic bottles, inkjet and toner cartridges, lamps, batteries, scrap metal, circuit boards, aerosol cans, and used oil.

To evaluate compliance with legal and other requirements, Isotek conducts an EMS audit every 3 years, annual management assessments, and periodic surveillances. Compliance with requirements is also evaluated through inspections performed by regulatory agencies. The results of the compliance evaluations are used for continual improvement of the EMS.

5.3. Compliance Programs and Status

During 2020 UT-Battelle, UCOR, NWSol, and Isotek operations were conducted to comply with contractual and regulatory environmental requirements. Table 5.1 presents a summary of environmental audits conducted at ORNL in 2020. The following discussions summarize the major environmental programs and activities carried out at ORNL during 2020 and provide an overview of the compliance status for the year.

Table 5.1. Summary of regulatory environmental audits, evaluations, inspections, and assessments conducted at ORNL, 2020

Date	Reviewer	Subject	Issues
March 4	TDEC	Hazardous Waste Compliance Evaluation Inspection (ORNL Warehouse)	0
March 11–12	TDEC	Hazardous Waste Compliance Evaluation Inspection (including UT-Battelle, Transuranic Waste Processing Center, and UCOR)	1
January 3	City of Oak Ridge	Carbon Fiber Technology Facility Wastewater Inspection	0
July 21	KCDAQM[a]	National Transportation Research Center Clean Air Act Inspection	0
August 25	City of Oak Ridge	CFTF Wastewater Inspection	0
October 22	TDEC[b]	Annual CAA Inspection for ORNL and CFTF	0

[a] *Knox County Department of Air Quality Management* [b] *Tennessee Department of Environment and Conservation*

5.3.1. Environmental Permits

Table 5.2 contains a list of environmental permits that were in effect in 2020 at ORNL.

Table 5.2. Environmental permits in effect at ORNL in 2020

Regulatory driver	Permit title/description	Permit number	Owner	Operator	Responsible contractor
CAA	Title V Major Source Operating Permit, ORNL	571359	DOE	UT-B	UT-B
CAA	Operating Permit, NTRC	17-0941-R1	DOE	UT-B	UT-B
CAA	Operating Permit, NWSol	071009P	DOE	NWSol	NWSol
CAA	Construction Permit, 3525 Area Off Gas System	971543P	DOE	UT-B	UT-B
CAA	Operating Permit, NWSol emergency generators	071010P	DOE	NWSol	NWSol
CAA	Title V Major Source Operating Permit, ORNL	569768	DOE	UCOR	UCOR
CAA	CFTF CAA Operating Permit (Conditional Major)	474951	DOE	UT-B	UT-B
CAA	CAA Title V Operating Permit for Isotek operations at ORNL Administrative Amendment #1	576448	DOE	Isotek	Isotek
CWA	ORNL NPDES Permit (ORNL sitewide wastewater discharge permit)	TN0002941	DOE	DOE	UT-B, UCOR, NWSol
CWA	Industrial and Commercial User Waste Water Discharge Permit (CFTF)	1-12	UT-B	UT-B	UT-B
CWA	Tennessee Operating Permit, Holding Tank/Haul System for Domestic Wastewater	SOP-07014	UCOR	UCOR	UCOR
CWA	Tennessee Operating Permit (sewage)	SOP-02056	DOE	NWSol	NWSol
CWA	Construction Storm Water Permit—ROSC Building	TNR 135617	DOE	UT-B	UT-B
CWA	Construction Storm Water Permit—Leadership Imaging Facility Building	TNR 135602	DOE	UT-B	UT-B
CWA	Aquatic Resources Alteration Permit—Leadership Imaging Facility Building	ARAP-NR1803.153	DOE	UT-B	UT-B
CWA	ARAP—General Permit for Maintenance of the Swan Pond Water Feature 5007	NR1903.038	DOE	UT-B	UT-B
CWA	Notice of Coverage Under the General NPDES Permit for Storm Water for 2000–3000 Area Utility Modernization	TNR136015	DOE	UT-B	UT-B
CWA	Notice of Coverage Under the General NPDES Permit for Storm Water for OLCF-5 Power Line	TNR135839	DOE	UT-B	UT-B

Table 5.2. Environmental permits in effect at ORNL in 2020 (continued)

Regulatory driver	Permit title/description	Permit number	Owner	Operator	Responsible contractor
CWA	NWP-12 - Utility Line Activities for OLCF-5 Power Line	LNR-2019-00571	UT-B	UT-B	UT-B
CWA	TVA Section 26A Permit for OLCF-5 Power Line	TVA 4003683	UT-B	UT-B	UT-B
CWA	Notice of Coverage Under the General NPDES Permit for Storm Water for 7000 Area Infrastructure Modernization	TNR136181	DOE	UT-B	UT-B
CWA	Notice of Coverage Under the General NPDES Permit for Storm Water for 2000-3000 Area Utility Modernization (TRC Project)	TNR136285	DOE	UT-B	UT-B
RCRA	Hazardous Waste Transporter Permit	TN1890090003	DOE	UT-B	UT-B, UCOR
RCRA	Hazardous Waste Corrective Action Permit	TNHW-164	DOE	DOE/all	DOE/all
RCRA	Hazardous Waste Container Storage and Treatment Units	TNHW-145	DOE	DOE/ UCOR/ NWSol	UCOR/NWSol
RCRA	Hazardous and Mixed Waste Storage Permit	TNHW-178	DOE	DOE/UT-B	UT-B

Acronyms:
ARAP = Aquatic Resources Alteration Permit
CAA = Clean Air Act
CFTF = Carbon Fiber Technology Facility
CWA = Clean Water Act
DOE = US Department of Energy
Isotek = Isotek Systems, LLC
NPDES = National Pollutant Discharge Elimination System
NTRC = National Transportation Research Center
NWSol = North Wind Solutions, LLC
OLCF = Oak Ridge Leadership Computing Facility
ROSC = Research Operations Support Center
RCRA = Resource Conservation and Recovery Act
TRC = Translational Research Capability
UT-B = UT-Battelle LLC

5.3.2. National Environmental Policy Act/National Historic Preservation Act

NEPA provides a means to evaluate the potential environmental impact of proposed federal activities and to examine alternatives to those actions. UT-Battelle, NWSol, and Isotek maintain compliance with NEPA using site-level procedures and program descriptions that establish effective and responsive communications with program managers and project engineers to establish NEPA as a key consideration in the formative stages of project planning. Table 5.3 summarizes NEPA activities conducted at ORNL during 2020.

Table 5.3. National Environmental Policy Act activities, 2020

Types of NEPA documentation	Number of instances
UT-Battelle LLC	
Approved under general actions or generic CX determinations[a]	127
Project-specific CX determinations[b]	0
North Wind Solutions, LLC	
Approved under general actions[a] or generic CX determinations	2

[a] Projects that were reviewed and documented through the site NEPA compliance coordinator
[b] Projects that were reviewed and approved through the DOE Site Office and the NEPA compliance officer
Acronyms:
CX = categorical exclusion
DOE = US Department of Energy
NEPA = National Environmental Policy Act

During 2020, UT-Battelle and NWSol continued to operate under site-level procedures that provide requirements for project reviews and NEPA compliance. The procedures call for a review of each proposed project, activity, or facility to determine the potential for impacts to the environment. To streamline the NEPA review and documentation process, the DOE has approved generic categorical exclusion determinations that cover proposed bench-scale and pilot-scale research activities and generic categorical exclusions that cover proposed nonresearch activities (e.g., maintenance activities, facilities upgrades, personnel safety enhancements). A categorical exclusion is one of a category of actions defined in 40 CFR 1508.4 that does not individually or cumulatively have a significant effect on the human environment and for which neither an environmental assessment nor an environmental impact statement is normally required.

UT-Battelle uses SBMS as the delivery system for guidance and requirements to manage and control work at ORNL. NEPA is an integral part of SBMS, and a UT-Battelle NEPA coordinator works with principal investigators, environmental compliance representatives, and environmental protection officers within each UT-Battelle division to determine appropriate NEPA decisions.

Compliance with the National Historic Preservation Act (NHPA 1966) is achieved and maintained at ORNL in conjunction with NEPA compliance. The scope of proposed actions is reviewed in accordance with the ORR cultural resource management plan (Souza et al. 2001).

5.3.3. Clean Air Act Compliance Status

The Clean Air Act (CAA 1970), passed in 1970 and amended in 1977 and 1990, forms the basis for the national air pollution control effort. This legislation established comprehensive federal and state regulations to limit air emissions. It includes four major regulatory programs: the national ambient air quality standards, state implementation plans, new source performance standards, and Rad-NESHAPs. Airborne discharges from DOE Oak Ridge facilities, both radioactive and nonradioactive, are subject to regulation by the US Environmental Protection Agency (EPA) and the Tennessee Department of Environment and Conservation (TDEC) Division of Air Pollution Control. The most recent sitewide UT-Battelle Title V Major Source Operating Permit was issued in October 2018. The Title V Major Source Operating Permit for the 3039 stack, operated by UCOR, was renewed in 2020. To demonstrate compliance with the Title V major source operating permits, more than 1,500 data points are collected and reported every year. In addition, nitrogen oxides, a family of poisonous, highly reactive gases and defined collectively as a criteria pollutant by the EPA (EPA 2016), are monitored continuously at one location. Samples are collected continuously from 8 major radionuclide sources and periodically from 14 minor radionuclide sources. There are numerous other demonstrations of compliance with generally applicable air quality protection requirements (e.g., asbestos, stratospheric ozone).

NTRC and CFTF are two off-site CAA-regulated facilities maintained and operated by UT-Battelle. An operating permit, issued by Knox County for two emergency generators located at NTRC, was issued in January 2020. The CFTF operates under a conditional major operating permit issued to UT-Battelle by TDEC in February 2020.

In summary, there were no UT-Battelle CAA violations and no Isotek, UCOR, or NWSol CAA violations or exceedances in 2020. Section 5.4 provides detailed information on 2020 activities conducted by UT-Battelle in support of the CAA.

5.3.4. Clean Water Act Compliance Status

The objective of the Clean Water Act (CWA 1972) is to restore, maintain, and protect the integrity of the nation's waters. The CWA serves as the basis for comprehensive federal and state programs to protect the nation's waters from pollutants. (See Appendix C for water quality reference standards.). One of the strategies developed to achieve the goals of CWA was the EPA's establishment of limits on specific pollutants allowed to be discharged to US waters by municipal sewage treatment plants (STPs) and industrial facilities. EPA established the National Pollutant Discharge Elimination System (NPDES) permitting program to regulate compliance with pollutant limitations. The program was designed to protect surface waters by limiting effluent discharges into streams, reservoirs, wetlands, and other surface waters. EPA has delegated authority for implementation and enforcement of the NPDES program to the State of Tennessee.

In 2020, compliance with the ORNL NPDES permit was determined by approximately 1,800 laboratory analyses and field measurements. ORNL wastewater treatment facilities achieved a numeric permit compliance rate of more than 99 percent in 2020. One numeric noncompliance was reported for a wastewater treatment facility during 2020. In June, the annual whole effluent toxicity test for the Sewage Treatment Plant (Outfall X01) did not pass the NPDES permit limit of more than 44.3 percent effluent for fathead minnow (*Pimephales promelas*) survival and reproduction. A follow-up test was initiated within 7 days per the testing requirements in the permit and passed at more than 44.3 percent. The NPDES permit limit compliance rate for all discharge points for 2020 was more than 99 percent (see Table 5.4).

In May 2020, a hose on a mobile generator failed, leaking diesel to a storm drain inlet to Outfall 227 on White Oak Creek (WOC). The event was reported to TDEC because it caused a sheen for a short period of time before absorbent booms could be placed at the spill site and in the creek.

ORNL received a renewed NPDES permit in May 2019. Several conditions in the permit were appealed and remained unresolved during 2020.

Table 5.4. National Pollutant Discharge Elimination System compliance at ORNL, January through December 2020

Effluent parameters[a,b]	Number of numeric noncompliances	Number of compliance measurements[c]	Percentage of compliance[d]
	X01 (Sewage Treatment Plant)		
IC_{25} Static renewal 7-day chronic *Ceriodaphnia dubia* (%)	0	2	100
IC_{25} Static renewal 7-day chronic *Pimephales promelas* (%)	1	2	50
Ammonia, as N (summer)	0	26	100
Ammonia, as N (winter)	0	26	100
Carbonaceous biological oxygen demand	0	53	100
Dissolved oxygen	0	53	100
Escherichia coliform (col/100 mL)	0	53	100
Peracetic acid	0	3	100
pH (standard units)	0	53	100
Total suspended solids	0	53	100
	X12 (Process Waste Treatment Complex)		
IC_{25} *C. dubia* survival (%)	0	1	100
IC_{25} *C. dubia* reproduction (%)	0	1	100
IC_{25} *P. promelas* survival (%)	0	1	100
IC_{25} *P. promelas* reproduction (%)	0	1	100
Oil and grease	0	4	100
pH (standard units)	0	53	100
Temperature (°C)	0	53	100
	X16 through X27 (twelve instream monitoring locations)		
Total residual oxidant	0	288	100
	X28 and X29 (two additional instream monitoring locations)		
Peracetic acid	0	6	100
Hydrogen peroxide	0	6	100

[a] *Only permit parameters with a numerical limit are listed.*

[b] *The inhibition concentration (IC_{25}) is the concentration (as a percentage of full-strength wastewater) that reduces survival or reproduction of the test species by 25 percent when compared to a control treatment.*

[c] *Total number of readings taken in the year by approved method for the given parameter.*

[d] *Percentage compliance = 100 – [(number of noncompliances/number of samples) × 100].*

5.3.5. Safe Drinking Water Act Compliance Status

ORNL's water distribution system is designated as a "non-transient, non-community" public water system by the TDEC Division of Water Supply. TDEC's water supply rules, Chapter 0400-45-01, "Public Water Systems" (TDEC 2020), set limits for biological contaminants and for chemical activities and chemical contaminants. TDEC requires sampling for the following constituents for compliance with state and federal regulations:

- Residual chlorine
- Bacteria (total coliform)
- Disinfectant by-product (trihalomethanes and haloacetic acids)
- Lead and copper (required once every 3 years)

The City of Oak Ridge supplies potable water to the ORNL water distribution system and meets all regulatory requirements for drinking water. The water treatment plant, located on ORR, north of the Y-12 Complex, is owned and operated by the City of Oak Ridge.

In 2020, sampling results for ORNL's water system residual chlorine levels, bacterial constituents, lead and copper, and disinfectant by-products were all within acceptable limits. Sampling for lead and copper is required in 2021.

5.3.6. Resource Conservation and Recovery Act Compliance Status

The Hazardous Waste Program under the Resource Conservation and Recovery Act (RCRA 1976) establishes a system for regulating hazardous wastes from the initial point of generation through final disposal. In Tennessee, TDEC has been delegated authority by EPA to implement the Hazardous Waste Program; EPA retains an oversight role. In 2020, DOE and its contractors at ORNL were jointly regulated as a "large-quantity generator of hazardous waste" under EPA ID TN1890090003 because, collectively, they generated more than 1,000 kg of hazardous/mixed wastes in at least one calendar month during 2020.

Mixed wastes are both hazardous (under RCRA regulations) and radioactive. Hazardous/mixed wastes are accumulated in satellite accumulation areas or in less-than-90-day accumulation areas and are stored and/or treated in RCRA-permitted units. In addition, hazardous/mixed wastes are shipped off site for treatment and disposal. The RCRA units operate under three permits at ORNL, as shown in Table 5.5. In 2020, UT-Battelle and UCOR were permitted to transport hazardous wastes under the EPA ID number issued for ORNL activities. TNHW-164 is a set of conditions pertaining to the current status of all solid waste management units and areas of concern at ETTP, ORNL, and the Y-12 Complex. The corrective action conditions require that the solid waste management units and areas of concern be investigated and, as necessary, remediated.

Reporting is required for hazardous waste activities on 12 active waste streams at ORNL, some of which involve mixed wastes. The quantity of hazardous/mixed waste generated at ORNL in 2020 was 338,357 kg; mixed wastewater accounted for 299,889 kg. ORNL generators treated 3,145 kg of hazardous waste by elementary neutralization. The quantity of hazardous/mixed waste treated in permitted treatment facilities at ORNL in 2020 was 431,687 kg. This included waste treated by macroencapsulation, size reduction, stabilization/solidification, and wastewater treatment at the Process Waste Treatment Complex (PWTC). The amount of hazardous/mixed waste shipped off site to commercial treatment, storage, and disposal facilities was 110,078 kg in 2020.

Table 5.5. ORNL Resource Conservation and Recovery Act operating permits, 2020

Permit number	Storage and treatment/description
	Oak Ridge National Laboratory
TNHW-178	Building 7651 Container Storage Unit Building 7652 Container Storage & Treatment Unit Building 7653 Container Storage Unit Building 7654 Container Storage & Treatment Unit
TNHW-145	Portable Unit 1 Building 7572 Contact-Handled Transuranic Waste Storage Facility Building 7574 Transuranic Storage Facility Building 7855 Remote-Handled Transuranic Retrievable Storage Facility Building 7860A Remote-Handled Transuranic Retrievable Storage Facility Building 7879 Transuranic/Low Level Waste Storage Facility Building 7883 Remote-Handled Transuranic Storage Bunker Building 7831F Flammable Storage Unit[a] Transuranic Waste Processing Center (TWPC)-1 Contact-Handled Storage Area TWPC-2 Waste Processing Building Second Floor TWPC-3 Drum Aging Criteria Area TWPC-4 Waste Processing Building First Floor TWPC-5 Container Storage Area TWPC-6 Contact-Handled Marshaling Building TWPC-7 Drum-Venting Building TWPC-8 Multipurpose Building T-1[a] Macroencapsulation Treatment T-2[a] Solidification/Stabilization Treatment T-3[a] Amalgamation Treatment T-4[a] Groundwater Absorption Treatment T-5[a] Size Reduction T-6[a] Groundwater Filtration Treatment T-7[a] Neutralization T-8[a] Oxidation/Deactivation
	Oak Ridge Reservation
TNHW-164	Hazardous Waste Corrective Action Document

[a] *Treatment methodologies within Transuranic Waste Processing Center facilities.*

In March 2020, TDEC Division of Solid Waste Management conducted a Hazardous Waste Compliance Evaluation inspection of ORNL generator areas; used oil storage areas; universal waste collection areas; RCRA-permitted treatment, storage, and disposal facilities; hazardous waste training records; site-specific contingency plans; Hazardous Waste Reduction Plan; and RCRA records. TDEC also reviewed the Hazardous Waste Transporter Permit, hazardous waste manifests, and US Department of Transportation training records. One violation was identified: UT-Battelle failed to record the inspection time on a total of five weekly inspection logs at a 90 day storage area. The operator corrected the violation when identified, returning the facility to compliance, so no follow-up inspections were conducted.

In 2018 ORNL requested an EPA ID number for hazardous waste activities at 115A Union Valley Road in Oak Ridge. This is ORNL's property sales warehouse for excessing and surplus sales. A surplus piece of equipment was determined to have contamination and had to be disposed of as hazardous waste. The equipment weighed

1,391 kg, which qualified Property Sales as a large quantity generator for the onetime shipment. The EPA ID number was subsequently deactivated. On March 4, 2020, the TDEC Division of Solid Waste Management conducted a Hazardous Waste Compliance Evaluation inspection to confirm that the status of the property sales warehouse had returned to non-generator status. No violations were observed.

DOE and UT-Battelle operations at the Jones Island Road 0800 Area, the HVC, and the CFTF were regulated as “conditionally exempt small-quantity generators” in 2020, meaning that less than 100 kg of hazardous waste was generated per month.

In 2020, no hazardous/mixed wastes were generated, accumulated, or shipped by DOE or UT-Battelle from Property Sales or the DOE Office of Scientific and Technical Information.

5.3.7. ORNL RCRA-CERCLA Coordination

The Federal Facility Agreement for the Oak Ridge Reservation (DOE 2014) is intended to coordinate the corrective action processes of RCRA required under the Hazardous and Solid Waste Amendments permit with CERCLA response actions. Annual updates for 2019 for ORNL’s solid waste management units and areas of concern were consolidated with updates for ETTP, the Y-12 Complex, and ORR and were reported to TDEC, DOE, and the EPA Region 4 in January 2020.

Periodic updates of proposed construction and demolition activities of facilities at ORNL have been provided to managers and project personnel from the TDEC Remediation Division and EPA Region 4. A CERCLA screening process is used to identify proposed construction and demolition projects and facilities that warrant CERCLA oversight. The goal is to ensure that modernization efforts do not adversely affect the effectiveness of previously completed CERCLA environmental remediation actions and that they do not adversely affect future CERCLA environmental remediation actions.

5.3.7.1. CERCLA Activities in Bethel Valley

In 2019, ORNL completed work on a CERCLA project initiated in 2018 to perform limited environmental remediation in the 3500 Area of the Central Campus to facilitate future brownfield redevelopment. Characterization of the area was completed in August 2018, and data were evaluated against remediation levels defined in the Bethel Valley Interim Record of Decision (DOE 2002) to identify required cleanup scope. An addendum to the approved Waste Handling Plan was developed and approved. Additionally, a technical memorandum was submitted and received regulatory approval in April 2019 as an appendix to the approved *Remedial Design Report/Remedial Action Work Plan for Bethel Valley Soils and Sediments* to document the proposed remedial actions (DOE 2021). In May 2019, a contractor was mobilized, and remedial actions and site restoration were completed in September 2019. Following completion of waste disposal, a phased construction completion report was developed and was submitted for regulatory approval in March 2020 to document completed actions, final waste volumes, and waste disposition. The phased construction completion report was approved June 3, 2020.

5.3.7.2. RCRA Underground Storage Tanks

Underground storage tanks (USTs) containing petroleum and hazardous substances are regulated under RCRA Subtitle I (40 CFR 280). TDEC has been granted authority by EPA to regulate USTs containing petroleum under TDEC Rule 400-18-01; however, hazardous-substance USTs are still regulated by EPA.

ORNL has two USTs registered with TDEC under Facility ID 0-730089. These USTs are in service (petroleum) and meet the current UST standards. No compliance inspections by TDEC occurred in 2020.

5.3.8. CERCLA Compliance Status

CERCLA, also known as Superfund, was passed in 1980 and was amended in 1986 by the Superfund Amendments and Reauthorization Act (SARA 1986). Under CERCLA, a site is investigated and remediated if it poses significant risk to health or the environment. The EPA National Priorities List is a comprehensive list of sites and facilities that have been found to pose a sufficient threat to human health and/or the environment to warrant cleanup under CERCLA.

In 1989, ORR was placed on the National Priorities List. In 1992, the ORR Federal Facility Agreement became effective among EPA, TDEC, and DOE and established the framework and schedule for developing, implementing, and monitoring remedial actions (RAs) on ORR. UCOR operates the on-site CERCLA Environmental Management Waste Management Facility (EMWMF) for DOE. Located in Bear Creek Valley, the EMWMF is used for disposal of waste resulting from CERCLA cleanup actions on ORR, including ORNL. The EMWMF is an engineered landfill that accepts low-level radioactive, hazardous, asbestos, and polychlorinated biphenyl (PCB) wastes and combinations of the wastes in accordance with specific waste acceptance criteria under an agreement with state and federal regulators.

5.3.9. Toxic Substances Control Act Compliance Status

PCB uses and waste at ORNL are regulated under the Toxic Substance Control Act (TSCA). PCB waste generation, transportation, and storage at ORNL are reported under EPA ID TN1890090003. In 2020, UT-Battelle operated six PCB waste storage areas. When longer-term storage was necessary, PCB/radioactive wastes were stored in RCRA-permitted storage buildings at ORNL. One of the PCB waste storage areas was operated at a UT-Battelle facility in the Y-12 Complex. The continued use of authorized PCBs in electrical systems and/or equipment (e.g., transformers, capacitors, rectifiers) is regulated at ORNL. Most of the equipment at ORNL that required regulation under TSCA has been dispositioned. However, some of the ORNL facilities at the Y-12 Complex continue to use (or store for future reuse) PCB equipment.

Because of the age of many of the ORNL facilities and the continued presence of PCBs in gaskets, grease, building construction, and equipment, DOE self-disclosed unauthorized use of PCBs to EPA in the late 1980s. As a result, DOE and ORNL contractors negotiated a compliance agreement with EPA (see Chapter 2, Table 2.1, under "Toxic Substances Control Act") to address the compliance issues related to these unauthorized uses and to allow for continued use pending decontamination or disposal. As a result of that agreement, DOE continues to notify EPA when additional unauthorized uses of PCBs, such as PCBs in paint, adhesives, electrical wiring, or floor tile, are identified at ORNL. No new unauthorized uses of PCBs were identified during 2020.

5.3.10. Emergency Planning and Community Right-to-Know Act Compliance Status

The Emergency Planning and Community Right-to-Know Act (EPCRA 1986) and Title III of SARA require that facilities report inventories and releases of certain chemicals that exceed specific release thresholds. The inventory report is submitted to the Emergency Response Information System (E-Plan), which is an electronic database managed by the University of Texas at Dallas and funded by the US Department of Homeland Security. The State of Tennessee Emergency Response Commission has access to ORNL EPCRA data via the E-Plan system.

Table 5.6 describes the main elements of EPCRA. UT-Battelle complied with these requirements in 2020 through the submittal of reports under EPCRA Sections 302, 303, 311, 312, and 313. The reports contain information on all DOE prime contractors and their subcontractors who reported activities at the ORNL site.

ORNL had no releases of extremely hazardous substances, as defined by EPCRA in 2020. Releases of toxic chemicals that were greater than the reportable threshold quantities designated in Section 313 are discussed in Section 5.3.10.2.

Table 5.6. Main elements of the Emergency Planning and Community Right-to-Know Act

Title	Description
Sections 302 and 303, Planning Notification	Requires that local planning committee and state emergency response commission be notified of EPCRA-related planning
Section 304, Extremely Hazardous Substance Release Notification	Addresses reporting to state and local authorities of off-site releases
Sections 311–312, Safety Data Sheet/Chemical Inventory	Requires that either safety data sheets or lists of hazardous chemicals for which they are required be provided to state and local authorities for emergency planning. Requires that an inventory of hazardous chemicals maintained in quantities over thresholds be reported annually to EPA
Section 313, Toxic Chemical Release Reporting	Requires that releases of toxic chemicals be reported annually to EPA

Acronyms:
EPA = US Environmental Protection Agency
EPCRA = Emergency Planning and Community Right-to-Know Act

5.3.10.1. Safety Data Sheet/Chemical Inventory (Section 312)

Inventories, locations, and associated hazards of hazardous chemicals and/or extremely hazardous substances were submitted in an annual report to the E-Plan as required by the State of Tennessee. In 2020, there were 28 hazardous and/or extremely hazardous substances at ORNL that met EPCRA reporting criteria.

Private-sector lessees were not included in the 2020 submittals. Under the terms of their leases, lessees must evaluate their own inventories of hazardous and extremely hazardous chemicals and must submit information as required by the regulations.

5.3.10.2. Toxic Chemical Release Reporting (EPCRA Section 313)

DOE submits annual toxic release inventory reports to EPA and the Tennessee Emergency Management Agency on or before July 1 of each year. The reports cover the previous calendar year and track the management of certain chemicals that are released to the environment and/or managed through recycling, energy recovery, and treatment. (A "release" of a chemical means that it is emitted to the air or water or that it is placed in some type of land disposal.) Operations involving certain chemicals were compared with regulatory reporting thresholds to determine which chemicals exceeded individual thresholds on amounts manufactured, amounts processed, or amounts otherwise used. Releases and other waste management activities were determined for each chemical that exceeded one or more threshold.

For 2020, ORNL exceeded the reporting threshold and reported on the otherwise use of nitric acid and the manufacture of nitrate compounds. Most of the nitric acid was used in wastewater treatment operations at the PWTC. Nitrate compounds were coincidentally manufactured as by-products of neutralizing the nitric acid waste and as by-products of on-site sewage treatment.

5.3.11. US Department of Agriculture/Tennessee Department of Agriculture

USDA, through Animal and Plant Health Inspection Services, issues permits for the import, transit, and controlled release of regulated animals, animal products, veterinary biologics, plants, plant products, pests, organisms, soil, and genetically engineered organisms. The Tennessee Department of Agriculture issues agreements and jointly regulates domestic soil. In 2020, UT-Battelle personnel had 21 permits and agreements for the receipt, movement, or controlled release of regulated articles.

5.3.12. Wetlands

Approximately 25 wetlands, encompassing 10 acres, were surveyed at potential project sites in 2020. Although no official delineations were conducted in 2020, surveys reconfirmed presence of historically known wetlands and provided approximate boundaries of newly discovered wetland locations for sensitive resource survey reports. Assessing the potential for jurisdictional wetlands during the site selection process and early planning stages can help projects reduce wetland impacts, design changes, and mitigation costs. Wetland delineations are conducted to facilitate compliance with TDEC and US Army Corps of Engineers wetland protection requirements.

5.3.13. Radiological Clearance of Property at ORNL

DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE 2011c), established standards and requirements for operations of DOE and its contractors with respect to protection of members of the public and the environment against undue risk from radiation. In addition to discharges to the environment, the release of property containing residual radioactive material is a potential contributor to the dose received by the public, and DOE Order 458.1 established requirements for clearance of property from DOE control and for public notification of clearance of property.

5.3.13.1. Graded Approach to Evaluate Material and Equipment for Release

At ORNL, UT-Battelle uses a graded approach for release of material and equipment for unrestricted public use. Material that may be released to the public has been categorized so that in some cases an administrative release can be accomplished without a radiological survey. Such material originates from nonradiological areas and includes items such as the following:

- Documents, mail, diskettes, compact disks, and other office media
- Nonradioactive items or materials received that are immediately (within the same shift) determined to have been delivered in error or damaged
- Personal items or materials
- Paper, plastic products, aluminum beverage cans, toner cartridges, and other items released for recycling
- Office trash
- Housekeeping materials and associated waste
- Breakroom, cafeteria, and medical wastes
- Compressed gas cylinders and fire extinguishers
- Medical and bioassay samples
- Other items with an approved release plan

Items that are not in the listed categories and that originate from nonradiological areas within ORNL's controlled areas are surveyed before release to the public, or a process knowledge evaluation is conducted to ensure that the material has not been exposed to radioactive material or beams of radiation capable of creating radioactive material. In some cases, both a radiological survey and a process knowledge evaluation are performed (e.g., a radiological survey is conducted on the outside of the item, and a process knowledge form is signed by the custodian for inaccessible surfaces). A similar approach is used for material released to state-permitted landfills on ORR. The only exception is for items that could be internally contaminated; those items are also sampled by laboratory analysis to ensure that landfill permit criteria are met.

When the process knowledge approach is used, the item's custodian is required to sign a statement that specifies that the history of the item or material is known and that the material is known to be free of contamination. This process knowledge certification is more stringent than what is allowed by DOE Order 458.1 (DOE 2011c) in that ORNL requires an individual to take personal responsibility and accountability for knowing the complete history of an item before it can be cleared using process knowledge alone. DOE Order 458.1 allows use of procedures for evaluating operational records and operating history to make process knowledge release decisions, but UT-Battelle has chosen to continue to require personal certification of the status of an item. This requirement ensures that each individual certifying the item is aware of the significance of this decision and encourages the individual to obtain a survey of the item if he or she is not confident that the item can be certified as being free of contamination.

A survey and release plan may be developed to direct the radiological survey process for large recycling programs or for clearance of bulk items with low contamination potential. For such projects, survey and release plans are developed based on guidance from the *Multi-Agency Radiation Survey and Site Investigation Manual* (MARSSIM) (NRC 2000) or the Multi-*Agency Radiation Survey and Assessment of Materials and Equipment Manual* (MARSAME) (NRC 2009). MARSSIM and MARSAME allow for statistically based survey protocols that typically require survey measurements for a representative portion of the items being released. The survey protocols are documented in separate survey and release plans, and the measurements from such surveys are documented in radiological release survey reports.

In accordance with DOE Order 458.1 Section k.(6)(f)2 b, "Pre-Approved Authorized Limits," UT Battelle continues to use the preapproved authorized limits for surface contamination originally established in Table IV-1 of DOE Order 5400.5 (cancelled in 2011) and the November 17, 1995, Pelletier memorandum (Pelletier 1995) for TRU alpha contamination. UT-Battelle also continues to follow the requirements of the scrap metal suspension. No scrap metal directly released from radiological areas is being recycled. In 2020, UT-Battelle cleared more than 10,889 items through the excess items and property sales processes. A summary of items requested for release through these processes is shown in Table 5.7.

Table 5.7. Excess items requested for release and/or recycling, 2020

Item	Process knowledge	Radiologically surveyed
Release request totals for 2020		
Totals	9,525	1,364
Recycling request totals for 2020		
Cardboard (tons)	310,460	
Scrap metal (nonradiological areas) (tons)	606.79	

5.3.13.2. Authorized Limits Clearance Process for Spallation Neutron Source and High Flux Isotope Reactor Neutron Scattering Experiment Samples

The SNS and High Flux Isotope Reactor (HFIR) facilities provide unique neutron scattering experiment capabilities that allow researchers to explore the properties of various materials by exposing samples to well-characterized neutron beams. Because materials exposed to neutrons can become radioactive, a process has been developed to evaluate and clear samples for release to off-site facilities. DOE regulations and orders governing radiological release of material do not specifically cover items that may have radioactivity distributed throughout the volume of the material. To address sample clearance, activity-based limits were established using the authorized limits process defined in DOE Order 458.1 (DOE 2011c) and associated guidance. The sample clearance limits are based on an assessment of potential doses against a threshold of 1 mrem/year to an individual and evaluation of other potentially applicable requirements (e.g., Nuclear Regulatory Commission) licensing regulations). Implementation of the clearance limits involves use of unique instrument screening and methods for prediction of sample activity to provide an efficient and defensible process to release neutron scattering experiment samples to researchers without further DOE control.

In 2020 ORNL cleared a total of 63 samples from neutron scattering experiments using the sample authorized limits process. Of those, 48 samples were from SNS and 15 were from HFIR.

5.4. Air Quality Program

Permits issued by the State of Tennessee convey the clean air requirements that are applicable to ORNL. These permits and the results of 2020 air monitoring activities are summarized in the following sections.

5.4.1. Construction and Operating Permits

New projects are governed by construction permits until the projects are converted to operating status. The sitewide Title V Major Source Operating Permits include requirements that are generally applicable to large operations such as national laboratories (e.g., asbestos and stratospheric ozone) as well as specific requirements directly applicable to individual air emission sources. Source-specific requirements include Rad-NESHAPs (see Section 5.4.3), requirements applicable to sources of radiological air pollutants, and requirements applicable to sources of other hazardous (nonradiological) air pollutants. In August 2017, the State of Tennessee issued Title V Major Source Operating Permit 571359 to DOE and UT-Battelle for operations at ORNL. DOE and UT-Battelle also maintained a valid minor source operating permit with the Knox County Department of Air Quality Management Division for the NTRC facilities, which are located in Knox County.

The CFTF was constructed at an off-site location in the Horizon Center Business Park in Oak Ridge, Tennessee. UT-Battelle applied for and received two construction permits for construction of the CFTF (Permit No. 965013P in 2012 and Permit No. 967180P in 2014). The initial start-up of the CFTF occurred in March 2013. A Conditional Major Source Operating Permit for the facility was issued in February 2020.

DOE/NWSol has two non-Title V Major Source Operating Permits for one emission source and two emergency generators at TWPC. During 2020 no permit limits were exceeded. Isotek has a Title V Major Source Operating Permit (576448) for the Radiochemical Development Facility (Building 3019 complex). During 2020 no permit limits were exceeded. UCOR was issued a Title V Major Source Operating Permit (569768) on September 18, 2015, for the Building 3039 Process Off-Gas and Hot Cell Ventilation System. Construction Permit 974744 was issued on November 19, 2018, to implement several proposed modifications to the Title V Operating Permit, and Significant Modification #1 to the Title V Operating Permit was issued on April 5, 2019, incorporating those modifications. Although the permit expired on September 17, 2020, it remains in effect because a timely application for renewal was submitted in March 2020. During 2020 no permit limits were exceeded.

5.4.2. National Emission Standards for Hazardous Air Pollutants—Asbestos

Numerous facilities, structures, and facility components and various pieces of equipment at ORNL contain asbestos-containing material. UT-Battelle's Asbestos Management Program manages the compliance of work activities involving the removal and disposal of asbestos-containing material, which include notifications to TDEC for all demolition activities and required renovation activities, approval of asbestos work authorization requests, current use of engineering controls and work practices, inspections, air monitoring, and waste tracking of asbestos-contaminated waste material. During 2020 there were no deviations or releases of reportable quantities of asbestos-containing material.

5.4.3. Radiological Airborne Effluent Monitoring

Radioactive airborne discharges at ORNL are subject to Rad-NESHAPs and consist primarily of ventilation air from radioactively contaminated or potentially contaminated areas, vents from tanks and processes, and ventilation for hot cell operations and reactor facilities. The airborne emissions are treated and then filtered with high-efficiency particulate air filters and/or charcoal filters before discharge. Radiological airborne emissions from ORNL consist of solid particulates, tritium, adsorbable gases (e.g., iodine), and nonadsorbable gases (e.g., noble gases).

The major radiological emission point sources for ORNL consist of the following eight stacks. Seven are located in Bethel and Melton Valleys, and one, the SNS Central Exhaust Facility stack, is located on Chestnut Ridge (Figure 5.6):

- 2026 Radioactive Materials Analytical Laboratory
- 3020 Radiochemical Development Facility
- 3039 central off-gas and scrubber system, which includes the 3500 cell ventilation system, isotope area cell ventilation system, 3025/3026 cell ventilation system, 3042 ventilation system, and 3092 central off-gas system
- 4501 Radiochemistry Laboratory Area Off-Gas System
- 7503 Molten Salt Reactor Experiment Facility
- 7880 TWPC
- 7911 Melton Valley complex, which includes HFIR and the Radiochemical Engineering Development Center
- 8915 SNS Central Exhaust Facility stack

In 2020 there were 14 minor point/group sources, and emission calculations/estimates were made for each of them.

5.4.3.1. Sample Collection and Analytical Procedure

- Three of the major point sources (stacks 3020, 3039, and 7503) are equipped with in-stack source-sampling systems that comply with criteria in the American National Standards Institute (ANSI) standard ANSI N 13.1-1969R (ANSI 1969). The sampling systems generally consist of a multipoint in-stack sampling probe, a sample transport line, a particulate filter, activated charcoal cartridges (or canister), a silica gel cartridge (if required), flow-measurement and totalizing instruments, a sampling pump, and a return line to the stack. The 2026 (Radioactive Materials Analytical Laboratory), 4501(Radiochemistry Laboratory), 7911 (Melton Valley complex), and 7880 (TWPC) stacks are equipped with in-stack source-sampling systems that comply with criteria in the ANSI–Health Physics Society standard ANSI/HPS N13.1-1999 (ANSI 1999).

The 2026, 4501 and 7911 sampling systems have the same components as the ANSI 1969 sampling systems used for the four major point sources but use a stainless-steel-shrouded probe instead of a multipoint in-stack sampling probe. The 7911 sampling system also consists of a high-purity germanium detector with an analog-to-digital converter and ORTEC GammaVision software, which allows for continuous isotopic identification and quantification of radioactive noble gases (e.g., ^{41}Ar) in the effluent stream. The 7880 sampling system consists of a stainless-steel-shrouded probe, an in-line filter-cartridge holder placed at the probe to minimize line losses, a particulate filter, a sample transport line, a rotary vane vacuum pump, and a return line to the stack. The sample probes from both the ANSI 1969 and ANSI 1999 stack-sampling systems are removed, inspected, and cleaned annually. The SNS Central Exhaust Facility (8915) stack is equipped with an in-stack radiation detector that complies with criteria in ANSI/HPS N13.1-1999 (ANSI 1999). The detector monitors radioactive gases flowing through the exhaust stack and provides a continual readout of activity detected by a scintillator probe. The detector is calibrated to correlate with isotopic emissions.

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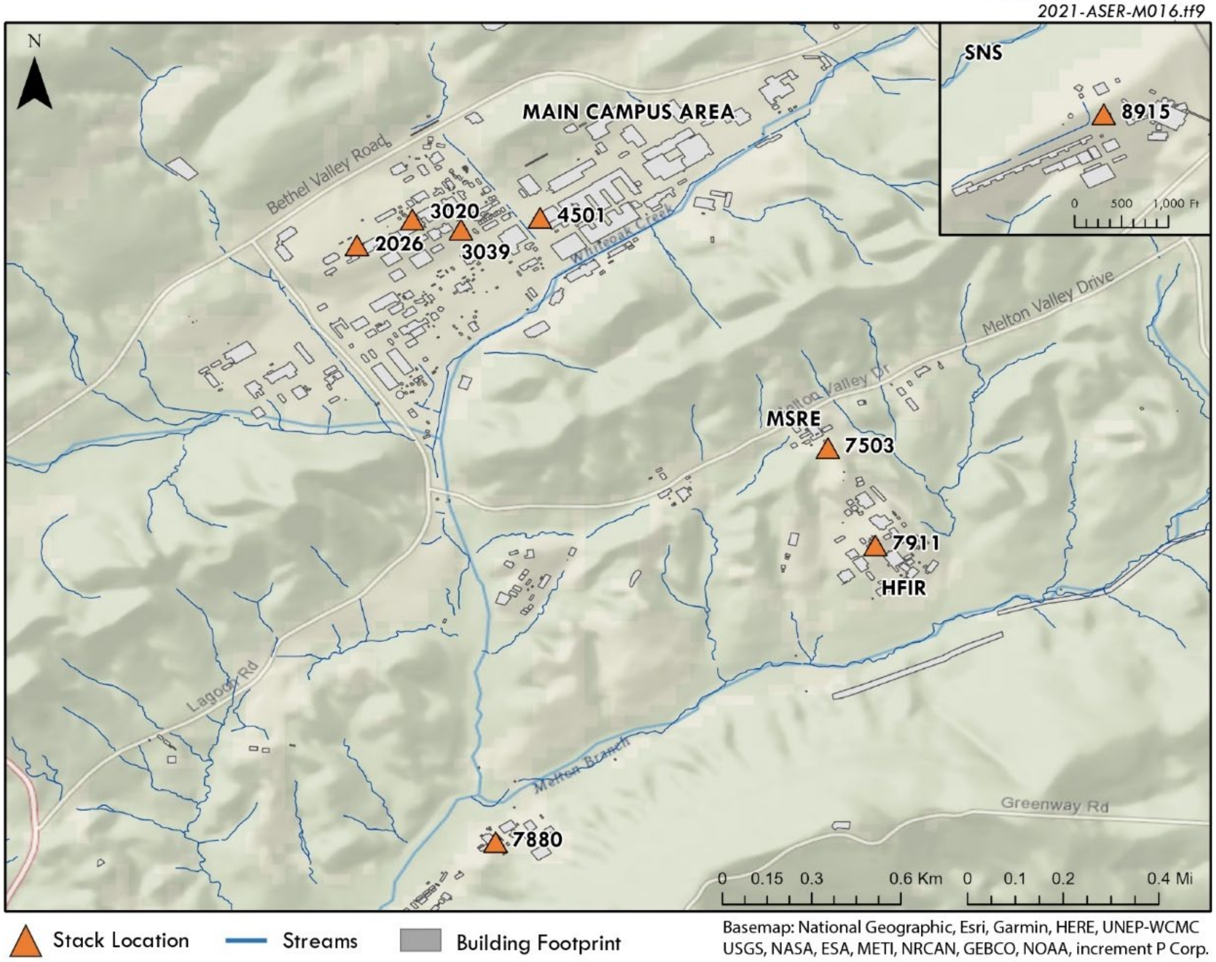
2021-ASER-M016.tf9



Acronyms:
HFIR = High Flux Isotope Reactor MSRE = Molten Salt Reactor Experiment SNS = Spallation Neutron Source

Figure 5.6. Locations of major radiological emission points at ORNL, 2020

Velocity profiles are performed quarterly at major sources (except for the 3039 stack) and at some minor sources; the criteria in EPA Method 2 (40 CFR Part 60, Appendix A-1, Method 2) are followed. The profiles provide accurate stack flow data for subsequent emission-rate calculations. An annual leak-check program is carried out to verify the integrity of the sample transport system. An annual comparison is performed for the 7880 stack between the effluent flow rate totalizer and EPA Method 2. The response of the stack effluent-flow-rate monitoring system is checked quarterly with the manufacturer's instrument test procedures. The stack sampler rotameter is calibrated at least quarterly in comparison with a secondary (transfer) standard. Only a certified secondary standard is used for all rotameter tests.

Starting in 2017, the 3039 emissions were calculated using a fixed stack flow rate. A fixed stack flow rate was used because the stack velocity at the sampling level is at or below the sensitivity of standard methods for measuring the velocity and therefore stack flow rates can no longer be determined. Low effluent velocity measurements are due to stack flow reductions resulting from the removal of facilities exhausting through the stack. The EPA Region 4 office approved a request to use an alternative fixed stack flow for emission calculations for the 3039 stack in a letter dated April 27, 2017 (V. Anne Heard, Acting Regional Administrator, United States Environmental Protection Agency Region 4 to Raymond J. Skwarek, Environmental Safety, Health and Quality Assurance Manager, UCOR, April 27, 2017). The 3039 stack velocity was successfully measured with new equipment in November 2019 and in July 2020. Both results were below the fixed stack flow rate, but the stack velocity result obtained in 2020 was used for emission calculation purposes.

In addition to the major sources, ORNL has several minor sources that have the potential to emit radionuclides to the atmosphere. A minor source is defined as any ventilation system or component such as a vent, laboratory hood, room exhaust, or stack that does not meet the approved regulatory criteria for a major source but that is located in or vents from a radiological control area as defined by Radiological Support Services of the UT-Battelle Nuclear and Radiological Protection Division. Various methods are used to determine the emissions from the various minor sources. Methods used for calculations of minor source emissions comply with EPA criteria. The minor sources are evaluated on a 1- to 5-year basis. Major and minor emissions are compiled annually to determine the overall ORNL source term and associated dose.

The charcoal cartridges/canisters, particulate filters, and silica-gel traps are collected weekly to biweekly. The use of charcoal cartridges (or canisters) is a standard method for capturing and quantifying radioactive iodine in airborne emissions. Gamma spectrometric analysis of the charcoal samples quantifies the adsorbable gases. Analyses are performed weekly to biweekly. Particulate filters are held for 8 days before a weekly gross alpha and gross beta analysis to minimize the contribution from short-lived isotopes such as ^{220}Rn and its daughter products. At stack 7911, a weekly gamma scan is conducted to better detect short-lived gamma isotopes. The filters are then composited quarterly or semiannually and are analyzed for alpha-, beta-, and gamma-emitting isotopes. At stack 7880, the filters are collected monthly and analyzed for alpha-, beta-, and gamma-emitting isotopes. The sampling system on stack 7880 requires no other type of radionuclide collection media. Monthly sampling provides a better opportunity for quantification of the low-concentration isotopes. Silica-gel traps are used to capture water vapor that may contain tritium. Analysis is performed weekly to biweekly. At the end of the year, the sample probes for all of the stacks are rinsed, except for the 8915 and 7880 probes, and the rinsate is collected and submitted for isotopic analysis identical to that performed on the particulate filters. A probe-cleaning program has been determined unnecessary for 8915 because the sample probe is a scintillator probe used to detect radiation and not to extract a sample of stack exhaust emissions. It is not anticipated that contaminant deposits would collect on the scintillator probe. A probe-cleaning program for 7880 has established that rinse analysis historically showed no detectable contamination. Therefore, the frequency of probe rinse collection and analysis is no more often than every 3 years unless there is an increase in particulate emissions, an increase in detectable radionuclides in the sample media, or process modifications.

The data from the charcoal cartridges or canisters, silica gel, probe wash, and filter composites are compiled to give the annual emissions for each major source and some minor sources.

5.4.3.2. Results

Annual radioactive airborne emissions for ORNL in 2020 are presented in Appendix G.

Historical trends for tritium (^{3}H) and ^{131}I are presented in Figures 5.7 and 5.8. For 2020, tritium emissions totaled about 1,023 Ci (Figure 5.8), comparable to what was seen in 2019; ^{131}I emissions totaled 0.07 Ci (Figure 5.8), comparable to what was seen in 2019. For 2020, of the 357 radionuclides (excluding radionuclides with multiple solubility type) released from ORNL operations and evaluated, the isotopes that contributed 10 percent or more to the off-site dose from ORNL included ^{212}Pb, which contributed about 48 percent, and ^{138}Cs, which contributed about 13 percent to the total ORNL dose.

Emissions of ^{212}Pb result from research activities and from the radiation decay of legacy material stored on-site and areas containing isotopes of ^{228}Th, ^{232}Th, and ^{232}U. Emissions of ^{212}Pb were from the following stacks: 2026, 3020, 3039, 4501, 7503, 7856, 7911, and the 3000, 4000 area, and 7000 laboratory hoods. Cesium-138 emissions result from Radiochemical Engineering Development Center research activities and HFIR operations. For 2020, ^{212}Pb emissions totaled 13.91 Ci, ^{138}Cs emissions totaled 1,070 Ci, and ^{41}Ar emissions totaled 1,119 Ci (see Figure 5.9).

The calculated radiation dose to the maximally exposed individual (MEI) from all radiological airborne release points at ORR during 2020 was 0.4 mrem. The dose contribution to the MEI from all ORNL radiological airborne release points was 1 percent of the ORR dose. This dose is well below the Rad-NESHAPs standard of 10 mrem and is equal to approximately 0.10 percent of the roughly 300 mrem that the average individual receives from natural sources of radiation. (See Section 7.1.2 for an explanation of how the airborne radionuclide dose was determined.)

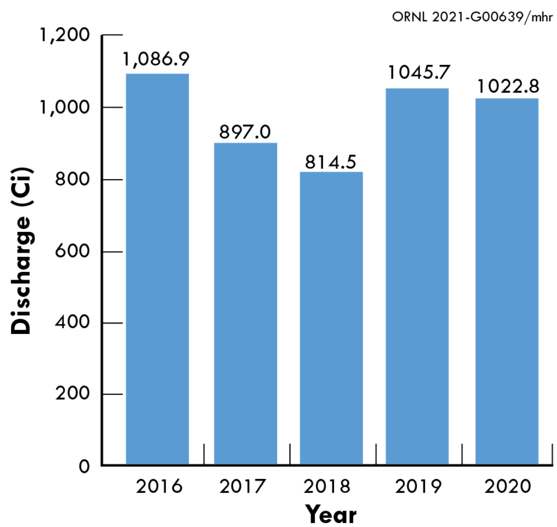


Figure 5.7. Total curies of tritium discharged from ORNL to the atmosphere, 2016–2020

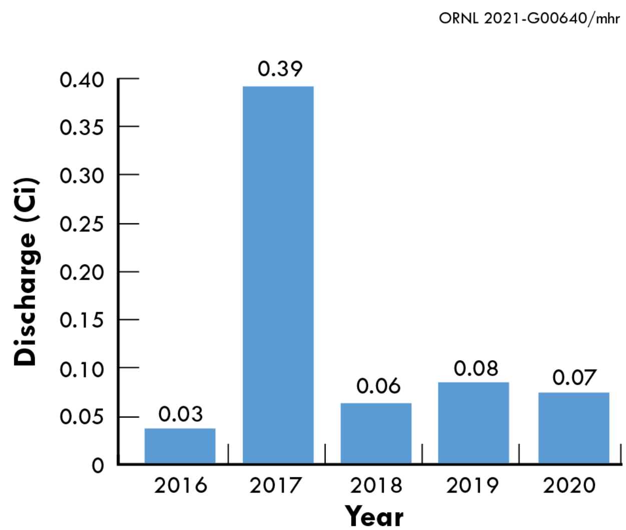


Figure 5.8. Total curies of ^{131}I discharged from ORNL to the atmosphere, 2016–2020

5.4.4. Stratospheric Ozone Protection

As required by the CAA Title VI Amendments of 1990 and in accordance with 40 CFR Part 82, actions have been implemented to comply with the prohibition against intentionally releasing ozone-depleting substances during maintenance activities performed on refrigeration equipment. In 2017, EPA enacted major revisions to the Stratospheric Ozone rules to include the regulation of substitutes for ozone-depleting substances as part of 40 CFR 82 Subpart F.

The revisions were effective January 1, 2018, for disposal of small appliances and January 1, 2019, for the leak rate provisions for large appliances. Necessary changes to the Stratospheric Ozone Protection compliance program were implemented to comply with the requirements of the new rule. Service requirements for refrigeration systems (including motor vehicle air conditioners), technician certification requirements, record-keeping requirements, and labeling requirements were implemented in accordance with 40 CFR 82 Subpart F.

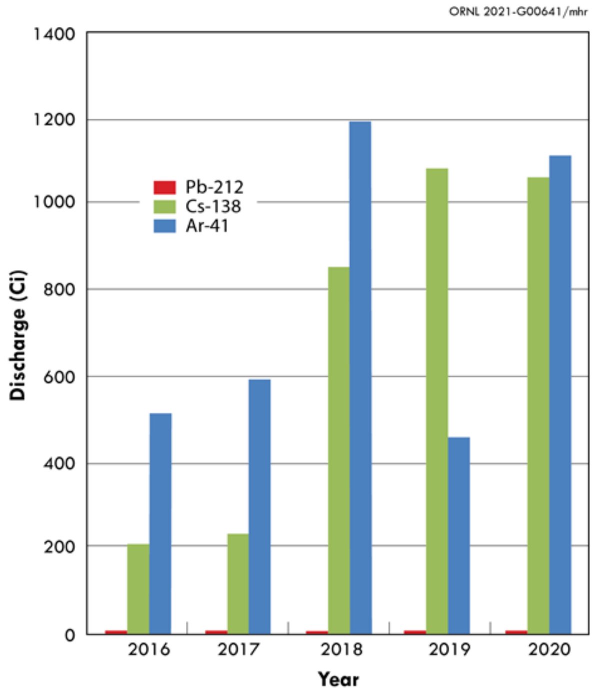


Figure 5.9. Total curies of ^{41}Ar, ^{138}Cs, and ^{212}Pb discharged from ORNL to the atmosphere, 2016–2020

5.4.5. Ambient Air

Station 7 in the ORNL 7000 maintenance area is the site-specific ambient air monitoring location. During 2020, the sampling system at Station 7 was used to quantify levels of tritium; uranium; and gross alpha-, beta-, and gamma-emitting radionuclides. A low-volume air sampler was used for particulate collection. The 47 mm glass-fiber filters were collected biweekly and were composited annually for laboratory analysis. A silica-gel column was used for collection of tritium as tritiated water. The silica gel was collected biweekly or weekly, depending on ambient humidity, and was composited quarterly for tritium analysis. Station 7 sampling data (Table 5.8) are compared with derived concentration standards (DCSs) for air established by DOE as guidelines for controlling exposure to members of the public (DOE 2011a). During 2020 average radionuclide concentrations at Station 7 were less than 1 percent of the applicable DCSs in all cases.

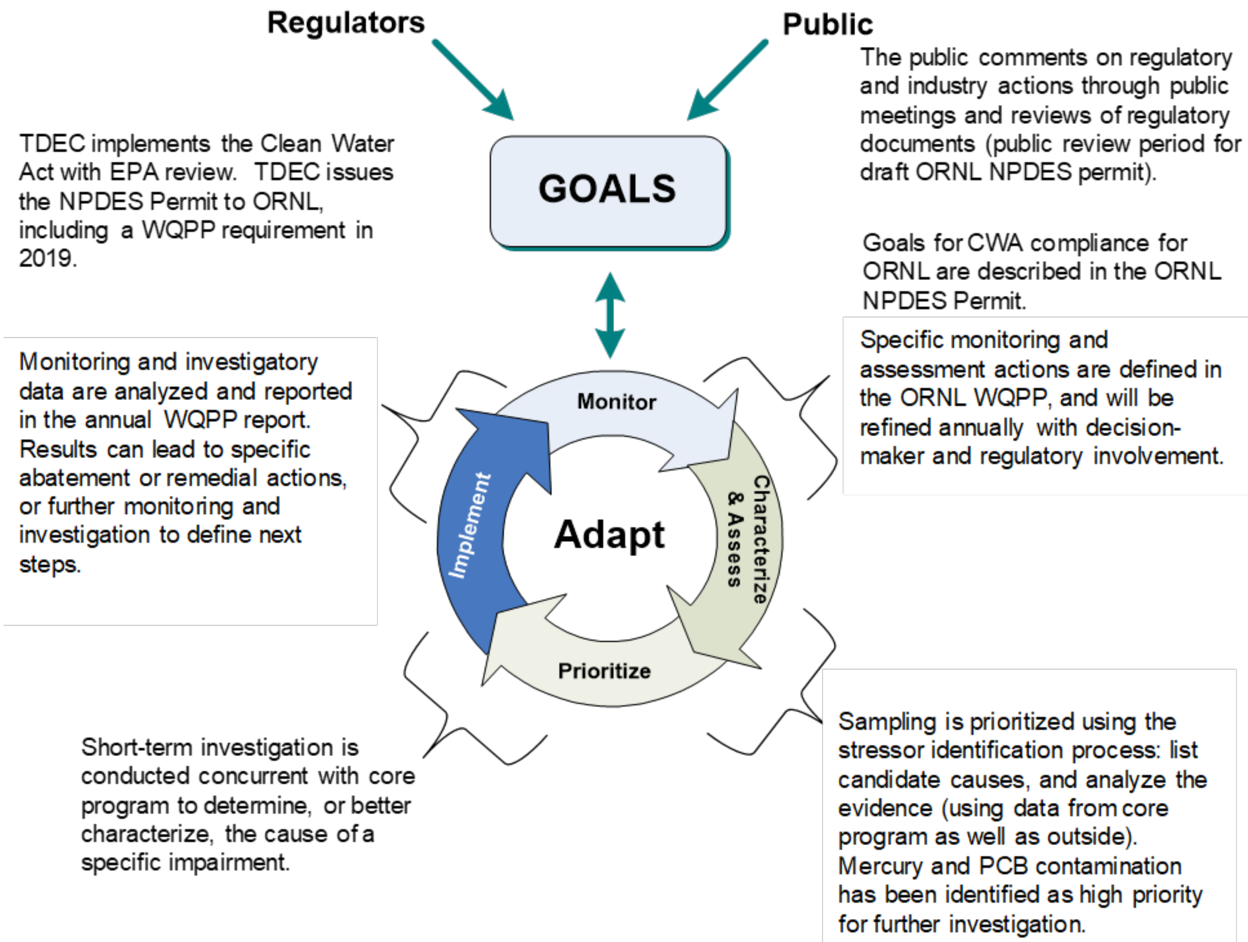
Table 5.8. Radionuclide concentrations measured at ORNL air monitoring Station 7, 2020

Parameter	Concentration (pCi/mL)[a]
Alpha	6.50E-09
^{7}Be	2.30E-08
Beta	1.49E-08
^{40}K	1.53E-09
Tritium	6.63E-06
^{234}U	1.90E-11
^{235}U	1.95E-12
^{238}U	1.60E-11
Total U	3.70E-11

[a]1 pCi = 3.7 × 10^{-2} Bq.

5.5. ORNL Water Quality Program

NPDES permit TN 0002941, issued to DOE for the ORNL site and renewed by the State of Tennessee in 2019, includes requirements for discharging wastewaters from the two ORNL on-site wastewater treatment facilities and from more than 150 category outfalls (outfalls with nonprocess wastewaters such as cooling water, condensate, groundwater, and storm water), and for the development and implementation of a water quality protection plan (WQPP). The permit calls for a WQPP to “efficiently utilize the facility’s financial resources to measure its environmental impacts.” Rather than prescribing rigid monitoring schedules, the ORNL WQPP is flexible and focuses on significant findings. It is implemented utilizing an adaptive management approach (Figure 5.10), whereby results of investigations are routinely evaluated and strategies for achieving goals are modified based on those evaluations. The goals established for the WQPP are to meet the requirements of the NPDES permit, improve the quality of aquatic resources on the ORNL site, prevent further impacts to aquatic resources from current activities, identify the stressors that contribute to impairment of aquatic resources, use available resources efficiently, and communicate outcomes with decision makers and stakeholders.



Adapted from the US Environmental Protection Agency (EPA) stressor guidance document (*Stressor Identification Guidance Document*. EPA-822-B-00-025. US Environmental Protection Agency, Office of Water, Washington, DC.).

Acronyms:
CWA = Clean Water Act
NPDES = National Pollutant Discharge Elimination System
PCB = polychlorinated biphenyl
TDEC = Tennessee Department of Environment and Conservation
WQPP = Water Quality Protection Plan

Figure 5.10. Diagram of the adaptive management framework with step-wise planning specific to the ORNL Water Quality Protection Plan

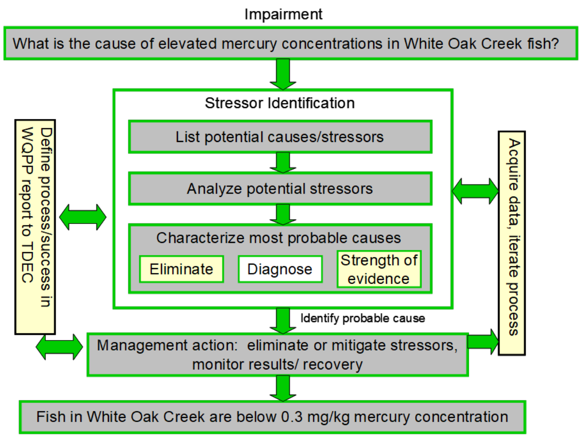
The ORNL WQPP was developed by DOE and was approved by TDEC in 2008, and the WQPP monitoring was initiated in 2009. Revisions to the WQPP are submitted to TDEC for review and comment. The WQPP incorporated several control plans that were required under the previous NPDES permit, including a biological monitoring and abatement plan, a chlorine control strategy, a storm water pollution prevention plan, a non-storm water best management practices plan, and an NPDES radiological monitoring plan.

To prioritize the stressors and/or contaminant sources that may be of greatest concern to water quality and to define conceptual models that would guide any special investigations, the WQPP strategy was defined using EPA's *Stressor Identification Guidance Document* (EPA 2000a). Figure 5.11 summarizes that process. The process involves three major steps for identifying the cause of any impairment:

1. List candidate causes of impairment (based on historical data and a working conceptual model).

2. Analyze the evidence (using both case study and outside data).

3. Characterize the causes.



Modified from Figure 1-1 in the US Environmental Protection Agency stressor guidance document (*Stressor Identification Guidance Document*. EPA-822-B-00-025. US Environmental Protection Agency, Office of Water, Washington, DC.).

Acronyms:
TDEC = Tennessee Department of Environment and Conservation
WQPP = water quality protection plan

Figure 5.11. Application of stressor identification guidance to address mercury impairment in the White Oak Creek watershed

The first two steps of the stressor identification process, which were initiated in 2009, focus first on mercury impairment and then on PCB impairment because mercury and PCB concentrations in fish from WOC are at or near human health risk thresholds (e.g., EPA ambient water quality criteria [AWQCs] and TDEC fish advisory limits). Some of the major sources of mercury to biota in the WOC watershed are known, providing a good basis from which to define an appropriate conceptual model for mercury contamination in WOC. A list of potential causes of PCB contamination was also developed.

After potential causes were listed and the available evidence of mercury and PCB contamination in the WOC watershed was analyzed, it was clear that additional investigation was needed to characterize the causes. Special investigations were designed to identify specific source areas and to revise the conceptual model of the major causes of contamination in the WOC watershed.

Monitoring and investigation data collected under the ORNL WQPP are analyzed, interpreted, reported, and compared with past results at least annually. The significant findings are reported in the *Annual Site Environmental Report*, and a more comprehensive report of findings is submitted to TDEC on a biannual basis. This information provides an assessment of the status of ORNL's receiving-stream watersheds and the impact of ongoing efforts to protect and restore those watersheds and will guide efforts to improve the water quality in the watershed.

5.5.1. Treatment Facility Discharges

The ORNL STP and the ORNL PWTC provide appropriate treatment of the various R&D, operational, and domestic wastewaters generated by site staff and activities. Both are permitted to discharge treated wastewater and are monitored under NPDES Permit TN0002941, issued by TDEC to DOE for the ORNL site. The ORNL NPDES permit requirements include monitoring the two ORNL wastewater treatment facility effluents for conventional, water-quality-based, and radiological constituents and for effluent toxicity, with numeric parameter-specific compliance limits established by TDEC as determined to be necessary. TDEC last renewed the ORNL NPDES permit in May 2019. The results of field measurements and laboratory analyses to assess compliance for the parameters required by the NPDES permit and rates of compliance with numeric limits established in the permit are provided in Section 5.3.4 (Table 5.4). Compliance with permit limits for ORNL wastewater treatment facilities was greater than 99 percent in 2020.

Toxicity testing provides an assessment of any harmful effects that could occur from the total combined constituents in discharges from ORNL wastewater treatment facilities. Effluents from the STP have been required to be tested for toxicity to aquatic species under the NPDES permit every year since 1986, and effluents from PWTC have been tested since it went into operation in 1990. Test species have been *Ceriodaphnia dubia*, an aquatic invertebrate, and fathead minnow (*Pimephales promelas*) larvae. Tests have been conducted using EPA chronic or acute test protocols at frequencies ranging from one to four times per year. PWTC effluent has always been shown to be nontoxic. The STP has shown isolated indications of effluent toxicity, but confirmatory tests conducted as required by the permit have shown that either the result of the routine test was an anomaly or that the condition of toxicity that existed at the time of the routine test was temporary and of short duration.

Toxicity test requirements under the current NPDES permit include annual testing for chronic toxicity from the ORNL STP and PWTC. Both test species are tested on a series of four aliquots of effluent, collected at 6 h intervals over a 24 h period. An "inhibition concentration" of 25 percent was used in the testing.

5.5.2. Residual Bromine and Chlorine Monitoring

ORNL receives potable water from the City of Oak Ridge Department of Public Works, which uses chlorine as a final disinfectant. The City adds 2 to 3 mg/L of free chlorine prior to distribution. On the ORNL site, the water is used for drinking, sanitary, and housekeeping purposes as well as for research processes and in cooling systems. After the water is used, residual chlorine remains, and if discharged to surface water, can be toxic to fish and other aquatic life. Residual chlorine in wastewater routed to the STP is generally consumed in reactions with other substances within the collection and treatment system (i.e., it is used up in reaction with organics), and any residual chlorine in wastewater routed to the PWTC is removed by final activated carbon filtration. Air-conditioning systems that used once-through cooling water and discharged to storm outfalls have been replaced (except for one) with air-cooled systems that discharge only condensate to the ground or a storm drain. Newer buildings and complexes have been constructed to utilize cooling towers for air-conditioning and dehumidifying and to remove heat from instrumentation and computer systems. Two main campus Outfalls (211 and 210) still receive research-generated, once-through cooling water, but flows have been reduced by water-recycling efforts.

Leaks or discharge from any of these systems to storm drains are dechlorinated and monitored via the WQQP Chlorine Control Strategy. DOE's NPDES Permit for ORNL establishes an action level of 1.2 g/day for total residual oxidant (TRO) loading at all outfalls. If that level is exceeded, ORNL is required to investigate and remove TRO sources to reduce chlorine/bromine loading to less than 1.2 g/day. TRO is monitored twice a month at outfalls that receive cooling tower discharges and once-through cooling water. Less frequent monitoring is conducted at other outfalls (semimonthly, monthly, quarterly, or semiannually if flow is present). Chlorine Control Strategy data were collected at 20 locations in 2020, and 376 sets of data were obtained. Activities in response to TRO monitoring in 2020 included several emergency repairs in addition to the routine mitigation measures at TRO sources. Although numerous TRO findings were made in 2020, no TRO was found at any of the 12 instream monitoring points during 2020.

5.5.2.1. Leaks and Emergency Repairs

The following emergency repairs were carried out in 2020 in response to the results of TRO monitoring (see Table 5.9):

- A bisulfate supply in the Building 4508 dechlorination system failed (Outfall 210).
- A valve replacement was required in the HFIR dechlorination system (Outfall 228).
- A fire hydrant weep-drain port required closure (Outfall 231).
- A leaking fire hydrant was removed from service (Outfall 304).
- A dechlorinator box was repaired (Outfall 281).

Table 5.9. Total residual oxidant mitigation summary: Emergency repairs, 2020

Location	Date	TRO (mg/L)	Flow (gpm)	Load (g/day)	Receiving stream	Downstream integration point	Location[a]	TRO source
082	9/21	0.4	2	4.36	MB	MEK 0.6	X27	MSRE air conditioner
082	10/22	0.3	1	1.64	MB	MEK 0.6	X27	MSRE air conditioner
207	4/16	0.1	2	1.09	WOC	WCK 4.1	X21	Unknown leak
210	3/9	0.8	50	218.04	WOC	WCK 4.1	X18	Sodium bisulfite hose replaced
231	5/11	0.2	12	13.08	WOC	WCK 4.4	X25	Hydrant weep-drain
231	5/26	0.2	20	21.80	WOC	WCK 4.4	X25	Hydrant weep-drain
231	6/9	0.3	20	32.71	WOC	WCK 4.4	X25	Hydrant weep-drain
231	6/29	0.2	10	10.90	WOC	WCK 4.4	X25	Hydrant weep-drain
231	7/16	0.4	80	174.43	WOC	WCK 4.4	X25	Hydrant or construction
231	8/28	0.2	10	10.90	WOC	WCK 4.4	X25	Hydrant weep-drain
231	9/16	0.3	15	24.53	WOC	WCK 4.4	X25	Hydrant weep-drain
231	9/23	0.2	12	13.08	WOC	WCK 4.4	X25	Hydrant weep-drain
235	2/25	0.1	10	5.45	WOC	WCK 3.4	X28	Steam Plant
235	7/16	0.1	10	5.45	WOC	WCK 3.4	X28	Steam Plant
281	11/23	0.1	50	27.25	MB	MEK.06	X27	Sodium bisulfite pump valve
282	1/30	0.3	5	8.18	MB	MEK 0.6	X13	Storm damage to dechlor box
304	3/9	0.1	0.1	0.05	WOC	WCK 3.9	X21	Hydrant removed from service
585	2/17	0.2	0.1	0.11	MB	MEK 0.6	X27	Melton Valley Steam Plant

[a] *Nearest downstream TRO monitoring location*

Acronyms:

MB = Melton Branch
MEK = Melton Branch kilometer
MSRE = Molten Salt Reactor Experiment
TRO = total residual oxidant
WCK White Oak Creek kilometer
WOC = White Oak Creek

Unresolved issues include identification of the source of chlorinated water leaking to Outfalls 281 and 207. Steam Plant discharges of chlorinated water may be related to overflow from the supply to a reverse-osmosis water treatment system.

Outfall 211 and 210 are the only two remaining outfalls that receive once-through cooling water discharges. Outfall 211 receives cooling water from multiple small sources. Two dechlorinator boxes are mounted in a weir located at the point where the outfall discharges to WOC. Each box is designed to treat chlorinated discharges at flow rates up to 50 gpm. Flows ranged from 25 to 65 gpm above the dechlorinator; TRO levels above the dechlorinator ranged from 0.5 to 1.2 mg/L TRO. There were no TRO exceedances at Outfall 211 (downstream of the dechlorinator) in 2020. A liquid sodium bisulfite dechlorinator, located inside Building 4508, is used to treat discharges from Outfall 210. The dechlorinator treats cooling water from instrumentation that cannot use the recycled cooling water system. On April 9, 2020, TRO was found at Outfall 210. It was dechlorinated with tablets until April 15, 2020, when the liquid sodium bisulfite dosing hose was replaced.

A sodium bisulfite dechlorination system is used at the HFIR to treat cooling tower discharges. In November 2020, TRO was detected at Outfall 281, and an investigation showed that a valve responsible for pumping sodium bisulfite had failed. Dechlorination tablets were used to treat the discharge until the valve was replaced 2 days later.

In past years, Outfall 231 received blowdown from multiple Building 5800 cooling towers; however, the cooling towers were taken off-line in 2020. Additional Oak Ridge Leadership Computing Facility (OLCF5) towers were installed on the west end of Building 5800 during 2020 and became operational in 2021. There were no discharges to Outfall 231 from the 5800 towers or the new OLCF5 towers in 2020. There had been three previous TRO exceedances at Outfall 231, and no cause was found. When an exceedance occurred in May 2020, sodium sulfite tablets were placed at the outfall, and a survey of laboratory drains and discharges from Building 5800 was conducted. No cooling water or supply discharges were found. Construction zones on top of the supply and storm piping complicated access, but a camera survey of the storm pipe was done in October 2020. No supply leaks were found, but flow was observed bubbling up between storm pipe sections. A Fire Department inspection found that Hydrant 4-44 on the construction site was not fully closed, allowing the valve weep/drain port to release supply water. The fire hydrant may have been leaking intermittently since 2019, and leaking water may have periodically been absorbed by soil during dry weather and/or neutralized by excess dechlorination chemicals when 5800 towers were discharging. No TRO exceedances have occurred at Outfall 231since the valve was fully closed.

Outfall 082, located on a tributary to Melton Branch, receives seasonal cooling water from the only remaining water-cooled air-conditioning system at ORNL's Molten Salt Reactor Experiment facility. During the fall, TRO loads exceeded 1.2 g/d on two occasions; dechlorination tablets were in use but were ineffective. Discharges from another Molten Salt Reactor Experiment Outfall (282) are also treated with a tablet-feeder dechlorinator. TRO was detected at Outfall 282 in 2020, after high storm water levels damaged the dechlorinator. Investigations into the source of the leak were initiated, and dechlorination resumed. Chlorinated discharges from within the building and hydrant leaks have been eliminated as potential sources of the chlorine at the outfall.

Outfall 207 has no known sources of chlorine, but TRO was found there on two occasions in 2019 and on one occasion in 2020. For the measured TRO concentration, the flow rate was low enough to result in a loading (1.09 g/day) that was below the 1.2 g/day action level. Dry and wet catch basin sampling completed in 2020 did not lead to the identification of the chlorine source. The limited-duration presence of detectable chlorine at the outfall may be dependent on an intermittent water-using process in a nearby facility.

5.5.2.2. Outfalls and Cooling Tower Discharge

Chlorine- and bromine-based chemicals are added to supply water to control bacterial growth.

(Anticorrosion chemicals are also added.) Residuals of chlorine and bromine remain in the water in cooling towers if they do not evaporate or are not consumed by bacterial growth. Additionally, as the cooling towers lose water by evaporation, higher conductivity (caused by an increase in the concentration of minerals such as calcium, which occur naturally in the water and do not evaporate), triggers a blowdown, resulting in a discharge that may contain chlorine and bromine residuals. The discharge must be treated to reduce the residual oxidants to less than 0.05 mg/L TRO. In the past, sodium sulfite tablets in four-tube tablet feeders at or near tower sources or additions of liquid sodium bisulfite solution (38 to 40 percent, in proportion to the flow rate), have been used at ORNL to neutralize the residual chlorine and bromine in the discharges.

In 2020, potassium sulfite was used as a pretreatment in one location and is proposed for use at the new OLCF 5 cooling towers. In some cases, pretreatment enhances the effectiveness of the primary dechlorination tablet feeders. Inspections of tablet feeders are conducted multiple times a week to ensure that sodium sulfite tablets are refilled, that those remaining are in good condition, and that any swollen or fouled tablets are removed for disposal. Table 5.10 summarizes 2020 cooling tower discharges that exceeded TRO permit action levels.

Outfall 014 discharges only cooling tower blowdown from towers 4510 and 4521. During 2020, weekly observations were made in an effort to monitor discharges at least twice a month. On a scheduled monitoring day, up to three observations were made. During the first several months of 2020, piping repairs were being made, and no flows were found until May 11, 2020. By the end of May, discharge flows at Outfall 014 were estimated to be greater than 90 gpm, and TRO loads exceeded 1.2 g/day. An additional dechlorination box was installed for 4521 tower discharges. Tower 4510 discharges were greater than 50 gpm with elevated TRO, so additional sodium sulfite tubes were added as a temporary remedy. In 2020 potassium sulfite injection was initiated to pretreat 4510 tower discharges prior to release through the sodium bisulfite box. A similar pretreatment system is being considered for 4521 blowdown. There were no further TRO exceedances after October 2020.

Outfall 227 receives large blowdown flows from multiple cooling towers in Building 5600 and 5511. There were no TRO exceedances in 2020. Primary dechlorination occurs in Building 5600, and a secondary dechlorination box located at WOC is continually utilized as backup. Combined use of two dechlorination boxes enables approximately 4 mg/L TRO to be removed before cooling tower discharges enter the creek. To better understand dechlorination needs, TRO is monitored above and below secondary dechlorination. In 2020, results of the monitoring indicated that TRO discharges would have exceeded 1.2 g/day at the outfall in four instances if it were not for the secondary treatment.

Outfall 363 also receives discharges from multiple cooling towers. Data show that residual oxidants remain in discharges after primary dechlorination at the tower/building sources. Since 2017, sodium sulfite tablet bags have been placed below the Outfall 363 pipe as secondary dechlorination. More than 1.2 g/day of TRO was discharged in August and November 2020 despite the secondary dechlorination. Without secondary treatment with sodium bisulfite below the outfall, data show that the TRO load would have exceeded 1.2 g/day in eight additional instances.

SNS Cooling Tower discharges are monitored to verify that dechlorination is adequate at the 435 Internal Monitoring Point 1 (435INT1) prior to merging with a larger wet weather channel above the west SNS storm water retention basin and Outfall 435. Outfall 435, which discharges to WOC several hundred feet downstream, is not monitored for TRO as it would not be expected there after it is dechlorinated at the cooling tower. The number of TRO findings at 435INT1 increased during 2020. Discharge flows for both towers were recorded as 70 gpm during 2019, but one is recorded as 70 to 180 gpm in 2020. There were instances in February, May, July, October, and December when more than 1.2 g/day of TRO were discharged to the west retention pond.

Table 5.10. Total residual oxidant mitigation summary: Cooling tower outfalls exceeding the total residual oxidant NPDES action level, 2020

Location	Date	TRO (mg/L)	Flow (gpm)	Load (g/day)	Receiving stream	Downstream integration point	Location[a]	TRO source
014	05/26/20	0.5	115	313.43	WOC	WCK 4.4	X23	4510/4521 Cooling towers
014	06/26/20	0.4	90	196.24	WOC	WCK 4.4	X23	4510/4521 Cooling towers
014	06/29/20	0.3	90	147.18	WOC	WCK 4.4	X23	4510/4521 Cooling towers
014	07/16/20	0.8	115	501.49	WOC	WCK 4.4	X23	4510/4521 Cooling towers
363	10/22/20	0.3	5	8.18	Fifth Creek	FFK 0.2	X18	5300/5309 Cooling towers
363	08/28/20	0.5	20	54.51	Fifth Creek	FFK 0.2	X18	5300/5309 Cooling towers
435IMP1	02/17/20	0.1	100	54.51	WOC	WCK 5.2	435	SNS Cooling towers
435IMP1	05/11/20	0.1	25	13.63	WOC	WCK 5.2	435	SNS Cooling towers
435IMP1	07/16/20	0.1	3	1.64	WOC	WCK 5.2	435	SNS Cooling towers
435IMP1	10/27/20	0.1	25	13.63	WOC	WCK 5.2	435	SNS Cooling towers
435IMP1	12/10/20	0.2	30	32.71	WOC	WCK 5.2	435	SNS Cooling towers

[a] Nearest downstream TRO monitoring location

Acronyms:

FFK = Fifth Creek kilometer
NPDES = National Pollutant Discharge Elimination System
SNS = Spallation Neutron Source
TRO = total residual oxidant
WCK =.White Oak Creek kilometer
WOC = White Oak Creek

5.5.3. Radiological Monitoring

At ORNL, monitoring of liquid effluents and selected instream locations for radioactivity is conducted under the WQPP. Table 5.11 details the analyses performed on samples collected in 2020 at two treatment facility outfalls, three instream monitoring locations, and 20 category outfalls (outfalls that are categorized into groups with similar effluent characteristics for the purposes of setting monitoring and reporting requirements in the site NPDES permit). Dry-weather discharges from category outfalls are primarily cooling water, groundwater, and condensate. Low levels of radioactivity can be discharged from category outfalls in areas where groundwater contamination exists and where contaminated groundwater enters category outfall collection systems by direct infiltration and from building sumps, facility sumps, and building footer drains. In 2020, dry-weather grab samples were collected at 13 of the 20 category outfalls targeted for sampling. Seven category outfalls (see Table 5.11) were not sampled because there was no discharge present during sampling attempts.

The two ORNL treatment facility outfalls that were monitored for radioactivity in 2020 were the STP outfall (Outfall X01) and the PWTC outfall (Outfall X12). The three instream locations that were monitored were X13 on Melton Branch, X14 on WOC, and X15 at White Oak Dam (WOD) (Figure 5.12). At each treatment facility and instream monitoring location, monthly flow-proportional composite samples were collected using dedicated automatic water samplers.

For each radioisotope, a DCS is published in DOE directives and is used to evaluate discharges of radioactivity from DOE facilities (DOE 2011a). DCSs were developed for evaluating effluent discharges and are not intended to be applied to instream values, but the comparisons can provide a useful frame of reference. Four percent of the DCS is used as a comparison point. Although comparisons are made, neither ORNL effluents nor ambient surface waters are direct sources of drinking water. The annual average concentration of at least one radionuclide exceeded 4 percent of the relevant DCS concentration in dry-weather discharges from Outfalls 085, 207, 302, 304, X01, and X12 and at instream sampling locations WOC (X14) and WOD (X15). (Figure 5.13).

In 2020, dry-weather discharges from two outfalls (207 and 304) had an annual mean radioactivity concentration greater than 100 percent of a DCS. Samples from both outfalls had an average total radioactive strontium ($^{89/90}Sr$) concentration that exceeded the DCS for ^{90}Sr (it is reasonable, for an ORNL environmental sample, to assume that $^{89/90}Sr$ activity is comparable to ^{90}Sr activity due to the relatively short half-life of ^{89}Sr [50.55 days]). The concentrations of $^{89/90}Sr$ at Outfalls 207 and 304 were 5,000 and 200 percent of the DCS, respectively. Consequently, concentrations of radioactivity in the discharge from Outfalls 207 and 304 was also greater than the DCS level on a sum-of-fractions basis (i.e., the summation of DCS percentages of multiple radiological parameters); and the sums of the fractions for Outfalls 207 and 304 were 5,030 and 212 percent, respectively.

Under normal baseflow conditions, ORNL storm drain Outfall 207 has no flow at the end of the pipe where its discharge enters WOC. As a result of rainfall events, surface water runoff is conducted to WOC via this outfall. It is believed that the elevated activity at the outfall was caused by the failure of the drywell pump that is located near the DOE Office of Environmental Management (OREM) WC-9 liquid LLW tank. Contaminated groundwater present in the area migrated to a nearby storm drain via the pipe backfill and infiltrated the pipe that leads to the outfall. The pump was replaced on October 23, 2020, immediately following discovery of elevated radiological concentrations at the outfall. and flow from Outfall 207 ceased within several days of the pump replacement.

Levels of radioactivity in discharges from Outfall 304 have been elevated since 2014 because of two unrelated infrastructure issues. In 2014, a sump pump failed in a groundwater suppression system near the WC-9 liquid LLW tank, which is within a CERCLA soil and groundwater contamination area. Without groundwater suppression in the tank farm area, contaminated groundwater enters the

Outfall 304 storm drain system. The pump failed again in 2020, and it was out of service for a relatively short period of time. This outage had a significant effect on $^{89/90}Sr$ concentrations at Outfall 207, but very little effect on $^{89/90}Sr$ concentrations at Outfall 304.

A second infrastructure issue, which had an even greater influence on Outfall 304 radiological concentrations, occurred in 2015. A leak developed in a pipe leading from Pump Station #2 in the Process Waste Collection System to a downstream diversion box. A dye tracer test confirmed that a hydraulic connection exists between the pipe and the storm water collection system that discharges through Outfall 304, and the pipe was subsequently bypassed and taken out of service. Before he pipe was bypassed, the $^{89/90}Sr$ concentration at Outfall 304 peaked at 29,000 pCi/L (August and September 2015). Since the bypass was implemented, $^{89/90}Sr$ levels in the outfall effluent have trended downward, but they remained above DCS levels in 2020.

No additional infrastructure issues affecting Outfall 304 have been discovered, and it is believed that concentrations of radioactivity at the outfall will continue to decline as concentrations of radioactivity in the groundwater surrounding the outfall pipe decline by means of normal hydrologic processes.

The total annual discharges (or amounts) of radioactivity measured in stream water at WOD, the final monitoring point on WOC before the stream flow leaves ORNL, were calculated from concentration and flow. Results of those calculations for each of the past 5 years are shown in Figures 5.14 through 5.18. Because discharges of radioactivity are somewhat correlated to stream flow, annual flow volumes measured at the WOD monitoring station are given in Figure 5.19. Discharges of radioactivity at WOD in 2020 were similar to discharges during other recent years, particularly when differences in annual flow volume are taken into account and continue to be generally lower than in the years preceding completion of the waste area caps in Melton Valley (substantially complete by 2006).

Radiological monitoring at category outfalls in 2020 also included monitoring during storm runoff conditions. Eight storm water outfalls were monitored. Storm water samples were analyzed for gross alpha, gross beta, ^{137}Cs, $^{89/90}Sr$, and tritium activities. A gamma scan analysis was also performed. The monitoring plan calls for additional analyses to be added when sufficient gross alpha and/or beta activity is present in a sample to indicate that levels of radioactivity may exceed DCS levels and if the radionuclides contributing to the gross activities are not identified by routine analyses. In 2020, Outfall 301 required additional analyses.

Concentrations of radioactivity in storm water discharges were compared with DCSs if a DCS existed for that parameter (no DCSs exist for gross alpha or gross beta activities) and if a concentration was greater than or equal to the minimum detectable activity for the measurement. In 2020, the radionuclide $^{89/90}Sr$ exceeded 4 percent of the relevant DCS concentration in wet-weather discharges from Outfalls 004, 204, 301, and 341 (see Figure 5.13).

In 2020, one storm water outfall (004) had a radioactivity concentration greater than 100 percent of a DCS. There was only one storm water sampling event at Outfall 004 for the year. Therefore, that single set of sample results is all that is available to estimate annual average concentrations. The $^{89/90}Sr$ concentration in that one storm water sample exceeded the DCS for ^{90}Sr (it is reasonable, for an ORNL environmental sample, to assume that $^{89/90}Sr$ activity is comparable to ^{90}Sr activity due to the relatively short half-life of ^{89}Sr [50.55 days]). The $^{89/90}Sr$ concentration in the storm water sample collected at Outfall 004 was 140 percent of the DCS.

Outfall 004 is a valve pit that has been abandoned for many years; it has no known active connections. Not being tied to any active infrastructure, all the radiological constituents are assumed to be coming from historically contaminated areas. The Outfall 004 pipe is very close in proximity to the Outfall 304 pipe; thus the $^{89/90}Sr$ source to Outfall 004 is suspected to be contaminated groundwater, the same as for Outfall 304.

Table 5.11. Radiological monitoring conducted under the ORNL Water Quality Protection Plan, 2020

Location	Frequency	Gross alpha/beta	Gamma scan	^{3}H	^{14}C	$^{89/90}Sr$	Isotopic uranium	Isotopic plutonium	^{241}Am	$^{243/244}Cm$
Outfall 001	Annual	X								
Outfall 080[a]	Monthly									
Outfall 081	Annual	X								
Outfall 085	Quarterly	X	X	X		X				
Outfall 203[a]	Annual									
Outfall 204[a]	Semiannual									
Outfall 205[a]	Annual									
Outfall 207	Quarterly	X								
Outfall 211	Annual	X								
Outfall 234	Annual	X	X							
Outfall 241[a]	Quarterly									
Outfall 265[a]	Annual									
Outfall 281	Quarterly	X		X						
Outfall 282	Quarterly	X								
Outfall 302	Monthly	X	X	X		X	X[b]	X[b]	X[b]	X[b]
Outfall 304	Monthly	X	X	X		X	X[b]	X[b]	X[b]	X[b]
Outfall 365	Semiannual	X								
Outfall 368[a]	Annual									
Outfall 383	Annual	X		X						
Outfall 484	Annual	X								
STP (X01)	Monthly	X	X	X	X	X				
PWTC (X12)	Monthly	X	X	X		X	X			
Melton Branch (X13)	Monthly	X	X	X		X				
WOC (X14)	Monthly	X	X	X		X				
WOD (X15)	Monthly	X	X	X		X				

[a] *The outfall was included in the monitoring plan, but samples were not collected because no discharge was present during sampling attempts.*

[b] *The Water Quality Protection Plan does not require this parameter for this location, and therefore it may have been monitored on a frequency less than indicated in the table. Additional analyses are sometimes performed on samples, the most common reason being that gross alpha and gross beta activities exceeded a screening criterion (as described in the May 2012 update to the Water Quality Protection Plan).*

Acronyms:

STP = Sewage Treatment Plan
WTC = Process Waste Treatment Complex
WOC = White Oak Creek
WOD = White Oak Dam

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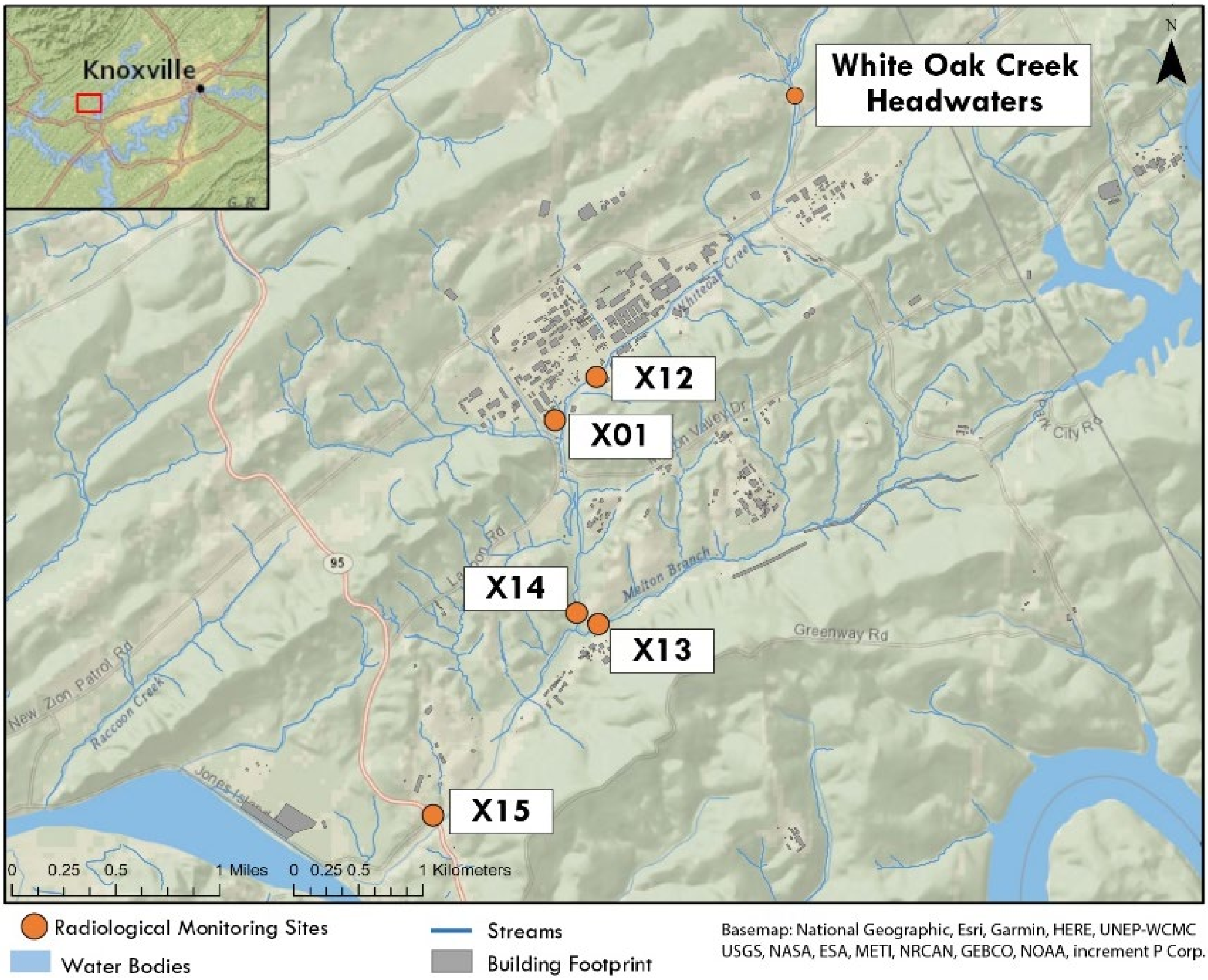
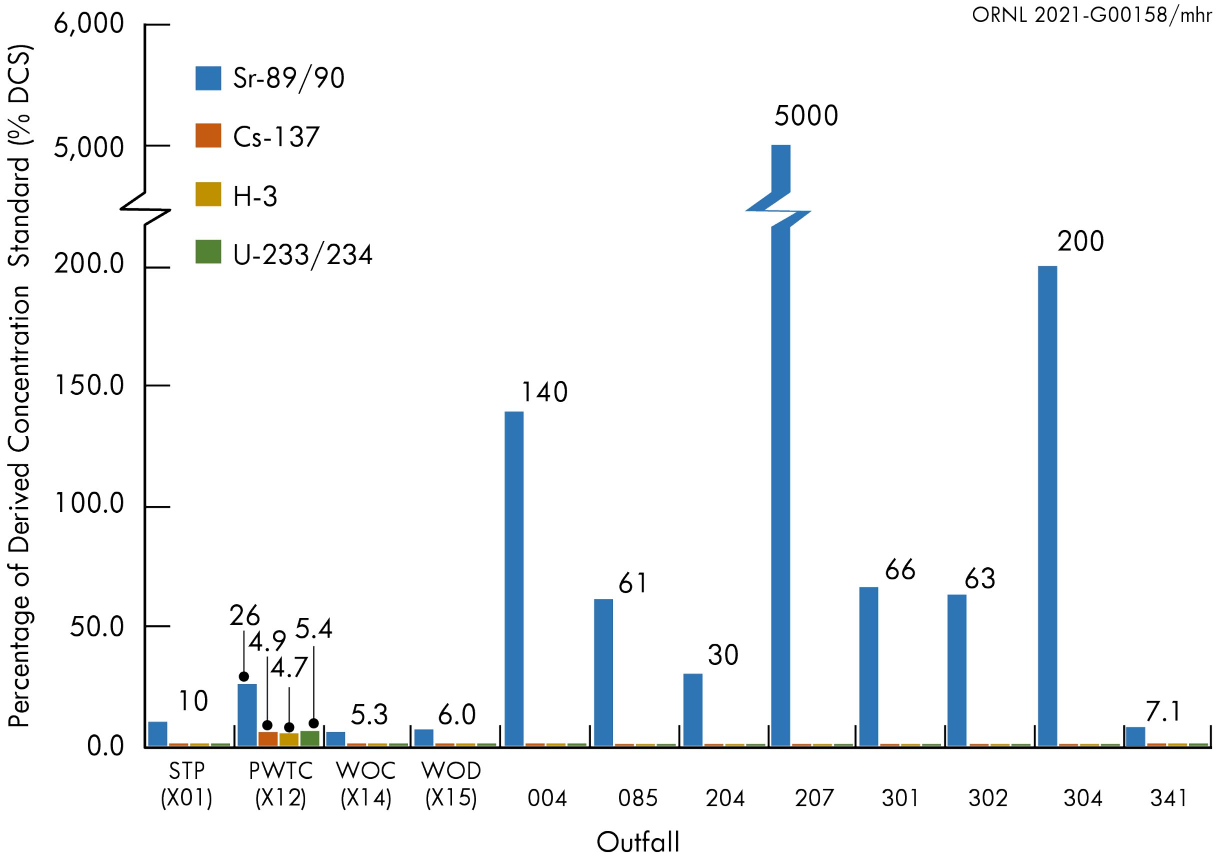


Figure 5.12. Selected surface water, National Pollutant Discharge Elimination System, and reference sampling locations at ORNL, 2020



Acronyms:
PWTC = Process Waste Treatment Complex
STP = Sewage Treatment Plant
WOC = White Oak Creek
WOD = White Oak Dam

Figure 5.13. Outfalls and instream locations at ORNL with average radionuclide concentrations greater than 4 percent of the relevant derived concentration standards in 2020

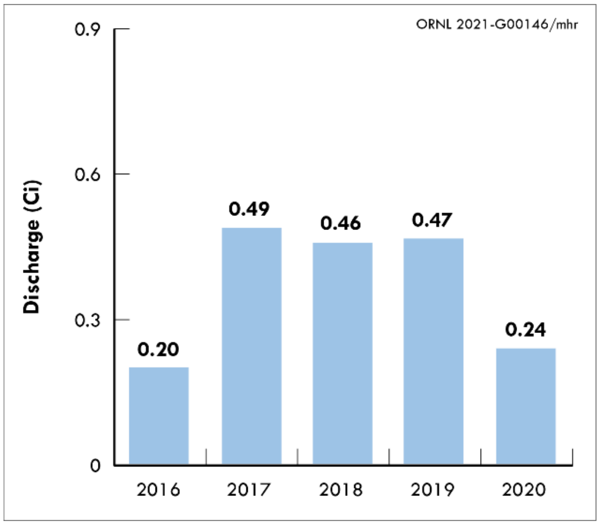


Figure 5.14. Cesium-137 discharges at White Oak Dam, 2016–2020

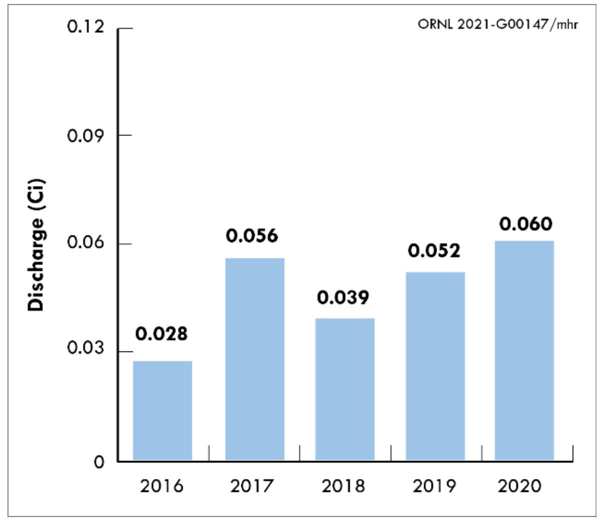


Figure 5.15. Gross alpha discharges at White Oak Dam, 2016–2020

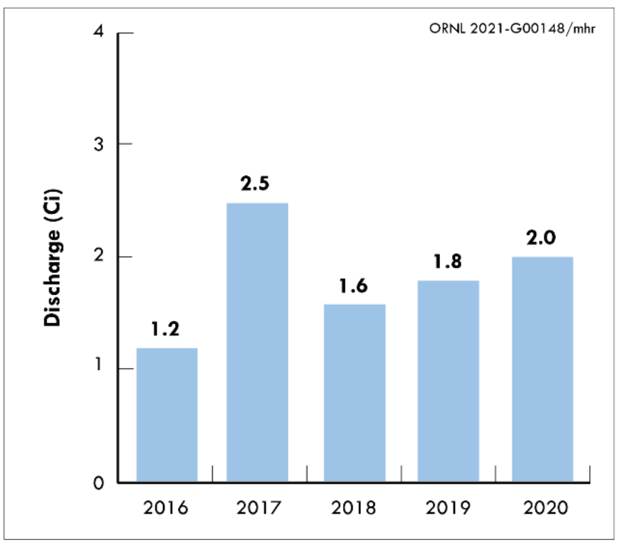


Figure 5.16. Gross beta discharges at White Oak Dam, 2016–2020

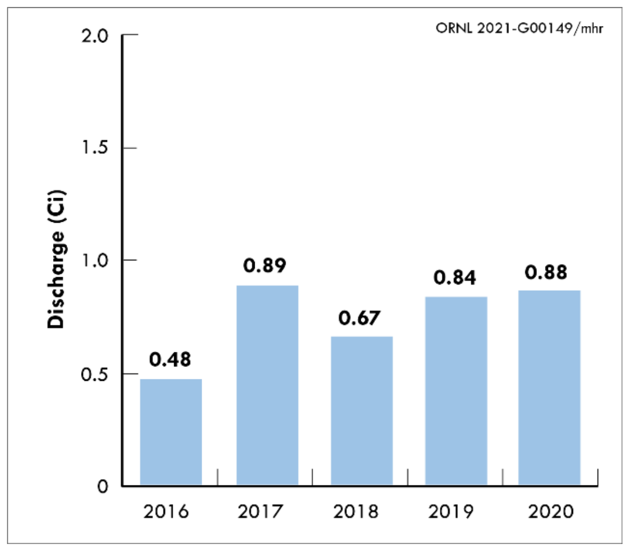


Figure 5.17. Total radioactive strontium discharges at White Oak Dam, 2016–2020

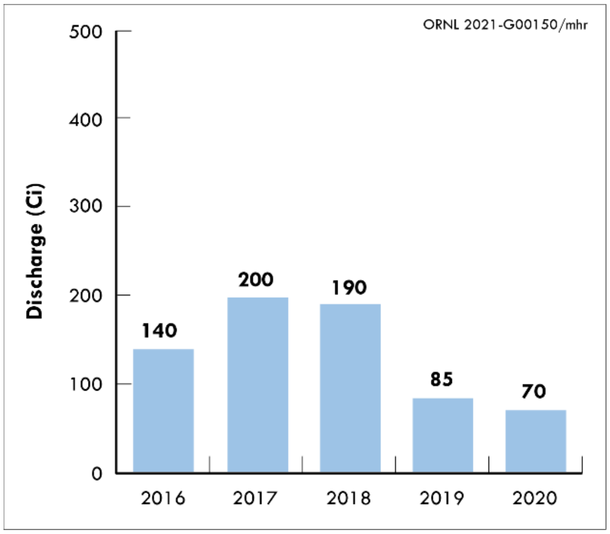


Figure 5.18. Tritium discharges at White Oak Dam, 2016–2020

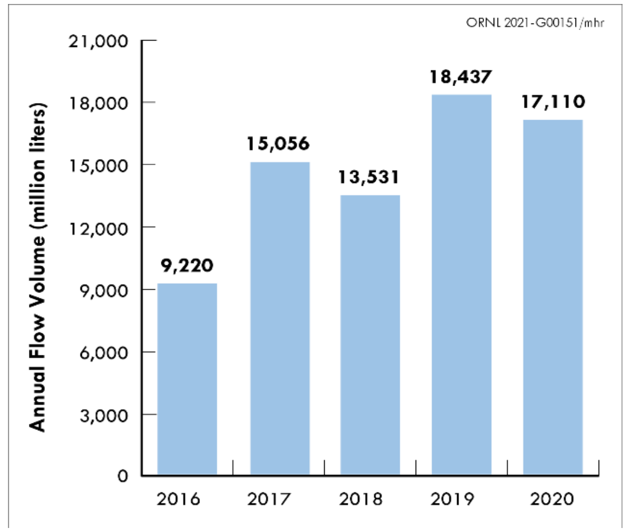


Figure 5.19. Annual flow volume at White Oak Dam, 2016–2020

5.5.4. Mercury in the White Oak Creek Watershed

During the mid-1950s, mercury (Hg) was used for pilot-scale isotope separation work in Buildings 4501, 4505, and 3592 and in spent-fuel reprocessing in Building 3503. By 1963 this work was transferred to Y-12.

Buildings 4501 and 4505 are active research facilities located east of Fifth Creek and north of WOC. In 1996, the Building 4501 foundation sump was found to contain legacy Hg due to its use and spills in the 1950s and to its volatility. The foundation sump discharged to storm Outfall 211 (Figure 5.20) on WOC; a smaller foundation sump in the building discharged to Outfall 263 on Fifth Creek. By 2011, an Hg pretreatment system had been installed on the larger sump. It had also been rerouted along with the smaller sump and a 4500N foundation sump to the PWTC. Outfall 211 and Outfall 363 storm piping still receive other sources of storm water, cooling water, and steam condensate discharges. Due to the persistence of elemental Hg, its volatility, and the complexity of its interactions in piping and soil, Hg continues to be monitored and assessed at these storm outfalls.

Buildings 3592 and 3503 were demolished under the CERCLA remedial process in 2011 and 2012, respectively; their footprints and associated storm water drains remain in the Outfall 207 storm water drainage system. Mercury associated with process infrastructure has been found in other areas, such as north of the Fifth Street and Central Avenue intersection and in the Outfall 304 drainage area. Storm water exchange with process leaks or overflows has occurred under certain situations.

5.5.4.1. Buildings 3592 and 3503

Buildings 3592 and 3503 were demolished under the CERCLA remedial process in 2011 and 2012, respectively; their footprints and associated storm water drains remain in the Outfall 207 storm water drainage system. Mercury associated with process infrastructure has been found in other areas, such as north of the Fifth Street and Central Avenue intersection and in the Outfall 304 drainage area. Storm water exchange with process leaks or overflows has occurred under certain situations.

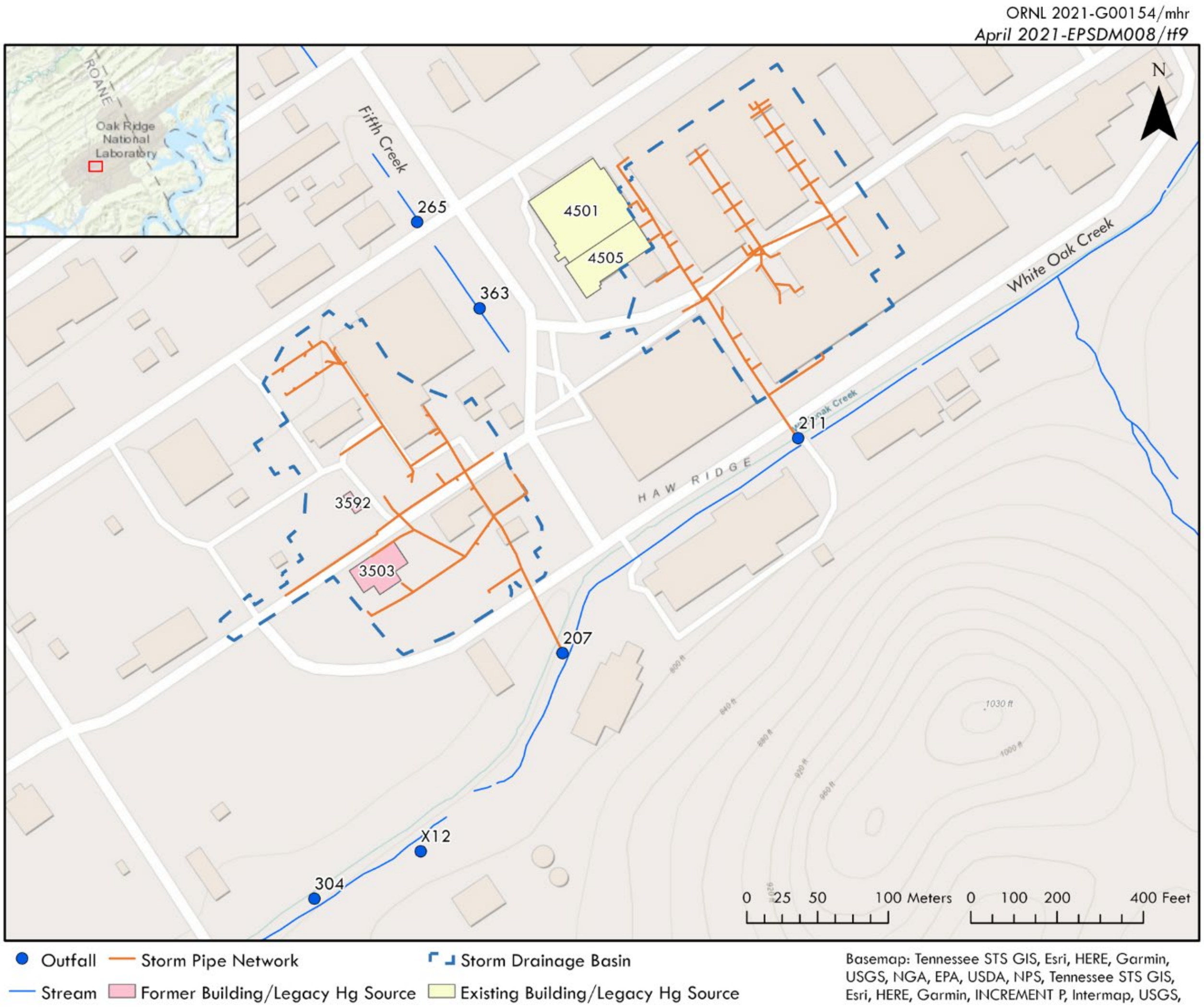


Figure 5.20. Outfalls 211 and 207 and associated storm drain connections that are potential mercury sources

5.5.4.2. Ambient Mercury in Water

Aqueous Hg monitoring in WOC was initiated in 1997 and continued in 2020 with quarterly sampling at four sites: White Oak Creek kilometer (WCK) 1.5, WCK 3.4, WCK 4.1, and WCK 6.8 (Figure 5.21). Samples were collected to be representative of seasonal-base flow conditions (dry weather, clear flow). Historical sampling results show that Hg concentrations are typically higher under those conditions.

The concentration of Hg in WOC upstream from ORNL (WCK 6.8) was less than 10 ng/L in 2020. Waterborne Hg concentrations downstream of ORNL (Figure 5.22) were above Tennessee water quality criteria (WQCs) from 1997 to 2007, but declined abruptly in 2008 and remained low through 2020 as a result of actions: (1) to lessen Hg discharges to WOC at Outfall 211 (sump reroutes to PWTC) and (2) to reduce discharges from PWTC. In general, ambient concentrations have remained low since 2008, with a few exceptions. A significant spike in Hg concentrations was seen at WCK 3.4, downstream of the PWTC and Sewage Treatment Plant outfalls (Outfalls X12 and X01, respectively) in September 2018, and was likely due to issues with filters at the PWTC. Filters were changed in 2019, and Hg concentrations measured at WCK 3.4 dropped below the WQCs, averaging 13.84 ± 6.64 ng/L in 2019, compared with 55.49 ± 76.05 ng/L in 2018.

In contrast, the mean total Hg concentration at WCK 4.1 (downstream of Fifth Creek but upstream of Outfall X12) increased from 26.46 ng/L in 2019 to 33.34 ng/L in 2020. This increase was due to elevated concentrations in samples collected from WCK 4.1 in August 2020 that exceeded the WQCs. The average concentration of August 2020 samples was 85 ng/L. The average aqueous Hg concentration at WOD (WCK 1.5) was 29.48 ng/L compared to 34.01ng/L in 2019. Mercury concentrations at WCK 1.5 are more variable than at other sites in WOC, likely because of the variability in total suspended solids at this site.

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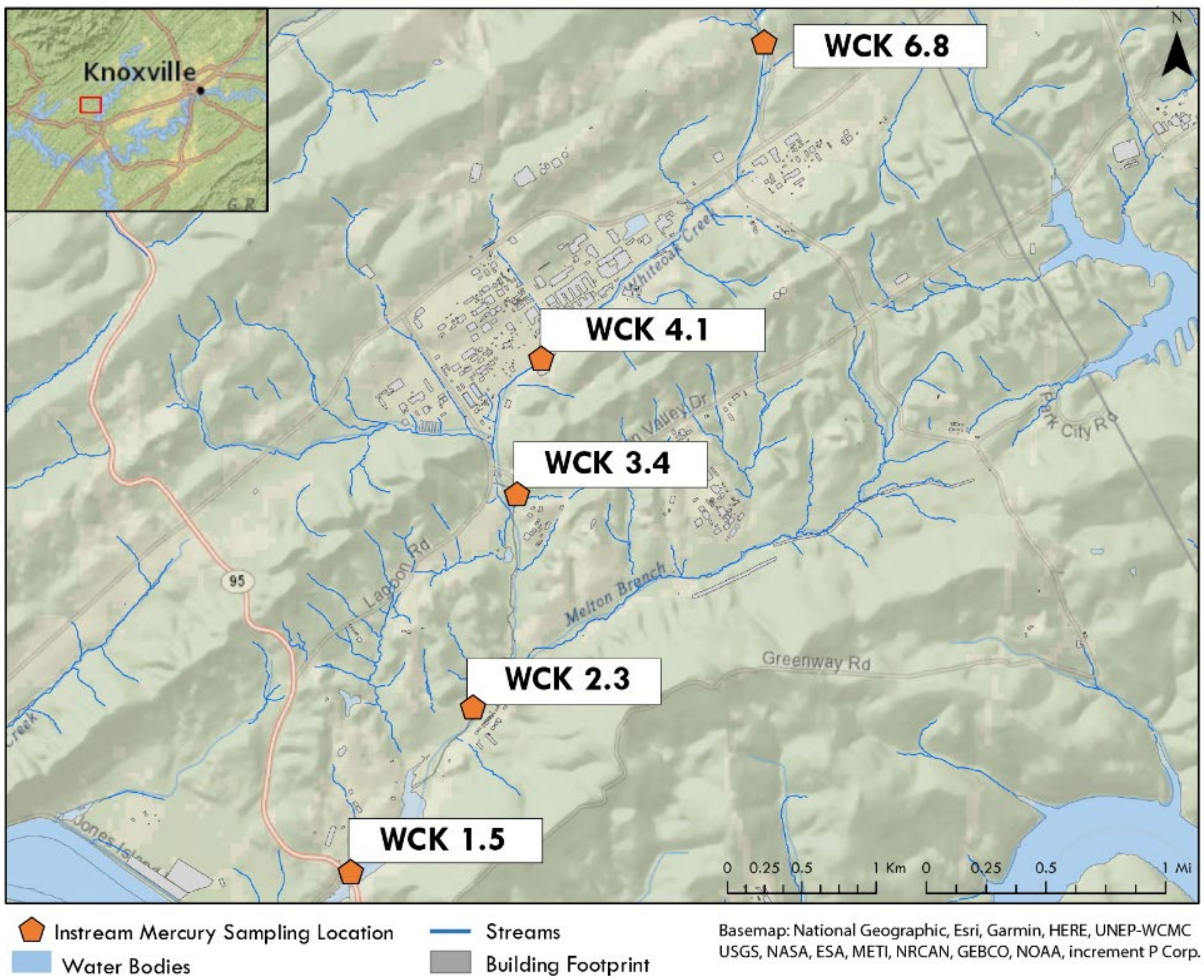
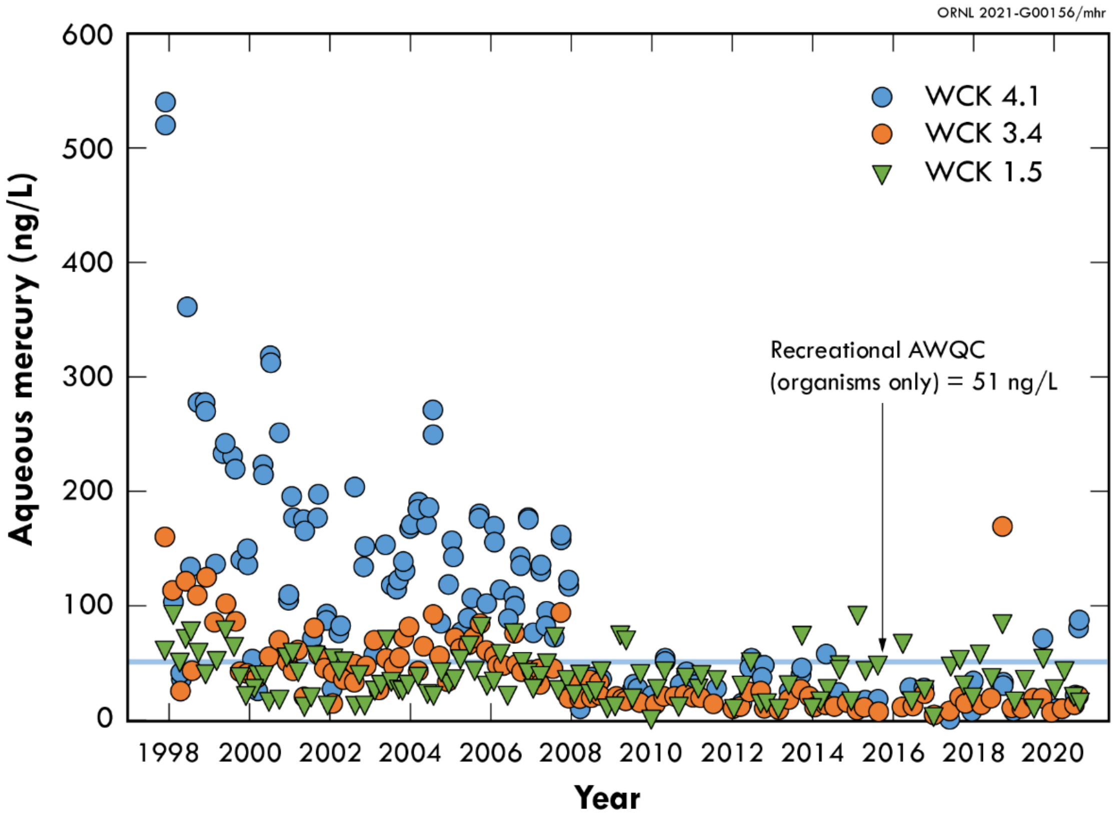


Figure 5.21. Instream mercury monitoring and data locations, 2020



Note: The blue line at 51 ng/L shows the Recreational Water Quality Criteria for Water and Organisms.
Acronym: *WCK = White Oak Creek kilometer*

Figure 5.22. Aqueous mercury concentrations at sites in White Oak Creek downstream from ORNL, 1998–2020

5.5.4.3. Water Quality Protection Plan Mercury Investigation

Outfalls X01 and X12 are monitored for Hg quarterly. Twenty-four–hour composite samples are taken, and discharge flows are measured and recorded. Figure 5.23 shows the total Hg concentration STP discharges to Outfall X01 from 2010 to 2020. Concentrations of Hg discharged from the STP at Outfall X01 have been less than 10 ng/L since 2014 until there was an increase to 46 ng/L in May 2019. After a sand filter media change-out on July 14, 2019, discharge concentrations dropped to 2 ng/L. In 2020, a preliminary investigation was undertaken to find out if and where mercury might be entering the sewage piping system. Samples taken from nine sewage manhole access points were evaluated for the presence of total Hg. Mercury was detected at Manhole M401 in the 4500 area south of Building 4501 and in wastewater coming from the west lagoon. A sample taken before sand filtering had a slightly higher concentration than the 24-hour composite value from X01 (2.33 ng/L) for the same day; the sand filter is backwashed weekly.

Figure 5.24 shows trends in X12 total Hg concentrations for 2009 through 2020 (worst-case loads are calculated in milligrams per day based on concentration and flow using 24-hour discharge rates). Concentrations of mercury in discharges from Outfall X12 (PWTC) reached 219 ng/L in January 2019. This concentration is higher than any measured since June 2009. It is thought that in the process of upgrading PWTC filters (September 2018–July 2019) there was fluctuation in total Hg flux discharge concentrations. After final replacement of dual-media and Mersorb filters on July 25, 2019, mercury concentrations and fluxes declined.

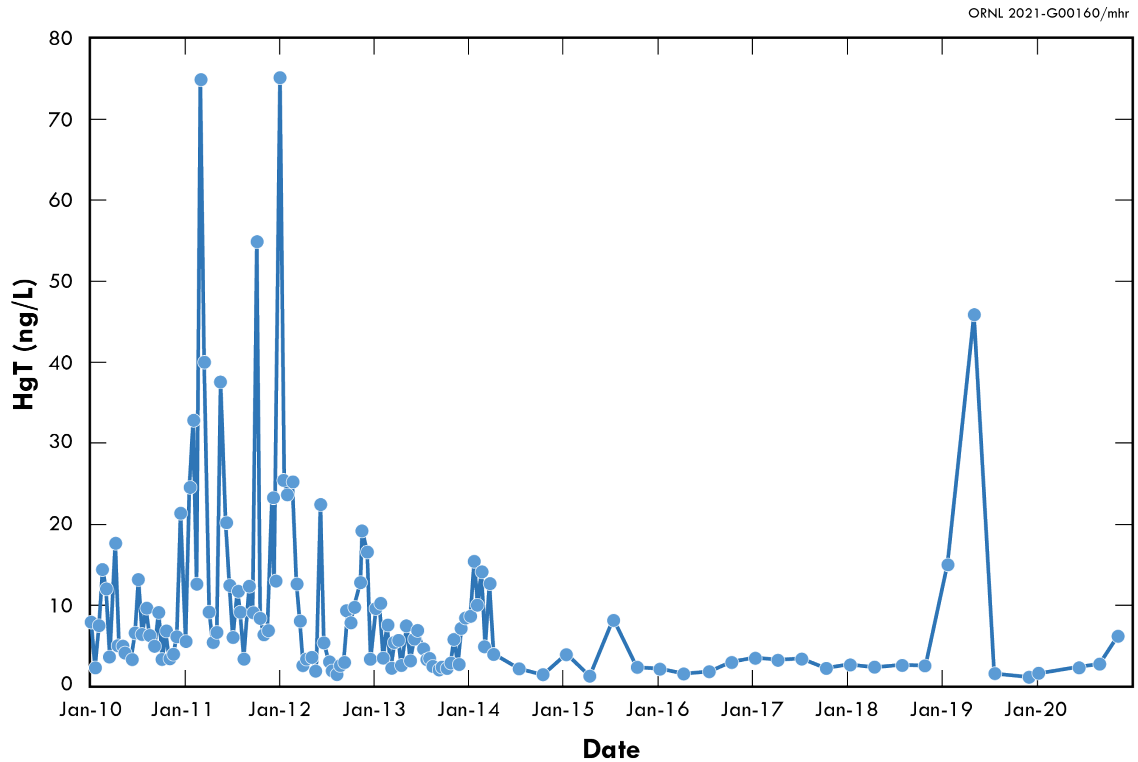
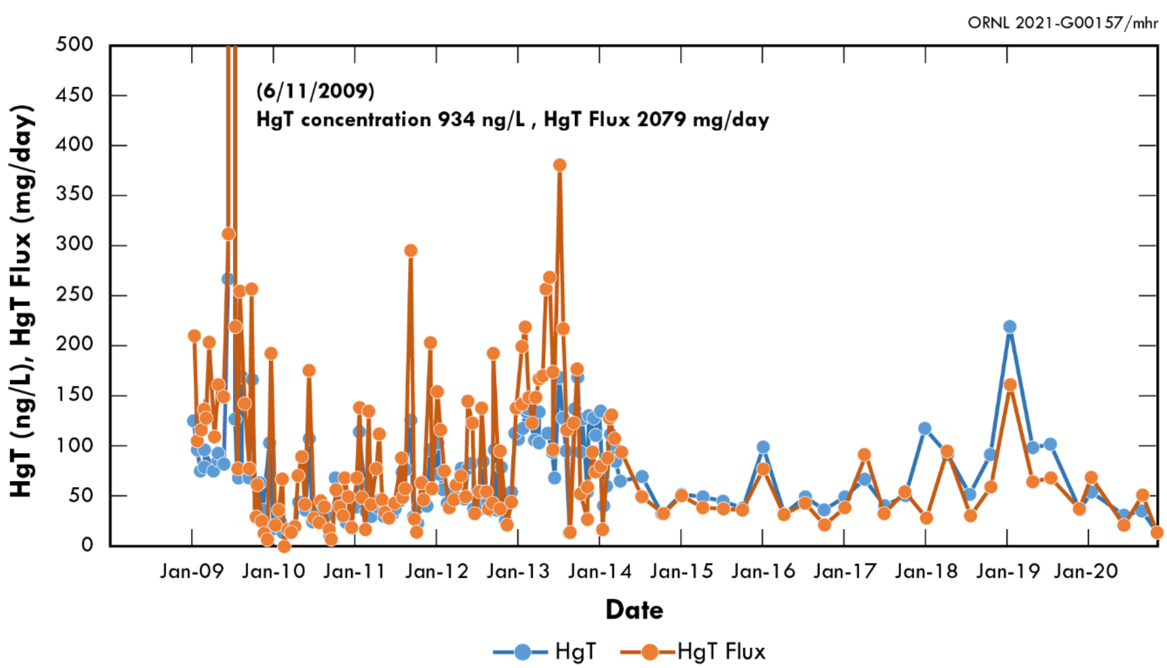


Figure 5.23. Total mercury concentration in discharges to Outfall X01 from the Sewage Treatment Plant, 2010–2020



Acronym: *PWTC: Process Waste Treatment Complex*

Figure 5.24. Total mercury concentrations and fluxes in Process Waste Treatment Complex discharges to Outfall X12, 2008–2020

Starting in the second quarter of 2020, dry weather sampling at Outfalls X01 and X12 was coordinated with 24-hour Hg sampling at three instream locations (Figure 5.25). Instream locations were WCK 4.4, which is upstream of the two treatment plant outfalls; WCK 3.4 at 7500 Bridge, downstream of both treatment plant outfalls; and X15 at WOD. Flow measurements were not available to calculate fluxes at the upstream point WCK 4.4 but were available for treatment plant discharges and for the two locations downstream of the treatment plants (see Figure 5.26). Total Hg concentration and flux measured in the third quarter of 2020 at WCK 3.4 (sample collected on September 1), were higher than concentrations and flux from WOD (Outfall X15). A sample of wastewater leaking from a PWTC transfer line to Outfall 403 (located on WOC just downstream of Outfalls X12 and 304) was collected on September 9, 2020. Total Hg concentrations in the sample were 44.9 to 55.7 ng/L, which indicates that the elevated third-quarter instream composite results may be due to the leaking PWTC transfer line. That transfer line was rerouted to the radiological treatment side of the PWTC on October 1, 2020, and will remain rerouted until piping repairs are made. Instream grab samples taken at WCK 3.4 on August 8, 2020, did not show elevated total Hg; concentrations were 21 to 22 ng/L.

ORNL 2021-G00161_VerC/mhr

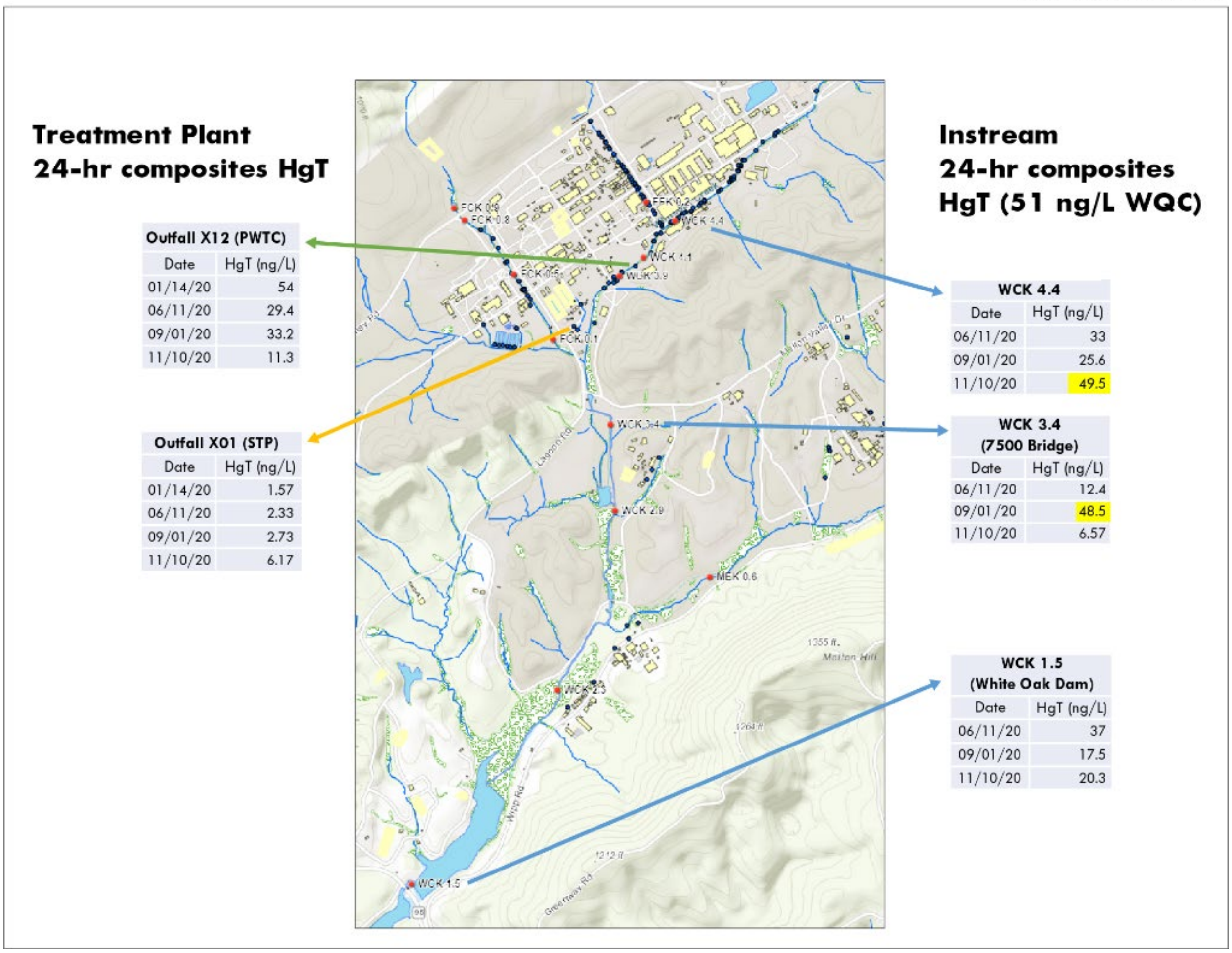
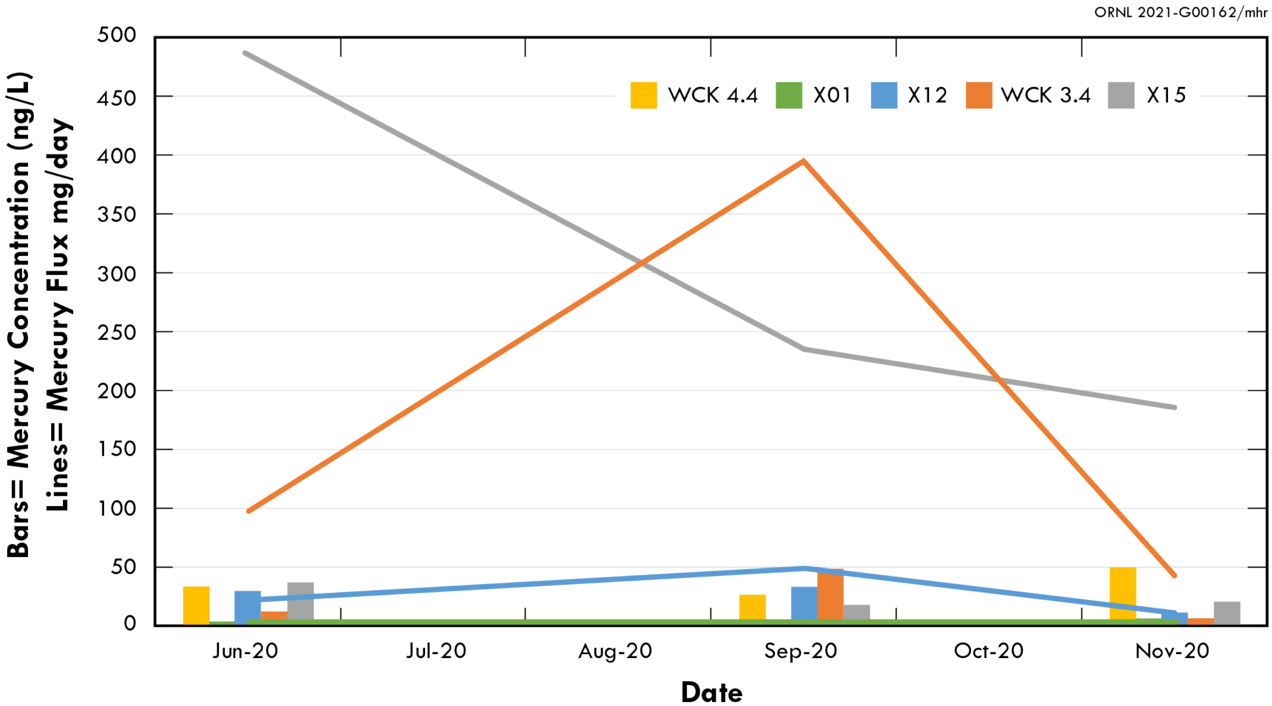


Figure 5.25. Locations and data for instream sampling sites coordinated with treatment plant sampling



Acronym: *WCK = White Oak Creek kilometer*

Figure 5.26. Mercury concentrations and fluxes of treatment plant discharges compared with instream values at WCK 4.4 (no flux available), WCK 3.4, and X15 (White Oak Dam)

5.5.4.4. Legacy Outfall Source Investigation

Legacy outfalls are investigated as part of the WQPP to better delineate Hg sources and to prioritize future abatement actions. In recent years, WQPP monitoring has focused on Outfalls 207 and 211, which generally contribute the highest Hg concentrations. Discharged water volumes (and therefore fluxes) from Outfall 211 are higher than discharges from Outfall 207. In 2020, Hg monitoring was performed at Outfalls 265 and 363, which both discharge to Fifth Creek. There was a period prior to 2014 when a supply water leak under Central Avenue mobilized Hg contamination located south of demolished Building 3026 to Outfall 265. The problem abated when the leak was repaired. The last leg of the Outfall 363 storm drain, which enters Fifth Creek just south of Central Avenue, contains significant debris. In a camera survey of the pipe in 2010, the camera was not able to pass through it. Because of its age and location near the Waste Area Grouping 1.0 Mercury Contaminated Soil Unit, it is suspected that the debris contains residual Hg. Large volumes of cooling tower blowdown, which still retain some chlorine after primary treatment, pass through this storm drain to Fifth Creek, potentially mobilizing Hg trapped behind debris.

Figure 5.27 shows sampling results for dissolved and total Hg at legacy outfalls and total Hg results for instream locations sampled during 2020. During the November 10 sampling event, the concentrations of total Hg in effluent from Outfall 211 was 312 ng/L, and the total Hg concentration measured at the closest instream location downstream of the outfall (WCK 4.4) was of 49.5 ng/L The available dilution provided by background flow in the stream at the time was not quantified, but based on historical water quality data for the relative difference between the outfall flow rate and the stream flow rate (during baseflow conditions), it is likely that Hg discharged from Outfall 211 accounts for the majority of the total Hg that is present at WCK 4.4 (see Figures 5.28 and 5.29 for historic Outfall 211 dry and wet weather trends). On the same day, the total Hg concentration in the stream further downstream at WCK 3.4 was 6.57 ng/L. Dilution provided by flow from tributaries and wastewater discharges entering WOC between WCK 4.4 and WCK 3.4 accounts for at least some of the reduction in concentration between the two instream sites. Separate grab samples are collected for the determination of dissolved and total Hg, and it is likely that the elapsed time between collection of the separate grab samples explains why dissolved Hg concentrations are higher than total Hg concentrations. Pollutant concentrations can change quickly at an outfall during a storm runoff event when flow rates and sediment loads are changing rapidly.

In 2010 a camera system was used to conduct an inspection inside the main Outfall 211 storm pipe. The upper, older pipe sections had debris upstream of each pipe joint. In places, pipe sections had settled, and gaps had formed. Mercury can reside behind and within these irregularities. It is thought that sheltered Hg beads oxidize during dry periods (Miller et al. 2015). The coatings are disturbed and dissolved by storm water and particularly by chlorinated once-through cooling water moving through the pipes. The volumes of dry-weather discharges dropped after 2012, when water conservation efforts were made to recirculate once-through cooling water. Figure 5.28 shows that Hg concentrations and fluxes in dry-weather discharges to Outfall 211 have been gradually increasing since then. The highest concentration (830 ng/L) was measured in December of 2019 (830 ng/L); and while flows have remained at about 50 mg/day, fluxes have trended slightly upward. During storms, there has been a downward trend in flux that may be the result of periodic sediment removal from the Outfall 211 weir box. Plans are being made to remove accumulated sediments from the Outfall 211 weir box on a regular basis.

Since 2015, Outfall 207 has had dry weather flows of 1 gpm or less, with fluxes of less than 1 mg/day total Hg. Flow rates for storm water discharged through Outfall 207 (Figure 5.30) have varied from 5 gpm to more than 100 gpm; higher fluxes occurred during storms. Maximum storm water fluxes of total Hg at Outfall 207 are less than half those contributed by Outfall 211.

Outfall 363 receives regular cooling tower blowdown, and monitoring is performed twice monthly. Dry weather flows ranged from about 3 to 35 gpm. Maximum flows measured in conjunction with dry weather sampling events have are about 8 gpm (total Hg concentrations are about 20 ng/L). Limited information regarding storm discharges from Outfall 363 shows less dissolved Hg than is seen at Outfall 211 (about 80 percent to 100 percent less in 2020). The difference may be due to the configuration and accessibility of contaminants remaining in storm piping.

The 2020 data for Outfall 265 show that storm concentrations of Hg remain low compared with the 176 ng/L measured during storm conditions on October 29, 2014. A leaking supply pipe that had been mobilizing Hg in the leak pathway was repaired on September 17, 2014.

ORNL 2021-G00163/mhr

Outfall 265			
Date	Flow (gpm)	HgD (ng/L)	HgT (ng/L)
3/10/2020 Wet	7	6.4	9.52
12/16/2020 Wet	1	10.2	16.50

Outfall 363			
Date	Flow (gpm)	HgD (ng/L)	HgT (ng/L)
6/11/2020 Dry	8		20.6
11/10/2020 Dry	8		20.3
3/10/2020 Wet	15	8.68	12.7
12/16/2020 Wet	12	9.94	43.4

Outfall 211 Weir Box			
Date	Flow (gpm)	HgD (ng/L)	HgT (ng/L)
6/11/2020 Dry	50		443
11/10/2020 Dry	40		312
3/10/2020 Wet	120	148	184
12/16/2020 Wet	50	420	375

WCK 4.4	
Date	HgT (ng/L)
06/11/2020	33.0
09/01/2020	25.6
11/10/2020	49.5

Outfall 207			
Date	Flow (gpm)	HgD (ng/L)	HgT (ng/L)
3/10/2020 Wet	5	10.5	47.7

Outfall 304			
Date	Flow (gpm)	HgD (ng/L)	HgT (ng/L)
6/4/2020 Dry			10.30
6/11/2020 Dry	0.5		11.20
11/10/2020 Dry	0.1		6.57
3/10/2020 Wet	12.0	5.87	14.50
5/28/2020 Wet			10.80
12/16/2020 Wet	2.0	1.26	9.97

WCK 3.4	
Date	HgT (ng/L)
06/11/2020	12.4
09/01/2020	48.5
11/10/2020	6.57

WCK 1.5 (X15)	
Date	HgT (ng/L)
06/11/2020	37.0
09/01/2020	17.5
11/10/2020	20.3

Acronym:
WCK = White Oak Creek kilometer

Figure 5.27. Dissolved and total mercury concentrations of legacy outfalls compared to instream (total mercury) values at WCK 4.4, WCK 3.4, and X15 (White Oak Dam)

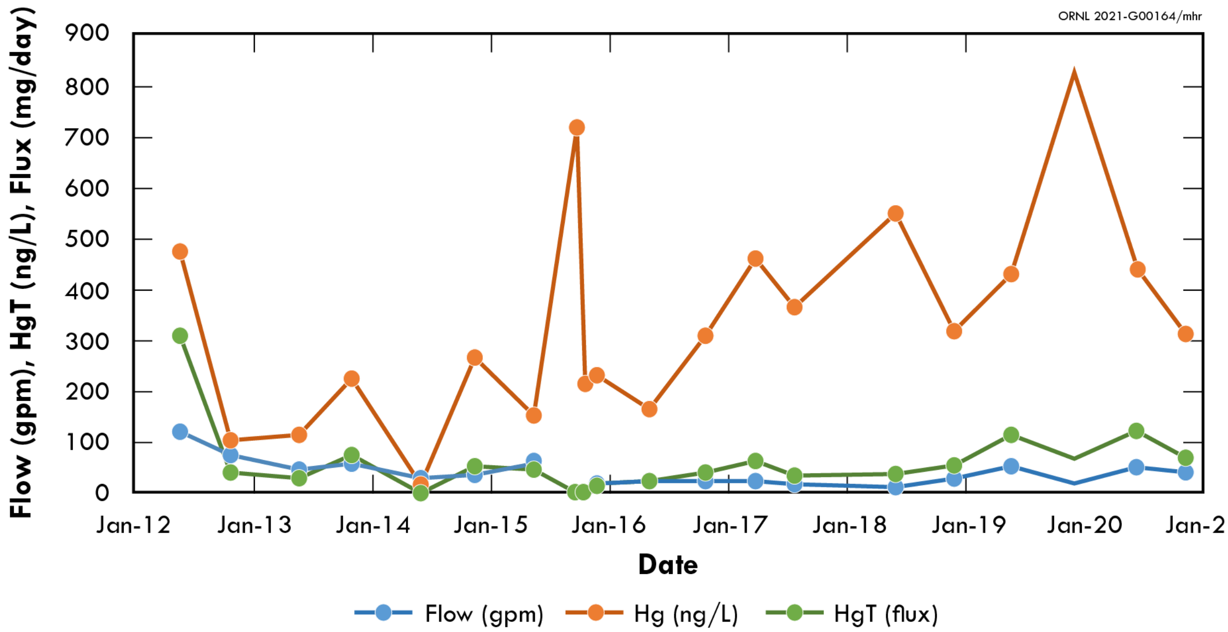


Figure 5.28. Outfall 211 dry-weather flow, concentration, and flux 2012–2020

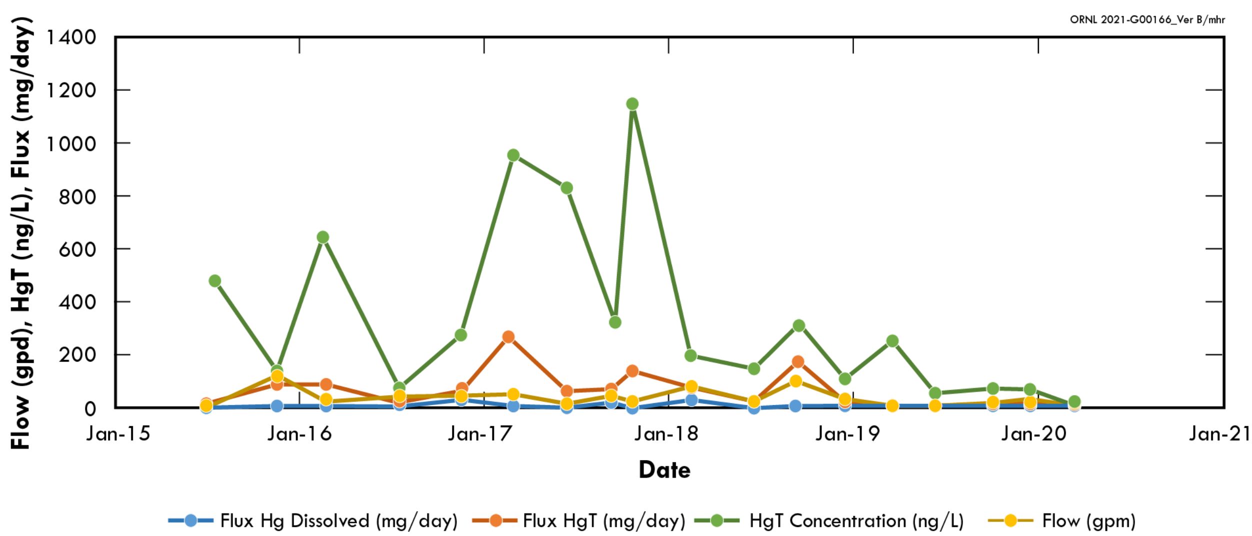


Figure 5.29. Outfall 211 storm flow, dissolved and total mercury flux 2015–2020

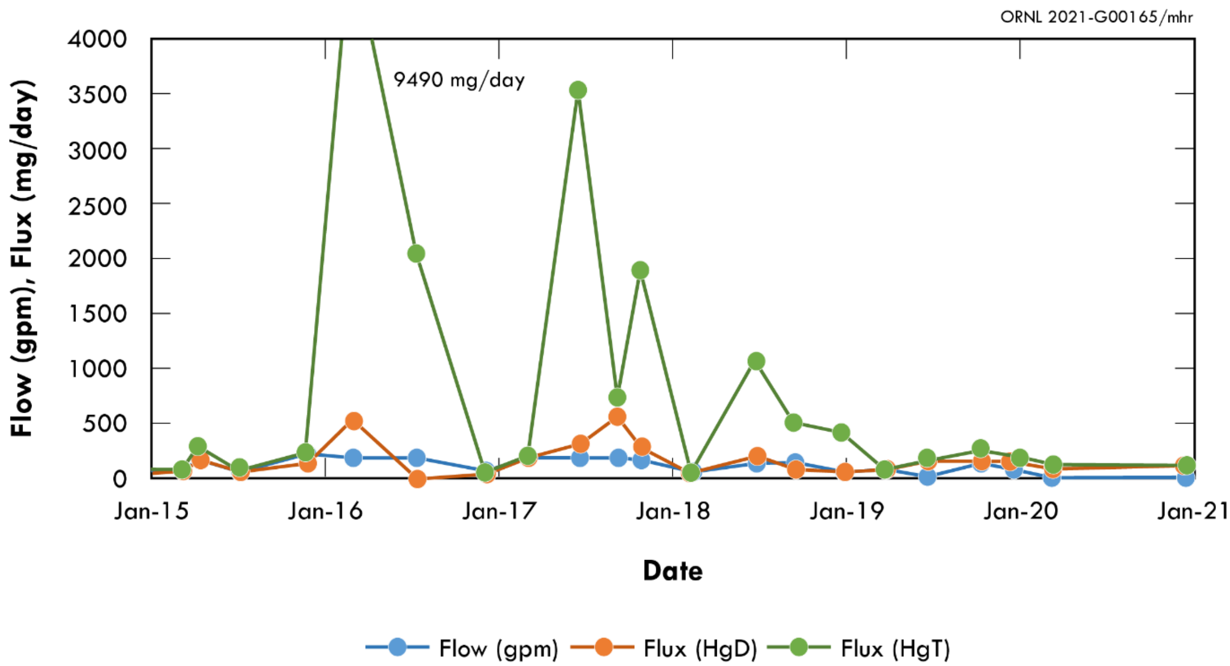
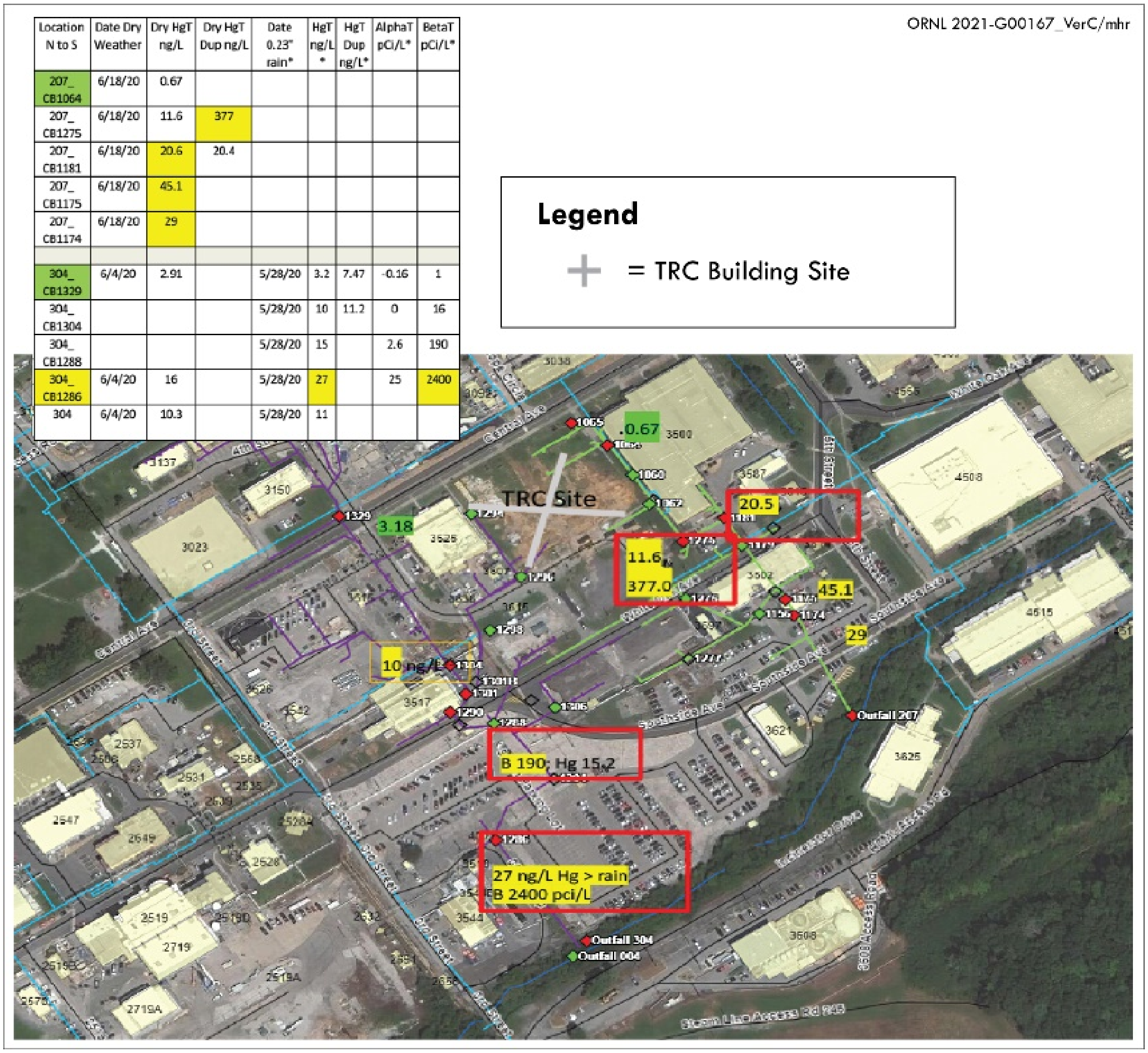


Figure 5.30. Outfall 207 storm flow, dissolved Hg flux, and total Hg flux

5.5.4.5. Baseline Preconstruction Investigation of 207 and 304 Storm Catch Basins

Redevelopment is planned for a central portion of the ORNL main plant area, west of Building 3500. The soil just south of the construction site contains legacy Hg contamination. It was thought that construction of the new building and/or subsequent discharges from its cooling towers or roof through old storm piping might increase Hg discharges through Outfalls 207 and 304. Sampling and preconstruction investigation of storm water catch basins in the Outfall 207 and 304 drainage areas were initiated in 2020 (Figure 5.31). However, construction plans were revised, and the cooling tower discharge and most of the roof drainage are being routed to Outfall 264 on Fifth Creek. The remaining roof and storm water discharges will be routed to Outfall 207. As construction plans changed, attempts were made to sample baseline discharges from Outfall 264; however, no water was flowing through Outfall 264 during any of the attempted sampling events. Efforts to collect samples will continue.

The storm drain systems at Outfalls 304 and 207 are original and currently have no cooling water discharge inputs. However, standing water (accumulated discharges from a groundwater sump, steam condensate discharges, and unknown leakage) was found and sampled in the storm water system during dry weather. Mercury was detected (~20.5 ng/L) in Building 3500 groundwater sump discharge to the Outfall 207 storm drain network. Mercury was also found in standing water in Catch Basin 1275, southeast of Building 3500 (11.6 ng/L and duplicate result 377 ng/L). The large discrepancy between duplicate sample results is likely due to the entrainment of particulates containing Hg. Sediment removal in Catch Basin 1275 is under consideration. North of Building 3502, Hg was also present in Catch Basin 1175 (45.1 ng/L) where a small flow (of unknown origin) entered and continued through Catch Basin 1174 (29 ng/L) south of Building 3523. Dry weather mercury concentrations at Outfall 207 (0.67 ng/L) were lower than in the contributing catch basins.



Location N to S	Date Dry Weather	Dry HgT ng/L	Dry HgT Dup ng/L	Date 0.23" rain*	HgT ng/L *	HgT Dup ng/L*	AlphaT pCi/L*	BetaT pCi/L*
207_ CB1064	6/18/20	0.67						
207_ CB1275	6/18/20	11.6	377					
207_ CB1181	6/18/20	20.6	20.4					
207_ CB1175	6/18/20	45.1						
207_ CB1174	6/18/20	29						
304_ CB1329	6/4/20	2.91		5/28/20	3.2	7.47	-0.16	1
304_ CB1304				5/28/20	10	11.2	0	16
304_ CB1288				5/28/20	15		2.6	190
304_ CB1286	6/4/20	16		5/28/20	27		25	2400
304	6/4/20	10.3		5/28/20	11			

Figure 5.31. Preconstruction surveillance of Outfalls 207 and 304 storm drainage catch basins

In 2020, the Outfall 304 drainage system was also sampled for Hg during dry weather (flow due to mainly steam condensate discharge), and follow-up sampling was performed during rainfall. Mercury concentrations (both dry and wet weather) were less than those found in the Outfall 207 storm drainage system. Samples were also evaluated for radioactivity because process wastewater overflowed into the Outfall 304 drainage system near Catch Basin 1306 during a large local rainfall on August 29, 2019, and other process piping problems are known to exist. During the 2020 sampling effort, the highest total Hg concentration (27 ng/L) was found during rainfall at Catch Basin 1286, just northeast of the old 3544 Radioactive Treatment Plant. Even during rainfall, samples were hard to obtain in the 304 drainage because of storm pipe leakage and low flow rates. As was the case at Outfall 207, the Hg concentration at Outfall 304 (3.2 ng/L), was lower than the concentrations of Hg in the catch basins contributing to it.

5.5.5. Storm Water Surveillances and Construction Activities

Storm water drainage areas at ORNL are inspected twice per year as directed in the WQPP. Land use within drainage areas is typical of office/industrial/research settings with surface features that include laboratories, support facilities, paved areas, and grassy lawns. Outdoor material is located temporarily in many places at ORNL, but most activity involving the movement and storage of outdoor material takes place in the 7000 area, which is located on the east end of the ORNL site and where most of the craft and maintenance shops are located. Smaller outdoor storage areas are located throughout the facility in and around loading docks and material delivery areas at laboratory and office buildings. The types of materials stored outside, as noted in field inspections, include finished metal items (pipes and parts); equipment awaiting use, disposal, or repair; aging (rusting) infrastructure; and construction equipment and material. While sites that are covered by a Tennessee construction general permit are considered to have more significant potential for runoff impacts, inspections and controls required by an approved storm water pollution prevention plan have proven effective at minimizing short-term and long-term impacts to nearby streams and waterways from construction sites.

Some construction activities are performed on third-party-funded construction projects on ORR under agreements with federal agencies other than DOE and with local and state agencies. There are mechanisms in place for ensuring effective storm water controls at the third-party sites, one of which includes staff from UT-Battelle acting as points of contact for communication interface on environmental conditions, erosion and sedimentation controls, spill/emergency responses, and other key issues.

5.5.6. Biological Monitoring

Biological monitoring programs conducted at ORNL in 2020 included bioaccumulation studies in the WOC watershed; benthic macroinvertebrate monitoring in WOC, First Creek, and Fifth Creek; and fish community monitoring in WOC and its major tributaries. The following sections summarize the biological monitoring programs at ORNL and the results for 2020.

5.5.6.1. Bioaccumulation Studies

The bioaccumulation task for the biological monitoring and abatement plan addresses two NPDES permit requirements at ORNL: (1) evaluate whether mercury at the site is contributing to streams at a level that will adversely affect fish and other aquatic life or that will violate the recreational criteria and (2) monitor the status of PCB contamination in fish tissue in the WOC watershed. Concentrations of mercury in fish in the WOC watershed are monitored annually and are evaluated relative to the EPA AWQC of 0.3 µg/g in fish fillets, a concentration considered protective of human health and the environment. Concentrations of PCBs in fish fillets are also monitored annually and are evaluated relative to the TDEC fish advisory limit of 1 µg/g.

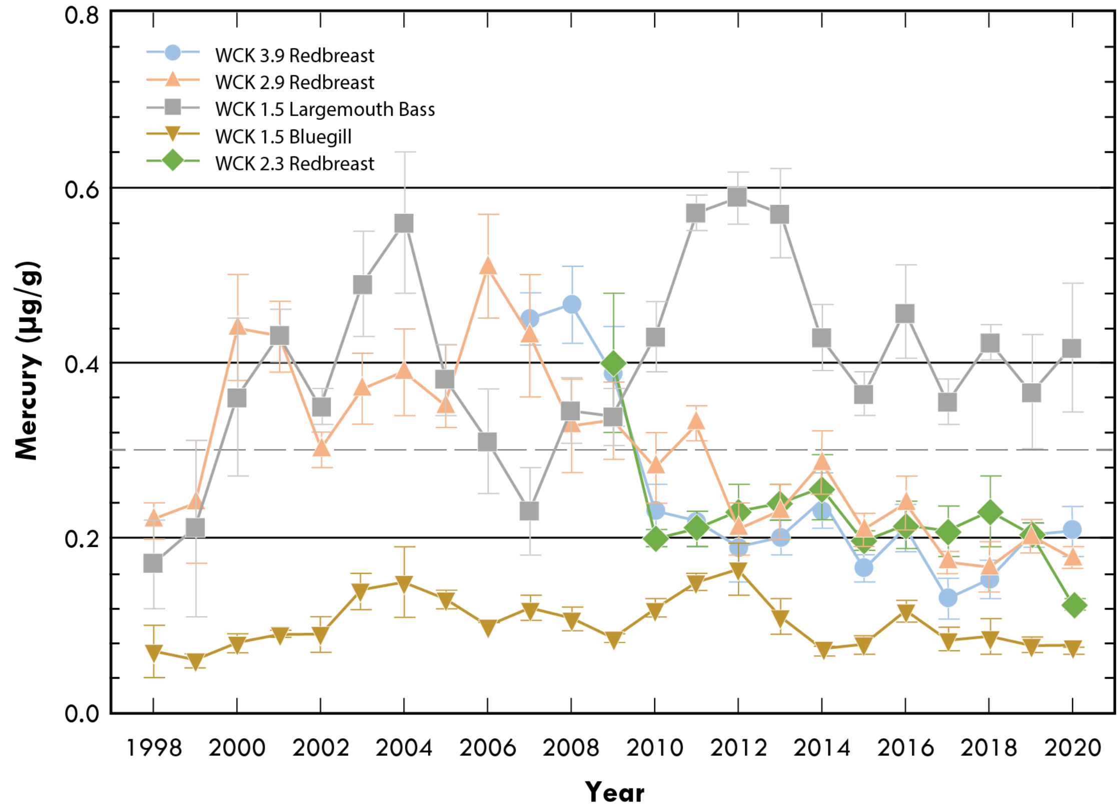
Bioaccumulation in Fish

In WOC, mercury and PCB concentrations in fish have been at or near human health risk thresholds (e.g., EPA recommended fish-based AWQC [0.3 µg/g for mercury], TDEC fish advisory limits for PCBs) (see Figure 5.32). Actions taken in 2007 to treat a mercury-contaminated sump resulted in significant decreases in mercury concentrations in fish throughout WOC. The decreases were most apparent at upstream locations closest to the sump water reroute. While the overall trends in the uppermost locations sampled in the creek suggest that fish tissue concentrations are decreasing overall, there is some interannual variability. Fillet concentrations remained consistent from 2019 to 2020 at the two uppermost WOC stream sites and stayed well below the AWQC for mercury in fish. Mean fillet concentrations increased from 0.20 µg/g in 2019 to 0.21 µg/g in 2020 at WCK 3.9 and decreased from 0.20 µg/g in 2019 to 0.18 µg/g in 2020 at WCK 2.9. Mercury concentrations in largemouth bass collected from WCK 1.5 (White Oak Lake) have been fluctuating in recent years and increased from 0.37 µg/g in 2019 to 0.42 µg/g in

2020 and remained above the guideline. No change in mercury concentrations in bluegill collected from WCK 1.5 was observed from 2019 to 2020 (0.08 µg/g), and mercury concentrations remained below the recommended guideline.

PCB concentrations (defined as the sum of Aroclors 1248, 1254, and 1260) in redbreast sunfish from the WOC watershed remained within historical ranges (see Figure 5.33). Mean concentrations in 2020 were 0.38 µg/g at WCK 3.9, 0.31 µg/g at WCK 2.9, and 0.18 µg/g at WCK 2.3 (compared to 0.33 µg/g at WCK 3.9, 0.32 µg/g at WCK 2.9, and 0.26 µg/g at WCK 2.3 in 2019). PCB concentrations in bluegill collected from WCK 1.5 decreased from 0.55 µg/g in 2019 to 0.46 µg/g in 2020 and were below the TDEC fish advisory limit of 1 µg/g; concentrations in largemouth bass collected from WCK 1.5 decreased from 2.66 µg/g in 2019 to 1.12 µg/g in 2020 and were slightly above the TDEC fish advisory.

ORNL 2021-G00782/MHR

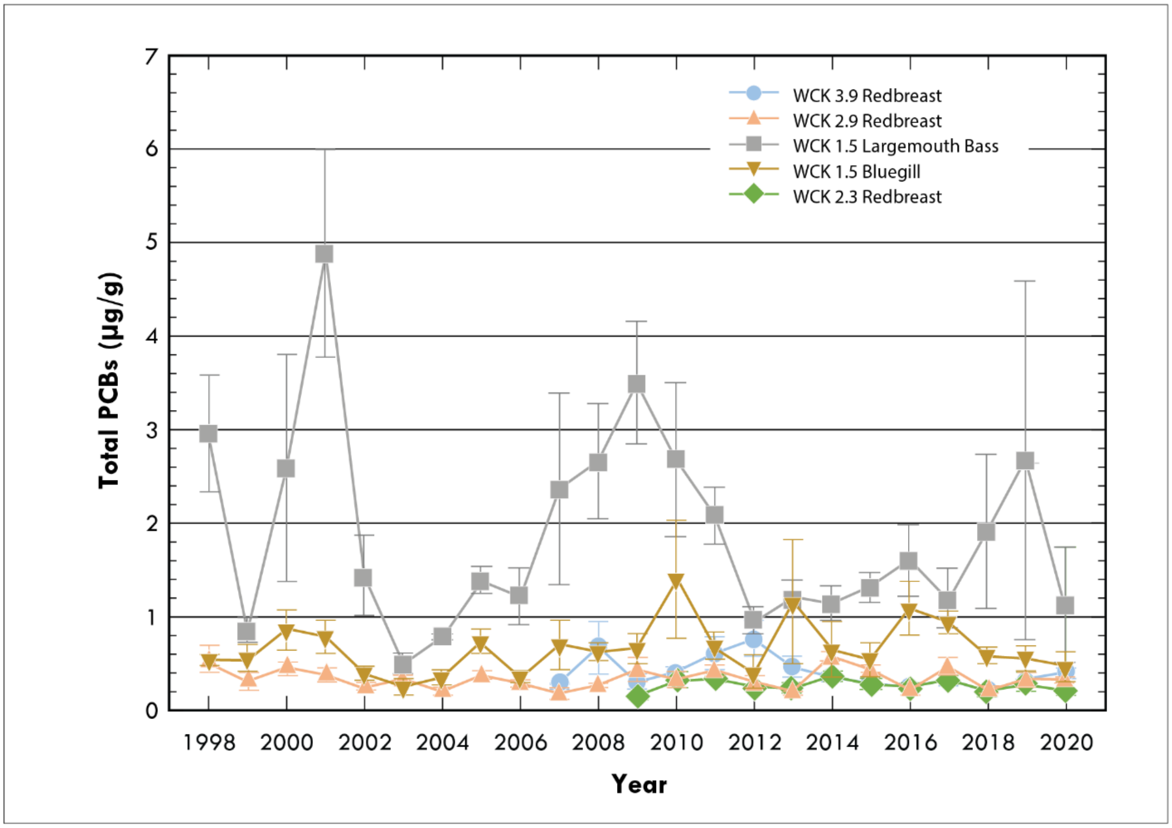


Notes:
1. *Mean concentrations of Hg (± standard error, N = 6) in tissue taken from sampled fish.*
2. *Thee dashed grey line at 0.3 µg/g indicates the US Environmental Protection Agency ambient water quality criterion for mercury in fish tissue.*

Acronym: *WCK = White Oak Creek kilometer*

Figure 5.32. Mean mercury concentrations in muscle tissue of sunfish and bass sampled from the White Oak Creek watershed, 1998–2020

ORNL 2021-G00783/MHR



Note: *Mean total PCB concentrations (± standard error, N = 6) found in fish fillets.*
Acronyms:
PCB = polychlorinated biphenyl
WCK = White Oak Creek kilometer

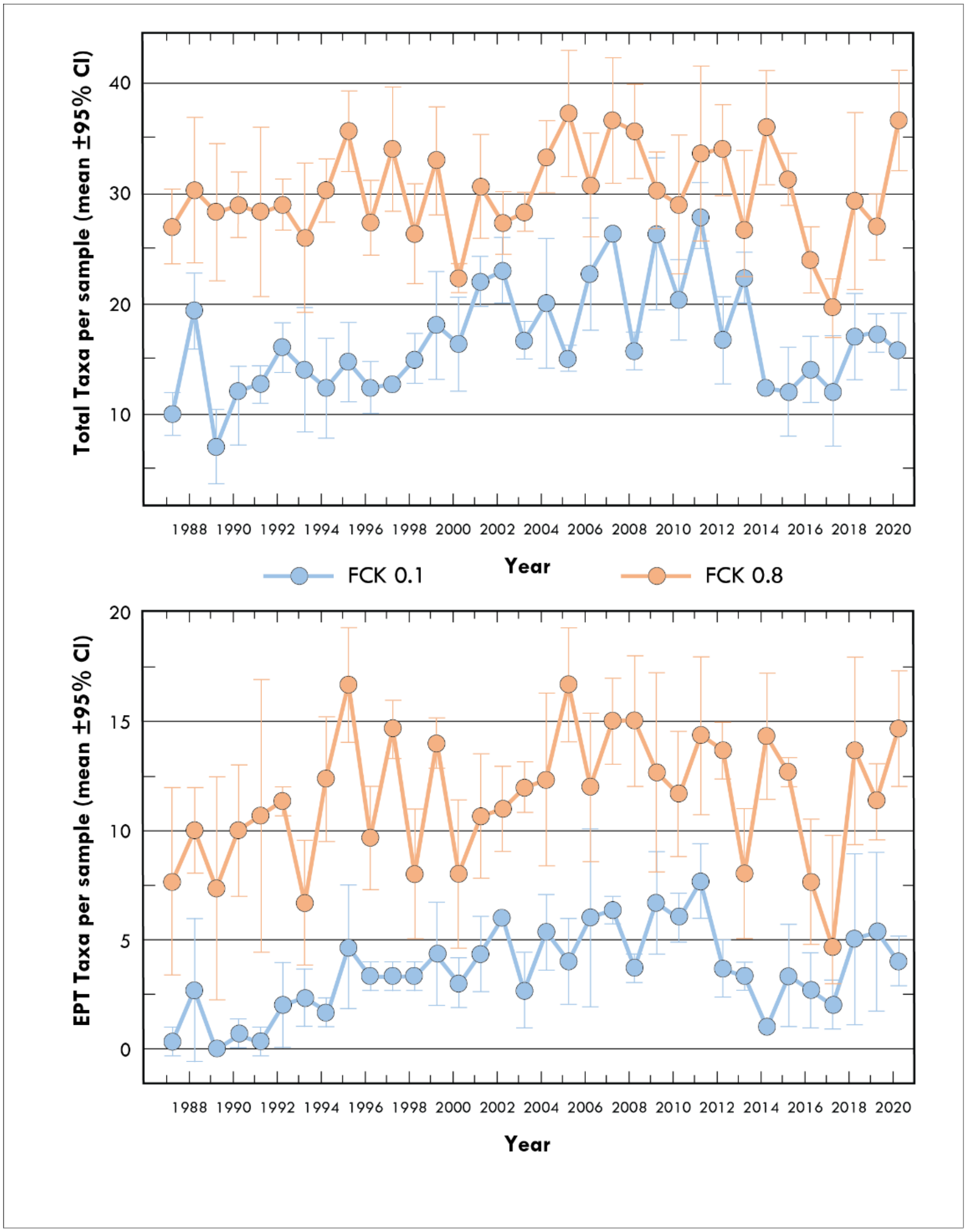
Figure 5.33. Mean total PCB concentrations in fish sampled from the White Oak Creek watershed, 1998–2020

5.5.6.2. Benthic Macroinvertebrate Communities

Monitoring of benthic macroinvertebrate communities in WOC, First Creek, and Fifth Creek continued in 2020. Additionally, monitoring of the macroinvertebrate community in lower Melton Branch (MEK 0.6) continued under the OREM Water Resources Restoration Program (WRRP). Benthic macroinvertebrate samples are collected annually following TDEC protocols (since 2009) and protocols developed by ORNL staff (since 1987). The protocols developed by ORNL staff provide a long-term record (34 years) of spatial and temporal trends in the invertebrate community from which the effectiveness of pollution abatement and remedial actions taken at ORNL can be evaluated and verified. The ORNL protocols also provide quantitative results that can be used to statistically evaluate changes in trends relative to historical conditions. The TDEC protocols provide a qualitative estimate of the condition of a macroinvertebrate community relative to a state-defined reference condition.

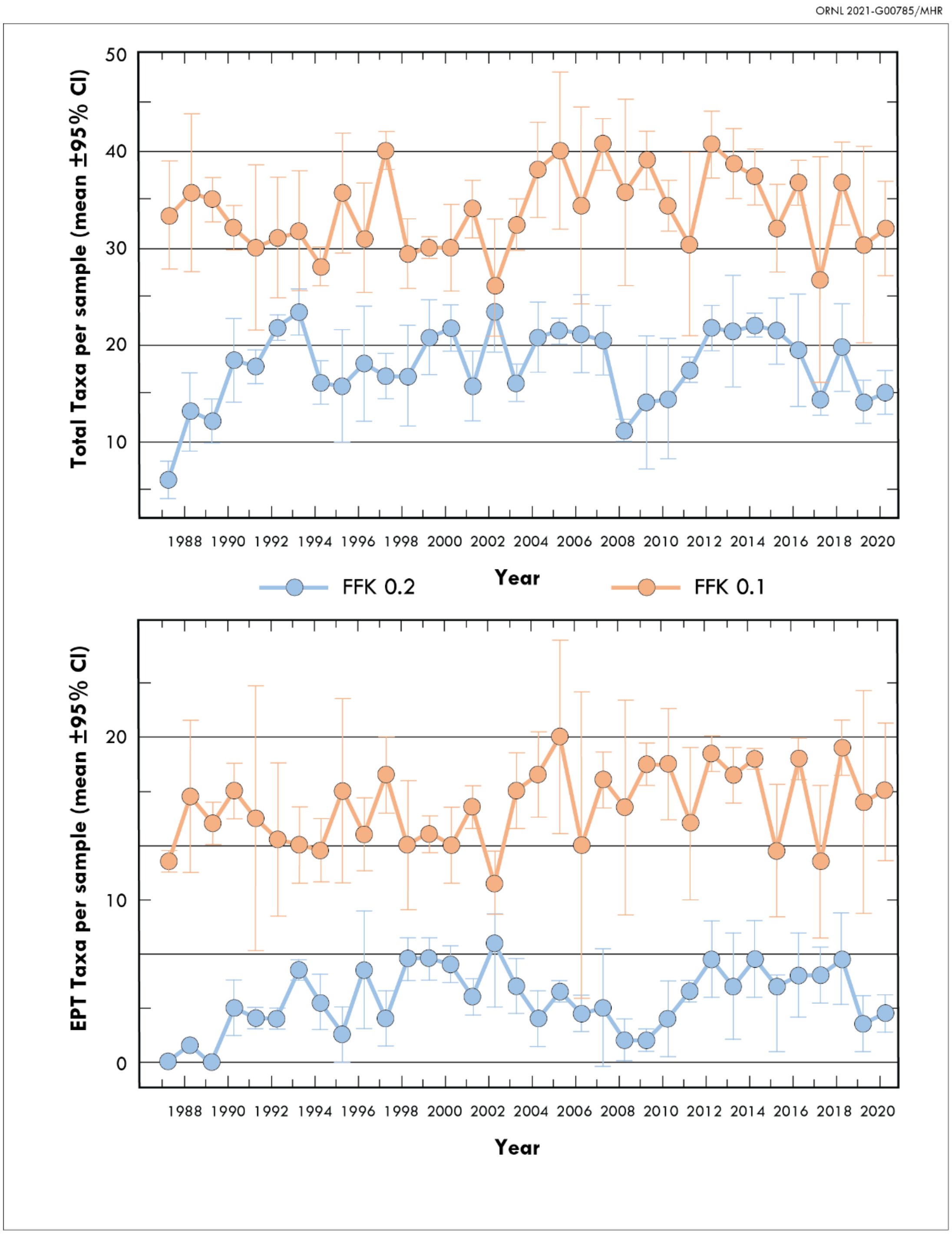
General trends in the results of ORNL protocols indicated significant recovery in these communities since 1987, but community characteristics suggest that ecological impairment remains (Figures 5.34–5.36). Relative to respective upstream reference sites, total taxonomic richness (i.e., the mean number of different species per sample) and richness of the pollution-intolerant taxa (i.e., the mean number of different mayfly, stonefly, and caddisfly species per sample or Ephemeroptera, Plecoptera, and Trichoptera [EPT] taxa richness) continued to be lower at these downstream sites.

ORNL 2021-G00784/MHR



Note: *Taxonomic richness (mean number of taxa per sample), 1987–2020. FCK 0.8 serves as a reference site.*
Top: Total taxonomic richness.
Bottom: Taxonomic richness of the pollution-intolerant taxa Ephemeroptera, Plecoptera, and Trichoptera (EPT).
Acronyms:
CI = confidence interval
FCK = First Creek kilometer

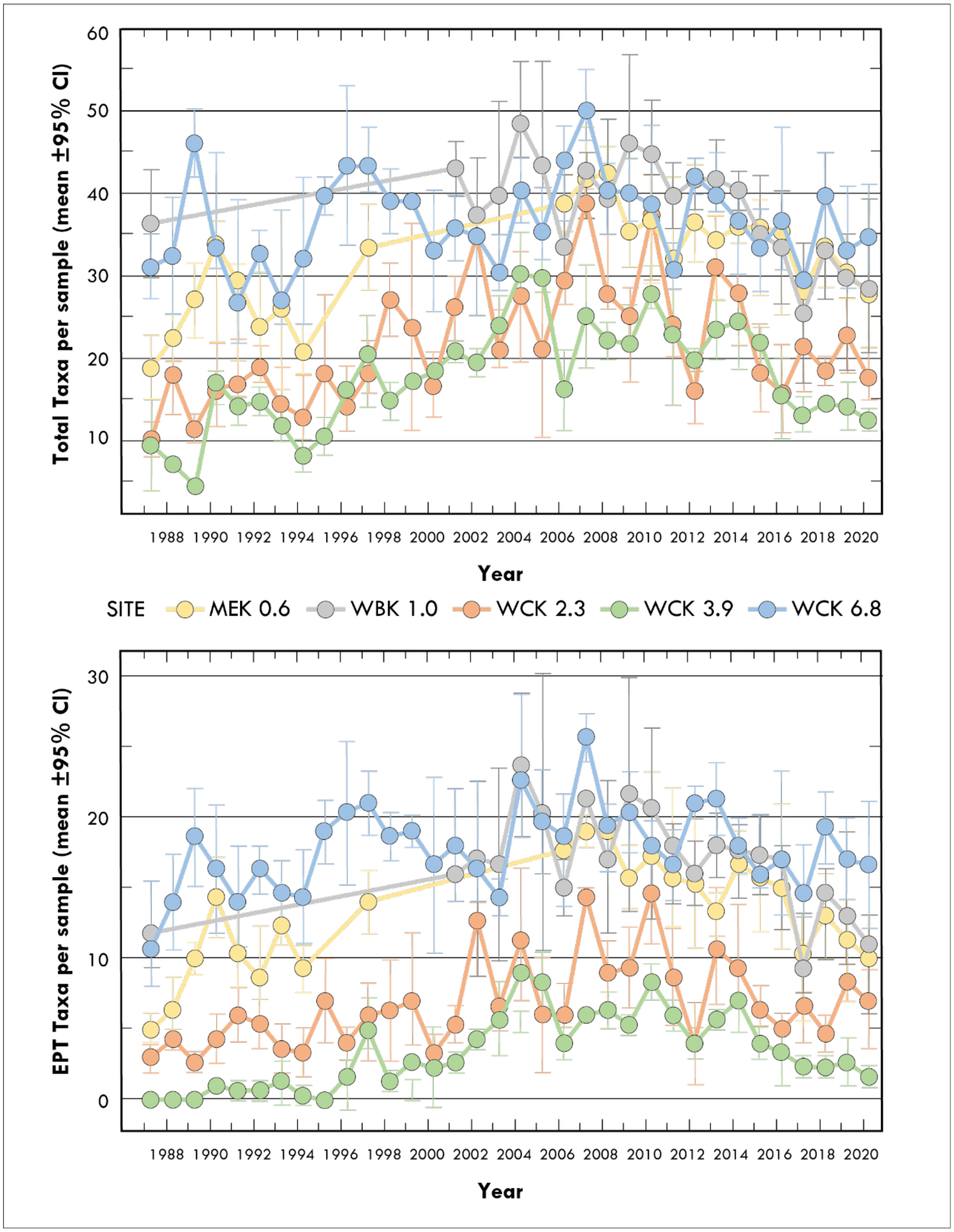
Figure 5.34. Benthic macroinvertebrate communities in First Creek



Note: *Taxonomic richness (mean number of taxa per sample), 1987–2020. FFK 1.0 serves as a reference site.*
Top: Total taxonomic richness.
Bottom: Taxonomic richness of the pollution-intolerant taxa Ephemeroptera, Plecoptera, and Trichoptera (EPT).
Acronyms:
CI = confidence interval
FFK = Fifth Creek kilometer

Figure 5.35. Benthic macroinvertebrate communities in Fifth Creek

ORNL 2021-G00786/mhr



Note: *Taxonomic richness (mean number of taxa per sample), 1987–2020. WCK 6.8 and WBK 1.0 serve as a reference site.*
Top: Total taxonomic richness.
Bottom: Taxonomic richness of the pollution-intolerant taxa Ephemeroptera, Plecoptera, and Trichoptera (EPT).
Acronyms:

CI = confidence interval
MEK = Melton Branch kilometer
WBK = Walker Branch kilometer
WCK = White Oak Creek kilometer

Figure 5.36. Benthic macroinvertebrate communities in Walker Branch, Melton Branch, and White Oak Creek

In lower First Creek (First Creek kilometer [FCK] 0.1), total taxa richness increased gradually in the 1990s and 2000s but was then lower for 4 years beginning in 2014 (Figure 5.34). Total taxa richness has increased at FCK 0.1 in the past three years (2018 to 2020), reaching values that were previously observed in the late 1990s. Similarly, the number of pollution-intolerant EPT taxa decreased in 2012, and in 2014, EPT taxa richness was the lowest it had been since the early 1990s. After 6 consecutive years of low EPT taxa richness, values increased in 2018 and 2019 to levels previously recorded in the late 2000s, while decreasing slightly in 2020. Additionally, in upper First Creek (FCK 0.8), which serves as a reference for FCK 0.1, metrics for total taxa richness and EPT taxa richness declined for three consecutive years (from 2014 to 2017) , but those metrics have since returned to levels near the highest values from previous years. The 6 year period of extremely low values in FCK 0.1 did not mirror those in FCK 0.8. This suggests that while climate or hydrological change may have influenced conditions within the entire stream (both FCK 0.1 and FCK 0.8), a more localized change may have also occurred in lower First Creek. If a change has occurred, it is not known whether it is related to a change in chemical conditions (e.g., change in water quality or the possible presence of a toxicant), physical conditions (e.g., unstable substrate, increased frequency of high-discharge events), or natural variation. Additionally, it is unclear at this time whether conditions at FCK 0.1 have improved temporarily or for the long term.

Total taxa richness at Fifth Creek kilometer (FFK) 0.2 increased in the late 1980s, and then reached a fairly consistent level until exhibiting a large decrease between 2007 and 2008 (Figure 5.35), suggesting a change in conditions occurred at the site during that time. Total taxa richness returned to predecline levels over a period of about 5 years. EPT taxa richness at FFK 0.2 increased slowly from the late 1980s to early 2000s before decreasing for several years (~2003–2011). More recently, EPT taxa richness has remained steady at about five to six EPT taxa per sample (2011–2018). However, EPT taxa richness in 2019 decreased by four (from six EPT taxa/sample in 2018 to two EPT taxa/sample in 2019) and remained low in 2020. It is not known whether this decrease will persist in future years or whether it instead reflects interannual variation in invertebrate community composition. This recent decline was also seen at upper Fifth Creek (FFK 1.0), which serves as a reference for FFK 0.2, though total and EPT richness values remained higher at the upstream site.

Invertebrate metric values for WCK 2.3 and WCK 3.9 continued to remain within the ranges of values found since the late 1990s and early 2000s, although total taxa richness and EPT taxa richness were lower at WCK 2.3 and WCK 3.9 over the past 5 to 6 years. As with FCK 0.1 and FFK 0.2, the total taxa richness and EPT taxa richness at WCK 2.3 and WCK 3.9 continued to be notably lower than those for the reference sites. Since 2001 (except for one sampling event in 1987), Walker Branch has served as an additional reference site for WOC mainstem sites downstream of Bethel Valley Road (Figure 5.36). Comparisons of WCK 6.8 to Walker Branch kilometer (WBK) 1.0 show that communities in WCK 6.8 represent ideal reference conditions. Additionally, the comparison of Walker Branch to downstream sites in WOC show that those WOC communities remain impaired. Interestingly, a pattern similar to FCK 0.8 and FFK 1.0 occurred in both WCK 6.8 and WBK 1.0, where consecutive declines in total taxa richness and EPT taxa richness were observed in 2018 and 2019, though responses in 2020 varied with sites increasing (FCK 0.8), decreasing (WBK 1.0), or showing little change (FFK 1.0, WCK 6.8). This suggests that similar climatological or environmental changes may be contributing to some of these patterns across the entire watershed, if not the entire ORR, but local drivers may also be present. Macroinvertebrate metrics for lower Melton Branch (Melton Branch kilometer [MEK] 0.6) suggested that total taxa and EPT taxa richness continued to be similar to those in reference sites in 2020 (Figure 5.36). However, other invertebrate community metrics at MEK 0.6 potentially sensitive to more specific types of pollutants, such as the density of pollution-intolerant and pollution-tolerant species (not shown), continued to fluctuate annually between comparable values and values below those of the reference sites. For the past five years (2016–2020), EPT density was generally lower in MEK 0.6 than WCK 6.8 and WBK 1.0 while the density of pollution-tolerant species (oligochaetes and chironomids) was higher in MEK 0.6 than in those two reference sites.

Based on 2017 TDEC protocols (TDEC 2017), scores for the TDEC Tennessee Macroinvertebrate Index (TMI) in 2020 rated the invertebrate communities at WCK 6.8 as passing biocriteria guidelines; scores from FCK 0.1, FFK 0.2, MEK 0.6, WCK 2.3, and WCK 3.9 were below these guidelines (Figure 5.37, Table 5.12). Of the five sites below the biocriteria threshold, scores improved at one site from 2019 to 2020 (FCK 0.1), declined at two sites (MEK 0.6 and FFK 0.2), and remained stable at two sites (WCK 2.3, WCK 3.9).

Low TMI scores in FCK 0.1, FFK 0.2, MEK 0.6, WCK 2.3, and WCK 3.9 were primarily due to low values for EPT percentage and EPT taxa richness (Table 5.12). However, all of the sites had low percentages of oligochaetes and chironomids (worms and non-biting midges) and thus received high scores for this category. WCK 6.8 received the highest attainable scores for all categories except for total taxa richness and EPT taxa richness.

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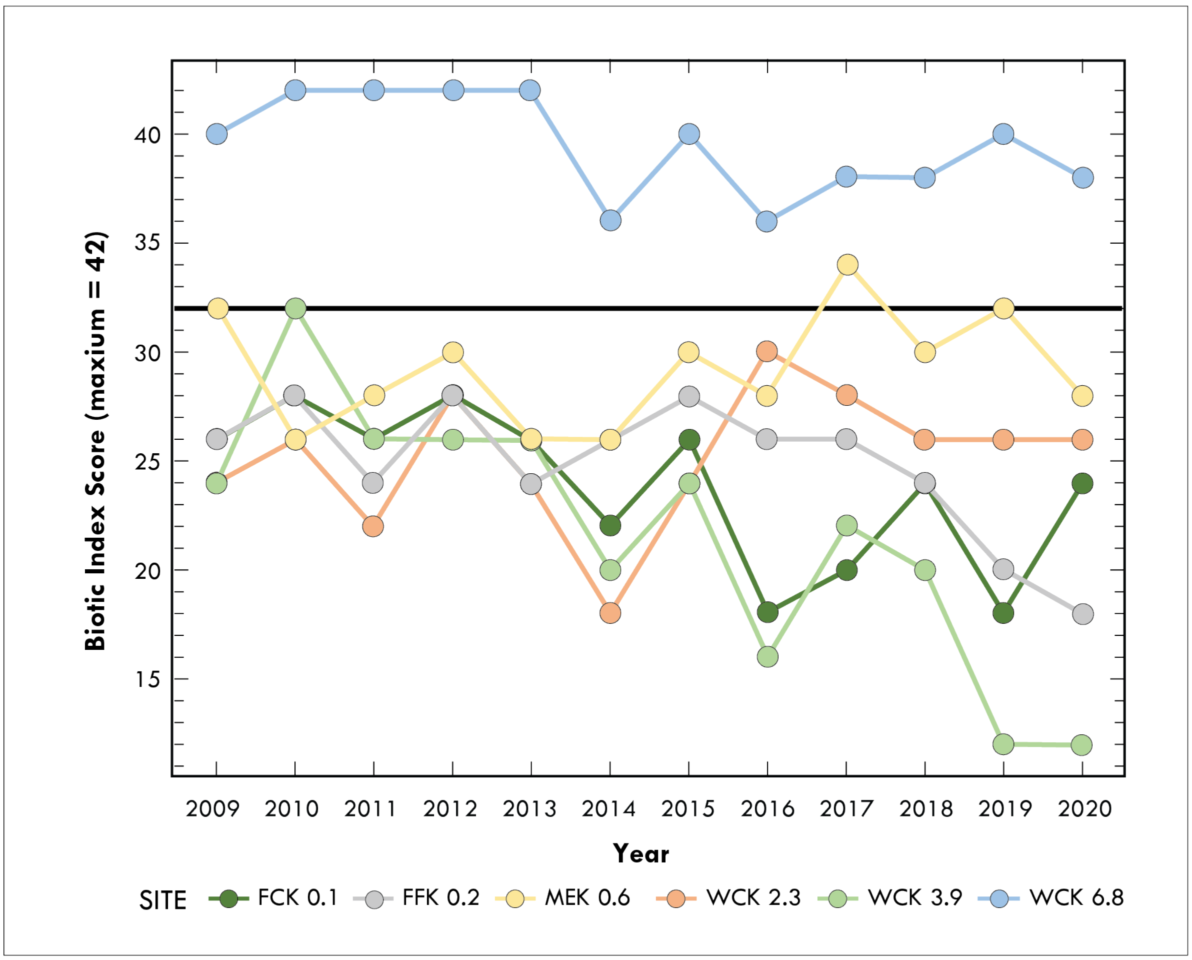

Note: *The black horizontal line shows the threshold for Tennessee Macroinvertebrate Index scores. The values above the threshold represent passing scores; those below do not.*

Acronyms:

FCK = First Creek kilometer
FFK = Fifth Creek kilometer
MEK = Melton Branch kilometer
WCK = White Oak Creek kilometer

Figure 5.37. Temporal trends in Tennessee Department of Environment and Conservation Tennessee Macroinvertebrate Index scores for White Oak Creek watershed streams, August sampling

Table 5.12. Tennessee Macroinvertebrate Index metric values, metric scores, and index scores for White Oak Creek, First Creek, Fifth Creek, and Melton Branch, August 15 and 16, 2020[a,b]

Site	Metric values							Metric scores							TMI[c]
	Taxa rich	EPT rich	EPT (%)	OC (%)	NCBI	Cling (%)	TN Nuttol (%)	Taxa rich	EPT rich	EPT (%)	OC (%)	NCBI	Cling (%)	TN Nuttol (%)	
WCK 2.3	19	6	39.7	6.4	5.4	34.8	41.8	4	2	4	6	4	2	4	26
WCK 3.9	10	2	5.3	21.2	6.2	13.3	77.9	2	0	0	6	4	0	0	12
WCK 6.8	27	11	57.9	6	2.7	83.3	12.5	4	4	6	6	6	6	6	38 [pass]
FCK 0.1	16	4	6.3	3.4	4.3	45.4	44.4	2	2	0	6	6	4	4	24
FFK 0.2	13	5	7	8	5.5	30.7	62.8	2	2	0	6	4	2	2	18
MEK 0.6	19	7	14.8	2.4	4	65.1	32	2	2	2	6	6	6	4	28

[a] *TMI metric calculations and scoring and index calculations are based on TDEC protocols for Ecoregion 67f (TDEC. 2017. Quality System Standard Operating Procedures for Macroinvertebrate Stream Surveys, TDEC Division of Water Pollution Control, Nashville, Tennessee. Available* ***here****.*

[b] *Taxa rich = Taxa richness; EPT rich = taxa richness of (mayflies, stoneflies, and caddisflies); EPT = EPT abundance excluding Cheumatopsyche spp.; OC = percent abundance of oligochaetes (worms) and chironomids (nonbiting midges); NCBI = North Carolina Biotic Index; Cling = percent abundance of taxa that build fixed retreats or otherwise attach to substrate surfaces in flowing water; TN Nuttol. = percent abundance of nutrient-tolerant organisms.*

[c] *TMI is the total index score. Higher index scores indicate higher quality conditions. A score of ≥ 32 is considered to pass biocriteria guidelines.*

Acronyms:

EPT = Ephemeroptera, Plecoptera, and Trichoptera
FCK = First Creek kilometer
FFK = Fifth Creek kilometer
MEK = Melton Branch kilometer
NCBI = North Carolina Biotic Index
OC = percent abundance of oligochaetes (worms) and chironomids (nonbiting midges)
TDEC = Tennessee Department of Environment and Conservation
TMI = Tennessee Macroinvertebrate Index Score
TN Nuttol = nutrient-tolerant organism
WCK = White Oak Creek kilometer

5.5.6.3. Fish Communities

Monitoring of the fish communities in WOC and its major tributaries continued in 2020. Fish community surveys were conducted at 11 sites in the WOC watershed, including 5 sites in the main channel, 2 sites in First Creek, 2 sites in Fifth Creek, and 2 sites in Melton Branch. Streams located near or within the city of Oak Ridge (Mill Branch and Brushy Fork) were also sampled as reference sites for comparison.

In the WOC watershed, the fish community continued to be slightly degraded in 2020 compared with communities in reference streams. Sites closest to outfalls within the ORNL campus had lower species richness (number of species) (Figure 5.38), and fewer pollution-sensitive species than a slightly larger reference site and more closely resembled values found in a smaller reference reach. WOC sites also had more pollution-tolerant species and elevated densities (number of fish per square meter) of pollution-tolerant species compared with reference streams. Seasonal fluctuations in diversity and density are expected and may explain some of the variability seen at these sites. However, the combination of these factors indicates degraded water quality and/or habitat conditions. Overall, the fish communities in tributary sites adjacent to and downstream of ORNL outfalls continued to be negatively affected by ORNL effluent in 2020 relative to reference streams and upstream sites.

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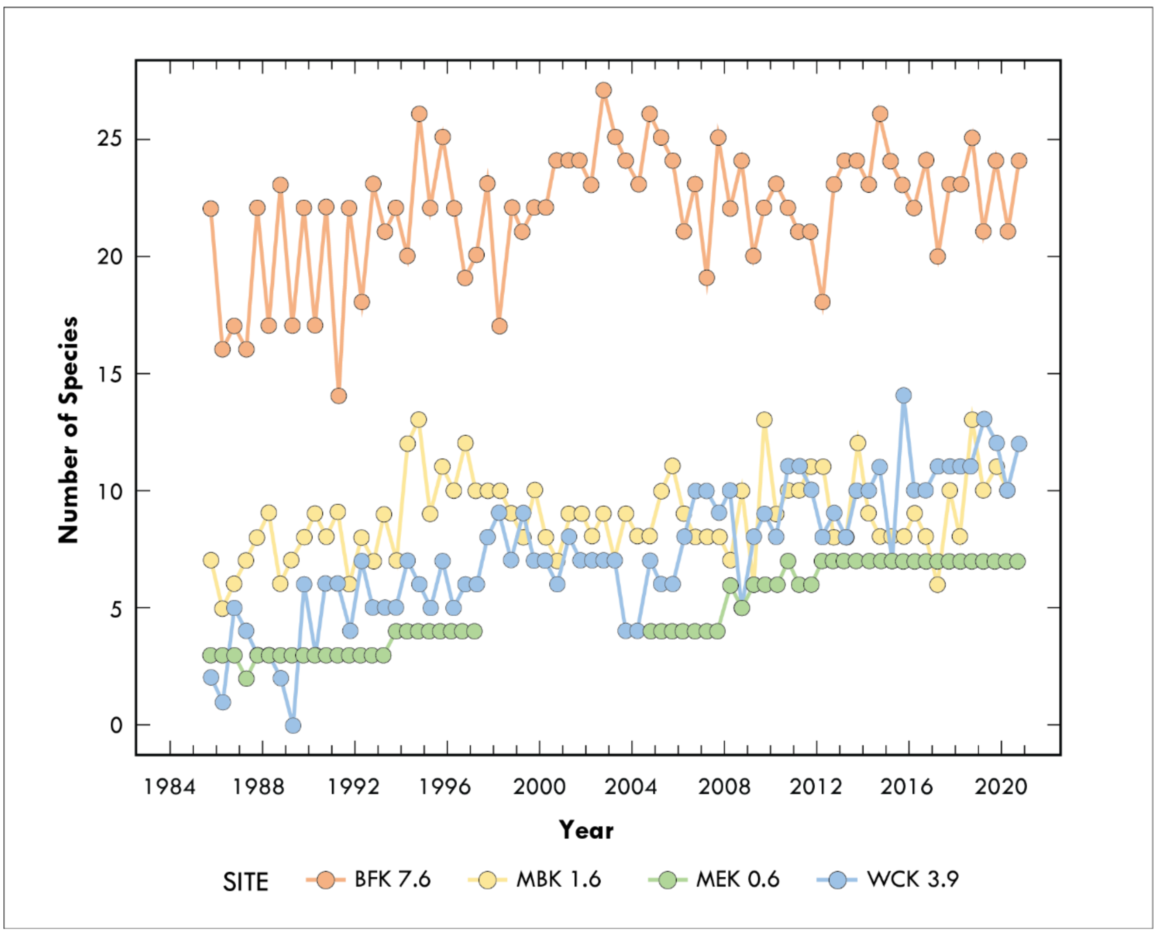


Acronyms:
BFK = Brushy Fork kilometer
MBK = Mill Branch kilometer
MEK = Melton Branch kilometer
WCK = White Oak Creek kilometer

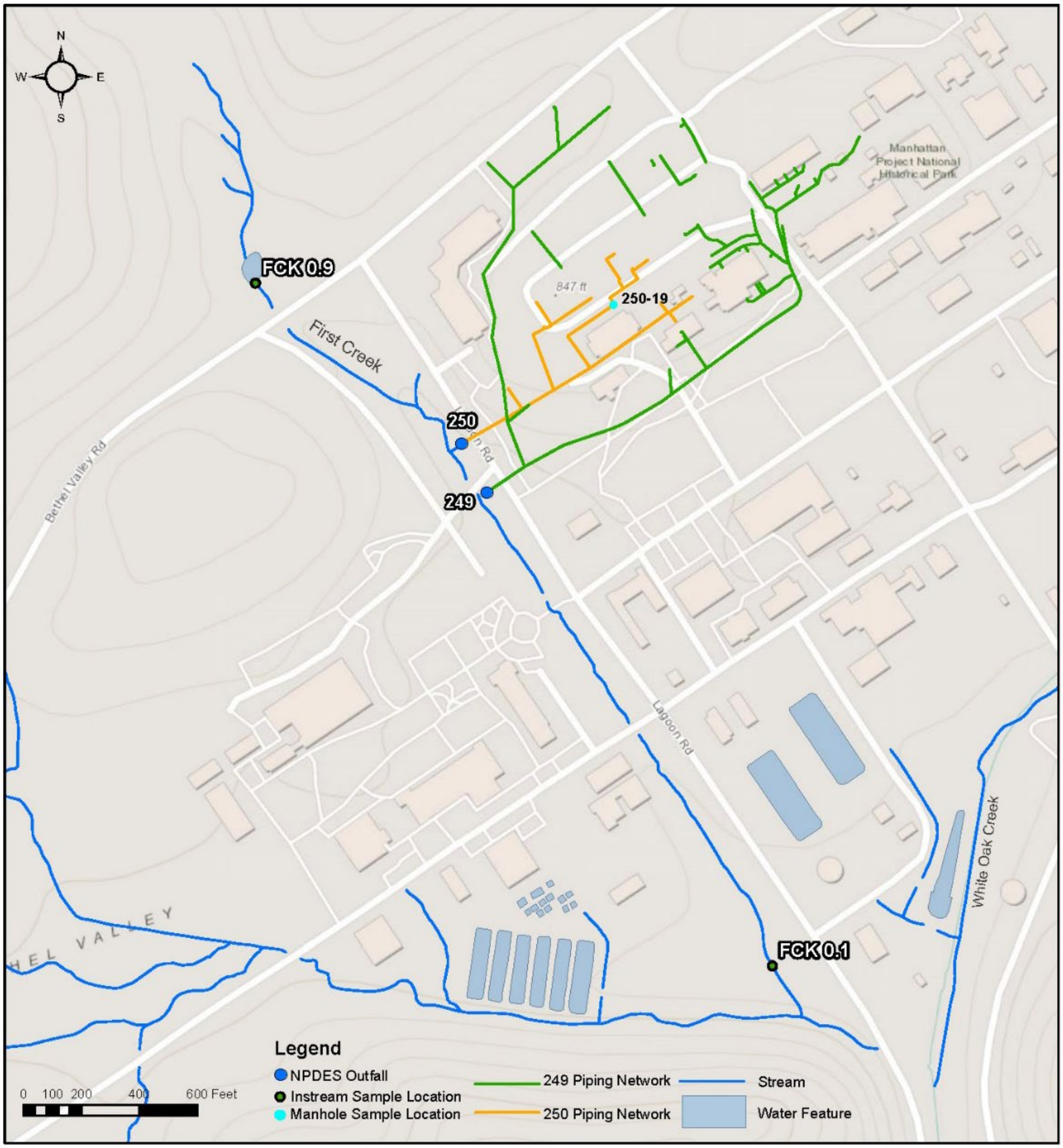
Figure 5.38. Fish species richness (number of species) in upper White Oak Creek and lower Melton Branch compared with two reference streams, Brushy Fork and Mill Branch, 1985–2020

A project to introduce fish species that were not found in the WOC watershed but that exist in similar systems on ORR and that may have historically existed in WOC was initiated in 2008 with the stocking of seven such native species. Continuing reproduction has been noted for six of the species, and several species have expanded their ranges downstream and upstream from initial introduction sites to establish new reproducing populations. In general, introduced species have had more difficulty establishing populations at upstream sites in both WOC and Melton Branch. This is likely due to numerous structures located within the watershed that act as barriers to upstream fish migration. As a result, introductions to supplement the small populations of those fish species were continued at sites within the watershed. One exception to this is the striped shiner (*Luxilus chrysocephalus*), which has expanded into upper Melton Branch, upper WOC, and lower First Creek, although established populations have not been observed in all of those locations. The introductions have enhanced species richness at almost all sample locations within the watershed and may indicate the capacity of this watershed to support increased fish diversity, which seems to be limited by impassible barriers such as dams, weirs, and culverts, and by limited access to source populations downstream in the Clinch River below White Oak Lake.

5.5.7. Polychlorinated Biphenyls in the White Oak Creek Watershed

The initial objective of the source identification task in the WOC watershed was to identify the stream reaches, outfalls, or sediment areas that are contributing to elevated PCB levels in the watershed (Figure 5.39). Sample results for largemouth bass collected from White Oak Lake showed tissue PCB concentrations higher than those recommended by TDEC and EPA for frequent consumption, but the mobility of the fish precluded the possibility of source identification. PCBs are hydrophobic and tend not to be dissolved in water, resulting in undetected PCB concentrations in water samples, using conventional analytical methods, even if collected from a contaminated site. Therefore, semipermeable membrane devices are used to assess the chronic low-level sources of PCBs at critical sites on the reservation. Semipermeable membrane devices are thin plastic sleeves filled with oil in which PCBs are soluble. Because semipermeable membrane devices are deployed at a given site for 4 weeks and have a high affinity for PCBs, they allow for a time-integrated semiquantitative index of the relative PCB concentrations in the water column rather than a “snapshot” value that would be obtained from a grab sample.

Over the past 10 years, ORNL’s PCB monitoring efforts have identified upper parts of First Creek as a source of PCBs. In September 2019, catch basin sediment in the drainage network leading to Outfall 250 was cleaned out and disposed of as solid waste. In 2020, semipermeable membrane devices were deployed in this piping network as well as in First Creek above and below Outfall 250 (Figure 5.39). Results from this assessment indicate that PCBs remained available in the area despite actions to remove PCB-contaminated materials from the upper part of Outfall 250 watershed, suggesting either that flows in 2020 remobilized PCBs or that another source is introducing PCBs to that section of piping. Future monitoring is needed to identify the sources of the PCBs found in to the Outfall 250 piping network.



Acronym:
FCK = First Creek kilometer

Figure 5.39. Locations of monitoring points for First Creek source investigation

5.5.8. Oil Pollution Prevention

CWA Section 311 regulates the discharge of oils or petroleum products to waters of the United States and requires the development and implementation of spill prevention, control, and countermeasures (SPCC) plans to minimize the potential for oil discharges. These requirements are provided in 40 CFR 112, "Oil Pollution Prevention." Each ORR facility implements a site-specific SPCC plan. The HVC (home of NTRC and the Manufacturing Demonstration Facility), which is located off ORR, also has an SPCC plan covering the oil inventory at that location. CFTF is also located off ORR; however, that facility was evaluated, and a determination was made that an SPCC plan was not required. The ORNL and HVC SPCC plans were not changed in 2020. There were no regulatory actions related to oil pollution prevention at ORNL or HVC in 2020. An oil-handler training program exists to comply with training requirements in 40 CFR 112.

5.5.9. Surface Water Surveillance Monitoring

The ORNL surface water monitoring program is conducted in conjunction with the ORR surface water monitoring activities discussed in Section 6.4 to enable assessing the impacts of ongoing DOE operations on the quality of local surface water. The sampling locations (Figure 5.40) are used to monitor conditions upstream of ORNL main plant waste sources (WCK 6.8), within the ORNL campus (FFK 0.1), and downstream of ORNL discharge points (WCK 1.0).

Sampling frequencies and parameters vary by site and are shown in Table 5.13. Monitoring at WCK 1.0 is conducted monthly for radiological parameters and quarterly for mercury under the ORNL WQPP (Section 5.5.3) and, therefore, those parameters are not duplicated by this program. Radiological monitoring at WCK 6.8 is also conducted monthly under the ORNL WQPP and therefore is not duplicated by the surface water monitoring program.

Samples are collected and analyzed for general water quality parameters and are screened for radioactivity at all locations (either under this program or under WQPP). Samples are further analyzed for specific radionuclides when general screening levels are exceeded. Samples from WCK 1.0 are also checked for volatile organic compounds (VOCs) and PCBs. WCK 6.8 is also checked for PCBs. WCK 6.8 and WCK 1.0 are classified by the State of Tennessee for freshwater fish and aquatic life. Tennessee WQCs associated with these classifications are used as references where applicable (TDEC 2015). The Tennessee WQCs do not include criteria for radionuclides. Four percent of the DOE DCS (DOE 2011a) is used for radionuclide comparison.

There were no radionuclides reported above 4 percent of DCS at the Fifth Creek location (FFK 0.1) in 2020. Beta activity and $^{89/90}$Sr were detected in samples from both sampling events at the Fifth Creek location and are related to known sources in the middle of the ORNL main campus. No $^{89/90}$Sr results above 4 percent of DCS were reported for samples collected at the upstream WOC sampling location (WCK 6.8). The other radionuclide results from WCK 6.8 and the radionuclide results from samples collected at WOD (before WOC empties into the Clinch River) are discussed in Section 5.5.3.

No PCBs were detected at WCK 1.0 in 2020. One VOC, acetone, was detected in samples from WCK 1.0 during 2020, once in June and once in August. Both detections were at low, estimated values. Acetone has been detected in surface water samples from WCK 1.0 before, and acetone has occasionally been detected in at least one on-site groundwater well in past monitoring, including wells located in nearby Solid Waste Storage Area (SWSA) 6.

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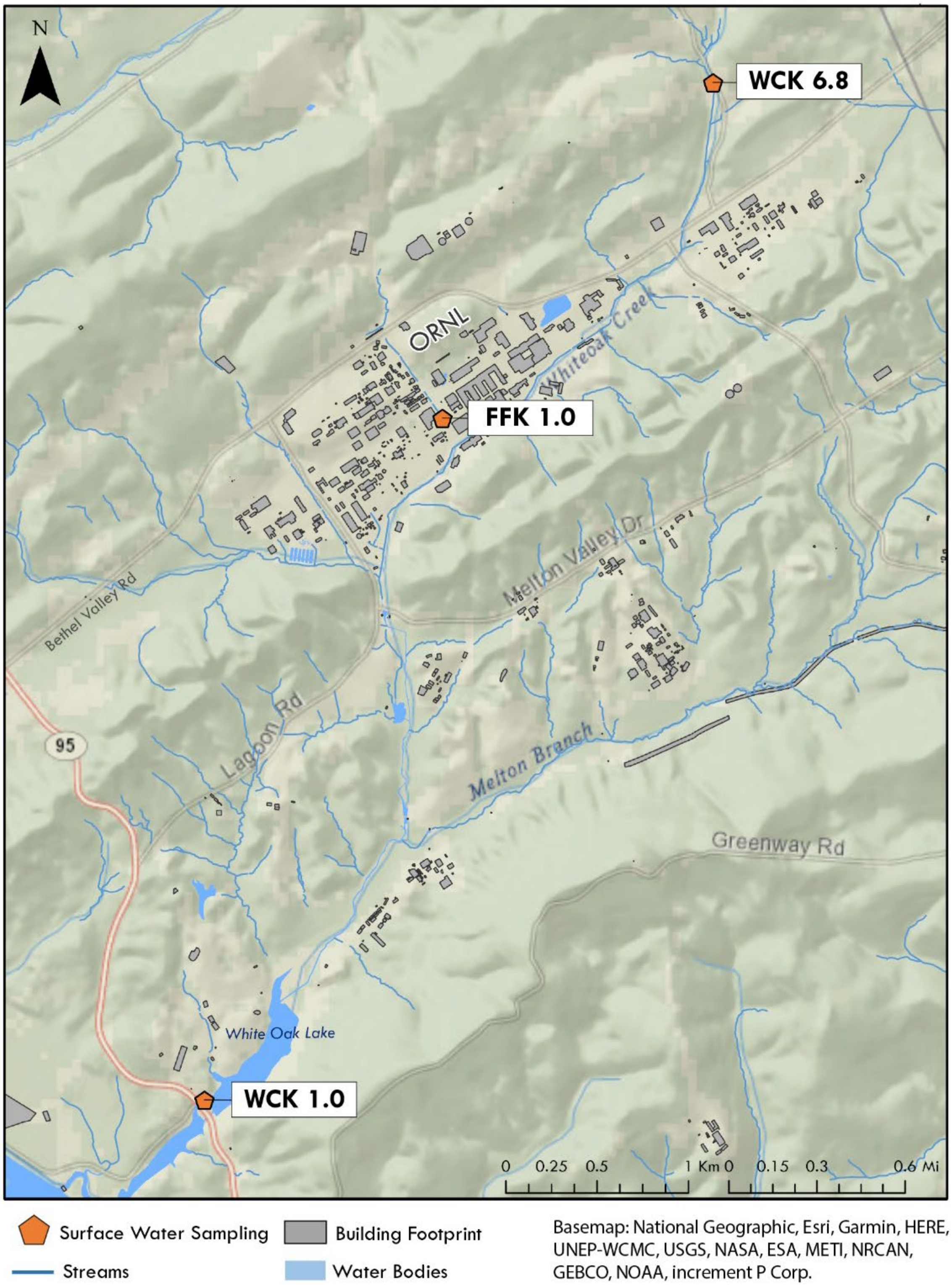

Acronyms: *FFK = Fifth Creek kilometer   WCK = White Oak Creek kilometer*

Figure 5.40. ORNL surface water sampling locations, 2020

Table 5.13. ORNL surface water sampling locations, frequencies, and parameters, 2020

Location[a]	Description	Frequency and type	Parameters
WCK 1.0[b]	White Oak Lake at WOD	Quarterly, grab	Volatiles, PCBs, field measurements[c]
WCK 6.8[d]	WOC upstream from ORNL	Quarterly, grab	PCBs, field measurements[c]
FFK 0.1	Fifth Creek just upstream of WOC (ORNL)	Semiannually, grab	Gross alpha, gross beta, total radioactive strontium, gamma scan, tritium, field measurements[c]

[a] *Locations identify bodies of water and locations on them (e.g., WCK 1.0 is 1 km upstream from the confluence of White Oak Creek and the Clinch River).*

[b] *For this location, radiological parameters and mercury are monitored under another program (the WQPP) and therefore are not included in this plan.*

[c] *Field measurements consist of dissolved oxygen, pH, and temperature.*

[d] *Radiological monitoring is performed at this location in by the WQPP.*

Acronyms:

FFK = Fifth Creek kilometer
ORNL= Oak Ridge National Laboratory
PCB = polychlorinated biphenyl
WCK = WOC kilometer
WOC = White Oak Creek
WOD = White Oak Dam
WQPP = Water Quality Protection Plan

5.5.10. Carbon Fiber Technology Facility Wastewater Monitoring

Facility and process wastewater from activities at CFTF are discharged to the City of Oak Ridge sanitary sewer system under conditions established in City of Oak Ridge Industrial Wastewater Discharge Permit 1-12. Permit limits, parameters, and 2020 compliance status for this permit are summarized in Table 5.14.

Table 5.14. Industrial and commercial user wastewater discharge permit compliance at the ORNL Carbon Fiber Technology Facility, 2020

Effluent parameters	Permit limits		Permit compliance		
	Daily max. (mg/L)	Monthly ave. (mg/L)	Number of noncompliances	Number of samples	Percentage of compliance[a]
		Outfall 01 (Underground Quench Water Tank)			
Cyanide	3.9	0.1	0	0	100
pH (standard units)	6–9		0	0	100
		Outfall 02 (Electrolytic Bath Tank)			
pH (standard units)	6–9		0	4	100
		Outfall 03 (Sizing Bath Tank)			
Copper	0.87	0.10	0	1	100
Zinc	1.24	0.60	0	1	100
Total phenol	4.20	-	0	1	100
pH (standard units)	6–9		0	1	100

[a] *Percentage compliance = 100 – [(number of noncompliances/number of samples) × 100]*

5.6. ORNL Groundwater Monitoring Program

Groundwater monitoring at ORNL was conducted under two sampling programs in 2019: DOE OREM monitoring and DOE Office of Science (SC) surveillance monitoring. The DOE OREM groundwater monitoring program was conducted by UCOR in 2019. The SC groundwater monitoring surveillance program was conducted by UT-Battelle.

5.6.1. Summary of US Department of Energy Office of Environmental Management Groundwater Monitoring

Monitoring was performed as part of an ongoing comprehensive CERCLA cleanup effort in Bethel and Melton Valleys, the two administrative watersheds at the ORNL site. Groundwater monitoring for baseline and trend evaluation in addition to measuring effectiveness of completed CERCLA RAs is conducted as part of the WRRP. The WRRP is managed by UCOR for the DOE OREM program. The results of CERCLA monitoring for ORR for FY 2020, including monitoring at ORNL, are evaluated and reported in the *Phased Groundwater Remedial Investigation Work Plan for the Bethel Valley Final Groundwater Record of Decision* (DOE 2021a) as required by the ORR Federal Facility Agreement.

Groundwater monitoring conducted as part of the OREM program at ORNL includes routine sampling and analysis of groundwater in Bethel Valley to measure performance of several RAs and to continue contaminant and groundwater quality trend monitoring. In Melton Valley, where CERCLA RAs were completed in 2006 for the extensive waste management areas, the groundwater monitoring program includes monitoring groundwater levels to evaluate the effectiveness of hydrologic isolation of buried waste units. Additionally, groundwater is sampled and analyzed for a wide range of general chemical and contaminant parameters in 46 wells within the interior portion of the closed waste management area.

In FY 2010 DOE initiated activities on a groundwater treatability study at the Bethel Valley 7000 Area VOC plume. This plume contains trichloroethylene and its transformation products cis-1,2-dichloroethene and vinyl chloride, all at concentrations greater than EPA primary drinking water standards. The treatability study is a laboratory and field demonstration to determine whether microbes inherent to the existing subsurface microbial population can fully degrade the VOCs to nontoxic end products. Post-treatment monitoring of the 7000 Area plume continues.

During FY 2020 postremediation monitoring continued at SWSA 3 to evaluate the effectiveness of the 2011 hydrologic isolation of the area that included construction of a multilayer cap and an upgradient storm flow/shallow groundwater diversion drain. RAs and monitoring were specified in a CERCLA RA work plan that was developed by DOE and approved by EPA and TDEC before the project was started.

5.6.1.1. Bethel Valley

During FY 2011 construction was completed for RAs at SWSA 1 and SWSA 3, two former waste storage sites that were used for disposal of radioactively contaminated solid wastes between 1944 and 1950. Wastes disposed of at SWSA 1 originated from the earliest operations of ORNL; those at SWSA 3 originated from ORNL, Y-12, the K-25 Site (ETTP), and off-site sources. Although most of the wastes disposed of at SWSA 3 were solids, some were containerized liquid wastes. Some wastes were encapsulated in concrete after placement in burial trenches, but most of the waste was covered with soil. The Bethel Valley Record of Decision (ROD) (DOE 2002) selected hydrologic isolation using multilayer caps and groundwater diversion trenches as the RA for the waste burial grounds and construction of soil covers over the former contractor's landfill and contaminated soil areas near SWSA 3. The baseline monitoring conducted during FY 2010 included measurement of groundwater levels to obtain baseline data to allow evaluation of postremediation groundwater-level suppression.

Sampling and analysis of groundwater quality and contaminants were also conducted. Postremediation monitoring was specified for SWSA 3 in the *Phased Construction Completion Report for the Bethel Valley Burial Grounds at the Oak Ridge National Laboratory, Oak Ridge, Tennessee* (DOE 2012). Required monitoring includes quarterly groundwater-level monitoring in 42 wells with continuous water-level monitoring in 8 wells to confirm cap performance. Groundwater samples are collected semiannually at 13 wells for laboratory analyses to evaluate groundwater contaminant concentration trends.

FY 2020 monitoring results showed that the cap was effective, although target groundwater elevations have not yet been attained at three of eight wells. Drinking water standards are used as screening water quality concentrations to evaluate the site response to remediation. Strontium-90, a signature contaminant at SWSA 3, shows decreasing annual maximum concentrations with 6 of 10 monitored wells exhibiting ^{90}Sr concentrations less than the 8 pCi/L maximum contaminant level (MCL) derived concentration. Benzene, potentially from natural sources, shows decreasing annual maximum concentrations with FY 2020 maxima of 0.006 and 0.007 mg/L in two wells, which is just slightly greater than the 0.005 mg/L MCL. During FY 2020, as part of the DOE OREM program, three groundwater monitoring wells in Bethel Valley to the west of Tennessee Highway 95 were monitored to detect and track contamination from the SWSA 3 area. Data from those three wells supplement data being collected from a multiport well (4579) near SWSA 3 for exit pathway groundwater monitoring in western Bethel Valley. Groundwater monitoring near SWSA 3, along with the exit pathway, and groundwater and surface water monitoring at the northwest tributary of WOC and in the headwaters of Raccoon Creek allow integration of data concerning SWSA 3 contaminant releases. The data are presented in the *Phased Groundwater Remedial Investigation Work Plan for the Bethel Valley Final Groundwater Record of Decision* (DOE 2021a). To enhance exit pathway groundwater monitoring near the ORR property boundary at the Clinch River in western Bethel Valley 3 deep boreholes were drilled and characterized. During FY 2021 Westbay® multizone sampling systems will be installed to enable discrete zone sampling in the carbonate bedrock units.

Groundwater monitoring continued at the ORNL 7000 Area during FY 2020 to evaluate treatability of the VOC plume at that site. Site characterization testing of the endemic microbial community showed that microbes were present that are capable of fully degrading trichloroethylene and its degradation products if sufficient electron donor compounds are present in the subsurface environment. During FY 2011 a mixture of emulsified vegetable oil and a hydrogen-releasing compound was injected into four existing monitoring wells in the 7000 area. Ongoing monitoring of VOC concentrations show that the effects of the biostimulation test continue to be apparent, although at decreasing levels.

The other principal element of the Bethel Valley ROD (DOE 2002) remedy that requires groundwater monitoring is the containment pumping to control and treat discharges from the ORNL Central Campus Core Hole 8 plume. The original action for the plume was a CERCLA removal action that was implemented in 1995 with the performance goal of reducing ^{90}Sr in WOC. The remedy had performed well until the latter portion of FY 2008, when conditions changed and ^{90}Sr and $^{233/234}$U concentrations in monitoring wells and the groundwater collection system began increasing. During FY 2009 the remedy did not meet its performance goal. In March 2012 DOE completed refurbishment and enhancement of the groundwater collection system to increase the effectiveness of the plume containment.

Between FY 2012 and FY 2015 the Bethel Valley ROD goal for ^{90}Sr concentrations at the 7500 Bridge Weir monitoring location was met. During FY 2020 that goal was exceeded because of contaminant releases from an ungauged Sr-90 see page into WOC. Continuing ^{90}Sr influxes to WOC from groundwater and storm drain discharges fed by releases from deteriorated infrastructure comprise the majority of ^{90}Sr measured at the 7500 Bridge Weir site.

5.6.1.2. Melton Valley

The Melton Valley ROD (DOE 2000) established goals for a reduction of contaminant levels in surface water, groundwater-level fluctuation reduction goals within hydrologically isolated areas, and minimization of the spread of groundwater contamination. Groundwater monitoring to determine the effectiveness of the remedy in Melton Valley includes groundwater-level monitoring in wells within and adjacent to hydrologically isolated shallow waste burial areas and groundwater quality monitoring in selected wells adjacent to buried waste areas.

Groundwater-level monitoring shows that the hydrologic isolation component of the Melton Valley remedy is effectively minimizing the amount of percolation water contacting buried waste and is reducing contaminated leachate formation. The total amount of rainfall on ORR during FY 2020 was about 75 in., which is about 20 in. greater than the long-term annual average for ORR. In a few areas, groundwater levels within capped areas continue to respond to groundwater fluctuations imposed from areas outside the caps, but contact of groundwater with buried waste is minimal. Overall, the hydrologic isolation systems are performing as designed.

Groundwater quality monitoring in the interior of Melton Valley shows that in general groundwater contaminant concentrations are declining or are stable following RAs. Groundwater quality monitoring that is substantively equivalent to the former RCRA monitoring continues at SWSA 6. Several VOCs continue to be detected in wells along the eastern edge of the site.

During the past 10 years of groundwater monitoring in the Melton Valley exit pathway, several site-related contaminants have been detected in groundwater near the Clinch River. Low concentrations of strontium, tritium, uranium, and VOCs have been detected intermittently in a number of the multizone sampling locations. Groundwater in the exit pathway wells has high alkalinity and sodium and exhibits elevated pH. During FY 2020 an off-site groundwater monitoring well array west of the Clinch River and adjacent to Melton Valley was monitored as part of the OREM program. Monitoring included groundwater-level monitoring to evaluate potential flowpaths near the river and sampling and analysis for a wide array of metals, anions, radionuclides, and VOCs. Groundwater-level monitoring showed that natural head gradient conditions cause groundwater seepage to converge toward the Clinch River from both the DOE (eastern) and off-site (western) sides of the river. Monitoring results are summarized in the *Phased Groundwater Remedial Investigation Work Plan for the Bethel Valley Final Groundwater Record of Decision* (DOE 2021a).

5.6.2. DOE Office of Science Groundwater Surveillance Monitoring

DOE Order 458.1 (DOE 2011c) is the primary requirement for a site-wide groundwater protection program at ORNL. As part of the groundwater protection program, and to be consistent with UT-Battelle management objectives, groundwater surveillance monitoring was performed to monitor ORNL groundwater exit pathways and UT-Battelle facilities ("active sites") potentially posing a risk to groundwater resources at ORNL. Results of the DOE SC groundwater surveillance monitoring are reported in the following sections.

Exit pathway and active-sites groundwater surveillance monitoring points sampled during 2020 included seep/spring and surface-water monitoring locations in addition to groundwater surveillance monitoring wells. Seep/spring and surface-water monitoring points located in appropriate groundwater discharge areas were used in the absence of monitoring wells.

Groundwater pollutants monitored under the exit pathway groundwater surveillance and active-sites monitoring programs are not regulated by federal or state rules. Consequently, no permit-required or other applicable standards exist for evaluating results. To assess groundwater quality at these monitoring locations, and to facilitate comparison of results between locations, results were compared to selected federal and state standards even though those standards are not directly applicable. For radionuclide parameters for which alternative standards were not identified, results were compared to 4 percent of the DCSs (DOE 2011a). Regardless of the standards selected for comparison, it is important to note that no members of the public consume groundwater from ORNL wells, nor do any groundwater wells furnish drinking water to personnel at ORNL.

5.6.2.1. Exit Pathway Monitoring

During 2020, exit pathway groundwater surveillance monitoring was performed in accordance with the exit pathway sampling and analysis plan (Bonine 2012). Groundwater exit pathways at ORNL include areas from watersheds or sub-watersheds where groundwater discharges to the Clinch River–Melton Hill Reservoir to the west, south, and east of the ORNL main campus. The exit pathway monitoring points were chosen based on hydrologic features, screened interval depths (for wells), and locations relative to discharge areas proximate to DOE facilities operated by, or under the control of, UT-Battelle. The groundwater exit pathways at ORNL include four discharge zones identified by a data quality objectives process. One of the original exit pathway zones was split into two zones for geographic expediency. The Southern Discharge Area Exit Pathway was carved from the East End Discharge Area Exit Pathway. The five zones are listed below. Figure 5.41 shows the locations of the exit pathway monitoring points sampled in 2020:

- The 7000–Bearden Creek Discharge Area Exit Pathway
- The East End Discharge Area Exit Pathway
- The Northwestern Discharge Area Exit Pathway
- The Southern Discharge Area Exit Pathway
- The WOC Discharge Area Exit Pathway

The efficacy of the exit pathway monitoring program was reviewed in late 2011. As a result, the groundwater monitoring program was modified through an optimization approach that included frequency analysis of parameters and their concentrations based on an exhaustive review of historical groundwater sampling data. The modification resulted in a 10-year staggered groundwater monitoring schedule and analytical suite selection. This approach was initiated in 2012. A summary of the groundwater monitoring that was conducted in 2020 is outlined in Table 5.15.

Unfiltered samples were collected. The organic suite was composed of VOCs and semivolatile organic compounds; the metallic suite included heavy and non-heavy metals; and the radionuclide suite was composed of gross alpha/gross beta activity, gamma emitters, $^{89/90}$Sr, and tritium. In 2020, wet season samples were collected in March and April and dry season samples were collected in September and October.

Exit Pathway Monitoring Results

Table 5.16 provides a summary of radiological parameters detected in samples collected from exit pathway monitoring points during 2020. Metals are ubiquitous in groundwater exit pathways and so are not summarized in the table.

Exit Pathway Groundwater Surveillance Summary

Concentrations of metals and man-made radionuclides observed in groundwater exit pathway discharge areas in 2020 at ORNL were generally consistent with observations reported in past annual site environmental reports for ORR. Based on the results of the 2020 monitoring effort, there is no indication that current SC operations are significantly introducing contaminants to the groundwater at ORNL.

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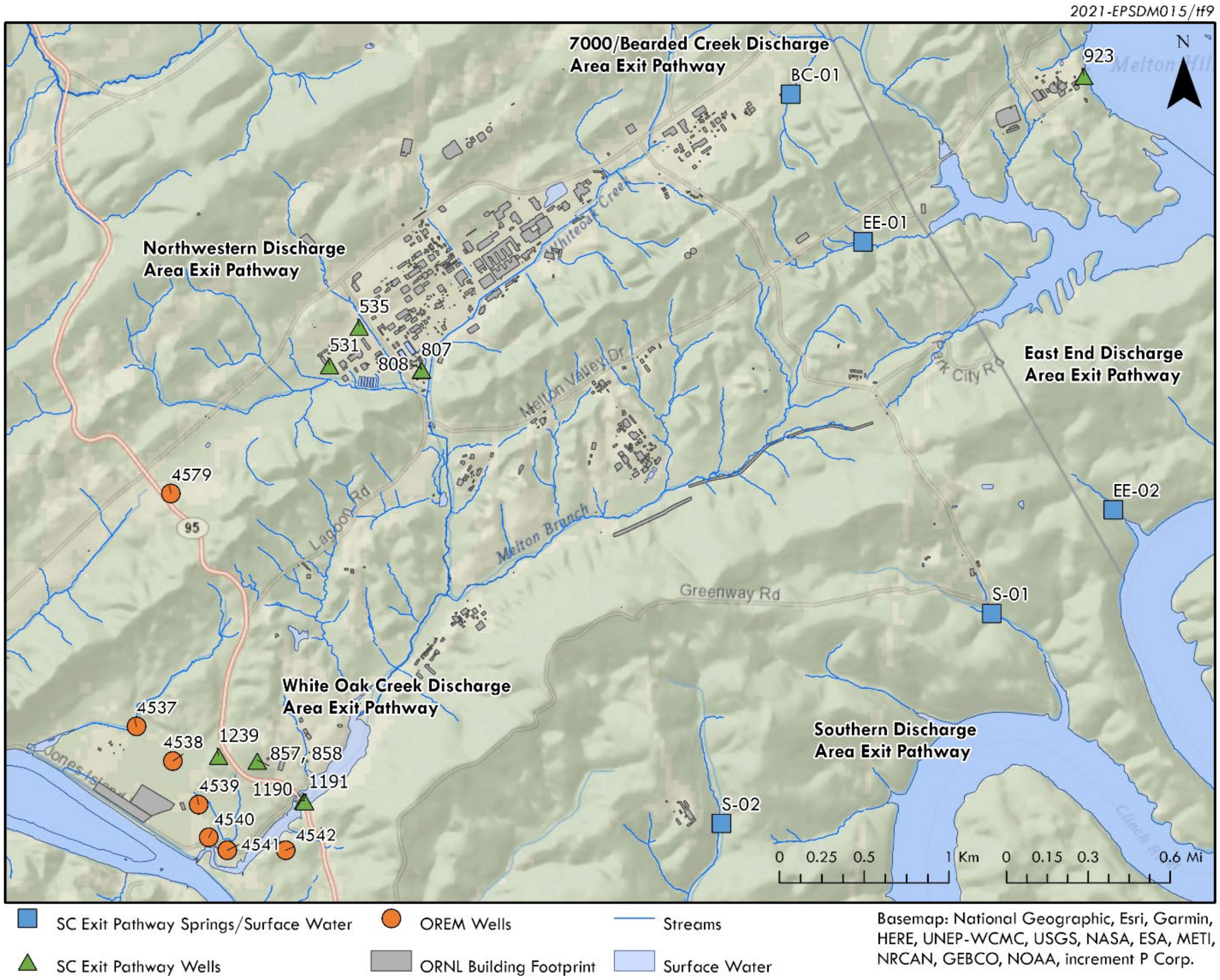

Acronyms:

OREM = DOE Office of Environmental Management

SC = DOE Office of Science

Figure 5.41. UT-Battelle exit pathway groundwater monitoring locations at ORNL, 2020

Table 5.15. Exit pathway groundwater monitoring conducted in 2020

Monitoring point	Season	
	Wet	Dry
	7000 Bearden Creek Discharge Area	
BC-01	Radiological	Not sampled[a]
	East End Discharge Area	
923	Radiological	Radiological
EE-01	Radiological	Radiological, organics, and metals
EE-02	Radiological	Not sampled[a]
	Northwestern Discharge Area	
531	Radiological	Radiological
535	Radiological, organics, and metals	Radiological
807	Radiological	Radiological
808	Radiological	Radiological
	Southern Discharge Area	
S-01	Radiological, organics, and metals	Not Sampled[a]
S-02	Radiological	Radiological
	White Oak Creek Discharge Area	
857	Radiological, organics, and metals	Radiological
858	Radiological	Radiological
1190	Radiological, organics, and metals	Radiological, organics, and metals
1191	Radiological, organics, and metals	Radiological, organics, and metals
1239	Radiological	Radiological

[a] *Locations BC-01, EE-02, and S-01 (stream locations) were not sampled in the 2020 dry season due to lack of water flow at those locations.*

Table 5.16. Radiological parameters detected in 2020 exit pathway groundwater monitoring

Monitoring location	Parameter	Concentration (pCi/L)		
		Wet season[a]	Dry season[a]	Reference value[b]
		7000 Bearden Creek Discharge Area		
Spring BC-01	^{214}Bi	14.2	NF	10,400
Spring BC-01	^{214}Pb	15.8	NF	8,000
		East End Discharge Area		
Well 923	Beta activity	U0.966	2.71	50
Well 923	^{214}Bi	8.4	ND	10,400
Well 923	^{212}Pb	11.1	ND	152
Stream EE-01	^{214}Bi	20.7	ND	10,400
Stream EE-01	^{40}K	U3.41	28.6	192
Stream EE-01	^{214}Pb	12.8	ND	8,000
Stream EE-02	Beta activity	4.09	NF	50
Stream EE-02	^{214}Bi	200	NF	10,400
Stream EE-02	^{214}Pb	232	NF	8,000
		Northwestern Discharge Area		
Well 531	Beta activity	2.29	3.97	50
Well 535	Alpha activity	3.15	U0.231	15
Well 535	Beta activity	2.25	U0.782	50
Well 535	^{212}Bi	ND	38.3	4,400
Well 535	^{214}Bi	65.8	39.1	10,400
Well 535	^{212}Pb	ND	5.03	152
Well 535	^{214}Pb	68.6	55.2	8,000
Well 807	Alpha activity	2.3	U0.329	15
Well 807	Beta activity	7.64	5.77	50
Well 807	^{214}Bi	18.1	47.7	10,400
Well 807	^{214}Pb	23	57	8,000
Well 807	$^{89/90}Sr$	2.34	U0.599	44
Well 808	Beta activity	3.7	6.71	50
		Southern Discharge Area		
Stream S-01	Beta activity	3.4	NF	50
Stream S-01	^{214}Bi	74.4	NF	10,400
Stream S-01	^{214}Pb	77.2	NF	8,000
Stream S-02	^{214}Bi	11.1	34.5	10,400
Stream S-02	^{214}Pb	14.4	40.6	8,000
		White Oak Creek Discharge Area		
Well 857	Beta activity	U1.67	3.12	50
Well 857	^{214}Bi	125	73.6	10,400
Well 857	^{214}Pb	134	78.5	8,000
Well 858	^{214}Bi	ND	5.47	10,400

Table 5.16. Radiological concentrations detected in 2020 exit pathway groundwater monitoring (continued)

Monitoring location	Parameter	Concentration (pCi/L)		
		Wet season[a]	Dry season[a]	Reference value[b]
Well 858	^{214}Pb	ND	9.93	8,000
Well 1190	Beta activity	2.07	5.01	50
Well 1190	^{214}Bi	70.1	42.5	10,400
Well 1190	^{212}Pb	5.09	ND	152
Well 1190	^{214}Pb	67.6	50	8,000
Well 1190	^{208}Tl	ND	4.25	NA
Well 1190	Tritium	13,000	20,500	20,000
Well 1191	Alpha activity	4.6	U1.33	15
Well 1191	Beta activity	220	198	50
Well 1191	^{214}Bi	44.4	28	10,400
Well 1191	^{212}Pb	4.66	ND	152
Well 1191	^{214}Pb	44	ND	8,000
Well 1191	$^{89/90}Sr$	123	120	44
Well 1191	Tritium	7,670	6,140	20,000
Well 1239	Alpha activity	2.96	U0.463	15
Well 1239	Beta activity	1.73	1.78	50

[a] *NF = there was no flow at the spring or stream sampling location during sampling attempts*
ND = the analyte was not detected in the gamma scan that was performed
U = the analyte was measured but not detected above the practical quantitation limit/contractor-required detection limit

[b] *NA = no applicable reference criteria for this parameter. Current federal and state standards were used as reference values. If no federal or state standard exists for the analyte, 4 percent of the DOE derived concentration standard is used as the reference value.*

Ten radiological contaminants were detected in exit pathway groundwater samples collected in 2020. Gross beta, $^{89/90}Sr$, and tritium were the only radiological parameters exceeding reference values at any of the discharge areas. Consistent with previous monitoring, these parameters were observed at concentrations above their respective reference values in the WOC discharge area.

A new maximum concentration was measured for one parameter at one monitoring location in the east end discharge area—surface water location EE-02—in the wet-season sampling event. The concentration of ^{214}Pb activity was measured at 232 pCi/L (compared to a previous maximum of 231 pCi/L). Lead-214 is short-lived radioisotope in the decay chain of ^{226}Ra (NIST 2020). Radium is a naturally occurring radioactive metal and the ^{226}Ra isotope is part of the uranium decay series (EPA 2019). Although this newest concentration is the highest measured to date at the EE-02 location, the concentration is similar to the previous maximum for the location when taking the analytical counting uncertainty into account. ^{214}Pb is often detected at this location, and sometimes detected at higher concentrations at other locations in the southern discharge area (locations S-01 and S-02).

First detections of ^{212}Bi and ^{212}Pb occurred at well number 535 in 2020. Both are short-lived radioisotopes in the decay chain of naturally occurring ^{232}Th (EPA 2021). Both isotopes are occasionally encountered at similar concentrations in groundwater from the ORNL area.

Twenty-four metallic parameters were detected in exit pathway groundwater samples collected in 2020. Only two metals, iron and manganese, were detected at concentrations exceeding reference values. Iron and manganese are commonly found in groundwater at ORNL.

One organic compound was detected at a concentration at or above the analytical report level in exit pathway groundwater monitoring in 2020. Acetone was detected in the wet-season sample from well 1191 at a concentration of 6.81 μg/L (the associated report level was 5 μg/L). Acetone is a common laboratory contaminant.

5.6.2.2. Active Sites Monitoring—High Flux Isotope Reactor

Two storm water outfall collection systems (Outfalls 281 and 383) intercept groundwater in the HFIR area and are routinely monitored under a monitoring plan associated with the ORNL NPDES permit. (See Section 5.5 for a discussion of results.)

5.6.2.3. Active Sites Monitoring—Spallation Neutron Source

Active sites groundwater surveillance monitoring was performed in 2019 at the SNS site under the SNS operational monitoring plan (Bonine, Ketelle, and Trotter 2007) due to the potential for adverse impact on groundwater resources at ORNL should a release occur. Operational monitoring was initiated following a 2-year (2004–2006) baseline monitoring program and will continue throughout the duration of SNS operations.

The SNS site is located atop Chestnut Ridge, northeast of the main ORNL facilities. The site slopes to the north and south, and small stream valleys, populated by springs and seeps, lie on the ridge flanks. Surface water drainage from the site flows into Bear Creek to the north and WOC to the south.

The SNS site is a hydrologic recharge area underlain by geologic formations that form karst geologic features. Groundwater flow directions at the site are based on the generally observed tendency for groundwater to flow parallel to geologic strike (parallel to the orientation of the rock beds) and via karst conduits that break out at the surface in springs and seeps located downgradient of the SNS site. A sizable fraction of infiltrating precipitation (groundwater recharge) flows to springs and seeps via the karst conduits. SNS operations have the potential for introducing radioactivity (via neutron activation) in the shielding berm surrounding the SNS linac, accumulator ring, and/or beam transport lines. A principal concern is the potential for water infiltrating the berm soils to transport radionuclide contamination generated by neutron activation to saturated groundwater zones. The ability to accurately model the fate and transport of neutron activation products generated by beam interactions with the engineered soil berm is complicated by multiple uncertainties resulting from a variety of factors, including hydraulic conductivity differences in earth materials found at depth, the distribution of water-bearing zones, the fate and transport characteristics of neutron activation products produced, diffusion and advection, and the presence of karst geomorphic features found on the SNS site. These uncertainties led to the initiation of the groundwater surveillance monitoring program at the SNS site. Objectives of the groundwater monitoring program outlined in the operational monitoring plan include the following: (1) maintain compliance with applicable DOE contract requirements and environmental quality standards and (2) provide uninterrupted monitoring of the SNS site.

A total of seven springs, seeps, and surface water sampling points were routinely monitored as analogues to, and in lieu of, groundwater monitoring wells. Locations were chosen based on hydrogeological factors and proximity to the beam line. Figure 5.42 shows the locations of the specific monitoring points sampled during 2019.

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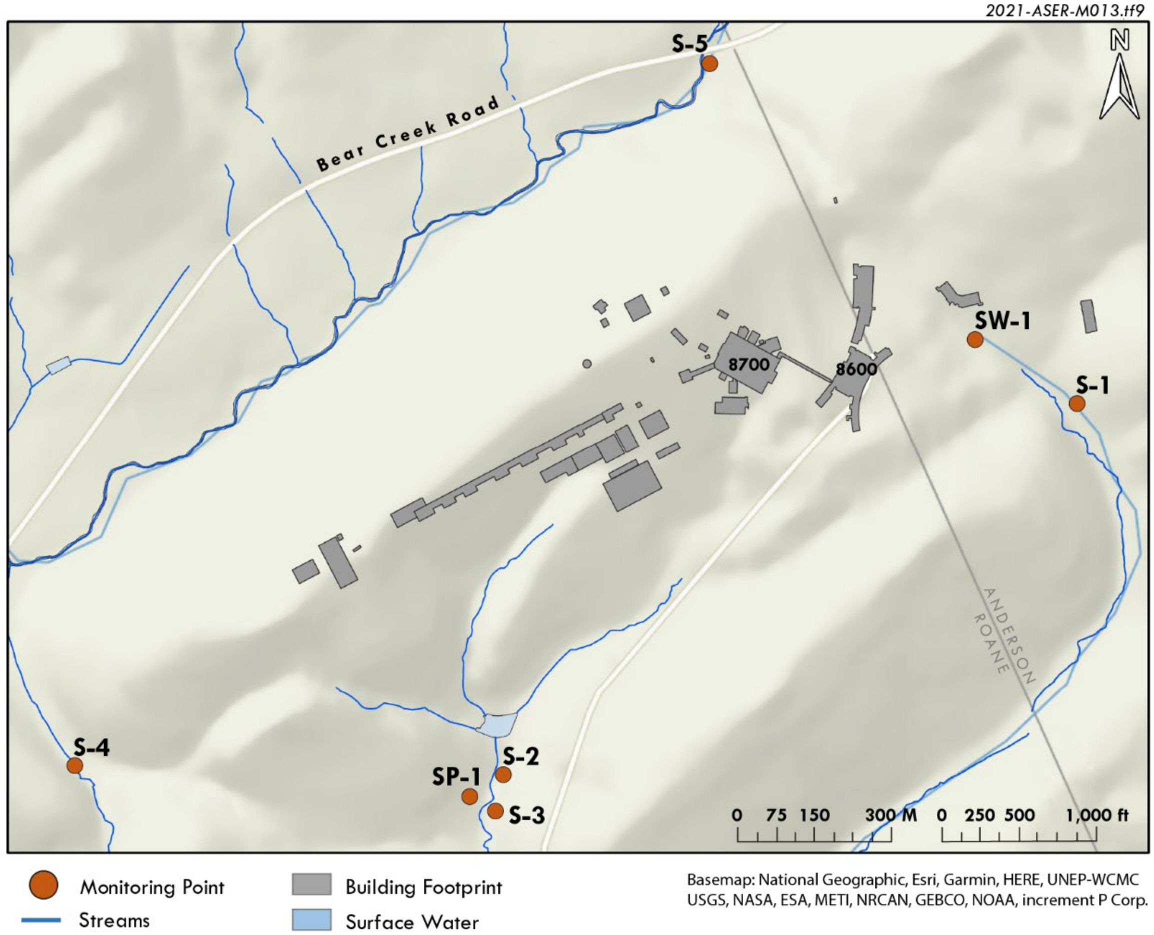

Acronyms: *S = springs SP = seeps SW = surface water sampling areas*

Figure 5.42. Groundwater monitoring locations at the Spallation Neutron Source, 2020

In November 2011 the SNS historical tritium data were evaluated to determine whether sampling could be optimized. The influence of flow condition on the proportion of tritium detects and nondetects in water samples collected at SNS from April 2004 through September 2011 was examined. In addition, the effect of seasonality on the proportion of detects and nondetects was examined for the same data set. The results of the analysis indicated that the proportion of detects to nondetects is not related to flow conditions or seasonality. This implies that samples could be collected during any flow condition and season with the expectation that there would be no statistical difference in the proportion of tritium detects to nondetects.

The results of the statistical analysis of the April 2004–September 2011 data set were the basis for the modified operational plan monitoring scheme implemented in 2012.

Quarterly sampling at each monitoring point continued in 2020, allowing the opportunity for monitoring in wet and dry seasons. All sampling performed in 2020 was performed in conjunction with rainfall events, with samples being collected during rising or falling (recession) limb flow conditions. In Figure 5.43, the curves represent spring or seep flow (base flow, through flow, overland flow, peak flow); the bars represent rainfall amounts. Table 5.17 shows the sampling and parameter analysis schedule followed in 2020.

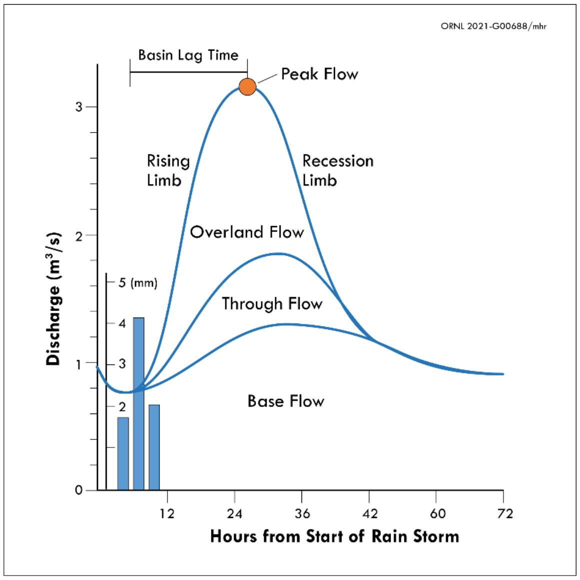

Figure 5.43. Simple hydrograph of spring discharge vs. time after initiation of rainfall

Spallation Neutron Source site results. Sampling at the SNS site occurred during each quarter in 2020. Low concentrations of several radionuclides were detected numerous times during 2020. The ^{214}Bi and ^{214}Pb are daughter radionuclides in the uranium decay series and are considered to be of natural origin in the SNS water samples because no man-made uranium sources are present at the site. The low values of alpha and beta activity detected at the S-5 monitoring location are attributed to CERCLA contaminants in Bear Creek Valley associated with legacy waste management practices at the Y-12 facility. Table 5.18 provides a summary of the locations for radionuclide detections observed during 2020.

Sampling results were compared with reference values. Reference values used for comparison are current federal or state standards or 4 percent of the DCS. No detected radionuclide exceeded its reference value at SNS monitoring locations in 2020.

Table 5.17. 2020 Spallation Neutron Source monitoring program schedule

Monitoring location	Quarter 1 January–March	Quarter 2 April–June	Quarter 3 July–September	Quarter 4 October–December
SW-1	Tritium	Tritium and expanded suite[a]	Tritium	Tritium
S-1	Tritium	Tritium and expanded suite[a]	Tritium	Tritium
S-2	Tritium	Tritium	Tritium and expanded suite[a]	Tritium
S-3	Tritium	Tritium	Tritium and expanded suite[a]	Tritium
S-4	Tritium	Tritium	Tritium	Tritium and expanded suite[a]
S-5	Tritium	Tritium	Tritium	Tritium and expanded suite[a]
SP-1	Tritium and expanded suite[a]	Tritium	Tritium	Tritium

[a] *The expanded suite includes gross alpha and gross beta activity, ^{14}C, and gamma emitters.*

Table 5.18. Radiological concentrations detected in samples collected at the Spallation Neutron Source during 2020[a]

Parameter	Concentrations (pCi/L)				Reference value[b]
	January	April	August	October	
			SW-1 [c]		
^{214}Bi		38.3			10,400
^{214}Pb		46.6			8,000
Tritium	627	3,240	1,870	381	20,000
			S-1 [c]		
^{214}Bi		21.4			10,400
Tritium	512	2,380	1,120	300	20,000
			S-2 [d]		
^{214}Bi			36.6		10,400
^{214}Pb			61.3		8,000
Tritium	515	399	1,340	795	20,000
			S-3 [d]		
^{214}Bi			52.1		10,400
^{214}Pb			71.1		8,000
Tritium	378	644	350	253	20,000
			S-4 [e]		
Beta				6.45	50
Tritium	290	596	477	180	20,000
			S-5 [e]		
Alpha				12.3	15
Beta				16.3	50
^{214}Bi				24.4	10,400
^{40}K				74.9	195
^{214}Pb				25.7	8,000
Tritium	274	535	478	255	20,000
			SP-1 [e]		
Alpha				6.02	15
Tritium	323	303	344	364	20,000

[a] *In addition to tritium analyses, analysis of an extended suite of parameters was completed at each location during one 2020 sampling event. The extended suite includes gross alpha, gross beta, gamma scan, and ^{14}C. Only detected concentrations from the extended suite are listed in the table.*

[b] *Current federal and state standards are used as reference values. If no federal or state standard exists for a particular radionuclide, 4 percent of the derived concentration standard for a radionuclide is used.*

[c] *Analysis of extended suite completed in April.*

[d] *Analysis of extended suite completed in August.*

[e] *Analysis of extended suite completed in October.*

5.6.2.4. Emerging Contaminant Assessment–Potential for Per- and Polyfluoroalkyl Substances in ORNL Area Groundwater

A group of fluorinated organic chemical compounds collectively referred to as per- and polyfluoroalkyl substances (PFASs) are contaminants of emerging concern. PFAS compounds are persistent in the environment, and some are known to bioaccumulate in humans and/or wildlife. They have been widely used in both consumer and industrial products, and traces have been detected in environmental media in many parts of the world.

Perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFOS) are the two PFAS compounds that have been produced in the largest amounts in the United States and that have received the most study. In May 2017, EPA established a drinking water health advisory of 70 µg/L of combined PFOA and PFOS, but EPA has not established an MCL for drinking water. Through 2001, PFOS and other PFAS compounds were used in the manufacture of aqueous film-forming foams (AFFFs), and use of such foams, including firefighting training activities, may have contributed to environmental releases. The information contained in this paragraph was summarized from EPA's *Technical Fact Sheet—Perfluorooctane Sulfonate (PFOS) and Perfluorooctanoic Acid (PFOA)* (EPA 2017).

Historically, training of firefighters at ORNL included training in the use of AFFFs, and it is believed that the foams that were used in past training activities contained PFAS compounds. It is suspected that discharges of these foams to the environment during the training activities are the most significant potential source of PFAS releases to the environment at ORNL. Most of the training was conducted at four locations: adjacent to the ORNL Fire Station (Building 2500), at the Fire Training and Test Facility (Building 2648), on the southeast corner of First Street and Bethel Valley Road (near where Building 2040 was later constructed), and at a location on the north side of Old Bethel Valley Road in the Bearden Creek watershed. In 2019, a sampling and analysis plan (SAP) was developed to assess these areas for the presence of PFAS compounds in groundwater and in surface water bodies draining these areas. The plan also includes monitoring of surface water locations draining other parts of the ORNL campus, including former waste storage areas, to determine if PFAS compounds from sources other than the use of AFFFs are present and are reaching surface water bodies. Surface water monitoring will include the use of passive sampling devices, which are deployed in stream environments for long periods of time (typically 4-week deployment periods) and which can accumulate PFAS compounds and allow the detection of trace concentrations that might not be detectable with traditional water sampling techniques. The sampling and analysis plan will be implemented in 2021.

Neither groundwater nor surface water at ORNL is a direct source of drinking water; ORNL's water supply is municipal water from the City of Oak Ridge.

5.7. Quality Assurance Program

The UT-Battelle Quality Management System (QMS) has been developed to implement the requirements defined in DOE Order 414.1D, Quality Assurance (DOE 2011d). The methods used for successful implementation of the QMS rely on the integration and implementation of quality elements/criteria flowed down through multiple management systems and daily operating processes. These management systems and processes are described in SBMS, where basic requirements are communicated to UT-Battelle staff. Additional or specific customer requirements are addressed at the project or work activity level. The QMS provides a graded approach to implementation based upon risk. The application of quality assurance (QA) and quality control (QC) programs specifically focused on environmental monitoring activities on ORR is essential for generating data of known and defensible quality. Each aspect of an environmental monitoring program from sample collection to data management and record keeping must address and meet applicable quality standards. The activities associated with administration, sampling, data management, and reporting for ORNL environmental programs are performed by the UT-Battelle Environmental Protection Services Division (EPSD).

UT-Battelle uses SBMS to provide a systematic approach for integrating QA, environmental, and safety considerations into every aspect of environmental monitoring at ORNL. SBMS is a web-based system that provides a single point of access to all the requirements for staff to safely and effectively perform work. SBMS translates laws, orders, directives, policies, and best-management practices into laboratory-wide subject areas and procedures.

5.7.1. Work/Project Planning and Control

UT-Battelle's work/project planning and control directives establish the processes and requirements for executing work activities at ORNL. All environmental sampling tasks are performed following the four steps required in the work control subject areas:

- Define scope of work.
- Perform work planning—analyze hazards and define controls.
- Execute work.
- Provide feedback.

In addition, EPSD has approved project-specific standard operating procedures for all activities controlled and maintained through the Integrated Document Management System.

Environmental sampling standard operating procedures developed for UT-Battelle environmental sampling programs provide detailed instructions on maintaining chain of custody; identifying, collecting, handling, and preserving samples; decontaminating equipment; and collecting QC samples such as field and trip blanks, duplicates, and equipment rinses.

5.7.2. Personnel Training and Qualifications

The UT-Battelle Training and Qualification Management System provides staff with the knowledge and skills necessary to perform their jobs safely, effectively, and efficiently with minimal supervision. The UT-Battelle Office of Technical Training is responsible for managing and integrating training activities, and it provides infrastructure of supporting systems and processes, including site-level procedures and guidance for training program implementation.

Likewise, the NWSol Training and Qualification program provides employees with the knowledge and skills necessary to perform their jobs safely, effectively, and efficiently with minimal supervision. This capability is accomplished by establishing site-level procedures and guidance for training program implementation with an infrastructure of supporting systems, services, and processes.

5.7.3. Equipment and Instrumentation

The UT-Battelle QMS includes subject area directives that require all UT-Battelle staff to use equipment of known accuracy based on appropriate calibration requirements and traceable standards to ensure measurement quality and traceability. The UT-Battelle Facilities and Operations Instrumentation and Control Services team tracks all equipment used in EPSD environmental monitoring programs through a maintenance recall program to ensure that equipment is functioning properly and within defined tolerance ranges.

5.7.3.1. Calibration

The determination of calibration schedules and frequencies is based on a graded approach at the activity planning level. EPSD environmental monitoring programs follow rigorous calibration schedules to eliminate gross drift and the need for data adjustments. Instrument tolerances, functions, ranges, and calibration frequencies are established based on manufacturer specifications, program requirements, actual operating environment and conditions, and budget considerations.

In addition, a continuous monitor used for CAA compliance monitoring at ORNL Boiler 6 is subject to rigorous QA protocols as specified by EPA methods. A relative accuracy test audit is performed annually to certify the Predictive Emissions Monitoring System for nitroxen oxides and oxygen. The purpose of a relative accuracy test audit is to provide a rigorous QA assessment in accordance with *Performance Specification 16* (40 CFR Parts 60 and 63.). The accuracy of Predictive Emissions Monitoring System is also evaluated by performing relative accuracy audits in accordance with *Performance Specification 16*. The results of the QA tests are provided to TDEC quarterly, semiannually, or annually as applicable.

5.7.3.2. Standardization

EPSD sampling procedures are maintained in Integrated Document Management System and include requirements and instructions for the proper standardization and use of monitoring equipment. Requirements include the use of traceable standards and measurements; performance of routine, before-use equipment standardizations; and actions to follow when standardization steps do not produce required values. Standard operating procedures for sampling also include instructions for designating nonconforming instruments as “out-of-service” and initiating requests for maintenance.

5.7.3.3. Visual Inspection, Housekeeping, and Grounds Maintenance

EPSD environmental sampling personnel conduct routine visual inspections of all sampling instrumentation and sampling locations. These inspections identify and address any safety, grounds keeping, general maintenance, and housekeeping issues or needs.

5.7.4. Assessment

Independent audits, surveillance, and internal management assessments are performed to verify that requirements have been accurately specified and that activities that have been performed conform to expectations and requirements. External assessments are scheduled based on requests from auditing agencies. Table 5.1 presents a list of environmental audits and assessments performed at ORNL in 2020 and information on the number of findings identified. EPSD also conducts internal assessments of UT-Battelle environmental monitoring activities. Surveillance results, recommendations, and completion of corrective actions, if required, are also documented and tracked in the UT-Battelle Assessment and Commitment Tracking System.

NWSol and Isotek perform independent audits, surveillances, and internal management assessments to verify that requirements have been accurately specified and that activities that have been performed conform to expectations and requirements. NWSol corrective actions, if required, are documented and tracked in an issues management database or a deficiency reporting database, and Isotek corrective actions are tracked in its Assessment and Commitment Tracking System.

5.7.5. Analytical Quality Assurance

Laboratories that perform analyses of environmental samples collected for EPSD environmental sampling programs are required to have documented QA/QC programs, trained and qualified staff, appropriately maintained equipment and facilities, and applicable certifications. As applicable, the laboratories also participate in accreditation, certification, and performance evaluation programs, such as the National Environmental Laboratory Accreditation Program (NELAP), Mixed Analyte Performance Evaluation Program (MAPEP), Discharge Monitoring Report Quality Assurance Study (DMRQA), and DOE Environmental Management Consolidated Audit Program (DOECAP). Any issues identified through accreditation/ certification programs or performance evaluation testing are addressed with analytical laboratories and are considered when determinations are made on data integrity. Blank and duplicate samples are submitted along with environmental samples to provide an additional check on analytical laboratory performance.

Analysis of environmental samples collected in support of EPSD environmental monitoring programs in 2020 were performed by either one of the three contracted commercial laboratories discussed below or by the UT-Battelle Radiochemical Materials Analytical Laboratory (RMAL) or the UT-Battelle Environmental Toxicology Laboratory. Contracts with analytical laboratories include statements of work that specify the scope of work, data deliverables, turnaround times, required methods, and detection limits. The laboratories are required to participate in third-party accreditation, certification, and approval programs, which evaluate laboratories according to stringent and widely accepted criteria for quality, accuracy, reliability, and efficiency.

GEL Laboratories, a contracted commercial radiochemistry and environmental laboratory in Charleston, South Carolina, holds more than 40 federal and state certifications, accreditations, and approvals, including ISO 17025 (general requirements for the competence of testing and calibration laboratories), Department of Defense Environmental Laboratory Accreditation Program (DOD-ELAP), DOECAP, and NELAP. No external audits were performed at GEL in 2020 due to social-distancing precautions implemented in response to COVID-19 concerns. Ten internal audits focusing on analytical and support service activities were conducted to verify compliance with the requirements of the GEL QA/QC program and with client-specified terms. No issues were identified that would negatively impact analytical data reported to clients. In 2020, GEL reported results from 5,476 performance test analyses (including DMRQA, MAPEP, DOECAP, and NELAP). Of these, 5,372 (98.1 percent) fell within acceptance ranges. Those that did not meet acceptance criteria were found to have no impact on data reported to clients.

ALS, a radiochemistry and environmental laboratory in Fort Collins, Colorado, is accredited, certified, or approved by 18 third-party programs including ISO 17025 (ISO 2017), NELAP. DOD-ELAP, DOECAP, and several state accrediting and licensing programs. In 2020, ALS was audited by the states of Arizona and California, and by a third party for DOECAP and DOD-ELAP certification. Several internal audits on adherence to methods and recordkeeping were also performed. There were no audit findings related to analyses or recordkeeping in support of EPSD environmental monitoring programs. ALS participated in 12 performance studies during 2020, and all applicable test results were in acceptable ranges.

Eurofins, a contracted environmental laboratory in Redmond, Washington, is accredited, licensed, or approved by 20 third-party programs, including ISO 17025, DOD-ELAP, DOECAP, NELAP, and several state licensing or accrediting programs. In November 2020, Eurofins was audited by the American National Standards Institute's National Accreditation Auditing Board and was recertified by DOECAP and DOD-ELAP. In addition, multiple internal system and method audits were conducted during the year. No audit findings required data corrections or repeated analyses of samples. In 2020, Eurofins participated in MAPEP and DMRQA, and all applicable test results were within acceptable ranges.

RMAL does not hold any outside accreditations. However, the laboratory operates in compliance with ISO-17025 (ISO 2017), *DOD/DOE Consolidated Quality Systems Manual* (DOD/DOE 2018), and requirements from DOE 414.1D (DOE 2011d) and 10 CFR 830 Subpart A, *Quality Assurance Requirements*. The UT-Battelle Chemical Sciences Division's quality assurance plan also meets applicable requirements of the American Society of Mechanical Engineers' Nuclear Quality Assurance Program. No external audits of RMAL activities were conducted in 2020, but 12 internal assessments that were focused on adherence to approved analytical methods, waste management, and recordkeeping were performed. No issues that would require reanalysis or data corrections related to environmental sampling results were identified. In 2020, RMAL participated in MAPEP and DMRQA, and all test results for analyses that RMAL performs in support in EPSD environmental monitoring programs were within acceptable ranges. Several analytes that were analyzed by RMAL for MAPEP testing were inadvertently not reported. Based on MAPEP acceptable ranges for that study, the unreported results were all within limits.

The Environmental Toxicology Laboratory does not hold any outside accreditations, but it operates in compliance with all EPA, TDEC, and NPDES required methods and the UT-Battelle Environmental Sciences Division's Quality Assurance Management Program. No external audits of the Environmental Toxicology Laboratory were conducted in 2020, but six internal assessments focused on adherence to approved analytical methods and data analysis were performed. No issues that would require reanalysis or data corrections related to standard toxicity testing results were identified. In addition, updates of all of the standard operating procedures, reference toxicity control charts, and training requirements in were completed in 2020. All standard operating procedures and lab methods comply with EPA's acute and chronic testing requirements for freshwater species (EPA 2002a and EPA 2002b, respectively). In 2020, the Environmental Toxicology Laboratory participated in the DRMQA program for whole effluent toxicity testing of *Pimephales promelas* (fathead minnow, a freshwater fish) and *Ceriodaphnia dubia* (water flea, a freshwater invertebrate). All results were in acceptable ranges for fathead minnows but a second test was required for *Ceriodaphnia dubia*. The results of the second test, conducted in December 2020, were acceptable.

5.7.6. Data Management and Reporting

Management of data collected by UT-Battelle in conjunction with ORR and ORNL environmental surveillance programs and with CWA activities at ORNL is accomplished using the Environmental Surveillance System (ESS), a web interface data management tool. A software QA plan for ESS has been developed to document ESS user access rules; verification and validation methods; configuration and change management rules; release history; software registration information; and the employed methods, standards, practices, and tools.

Field measurements and sample information are entered into ESS, and an independent verification is performed on all records to ensure accurate data entry. Sample results and associated information are loaded into ESS from electronic files provided by analytical laboratories. An automated screening is performed to ensure that all required analyses were performed, appropriate analytical methods were used, holding times were met, and specified detection levels were achieved.

Following the screening, a series of checks is performed to determine whether results are consistent with expected outcomes and historical data. QC sample results (i.e., blanks and duplicates) are reviewed to check for potential sample contamination and to confirm repeatability of analytical methods within required limits. More in-depth investigations are conducted to explain results that are questionable or problematic.

ORNL radiological airborne effluent monitoring data are managed using the Rad-NESHAPs Inventory Web Application and the Rad-NESHAPs Source Data Application. Field measurements, analytical data inputs, and emission calculations results are independently verified.

5.7.7. Records Management

The UT-Battelle Requirements, Documents, and Records Management System provides the requirements for managing all UT-Battelle records. Requirements include creating, maintaining and using records; scheduling, protecting, and storing records in office areas and in the UT-Battelle Inactive Records Center; and destroying records.

NWSol and Isotek maintain all records specific to their projects at ORNL, and associated records management programs include the requirements for creating and identifying record material, protecting and storing records in applicable areas, and destroying records.

5.8. Environmental Management and Waste Management Activities at ORNL

The three campuses on ORR have a rich history of research, innovation, and scientific discovery that shaped the course of the world. Unfortunately, today, despite their vitally important missions, they are hindered by environmental legacies remaining from past operations. The contaminated portions of ORR are on the EPA National Priorities List, which includes hazardous waste sites across the nation that are to be cleaned up under CERCLA. Areas that require cleanup or further action on ORR have been clearly defined, and OREM is working to clean those areas under the Federal Facility Agreement with the EPA and TDEC. The *2020 Cleanup Progress Annual Report to the Oak Ridge Regional Community* (UCOR 2020) provides detailed information on DOE OREM's 2020 cleanup activities.

5.8.1. Wastewater Treatment

At ORNL, DOE OREM operates PWTC and the Liquid Low-Level Waste Treatment Facility. In 2020, 347.5 million L of wastewater were treated and released at PWTC. In addition, the liquid LLW system at ORNL received 141,676 L of waste. The waste treatment activities of these facilities support both DOE OREM and DOE SC mission activities, ensuring that wastewaters from activities associated with projects of both offices are managed in a safe and compliant manner.

5.8.2. Newly Generated Waste Management

ORNL is the largest, most diverse DOE SC laboratory in the DOE complex. Although much effort is expended to prevent pollution and to eliminate waste generation, some waste streams are generated as a by-product of performing research and operational activities and must be managed to ensure that the environment is protected from associated hazards. As the prime contractor for the management of ORNL, UT-Battelle is responsible for management of most of the wastes generated from R&D activities and wastes generated from operation of the R&D facilities. Waste streams that can be treated by on-site liquid and/or gaseous waste treatment facilities operated by OREM are treated via these systems. Other R&D waste streams are generally packaged by UT-Battelle in appropriate shipping containers for off-site transport to commercial waste-processing facilities. In 2020, ORNL performed 91 waste and recycle shipments to off-site hazardous/radiological/mixed waste treatment and/or disposal vendors with no shipment rejections.

5.8.3. Transuranic Waste Processing Center

TRU waste-processing activities carried out for DOE in 2020 by NWSol addressed contact-handled solids/debris and remotely handled solids/debris, which involved processing, treating, and repackaging of waste. In 2020, LLW/mixed LLW was transported to the Nevada National Security Site or to another approved offsite facility for disposal. TRU waste disposal at the Waste Isolation Pilot Plant resumed in 2017. In 2020, NWSol shipped 7.4 m^3 of contact-handled TRU waste from TWPC in 1 shipment (35 containers).

During 2020, 6.5 m^3 of contact-handled waste and 0.2 m^3 of remotely handled waste were processed, and 35.7 m^3 of mixed LLW (TRU waste that was recharacterized as LLW) was shipped off the site.

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Members of the public could be exposed to contaminants originating from the ORR through consumption of fish caught in area waters. To characterize this exposure pathway, fish are collected annually from three locations on the Clinch River and edible flesh are analyzed for specific contaminants. Photograph by Carlos Jones.

6

Oak Ridge Reservation Environmental Monitoring Program

ORR environmental surveillance is conducted to comply with DOE requirements to protect the public and the environment against undue risks associated with activities carried out by DOE. These requirements are established in DOE O 458.1, *Radiation Protection of the Public and the Environment* (DOE 2020a), and related guidance is provided in DOE-HDBK-1216-2015, *Radiological Environmental Effluent Monitoring and Environmental Surveillance* (DOE 2015). The objective of the ORR environmental surveillance program is to characterize environmental conditions in areas outside the ORR facility boundaries, both on and off ORR.

In 2020, sampling and monitoring activities associated with some ORR environmental surveillance programs were scaled down or cancelled due to social-distancing precautions taken in response to the COVID-19 pandemic. Deer and turkey hunts are typically conducted on ORR each year, and muscle and bone samples are obtained to calculate doses to hunters. The ORR hunts were cancelled in 2020 but are expected to resume in 2021. Vegetable samples from home gardens near ORR are collected to enable estimating radiological doses to members of the public from consuming crops raised near ORR. In 2020, sampling was limited to one crop. As more people are vaccinated, and the rates of new COVID-19 cases decline, vegetable sampling is expected to be expanded to include three crops, depending on availability. ORR surveillance programs are not required by federal or state regulations, and there are no compliance issues related to the COVID-19 precautions taken in 2020.

6.1. Meteorological Monitoring

Ten meteorological towers provide data on meteorological conditions and on the transport and diffusion qualities of the atmosphere on ORR. Data collected at the towers are used in routine dispersion modeling to predict impacts from facility operations and as input to emergency response atmospheric models, which are used for simulated and actual accidental releases from a facility. Data from the towers are also used to support various research and engineering projects.

6.1.1. Data Collection and Analysis

The 10 meteorological towers on ORR are described in Table 6.1 and are depicted in Figure 6.1. In this document, the individual ORR-managed towers are designated by “MT” followed by a numeral. Other commonly used names for these sites are also provided in Table 6.1. Meteorological data are collected at different levels above the ground (2, 10, 15, 30, 33, 35, and 60 m) to assess the vertical structure of the atmosphere, particularly with respect to wind shear and stability. Stable boundary layers and significant wind shear zones (associated with the local ridge-and-valley terrain and the Great Valley of Eastern Tennessee; see Appendix B) can significantly affect the movement of a plume after a facility release (Bowen et al. 2000). Data are collected at the 10 or 15 m level at most towers, but the wind measurement height is 25 m for MT11 and 20 m for MT13. Data are collected at some towers at 30, 33, 35, and 60 m levels. Temperature, relative humidity, and precipitation are measured at some sites at 2 m, but wind speed and wind direction typically are not. Atmospheric stability (a measure of the vertical mixing properties of the atmosphere) is measured at most towers; however, measurements involving vertical temperature profiles (i.e., measurements made by the solar radiation delta-T method) limit accurate determination of nighttime stability to the 60 m towers. Stability is also calculated for most sites using the sigma phi method, which relies heavily on the measurement of the standard deviation of vertical wind speed using three-dimensional sonic wind monitors. Barometric pressure is measured at one or more of the towers at each ORR plant (MT2, MT4, MT6, MT7, MT9, MT12, and MT13). Precipitation is measured at MT6 and MT9 at the Y-12 Complex; at MT7 and MT13 at ETTP; and at MT2, MT3, MT4, and MT12 at ORNL. Solar radiation is measured at MT6 and MT9 at the Y-12 Complex, MT7 at ETTP, and at MT2 and MT12 at ORNL. Instrument calibrations are managed by UT-Battelle and are performed every 6 months by an independent auditor (Holian Environmental). Additionally, Holian Environmental audits the Y-12-owned sites every 3 months (MT6, MT9, MT11).

Sonic detection and ranging (SODAR) devices have been installed at the east end of the Y-12 Complex (Pine Ridge) and adjacent to Tower MT2 at ORNL. The SODAR devices use acoustic waves to estimate wind direction, wind speed, and turbulence at altitudes higher than the reach of meteorological towers (40 m up to 800 m above ground level). Although SODAR measurements are somewhat less accurate than measurements made on the meteorological towers, the SODAR devices provide useful information regarding stability, upper air winds, and mixing depth. Mixing depth represents the thickness of the air layer adjacent to the ground over which an emitted or entrained inert nonbuoyant tracer could potentially be mixed by turbulence within 1 h or less.

Meteorological data are collected in real time for 1 min, 15 min, and hourly average intervals for emergency response purposes and for dispersion modeling at the ORNL and Y-12 Complex Emergency Operations Centers.

Annual dose estimates are calculated from the archived hourly data. Data quality is checked continuously against predetermined data constraints, and out-of-range parameters are marked as invalid and are excluded from compliance modeling. Appropriate substitution data are identified when possible. Quality assurance records of missing and erroneous data are routinely kept for the 10 ORR towers.

Table 6.1. ORR meteorological towers

Tower	Alternate tower names	Location (latitude, longitude)	Altitude (meters above MSL)	Measurement heights (meters)
		ETTP		
MT7	L, 1209	35.92522N, -84.39414W	233	2, 15, 30
MT13	J, YEOC	35.93043N, -84.39346W	237	20
		ORNL		
MT2	D,[a] 1047	35.92559N, -84.32379W	261	2, 15, 35, 60
MT3	B, 6555	35.93273N, -84.30254W	256	15, 30
MT4	A, 7571	35.92185N, -84.30470W	266	15, 30
MT10	M, 208A	35.90947N, -84.38796W	244	10
MT12	F	35.95285N, -84.30314W	354	10
		Y-12 Complex		
MT6	W, West	35.98058N, -84.27358W	326	2, 10, 30, 60
MT9	Y, PSS Tower	35.98745N, -84.25363W	290	2, 15, 33
MT11	S, South Tower	35.98190N, -84.25504W	352	25

[a] *Tower "C" before May 2014.*

Acronyms:

ETTP = East Tennessee Technology Park
MSL = mean sea level
ORNL = Oak Ridge National Laboratory
PSS = plant shift superintendent
Y-12 Complex = Y-12 National Security Complex
YEOC = Y-12 Complex Emergency Operations Center

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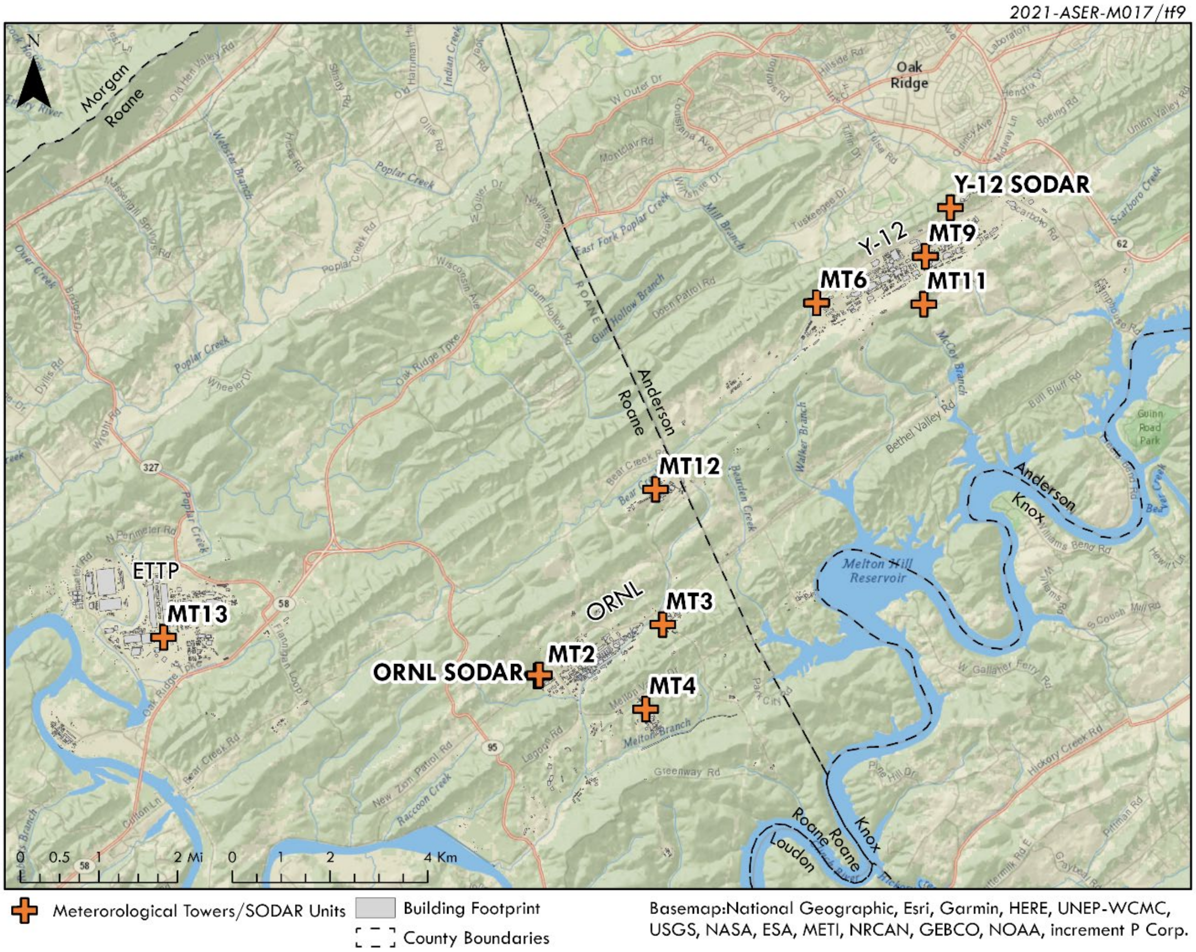


Figure 6.1. The ORR meteorological monitoring network, including sonic detection and ranging (SODAR) devices

6.1.2. Results

Prevailing winds are generally up-valley from the southwest and west-southwest or down-valley from the northeast and east-northeast, a pattern that typically results from channeling effects produced by the parallel ridges flanking the ORR sites. Winds in the valleys tend to follow the ridge axes, limiting cross-ridge flow within local valley bottoms. These conditions dominate over most of ORR, but flow variation is greater at ETTP, which is located within a less-constrained open valley bottom.

On ORR, low wind speeds dominate near the valley surfaces, largely because of the decelerating influence of nearby ridges and mountains. Wind acceleration sometimes is observed at ridgetop level, particularly when flow is not parallel to the ridges (see Appendix B).

The atmosphere over ORR is often dominated by stable conditions at night and for a few hours after sunrise. These conditions, when coupled with low wind speeds and channeling effects in the valleys, result in poor dilution of emissions from the facilities. However, high roughness values (caused by terrain and obstructions such as trees and buildings) may significantly mitigate these factors through an increase in turbulence (atmospheric mixing). These features are captured in dispersion model data input and are reflected in modeling studies conducted for each facility.

Precipitation data from tower MT2 are used in stream-flow modeling and in certain research efforts. The data indicate the variability of regional precipitation: the high winter rainfall resulting from frontal systems and the uneven, but occasionally intense, summer rainfall associated with frequent air mass thunderstorms. The total precipitation at ORNL during 2020 (1,705.4 mm or 67.12 in.) was almost 25 percent above the long-term 1991–2020 average of 1,372.0 mm (54.00 in.). The average annual wind data recovery rates (a measure of acceptable data) across locations used for modeling during 2020 were greater than 99.4 percent for wind sensors at ORNL sites MT2, MT3, MT4, MT10, and MT12. Annual wind data recovery from Y-12 meteorological towers during 2020 exceeded 95.4 percent (towers MT6, MT9, and MT11). At ETTP, annual wind data recovery exceeded 99.8%.

6.2. Ambient Air Monitoring

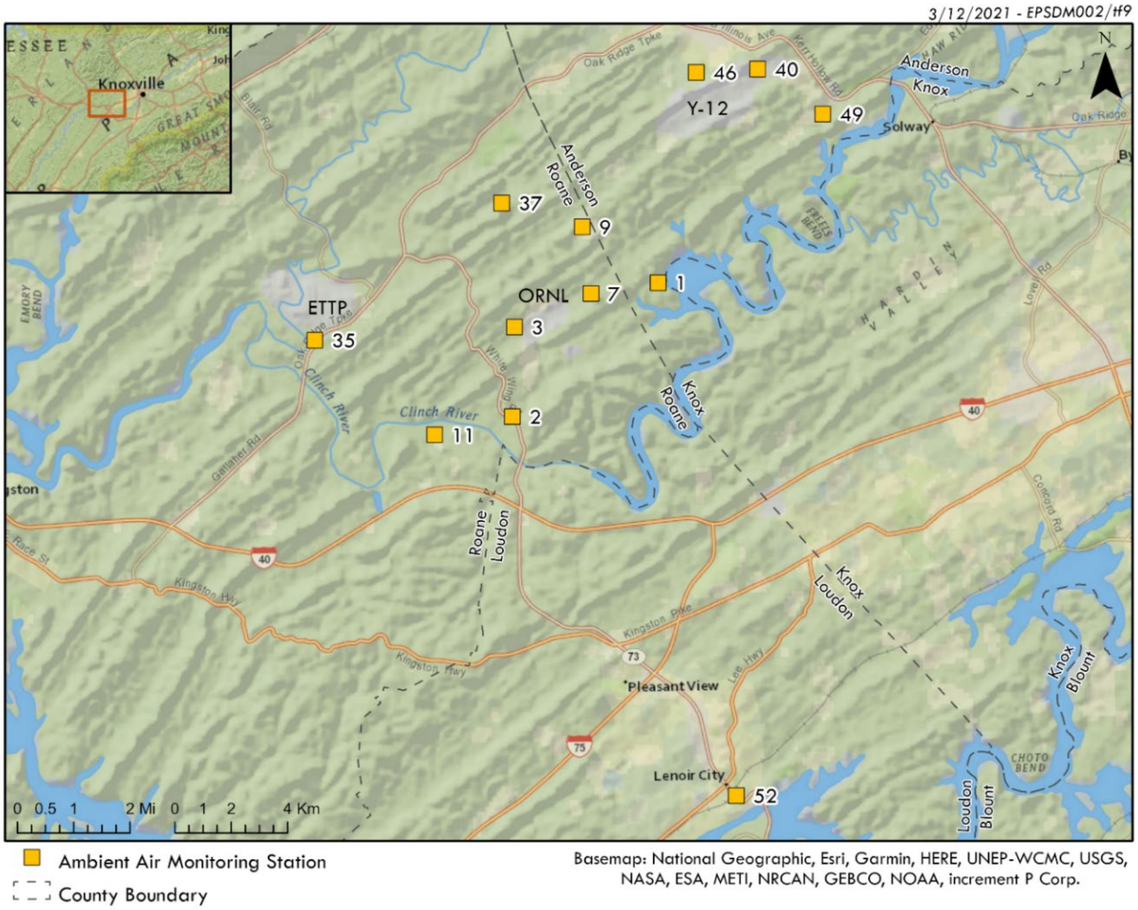
In addition to exhaust stack monitoring conducted at ORR installations (see chapters 3, 4, and 5), ambient air monitoring is performed to measure radiological parameters directly in the ambient air adjacent to the facilities (Figure 6.2). Ambient air monitoring provides a means to verify that contributions of fugitive and diffuse sources are insignificant, serves as a check on dose-modeling calculations, and would allow determination of contaminant levels at monitoring locations in the event of an emergency.

Figure 6.2. ORR ambient air station

6.2.1. Data Collection and Analysis

Ambient air monitoring conducted by individual site programs is discussed in chapters 3, 4, and 5. The ORR ambient air monitoring program complements the individual site programs and permits the impacts of ORR operations to be assessed on an integrated basis.

The objectives of the ORR ambient air monitoring program are to perform surveillance of airborne radionuclides at the reservation perimeter and to collect reference data from a location not affected by activities on ORR. The perimeter air monitoring network was established in the early 1990s and was modified in 2016 to reflect changes in DOE activities and operations that had occurred since the 1990s. The stations monitored in 2020 are shown in Figure 6.3. Reference samples are collected at Station 52 (Fort Loudoun Dam). Sampling was conducted at each ORR station during 2020 to quantify levels of alpha-, beta-, and gamma-emitting radionuclides.



Notes:
1. Reference samples are collected at Station 52 (Fort Loudoun Dam).
2. Station 7 is an ORNL site-specific monitoring location and is not part of the ORR perimeter network.

Figure 6.3. Locations of ORR perimeter air monitoring stations

Atmospheric dispersion modeling was used to select appropriate sampling locations. The locations selected are those likely to be affected most by releases from the Oak Ridge facilities. Therefore, in the event of a release, no residence or business near ORR should receive a radiation dose greater than doses calculated at the sampled locations.

The sampling system consists of two separate instruments. Particulates are captured by high-volume air samplers equipped with glass-fiber filters. The filters are collected weekly, composited quarterly, and then submitted to an analytical laboratory to quantify gross alpha and beta activity and to determine the concentrations of specific isotopes of interest on ORR. The second system is designed to collect tritiated water vapor. The sampler consists of a prefilter followed by an adsorbent trap that contains indicating silica gel. The samples are collected weekly or biweekly, composited quarterly, and then submitted to an analytical laboratory for tritium analysis.

6.2.2. Results

Data from the ORR ambient air network are analyzed to assess the impact of DOE operations on the local air quality. Each measured radionuclide concentration (Table 6.2) is compared with derived concentration standards (DCSs) for air established by DOE as guidelines for controlling exposure to members of the public (DOE 2011). All radionuclide concentrations measured at the ORR ambient air stations during 2020 were less than 1 percent of applicable DCSs.

Table 6.2. Radionuclide concentrations at ORR perimeter air monitoring stations, 2020

Station	Average concentration (pCi/mL)[a] (Number detects/n)						
	^{7}Be	^{40}K	^{3}H	^{234}U	^{235}U	^{238}U	^{99}Tc
01	4.24E-08 (4/4)	4.61E-10 (0/4)	1.98E-06 (0/4)	2.06E-12 (4/4)	2.44E-13 (1/4)	1.72E-12 (4/4)	
02	3.61E-08 (4/4)	2.11E-10 (0/4)	4.08E-06 (0/4)	1.73E-12 (4/4)	1.36E-13 (0/4)	1.20E-12 (3/4)	
03[b]	4.00E-08 (4/4)	-5.83E-11[c] (0/4)	4.66E-06 (0/4)	2.20E-12 (4/4)	2.88E-13 (2/4)	1.64E-12 (4/4)	
09	4.29E-08 (4/4)	2.55E-10 (0/4)	3.09E-05 (3/4)	3.67E-12 (4/4)	2.78E-13 (1/4)	1.82E-12 (4/4)	
11	4.20E-08 (4/4)	9.89E-11 (0/4)	2.16E-06 (0/4)	1.74E-12 (4/4)	2.70E-14 (0/4)	1.13E-12 (3/4)	
35	3.60E-08 (4/4)	-6.71E-12[c] (0/4)	4.25E-06 (1/4)	1.71E-12 (4/4)	1.60E-13 (1/4)	1.52E-12 (4/4)	-2.32E-11[c] (0/4)
37	3.60E-08 (4/4)	-6.08E-13[c] (0/4)	2.51E-06 (1/4)	2.31E-12 (4/4)	2.93E-13 (1/4)	1.19E-12 (4/4)	
40	4.27E-08 (4/4)	2.52E-10 (0/4)	3.93E-06 (0/4)	9.93E-12 (4/4)	8.09E-13 (3/4)	2.76E-12 (4/4)	
46	3.75E-08 (4/4)	-1.55E-10[c] (0/4)	-2.28E-07[c] (0/4)	5.18E-12 (4/4)	4.46E-13 (3/4)	1.69E-12 (4/4)	
49	3.84E-08 (4/4)	-5.10E-10[c] (0/4)	2.51E-06 (0/4)	2.32E-12 (4/4)	1.45E-13 (0/4)	1.57E-12 (4/4)	
52[d]	3.98E-08 (4/4)	5.48E-10 (1/4)	7.48E-07 (0/4)	1.70E-12 (4/4)	1.10E-13 (0/4)	1.45E-12 (4/4)	-3.09E-11[c] (0/4)

[a] 1 pCi = 3.7 × 10^{-2} Bq.

[b] An additional radionuclide, ^{124}Sb, was detected at Station 03 in the second quarter of 2020 with a concentration of 2.36E-10 pCi/mL. The ^{124}Sb radionuclide was not detected and not reported in the other quarters.

[c] A negative concentration of radioactivity is reported by the laboratory when the sample count rate minus the background count rate is negative (i.e., the background count rate was greater than the sample count rate). When the background activity is subtracted from the sample activity to obtain a net value, a negative value results.

[d] Station 52 is the reference location.

6.3. External Gamma Radiation Monitoring

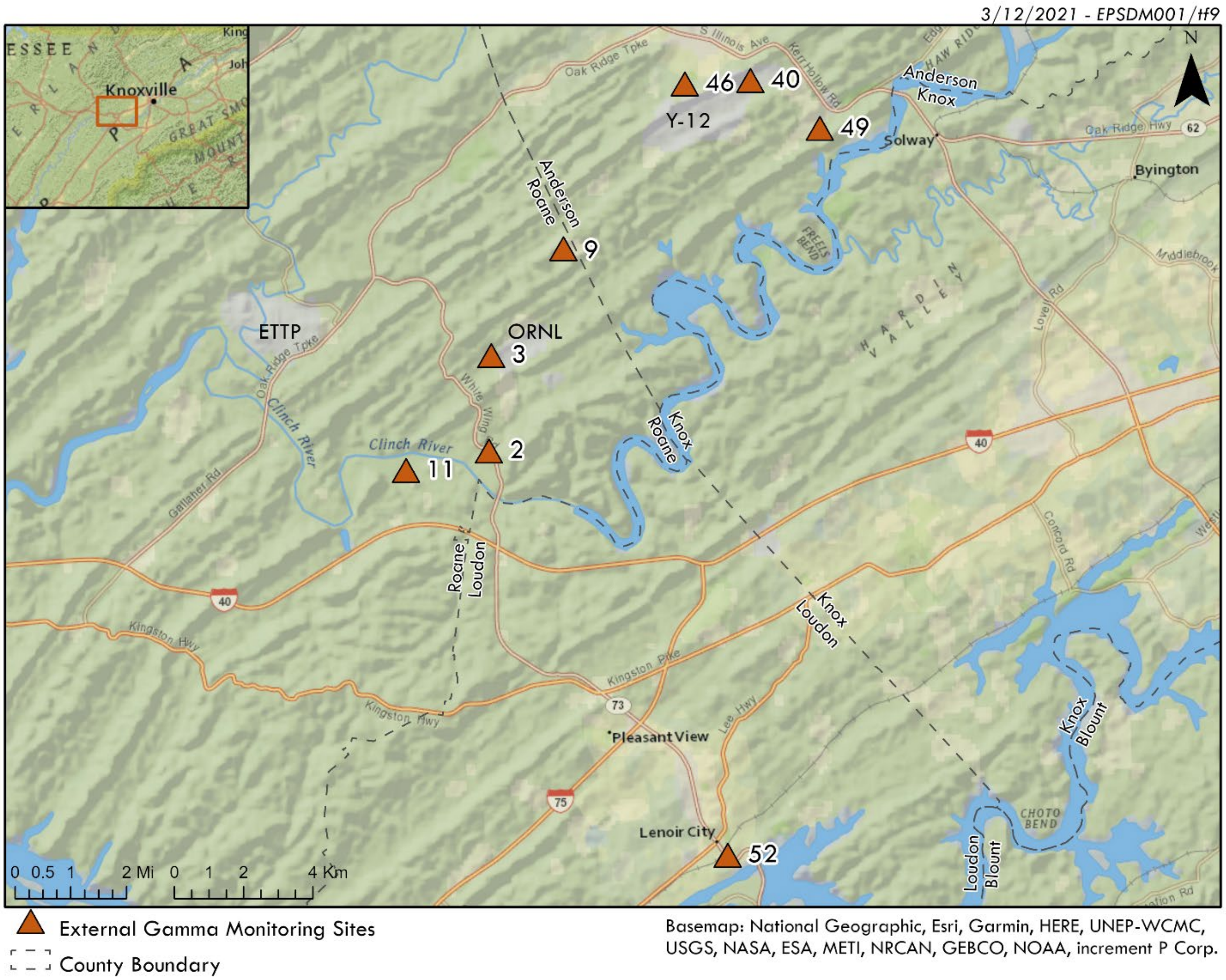
Members of the public could hypothetically be exposed directly to gamma radiation from radionuclides released into the environment, previously released radionuclides deposited on soil and vegetation or in sediments, radiation-generating facilities, especially high-energy accelerators, and the storage of radioactive materials (DOE 2021a). Continuous direct radiation levels are monitored at locations around ORR to complement the sample data collected as part of the ORR ambient air monitoring program (see Section 6.2). Unlike the quantified filter and silica gel results for a range of radionuclides obtained by the ambient air monitoring program, external gamma radiation is monitored continuously; data are logged at 1 min intervals and averaged for the entire year.

6.3.1. Data Collection and Analysis

External gamma exposure rates are continuously recorded by dual-range Geiger-Müller tube detectors co-located with ORR ambient air stations (see Section 6.2). Dose rates are recorded by the instruments every minute, and the data are downloaded weekly. Figure 6.4 shows locations that were monitored during 2020; Table 6.3 summarizes the data for each station.

6.3.2. Results

The mean exposure rate for the reservation network in 2020 was 9.7 μR/h, and the mean rate at the reference location (Fort Loudoun Dam) was 8.9 μR/h. Background direct radiation exposure rates have been collected at the Fort Loudoun Dam (Station 52) reference location for many years. From 2010 through 2019 (the preceding 10 years), the exposure rates at the reference location ranged from 6.3 to 11.4 μR/h and averaged 8.4 μR/h (rounded to 8 μR/h).



Notes:
1. Reference samples are collected at Station 52 (Fort Loudoun Dam).
2. Station 7 is an ORNL site-specific monitoring location and is not part of the ORR perimeter network.

Figure 6.4. External gamma radiation monitoring locations on ORR

Table 6.3. External gamma exposure rate averages for ORR, 2020

Air station number	Number of data points (daily)	Measurement (μR/h)[a]		
		Min	Max	Mean
02	364	8.4	11.0	9.1
03	366	8.9	11.3	9.4
09	366	8.4	12.1	9.4
11	360	9.5	12.7	10.4
40	366	8.9	11.6	9.8
46	360	9.9	12.0	10.6
49	366	8.9	12.1	9.6
52	361	8.1	10.8	8.9

[a] *To convert microroentgens per hour (μR/h) to milliroentgens per year, multiply by 8.760.*

6.4. Surface Water Monitoring

The ORR surface water monitoring program consists of sample collection and analysis from four locations on the Clinch River, including public water intakes (Figure 6.5). The program is conducted in conjunction with site-specific surface water monitoring activities to enable an assessment of the impacts of past and current DOE operations on the quality of local surface water.

6.4.1. Data Collection and Analysis

Grab samples are collected quarterly at all four locations and are analyzed for general water quality parameters, screened for radioactivity, and analyzed for mercury and specific radionuclides when appropriate. Table 6.4 lists the specific locations and associated sampling frequencies and parameters.

At the sampling locations, the Clinch River is classified by the State of Tennessee for multiple uses, including recreation and domestic supply. These two designated uses have numeric Tennessee Water Quality Criteria (WQCs) related to protection of human health. These WQCs are used as references where applicable (TDEC 2014). The Tennessee WQCs do not include criteria for radionuclides. Four percent of the DOE DCS is used for radionuclide comparison.

6.4.2. Results

In 2020, as has been the case since 2009, there were no statistical differences in radionuclide concentrations in surface water samples collected from the Clinch River upstream and downstream of DOE inputs. No radionuclides were detected above 4 percent of the respective DCSs.

Mercury was not detected in 2020 in samples from any of the three sampling locations where mercury samples are collected, Clinch River kilometer (CRK) 66, CRK 32, and CRK 16.

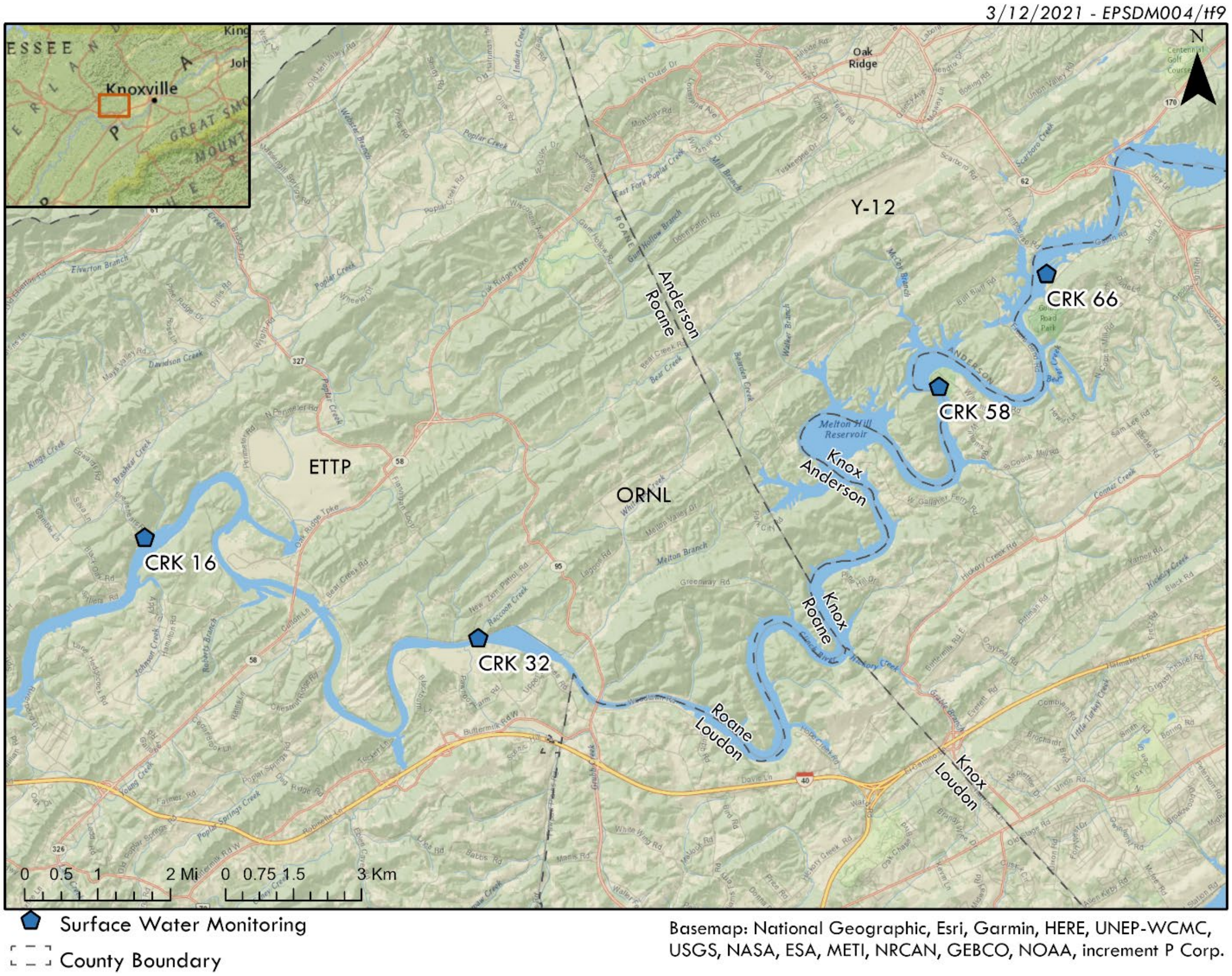


Figure 6.5. ORR surface water surveillance sampling locations

Table 6.4. ORR surface water sampling locations, frequencies, and parameters, 2020

Location[a]	Description	Frequency	Parameters
CRK 16	Clinch River downstream from all DOE ORR inputs	Quarterly	Mercury, gross alpha, gross beta, gamma scan, ^{3}H, field measurements[b]
CRK 32	Clinch River downstream from ORNL	Quarterly	Mercury, gross alpha, gross beta, gamma scan, total radioactive strontium, ^{3}H, field measurements[b]
CRK 58	Water supply intake for Knox County	Quarterly	Gross alpha, gross beta, gamma scan, ^{3}H, field measurements[b]
CRK 66	Melton Hill Reservoir above City of Oak Ridge water intake	Quarterly	Mercury, gross alpha, gross beta, gamma scan, total radioactive strontium, ^{3}H, field measurements[b]

[a] *Locations indicate the water body and distances upstream of the confluence of the Clinch and Tennessee Rivers (e.g., CRK 16 is 16 km upstream from the confluence of the Clinch River with the Tennessee River in the Watts Bar Reservoir).*

[b] *Field measurements consist of dissolved oxygen, pH, and temperature.*

Acronyms:

CRK = Clinch River kilometer
DOE = US Department of Energy
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation

6.5. Groundwater Monitoring

Work continued in 2020 to implement key recommendations from the *Groundwater Strategy for the U.S. Department of Energy Oak Ridge Reservation* (DOE 2013), which was agreed to in 2014 by DOE, EPA, and the Tennessee Department of Environment and Conservation (TDEC). During 2020 the ORR Groundwater Program transitioned from previous tasks, including off-site groundwater quality assessment and regional-scale groundwater flow model development, to planning continued off-site monitoring and development of site-scale groundwater flow models for the ORNL site.

6.5.1. Off-Site Groundwater Assessment

During FY 2020 the Oak Ridge Office of Environmental Management (OREM) continued to collect and analyze samples from the off-site groundwater monitoring well array west of the Clinch River adjacent to Melton Valley. In addition, exit pathway groundwater monitoring in Melton Valley is conducted as part of the OREM program, including sampling at six multiport monitoring wells in western Melton Valley (wells 4537, 4538, 4539, 4540, 4541, and 4542). Results of this monitoring are summarized in the 2020 remediation effectiveness report (DOE 2020b).

DOE completed an off-site groundwater assessment project and issued a final report on the off-site groundwater study in October 2017 (DOE 2017). The project was a cooperative effort among the parties to the ORR Federal Facility Agreement to investigate off-site groundwater quality and potential movement. As follow-on work from the off-site groundwater assessment, DOE conducts annual sampling and analysis of groundwater from several off-site residential wells and springs.

6.5.2. Regional and Site-Scale Flow Model

During FY 2017 DOE completed a project to construct and calibrate a regional-scale groundwater flow model that encompasses ORR and adjacent areas. The regional model provides an underlying framework to support creation of smaller, site-scale groundwater flow models for use in planning and monitoring effectiveness of future cleanup decisions and actions. During FY 2020 DOE developed more refined groundwater flow models for the ORNL site to support the *Phased Groundwater Remedial Investigation Work Plan for the Bethel Valley Final Groundwater Record of Decision* (DOE 2021b). The new models can be used for evaluating groundwater contaminant migration in the vicinity of Bethel and Melton Valleys.

6.6. Food

Food sources are analyzed to evaluate potential radiation doses to consumers of local food crops, fish, and harvested game and to monitor trends in environmental contamination and possible long-term accumulation of radionuclides. Samples of hay, vegetables, milk, fish, deer, Canada geese, and turkeys are usually collected every year from areas that could be affected by activities on the reservation and from off-site reference locations. Milk was not collected in 2020 because no dairies in potential ORR deposition areas were located. Surveys are conducted annually to determine if any dairies are operating in areas of interest.

The wildlife administrative release limits associated with deer, turkey, and geese harvested on ORR are conservative and were established based on the "as low as reasonably achievable" principle to ensure that doses to consumers are managed at levels well below regulatory dose thresholds. The as-low-as-reasonably-achievable concept is not a dose limit but rather a philosophy that has the objective of maintaining exposures to workers, members of the public, and the environment below regulatory limits and as low as can be reasonably achieved. An administrative release limit of 5 pCi/g ^{137}Cs is based on the assumption that one person consumes all of the meat from a maximum-weight deer, goose, or turkey. This limit ensures that members of the public who harvest wildlife on the reservation will not receive significant radionuclide doses from that consumption pathway. In addition, a conservative administrative limit of 1.5 times background for gross beta activity has been established, a threshold that is near the detection limit for field measurements of $^{89/90}$Sr in deer leg bone.

6.6.1. Hay

Hay from an area on the eastern edge of ORR is made available to an off-site farming operation and is sampled annually. Eating beef and drinking milk obtained from cattle that eat hay is a potential radiation exposure pathway to humans, and hay is sampled to characterize any possible doses from this pathway.

6.6.1.1. Data Collection and Analysis

Hay is collected and analyzed from one location on ORR. Hay samples collected on ORR during July 2020 were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes. Once every 5 years, additional radiological analyses are performed to confirm the dose model (see Chapter 7). In 2020, additional radionuclides analyzed included neptunium, plutonium, strontium, and thorium.

6.6.1.2. Results

Radionuclides detected in hay are shown in Table 6.5. Statistically significant concentrations of gross alpha activity, gross beta activity, ^{7}Be, ^{40}K, ^{234}U, ^{235}U, and ^{238}U were detected in July 2020.

6.6.2. Vegetables

Contaminants may reach vegetation by deposition of airborne materials, uptake from soil, and deposition of materials contained in irrigation water. As available, food crops are sampled annually from garden locations that have the potential to be affected by airborne releases from ORR to evaluate possible radiation doses received by consumers. Vegetables are also sampled from a reference location for comparison. If available, crops that represent broad-leaf systems (e.g., lettuce, turnip greens), root-plant-vegetable systems (e.g., tomatoes), and root-system vegetables (e.g., turnips, potatoes) are obtained from each location and analyzed for radionuclides. Vegetable availability varies greatly from year to year.

Table 6.5. Concentrations of radionuclides detected in hay, July 2020 (pCi/kg)[a]

Radionuclide	Result
Gross alpha	240
Gross beta	12,600
Be-7	6,350
K-40	17,100
Np-237	*b*
Pu-238	*b*
Pu-239/240	*b*
Sr-90	*b*
Th-228	*b*
Th-230	*b*
Th-232	*b*
Tritium	*b*
U-234	7.77
U-235	1.79
U-238	6.08

[a] *Detected radionuclides are those at or above minimum detectable activity. 1 pCi = 3.7 × 10^{-2} Bq.*
[b] *Value was less than or equal to minimum detectable activity.*

6.6.2.1. Data Collection and Analysis

Tomatoes were purchased in 2020 from farms near ORR and from reference locations. The locations were chosen based on availability and on the likelihood of effects from routine releases from the Oak Ridge facilities. No sources for root vegetables or leafy greens near ORR were found in 2020. The tomato samples were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes.

6.6.2.2. Results

Analytical results for vegetable samples are provided in Table 6.6. No gamma-emitting radionuclides were detected above the minimum detectable activity, except for the naturally occurring radionuclides ^{7}Be and ^{40}K.

6.6.3. Milk

Milk is a potentially significant exposure pathway to humans for some radionuclides deposited from airborne emissions because of the relatively large surface area on which a cow can graze daily, the rapid transfer of milk from producer to consumer, and the importance of milk in the diet. Since 2016, no dairies in potential ORR deposition areas have been located, and no milk samples have been collected. Surveys to identify dairies in potential deposition areas are conducted each year, and milk sampling will resume when dairy operations in appropriate areas are located.

6.6.4. Fish

Members of the public could be exposed to contaminants originating from DOE ORR activities through consumption of fish caught in area waters. This potential exposure pathway is monitored annually by collecting fish from three locations on the Clinch River and by analyzing edible flesh for specific contaminants. The locations are as follows (Figure 6.6):

- Clinch River upstream from all DOE ORR inputs (CRK 70)
- Clinch River downstream from ORNL (CRK 32)
- Clinch River downstream from all DOE ORR inputs (CRK 16)

Table 6.6. Concentrations of radionuclides detected in tomatoes, 2020 (pCi/kg)[a]

Location	Gross alpha	Gross beta	^{7}Be	^{40}K	^{234}U	^{235}U	^{238}U
North of Y-12	40.7	993	*b*	*b*	2.17	*b*	*b*
South of ORNL	*b*	1,240	*b*	1,800	*b*	*b*	*b*
East of ORNL	22.6	899	*b*	*b*	5.2	*b*	*b*
West of ETTP	52.5	1,160	*b*	1,360	6.08	*b*	1.01
Reference location	61.4	1,150	*b*	*b*	3.78	*b*	*b*

[a] *Detected radionuclides are those at or above minimum detectable activity. 1 pCi = 3.7 × 10^{-2} Bq.*
[b] *Value was less than or equal to minimum detectable activity.*
Acronyms:
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
Y-12 = Y-12 National Security Complex

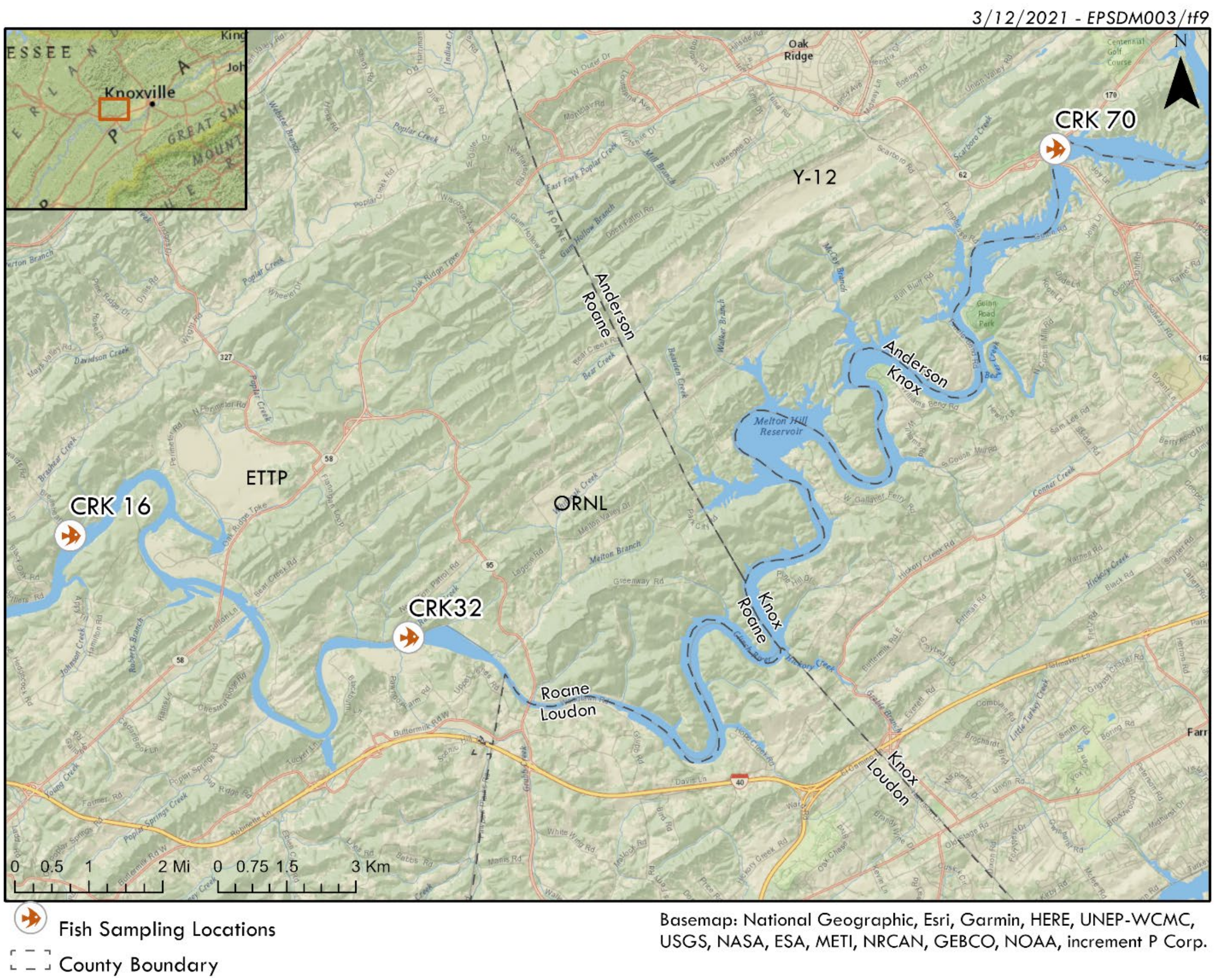


Figure 6.6. Fish-sampling locations for the ORR Surveillance Program

6.6.4.1. Data Collection and Analysis

Sunfish (*Lepomis macrochirus*, *L. auritus*, and *Ambloplites rupestris*) and catfish (*Ictalurus punctatus*) are collected from each of the three locations to represent both top-feeding and bottom-feeding-predator species. In 2020, a composite sample of each of those species at each location was analyzed for selected metals, polychlorinated biphenyls (PCBs), tritium, gross alpha, gross beta, gamma-emitting radionuclides, and total radioactive strontium. To accurately estimate exposure levels to consumers, only edible portions of the fish were submitted for analysis. Once every 5 years, additional radiological analyses are performed to confirm the dose model (see Chapter 7). In 2019, additional radionuclides detected included neptunium, plutonium, thorium, and uranium isotopes. Based on the 2019 results, some additional radionuclide analyses were again performed in 2020, including americium, neptunium, plutonium, and thorium. Results are presented in Table 6.7.

TDEC issues advisories on consumption of certain fish species caught in specified Tennessee waters. These advisories apply to fish that could contain potentially hazardous contaminants. TDEC has issued a “do not consume” advisory for catfish in the Melton Hill Reservoir in its entirety, not just in areas that could be affected by ORR activities, because of PCB contamination. Similarly, a precautionary advisory for catfish in the Clinch River arm of Watts Bar Reservoir has been issued because of PCB contamination (TDEC 2020). TDEC also issues advisories for consumption of fish when mercury levels are over 0.3 ppm; the three locations on the Clinch River where ORR fish are collected do not have mercury “do not consume” advisories waters (Denton 2007).

Table 6.7. Tissue concentrations in catfish and sunfish for detected mercury, PCBs, and radionuclides, 2020[a]

	CRK 16 Downstream		CRK 32		CRK 70 Upstream	
	Species					
Metals (mg/kg)	**Catfish**	**Sunfish**	**Catfish**	**Sunfish**	**Catfish**	**Sunfish**
Hg	0.049	0.12	0.053	0.041	0.08	J0.025[b]
Pesticides and PCBs (μg/kg)						
PCB-1260	170	J10[b]	140	J7.3[b]	33	J13[b]
Radionuclides (pCi/g)						
Alpha activity	c	0.37	0.33	0.36	c	c
Beta activity	3.4	4.1	3.1	4.3	3.7	3.2
^{40}K	3.1	4.3	3.1	3.4	4.4	3.5
Tritium	c	c	0.21	c	c	c
^{237}Np	0.0050	c	0.018	c	c	c
^{238}Pu	c	c	0.006	c	c	c
$^{239/240}$Pu	c	c	c	c	0.011	0.0073

[a] *Only parameters that were detected for at least one species are listed in the table.*
[b] *“J” indicates that the result is an estimated value.*
[c] *Value was less than or equal to minimum detectable activity.*
Acronyms:
CRK = Clinch River kilometer
PCB = polychlorinated biphenyl

6.6.4.2. Results

PCBs, specifically Aroclor-1260, and mercury were detected in both sunfish and catfish at all three locations in 2020. These results are consistent with the TDEC advisories. Detected PCBs, mercury, and radionuclide concentrations are shown in Table 6.7.

6.6.5. White-Tailed Deer

Three quota hunts were scheduled for 2020: November 3–4, November 10–11, and December 8–9. However, the hunts were cancelled due to the COVID-19 pandemic.

Since 1985, 13,334 deer have been harvested from the Oak Ridge Wildlife Management Area, of which 218 (approximately 1.67 percent) have been retained because of potential radiological contamination. The heaviest buck ever harvested weighed 218 lb (1998), and the heaviest doe ever harvested weighed 139 lb (1985). The average weight of all harvested deer is approximately 86 lb. The oldest deer harvested was a doe estimated to be 12 years old (1989); the average age of all harvested deer is approximately 2 years. See the ORR hunt information website **here** for more information.

6.6.6. Waterfowl

Canada goose hunting was allowed on the Three Bends Area of ORR (excluding the shoreline of Gallaher Bend) during the statewide season in 2020, one half hour before sunrise until noon on 5 days during September and 4 days during October. Hunting was allowed for wood duck and teal for 2 days in September. The consumption of waterfowl is a potential pathway for exposing members of the public to radionuclides released from ORR operations.

6.6.6.1. Data Collection and Analysis

Canada geese are rounded up each summer for noninvasive gross radiological surveys to characterize concentrations of gamma-emitting radionuclides accumulated by waterfowl that feed and live on ORR.

6.6.6.2. Results

Twenty-eight geese (all adults) were captured during the June 25, 2020, roundup on ORR. All 28 captured geese were subjected to live whole-body gamma scans. Gamma scan results showed that all were all well below the administrative release limit of 5 pCi/g ^{137}Cs.

6.6.7. Wild Turkey

Two wild turkey quota hunts were scheduled to occur on April 13–14 and April 27–28. However, the turkey hunts were cancelled due to the COVID-19 pandemic.

Since 1997, 924 turkeys have been harvested on spring turkey hunts. Eleven additional turkeys have been harvested since 2012 by archery hunters during fall deer hunts. The largest turkey ever harvested on ORR weighed 25.7 lb (harvested in 2009). Of all turkeys harvested, only three (less than 0.34 percent) have been retained because of potential radiological contamination; one in 1997, one in 2001, and one in 2005. Additional information is available on the ORR hunt website **here**.

6.7. Invasive Plant Management

Invasive non-native plant species are among the greatest ecological threats across the country and around the world. Maintaining ecosystems, protecting natural areas, and ensuring functioning of facilities and their support infrastructures, power and communications rights-of-way, roadways, and waterways through actively managing invasive plant incursions is crucial, not only in natural areas, but in developed areas as well. Invasive plants can threaten forests, wetlands, cultural assets, and other resources through increased risk of fire; storm damage; and encroachment onto roads, railroads, power structures, waterways, and farmland. Invasive plants disrupt vital habitats of threatened and endangered species as well as other native wildlife and plant life by decreasing native plant diversity, crowding out native plants, and disrupting natural plant-animal interactions.

The Federal Noxious Weed Act (1974) was amended and incorporated into the Federal Plant Protection Act (2000), which mandates federal agencies to develop and coordinate a management program for control of invasive plants on lands under each agency's respective jurisdiction. Each agency must adequately fund the publication of an integrated pest management plan that will meet the regulatory requirements of federal laws, executive orders, presidential memorandums, contracts, and agreements. Other federal directives regarding control of invasive plants and subsequent restoration practices include the following:

- Presidential Memorandum, "Environmentally and Economically Beneficial Practices on Federal Landscaped Ground" (1994), which was replaced in 2000 by Executive Order 13148, "Greening the Government Through Leadership in Environmental Management" (2000)
- "Federal Memorandum of Understanding to Establish a Federal Inter-agency Committee for the Management of Noxious and Exotic Weeds" (1994)
- Executive Order 13112, "Invasive Species" (1999)
- Presidential Memorandum, "Creating a Federal Strategy to Promote the Health of Honey Bees and Other Pollinators," (2014), which involves "creating a federal strategy to promote the health of honeybees and other pollinators," including control and removal of invasive plants and restoration and establishment of natural habitats
- Executive Order 13751, "Safeguarding the Nation from the Impacts of Invasive Species." (2016)

The DOE has maintained an invasive plant management plan on ORR since 2004. For details of federal and state laws and regulations driving the DOE plan, see *Invasive Plant Management Plan for the Oak Ridge Reservation* (*Invasive Plant Management Plan for the Oak Ridge Reservation* (Parr et al. 2004, Quarles et al. 2011, McCracken and Giffen 2017).

A technical report, *Assessment of Nonnative Invasive Plants in the DOE Oak Ridge National Environmental Research Park* (Drake et al. 2002) details the results of extensive survey efforts. These and subsequent surveys have been done to identify invasive plant problems on ORR. The data are used to develop control plans identifying which invasive species to target and in which locations.

More than 1,100 species of plants are found on ORR, and of these approximately 170 plant species are non-native plants. Fifty-seven aggressive non-native (invasive) plant species have been identified on ORR, but control efforts are primarily focused on a subset of 10 species (see Table 6.8). The selected invasive species have been found across ORR in disturbed areas; on powerline and gas line rights-of-way; throughout riparian buffer zones; and along state highways, railroad lines, and remote-access fire roads. They have invaded natural areas to varying degrees, causing vast ecological harm in both plant and animal communities. Other invasive plant species are targets for control as well, using US Department of the Interior Early Detection and Rapid Response guidance (DOI 2020) and in concert with control efforts on the 10 highly invasive species listed in Table 6.8.

Table 6.8. Ten most problematic invasive plants on the ORR

Common name	Scientific name
Japanese grass, Nepal grass	*Microstegium vimineum*
Japanese honeysuckle	*Lonicera japonica*
Chinese privet	*Ligustrum sinense*
Kudzu	*Pueraria montana*
Multiflora rose	*Rosa multiflora*
Tree-of-heaven	*Ailanthus altissima*
Autumn olive	*Elaeagnus umbellate*
Oriental bittersweet	*Celastrus orbiculatus*
Princess tree	*Paulownia tomentosa*
Winter creeper	*Euonymus hederaceus*

The 32,800-acre ORR consists mostly of undeveloped land, such as forested land, extensive areas of undisturbed wetlands, open waterways and riparian vegetation, and several hundred acres of grassland communities and fallow fields. Three major developed facilities lie within ORR boundaries—ORNL, the Y-12 Complex, and ETTP. Surrounding these developed facilities and woven throughout ORR are safety and security areas, utility corridors, access roads, research and education areas, cultural and historic preservation sites, contamination areas that are undergoing cleanup and remediation, regulatory and monitoring sites, emergency corridors, new facility construction and laydown areas, and public use areas. This multiplicity of land uses presents challenges for effectively preventing and managing invasive species.

Numerous DOE contractors have responsibilities for land management of portions of ORR, as do other federal and state agencies, such as the Tennessee Valley Authority and the Tennessee Wildlife Resources Agency. The Natural Resources Management Team for ORR receives site-wide funding annually, a portion of which is designated for creation and implementation of an invasive plant management plan, mainly directed toward control efforts in natural areas and reference areas; however, efforts have included specific invasive plant incursions into locations within and surrounding campuses of developed facilities on ORR. The *Invasive Plant Management Plan for the Oak Ridge Reservation* (Parr et al. 2004) and two subsequent revisions (Quarles et al. 2011 and McCracken and Giffen. 2017) explain options for addressing the problem of invasive plants on ORR and discuss selection of appropriate control measures. Areas selected for invasive plant control tend to cover several acres or are spread out across portions of ORR. Use of selected herbicides is the most cost-effective treatment method in most cases, and the invasive plants present inform which herbicides will be most effective without causing harm to surrounding native plant and animal habitats.

Invasive plant control on ORR has been conducted annually from 2003, when the invasive plant management program began, through 2020. Table 6.9 indicates the extent of annual invasive plant treatments; Figure 6.7 shows the major treatment areas.

Table 6.9. Invasive plant control on ORR, 2003–2020

Year	Treated area	
	Acres	Road miles
2003	98	
2004	136	
2005	125	
2006	254	
2007	236	
2008	427	
2009	526	
2010	884	
2011	806	
2012	615	
2013	329	
2014	950	
2015	629	
2016	952	
2017	542	47
2018	507	53
2019	450	57
2020	400	65

Restoration of selected natural areas is done in addition to herbicide treatment of invasive plants. *The Native Grass Community Management Plan for the Oak Ridge Reservation* (Ryon et al. 2007) and the *Grassland Ecosystem Management Plan for the Oak Ridge Reservation* (Herold and McCracken 2018) discuss demonstration projects and larger grassland restoration projects across ORR. Demonstration projects have been done at ETTP, the Y-12 Complex, and ORNL. Native plant restoration projects totaling several hundred acres across ORR are located within the Oak Ridge National Environmental Research Park's natural areas.

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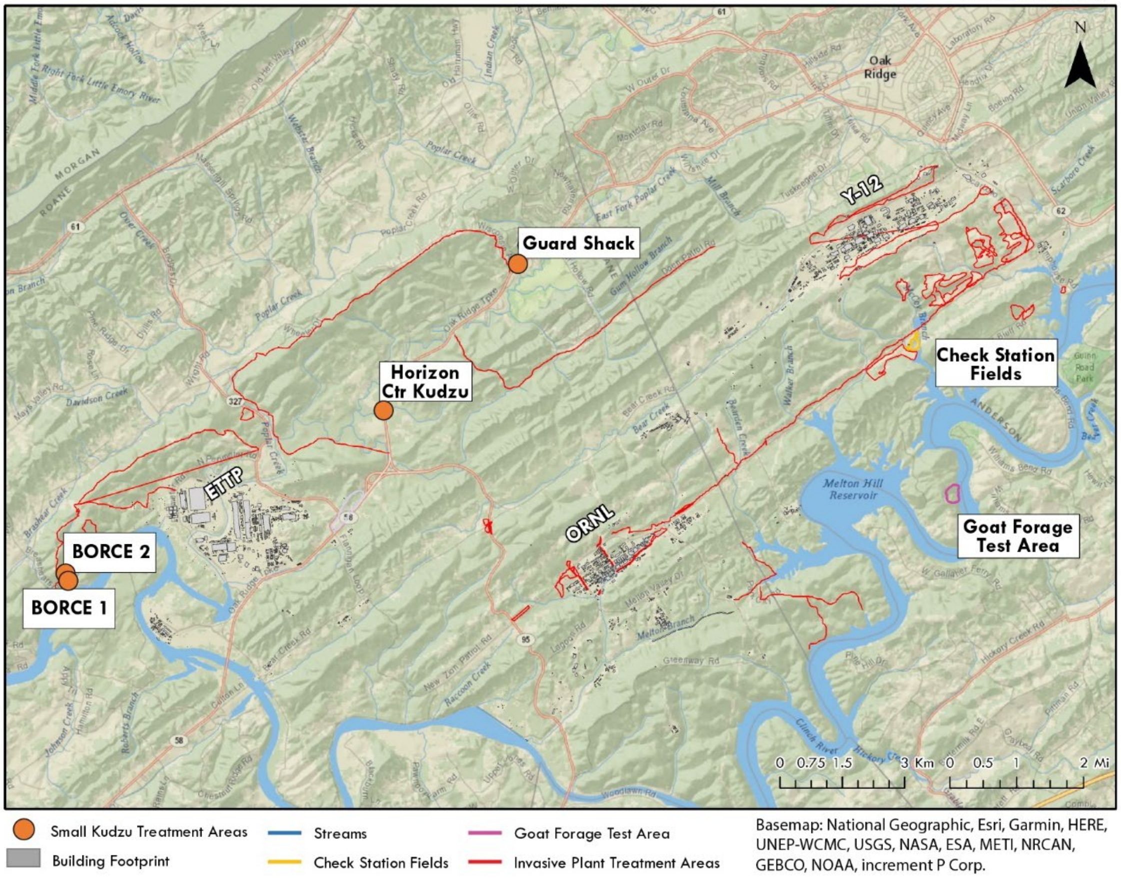

Acronym: *BORCE = Black Oak Ridge Conservation Easement*

Figure 6.7. Map of invasive plant treatment areas on ORR for 2020

Invasive Plant management and grassland restoration completed in 2020 at each of the three facilities on ORR include the following:

- ORNL
  - First Creek grassland area management
  - First Creek riparian buffer zone
  - Fifth Creek riparian buffer zone
  - White Oak Creek riparian buffer zone
  - 1000 area invasive plant control
  - Demonstration plot at Spallation Drive and Bethel Valley Road management
  - Bethel Valley Road and Old Bethel Valley Road invasive plant control
  - East Bethel Valley Road native grasslands
  - Check Station native grasslands
  - Park City Road/Price Road invasive plant treatment
  - Three Bends Area invasive plant control
  - Gallaher Bend kudzu control using goats
- Y-12
  - Y-12 Native Grassland Area invasive plant treatment
  - Kudzu control on Pine Ridge and Chestnut Ridge overlooking the Y-12 campus
  - Midway Turnpike invasive plant control

  - Coal ash ponded area kudzu control
  - Walnut Orchard four corners kudzu control
  - Fire road invasive plant control
  - Mt. Vernon Road pine removal area
- ETTP
  - EU-29 demonstration field invasive plant control
  - Black Oak Ridge Conservation Easement kudzu and invasive plant control
  - Black Oak Ridge Conservation Easement greenway and trail invasive plant control

6.8. Fire Protection Management and Planning

Wildland fire management plays a major part in DOE's overall management of ORR. A comprehensive wildfire management program has been established and implemented for the entire ORR. The *Wildland Fire Management Plan at the Oak Ridge Reservation* (DOE 2005), assigns responsibilities for wildland fire management, and Appendix A of the *Oak Ridge Reservation Wildland Fire Implementation Plan* (DOE 2008) provides specific details on achieving complete implementation of the program. The most recent guidance for forest management is defined in a DOE Oak Ridge Wildland Fire Memorandum dated April 5, 2007. A revised ORR wildland fire management plan and ORR wildland fire implementation plan are to be introduced during 2021. DOE actions associated with wildland fire management include the following:

- Development of burn plans and authorization by the reservation manager
- Conducting routine operational controlled burns
- Incorporation of wildland fire mitigation and response activities and procedures into the ORR land-use planning process
- Preparing and updating pre-fire planning maps
- Ensuring that hard-copy maps of ORR are available for wildland fire response and mitigation
- Conducting wildland fire scenarios in emergency management exercises as necessary or appropriate, and developing after-action reports identifying areas of weakness or needs for improvement
- Development of stakeholder involvement plans in support of the wildland fire program
- Review of current wildland fire-potential data, including indications of wildland fire risk
- Preparing a wildland fire risk report, including a wildland fire hazard severity analysis based on the National Fire Protection Association *Standard for Wildland Fire Management* (NFPA 2018)
- Identifying equipment necessary to perform forest management activities and assignments

The DOE roads and grounds contractor has the responsibility for establishing and maintaining the wildland fire roads, many of which delineate wildland management units (Figure 6.8), and maintaining barricades that control access to ORR secondary roads. The management contractors at each of the three major sites are responsible for providing personnel and equipment for initial response to wildland fire events and for establishing incident command. The City of Oak Ridge has entered into a mutual aid agreement with DOE to provide assistance for wildland fire activities. The State of Tennessee Department of Agriculture Division of Forestry has entered into a memorandum of understanding to provide personnel who are trained and equipped to respond to wildland fires and heavy equipment, including fire plows, when requested to assist with wildland fires.

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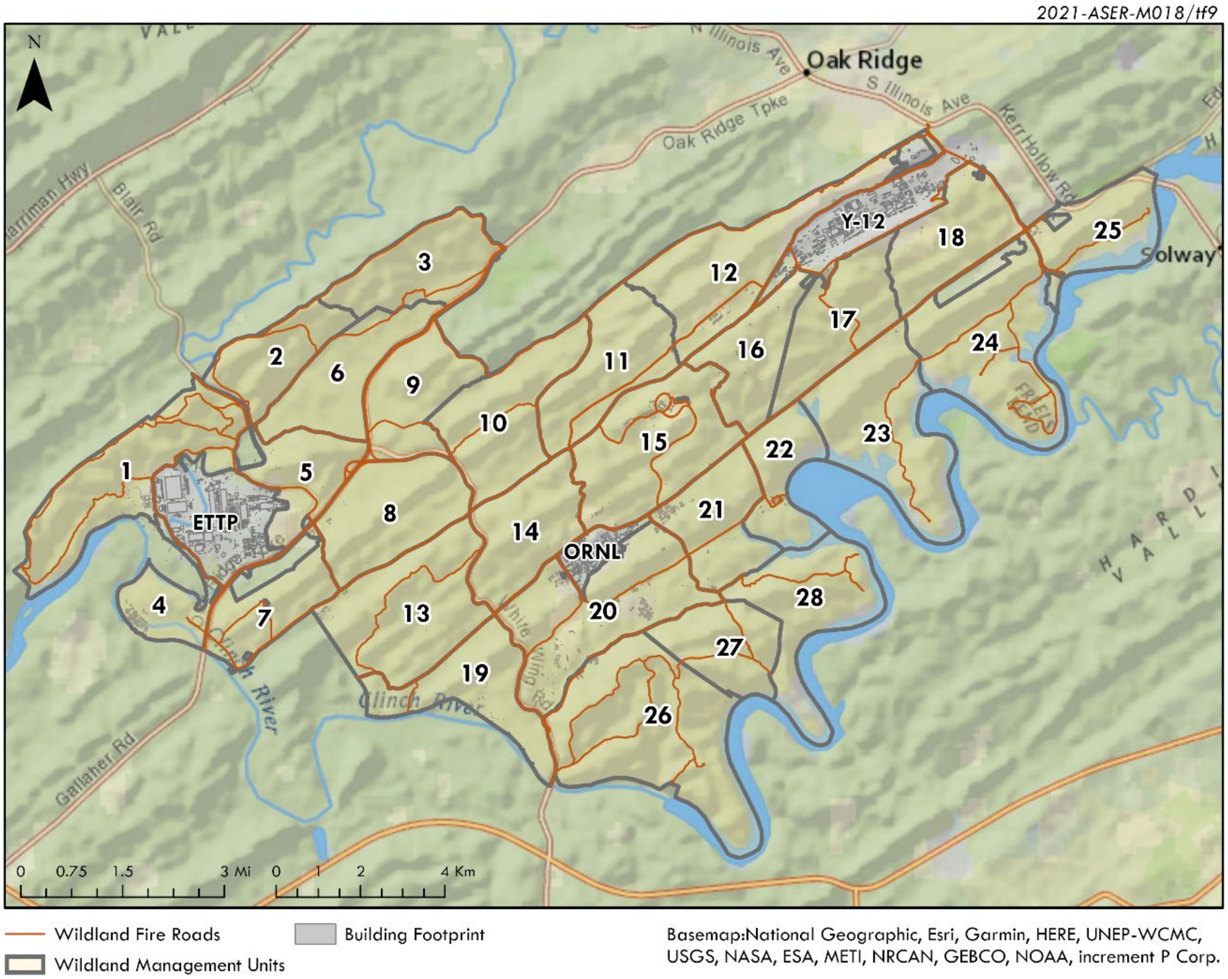

Figure 6.8. Wildland management units on ORR

Because ORR is a large (32,866.54 acres), mainly forested property with access restrictions, it is a challenge for most site emergency personnel to maintain familiarity with all remote areas and back roads and to quickly recognize and size up concerns associated with those areas. The ORR wildland management unit pre-fire plans are designed to aid those not familiar with an area and to assist the recall of those who are. Because DOE's wildfire strategy now relies on outside agencies for assistance with large or difficult wildfires, the plans also serve as guidance for those responders who may have little or no experience on ORR. The plans offer awareness of ORR's unique hazards and can help avoid inadvertent impacts to structural, cultural, environmental, and research assets.

The pre-fire plans are a series of brief documents covering each of 28 ORR wildlife management units (Figure 6.8). Each plan summarizes access issues, assets, and hazard concerns within its area. Hard copies of the plans are intended to remain in responder vehicles for immediate reference during remote events. Terse and compact in format, the plans are easily updated, stored, and shared electronically. Pre-fire plan copies are also maintained at site fire departments and emergency operations centers and by shift superintendents and certain managers. The plans are meant to influence quick decisions but are not meant to dictate tactics.

A pre-fire plan is a single-page synopsis that provides a wildlife management unit's identification number and name, general location within ORR, and its boundaries and size. The most important information or hazards are highlighted near the top of the form, followed by topical guidance on tactics, access, vegetation and fuels, water sources, topographic considerations, and hazards. Plan maps depict access, fuel types, water sources, and urban interface areas. Utilities, hazards, research areas, and sensitive resources are also depicted. Pre-fire plans are reviewed on a 3-year cycle and are updated as significant changes occur. The ORR forester is the point of contact for plan distribution.

Events during 2016 demonstrated that large fires, more frequent in the western states, can occur in the region containing ORR. As a result, issues related to wildland/urban interface are a growing concern. These areas may feature relatively high housing density and increasing recreational use by the public. DOE has prioritized interface areas and has conducted controlled wildfire fuel reduction burns to limit fire spread to and from the community. Actions have also been taken in areas exposed to potential high-intensity wildfires due to the presence of dense pine forests, including harvests to thin or replace dense pine, mechanical treatments to proactively thin younger pine, and mulching heavy logging slash and insect-damaged timber to interrupt fuel beds.

6.9. Quality Assurance

UT-Battelle performs the activities associated with administration, sampling, data management, and reporting for ORR environmental surveillance programs. Project scope is established by a task team whose members represent DOE; UT-Battelle; Consolidated Nuclear Security, LLC; and UCOR. UT-Battelle integrates quality assurance, environmental, and safety considerations into every aspect of ORR environmental monitoring. (See Chapter 5, Section. 5.7, for a detailed discussion of UT-Battelle quality assurance program elements for environmental monitoring and surveillance activities.)

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Consumption of wildlife is one of the pathways by which radionuclides released to the environment from ORR facilities can reach members of the public. Annual turkey hunts are held near ORR, and all harvested turkeys are screened to ensure that hunters are not exposed to harmful levels of radioactivity.

7

Dose

Activities on ORR have the potential to release small quantities of radionuclides and hazardous chemicals to the environment. The releases could expose members of the public to low concentrations of radionuclides or hazardous chemicals. Monitoring of materials released from the reservation and environmental monitoring and surveillance on and around the reservation provide data used to show that doses from released radionuclides and chemicals are in compliance with the law.

In 2020, a hypothetical maximally exposed individual (MEI) could have received an effective dose (ED) of about 0.4 mrem from radionuclides emitted to the atmosphere from all ORR sources; this is well below the National Emission Standards for Hazardous Air Pollutants for Radionuclides standard of 10 mrem/year for protection of the public.

A worst-case analysis of exposures to waterborne radionuclides for all pathways combined gives a maximum possible individual ED of about 2 mrem. This dose is based on a person eating 27 kg/year (60 lb/year) of fish, drinking 730 L/year (193 gal/year) of drinking water, and using the shoreline for 60 h/year as well as swimming, boating, and irrigation. In addition, if a hypothetical person consumed two geese (containing the maximum ^{137}Cs concentration and maximum weight), that person could have received an ED of about 0.07 mrem. This calculation provides an estimated upper-bound ED from consuming wildlife harvested from ORR during 2020. Deer and turkey hunts normally conducted on ORR were canceled in 2020 due to the COVID-19 pandemic.

Therefore, the annual dose to an MEI from the combined exposure pathways was estimated to be about 3 mrem. No significant doses from discharges of radioactive constituents from ORR other than those reported are known. DOE Order 458.1, *Radiation Protection of the Public and the Environment* (DOE 2020), limits the ED that an individual member of the public may receive from all radionuclide exposure pathways during 1 year to no more than 100 mrem. The 2020 maximum ED from ORR was about 3 percent of the DOE Order 458.1 limit.

The potential doses to aquatic and terrestrial biota from contaminated soil and water were evaluated using a graded approach. Results of the screening calculations indicate that contaminants released from ORR site activities do not have an adverse impact on aquatic or terrestrial biota.

7.1. Radiation Dose

Small quantities of radionuclides were released to the environment from operations at ORR facilities in 2020. Those releases were described, characterized, and quantified in previous chapters of this report. This chapter presents estimates of potential radiation doses to the public from the releases. Dose estimates were obtained using monitored and estimated release data, environmental monitoring and surveillance data, estimated exposure conditions that tend to maximize calculated doses, and environmental transport and dosimetry codes that may also tend to overestimate the calculated doses. Therefore, the presented doses are likely overestimates of the doses received by actual people in the ORR vicinity.

7.1.1. Terminology

Exposures to radiation from nuclides located outside the body are called "external exposures"; exposures to radiation from nuclides deposited inside the body are called "internal exposures." This distinction is important because external exposures occur only when a person is near or in a radionuclide-containing medium, whereas internal exposures continue while the radionuclides remain inside a person. Also, external exposures may result in uniform irradiation of the entire body, including all organs, whereas internal exposures usually result in nonuniform irradiation of the body and organs. When taken into the body, most radionuclides deposit preferentially in specific organs or tissues and typically do not irradiate the body uniformly.

Several specialized terms and units used to characterize exposures to ionizing radiation are defined in Appendix E. Effective dose is a risk-based dose equivalent that is used to estimate health effects or risks to exposed persons. It is a weighted sum of dose equivalents to specified organs and is expressed in rem or sieverts (1 rem = 0.01 Sv). One rem of ED, regardless of radiation type or method of delivery, has the same total radiological (in this case, also biological) risk effect. Because the doses discussed here are very small, EDs are expressed in millirem (mrem), which is one one-thousandth of a rem. (See Appendix E for a comparison and description of various dose levels.)

7.1.2. Methods of Evaluation

The following sections summarize the methods and pathways used to determine potential doses to members of the public and to aquatic and terrestrial biota from radionuclides originating from ORR. Dose calculations are made for a variety of media using both computer models and measured radionuclide concentrations in samples collected on or near ORR.

7.1.2.1. Airborne Radionuclides

The radiological consequences of radionuclides released to the atmosphere from ORR operations during 2020 were characterized by calculating EDs to maximally exposed on- and off-site members of the public and to the entire population residing within 80 km (50 miles) of ORR center. The calculations were performed for each major facility and for the entire ORR. The dose calculations were made using the Clean Air Act Assessment Package—1988 (CAP-88 PC) Version 4 (EPA 2015), a software program developed under EPA sponsorship to demonstrate compliance with 40 CFR 61, Subpart H, which governs the emissions of radionuclides other than radon from DOE facilities. CAP-88 PC implements a steady-state Gaussian plume atmospheric dispersion model to calculate concentrations of radionuclides in the air and on the ground and uses food-chain models to calculate radionuclide concentrations in foodstuffs (vegetables, meat, and milk) and subsequent intakes by humans.

In this assessment, adult dose coefficients were used to estimate doses. The coefficients are weighted sums of equivalent doses to 12 specified tissues or organs plus a remainder term that accounts for the rest of the tissues and organs in the body.

A total of 26 emission points on ORR were modeled during 2020. The total includes 3 (2 combined) points at Y-12, 22 points at ORNL, and 1 point at ETTP. Table 7.1 lists the emission-point parameter values and receptor locations used in the dose calculations.

Meteorological data used in the calculations for 2020 were in the form of joint frequency distributions of wind direction, wind speed class, and atmospheric stability category. (See Table 7.2 for a summary of tower locations used to model the various sources.) During 2020, rainfall, as averaged over the six rain gauges located on ORR, was about 177.7 cm (70 in.). The average air temperature was 15.0°C (59°F) at the 10 to 15 m levels. The average mixing-layer height (i.e., the depth of the atmosphere adjacent to the surface within which air is mixed) was 700.1 m (2,297ft) for ETTP, 677.0 m (2,221 ft) for ORNL, and 722.7 m (2,371 ft) for Y-12.

Table 7.1. Emission point parameters and receptor locations used in the dose calculations, 2020

Source	Stack height (m)	Stack diameter (m)	Effective exit gas velocity (m/s)[a]	Distance (m) and direction to the maximally exposed individual			
				From each site		From ORR	
			ORNL				
X-laboratory hoods							
X-1000	15	0.5	0	4,270	SW	11,260	NE
X-2000	15	0.5	0	4,630	SW	10,910	NE
X-3000	15	0.5	0	5,030	SW	10,510	NE
X-4000	15	0.5	0	5,200	SW	10,360	NE
X-7000	15	0.5	0	5,210	WSW	10,750	NNE
X-2026	22.9	1.05	8.63	4,750	SW	10,790	NE
X-2099	3.66	0.18	16.42	4,740	SW	10,800	NE
X-2531 east pipe tunnel	1.07	0.31	0[b]	4,700	SW	10,840	NE
X-portable ventilation units	0.20	0.15	3.23	4,780	SW	10,760	NE
X-3018	61	1.75	0.95	4,960	SW	10,570	NE
X-3020	61	1.22	13.42	4,900	SW	10,640	NE
X-3039	76.2	2.44	5.36	4,970	SW	10,570	NE
X-3544	9.53	0.28	25.35	4,740	SW	10,820	NE
X-3608 filter press	8.99	0.36	9.27	4,860	SW	10,720	NE
X-4501	19.81	0.71	8.75	5,150	SW	10,400	NE
X-7503	30.5	0.91	13.00	5,230	SW	10,580	NNE
X-7830 group	4.6	0.25	7.96	3,840	WSW	12,130	NNE
X-7856-CIP	18.29	0.48	7.69	3,840	WSW	12,190	NNE
X-7877	13.9	0.41	13.56	3,810	WSW	12,180	NNE
X-7880	27.7	1.52	15.10	3,770	WSW	12,200	NNE
X-7911	76.2	1.52	14.25	5,160	WSW	10,810	NNE
X-7935 building stack	15.24	0.51	27.18	5,170	SW	10,740	NNE
X-7935 glove box	9.14	0.25	0[b]	5,170	SW	10,740	NNE
X-7966	6.10	0.29	6.40	5,240	SW	10,660	NNE
X-8915	104.0	1.22	7.12	8,000	SSW	7,580	NE
X-decom areas	15	0.5	0	5,240	SW	10,310	NE
			ETTP				
K-1407-AL CWTS	2.74	0.15	0[b]	460	WSW	14,770	ENE

Table 7.1. Emission point parameters and receptor locations used in the dose calculations, 2020 (continued)

Source	Stack height (m)	Stack diameter (m)	Effective exit gas velocity (m/s)[a]	Distance (m) and direction to the maximally exposed individual: From each site		From ORR	
Y-12 Complex							
Y-monitored	20	0.5	0	2,270	NE	2,270	NE
Y-unmonitored processes	20	0.5	0	2,270	NE	2,270	NE
Y-unmonitored lab hoods	20	0.5	0	2,270	NE	2,270	NE

[a] Exit gas temperatures are "ambient air."
[b] The direction of exhaust is horizontal. Therefore, a zero exit velocity is used.

Acronyms:
CIP = Capacity Increase Project
CWTS = Chromium Water Treatment System
ETTP = East Tennessee Technology Park
Decom = Decommissioned
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
Y-12 Complex = Y-12 National Security Complex

For occupants of residences, the dose calculations assume that the occupant remained at home during the entire year and obtained food according to the rural pattern. This pattern specifies that 70 percent of the vegetables and produce, 44 percent of the meat, and 40 percent of the milk consumed are produced in the local area (e.g., a home garden). The remaining portion of each food category is assumed to be produced within 80 km (50 miles) of ORR. The same assumptions are used for occupants of businesses, but the resulting doses are divided by 2 to compensate for the fact that businesses are occupied for less than half a year and less than half of a worker's food intake occurs at work. For collective ED estimates, production of beef, milk, and crops within 80 km (50 miles) of ORR was calculated using the production rates provided with CAP-88 PC Version 4.

Table 7.2. Meteorological towers and heights used to model atmospheric dispersion from source emissions, 2020

Tower	Height (m)	Source
Y-12 Complex		
MT6 (West Y-12)	30	All Y-12 sources
ETTP		
MT7 (L1209)	15	K-1407-AL CWTS
ORNL		
MT4 (Tower A)	15	X-7830 group, X-7935 glove box, X-7966, and X-7000 lab hoods
	30	X-7503, X-7856-CIP, X-7877, X-7880, X-7911, and X-7935 Building
MT2 (Tower D)	15	X-2099, X-2351 east pipe tunnel, X-portable ventilation units, X-3608 FP, X-decom hoods, X-1000, X-2000, X-3000, and X-4000 lab hoods
	35	X-2026, X-3544, X-4501
	60	X-3018, X-3020, and X-3039
MT12 (Tower F)	10	X-8515 (SNS)

Acronyms:
CIP = Capacity Increase Project
CWTS = Chromium Water Treatment System
Decom = Decommissioned
ETTP = East Tennessee Technology Park
FP = Filter Press
ORNL = Oak Ridge National Laboratory
SNS = Spallation Neutron Source
Y-12 Complex = Y-12 National Security Complex

Results

EDs from radionuclides released to the atmosphere from ORR were calculated for ORR as a whole and for each site on ORR for (1) maximally exposed individuals (MEIs) and (2) for the collective population (1,172,530 persons) residing within 80 km (50 miles) of ORR (based on 2010 census data). CAP-88 PC Version 4 was used in 2020 to calculate both individual and collective doses.

The location of the MEI with reference to ORR (i.e., the location where a hypothetical individual would receive the maximum ED from radionuclides emitted to the atmosphere on ORR) is about 2,270 m (1.4 miles) northeast of the main Y-12 release point, about 10,810 m (6.7 miles) north-northeast of the 7911 stack at ORNL, and about 14,770 m (9.2 miles) east-northeast of the K-1407-AL Chromium Water Treatment System (CWTS) at ETTP (see Figure 7.1). This individual could have received an ED of about 0.4 mrem, which is well below the National Emission Standards for Hazardous Air Pollutants for Radionuclides standard of 10 mrem and is about 0.1 percent of the roughly 300 mrem that the average individual receives from natural sources of radiation (40 CFR 61 Subpart H). The maximum individual EDs calculated for each site and for ORR are listed in Table 7.3.

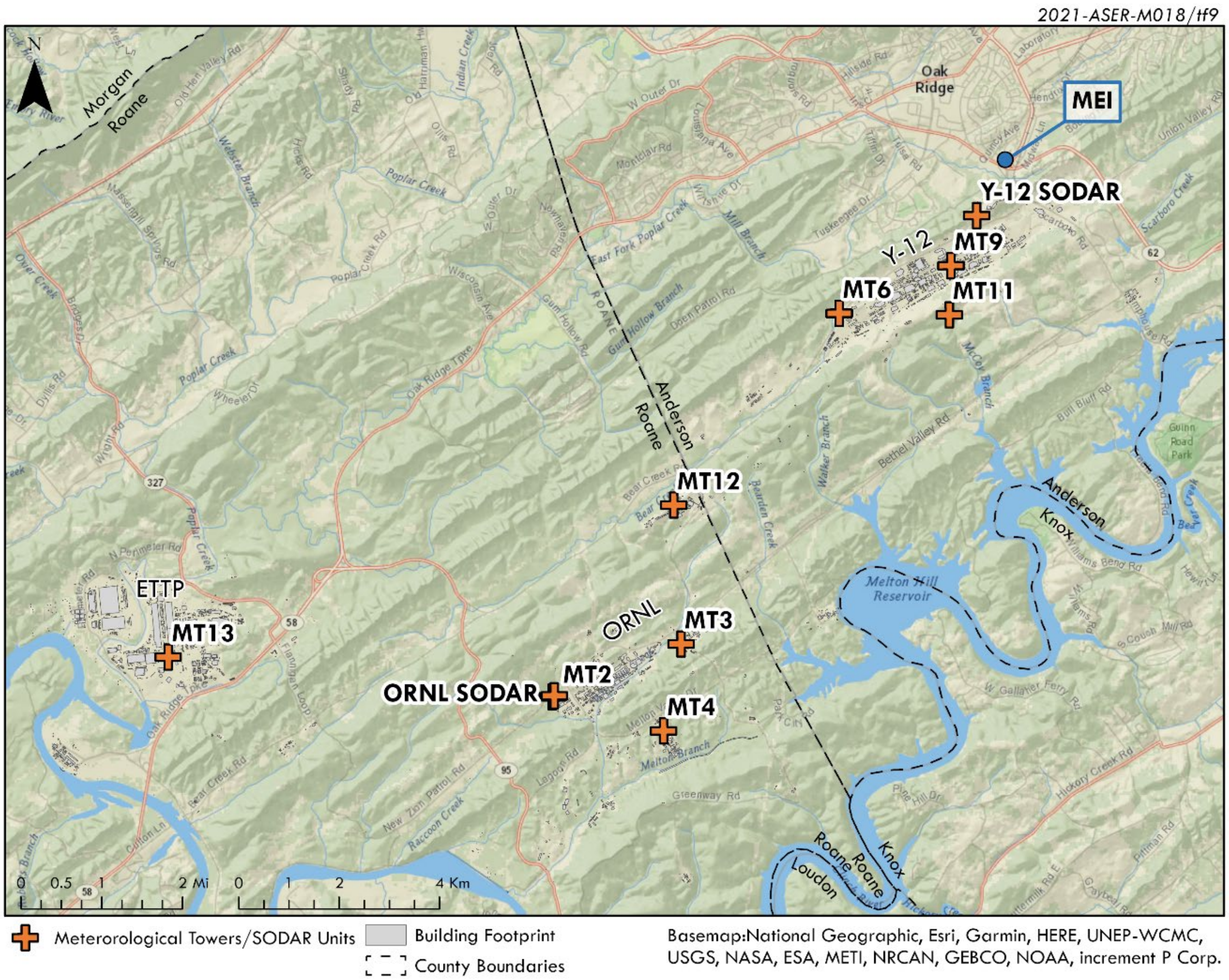

Figure 7.1. Location of the maximally exposed individual for ORR (2020 data)

Table 7.4 lists the collective EDs. The calculated collective ED was about 13.9 person-rem, which is about 0.004 percent of the 351,759 person-rem that this population received from natural sources of radiation (based on an individual dose of about 300 mrem/year).

Table 7.3. Calculated radiation doses to maximally exposed individuals from airborne releases from ORR, 2020

Plant	Maximum effective dose, mrem (mSv)			
	From each site		From ORR	
	mrem	mSv	mrem	mSv
ORNL	0.3[a]	0.003	0.1	0.001
ETTP	0.0002[b]	2×10^{-6}	2×10^{-6}	2×10^{-8}
Y-12 Complex	0.3[c]	0.003	0.3	0.003
Entire ORR	*d*	*d*	0.4[e]	0.004

[a] *The MEI was located 4,970 m SW of X-3039 and 5,160 m WSW of X-7911.*
[b] *The MEI was located 460 m WSW of K-1407-AL Chromium Water Treatment System.*
[c] *The MEI was located 2,270 m NE of Y-12 Complex release point.*
[d] *Not applicable.*
[e] *The MEI for the entire ORR is also the Y-12 MEI.*
Acronyms:
ETTP = East Tennessee Technology Park
MEI = maximally exposed individual
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
Y-12 Complex = Y-12 National Security Complex

Table 7.4. Calculated collective effective doses from airborne releases, 2020

Plant	Collective effective dose[a]	
	Person-rem	Person-Sv
ORNL	10.6	0.106
ETTP	0.0001	1×10^{-6}
Y-12 Complex	3.3	0.033
Entire ORR	13.9	0.139

[a] *Collective effective dose to the 1,172,530 persons residing within 80 km (50 miles) of the ORR (based on 2010 census data).*
Acronyms:
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation
Y-12 Complex = Y-12 National Security Complex

The MEI for Y-12 was located at a residence about 2,270 m (1.4 miles) northeast of the main Y-12 release point. This individual could have received an ED of about 0.3 mrem from Y-12 airborne emissions. Inhalation and ingestion of uranium radioisotopes (i.e., ^{233}U, ^{234}U, ^{235}U, ^{236}U, and ^{238}U) accounted for about 94 percent, and other radionuclides accounted for about 6 percent of the dose (Figure 7.2). The contribution of Y-12 emissions to the 50-year committed collective ED to the population residing within 80 km (50 miles) of ORR was calculated to be about 3.3 person-rem, which is about 24 percent of the collective ED for ORR.

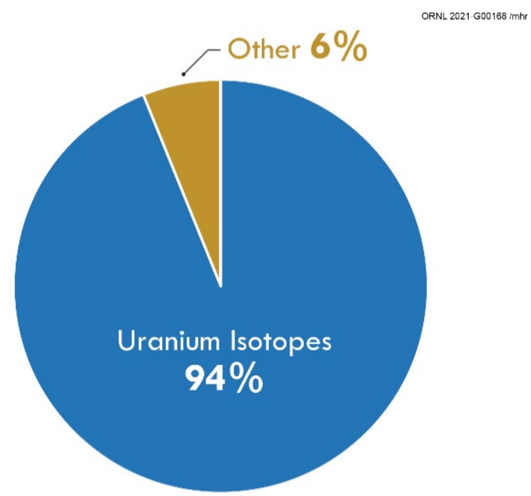

Figure 7.2. Nuclides contributing to effective dose at Y-12 Complex, 2020

The MEI for ORNL was located at a residence about 4,970 m (3.1 miles) southwest of the 3039 stack and 5,160 m (3.2 miles) west-southwest of the 7911 stack. This individual could have received an ED of about 0.3 mrem from ORNL airborne emissions. Lead-212 contributed 54 percent, ^{138}Cs contributed about 13 percent, and ^{41}Ar contributed about 6 percent of the ORNL ED (Figure 7.3). The total contribution from uranium radioisotopes (i.e., ^{230}U, ^{232}U, ^{233}U, ^{234}U, ^{235}U, ^{236}U, ^{238}U, ^{239}U, and ^{240}U) accounted for about 4 percent of the dose. Of those, ^{238}U made the largest contribution. The contribution of ORNL emissions to the collective ED to the population residing within 80 km (50 miles) of ORR was calculated to be about 10.6 person-rem or about 76 percent of the collective ED for ORR.

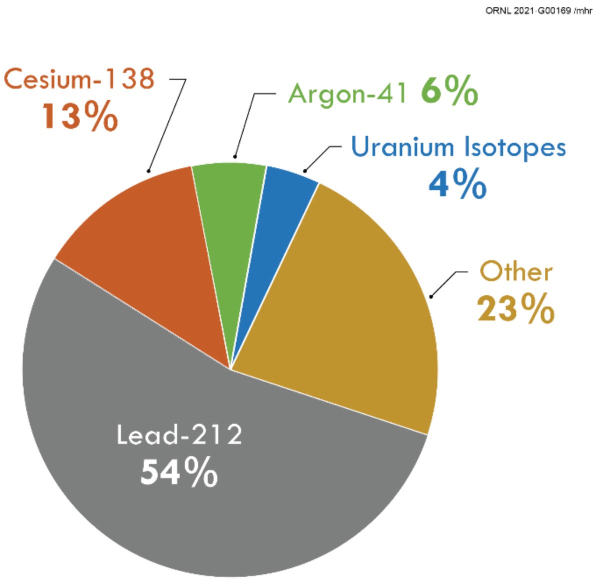

Figure 7.3. Nuclides contributing to effective dose at ORNL, 2020

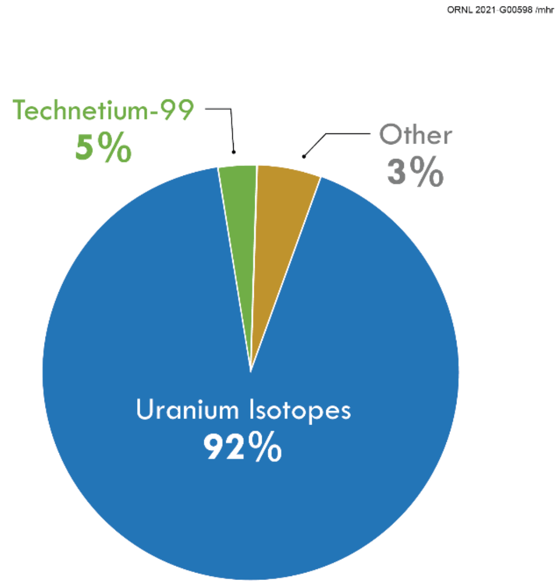

Figure 7.4. Nuclides contributing to effective dose at ETTP, 2020

The MEI for ETTP was located at a business about 460 m (0.3 miles) west-southwest of the K-1407-AL CWTS. The ED received by this individual from airborne emissions was calculated to be about 0.0002 mrem. About 92 percent of the dose is from uranium radioisotopes (^{233}U, ^{234}U, ^{235}U, ^{236}U, and ^{238}U), and about 5 percent of the dose is from ^{99}Tc (Figure 7.4). The contribution of ETTP emissions to the collective ED to the population residing within 80 km (50 miles) of ORR was calculated to be about 0.0001 person-rem, or about 0.0009 percent of the collective ED for ORR.

To evaluate the validity of the estimated doses calculated using CAP-88 PC Version 4 and emissions data (Table 7.5), the doses were compared to the EDs calculated using radionuclide air concentrations (excluding naturally occurring ^{7}Be and ^{40}K) measured in samples collected at the ORR ambient air locations (Figure 6.3). Based on measured air concentrations, hypothetical individuals assumed to reside at the ambient air stations could have received EDs between 0.0005 and 0.01 mrem/year, while EDs calculated using CAP-88 PC Version 4 and emissions data were between 0.07 and 0.8 mrem/year. As shown in Table 7.5, EDs calculated using CAP-88 PC Version 4 and emissions data were greater than EDs calculated using measured air concentrations at all monitoring stations.

Table 7.5. Hypothetical effective doses from living near ORR and ETTP ambient air monitoring stations, 2020

Station	Calculated effective doses			
	Using air monitor data		Using CAP-88[a] and emission data	
	mrem/year	mSv/year	mrem/year	mSv/year
		ORR		
1	0.0007	7×10^{-6}	0.4	0.004
2	0.0007	7×10^{-6}	0.3	0.003
3	0.0009	9×10^{-6}	0.8	0.008
11	0.0005	5×10^{-6}	0.3	0.003
35[b]	0.01	1×10^{-4}	0.07	0.0007
37	0.007	7×10^{-5}	0.2	0.002
40	0.002	2×10^{-5}	0.5	0.005
46	0.001	1×10^{-5}	0.2	0.002
49	0.0007	7×10^{-6}	0.2	0.002
52[b,c]	0.0005	5×10^{-6}	0.02	0.0002
		ETTP		
K2	*d*	*d*	0.09	0.0009
K11	*d*	*d*	0.04	0.0004
K12	*d*	*d*	0.04	0.0004

[a] CAP-88 PC Version 4 software, developed under US Environmental Protection Agency sponsorship to demonstrate compliance with 40 CFR 61, Subpart H.
[b] At Stations 35 and 52, ^{99}Tc was requested for analyses as well as other radionuclides.
[c] Background ambient air monitoring station.
[d] No radionuclides were detected during 2020 at these locations.
Acronyms:
ETTP = East Tennessee Technology Park
ORNL = Oak Ridge National Laboratory
ORR = Oak Ridge Reservation

Station 52, located remotely from ORR, gives an indication of potential EDs from background sources. Samples from Stations 35 and 52 were analyzed for ^{99}Tc in 2020. No ^{99}Tc was detected in either sample. Based on measured air concentrations, the ED at Station 52 was estimated to be 0.0005 mrem/year (the naturally occurring isotopes ^{7}Be and ^{40}K were not included in the background air monitoring station calculation); based on air concentrations calculated using CAP-88 PC Version 4, the ED was estimated to be 0.02 mrem/year. The measured air concentrations of ^{7}Be were similar at ORR stations, and at the background air monitoring station.

EDs calculated using measured air concentrations of radionuclides at ambient air stations located near the MEIs for each are significantly less than EDs calculated using source emissions data.

- Station 11 is located near the off-site MEI for ORNL. The ED calculated with measured air concentrations was 0.0005 mrem/year, and the ED estimated using source emissions data was 0.3 mrem/year.
- Station 40 is located near the off-site MEI for the Y-12 Complex and ORR, and the ED calculated with measured air concentrations was 0.002 mrem/year, and the ED estimated using source emissions data was 0.5 mrem/year.
- Station K11 is located near the on-site MEI for ETTP. There were no detected radionuclide air concentrations at the ETTP stations in 2020; however, the ED calculated using source emissions data was 0.04 mrem/year.

7.1.2.2. Waterborne Radionuclides

Radionuclides discharged to surface waters from ORR enter the Tennessee River system by way of the Clinch River. Discharges from Y-12 enter the Clinch River via Bear Creek and East Fork Poplar Creek (EFPC), which both enter Poplar Creek before it enters the Clinch River. Discharges from Rogers Quarry enter McCoy Branch, which flows into Melton Hill Lake. Discharges from ORNL enter the Clinch River via White Oak Creek (WOC) and enter Melton Hill Lake via small drainage creeks. Discharges from ETTP enter the Clinch River either directly or via Poplar Creek. This section discusses the potential radiological impacts of these discharges to persons who drink water; eat fish; and swim, boat, and use the shoreline at various locations along the Clinch and Tennessee Rivers.

For assessment purposes, surface waters potentially affected by ORR are divided into seven segments:

- Melton Hill Lake above all possible ORR inputs
- Melton Hill Lake
- Upper Clinch River (from Melton Hill Dam to confluence with Poplar Creek)
- Lower Clinch River (from confluence with Poplar Creek to confluence with the Tennessee River)
- Upper Watts Bar Lake (from near the confluence of the Clinch and Tennessee Rivers to below Kingston)
- the lower system (the remainder of Watts Bar Lake and Chickamauga Lake to Chattanooga)
- Poplar Creek (including the confluence of EFPC)

Two methods are used to estimate potential radiation doses to the public. The first method uses radionuclide concentrations in the medium of interest (i.e., in water and fish) determined by laboratory analyses of water and fish samples (see Sections 6.4 and 6.6). The second method calculates possible radionuclide concentrations in water and fish from measured radionuclide discharges and known or estimated stream flows. In both methods, reported concentrations of radionuclides were used if the reported value was statistically significant and/or detected. The advantage of the first method is the use of radionuclide concentrations measured in water and fish; disadvantages are the inclusion of naturally occurring radionuclides (e.g., ^{40}K, uranium and its progeny, thorium and its progeny, and unidentified alpha and beta activities); the possible inclusion of radionuclides discharged from sources not part of ORR; and the possibility that some radionuclides of ORR origin might be present in quantities too low to be measured. The advantages of the second method are that most radionuclides discharged from ORR can be quantified and that naturally occurring radionuclides may not be considered or may be accounted for separately. The disadvantage is the use of models to estimate the concentrations of the radionuclides in water and fish. Both methods use the same models (Hamby 1991) to estimate radionuclide concentrations in media and at locations other than those that are sampled (e.g., downstream). However, utilizing the two methods to estimate potential doses takes into account both field measurements and discharge measurements.

Drinking Water Consumption

Estimated maximum EDs to a person drinking water were calculated using both measured radionuclide concentrations in off-site surface water and measured radionuclide discharges to the off-site surface water, excluding naturally occurring radionuclides such as ^{40}K and ^{7}Be. During FY 2020 the Oak Ridge Office of Environmental Management (OREM) continued to collect and analyze samples from the off-site groundwater monitoring well array west of the Clinch River adjacent to Melton Valley. Currently, no water is consumed from these off-site groundwater wells.

Water drawn into treatment plants from the Clinch and Tennessee River systems could be affected by discharges from ORR. No in-plant radionuclide concentration data are available for these plants; however, the dose estimates given in this section likely are high because they are based on radionuclide concentrations in water before it enters a processing plant. Based on a nationwide food consumption survey (EPA 2011) and weighted based on the combined population of Anderson, Knox, Loudon, and Roane counties, the drinking water consumption rate for the MEI is 730 L/year (193 gal/year), and the drinking water consumption rate for the average person is 370 L/year (98 gal/year). The average drinking water consumption rate is used to estimate the collective ED.

- **Upper Melton Hill Lake above all possible ORR inputs.** Based on samples from Melton Hill Lake above possible ORR inputs (at Clinch River kilometer [CRK] 66 near the City of Oak Ridge Water Intake Plant), an MEI drinking water at this location could have received an ED of about 4×10^{-3} mrem. The collective ED to the 49,253 persons who drink water from the City of Oak Ridge Water Plant would be 0.1 person-rem.
- **Melton Hill Lake.** The only water treatment plant located on Melton Hill Lake that could be affected by discharges from ORR is a Knox County plant. This plant is located near surface water sampling location CRK 58. An MEI could have received an ED of about 4×10^{-3} mrem; the collective dose to the 65,346 persons who drink water from this plant could have been 0.1 person-rem.
- **Upper Clinch River.** There are no known drinking water intakes in this river segment.
- **Lower Clinch River.** There are no known drinking water intakes in this river segment (from the confluence of Poplar Creek with the lower Clinch River to the confluence of the lower Clinch River with the Tennessee River).
- **Upper Watts Bar Lake.** The Kingston and Rockwood municipal water plants draw water from the Tennessee River not far from its confluence with the Clinch River. An MEI could have received an ED of about 0.02 mrem. The collective dose to the 31,314 persons who drink water from these plants could have been about 0.3 person-rem.
- **Lower system.** Several water treatment plants are located on tributaries of Watts Bar Lake and Chickamauga Lake. Persons drinking water from those plants could not have received EDs greater than about 0.02 mrem. The collective dose to the 310,667 persons who drink water within the lower system could have been about 2 person-rem.
- **Poplar Creek/Lower EFPC.** No drinking water intakes are located on Poplar Creek or on Lower EFPC.

Fish Consumption

Fishing is quite common on the Clinch and Tennessee River systems. Based on a nationwide food consumption survey (EPA 2011) and weighted based on the combined population of Anderson, Knox, Loudon, and Roane counties, it was assumed that avid fish consumers would have eaten 27 kg (60 lb) of fish during 2020. For the average person used for collective dose calculations, it was assumed that 11 kg (24 lb) of fish was consumed in 2020. The estimated maximum ED at each location is based on either the first method, measured radionuclide concentrations in fish, or by the second method, which calculates possible radionuclide concentrations in fish from measured radionuclide discharges and known or estimated stream flows. The number of individuals who could have eaten fish is based on lake creel surveys and commercial fishing reporting conducted annually by the Tennessee Wildlife Resources Agency (TWRA 2019, TWRA 2020, TWRA 2021). In 2020, the maximum EDs from fish consumption at Upper Melton Hill Lake, and in the Upper and Lower areas of the Clinch River were determined using measured radionuclide concentrations in fish samples, which were collected at three different locations. The maximum EDs at the remaining locations were estimated using the second method as described above. In addition to analyses for alpha, beta, and gamma emitters and tritium, additional radionuclides are included in the analytical suite every 5 years. In 2019, additional detected radionuclides included neptunium, plutonium, thorium, and uranium isotopes. Based on the 2019 results, additional radionuclide analyses were performed again in 2020 and included americium, neptunium, plutonium, and thorium. The primary contributors to dose due to fish consumption at CRK 70, which is above all ORR discharge locations were ^{228}Th and ^{232}Th (29 percent and 35 percent). Plutonium-239/240 and ^{90}Sr each contributed 18 percent of the dose at that location. The primary contributors to dose at CRK 32 were ^{90}Sr and ^{238}Pu (78 percent and 22 percent respectively), and tritium contributed less than 1 percent. At CRK 16, ^{228}Th and ^{230}Th were the primary dose contributors (21 percent and 46 percent respectively), and ^{238}Pu, $^{239/240}$Pu, and ^{90}Sr accounted for the remainder of the dose (11 percent, 17 percent, and 5 percent respectively) at that location.

- **Upper Melton Hill Lake above All Possible ORR Inputs.** For reference purposes, a hypothetical avid fish consumer who ate fish caught at CRK 70, which is above all possible ORR inputs, could have received an ED of about 1 mrem. The collective ED to the 13 persons who could have eaten fish harvested at that location was about 0.006 person-rem.

- **Melton Hill Lake.** An avid fish consumer who ate fish from Melton Hill Lake could have received an ED of about 0.04 mrem. The collective ED to the 119 persons who could have eaten fish harvested at that location could be about 0.002 person-rem.

- **Upper Clinch River.** An avid fish consumer who ate fish from the upper Clinch River (CRK 32) could have received an ED of about 0.7 mrem. The collective ED to the 139 persons who could have eaten fish harvested at that location could have been about 0.04 person-rem.

- **Lower Clinch River.** An avid fish consumer who ate fish from the lower Clinch River (CRK 16) could have received an ED of about 2 mrem. The collective ED to the 325 persons who could have eaten fish harvested at that location could have been about 0.2 person-rem.

- **Upper Watts Bar Lake.** An avid fish consumer who ate fish from upper Watts Bar Lake could have received an ED of about 0.008 mrem. The collective ED to the 930 persons who could have eaten fish harvested at that location could be about 0.003 person-rem.

- **Lower System.** An avid fish consumer who ate fish from the lower system could have received an ED of about 0.007 mrem. The collective ED to the about 12,982 persons who could have eaten fish harvested at that location could have been about 0.03 person-rem.

- **Poplar Creek/Lower East Fork Poplar Creek.** An avid fish consumer who ate fish from Poplar Creek/Lower East Fork Poplar Creek could have received an ED of about 0.3 mrem; it is considered unlikely that a person would consume fish from those locations. Assuming 100 people could have eaten fish from lower EFPC and from Poplar Creek, the collective ED could have been about 0.02 person-rem.

Other Uses

A highly exposed "other user" was assumed to swim or wade for 30 h/year, boat for 63 h/year, and use the shoreline for 60 h/year. The average individual, who is used for collective dose estimates, was assumed to swim or wade for 10 h/year, boat for 21 h/year, and use the shoreline for 20 h/year. The potential EDs from these activities were estimated from measured and calculated concentrations of radionuclides in water; the equations that were used were derived from the LADTAP XL code (Hamby 1991) and were modified to account for radioactive data and shoreline use. The number of individuals who could have been other users are different for each section of water. Recreational activities for Melton Hill Reservoir are based on surveys conducted by the University of Tennessee (Stephens et al. 2006).

A recent survey was conducted regarding visitor and property owner activities for Chickamauga and Watts Bar Reservoirs (Poudyal et al. 2017). The survey data from these reports were used to identify the variety of recreational activities on these water bodies. It was found that respondents often participated in more than one recreational activity. This information has replaced earlier assumptions regarding number of people involved in water recreational activities.

- **Upper Melton Hill Lake above all possible ORR inputs.** A hypothetical maximally exposed other user of upper Melton Hill Lake above possible ORR inputs (CRK 66) could have received an ED of about 6×10^{-6} mrem. The collective ED to the 14,483 other users could have been 2×10^{-6} person-rem.
- **Melton Hill Lake.** An individual other user of Melton Hill Lake could have received an ED of about 0.0003 mrem. The collective ED to the 40,044 other users could have been about 0.0008 person-rem.
- **Upper Clinch River.** An individual other user of the upper Clinch River could have received an ED of about 0.002 mrem. The collective ED to the 13,114 other users could have been about 0.002 person-rem.
- **Lower Clinch River.** An individual other user of the lower Clinch River could have received an ED of about 0.007 mrem. The collective ED to the 30,599 other users could have been about 0.03 person-rem.
- **Upper Watts Bar Lake.** An individual other user of upper Watts Bar Lake could have received an ED of about 6×10^{-5} mrem. The collective ED to the 87,424 other users could have been about 0.0005 person-rem.
- **Lower system (Watts Bar and Chickamauga Lakes).** An individual other user of the lower system could have received an ED of about 6×10^{-5} mrem. The collective ED to the 3,173,423 other users could have been about 0.01 person-rem.
- **Poplar Creek/Lower EFPC.** An individual other user of Lower EFPC, above its confluence with Poplar Creek, could have received an ED of about 0.0002 mrem. The collective ED to the 200 other users of Poplar Creek and Lower EFPC could have been about 7×10^{-6} person-rem.

Irrigation

Although there are no known locations that use water from water bodies around ORR to irrigate food or feed crops, it was decided to determine whether irrigation could contribute to radiation doses to a member of the public. To make this determination, the method described by the Nuclear Regulatory Commission (NRC 1977) was used. Based on measured and calculated concentrations of radionuclides at CRK 16, which is a location on the lower Clinch River and downstream of ORR, the maximum potential dose (excluding the naturally occurring radionuclides ^{7}Be and ^{40}K) to an individual due to irrigation ranged from 2×10^{-7} to 0.06 mrem in 2020. The individual was assumed to consume 24 kg of leafy vegetables, 90 kg of produce, 321 L of milk, and 63 kg of meat (beef) during the year.

Summary

Table 7.6 is a summary of potential EDs from identified waterborne radionuclides around ORR. Excluding Lower EFPC and Poplar Creek from the other water systems evaluated (Melton Hill, Clinch River, Watts Bar Lake, and Chickamauga Lake), the estimated maximum individual ED would be about 2 mrem to a person obtaining his or her drinking water and annual complement of fish from those water systems and participating in other water uses throughout those systems. The maximum collective ED to the 80 km (50 mile) population was estimated to be about 3 person-rem. The percentages of individual and collective doses are small, and they constitute about 0.7 percent of the average individual background dose of roughly 300 mrem/year and 0.0009 percent of the 351,759 person-rem that this population received from natural sources of radiation.

Table 7.6. Summary of annual maximum individual (mrem) and collective (person-rem) effective doses from waterborne radionuclides, 2020[a,b]

Effective dose	Source			Total[c]
	Drinking water	Eating fish	Other uses	
Upstream of all Oak Ridge Reservation discharge locations (CRK 66, City of Oak Ridge Water Plant)				
Individual	0.004	1[d]	6×10^{-6}	1
Collective	0.1	0.006[d]	2×10^{-6}	0.1
Melton Hill Lake (CRK 58, Knox County Water Plant)				
Individual	0.004	0.04	0.0003	0.05
Collective	0.1	0.002	0.0008	0.1
Upper Clinch River (CRK 23, 32)				
Individual	NA[e]	0.7[d]	0.002	1
Collective	NA[e]	0.04[d]	0.002	0.04
Lower Clinch River (CRK 16)				
Individual	NA[e]	2[d]	0.007	2
Collective	NA[e]	0.2[d]	0.03	0.3
Upper Watts Bar Lake, Kingston Municipal Water Plant				
Individual	0.02	0.008	6×10^{-5}	0.03
Collective	0.3	0.003	0.0005	0.3
Lower system (Lower Watts Bar Lake and Chickamauga Lake)				
Individual	0.02	0.007	6×10^{-5}	0.02
Collective	2	0.03	0.01	2
Lower East Fork Poplar Creek and Poplar Creek				
Individual	NA[e]	0.3	0.0002	0.3
Collective	NA[e]	0.02	7×10^{-6}	0.02

[a] 1 mrem = 0.01 mSv.
[b] Doses based on measured radionuclide concentrations in water or estimated from measured discharges and known or estimated stream flows.
[c] Total doses and apparent sums over individual pathway doses may differ because of rounding.
[d] Doses based on measured radionuclide concentrations in fish samples collected at CRK 16, CRK 32, and CRK 70.
[e] Not at or near drinking water supply locations.
Acronym:
CRK = Clinch River kilometer

7.1.2.3. Radionuclides in Food

The CAP-88 PC computer codes are used to calculate radiation doses from ingestion of meat, milk, and vegetables that could potentially contain radionuclides released from ORR.

Milk, vegetables, hay, wildlife and fish are sampled annually, as available, for analysis to characterize doses from radionuclides that could be consumed in food products that originated at local farms and gardens and in game harvested by hunting and fishing on or near ORR. Lack of availability and social distancing procedures established in response to the COVID-19 pandemic restricted some sampling in 2020, as described in the following sections. (Fish consumption is discussed in Section 7.1.2.2 in conjunction with potential doses from waterborne radionuclides originating on ORR.)

Milk

Since 2016, no dairies in potential ORR deposition areas have been located, and no milk samples have been collected. Surveys to identify dairies in potential deposition areas are conducted each year. A small dairy operation located in the vicinity of ORR was identified in 2020, but milk samples could not be to be obtained. Milk sampling will resume when dairy operations in appropriate areas are located.

Vegetables

The food-crop sampling program is described in Chapter 6. Due to the COVID-19 pandemic, samples of leafy greens and root vegetables were not able to be obtained in 2020. Samples of tomatoes were collected in 2020 from a total of four local gardens and one distant background location. The background location used for tomatoes was in Claiborne County. All radionuclides detected in the food crops can be found in the natural environment, and all but ^{7}Be and ^{40}K may also be emitted from ORR. Dose estimates are based on hypothetical consumption rates of vegetables that contain statistically significant amounts and/or detected radionuclides that could have come from ORR. Based on a nationwide food consumption survey (EPA 2011), a hypothetical home gardener (weighted based on the combined population of Anderson, Knox, Loudon, and Roane counties) was assumed to have eaten a maximum of about 72 kg (159 lb) of homegrown tomatoes (Scofield 2015). The hypothetical local gardener could have received a committed ED of between 0.03 and 0.1 mrem from eating tomatoes, depending on garden location. A person eating tomatoes from the distant (background) garden could have received a committed ED of 0.1 mrem.

An example of a naturally occurring and fertilizer-introduced radionuclide is ^{40}K, which is specifically identified in the samples and accounts for most of the beta activity found in them. The presence of ^{40}K in the samples adds, on average, about 3 mrem to the hypothetical home gardener's ED. In 2020, the gardeners were asked about water sources and fertilizers used. It was reported that fertilizers were used at all garden locations. The water source for the gardens was city water, and spring water was used at the background location. It is believed ^{40}K and most of the excess unidentified alpha activities are due to naturally occurring radionuclides, not radionuclides discharged from ORR.

Hay

Another environmental pathway that was evaluated was eating beef and drinking milk obtained from hypothetical cattle that ate hay harvested from one location on ORR. Hay samples collected on ORR during July 2020 were analyzed for gross alpha, gross beta, gamma emitters, and uranium isotopes. Once every 5 years, additional radionuclides are included in the analyses of hay samples. Additional radiological analyses in 2020, included neptunium, plutonium, strontium, and thorium. Radionuclides detected in hay are shown in Chapter 6, Table 6.5. Statistically significant concentrations of ^{7}Be, ^{40}K, ^{90}Sr, ^{3}H, ^{234}U, ^{235}U, and ^{238}U were detected. Excluding the doses from ^{7}Be and ^{40}K (both naturally occurring radionuclides), the average ED from drinking milk and eating beef was estimated to be 0.09 mrem.

White-Tailed Deer

Due to the COVID-19 pandemic, deer hunts typically conducted by the Tennessee Wildlife Resources Agency (TWRA) on the Oak Ridge Wildlife Management Area were canceled for 2020. In previous years, harvested deer were taken to the TWRA checking station, and a bone and muscle tissue sample were obtained from each deer. The samples are field-counted for radioactivity to ensure that the deer meet the wildlife release criteria of net counts not greater than 1½ times background (~20 pCi/g $^{89/90}$Sr) of beta activity in bone or the administrative limit of 5 pCi/g of ^{137}Cs in edible tissue (ORNL 2011; ORNL 2020)[1]. For perspective, in 2015, one deer

[1] The 2020 version of CSD-AM-RML-RA01 supersedes the 2011 version.

exceeded the release criteria, and in 2016 two deer exceeded the release criteria. No deer harvested in 2017, 2018, or 2019 exceeded the wildlife release criteria.

The average ^{137}Cs concentration in muscle tissue of the released deer in the years 2015 through 2019, as determined by field counting, ranged from 0.4 to 0.5 pCi/g. The maximum ^{137}Cs concentration in released deer ranged from 0.6 to 0.9 pCi/g. Most of the ^{137}Cs concentrations were less than minimum detectable levels. The average weight of released deer in 2015 to 2019 ranged from approximately 35 to 42 kg (77 to 92 lb); the maximum weight ranged from 76 to 82 kg (167 to 181 lb). The EDs attributed to field-measured ^{137}Cs concentrations and actual field weights of the released deer from 2015 to 2019 ranged from about 0 to 1 mrem. The average ED ranged from 0.4 to 0.6 mrem.

Potential doses attributed to the consumption of deer that might have moved off ORR and been harvested elsewhere were also evaluated in 2015 through 2019. EDs were calculated using average weights and ^{137}Cs concentrations of deer harvested at the ORR hunts. In that scenario, an individual who consumed one average-weight deer (assuming that 55 percent of the field weight is edible meat) containing the average field-measured concentration of ^{137}Cs could have received an ED ranging from 0.4 to 0.6 mrem. A hunter who consumed a deer of maximum weight and ^{137}Cs content could have received an ED of between 1 to 2 mrem.

Muscle tissue samples collected from released deer are subjected to laboratory analyses. Requested radioisotopic analyses include ^{137}Cs, ^{90}Sr, and ^{40}K radionuclides. Comparison of released-deer field results to analytical ^{137}Cs concentrations typically find that field concentrations are equal to or greater than analytical results. Using analytically measured ^{137}Cs and ^{90}Sr (excluding ^{40}K, a naturally occurring radionuclide) and actual deer weights, the estimated doses for the released deer in the years 2015 through 2019 ranged from about 0 to 0.7 mrem.

The maximum ED to an individual consuming venison from two or three deer was also evaluated. Based on ^{137}Cs concentrations determined by field counting and actual field weight, the ED to a hunter who consumed two or more harvested deer in the years 2015 through 2019 was between about 0.2 and 2 mrem.

The collective ED from eating all the harvested venison from ORR between the years 2015 and 2019 using average field-derived ^{137}Cs concentrations and average deer weight ranged from about 0.06 to 0.2 person-rem.

Canada Geese

Twenty-eight geese were captured during the 2020 goose roundup and were subjected to live whole-body gamma scans. The geese were field-counted for radioactivity to ensure that they met wildlife release criteria (< 5 pCi/g of ^{137}Cs in tissue). The average ^{137}Cs concentration was 0.2 pCi/g. The maximum ^{137}Cs concentration in the released geese was 0.27 pCi/g. All ^{137}Cs concentrations were below minimum detectable activity levels. The average weight of the geese screened during the roundup was about 3.9 kg (8.7 lb), and the maximum weight was about 5.2 kg (11.4 lb).

The EDs attributed to field-measured ^{137}Cs concentrations of the geese ranged from 0.017 to 0.02 mrem. However, for bounding purposes, if a person consumed a released goose with an average weight of 3.9 kg (8.7 lb) and an average ^{137}Cs concentration of 0.2 pCi/g, the estimated ED would be approximately 0.02 mrem. It is assumed that about half the weight of a Canada goose is edible. The estimated ED to an individual who consumed a hypothetical goose with the maximum ^{137}Cs concentration of 0.27 pCi/g and maximum weight of 5.2 kg (11.4 lb) is about 0.03 mrem.

It is possible that a person could eat more than one goose that spent time on ORR. The average seasonal goose bag per active hunter from Tennessee in the Mississippi Flyway has ranged from 1.9 to 3.0 geese per hunting season between 1999 and 2010 (TWRA 2010). Hypothetically, if one person consumed two geese of maximum weight with the highest measured concentration of ^{137}Cs, that person could have received an ED of about 0.07 mrem.

Between 2000 and 2009, 22 samples of goose tissue were analyzed. An evaluation of potential doses was made based on laboratory-determined concentrations of the following radionuclides: ^{40}K, ^{137}Cs, ^{90}Sr, thorium (^{228}Th, ^{230}Th, ^{232}Th), uranium ($^{233/234}U$, ^{235}U, ^{238}U), and transuranic elements (^{241}Am, $^{243/244}Cm$, ^{238}Pu, $^{239/240}Pu$). The total potential dose, less the contribution of ^{40}K, ranged from 0.01 to 0.5 mrem. The average potential dose was 0.2 mrem (EP&WSD 2010).

Eastern Wild Turkey

Wild turkey hunts scheduled on the ORR for 2020 (March 28–29 and April 18–19) were canceled because of the COVID-19 pandemic. Typically, hunters are permitted to harvest one turkey from the reservation in a given season. Harvested turkeys are field-counted for radioactivity to ensure that they meet wildlife release criteria (< 5 pCi/g of ^{137}Cs in tissue). If the release criteria are not met, the turkey is retained, and the hunter is permitted to harvest another turkey.

No turkeys were retained during years 2015 through 2019. The average weight of the released turkeys for the years 2015 through 2019 ranged from 8.1 kg (17.8 lb) to 8.9 kg (19.5 lb). The maximum turkey weight for those same years ranged from 10 kg (22 lb) to 11.3 kg (25 lb). The average ^{137}Cs concentration from 2015 through 2019 was 0.1 pCi/g, and maximum ^{137}Cs concentrations ranged from 0.16 to 0.3 pCi/g in the released turkeys. Almost all ^{137}Cs concentrations were below minimum detectable activity levels.

The EDs attributed to ^{137}Cs concentrations field-measured in the turkeys from 2015 through 2019 ranged from 0.004 to 0.04 mrem. For bounding purposes, if a person consumed a released turkey with an average weight and an average ^{137}Cs concentration during years 2015 through 2019, the estimated ED would have been approximately 0.02 mrem. It is assumed that about half the weight of a turkey is edible. The estimated ED to an individual who consumed a turkey with the maximum ^{137}Cs concentration and maximum weight ranged from about 0.04 to 0.08 mrem.

No tissue samples were analyzed from 2015 through 2020. Earlier evaluations of doses based on laboratory-determined concentrations of radionuclides included ^{40}K, ^{137}Cs, ^{90}Sr, ^{230}Th, ^{3}H, ^{234}U, ^{235}U, ^{238}U, and transuranic elements (^{241}Am, ^{244}Cm, ^{237}Np, ^{239}Pu). The total dose, less the contribution of ^{40}K, ranged from 0.06 to 0.2 mrem (EP&WSD 2010).

7.1.2.4. Direct Radiation

The principal sources of natural external exposure are the penetrating gamma radiations emitted by ^{40}K and the series originating from ^{238}U and ^{232}Th (NCRP 2009). Due to radiological activities on ORR, external radiation exposure rates are measured at six of the ORR ambient air monitoring stations and at Station 52, the reference ambient air station (Figure 6.4). External gamma exposure rates were continuously recorded by dual-range Geiger-Müller tube detectors co-located with ORR ambient air stations. In 2020, exposure rates averaged about 10 μR/h and ranged from 8.4 to 12.7 μR/h. The exposure rates correspond to an annual average dose of about 60 mrem with a range of 52 to 78 mrem. At the background ambient air station, the exposure rate averaged about 9 μR/h and ranged from 8.2 to 10.8 μR/h. The resulting average annual dose was about 55 mrem with a range of 50 to 67 mrem. The annual doses based on measured exposure rates at or near ORR boundaries were typically within the range of the doses measured at the background location; slightly higher exposure rates were observed at ambient air monitoring stations 11 and 46.

7.1.3. Current-Year Summary

A summary of the maximum EDs to individuals by pathway of exposure is given in Table 7.7. In the unlikely event that any person was exposed to all those sources and pathways for the duration of 2020, that person could have received a total ED of about 3 mrem. Of that total, 0.4 mrem would have come from airborne emission approximately

2 mrem from waterborne emissions (0.02 mrem from drinking water, 2 mrem from consuming fish, 0.007 mrem from other water uses along the Clinch River, and 0.06 mrem from irrigation at CRK 16) and about 0.07 mrem from consumption of wildlife. Direct radiation measurements at six ORR ambient air monitoring stations were at or near background levels in 2020. There are no known significant doses from discharges of radioactive constituents from ORR other than those reported.

Table 7.7. Summary of maximum estimated effective doses from ORR activities to an adult by exposure pathway, 2020

Pathway	Dose to maximally exposed individual		Percentage of DOE mrem/year limit (%)	Estimated collective radiation dose[a]			
				Pathway		Background (person-rem)	Total Population
	mrem	mSv		person-rem	person-Sv		
			Airborne effluents				
All pathways	0.4	0.004	0.4	13.9	0.139		1,172,530[b]
			Liquid effluents				
Drinking water	0.02	0.0002	0.02	2.5	0.025		456,580[c]
Eating fish	2	0.02	2	0.4	0.004		14,708[d]
Other activities	0.007	7×10^{-5}	0.007	0.04	0.0004		3,359,287[d]
Irrigation	0.06	0.0006	0.06				
			Other pathways				
Eating deer	e	e		e	e		
Eating geese	0.07[f]	0.0007	0.07	g	g		
Eating turkey	h	h		h	h		
Direct radiation	NA[i]	NA					
			All pathways				
Total	3[j]	0.03	3	16.8	0.168	351,759	

[a] *Estimated background collective dose is based on the roughly 300 mrem/year individual dose and the population within 80 km (50 miles) of the Oak Ridge Reservation (ORR).*

[b] *Population based on 2010 census data.*

[c] *Population estimates based on community and non-community drinking water supply data from the Tennessee Department of Environment and Conservation Division of Water.*

[d] *Population estimates for fish based on creel and commercial fishing data. Fraction of fish harvested from Melton Hill, Watts Bar, and Chickamauga Reservoirs were based on creel survey data. Melton Hill, Watts Bar, and Chickamauga recreational use information was obtained from the Tennessee Valley Authority (Stephens et al. 2006 and Poudyal et al. 2017). Other activities include swimming, boating, and shoreline use; the population estimates include individuals involved in more than one activity and also include visitors that may live outside the 80 km radius.*

[e] *No deer were harvested on the ORR during 2020 due to the COVID-19 pandemic.*

[f] *Estimates for eating geese are based on consuming two hypothetical worst-case geese, each a combination of the heaviest goose harvested and the highest measured concentrations of ^{137}Cs in released geese.*

[g] *Collective doses were not estimated for the consumption of geese because no geese were harvested for consumption during the goose roundup.*

[h] *No turkeys were harvested on the ORR during 2020 due to the COVID-19 pandemic.*

[i] *Current exposure rate measurements at perimeter air monitoring stations are at or near background levels.*

[j] *Dose estimates have been rounded.*

The dose of 3 mrem is about 1 percent of the annual dose (roughly 300 mrem) from background radiation. DOE Order 458.1 (DOE 2020) limits the ED that an individual may receive from all exposure pathways from all radionuclides released from ORR during 1 year to no more than 100 mrem. The 2020 maximum ED should not have exceeded about 3 mrem, or about 3 percent of the limit given in DOE Order 458.1.

The total collective ED to the population living within an 80 km (50 mile) radius of ORR was estimated to be about 16.8 person-rem, or about 0.005 percent of the 351,759 person-rem this population received from natural sources in 2020.

7.1.4. Five-Year Trends

EDs associated with selected exposure pathways for years 2016 through 2020 are given in Table 7.8. In 2020, the air pathway dose is within the range of air pathway doses that have been estimated over the last 5 years. Starting in 2016, dose estimates take into account terrain height for the Spallation Neutron Source because it is located on a ridge above most of ORR. In 2016, some issues associated with cross-contamination in analytical equipment used to quantify radionuclides in ORR-wide surface water samples from CRK 66, 58, 32, 23, and 16 led to biased results for several 2016 sampling events. The increase in the 2019 fish consumption dose was due to a catfish sample collected at CRK 16, in which $^{239/240}Pu$ was a primary dose contributor; however, the catfish sample collected at CRK 70, which is above ORR discharge locations, also contained $^{239/240}Pu$. Catfish and sunfish samples from both CRK 16 and CRK 70 were reanalyzed, and while results were generally lower, there was not a statistically significant difference, and the original results were used in dose calculations. There was a decrease in drinking water dose in 2019, but the doses are comparable to other earlier estimated doses. Recent direct radiation measurements indicate doses near background levels. Doses from consumption of wildlife have been similar for the last 5 years. (No deer or turkey were harvested on ORR during 2020 due to the COVID-19 pandemic.)

Table 7.8. Trends in effective dose from ORR activities, 2016–2020 (mrem)[a]

Pathway	2016	2017	2018	2019	2020
All routes—inhalation	0.2	0.3	0.2	0.4	0.4
Fish consumption (Clinch River)	1.3	0.05	0.09	4	2
Drinking water (Kingston)	0.03	0.01	0.03	0.01	0.02
Deer	1	2	2	2	*b*
Geese	0.2	0.08	0.1	0.1	0.07
Turkey	0.05	0.08	0.05	0.04	*b*

[a] 1 mrem = 0.01 mSv
[b] No deer or turkey were harvested on ORR in 2020.
***Acronym:** ORR = Oak Ridge Reservation*

7.1.5. Doses to Aquatic and Terrestrial Biota

The following sections summarize the results of assessments conducted to determine the potential effect of radionuclides originating from ORR on aquatic and terrestrial biota.

7.1.5.1. Aquatic Biota

DOE Order 458.1 (DOE 2020) sets an absorbed dose rate limit of 1 rad/day to native aquatic organisms from exposure to radioactive material in liquid wastes discharged to natural waterways (see Appendix E for definitions of absorbed dose and rad). To demonstrate compliance with this limit, the aquatic organism assessment was conducted using the RESRAD-Biota code (1.8), a companion tool for implementing DOE technical standard *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2019). The code serves as DOE's biota dose evaluation tool and uses the screening (i.e., biota concentration guides [BCGs]) and analysis methods in the technical standard. The BCG is the limiting concentration of a radionuclide in sediment or water that would not cause dose limits for protection of aquatic biota populations to be exceeded.

The intent of the graded approach is to protect populations of aquatic organisms from the effects of exposure to anthropogenic ionizing radiation. Certain organisms are more sensitive to ionizing radiation than others. Therefore, it is generally assumed that protecting the more-sensitive organisms will adequately protect other, less-sensitive organisms. Depending on the radionuclide, either aquatic organisms (e.g., crustaceans) or riparian organisms (e.g., raccoons) may be the more sensitive and are typically the limiting organisms for the general screening phase of the graded approach for aquatic organisms.

At ORNL, doses to aquatic organisms are based on surface water concentrations at the following instream sampling locations:

- Melton Branch (X13) and Melton Branch Weir
- WOC headwaters (WOC 6.8), WOC (X14), and White Oak Dam (WOD) (X15)
- WOC 7500 Bridge
- First Creek
- Fifth Creek
- Northwest Tributary
- Raccoon Creek
- Solid Waste Storage Area (SWSA) 4 SW1(tributary to WOC)
- Waste Area Grouping 6 Monitoring Station 3 (tributary to WOC at WOD)
- Clinch River CRKs 16, 32, 58, and 66

All locations passed the general screening phase (comparison of maximum radionuclide water concentrations to default BCGs), with the exception of Melton Branch (X13), WOC (X14), WOC 7500 Bridge, WOD (X15), and SWSA 4 SW1. These locations passed second-level screening, for which BCG default parameters and average water concentrations were used. Second-level screening resulted in absorbed dose rates to aquatic organisms below DOE aquatic dose limit of 1 rad/day at the ORNL sampling locations.

At Y-12, doses to aquatic organisms were estimated from surface water concentrations and sediment concentrations (at Station 9422-1 and S24) at the following instream sampling locations:

- Surface Water Hydrological Information Support System Station 9422-1 (also known as Station 17)
- Bear Creek at Bear Creek kilometer 9.2 (BCK 9.2)
- Discharge Point S24 (Bear Creek at BCK 9.4)
- Discharge Point S17 (unnamed tributary to the Clinch River)
- Discharge Point S19 (Rogers Quarry)
- Outfall 200 on EFPC

All locations passed the general screening phase (maximum water concentrations and default parameters for BCGs) except Surface Water Hydrological Information Support System Station 9422-1 (Station 17) and Outfall 200; however, both locations passed second-level screening, for which BCG default parameters and average water concentrations were used. This resulted in absorbed dose rates to aquatic organisms at the Y-12 locations that were below the DOE aquatic dose limit of 1 rad/day.

At ETTP, doses to aquatic organisms were estimated from surface water concentrations at the following instream sampling locations:

- Mitchell Branch at K1700; Mitchell Branch kilometers 0.45, 0.59, 0.71, and 1.4 (upstream location)
- Poplar Creek at K-716 (downstream)
- K1007-B and K-1710 (upstream location)

- K-702A and K901-A (downstream of ETTP operations)
- Discharge point at the CWTS
- Clinch River (CRK 16 and CRK 23)

All locations, except for the discharge point at the CWTS, passed the initial general screening (using maximum concentrations and default parameters for BCGs). The discharge point at the CWTS passed second-level screening, for which BCG default parameters and average water concentrations were used. This resulted in absorbed dose rates to aquatic organisms that were below the DOE aquatic dose limit of 1 rad/day at the ETTP sampling locations.

7.1.5.2. Terrestrial Biota

A terrestrial organism assessment was conducted to evaluate impacts on biota in accordance with requirements in DOE Order 458.1 (DOE 2020). An absorbed dose rate of 0.1 rad/day is recommended as the limit for terrestrial animal exposure to radioactive material in soils. As for aquatic and riparian biota, certain terrestrial organisms are more sensitive to ionizing radiation than others, and it is generally assumed that protecting the more-sensitive organisms will adequately protect other, less-sensitive organisms. Initial soil sampling for terrestrial dose assessment was initiated in 2007 and was reassessed in 2014. This biota sampling strategy was developed by taking into account guidance provided in *A Graded Approach for Evaluating Radiation Doses to Aquatic and Terrestrial Biota* (DOE 2019) and existing radiological information on the concentrations and distribution of radiological contaminants on ORR. In 2014, as well as in 2007, the soil sampling focused on unremediated areas, such as floodplains and some upland areas. Floodplains are often downstream of contaminant source areas and are dynamic systems where soils are eroding in some places and being deposited in others. Soil sampling locations are identified as follows:

- WOC floodplain and upland location
- Bear Creek Valley floodplain
- Mitchell Branch floodplain
- Two background locations: Gum Hollow and near Bearden Creek

The soil samples collected in 2014 were in similar locations as in 2007, except one location where a soil sample was not collected due to site inaccessibility. Except for samples collected on the WOC floodplain (collected on the WOC floodplain upstream from WOD), samples collected at all other soil sampling locations passed either the initial-level screening (comparison of maximum radionuclide soil concentrations to default BCGs) or second-level screening, for which BCG default parameters and average soil concentrations were used. Cesium-137 is the primary dose contributor in the soil samples collected on the WOC floodplain. Soil samples were scheduled to be collected in 2020 for a reassessment of exposure to terrestrial organisms; however, due to issues related to the COVID-19 pandemic, samples were not obtained. The collection of soil samples and evaluation of exposure to terrestrial organisms have been rescheduled for 2021.

Biota sampling in the WOC floodplain was conducted in 2009. White-footed mice (*Peromyscus leucopus*), deer mice (*Peromyscus maniculatus*), and hispid cotton rats (*Sigmodon hispidus)* were selected for sampling because they live and forage in these areas, are food for other mammals, and have relatively small home ranges. The biota sampling locations were at the confluence of Melton Branch and WOC and in the floodplain upstream of White Oak Lake. Based on the current measured concentrations in soil and tissue concentrations collected, the absorbed doses to the terrestrial organisms collected along the confluence of Melton Branch and WOC and in the floodplain upstream of White Oak Lake were less than 0.1 rad/day.

7.2. Chemical Dose

Chemicals released as a result of ORR operations can move through the environment to off-site locations, resulting in potential exposure of the public. The following sections summarize the results of risk assessments for chemicals found in drinking water and fish on or near ORR.

7.2.1. Drinking Water Consumption

Surface water and groundwater are both potential sources of drinking water for populations in areas adjacent to ORR. Samples of surface water and groundwater are collected from water sources near ORR and are analyzed for their chemical content to determine the presence and concentration of chemicals that could pose a health risk for the local population.

7.2.1.1. Surface Water

To evaluate the drinking water exposure pathway, hazard quotients (HQs) and risks were estimated downstream of ORNL and downstream of ORR discharge points to the Clinch River (Table 7.9). The HQ is a ratio that compares the estimated exposure dose or intake to the reference dose for noncarcinogens. HQ values of less than 1 indicate an unlikely potential for adverse noncarcinogenic health effects. Likewise, risks are evaluated from estimated exposure dose or intake and cancer slope factors. Acceptable risk levels for carcinogens range from 10^{-4} (risk of developing cancer over a human lifetime is 1 in 10,000) to 10^{-6} (risk of developing cancer over a human lifetime is 1 in 1,000,000) (see Appendix F). Based on a nationwide food consumption survey (EPA 2011) and weighted based on the combined population of Anderson, Knox, Loudon, and Roane Counties, it was assumed that the drinking water consumption rate for the MEI is 730 L/year (2 L/day). This is the same drinking water consumption rate used in the estimation of the maximum exposed radiological dose from consumption of drinking water. Chemical analytes were measured in surface water samples collected at CRK 66, CRK 32, CRK 23, and CRK 16. Mercury concentrations were measured but not detected above the analytical method detection limit in surface water samples collected at CRK 66 and CRK 32 during 2020.

As shown in Table 7.9, at all locations, HQs were less than 1 for detected chemical analytes in water for which there are reference doses or a maximum contaminant levels. For carcinogens, risk values greater than 10^{-6} were calculated for the hypothetical intake of drinking water containing chromium (as Cr^{+6}), arsenic, and vinyl chloride at locations CRK 23 and 16; however, the estimated risk values are within the EPA's acceptable risk range of 10^{-4} to 10^{-6}. CRK 16, located downstream of all ORR discharge points, is not a source of drinking water, but data from that location were used as surrogates to evaluate potential exposure to drinking water from the Clinch River.

Table 7.9. Chemical hazard quotients and estimated risks for drinking water from the Clinch River at CRK 23 and 16, 2020

Analyte	Hazard quotient	
	CRK 23[a]	CRK 16[b]
Metals		
Antimony	8×10^{-3}	8×10^{-3}
Arsenic	4×10^{-2}	4×10^{-2}
Cadmium	7×10^{-3}	7×10^{-3}
Chromium	5×10^{-2}	5×10^{-2}
Copper	2×10^{-3}	2×10^{-3}
Lead	5×10^{-2}	6×10^{-2}
Mercury	4×10^{-5}	2×10^{-4}
Nickel	2×10^{-3}	2×10^{-3}
Selenium	3×10^{-3}	3×10^{-3}
Silver	2×10^{-4}	2×10^{-4}
Thallium	5×10^{-2}	5×10^{-2}
Uranium	2×10^{-2}	3×10^{-2}
Zinc	8×10^{-4}	8×10^{-4}
Volatile organics		
1,1,1-Trichloroethane	4×10^{-6}	4×10^{-6}
cis-1,2-Dichloroethene	5×10^{-3}	5×10^{-3}
Trichloroethene	2×10^{-2}	2×10^{-2}
Vinyl chloride	3×10^{-3}	3×10^{-3}
Risks for carcinogens		
Arsenic	6×10^{-6}	6×10^{-6}
Chromium	3×10^{-5}	3×10^{-5}
Lead	2×10^{-8}	2×10^{-8}
Trichloroethene	2×10^{-7}	2×10^{-7}
Vinyl chloride	5×10^{-6}	5×10^{-6}

[a] *CRK 23 is no longer a water intake location.*
[b] *CRK 16 is downstream of all US Department of Energy inputs and not a water intake location.*
Acronym:
CRK = Clinch River kilometer.

7.2.1.2. Groundwater

During FY 2020 OREM continued to collect and analyze samples from the off-site groundwater monitoring well array west of the Clinch River adjacent to Melton Valley (see Section 6.5). Currently, no water is consumed from these off-site groundwater wells.

7.2.2. Fish Consumption

Chemicals in water can be accumulated by aquatic organisms that may be consumed by humans. To evaluate the potential health effects from the fish consumption pathway, HQs were estimated for the consumption of noncarcinogens, and risk values were estimated for the consumption of carcinogens detected in sunfish and catfish collected both upstream and downstream of ORR discharge points. Based on a nationwide food consumption survey (EPA 2011) and weighted based on the combined population of Anderson, Knox, Loudon, and Roane Counties, it was assumed that avid fish consumers would have eaten 27 kg (60 lb) of fish during 2020. This fish consumption rate of 74 g/day (27 kg/year) is assumed for estimating exposure for both the noncarcinogenic and carcinogenic chemicals. This is the same fish consumption rate used in the estimation of the radiological dose from consumption of fish.

As shown in Table 7.10, for consumption of sunfish and catfish, HQ values of less than 1 were calculated for all detected analytes except for Aroclor-1260, a polychlorinated biphenyl (PCB), also referred to as PCB-1260. HQs greater than 1 for Aroclor-1260 were estimated in catfish at all three locations (CRKs 70, 32, and 16), including the upstream reference location.

For carcinogens, risk values at or greater than 10^{-6} were calculated for the intake of chromium (as Cr^{+6}) and Aroclor-1260 for sunfish and catfish collected at all three locations (CRKs 70, 32, and 16). Risk values greater than 10^{-6} were also calculated for the intake of arsenic for both sunfish and catfish at CRK 32 and CRK 16. The estimated risk values for consumption of sunfish and catfish are within the EPA's acceptable risk range of 10^{-4} to 10^{-6}. However, the Tennessee Department of Environment and Conservation (TDEC) has issued a fish advisory that states that catfish should not be consumed from Melton Hill Reservoir (in its entirety) because of PCB contamination (TDEC 2020). TDEC has also issued a precautionary fish consumption advisory for catfish in the Clinch River arm of Watts Bar Reservoir (TDEC 2020).

Table 7.10. Chemical hazard quotients and estimated risks for fish caught and consumed from locations on ORR, 2020[a]

	Sunfish			Catfish		
	CRK 70[b]	CRK 32[c]	CRK 16[d]	CRK 70[b]	CRK 32[c]	CRK 16[d]
			Hazard quotients for metals			
Aluminum	J0.001					
Antimony	J0.3					
Arsenic		J0.6	J0.9		J0.5	J0.5
Barium	J0.002	J0.0007	J0.001			
Boron						J0.0007
Cadmium	J0.03	J0.02				
Chromium	0.06	J0.03	J0.03	J0.02	J0.06	J0.02
Cobalt					J0.1	J0.07
Copper	0.005	0.007	0.005	0.006	0.006	0.006
Iron	0.007	0.004	0.004	0.005	0.004	0.003
Manganese	0.03	0.003	0.004	J0.001	J0.001	J0.001
Mercury	J0.07	0.1	0.4	0.2	0.2	0.1
Selenium	0.2	0.3	0.3	0.1	0.2	0.2
Strontium	0.01	0.001	0.002	J0.0001	J0.0002	J0.00008
Thallium	0.3	0.3	0.3	0.2	J0.1	0.2
Zinc	0.05	0.04	0.04	0.02	0.02	0.02
			Hazard quotients for Aroclors			
Aroclor-1260	0.6	J0.3	J0.4	2	6.2	8
			Risks for carcinogens			
Arsenic		J1E-04	J1E-04		J8E-05	J9E-05
Chromium	4E-05	J2E-05	J2E-05	J1E-05	J3E-05	J1E-05
Aroclor-1260	9E-06	J5E-06	J7E-06	2E-05	9E-05	1E-04
PCBs (mixed)[e]	9E-06	J5E-06	J7E-06	2E-05	9E-05	1E-04

[a] blank space for a location indicates that the parameter was undetected. A prefix "J" indicates that the concentration was estimated at or below the analytical detection limit by the laboratory.

[b] Melton Hill Reservoir, reference location above the City of Oak Ridge Water Plant.

[c] Clinch River downstream of Oak Ridge National Laboratory.

[d] Clinch River downstream of all US Department of Energy inputs.

[e] Mixed PCBs consist of the summation of Aroclors detected or estimated.

Acronyms:

CRK = Clinch River kilometer

ORR = Oak Ridge Reservation

PCB = polychlorinated biphenyl

7.3. References

40 CFR 61, Subpart H. "Subpart H—National Emission Standards for Emissions of Radionuclides Other than Radon from Department of Energy Facilities." https://www.ecfr.gov/cgi-bin/text-idx?SID=eff89c419f5d1ed63e14b4d1765f4bf9&mc=true&node=pt40.10.61&rgn=div5#sp40.10.61.h (Accessed February 25, 2021)

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A

Appendix A Glossary

accuracy—The closeness of the result of a measurement to the true value of the quantity.

aliquot—The quantity of a sample being used for analysis.

alkalinity—The capacity of an aqueous solution to neutralize an acid. Alkalinity measurements are important in determining the sensitivity of a body of water to acid inputs such as acidic pollution from rainfall or wastewater.

alpha particle—A positively charged particle emitted from the nucleus of an atom; it has the same charge and mass as that of a helium nucleus (two protons and two neutrons).

ambient air—The surrounding atmosphere as it exists around people, plants, and structures.

analyte—A constituent or parameter that is being analyzed.

analytical detection limit—The lowest reasonably accurate concentration of an analyte that can be detected; this value varies depending on the method, instrument, and dilution used.

anion—A negatively charged ion.

aquifer—A saturated, permeable geologic unit that can transmit significant quantities of water under ordinary hydraulic gradients.

aquitard—A geologic unit that inhibits the flow of water.

beta particle—A negatively charged particle emitted from the nucleus of an atom. It has a mass and charge equal to those of an electron.

biota—The animal and plant life of a particular region considered as a total ecological entity.

blank—A control sample that is identical in principle to the sample of interest, except the substance being analyzed is absent. In such cases, the measured value or signal for the substance being analyzed is believed to be a result of artifacts. Under certain circumstances, that value may be subtracted from the measured value to give a net result reflecting the amount of the substance in the sample. EPA does not permit the subtraction of blank results in EPA-regulated analyses.

calibration—Determination of variance from a standard of accuracy of a measuring instrument to ascertain necessary correction factors.

CERCLA Off-site Rule—Requires that CERCLA wastes be placed only in a facility operating in compliance with the Resource Conservation and Recovery act or other applicable federal or state requirements. The regulatory citation is 40 *CFR* 300.440.

CERCLA-reportable release—A release to the environment that exceeds reportable quantities as defined by the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA).

chemical oxygen demand—Indicates the quantity of oxidizable materials present in water and varies with water composition, concentrations of reagent, temperature, period of contact, and other factors.

closure—Specifically, closure of a hazardous waste management facility under Resource Conservation and Recovery Act (RCRA) requirements.

compliance—Fulfillment of applicable requirements of a plan or schedule ordered or approved by government authority.

concentration—The amount of a substance contained in a unit volume or mass of a sample.

conductivity—A measure of water's capacity to convey an electric current. This property is related to the total concentration of the ionized substances in water and the temperature at which the measurement is made.

confluence—The point at which two or more streams meet; the point where a tributary joins the main stream.

contamination—Deposition of unwanted material on the surfaces of structures, areas, objects, or personnel.

cosmic radiation—Ionizing radiation with very high energies, originating outside the earth's atmosphere. Cosmic radiation is one source contributing to natural background radiation.

count—A measure of the radiation from an object or device; the signal that announces an ionization event within a counter.

curie (Ci)—A unit of radioactivity. One curie is defined as 3.7×10^{10} (37 billion) disintegrations per second. Several fractions and multiples of the curie are commonly used:

- **kilocurie (kCi)**—10^{3} Ci, one thousand curies; 3.7×10^{13} disintegrations per second.
- **millicurie (mCi)**—10^{-3} Ci, one-thousandth of a curie; 3.7×10^{7} disintegrations per second.
- **microcurie (µCi)**—10^{-6} Ci, one-millionth of a curie; 3.7×10^{4} disintegrations per second.
- **picocurie (pCi)**—10^{-12} Ci, one-trillionth of a curie; 0.037 disintegrations per second.

daughter—A nuclide formed by the radioactive decay of a parent nuclide.

decay, radioactive—The spontaneous transformation of one radionuclide into a different radioactive or nonradioactive nuclide, or into a different energy state of the same radionuclide.

dense nonaqueous phase liquid (DNAPL)—The liquid phase of chlorinated organic solvents. These liquids are denser than water and include commonly used industrial compounds such as tetrachloroethene and trichloroethene.

derived concentration guide (DCG)—The concentration of a radionuclide in air or water that, under conditions of continuous exposure for 1 year by one exposure mode (i.e., ingestion of water, submersion in air, or inhalation), would result in either an effective dose equivalent of 0.1 rem (1 mSv) or a dose equivalent of 5 rem (50 mSv) to any tissue, including skin and lens of the eye. The guides for radionuclides in air and water are given in DOE Order 5400.5.

derived concentration standard (DCS)—Quantities used in the design and conduct of radiological environmental protection programs at US Department of Energy facilities and sites. These quantities represent the concentration of a given radionuclide in either water or air that results in a member of the public receiving a 1 mSv (100 mrem) effective dose following continuous exposure for 1 year for each of the following pathways: ingestion of water, submersion in air, and inhalation.

disintegration, nuclear—A spontaneous nuclear transformation (radioactivity) characterized by the emission of energy and/or mass from the nucleus of an atom.

dissolved oxygen—A measurement of the amount of gaseous oxygen in an aqueous solution. Adequate dissolved oxygen is necessary for good water quality.

dose—A general term for absorbed dose, equivalent dose, or effective dose.

- absorbed dose—The average energy imparted by ionizing radiation to the matter in a volume element per unit mass of irradiated material. The absorbed dose is expressed in units of rad (or gray) (1 rad = 0.01 gray).
- collective dose/collective effective dose—The sum of the total effective dose to all persons in a specified population received in a specified period of time. It can be approximated by the sum of the average effective dose for a given subgroup i, and Ni is the number of individuals in this subgroup. Collective dose is expressed in units of person-rem (or person-sievert).
- effective dose (E or ED)—The summation of the products of the equivalent dose (HT) received by specified tissues or organs of the body and the appropriate tissue weighting factor (wT). It includes the dose from radiation sources internal and/or external to the body. The effective dose is expressed in units of rems (or sieverts).
- equivalent dose (HT)—The product of average absorbed dose (DT,R) in rad (or gray) in a tissue or organ (T) and a radiation (R) weighting factor (wR).

dosimetry—Measurement and calculation of radiation doses from exposure to ionizing radiation.

drinking water standard (DWS)—Federal primary drinking water standards, both proposed and final, as set forth by the US Environmental Protection Agency.

duplicate samples—Two or more samples collected simultaneously into separate containers.

effluent—A liquid or gaseous waste discharge to the environment.

effluent monitoring—The collection and analysis of samples or measurements of liquid and gaseous effluents for purposes of characterizing and quantifying the release of contaminants, assessing radiation exposures of members of the public, and demonstrating compliance with applicable standards.

energy intensity—Energy consumption per square foot of building space, including industrial or laboratory facilities [EO 13514, Section 19(f)].

Environmental Management—A US Department of Energy program that directs the assessment and cleanup (remediation) of its sites and facilities contaminated with waste as a result of nuclear-related activities.

exposure (radiation)—The incidence of radiation on living or inanimate material by accident or intent. Background exposure is the exposure to natural background ionizing radiation. Occupational exposure is the exposure to ionizing radiation that takes place during a person's working hours. Population exposure is the exposure to the total number of persons who inhabit an area.

external radiation—Exposure to ionizing radiation when the radiation source is located outside the body.

flux—A flow or discharge of a substance (in units of mass, radioactivity, etc.) per unit of time.

gamma ray—High-energy, short-wavelength electromagnetic radiation emitted from the nucleus of an excited atom. Gamma rays are identical to x-rays except for the source of the emission.

grab sample—A sample collected instantaneously with a glass or plastic bottle placed below the water surface to collect surface water samples (also called dip samples).

greenhouse gas (GHG)—Gas that traps heat in the atmosphere. The four major greenhouses gases are carbon dioxide, methane, nitrous oxide, and fluorinated gases.

groundwater—The water located beneath the earth's surface in soil pore spaces and in the fractures of rock formations.

hardness—Water hardness is caused by polyvalent metallic ions dissolved in water. In fresh water, these are mainly calcium and magnesium, although other metals such as iron, strontium, and manganese may contribute to hardness.

hectare—A metric unit of area equal to 10,000 square meters or 2.47 acres.

hydrology—The science dealing with the properties, distribution, and circulation of natural water systems.

internal radiation—Internal radiation occurs when radionuclides enter the body by ingestion of foods, milk, and water, and by inhalation. Radon is the major contributor to the annual dose equivalent for internal radionuclides.

ion—An atom or compound that carries an electrical charge.

irradiation—Exposure to radiation.

isotopes—Forms of an element having the same number of protons in their nuclei but differing in the number of neutrons.

Leadership in Energy and Environmental Design (LEED)—A suite of rating systems for the design, construction, operation, and maintenance of green buildings, homes, and neighborhoods. LEED is intended to help building owners and operators find and implement ways to be environmentally responsible and resource-efficient.

maximally exposed individual (MEI)—A hypothetical individual who, because of proximity, activities, or living habits, could potentially receive the maximum possible dose of radiation from a given event or process.

microbes—Microscopic organisms.

migration—The transfer or movement of a material through the air, soil, or groundwater.

millirem (mrem)—The dose equivalent that is one one-thousandth of a rem.

milliroentgen (mR)—A measure of x-ray or gamma radiation. The unit is one-thousandth of a roentgen.

minimum detectable activity (MDA)—The smallest activity of a radionuclide that can be distinguished in a sample by a given measurement system at a preselected counting time and at a given confidence level.

monitoring—A process whereby the quantity and quality of factors that can affect the environment and/or human health are measured periodically to regulate and control potential impacts.

natural radiation—Radiation arising from cosmic and other naturally occurring radionuclide sources (such as radon) present in the environment.

nuclide—An atom specified by its atomic weight, atomic number, and energy state. A radionuclide is a radioactive nuclide.

outfall—The point of conveyance (e.g., drain or pipe) of wastewater or other effluents into a ditch, pond, or river.

ozone—A gas made up of three oxygen atoms that occurs both in earth's upper atmosphere and at ground level. Ozone can be "good" or "bad" for human health and the environment, depending on its location in the atmosphere. Ozone acts as a protective layer high above the earth, but it can be harmful to breathe.

parts per billion (ppb)—A unit measure of concentration equivalent to the weight/volume ratio expressed as micrograms per liter or nanograms per milliliter.

parts per million (ppm)—A unit measure of concentration equivalent to the weight/volume ratio expressed as milligrams per liter or milligrams per kilogram.

person-rem—Collective dose to a population group. For example, a dose of 1 rem to 10 individuals results in a collective dose of 10 person-rem.

pH—A measure of the hydrogen ion concentration in an aqueous solution. Acidic solutions have a pH from 0 through < 7, basic solutions have a pH > 7, and neutral solutions have a pH = 7.

precision—The degree to which repeated measurements under unchanged conditions show the same results (also called reproducibility or repeatability).

quality assurance (QA)—Any action in environmental monitoring to ensure the reliability of monitoring and measurement data.

quality control (QC)—The routine application of procedures within environmental monitoring to obtain the required standards of performance in monitoring and measurement processes.

rad—The unit of absorbed dose deposited in a volume of material.

radioactivity—The spontaneous emission of radiation, generally alpha or beta particles or gamma rays, from the nucleus of an unstable isotope.

radioisotopes—Radioactive isotopes.

radionuclide—An unstable nuclide capable of spontaneous transformation into other nuclides by changing its nuclear configuration or energy level. This transformation is accompanied by the emission of photons or particles.

reclamation—Recovery of wasteland, desert, etc. by ditching, filling, draining, or planting.

reference material—A material or substance with one or more properties that is sufficiently well established and is used to calibrate an apparatus, to assess a measurement method, or to assign values to materials.

release—Any discharge to the environment. "Environment" is broadly defined as any water, land, or ambient air.

rem—The unit of dose equivalent (absorbed dose in rads × the radiation quality factor). Dose equivalent is frequently reported in units of millirem (mrem), which is one one-thousandth of a rem.

remediation—The correction of a problem. On the Oak Ridge Reservation remediation efforts focus on the safe cleanup of the environmental legacy resulting from research activities and weapons production over the past 5 decades.

roentgen—A unit of radiation exposure equal to the quantity of ionizing radiation that will produce one electrostatic unit of electricity in one cubic centimeter of dry air at 0°C and standard atmospheric pressure. One roentgen equals 2.58 × 10^{-4} coulombs per kilogram of air. [Note: A coulomb is a unit of electric charge—the SI (International System of Units) unit of electric charge equal to the amount of charge transported by a current of one ampere in one second.]

sensitivity—The capability of a methodology or an instrument to discriminate among samples with differing concentrations or containing varying amounts of analyte.

sievert (Sv)—The SI (International System of Units) unit of dose equivalent; 1 Sv = 100 rem.

spike—The addition of a known amount of reference material containing the analyte of interest to a blank sample.

spiked sample—A sample to which a known amount of some substance has been added.

stable—Not radioactive or not easily decomposed or otherwise modified chemically.

stack—A vertical pipe or flue designed to exhaust airborne gases and suspended particulate matter.

standard reference material (SRM)—A reference material distributed and certified by the National Institute of Standards and Technology.

storm water runoff—Rainfall that flows over the ground surface.

stratospheric ozone—The stratosphere or "good" ozone layer extends upward from about 6 to 30 miles above the earth's surface and protects the earth from the sun's harmful ultraviolet rays.

substrate—The substance, base, surface, or medium in which an organism lives and grows.

Superfund—The Superfund Amendments and Reauthorization Act amended the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) in 1986. CERCLA, the federal program to clean up the nation's uncontrolled hazardous waste, is now known as Superfund.

surface water—All water on the surface of the earth, as distinguished from groundwater.

terrestrial radiation—Ionizing radiation emitted from radioactive materials, primarily potassium-40, thorium, and uranium, in the earth's soils. Terrestrial radiation contributes to natural background radiation.

total dissolved solids—Dissolved solids and total dissolved solids (generally associated with freshwater systems) consist of inorganic salts, small amounts of organic matter, and dissolved materials.

transect—A line across an area being studied. The line is composed of points where specific measurements or samples are taken.

transuranic (or transuranium)—Of or relating to elements with higher atomic weights than uranium; all 13 known transuranic elements are radioactive and are produced artificially.

transuranic waste—Solid radioactive waste containing primarily alpha-emitting elements heavier than uranium.

trip blank—A sample container of deionized water that is transported to a sampling location, treated as a sample, and sent to the laboratory for analysis; trip blanks are used to check for contamination resulting from transport, shipping, and site conditions.

turbidity—A measure of the concentration of sediment or suspended particles in solution.

volatile organic compounds—Organic chemicals that have a high vapor pressure at ordinary conditions. They include both human-produced and naturally occurring chemical compounds and are used in many industrial processes. Common examples include trichloroethane, tetrachloroethene, and trichloroethene.

watershed—The region draining into a river, river system, or body of water. Large watersheds may be subdivided into smaller units called **subwatersheds**, which collectively flow together to form larger sub-basins and river basins.

wetlands—Lowland areas, such as a marshes or swamps, sufficiently inundated or saturated by surface water or groundwater to support aquatic vegetation or plants adapted for life in saturated soils. Wetlands are those areas that are inundated or saturated by surface or groundwater at a frequency and duration sufficient to support, and that under normal circumstances do support, a prevalence of vegetation typically adapted for life in saturated soil conditions. Wetlands include swamps, marshes, bogs, and similar areas.

wind rose—A diagram that summarizes statistical information concerning wind direction and speed at a specific location.

B

Appendix B Climate Overview of the Oak Ridge Area

B.1. Regional Climate

The climate of the Oak Ridge area and its surroundings may be broadly classified as humid subtropical. The term “humid” indicates that the region receives an overall surplus of precipitation compared to the level of evaporation and transpiration normally experienced throughout the year. The “subtropical” designation indicates that the region experiences a wide range of seasonal temperatures. Such areas are typified by significant differences in temperature between summer and winter. More specifically, the coldest month’s average temperature is above –3°C (27°F), and at least one summer month has an average temperature above 22°C (72°F). Also, the definition of the humid subtropical climate means that at least 4 months have an average temperature above 10°C (50°F). There are no major differences in monthly precipitation throughout the year, but the sources of precipitation may vary.

Oak Ridge winters are characterized by synoptic midlatitude cyclones that produce significant precipitation events roughly every 3 to 5 days. These wet periods are occasionally followed by arctic air outbreaks. Although snow and ice are not associated with many of these systems, occasional snowfall does result. Winter cloud cover tends to be enhanced by the regional terrain due to cold air wedging and moisture trapping.

Severe thunderstorms, which can occur at any time of the year, are most frequent during spring and rarely occur in winter. The Cumberland Mountains and Cumberland Plateau frequently inhibit the intensity of severe systems that traverse the region, particularly those moving from west to east, due to the downward momentum created as the storms move off higher terrain into the Great Valley. Summers are characterized by very warm, humid conditions. Occasional frontal systems may produce organized lines of thunderstorms and rare damaging tornados. More frequently, however, summer precipitation results from "air mass" thundershowers that form as a consequence of daytime heating, rising humid air, and local terrain features. Although fall precipitation is usually adequate, August through October often are the driest months of the year. The occurrence of precipitation during the fall tends to be less cyclical than for other seasons, but is occasionally enhanced by decaying tropical cyclones moving north from the Gulf of Mexico. In November, midlatitude cyclones again begin to dominate the weather and typically continue to do so until May.

Decadal-scale climate change regularly affects the East Tennessee region. Most of these changes appear related to the hemispheric temperature and precipitation effects caused by the frequency and phase of the El Niño–Southern Oscillation (ENSO), the Pacific Decadal Oscillation (PDO), and the Atlantic Multidecadal Oscillation (AMO). The ENSO and PDO patterns, with cycles of 3 to 7 years and about 60 years, respectively, affect Pacific Ocean sea surface temperature patterns. The AMO, with a cycle of 40 to 70 years, affects Atlantic sea surface temperature similar to the PDO. These medium- and long-range sea surface temperature patterns collectively modulate decadal-scale and longer regional temperature and precipitation trends in eastern Tennessee. The AMO shifted from a cold to a warm sea surface temperature phase in the mid-1990s and may continue in its present state for another decade or so. The PDO entered an either cool or transitional sea surface temperature state around 2000. Although the ENSO pattern had frequently brought about warmer Eastern Pacific sea surface temperatures during the 1990s, that phenomenon had subsided somewhat in the 2000s. A very strong El Niño occurred in 2015–2016, leading to above-normal temperatures both locally and across much of the globe by 2016. In general, a return to the dominance of El Niño has occurred during the 2010s. Additionally, evidence exists that human-induced climate change may be producing some effect on local temperatures via an array of first-order influences such as well-mixed greenhouse gases, land cover change, carbon soot, aerosols, and other effects. Solar influences on the jet stream, via changes to the stratospheric temperature gradient with respect to the 11-year solar cycle (and perhaps longer cycles), also play a role in inter-annual climate variability (Ineson et al. 2011). Perhaps in part due to the effects of the AMO and ENSO, the Oak Ridge climate warmed about 1.2°C from the 1970s to the 1990s but has remained within 0.2°C of the 1990s observed value through the 2010s. The late-20th-century warming appears to have lengthened the growing season (i.e., the period with temperatures above 0°C, or 32°F) by about 2 to 3 weeks over the last 30 years. This warming has primarily affected minimum temperature over the last 30 years; the effect is presumably related to changes in the interaction of the surface boundary layer with greenhouse gases and/or aerosol concentration changes. The effects of greenhouse gases on the nocturnal inversion layer (and thus on minimum temperatures) represent a redistribution of heat in the lower portion of the surface atmospheric layer. Temperature averages for individual years may vary significantly, as noted by the recent contrast of greater than 1°C between 2014 (14.8°C average) and 2015 (16.0°C average), largely the result of the recent strong El Niño. During the post-El Niño years of 2017 and 2018, the annual average temperature at ORNL returned to approximately the same level as in 2014 (i.e., 14.5°C in 2018). Values rose again in 2019 under the influence of weak El Niño conditions (15.2°C) but declined in 2020 to 14.7°C with the onset of La Niña conditions.

B.2. Winds

Five major terrain-related wind regimes regularly affect the Great Valley of eastern Tennessee:

- Pressure-driven channeling
- Downward-momentum transport or vertically coupled flow
- Forced channeling
- Along-valley and mountain-valley thermal circulations
- Down sloping

Pressure-driven channeling and vertically coupled flow affect winds on scales comparable to those of the Great Valley (hundreds of kilometers). Forced channeling occurs on similar scales but is also quite important at small spatial scales, such as those characterizing the ridge-and-valley terrain within ORR (Birdwell 2011). Along-valley and mountain-valley circulations are thermally driven and occur within a broad range of spatial scales. Thermally driven flows are more prevalent under conditions of clear skies and low humidity, favoring summer and especially fall months. Down sloping frequently is responsible for a slight temperature elevation when the Cumberland Mountains are on the windward side of ORR. Such windward flow also favors reduced wind speeds.

Forced channeling is defined as the direct deflection of wind by terrain. This form of channeling necessitates some degree of vertical motion transfer, implying that the mechanism is less pronounced during strong temperature-inversion conditions. Although forced channeling may result from interactions between large valleys and mountain ranges (such as the Great Valley and the surrounding mountains), the mechanism is especially important in narrow, small valleys such as those within ORR and the Great Valley (Kossman and Sturman 2002).

Forced channeling within the Central Great Valley is the dominant large-scale wind mechanism, influencing 50 to 60 percent of all winds observed in the area. For up-valley (southwest to northeast) flow cases, these winds are frequently associated with large wind shifts (45°–90°) when they initiate or terminate. At small scales, ridge-and-valley terrain produces forced-channeled local flow in more than 90 percent of cases. Most forced-channeled winds prefer weak to moderate synoptic pressure gradients of less than 0.010 mb/km (Birdwell 2011).

Large-scale forced channeling occurs regularly within the Great Valley when northwest to north winds (perpendicular to the axis of the central Great Valley) coincide with vertically coupled flow. The phenomenon sometimes results in a split-flow pattern, with winds southwest of Knoxville moving down-valley and those east of Knoxville moving up-valley. The causes of such a flow pattern may include the shape characteristics of the Great Valley (Kossman and Sturman 2002) but also may be associated with the specific location of the Cumberland and Smoky Mountains relative to upper-level wind flow (Eckman 1998). The convex shape of the Great Valley with respect to a northwest wind flow may lead to a divergent wind flow pattern in the Knoxville area, resulting in downward air motion. Horizontal flow is also reduced by the windward mountain range, the Cumberland Mountains, which increases buoyancy and Coriolis effects (also known as Froude and Rossby ratios). Consequently, the leeward mountain range, the Smoky Mountains, becomes more effective at blocking or redirecting the winds.

Vertically coupled winds tend to occur when the atmosphere is unstably or neutrally buoyant. When a strong horizontal wind component is present, as in conditions behind a winter cold front or during strong regional cold air advection, winds tend to override the terrain, flowing roughly in the same direction as the winds aloft. This phenomenon is a consequence of the horizontal transport and momentum aloft being transferred to the surface. However, Coriolis effects may turn the winds by up to 40° to the left (Birdwell 1996).

In the Central Valley, vertically coupled winds dominate about 25 to 35 percent of the time; however, most such winds are turned toward an up-valley or down-valley direction when small-scale ridge-and-valley terrain is factored in. Wintertime vertically coupled flow is typically dominated by strong, large-scale pressure forces, whereas the summertime cases tend to be associated with a deep mixing depth (greater than 500 m). Most vertically coupled flows are associated with major wind shifts (90°–135°) when they begin or terminate (Birdwell 2011).

Another wind mechanism, pressure-driven channeling, is the redirection of synoptically induced wind flow through a valley channel. The direction of wind flow through the valley is determined by the axis of the pressure gradient superimposed on a valley axis (Whiteman 2000).

The process is affected by Coriolis forces, a leftward deflection of winds in the Northern Hemisphere. Eckman (1998) suggested that pressure-driven channeling plays a significant role in the Great Valley. Winds driven purely by such a process shift from up-valley to down-valley flow or conversely as large-scale pressure systems induce reversals in air pressure gradients across the axis of the Great Valley. Since the processes involved in pressure-driven flow primarily affect the horizontal motion of air, the presence of a temperature inversion enhances this pattern significantly. Weak vertical air motion and momentum associated with such inversions allow different layers of air to slide over each other with varied direction of movement (Monti et al. 2002).

Within the Central Great Valley, and especially for ORR, winds dominated by down-valley pressure-driven channeling range in frequency from 2 to 10 percent, with the lowest values in summer and the highest in winter. Up-valley pressure-driven channeling usually does not dominate winds in the Central Great Valley but co-occurs with forced-channeled winds 50 percent of the time. Winds dominated by pressure-driven channeling often result in large wind shifts (90°–180°) before and after the occurrence of the wind pattern. These wind shifts occur about twice as frequently within and near ORR when compared with wind shifts that take place in other parts of the Great Valley (Birdwell 2011). Most pressure-driven channeled winds occur in association with moderate (0.006–0.016 mb/km) synoptic pressure gradients.

Thermally driven winds are common in areas of significant complex terrain. These winds occur as a result of pressure and temperature differences caused by varied surface-air energy exchange at similar altitudes along a valley's axis, sidewalls, or slopes. Thermal flows operate most effectively when synoptic winds are light and when thermal differences are exacerbated by clear skies and low humidity (Whiteman 2000). Ridge-and-valley terrain may be responsible for enhancing or inhibiting such flow, depending on ambient weather conditions. Large-scale thermally driven wind frequency varies from 2 percent to 20 percent with respect to season in the Central Great Valley. Frequencies are highest during summer and especially fall, when surface heating and/or low humidity help drive flow patterns (Birdwell 2011).

Annual wind roses have been compiled for 2020 for each of the 10 DOE-managed ORR meteorological towers (towers MT2, MT3, MT4, MT6, MT7, MT9, MT10, MT11, MT12, and MT13). These, along with other annual wind rose data, may be viewed on the ORNL meteorology website here. The wind roses represent large-scale trends and should be used with caution for estimates involving short-term variations.

A wind rose depicts the typical distribution of wind speed and direction for a given location. The winds are represented in terms of the direction from which they originate. The rays emanating from the center correspond to points of the compass. The length of each ray is related to the frequency at which winds blow from the given direction. The concentric circles represent increasing frequencies from the center outward, given in percentages. Precipitation wind roses display similar information except that wind speed frequencies are replaced with data associated with the rate of hourly precipitation. Likewise, wind direction stability and wind direction mixing height roses replace wind speeds with data on stability class and mixing height, respectively. Wind direction peak gust roses reflect the frequency of peak 1 to 10 s wind gusts for various wind directions.

B.3. Temperature and Precipitation

Temperature and precipitation normals (1991-2020) and extremes (1948–2020) and their durations for the city of Oak Ridge and ORNL are summarized in Table B.1. Decadal temperature and precipitation averages for the five decades of the 1970s to 2010s are provided in Table B.2. Hourly freeze data (1985–2020) are given in Table B.3. Overall, at ORNL, 2020 was 0.4°C below normal with regard to temperatures compared to the 1991–2020 Oak Ridge base period, and precipitation was 27 percent above normal compared to the 1991–2020 mean.

Recent climate change with respect to temperature and precipitation

Table B.2 presents a decadal analysis of temperature patterns for the decades of the 1970s to the 2010s. In general, temperatures in the Oak Ridge area rose from the 1970s to the 1990s and then nearly stabilized since the 1990s. Based on these average decadal temperatures, temperatures have risen 1.2°C between the decades of the 1970s and the 1990s, from 13.8°C to 15.0°C (56.8°F to 59.0°F). The warmest decade of the last five was the 2000s at 15.2°C (59.3°F), although the 2010s where virtually the same (15.2°C or 59.2°F). More detailed analysis reveals that these temperature changes have been neither linear nor equal with respect to the seasons.

From the 1970s to the 1990s, January and February average temperatures have seen increases of about 2.5°C, followed by a decline of just over 1°C since the 1990s. The observed peak in the 1990s may be associated with the effects of the AMO, though this climate response may include both natural and anthropogenic effects. The Arctic has seen the largest increase in temperatures anywhere in the Northern Hemisphere over the last 30 years, and this has an effect on Oak Ridge temperatures in winter due to the presence of Arctic air masses during that season.

During the winter months of January and February, much of the air entering eastern Tennessee comes from the Arctic. As a result, Oak Ridge temperatures have warmed more dramatically during those months in which Arctic air dominates. However, the changes affecting the months of January and February do not seem to be the case for December temperature averages. December averages were relatively warm in the 1970s (4.6°C), bottomed out in the 1980s (3.1°C), returned to approximately 1970s levels in the 1990s and 2000s, and finally warmed (to about 6.0°C) by the 2010s.

Compared to the 1970s, temperatures have warmed 1.0°C, 1.5°C, and 2.1°C during the climatological spring months of March, April, and May, respectively. However, most of that warming did not occur until the 2000s for the months of March and April. The tendency toward warmer springs has had the effect of slightly lengthening the growing season.

Summer months (June, July, and August) were 1.8°C, 1.3°C, and 0.9°C warmer on average in the 2010s versus the 1970s; however, most observed warming during summer can be attributed to a rise in minimum temperatures. In fact, August maximum temperatures have declined about 1.0°C since the 2000s. Warming for June and July has virtually stopped since the 2000s.

Climatological fall months (September, October, and November) generally had the weakest average temperature increases (of 0.9°C, 1.3°C, and 0.1°C) since the 1970s. In fact, September and October have seen virtually no change in average temperature since the 1990s, while November has not shown a clear trend across the decades since the 1970s.

The mean annual temperature increased by 1.4°C between the 1970s and the 2000s and then remained about the same in the 2010s (1.3°C warming compared to the 1970s). About 90 percent of the observed increase occurred between the 1980s and 1990s. Mean annual decadal-averaged temperatures have varied by only 0.2°C since the 1990s. The base period used to determine the mean annual temperature was updated for the 2020 ASER from a range of 1981 to 2010 to a range of 1991 to 2020. The mean annual temperature increased by about 0.6°C, mainly because the cooler 1980s values had been eliminated.

Decadal precipitation averages suggest some important changes in precipitation patterns in Oak Ridge over the period from the 1970s to 2010s. Although overall decadal precipitation averages have remained within a window of about 48 to 60 in. annually, there have been some decadal shifts in the patterns of rainfall on a monthly and seasonal scale. During winter (December, January, and February), precipitation remained fairly constant since the 1970s, but there has been a significant increase in February precipitation in the 2010s (as well as an increase for winter overall since the 2000s). Spring precipitation (March, April, and May) has declined about 20 percent since the 1970s. For summer precipitation (June, July, and August), changes in precipitation are mixed. June values have changed little in the 2010s versus the 1970s, but July values have increased about 20 percent, and August values declined about 20 percent. Similar patterns are revealed for the fall months. September in the 2010s shows about a 10 percent increase compared to the 1970s while October shows about a 10 percent decrease. There was little change in precipitation for November. Overall, annual average precipitation in the 2010s is only about 3 percent less than in the 1970s (59.68 versus 58.18 in.). Also, both the 1980s and 2000s were 10 percent to 20 percent drier than the 2010s while the 1990s exhibited similar precipitation. The precipitation total for CY 2020, 1,801 mm (70.89 in.), was about 20 percent above the 30-year mean. The total period of observed precipitation for Oak Ridge covers the period from 1948 to 2020.

The previously discussed increase in winter temperatures by the 2000s and 2010s has affected monthly and annual snowfall amounts. During the 1970s and 1980s, snowfall averaged about 25.4 to 28 cm (10 to 11 in.) annually in Oak Ridge. However, during the most recent two decades (2000s and 2010s), snowfall has averaged only 9.8 cm (3.9 in.) per year. This decrease seems to have occurred largely since the mid-1990s. There has been a slight cooling of January and February temperatures in the 2010s compared to the 2000s, which seems to have reversed the decrease in snowfall slightly, with annual averages of 13.2 cm (5.2 in.). Concurrent with the overall decrease in snowfall, the annual number of hours of subfreezing weather has generally declined since the 1980s (see Table B.3). However, the number of subfreezing hours during 2010 (1,123 h) was the highest recorded since 1988. January 2014 was the coldest January since 1985, with 371 subfreezing hours, and February 2015 was the coldest February since 1978, also with 371 subfreezing hours.

Table B.1. Climate normals (1991–2020) and extremes (1948–2020) for ORNL

Monthly variables	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Temperature, °C (°F)[a]													
30-Year Average Max	8.8 (47.8)	11.4 (52.6)	16.4 (61.7)	21.9 (71.4)	26.2 (79.2)	29.8 (85.7)	31.4 (88.6)	31.2 (88.1)	28.1 (82.6)	22.2 (72.0)	15.3 (59.7)	10.2 (50.5)	21.1 (70.0)
2020 Average Max	11.1 (52.0)	11.7 (53.0)	17.8 (64.1)	19.8 (67.6)	23.6 (74.4)	28.6 (83.5)	33.0 (91.3)	30.0 (86.0)	26.5 (79.8)	22.3 (72.1)	17.8 (64.1)	9.3 (48.9)	20.8 (69.4)
73-Year Record Max	25 (77)	27 (80)	30 (86)	33 (92)	35 (95)	41 (105)	41 (105)	39 (103)	39 (102)	35 (96)	28 (83)	26 (78)	41 (105)
30-Year Average Min	-1.5 (29.4)	0.1 (32.3)	3.9 (39.0)	8.1 (46.7)	13.4 (56.1)	17.9 (64.1)	20.1 (68.2)	19.5 (67.1)	15.9 (60.6)	9.1 (48.4)	3.0 (37.4)	0.2 (32.5)	8.5 (48.5)
2020 Average Min	1.2 (34.2)	1.4 (34.4)	7.7 (45.8)	6.0 (42.7)	11.2 (52.1)	16.6 (61.8)	20.0 (68.0)	19,7 (67.5)	15.7 (60.2)	10.0 (50.0)	3.4 (38.1)	-1.7 (29.0)	9.3 (48.6)
73-Year Record Min	-27 (-17)	-25 (-13)	-17 (1)	-7 (20)	-1 (30)	4 (39)	9 (49)	10 (50)	1 (33)	-6 (21)	-16 (3)	-22 (-7)	-27 (-17)
30-Year Average	3.5 (38.5)	5.8 (42.4)	10.2 (50.4)	15.1 (59.2)	19.6 (67.5)	23.7 (74.7)	25.7 (78.1)	25.1 (77.3)	21.8 (71.3)	15.5 (59.9)	9.1 (48.4)	5.2 (41.4)	15.1 (59.1)
2020 Average	6.1 (43.0)	6.3 (43.4)	12.7 (54.8)	12.7 (54.9)	17.1 (62.9)	22.2 (71.9)	25.6 (78.1)	23.9 (75.0)	20.4 (68.7)	15.5 (59.8)	9.8 (49.7)	3.4 (38.2)	14.7 (58.4)
2020 Departure from Average	2.6 (4.5)	0.5 (1.0)	2.5 (4.4)	-2.4 (-4.3)	-2.5 (-4.6)	-1.5 (-2.8)	-0.1 (-0.3)	-1.2 (-2.3)	-1.4 (-2.6)	-0.0 (-0.1)	0.7 (1.3)	-1.8 (-3.2)	-0.4 (-0.7)
30-year average heating degree days, °C (°F)													
	451 (811)	351 (631)	252 (453)	110 (198)	31 (55)	1 (2)	0	0	9 (16)	101 (181)	271 (487)	399 (718)	1973 (3552)
30-year average cooling degree days, °C (°F)													
	0	0 (1)	7 (12)	18 (32)	80 (144)	170 (306)	235 (423)	221 (398)	119 (215)	22 (40)	1 (2)	0	874 (1573)
Precipitation, mm (in.)													
30-Year Average	132.6 (5.22)	138.7 (5.46)	129.8 (5.11)	132.1 (5.20)	106.5 (4.19)	112.3 (4.42)	141.5 (5.57)	85.1 (3.35)	101.4 (3.99)	80.8 (3.18)	120.9 (4.76)	138.5 (5.45)	1420.3 (55.90)
2020 Totals	223.3 (8.79)	311.2 (12.25)	207.1 (8.15)	184.5 (7.26)	113.3 (4.46)	58.2 (2.29)	72.7 (2.86)	124.5 (4.90)	128.8 (5.07)	184.2 (7.25)	90.7 (3.57)	102.6 (4.04)	1801.2 (70.89)
2020 Departure from Average	90.7 (3.57)	172.5 (6.79)	77.2 (3.04)	52.4 (2.06)	6.8 (0.27)	-54.1 (-2.13)	-68.8 (-2.71)	39.4 (1.55)	27.4 (1.12)	83.4 (4.07)	-30.2 (-1.19)	-35.9 (-1.41)	380.9 (14.99)
73-Year Max Monthly	337.2 (13.27)	384.7 (15.14)	311.0 (12.24)	356.5 (14.03)	271.9 (10.70)	283.0 (11.14)	489.6 (19.27)	265.8 (10.46)	257.4 (10.14)	203.8 (8.02)	310.5 (12.22)	321.2(12.64)	1939.4 (76.33)
73-Year Max 24-h	108.0 (4.25)	131.6 (5.18)	120.4 (4.74)	158.5 (6.24)	112.0 (4.41)	94.0 (3.70)	124.8 (4.91)	190.1 (7.48)	160.1 (6.30)	67.6 (2.66)	130.1 (5.12)	130.1 (5.12)	190.1 (7.48)
73-Year Min Monthly	23.6 (0.93)	21.3 (0.84)	54.1 (2.13)	46.2 (1.82)	20.3 (0.80)	13.5 (0.53)	31.3 (1.23)	13.7 (0.54)	Trace	Trace	34.8 (1.37)	17.0 (0.67)	911.4 (35.87)
Snowfall, cm (in.)													
30-Year Average	3.6 (1.4)	5.1 (2.0)	2.0 (0.8)	0	0	0	0	0	0	0	2.5 (0.1)	1.8 (0.7)	12.7 (5.0)
2020 Totals	Trace	1.5 (0.6)	0	0	0	0	0	0	0	0	Trace	4.8 (1.9)	6.4 (2.5)
73-Year Max Monthly	24.4 (9.6)	43.7 (17.2)	53.4 (21.0)	15.0 (5.9)	Trace	0	0	0	0	Trace	16.5 (6.5)	53.4 (21.0)	105.2 (41.4)
73-Year Max 24-h	21.1 (8.3)	28.7 (11.3)	30.5 (12.0)	13.7 (5.4)	Trace	0	0	0	0	Trace	16.5 (6.5)	30.5 (12.0)	30.5 (12.0)

Table B.1. Climate normals (1991–2020) and extremes (1948–2020) for ORNL (continued)

Monthly variables	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Days w/temp													
30-Year Max ≥ 32°C	0	0	0	0.1	1.5	7.7	14.4	12.7	4.9	0.1	0	0	41.4
2020 Max ≥ 32°C	0	0	0	0	0	1	23	4	1	0	0	0	29
30-Year Min ≤ 0°C	19.8	15.4	8.7	1.8	0.1	0	0	0	0	0.9	10.3	16.5	73.5
2020 Min ≤ 0°C	15	13	3	4	2	0	0	0	0	0	6	22	65
30-Year Max ≤ °C	2.6	0.8	0.1	0	0	0	0	0	0	0	0	0.8	4.3
2020 Max ≤ 0°C	1	0	0	0	0	0	0	0	0	0	0	1	2
Days w/precipitation													
30-Year Avg ≥ 0.01 in.	11.8	11.6	12.4	11.1	11.5	11.4	12.3	9.8	8.1	8.3	9.2	12.2	129.7
2020 Days ≥ 0.01 in.	12	15	16	13	12	12	11	17	9	8	7	9	141
30-Year Avg ≥ 1.00 in.	1.7	1.4	1.4	1.5	1.1	1.2	1.6	0.9	1.2	1.0	1.7	1.7	16.4
2020 Days ≥ 1.00 in.	3	4	3	1	1	0	1	2	1	3	1	2	22

[a] *Temperature values are rounded averages of annual measurements for multiple years. Fahrenheit and Celsius values are provided for reader reference but, due to rounding and changes in instrument precision over the years, the equivalent values shown may differ from those calculated using the standard conversion formula.*

Table B.2. Decadal climate change (1970–2019) for city of Oak Ridge/ORNL, with 2020 comparisons

Monthly variables	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Temperature, °C (°F)													
1970–1979 Avg Max	6.6 (43.8)	9.7 (49.5)	15.6 (60.1)	21.4 (70.6)	24.8 (76.7)	28.5 (83.3)	30.0 (85.9)	29.7 (85.5)	26.8 (80.2)	20.8 (69.4)	14.5 (58.2)	10.0 (49.9)	19.9 (67.8)
1980–1989 Avg Max	6.9 (44.4)	10.2 (50.3)	15.9 (60.7)	21.0 (69.8)	25.6 (78.1)	29.8 (85.7)	31.6 (88.8)	30.7 (87.3)	27.1 (80.8)	21.3 (70.3)	15.6 (60.2)	8.6 (47.5)	20.3 (68.6)
1990–1999 Avg Max	9.4 (48.8)	12.3 (54.1)	16.2 (61.2)	21.9 (71.3)	26.2 (79.1)	29.7 (85.5)	32.1 (89.8)	31.4 (88.6)	28.4 (83.2)	22.6 (72.8)	15.2 (59.4)	10.4 (50.8)	21.3 (70.4)
2000–2009 Avg Max	8.8 (47.9)	11.2 (52.1)	17.0 (62.7)	21.4 (70.6)	25.8 (78.4)	29.8 (85.6)	30.8 (87.5)	31.4 (88.5)	27.6 (81.8)	21.8 (71.2)	15.9 (60.6)	9.8 (49.6)	21.0 (69.7)
2010–2019 Avg Max	8.1 (46.7)	11.2 (52.1)	16.3 (61.3)	22.6 (72.7)	26.8 (80.2)	30.2 (86.4)	31.2 (88.4)	30.8 (87.4)	28.5 (83.3)	22.3 (72.1)	15.1 (59.2)	11.4 (51.6)	21.2 (70.1)
1980s vs. 2010s	1.2 (2.2)	1.0 (0.6)	0.3 (0.6)	1.6 (2.8)	1.2 (2.1)	0.4 (0.8)	-0.2 (-0.4)	0.0 (0.1)	1.4 (2.6)	1.0 (1.8)	-0.5 (-0.9)	2.3 (4.1)	0.8 (1.5)
2000s vs. 2010s	-0.7 (-1.2)	0.0 (0.0)	-0.8 (-1.4)	1.2 (2.1)	1.0 (1.8)	0.4 (0.8)	0.5 (1.0)	-0.6 (-1.1)	0.9 (1.6)	0.5 (0.9)	-0.8 (-1.4)	1.1 (2.0)	0.2 (0.4)
2020 Avg Max	8.8 (47.8)	11.7 (53.0)	17.8 (64.0)	19.8 (67.6)	23.6 (74.4)	28.6 (83.5)	33.0 (91.3)	30.0 (86.0)	26.5 (79.8)	22.3 (72.1)	17.8 (64.1)	9.4 (49.0)	20.8 (69.4)
1970–1979 Avg Min	-3.4 (25.8)	-2.4 (27.6)	3.0 (37.4)	6.7 (44.1)	11.6 (52.8)	15.7 (60.2)	18.3 (64.9)	18.1 (64.6)	15.5 (59.9)	7.5 (45.5)	2.6 (36.8)	-0.8 (30.5)	7.7 (45.8)
1980–1989 Avg Min	-4.1 (24.7)	-2.1 (28.3)	1.7 (35.0)	6.0 (42.9)	11.4 (52.4)	16.2 (61.2)	19.0 (66.2)	18.4 (65.1)	14.4 (57.9)	7.5 (45.4)	3.1 (37.5)	-2.3 (27.8)	7.4 (45.3)
1990–1999 Avg Min	-0.9 (30.3)	0.0 (32.0)	2.9 (37.1)	7.2 (45.0)	12.5 (54.5)	17.2 (63.0)	20.0 (67.9)	18.9 (66.1)	15.1 (59.2)	8.2 (46.8)	2.2 (36.0)	0.1 (32.2)	8.6 (47.6)
2000–2009 Avg Min	-1.4 (29.5)	0.0 (32.0)	4.4 (39.9)	8.6 (47.5)	13.6 (56.4)	18.0 (64.3)	20.0 (67.9)	20.0 (68.0)	16.1 (61.0)	9.5 (49.0)	3.9 (39.0)	-0.4 (31.4)	9.4 (48.9)
2010–2019 Avg Min	-2.0 (28.3)	0.6 (33.0)	4.2 (39.5)	8.8 (47.7)	14.1 (57.3)	18.2 (64.9)	20.3 (68.5)	19.5 (67.1)	16.4 (61.4)	9.4 (48.9)	2.7 (36.9)	1.2 (34.2)	9.5 (49.1)
1980s vs. 2010s	2.0 (3.6)	2.6 (4.8)	2.5 (4.4)	2.7 (4.9)	2.7 (4.9)	2.1 (3.8)	1.3 (2.4)	1.1 (2.0)	2.0 (3.5)	2.0 (3.5)	-0.4 (-0.6)	3.6 (6.5)	2.1 (3.8)

Table B.2. Decadal climate change (1970–2019) for city of Oak Ridge/ORNL, with 2020 comparisons (continued)

Monthly variables	January	February	March	April	May	June	July	August	September	October	November	December	Annual
2000s vs. 2010s	-0.6 (-1.2)	0.6 (1.0)	-0.2 (0.4)	0.1 (0.2)	0.5 (0.9)	0.4 (0.6)	0.3 (0.6)	-0.5 (-1.0)	0.3 (0.5)	-0.1 (-0.1)	-1.2 (-2.1)	1.6 (2.9)	0.1 (0.2)
2020 Avg Min	1.1 (34.0)	1.4 (34.4)	7.7 (45.8)	6.0 (42.7)	11.2 (52.1)	16.6 (61.8)	20.0 (68.0)	19.7 (67.5)	15.7 (60.2)	10.0 (50.0)	3.4 (38.1)	-1.7 (29.0)	9.3 (48.6)
1970–1979 Avg	1.6 (34.9)	3.7 (38.6)	9.3 (48.8)	14.1 (57.4)	18.1 (64.7)	22.1 (71.8)	24.1 (75.4)	23.9 (75.0)	21.1 (70.0)	14.2 (57.5)	8.6 (47.5)	4.6 (40.3)	13.8 (56.8)
1980–1989 Avg	1.4 (34.6)	4.1 (39.3)	8.8 (47.9)	13.5 (56.4)	18.5 (65.3)	23.0 (73.4)	25.3 (77.5)	24.6 (76.2)	20.8 (69.4)	14.4 (57.9)	9.4 (48.8)	3.1 (37.7)	13.9 (57.0)
1990–1999 Avg	4.2 (39.6)	6.2 (43.1)	9.6 (49.2)	14.5 (58.2)	19.4 (66.8)	23.5 (74.3)	26.0 (78.9)	25.2 (77.4)	21.9 (71.4)	15.5 (59.8)	8.8 (47.8)	5.3 (41.5)	15.0 (59.0)
2000–2009 Avg	3.7 (38.7)	5.6 (42.1)	10.7 (51.3)	15.3 (59.6)	19.7 (67.5)	23.9 (75.1)	25.4 (77.7)	25.7 (78.3)	21.9 (71.4)	15.6 (60.1)	9.9 (49.8)	4.7 (40.5)	15.2 (59.3)
Precipitation, mm (in.)													
2010–2019 Avg	3.0 (37.3)	5.3 (42.5)	10.3 (50.5)	15.7 (60.1)	20.3 (68.5)	24.0 (75.1)	25.4 (77.8)	24.6 (76.5)	21.9 (71.5)	15.4 (59.8)	8.7 (47.6)	6.4 (42.7)	15.1 (59.2)
1980s vs. 2010s	1.5 (2.8)	1.8 (3.2)	1.5 (2.6)	2.1 (3.8)	1.8 (3.2)	0.9 (1.7)	0.1 (0.3)	0.2 (0.3)	1.2 (2.1)	1.1 (1.9)	-0.7 (-1.2)	2.8 (5.0)	1.2 (2.2)
2000s vs. 2010s	-0.7 (-1.3)	0.2 (0.4)	-0.4 (-0.8)	0.3 (0.6)	0.6 (1.0)	0.0 (0.1)	0.0 (0.1)	-1.0 (-1.8)	0.1 (0.1)	-0.2 (-0.3)	-1.2 (-2.2)	1.2 (2.2)	-0.1 (-0.1)
2020 Avg	6.1 (43.0)	6.3 (43.4)	12.7 (54.9)	13.0 (55.4)	17.1 (62.9)	22.2 (71.9)	25.6 (78.1)	23.9 (75.0)	20.4 (68.7)	15.5 (59.8)	9.8 (49.7)	3.4 (38.2)	14.7 (58.4)
1970–1979 Avg	143.4 (5.65)	94.6 (3.72)	169.4 (6.67)	118.3 (4.66)	149.8 (5.89)	120.5 (4.74)	130.4 (5.13)	109.8 (4.32)	107.2 (4.22)	99.8 (3.93)	129.6 (5.10)	145.3 (5.72)	1516.4 (59.68)
1980–1989 Avg	100.4 (3.95)	109.1 (4.29)	112.6 (4.43)	88.8 (3.49)	110.6 (4.35)	84.1 (3.31)	120.4 (4.74)	82.6 (3.25)	108.9 (4.29)	79.8 (3.14)	128.0 (5.04)	107.6 (4.23)	1236.2 (48.66)
1990–1999 Avg	141.4 (5.57)	136.5 (5.37)	149.0 (5.86)	126.3 (4.97)	113.4 (4.47)	110.0 (4.33)	134.8 (5.31)	83.6 (3.29)	71.9 (2.83)	67.3 (2.65)	109.8 (4.32)	161.0 (6.34)	1429.4 (56.26)
2000–2009 Avg	116.9 (4.60)	121.8 (4.80)	115.6 (4.55)	125.0 (4.92)	117.8 (4.64)	95.2 (3.75)	138.9 (5.47)	78.4 (3.09)	108.8 (4.28)	74.0 (2.91)	121.4 (4.78)	124.4 (4.90)	1333.4 (52.48)
2010–2019 Avg	130.1 (5.12)	146.6 (5.77)	117.4 (4.62)	131.9 (5.19)	93.8 (3.69)	132.4 (5.21)	156.8 (6.17)	92.5 (3.64)	114.1 (4.49)	91.0 (3.58)	128.0 (5.04)	151.7 (5.97)	1478.2 (58.18)
1980s vs. 2010s	29.5 (1.16)	37.6 (1.48)	4.6 (0.18)	42.9 (1.69)	-16.8 (-0.66)	15.2 (0.60)	36.3 (1.43)	9.9 (0.39)	5.3 (0.21)	11.2 (0.44)	0.0 (0.00)	44.3 (1.74)	239.3 (9.42)
2000s vs. 2010s	13.2 (0.52)	24.9 (0.98)	1.7 (0.07)	6.9 (0.27)	-24.1 (-0.95)	13.5 (0.53)	17.8 (0.70)	14.0 (0.55)	5.3 (0.21)	17.0 (0.67)	6.7 (0.26)	27.2 (1.07)	146.9 (5.78)
2020 Totals	223.3 (8.79)	311.2 (12.25)	203.5 (8.01)	184.5 (7.26)	113.3 (4.46)	58.2 (2.29)	72.7 (2.86)	124.5 (4.90)	97.1 (3.82)	184.2 (7.25)	90.7 (3.57)	102.6 (4.04)	1765.9 (69.50)
Snowfall, cm (in.)													
1970–1979 Avg	11.1 (4.4)	12.5 (4.9)	4.2 (1.7)	0.2 (0.1)	0	0	0	0	0	0	0.5 (0.2)	4.4 (1.8)	35.1 (13.8)
1980–1989 Avg	11.4 (4.5)	8.8 (3.5)	2.2 (0.9)	2.2 (0.9)	0	0	0	0	0	0	0	7.5 (3.0)	32.8 (12.9)
1990–1999 Avg	6.9 (2.7)	7.8 (3.1)	8.1 (3.2)	Trace	0	0	0	0	0	0	0.3 (0.1)	3.1 (1.2)	10.9 (4.3)
2000–2009 Avg	2.1 (0.8)	4.5 (1.8)	Trace	Trace	0	0	0	0	0	0	Trace	1.7 (0.7)	8.3 (3.3)
2010–2019 Avg	5.3 (2.1)	6.4 (2.5)	0.3 (0.1)	Trace	0	0	0	0	0	0	0.3 (0.1)	1.4 (0.6)	13.2 (5.2)
1980s vs. 2010s	-5.2 (-2.0)	-1.8 (-0.7)	-1.0 (-0.4)	0.0 (0.0)	0	0	0	0	0	0	0.3 (0.1)	-2.8 (-1.2)	-12.4 (-4.9)
2000s vs. 2010s	3.6 (1.4)	2.8 (1.1)	0.3 (0.1)	0.0 (0.0)	0	0	0	0	0	0	0.3 (0.1)	0.3 (0.1)	6.6 (2.6)
2020 Totals	Trace	1.5 (0.6)	0.0	0.0	0	0	0	0	0	0	Trace	4.8 (1.9)	6.4 (2.5)

Table B.3. Hourly subfreezing temperature data for Oak Ridge, Tennessee, 1985–2020[a]

(Hours at or below 0, −5, −10, and −15°C)

Year	January				February				March			April		May		October		November			December				Annual			
	≤0	<-5	<-10	<-15	≤0	<-5	<-10	<-15	≤0	<-5	<-10	≤0	<-5	≤0	<-5	≤0	<-5	≤0	<-5	<-10	≤0	<-5	<-10	<-15	≤0	<-5	<-10	<-15
1985	467	195	103	39	331	127	26	0	105	6	0	43	3	0	0	0	0	22	0	0	431	201	66	2	1399	532	195	41
1986	308	125	38	10	161	29	3	0	124	28	0	17	0	0	0	0	0	32	10	0	232	34	0	0	874	226	41	10
1987	302	53	7	0	111	19	3	0	95	0	0	55	4	0	0	36	0	103	18	0	151	16	0	0	853	110	10	0
1988	385	182	43	0	294	102	19	0	97	9	0	6	0	0	0	45	0	62	3	0	301	55	0	0	1190	351	62	0
1989	163	27	0	0	190	66	10	0	35	0	0	18	0	3	0	7	0	125	14	0	421	188	71	30	962	295	81	30
1990	142	13	0	0	115	5	0	0	35	0	0	35	0	0	0	19	0	62	1	0	172	43	5	0	580	62	5	0
1991	186	44	0	0	158	47	15	0	49	0	0	0	0	0	0	4	0	148	16	0	192	38	0	0	737	145	15	0
1992	230	65	8	0	116	22	0	0	116	4	0	27	2	0	0	7	0	100	0	0	166	9	0	0	762	102	8	0
1993	125	11	0	0	245	47	8	0	124	32	9	3	0	0	0	0	0	152	2	0	223	44	0	0	872	136	17	0
1994	337	191	85	26	196	46	3	0	66	0	0	18	0	0	0	0	0	53	1	0	142	0	0	0	812	238	88	26
1995	240	45	6	0	217	84	18	0	37	0	0	0	0	0	0	0	0	142	3	0	288	84	10	0	924	216	34	0
1996	301	91	0	0	225	110	62	27	182	49	6	23	0	0	0	3	0	101	0	0	194	40	4	0	1029	290	72	27
1997	254	101	24	0	67	0	0	0	25	0	0	6	0	0	0	6	0	96	10	0	232	14	0	0	686	125	24	0
1998	97	10	7	0	25	0	0	0	74	20	0	0	0	0	0	0	0	38	0	0	132	4	0	0	366	34	7	0
1999	181	68	0	0	113	14	0	0	62	0	0	0	0	0	0	4	0	41	0	0	177	23	0	0	578	105	0	0
2000	273	62	5	0	127	30	0	0	18	0	0	8	0	0	0	11	0	94	11	0	345	124	7	0	876	227	12	0
2001	281	60	5	0	79	9	0	0	53	0	0	2	0	0	0	18	0	28	0	0	137	35	0	0	598	104	5	0
2002	185	28	0	0	121	16	0	0	91	17	0	2	0	0	0	0	0	41	0	0	82	6	0	0	522	67	0	0
2003	345	123	26	0	117	12	0	0	19	0	0	0	0	0	0	0	0	37	0	0	102	9	0	0	620	144	26	0
2004	285	50	2	0	76	0	0	0	18	0	0	0	0	0	0	0	0	9	0	0	247	41	4	0	635	91	6	0
2005	151	65	6	0	52	1	0	0	81	1	0	0	0	0	0	1	0	55	0	0	176	28	0	0	516	95	6	0
2006	70	0	0	0	169	19	0	0	44	0	0	0	0	0	0	15	0	37	0	0	126	41	1	0	461	60	1	0
2007	189	30	5	0	283	70	0	0	29	0	0	32	0	0	0	0	0	60	0	0	83	8	0	0	673	111	5	0
2008	242	86	11	0	114	7	0	0	69	6	0	0	0	0	0	15	0	89	18	0	157	34	5	0	686	151	16	0
2009	238	93	29	0	178	64	5	0	55	15	0	5	0	0	0	0	0	8	0	0	178	22	0	0	662	194	34	0
2010	384	181	14	0	289	32	0	0	40	2	0	0	0	0	0	0	0	46	0	0	364	109	11	0	1123	324	25	0
2011	300	61	0	0	108	14	0	0	2	0	0	0	0	0	0	5	0	29	0	0	91	0	0	0	535	75	0	0
2012	169	27	0	0	78	19	0	0	9	0	0	1	0	0	0	0	0	46	0	0	76	0	0	0	379	46	0	0
2013	245	49	0	0	120	12	0	0	95	7	0	0	0	0	0	11	0	121	0	0	173	6	0	0	765	74	0	0
2014	371	208	76	12	109	5	0	0	68	0	0	5	0	0	0	0	0	122	10	0	94	1	0	0	769	224	76	12
2015	228	52	16	0	371	120	31	6	52	16	0	0	0	0	0	0	0	11	0	0	41	0	0	0	703	188	47	6

Table B.3. Hourly subfreezing temperature data for Oak Ridge, Tennessee, 1985–2020[a] (continued)

(Hours at or below 0, −5, −10, and −15°C)

Year	January				February				March			April		May		October		November			December				Annual			
	≤0	<-5	<-10	<-15	≤0	<-5	<-10	<-15	≤0	<-5	<-10	≤0	<-5	≤0	<-5	≤0	<-5	≤0	<-5	<-10	≤0	<-5	<-10	<-15	≤0	<-5	<-10	<-15
2016[a]	333	82	12	0	211	17	0	0	35	0	0	9	0	0	0	0	0	44	3	0	163	32	0	0	795	134	12	0
2017	130	47	11	1	64	5	0	0	82	8	0	0	0	0	0	8	0	67	0	0	252	20	0	0	603	44	10	0
2018	362	199	86	4	67	7	0	0	49	2	0	11	0	0	0	0	0	89	6	0	102	11	0	0	680	225	86	4
2019	146	46	1	0	46	0	0	0	80	9	0	5	0	0	0	0	0	93	11	0	90	0	0	0	466	66	1	0
2020	124	14	0	0	102	11	0	0	20	1	0	12	0	4	0	0	0	30	0	0	210	49	11	0	502	75	11	0
Avg.	244	77	17	3	151	33	6	1	62	6	0	10	0	0	0	6	0	68	4	0	187	38	5	1	727	159	29	4

[a] *Source: 1985–2015 National Oceanic and Atmospheric Administration, Atmospheric Turbulence and Diffusion Division, KOQT Station, Automated Surface Observing System; 2016–2020 ORNL, Tower "D"*

Selected wind roses for ORR towers that show wind direction for hours with precipitation and other relevant meteorological parameters have been compiled for 2020 and may be reviewed on the ORNL meteorology website **here**.

Hourly values of subfreezing temperatures in Oak Ridge are presented in Table B.3 for 1985 through 2020. During the middle to late 1980s, a typical year experienced about 900–1,000 hours of subfreezing temperatures. In recent years, the value has fallen to about 600–700 hours, though higher values have occurred relatively recently (2010 at 1,123 hours). However, some years within the 2010s only experience 350 to 500 hours of subfreezing weather. Other statistics on winter precipitation may be found **here**.

B.4. Moisture

ORR's humid environment results in frequent saturation of the surface layer, especially at night. Average annual humidity at ORNL (Tower MT2) is 75.1 percent (2015–2020) at 2 m above ground level and 72.6 percent at 15 m above the ground. In terms of absolute humidity (grams per cubic meter), the average annual humidity for the same location is 10.3 g/m^3 at both 2 and 15 m above ground level. This value varies greatly throughout the annual cycle, ranging from a monthly minimum of about 4.7 g/m^3 during winter to a maximum of about 16.9 g/m^3 during summer. These data are summarized for absolute and relative humidity and dew point on the ORNL meteorology website **here**.

B.5. Severe Weather

On average, thunderstorms and associated lightning occur in the Oak Ridge area at a rate of 48 days per year, with a monthly maximum of about 11 days occurring in July. About 41 of these thunderstorm days occur during the 7-month period from April through October, with the remainder spread evenly throughout the late fall and winter. The highest number of thunderstorm days at ORNL (65) was observed during 2012; the lowest (34) was observed during 2007. Monthly and annual average numbers of thunderstorm days for ORNL and Knoxville McGhee-Tyson Airport, respectively, during 2001–2020 can be viewed on the ORNL meteorology website **here**.

Hailstorms are infrequent on ORR and typically occur in association with severe thunderstorms. The phenomenon usually occurs as a result of high-altitude thunderstorm updrafts, which propel water droplets above the freezing level. Some hail events have been known to occur in association with non-thunder rain showers and low freezing levels (particularly during winter or spring). Most hailstorm occurrences (77 percent) do not produce hailstones larger than 2 cm (about ¾ in.). During the period from 1961 through 1990, about six hail events (with hailstones larger than about 2 cm) were documented to have occurred at locations within 40 km (25 miles) of ORNL. Nearly all of these events occurred during the summer and fall seasons. During the 2011 significant tornado outbreak in East Tennessee, large hail (greater than 2 cm) was observed in Farragut, Tennessee, about 15 km (9 miles) southeast of ORNL.

East Tennessee experiences a tornado "outbreak" about once every 3 to 6 years on average. Tornadoes occur more frequently in Middle and West Tennessee. Tornado indices from the National Weather Service in Morristown, Tennessee, show that since 1950, three tornadoes have been documented within 10 km (6 miles) of ORNL, represented by two F0 (Fujita Scale) tornadoes and one F3 tornado. A moderately strong F3 tornado occurred in February 1993 and moved through Bear Creek Valley near the Y-12 National Security Complex, with winds damaging the roofs of several buildings along Union Valley Road. To date, the February 1993 tornado has been the only documented tornado to occur within ORR.

Nine additional tornadoes have been documented since 1950 within 20 km (12 miles) of ORNL, ranging in intensity from F0/EF0 (Enhanced Fujita Scale) to F2/EF2. The most recent of these were three EF0–EF1 tornadoes that occurred during the April 27, 2011, tornado outbreak and an EF0 tornado near Kingston, Tennessee, on June 10, 2014. The storm system that produced the latter tornado brought a squall line through ORNL that produced high winds and some minor damage. The remaining group of tornadoes that were within 20 km (12 miles) of ORNL affected eastern Roane County to the south and the Edgemoor Road area to the northeast of ORR. Another 10 tornadoes, ranging from F0/EF0 to F3/EF3 in intensity, have occurred within 35 km (22 miles) of ORNL since 1950. Most of them occurred to the east and south of ORR in Knox and Roane Counties; however, a few occurred in the Rocky Top and Norris areas. Tornado statistics relevant to ORR are provided on the ORNL meteorology website **here** for Anderson, Knox, Loudon, and Roane Counties.

The annual probability that a tornado will strike any location in a grid square may be estimated by multiplying the number of tornadoes per year per square kilometer (in that particular grid square) by the path area of a tornado. The result of such a calculation is seen to be greatly affected by the assumption of the size of the path area of a tornado. In total, about 22 tornadoes have been documented within 35 km (22 miles) of ORNL since 1950. This represents a surface area of 3,848 km^2 (1,485 $miles^2$) and yields a probability of about 0.006 tornadoes per square kilometer per 50-year period.

B.6. Stability

The local ridge-and-valley terrain plays a role in the development of stable surface air under certain conditions and influences the dynamics of airflow. Although ridge-and-valley terrain creates identifiable patterns of association during unstable conditions as well, strong vertical mixing and momentum tend to reduce these effects. "Stability" describes the tendency of the atmosphere to mix (especially vertically) or overturn. Consequently, dispersion parameters are influenced by the stability characteristics of the atmosphere. Stability classes range from A (very unstable) to G (very stable), with D being a neutral state.

The suppression of vertical motions during stable conditions increases the effect of local terrain on air motion. Conversely, stable conditions isolate wind flows within the ridge-and-valley terrain from the effects of more distant terrain features and from winds aloft. These effects are particularly significant with respect to mountain waves. Deep, stable layers of air tend to reduce the vertical space available for oscillating vertical air motions caused by local mountain ranges (Smith et al. 2002). This effect on mountain wave formation may be important to the impact that the nearby Cumberland Mountains may have on local airflow.

A second factor that may decouple large-scale wind flow effects from local ones (and thus produce stable surface layers) occurs with overcast sky conditions. Clouds overlying the Great Valley may warm due to direct insolation on the cloud tops. Warming may also occur within the clouds as latent energy, which is released due to the condensation of moisture. Surface air underlying the clouds may remain relatively cool as the layer remains cut off from direct exposure to the sun. Consequently, the vertical temperature gradient associated with the air mass becomes more stable (Lewellen and Lewellen 2002). Long wave cooling of fog decks has also been observed to help modify stability in the surface layer (Whiteman et al. 2001).

Stable boundary layers typically form as a result of radiational cooling processes near the ground (Van De Weil et al. 2002); however, they are also influenced by the mechanical energy supplied by horizontal wind motion, which is in turn influenced by the synoptic-scale weather-related pressure gradient. Ridge-and-valley terrain may have significant ability to block such winds and their associated mechanical energy (Carlson and Stull 1986). Consequently, radiational cooling at the surface is enhanced because less wind energy is available to remove chilled air.

Stable boundary layers also exhibit intermittent turbulence, which has been associated with the above factors. The process results from a give-and-take between the effects of friction and radiational cooling. As a stable surface layer intensifies via a radiational cooling process, it tends to decouple from air aloft, thereby reducing the effects of surface friction. The upper air layer responds with an acceleration in wind speed. Increased wind speed aloft results in an increase in mechanical turbulence and wind shear at the boundary with the stable surface layer. Eventually, the turbulence works into the surface layer and weakens it. As the inversion weakens friction again increases, reducing wind speeds aloft. The reduced wind speeds aloft allow enhanced radiation cooling at the surface, which re-intensifies the inversion and allows the process to start again. Van De Weil et al. (2002) have shown that cyclical temperature oscillations up to 4°C (7°F) may result from these processes. Since these intermittent processes are driven primarily by large-scale horizontal wind flow and radiational cooling of the surface, ridge-and-valley terrain significantly affects the intensity of these oscillations.

Wind roses for stability and mixing depth have been compiled for all ORR tower sites for 2020. They may be viewed on the ORNL meteorology website **here**. The wind roses in general reveal that both unstable conditions and/or deep mixing depths are associated with less channeling of winds and that stable conditions and/or shallow mixing depths tend to promote channeled flow. Associated mixing height tables for 2020 can be accessed on the ORNL meteorology website **here**.

B.7. References

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C

Appendix C Reference Standards and Data for Water

Table C.1. Reference standards for radionuclides in water

Parameter[a]	National primary drinking water standard[b]	DCS[c]
^{241}Am		170
^{214}Bi		260,000
^{109}Cd		16,000
^{143}Ce		26,000
^{60}Co		7,200
^{51}Cr		790,000
^{137}Cs		3,000
^{155}Eu		87,000
Gross alpha[d]	15	
Gross beta (mrem/year)	4	
^{3}H		1,900,000
^{131}I		1,300
^{40}K		4,800
^{237}Np		320
^{234m}Pa		71,000
^{238}Pu		150
$^{239/240}Pu$		140
^{226}Ra		87
^{228}Ra		25
^{106}Ru		4,100
^{90}Sr		1,100
^{99}Tc		44,000
^{228}Th		340
^{230}Th		160
^{232}Th		140
^{234}Th		8,400
^{234}U		680
^{235}U		720
^{236}U		720
^{238}U		750

[a] Only the radionuclides included in the Oak Ridge Reservation monitoring programs are listed. Unless labeled otherwise, units are pCi/L.
[b] 40 Code of Federal Regulations Part 141, National Primary Drinking Water Regulations, Subparts B and G. The drinking water standards are presented strictly for reference purposes and have regulatory applicability only for public water supplies.
[c] DOE. "Derived Concentration Technical Standard, DOE-STD-1196-2011, April 2011."
[d] Excludes radon and uranium.

Table C.2. TDEC and EPA nonradiological water quality standards and criteria (µg/L)

Chemical	TDEC and EPA drinking water standards[a]	TDEC fish and aquatic life criteria		TDEC recreation criteria water + organisms, organisms only[b]
		Maximum	Continuous	
Acenaphthene				670, 990
Acrolein		3.0	3.0	6, 9
Acrylonitrile (c)				0.51, 2.5
Alachlor	2 (E1, T)			
Aldrin (c)		3.0	–	0.00049, 0.00050
Aldicarb	3 (E1)			
Aldicarb sulfoxide	4 (E1)			
Aldicarb sulfone	2 (E1)			
Aluminum	200 (E2)			
Anthracene				8,300, 40,000
Antimony	6 (E1, T)			5.6, 640
Arsenic (c)	10 (E1, T)			10.0, 10.0
Arsenic(III)[c]		340[c]	150[c]	
Asbestos	7 million fibers/L (MFL) (E1)			
Atrazine	3 (E1, T)			
Barium	2,000 (E1, T)			
Benzene (c)	5 (E1, T)			22, 510
Benzidine (c)				0.00086, 0.0020
Benzo(a)anthracene (c)				0.038, 0.18
Benzo(a)pyrene (c)	0.2 (E1, T)			0.038, 0.18
Benzo(b)fluoranthene (c)				0.038, 0.18
Benzo(k)fluoranthene (c)				0.038, 0.18
Beryllium	4 (E1, T)			
a-BHC (c)				0.026, 0.049
b-BHC (c)				0.091, 0.17
g-BHC (Lindane)	0.2 (E1, T)	0.95	–	0.98, 1.8
Bis(2-chloroethyl) ether (c)				0.30, 5.3
Bis(2-chloro-isopropyl) ether				1,400, 65,000
Bis(2-ethylhexyl) phthalate (c)				12, 22
Bis (Chloromethyl) ether (c)				0.0010, 0.0029
Bromate	10 (E1)			
Bromoform (c)				43, 1,400
Butylbenzyl phthalate				1,500, 1,900
Cadmium	5 (E1, T)	1.8[d]	0.72[d]	
Carbaryl		2.1	2.1	
Carbofuran	40 (E1, T)			

Table C.2. TDEC and EPA nonradiological water quality standards and criteria (µg/L) (continued)

Chemical	TDEC and EPA drinking water standards[a]	TDEC fish and aquatic life criteria		TDEC recreation criteria water + organisms, organisms only[b]
		Maximum	Continuous	
Carbon tetrachloride (c)	5 (E1, T)			2.3, 16
Chlordane (c)	2 (E1, T)	2.4	0.0043	0.0080, 0.0081
Chloride	250,000 (E2)			
Chlorine (TRC)	4,000 (E1)	19	11	
Chlorite	1,000 (E1)			
Chlorobenzene	100			130, 1,600
Chlorodibromomethane (c)				4.0, 130
Chloroform (c)				57, 4,700
Chloromines (as Cl2)	4,000 (E1)			
Chlorine dioxide (as Cl2)	800 (E1)			
2-Chloronaphthalene				1,000, 1,600
2-Chlorophenol				81, 150
Chloropyrifos		0.083	0.041	
Chromium (total)	100 (E1, T)			
Chromium(III)		570[d]	74[d]	
Chromium(VI) [c]		16[c]	11[c]	
Chrysene (c)				0.038, 0.18
Coliforms	no more than 5% of samples per month can be positive for total coliforms (E1)	2880/100 mL, *E. coli* (single sample)	630/100 mL, *E. coli* (geometric mean)	126/100 mL, geometric mean, *E. coli* 487, maximum lakes/ reservoirs, *E. coli* 941, maximum, other water bodies, *E. coli*
Color	15 color units (E2)			
Copper	1,000 (E2) 1,300 (E1 "Action Level")	13[d]	9.0[d]	
Cyanide (as free cyanide)	200 (E1, T)	22	5.2	140, 140
2,4-D (Dichlorophenoxyacetic acid)	70 (E1, T)			
4,4'-DDT (c)		1.1	0.001	0.0022, 0.0022
4,4'-DDE (c)				0.0022, 0.0022
4,4'-DDD (c)				0.0031, 0.0031
Dalapon	200 (E1, T)			
Demeton			0.1	
Diazinon		0.17	0.17	
Dibenz(a,h)anthracene (c)				0.038, 0.18
1,2-dibromo-3-chloropropane (DBCP)	0.2 (E1, T)			
1,2-Dichlorobenzene (*ortho*-)	600 (E1, T)			420, 1,300
1,3-Dichlorobenzene (*meta*-)				320, 960
1,4-Dichlorobenzene (*para*-)	75 (E1, T)			63, 190
3,3-Dichlorobenzidine (c)				0.21, 0.28
Dichlorobromomethane (c)				5.5, 170
1,2-Dichloroethane (c)	5 (E1, T)			3.8, 370
1,1-Dichloroethylene	7 (E1, T)			330, 7,100

Table C.2. TDEC and EPA nonradiological water quality standards and criteria (µg/L) (continued)

Chemical	TDEC and EPA drinking water standards[a]	TDEC fish and aquatic life criteria		TDEC recreation criteria water + organisms, organisms only[b]
		Maximum	Continuous	
Cis-1,2-Dichloroethylene	70 (E1, T)			
trans 1,2-Dichloroethylene	100 (E1, T)			140, 10,000
Dichloromethane	5 (E1, T)			
2,4-Dichlorophenol				77, 290
1,2-Dichloropropane (c)	5 (E1, T)			5.0, 150
1,3-Dichloropropene (c)				3.4, 210
Dieldrin (b)(c)		0.24	0.056	0.00052, 0.00054
Diethyl phthalate				17,000, 44,000
Di (2-ethylhexyl) adipate	400 (E1, T)			
Di (2-ethylhexyl) phthalate	6 (E1, T)			
Dinoseb	7 (E1, T)			
Dimethyl phthalate				270,000, 1,100,000
Dimethylphenol				380, 850
Di-n-butyl phthalate				2,000, 4,500
2,4-Dinitrophenol				69, 5,300
2,4-Dinitrotoluene (c)				1.1, 34
Dioxin (2,3,7,8-TCDD) (c)	3 E-5 (E1, T)			0.000001, 0.000001
Diquat	20 (E1, T)			
1,2-Diphenylhydrazine (c)				0.36, 2.0
a-Endosulfan		0.22	0.056	62, 89
b-Endosulfan		0.22	0.056	62, 89
Endosulfan sulfate				62, 89
Endothall	100 (E1, T)			
Endrin	2 (E1, T)	0.086	0.036	0.059, 0.06
Endrin aldehyde				0.29, 0.30
Ethylbenzene	700 (E1)			530, 2,100
Ethylene dibromide	0.05 (E1, T)			
Fluoranthene				130, 140
Fluorene				1,100, 5,300
Fluoride	2,000 (E2) 4,000 (E1,T)			
Foaming agents	500 (E2)			
Glyphosate	700 (E1, T)			
Guthion			0.01	
Haloacetic acids (five)	60 (E1)			
Heptachlor (c)	0.4 (E1, T)	0.52	0.0038	0.00079, 0.00079
Heptachlor epoxide (c)	0.2 (E1, T)	0.52	0.0038	0.00039, 0.00039
Hexachlorobenzene (b)(c)	1 (E1, T)			0.0028, 0.0029
Hexachlorobutadiene (b)(c)				4.4, 180
Hexachlorocyclohexane-Technical (b)(c)				0.123, 0.414
Hexachlorocyclopentadiene	50 (E1, T)			40, 1,100
Hexachloroethane (c)				14, 33
Ideno(1,2,3-cd)pyrene (c)				0.038, 0.18

Table C.2. TDEC and EPA nonradiological water quality standards and criteria (µg/L) (continued)

Chemical	TDEC and EPA drinking water standards[a]	TDEC fish and aquatic life criteria		TDEC recreation criteria water + organisms, organisms only[b]
		Maximum	Continuous	
Iron	300 (E2)			
Isophorone (c)				350, 9,600
Lead	5 (E1 "Action Level")	65[d]	2.5[d]	
Lindane	0.2 (T)			
Malathion			0.1	
Manganese	50 (E2)			
Mercury (inorganic) [c]	2 (E1)	1.4[c]	0.77[c]	0.05, 0.051
Methoxychlor	40 (E1, T)		0.001	
Methyl bromide				47, 1,500
2-Methyl-4,6-dinitrophenol				13, 280
Methylene chloride (Dichloromethane) (c)				46, 5,900
Mirex (b)			0.001	
Monocholorobenzene	100 (E1, T)			
Nickel	100 (T)	470[d]	52[d]	610, 4,600
Nitrate as N	10,000 (E1,T)			
Nitrite as N	1,000 (E1, T)			
Nitrobenzene				17, 690
Nitrosamines				0.0008, 1.24
Nitrosodibutylamine (c)				0.063, 2.2
Nitrosodiethylamine (c)				0.008, 2.4
Nitrosopyrrolidine (c)				0.16, 340
N-Nitrosodimethylamine (c)				0.0069, 30
N-Nitrosodi-n-propylamine (c)				0.05, 5.1
N-Nitrosodiphenylamine (c)				33, 60
Nonylphenol		28.0	6.6	
Odor	3 threshold odor number (E2)			
Oxamyl (Vydate)	200 (E1, T)			
Parathion		0.065	0.013	
Pentachlorobenzene (b)				1.4, 1.5
Pentachlorophenol (c)	1 (E1, T)	19[e]	15[e]	2.7, 30
pH	6.5 to 8.5 units (E2) 6.0 to 9.0 units (T)		6.0 to 9.0 units, wade-able streams 6.5 to 9.0 units, larger rivers, lakes, etc.	6.0 to 9.0 units
Phenol				10,000, 860,000
Picloram	500 (E1,T)			
PCBs, total (c)	0.5 (E1, T)	–	0.014	0.00064, 0.00064
Pyrene				830, 4,000
Selenium	50 (E1, T)			170, 4,200

Table C.2. TDEC and EPA nonradiological water quality standards and criteria (µg/L) (continued)

Chemical	TDEC and EPA drinking water standards[a]	TDEC fish and aquatic life criteria		TDEC recreation criteria water + organisms, organisms only[b]
		Maximum	Continuous	
Selenium (lentic)		20	1.5	
Selenium (lotic)		20	3.1	
Silver	100 (E2)	3.2[d]	–	
Simazine	4 (E1, T)			
Styrene	100 (E1, T)			
Sulfate	250,000 (E2)			
1,1,2,2-Tetrachloroethane (c)				1.7, 40
1,2,4,5-Tetrachlorobenzene (b)				0.97, 1.1
Tetrachloroethylene (c)	5 (E1, T)			6.9, 33
Thallium	2 (E1, T)			0.24, 0.47
Toluene	1,000 (E1, T)			1,300, 15,000
Total dissolved solids	500,000 (E2)			
Total nitrate and nitrite	10,000 as N (E1,T)			
Total trihalomethanes	80 (E1)			
Toxaphene (b)(c)	3 (E1, T)	0.73	0.0002	0.0028, 0.0028
2,4,5-TP (Silvex)	50 (E1, T)			1,800, 3,600
Tributyltin (TBT)		0.46	0.072	
1,2,4-Trichlorobenzene	70 (E1, T)			35, 70
1,1,1-Trichloroethane	200 (E1, T)			
1,1,2-Trichloroethane (c)	5 (E1, T)			5.9, 160
Trichloroethylene (c)	5 (E1, T)			25, 300
2,4,6-Trichlorophenol (c)				14, 24
Vinyl chloride (c)	2 (E1, T)			0.25, 24
Xylenes (total)	10,000 (E1, T)			
Zinc	5,000 (E2)	120[d]	120[d]	7,400, 26,000

[a] *E1 = EPA Primary Drinking Water Standards; E2 = EPA Secondary Drinking Water Standards; T = TDEC domestic water supply criteria.*

[b] *For each parameter, the first recreational criterion is for "water and organisms" and is applicable on the Oak Ridge Reservation (ORR) only to the Clinch River because the Clinch is the only stream on ORR that is classified for both domestic water supply and for recreation. The second criterion is for "organisms only" and is applicable to the other streams on ORR. TDEC uses a 10^{-5} risk level for recreational criteria for all carcinogenic pollutants (designated as (c) under "Chemical" column). Recreational criteria for noncarcinogenic chemicals are set using a 10^{-6} risk level. (Note: All federal recreational criteria are set at a 10^{-6} risk level.)*

[c] *Criteria are expressed as dissolved.*

[d] *Criteria are expressed as dissolved and are a function of total hardness (mg/L). Criteria displayed correspond to a total hardness of 100 mg/L.*

[e] *Criteria are expressed as a function of pH; values shown correspond to a pH of 7.8.*

Acronyms:

TDEC = Tennessee Department of Environment and Conservation

EPA = US Environmental Protection Agency

D

Appendix D National Pollutant Discharge Elimination System Noncompliance Summaries for 2020

D.1. East Tennessee Technology Park

The East Tennessee Technology Park program was 100 percent compliant with the numerical permit limits during 2020. The current ETTP National Pollution Discharge Elimilation System (NPDES) permit was effective on February 1, 2015 and was set to expire March 31, 2020. The permit renewal application was submitted to Tennessee Department of Environment and Conservation on September 18, 2019. The current permit will continue in effect until a new permit is issued by the State of Tennessee.

D.2. Y-12 National Security Complex

The Y-12 National Security Complex was 99.8 percent compliant with the NPDES permit in 2020. Approximately 2,600 data points were obtained from sampling required by the NPDES permit, and five noncompliances were reported.

D.3. Oak Ridge National Laboratory

In 2020, compliance with the Oak Ridge National Laboratory NPDES permit was determined by approximately 1,800 laboratory analyses and field measurements. The NPDES permit limit compliance rate for all discharge points for 2020 was greater than 99 percent. There was one nonnumeric permit noncompliance at ORNL for a wastewater treatment facility in June 2020 when the annual whole effluent toxicity test for the Sewage Treatment Plant (Outfall X01) did not pass the NPDES permit limit of more than 44.3 percent effluent for fathead minnow (*Pimephales promelas*) survival and reproduction. A follow-up test seven days later indicated the effluent was back in compliance.

E

Appendix E Radiation

This appendix presents basic information about radiation. The information is intended to serve as a basis for understanding the potential doses associated with releases of radionuclides from the Oak Ridge Reservation, not as a comprehensive discussion of radiation and its effects on the environment and on biological systems.

Radiation comes from natural and human sources. People are constantly exposed to naturally occurring radiation. For example, cosmic radiation, radon in air, potassium in food and water, and uranium, thorium, and radium in the earth's crust are all sources of radiation. The following discussion describes important aspects of radiation and its types, sources, and pathways, as well as radiation measurement and dose information.

E.1. Atoms and Isotopes

All matter is made up of atoms. An atom is "a unit of matter consisting of a single nucleus surrounded by a number of electrons equal to the number of protons in the nucleus" (Alter 1986). The number of protons in the nucleus determines an element's atomic number or chemical identity. With the exception of hydrogen, the nucleus of each type of atom also contains at least one neutron. Unlike protons, the neutrons may vary in number among atoms of the same element. The number of neutrons and protons determines the atomic weight. Atoms of the same element that have different numbers of neutrons are called isotopes. In other words, isotopes have the same chemical properties but different atomic weights, as illustrated in Figure E.1.

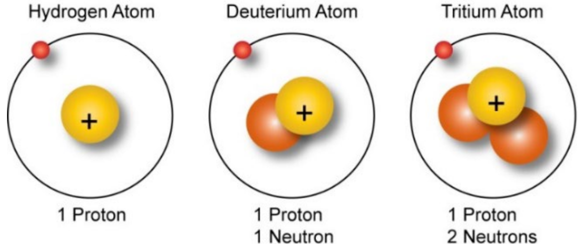


Figure E.1 The hydrogen atom and its isotopes

For example, the element uranium has 92 protons. All isotopes of uranium, therefore, have 92 protons. However, each uranium isotope has a different number of neutrons:

- Uranium-238 has 92 protons and 146 neutrons
- Uranium-235 has 92 protons and 143 neutrons
- Uranium-234 has 92 protons and 142 neutrons

Some isotopes are stable, or nonradioactive, and some are radioactive. Radioactive isotopes are called radionuclides or radioisotopes. In an attempt to become stable, radionuclides emit rays or particles. This emission of rays and particles is known as radioactive decay. Each radioisotope has a radioactive half-life, which is the average time required for half of a specified number of atoms to decay. Half-lives can be very short (fractions of a second) or very long (millions of years), depending on the isotope. Table E.1 shows the half-lives of selected radionuclides.

Table E.1 Selected radionuclide half-lives

Radionuclide	Symbol	Half-life (in years unless otherwise noted)	Radionuclide	Symbol	Half-life (in years unless otherwise noted)
Americium-241	^{241}Am	432.2	Plutonium-238	^{238}Pu	87.74
Americium-243	^{243}Am	7.37E+3	Plutonium-239	^{239}Pu	2.411E+4
Argon-41	^{41}Ar	1.827 hours	Plutonium-240	^{240}Pu	6.564E+3
Beryllium-7	^{7}Be	53.22 days	Potassium-40	^{40}K	1.251E+9
Californium-252	^{252}Cf	2.645	Radium-226	^{226}Ra	1.6E+3
Carbon-11	^{11}C	20.39 minutes	Radium-228	^{228}Ra	5.75
Carbon-14	^{14}C	5.70E+3	Ruthenium-103	^{103}Ru	39.26 days
Cerium-141	^{141}Ce	32.508 days	Samarium-153	^{153}Sm	46.5 hours
Cerium-144	^{144}Ce	284.91 days	Strontium-89	^{89}Sr	50.53 days
Cesium-134	^{134}Cs	2.0648	Strontium-90	^{90}Sr	28.79
Cesium-137	^{137}Cs	30.167	Technetium-99	^{99}Tc	2.111E+5
Cesium-138	^{138}Cs	32.41 minutes	Thorium-228	^{228}Th	1.9116
Cobalt-58	^{58}Co	70.86 days	Thorium-230	^{230}Th	7.538E+4
Cobalt-60	^{60}Co	5.271	Thorium-232	^{232}Th	1.405E+10
Curium-242	^{242}Cm	162.8 days	Thorium-234	^{234}Th	24.1 days
Curium-244	^{244}Cm	18.1	Tritium	^{3}H	12.32
Iodine-129	^{129}I	157E+7	Uranium-234	^{234}U	2.455E+5
Iodine-131	^{131}I	8.02 days	Uranium-235	^{235}U	7.04E+8
Krypton-85	^{85}Kr	10.756	Uranium-236	^{236}U	2.342E+7
Krypton-88	^{88}Kr	2.84 hours	Uranium-238	^{238}U	4.468E+9
Lead-212	^{212}Pb	10.64 hours	Xenon-133	^{133}Xe	5.243 days
Manganese-54	^{54}Mn	312.12 days	Xenon-135	^{135}Xe	9.14 hours
Neptunium-237	^{237}Np	2.144E+6	Yttrium-90	^{90}Y	64.1 hours
Niobium-95	^{95}Nb	34.991 days	Zirconium-95	^{95}Zr	64.032 days

Source: ICRP 2008

E.2. Radiation

Radiation, or radiant energy, is energy in the form of waves or particles moving through space. Visible light, heat, radio waves, and alpha particles are examples of radiation. When people feel warmth from sunlight, they are actually absorbing the radiant energy emitted by the sun.

Electromagnetic radiation is a form of energy that travels in waves. It comes from natural and man-made sources and includes gamma rays, x-rays, ultraviolet light, and radio waves. Particulate radiation consists of particles that have mass and energy, such as alpha and beta particles. Radiation also is characterized as ionizing or nonionizing because of the way it interacts with matter.

Ionizing Radiation

Normally an atom has an equal number of protons, which are positively charged, and electrons, which are negatively charged; but atoms can lose or gain electrons in a process known as ionization. Some forms of radiation (called ionizing radiation) can ionize atoms by removing bound electrons from an electrically neutral atom. This leaves the atom with a net positive charge. Examples of ionizing radiation include alpha and beta particles, gamma rays, and x-rays.

Ionizing radiation is capable of changing the chemical state of matter and subsequently causing biological damage. By this mechanism, it is potentially harmful to human health.

Nonionizing Radiation

Nonionizing radiation is described as a series of energy waves composed of oscillating electric and magnetic fields traveling at the speed of light. Nonionizing radiation is lower in energy than ionizing radiation. It includes the spectrum of ultraviolet light, visible light, infrared radiation, microwaves, radio waves, and other extremely low frequency fields. Lasers commonly operate in the ultraviolet, visible, and infrared frequencies. Microwave radiation is absorbed near the skin, while radio frequency radiation may be absorbed throughout the body. At high enough intensities, both will damage tissue through heating. Excessive visible radiation can damage the eyes and skin (Department of Labor 2020). However, in the discussion that follows, the term "radiation" is used to describe ionizing radiation.

E.3. Measuring Ionizing Radiation

To determine the possible effects of radiation on the health of the environment and the public, the radiation must be measured. More precisely, its potential to cause damage must be ascertained.

Activity

To determine the level of radiation in the environment, the rate of radioactive decay or activity is measured. The rate of decay varies widely among radioisotopes. For that reason, 1 gram of a radioactive substance may contain the same amount of activity as several tons of another material. This activity is expressed in a unit of measure known as a curie (Ci). More specifically, 1 Ci equals 3.7×10^{10} (37,000,000,000) atomic disintegrations per second (dps). In the International System of Units, 1 dps equals 1 becquerel (Bq).

Absorbed Dose

The total amount of energy absorbed per unit mass of an exposed material as a result of exposure to radiation is expressed in a unit of measure known as a rad, short for "radiation absorbed dose." The effect of the absorbed energy (the biological damage that occurs) is important, not the actual amount. In the International System of Units, 100 rad equals 1 gray (Gy).

Effective Dose

The measure of potential biological damage to the body caused by exposure to and subsequent absorption of radiation is expressed in a unit of measure known as a rem, an abbreviation for "roentgen equivalent man." For radiation protection purposes, 1 rem of any type of radiation has the same damaging effect. Because a rem represents a fairly large dose, the measure is usually expressed as millirem (mrem), which is 1/1000 of a rem. In the International System of Units, 1 sievert (Sv) equals 100 rem; 1 millisievert (mSv) equals 100 mrem. The effective dose (ED) is the weighted sum of equivalent dose over specified tissues or organs. The ED is based on tissue-weighting factors for 12 specific tissues or organs plus a weight factor for the remaining organs and tissues. In addition, the ED is based on the recent lung model, gastrointestinal absorption fractions, and biokinetic models used for selected elements. Specific types of EDs are defined as follows (ICRP 2007):

- Committed ED – the weighted sum of the committed organ or tissue equivalent doses in the human body during the 50-year period following intake (70 years for children)
- Collective ED – the product of the mean ED for a population and the number of persons exposed

E.4. Radiation Exposure Pathways

People can be exposed to radionuclides in the environment through a number of routes, as shown in Figure E.2. Potential routes for internal and external exposure are referred to as pathways. For example, radionuclides in air could be inhaled directly or could fall on grass in a pasture. If the grass were then consumed by cows, it would be possible for the radionuclides to impact the cow's milk, then the people drinking the milk. Similarly, radionuclides in water could be ingested by fish, and fishermen or other consumers could then ingest the radionuclides in the fish tissue. People swimming in the water also would be exposed. Exposure to ionizing radiation varies significantly with geographic location, diet, drinking water source, and building construction.

Figure E.2 Examples of radiation pathways

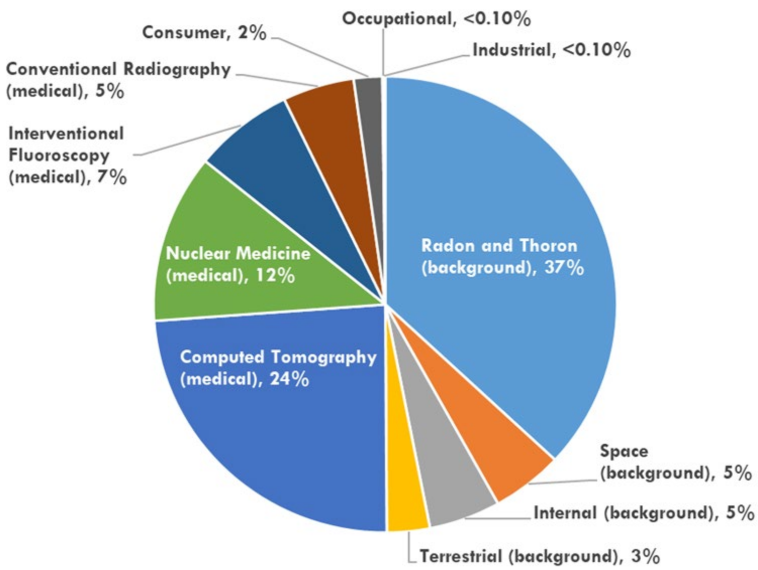
E.5. Radiation Sources and Doses

Basically, radioactive decay, or activity, generates radiant energy. People absorb some of the energy to which they are exposed, either from external or internal radiation. The effect of this absorbed energy is responsible for an individual's dose. Whether radiation is natural or human-made, it has the same effect on people.

There are five broad categories for radiation exposure to the US population (NCRP 2009):

- Exposure to ubiquitous background radiation, including radon in homes
- Exposure to patients from medical procedures
- Exposure from consumer products or activities involving radiation sources
- Exposure from industrial, security, medical, educational, and research radiation sources
- Exposure to workers that results from their occupations

Figure E.3 shows the percent contributions of various sources of exposure to the total collective dose for the US population in 2006. As shown, the major sources are radon and thoron (37 percent), computed tomography (24 percent), and nuclear medicine (12 percent) (NCRP 2009). Consumer, occupational, and industrial sources contribute about 2 percent to the total US collective dose.



Source: NCRP 2009

Figure E.3 All exposure categories for collective effective dose for 2006

E.5.1. Background Radiation

Naturally occurring radiation is the major source of radiation in the environment. Sources of background radiation exposure include the following:

- External exposure from space or cosmic radiation
- External exposure from terrestrial radiation
- Internal exposure from inhalation of radon, thoron, and their progeny
- Internal exposure from radionuclides in the body

E.5.1.1. External Exposures

Space or Cosmic Radiation

Energetically charged particles from outer space continuously hit the earth's atmosphere. These particles and the secondary particles and photons they create are called cosmic radiation. Because the atmosphere provides some shielding against cosmic radiation, the intensity of this radiation increases with altitude above sea level. For example, a person in Denver is exposed to more cosmic radiation than a person in New Orleans.

The average annual effective dose to people in the United States from cosmic radiation is about 33 mrem, or 0.33 mSv (NCRP 2009). Effective dose rates from cosmic radiation depend on geomagnetic latitude and elevation above sea level.

Terrestrial Radiation

Terrestrial radiation refers to radiation emitted from radioactive materials in the earth's rocks, soils, and minerals. Radon (Rn), radon progeny (the relatively short-lived decay products from the decay of the radon isotope ^{222}Rn), potassium (^{40}K), isotopes of thorium (Th), and isotopes of uranium (U) are the elements responsible for most terrestrial radiation.The average annual dose from terrestrial gamma radiation is about 21 mrem (0.21 mSv) in the United States, but it varies geographically across the country (NCRP 2009). Typical reported values are about 23 mrem (0.23 mSv) on the Atlantic and Gulf coastal plains, about 90 mrem (0.9 mSv) on the eastern slopes of the Rocky Mountains, and about 46 mrem (0.46 mSv) elsewhere (EPA 2020).

E.5.1.2. Internal Exposures

Radionuclides in the environment enter the body with the air people breathe and the foods they eat. They also can enter through an open wound. Natural radionuclides that can be inhaled and ingested include isotopes of uranium and their progeny, especially radon (^{222}Rn) and its progeny, thoron (^{220}Rn) and its progeny, potassium (^{40}K), rubidium (^{87}Rb), and carbon (^{14}C). Radionuclides contained in the body are dominated by ^{40}K and polonium (^{210}Po); others include ^{87}Rb and ^{14}C (NCRP 1987).

Radon and Thoron and Decay Products

The major contributors to the annual effective dose from background radiation sources are radon and thoron and their short-lived decay products. As shown in Figure E.3, 37 percent of the dose from all exposure categories is from radon and thoron and their decay products, which contribute an average dose of about 228 mrem (2.28 mSv) per year (NCRP 2009). Radon is an inert gas and a small fraction is retained in the body; however, the dose to the lung comes from the short-lived radon decay products. Radon levels vary widely across the United States. Elevated levels are most commonly found in the Appalachians, the upper Midwest, and the Rocky Mountain states (NCRP 2009).

Other Internal Radiation Sources

Other sources of internal radiation include ^{40}K, ^{232}Th, and the ^{238}U series. The primary source of ^{40}K in body tissues is food, primarily fruits and vegetables. Sources of radionuclides from the ^{232}Th and ^{238}U series are food and water (NCRP 2009). The average dose from these other internal radionuclides is about 29 mrem (0.29 mSv) per year. This dose is attributed predominantly to the naturally occurring radioactive isotope of potassium, ^{40}K.

E.5.2. Human-Made Radiation

In addition to background radiation, most people are exposed to human-made sources of radiation such as consumer products, medical sources, industrial by-products, and fallout from atmospheric atomic bomb tests. No atmospheric testing of atomic weapons has occurred since 1980 (NCRP 1987).

Consumer Products

Some consumer products are sources of radiation. The radiation in these products—which include smoke detectors, radioluminous products such as self-illuminating exit signs in commercial buildings, and airport x-ray baggage inspection systems—is essential to the performance of the device. In other products, such as tobacco products and building materials, the radiation occurs incidentally to the product's function (NCRP 1987, NCRP 2009).

The US annual dose to an individual from consumer products and activities averages about 13 mrem (0.13 mSv), ranging between 0.1 and 40 mrem (0.001 and 0.4 mSv). Cigarette smoking accounts for about 35 percent of this dose. Other important sources are building materials (27 percent), commercial air travel (26 percent), mining and agriculture (6 percent), miscellaneous consumer-oriented products (3 percent), combustion of fossil fuels (2 percent), highway and road construction materials (0.6 percent), and glass and ceramics (less than 0.003 percent). Television and video, sewage sludge and ash, and self-illuminating signs contribute negligible doses (NCRP 2009).

Medical Sources

Radiation is an important tool in diagnostic medicine and treatment, which are the main sources of exposure to the public from human-made radiation. Exposure is deliberate and is directly beneficial to the patients exposed. In general, medical exposures from diagnostic or therapeutic x-rays result from beams directed to specific areas of the body, so not all organs are uniformly irradiated. Nuclear medicine examinations and treatments involve the internal administration of radioactive compounds, or radiopharmaceuticals, by injection, inhalation, consumption, or insertion. Radiation and radioactive materials also are used in preparing medical instruments, including sterilizing heat-sensitive products such as plastic heart valves.

Nuclear medicine examinations, which internally administer radiopharmaceuticals, generally account for the largest portion of dose from human-made sources. However, the radionuclides used for specific tests are not uniformly distributed throughout the body. In these cases the concept of ED, which relates the significance of exposures of organs or body parts to the effect on the entire body, is useful in making comparisons.

The average annual ED from medical examinations is roughly 300 mrem (3 mSv), including 147 mrem (1.47 mSv) from computed tomography scans, 77 mrem (0.77 mSv) from nuclear medicine procedures, 43 mrem (0.43 mSv) from interventional fluoroscopy, and 33 mrem (0.33 mSv) from conventional radiography and fluoroscopy (NCRP 2009). Not everyone receives such exams each year.

Other Sources

Other sources of radiation include emissions of radioactive materials from nuclear facilities such as uranium mines, fuel-processing plants, and nuclear power plants; transportation of radioactive materials; and emissions from mineral-extraction facilities. The dose to the general public from nuclear fuel cycle facilities, such as uranium mines, mills, fuel-processing plants, nuclear power plants, and transportation routes, has been estimated at less than 1 mrem (0.01 mSv) per year (NCRP 1987).

Small doses to individuals occur because of radioactive fallout from atmospheric atomic bomb tests, emissions of radioactive materials from nuclear facilities, emissions from certain mineral extraction facilities, and transportation of radioactive materials. The combination of these sources contributes less than 1 mrem (0.01 mSv) per year to an individual's average dose (NCRP 1987).

E.6. References

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F

Appendix F Chemicals

This appendix presents basic information about chemicals. The information is intended to serve as a basis for understanding the dose or relative toxicity assessment associated with possible releases from the Oak Ridge Reservation (ORR), and is not a comprehensive discussion of chemicals and their effects on the environment and biological systems.

F.1. Perspective on Chemicals

The lives of modern humans have been greatly improved by the development of chemicals such as pharmaceuticals, building materials, housewares, pesticides, and industrial chemicals. Through the use of chemicals, we can increase food production, cure diseases, build more efficient houses, and send people into space. At the same time, we must be cautious to ensure uncontrolled and over-expanded use of chemicals does not endanger our own existence (Chan et al. 1982).

Just as all humans are exposed to radiation in their normal daily routines, humans are also exposed to chemicals. Some potentially hazardous chemicals exist in the natural environment. In many areas of the country, soils contain naturally elevated concentrations of metals such as selenium, arsenic, or molybdenum, which may be hazardous to humans or animals. Even some of the foods we eat contain natural toxins. Aflatoxins are found in chili peppers, corn, millet, peanuts, rice, sorghum, sunflower seeds, tree nuts, and wheat. Cyanide is found in apple seeds. However, exposure to many more hazardous chemicals results from direct or indirect human actions. Building materials used in home construction may contain chemicals such as formaldehyde (in some insulation materials), asbestos (formerly used in insulation and ceiling tiles), and lead (formerly used in paints and gasoline). Some chemicals are present as a result of applying pesticides and fertilizers to soil. Other chemicals may have been transported long distances through the atmosphere from industrial sources and then deposited on soil or water.

F.2. Pathways of Chemicals from the Oak Ridge Reservation to the Public

Pathways are the routes or ways through which a person can come in contact with a chemical substance. Chemicals released to the air may remain suspended for long periods, or they may be rapidly deposited on plants, soil, and water. Chemicals may also be released as liquid wastes, called effluents, which can enter streams and rivers.

People are exposed to chemicals by inhalation (breathing air), ingestion (eating exposed plants and animals or drinking water), or dermal contact (touching soil or swimming in water). For example, fish that live in a river that receives effluents may take in some of the chemicals present in the water. People eating fish and drinking water from the river would then be exposed to the chemicals. The public is not normally exposed to chemicals on ORR because access to the reservation is limited. However, chemicals released as a result of ORR operations can move through the environment to off-site locations, resulting in potential exposure of the public.

F.3. Toxicity

Health effects from chemicals vary. Chemical health effects are divided into two broad categories: adverse or systemic effects from noncarcinogens and cancer from carcinogens. A chemical can have both carcinogenic and noncarcinogenic effects. The toxic effect can be acute (a short-term, possible severe health effect) or chronic (a longer-term, persistent health effect). Noncarcinogenic toxicity is often evident in a shorter length of time than a carcinogenic effect. The potential health effects of noncarcinogens range from skin irritation to death. Carcinogens cause or increase the incidence of malignant neoplasms or cancers.

Toxicity refers to an adverse effect of a chemical on human health. Every day we ingest chemicals in food and water, and sometimes in medications. Even chemicals typically considered toxic are usually nontoxic or harmless below a certain concentration.

Concentration limits or advisories are set by government agencies for some chemicals that are known or thought to have adverse effects on human health. These concentration limits can be used to calculate chemical doses that would not harm even those individuals who may be particularly sensitive to the chemical.

F.3.1. Dose Terms for Noncarcinogens

A reference dose is an estimate of a daily exposure level for the human population, including sensitive subpopulations. These reference doses are likely to be without appreciable risk of deleterious effects during a lifetime. Units are expressed as milligrams of chemical per kilogram of an adult's body weight per day (mg/kg-day). Values for reference doses are derived from doses of chemicals that resulted in no adverse effect, or the lowest dose that showed an adverse effect, on humans or laboratory animals.

Uncertainty factors are typically used in deriving reference doses. Uncertainty adjustments may be made if animal toxicity data are extrapolated to humans to account for human sensitivity; extrapolated from subchronic to chronic no-observed-adverse-effect levels; extrapolated from lowest-observed-adverse-effect levels to no-observed-adverse-effect levels; and to account for data deficiencies. The use of uncertainty factors in deriving reference doses is thought to help protect sensitive human populations. The US Environmental Protection Agency (EPA) maintains the Integrated Risk Information System (IRIS) database, which contains verified reference doses and up-to-date health risk and EPA regulatory information for numerous chemicals.

For chemicals that do not have reference dose values available in IRIS, Tennessee Water Quality Criteria values for domestic water supply (TDEC 2019) may be used to calculate a reference dose by multiplying the chemical criteria in milligrams per liter by 2 liters (the average daily adult water intake) and dividing by 80 kg (the reference adult body weight). The result is a derived reference dose expressed in mg/kg-day.

F.3.2. Dose Term for Carcinogens

A slope factor is a plausible upper-bound estimate of the probability of a response per unit intake of a chemical during a lifetime. The slope factor is used to estimate an upper-bound probability of an individual developing cancer as a result of a lifetime exposure to a particular level of a chemical. Units are expressed as risk per dose in mg/kg-day.

The slope factor converts the estimated daily intake averaged over a lifetime exposure to the incremental risk of an individual developing cancer. Because it is unknown for most chemicals whether a threshold (a dose below which no adverse effect occurs) exists for carcinogens, units for carcinogens are set in terms of risk factors. The standard cancer benchmarks used by EPA range from 1 in 1,000,000 to 1 in 10,000 (i.e., 10^{-6} to 10^{-4}) depending on the subpopulation exposed. In other words, a certain chemical concentration in food or water could cause a risk of one additional cancer for every 1,000,000 (10^{-6} risk level) to 10,000 (10^{-4} risk level) exposed persons.

F.4. Measuring Chemicals

Environmental samples are collected in areas surrounding ORR and are analyzed for those chemical constituents most likely to be released from ORR. Chemical concentrations in liquids are typically expressed in milligrams or micrograms of chemical per liter of water (mg/L or µg/L, respectively); concentrations in solids, such as soil and fish tissue, are expressed in milligrams or micrograms of chemical per gram or kilogram of sample material (mg/kg or µg/kg, respectively).

The instruments used to measure chemical concentrations are sensitive; however, there are limits below which they cannot detect chemicals of interest. Concentrations below the reported analytical detection limits of the instruments are recorded by the laboratory as estimated values, which have a greater uncertainty than concentrations detected above the detection limits of the instruments. Health effect calculations that use these estimated values are indicated by the less-than symbol (<), which indicates that the value for a parameter could not be quantified at the analytical detection limit.

F.5. Risk Assessment Methodology

The paragraphs below describe the method for assessing the risk of adverse health effects from a particular chemical.

Exposure Assessment

To estimate an individual's potential exposure via a specific exposure pathway, the intake amount of the chemical must be determined. For example, chemical exposure from drinking water and eating fish from the Clinch River is assessed in the following manner:

Clinch River surface water and fish samples are analyzed to measure chemical contaminant concentrations. For this assessment, it is assumed that individuals drink about 2 liters (0.5 gal) of water per day directly from the river, and that they eat 0.07 kg (roughly 0.2 lb) of fish per day from the river. Estimated daily intakes or estimated doses to the public are calculated by multiplying measured (statistically significant) chemical concentrations in Clinch River surface water by 2 liters, or those in fish from the Clinch River by 0.07 kg. This intake is first multiplied by the exposure duration (26 years) and exposure frequency (350 days per year) and then divided by an averaging time (26 years for non-carcinogens and 70 years for carcinogens) and an 80 kg adult body weight. These exposure assumptions are conservative, and in many cases result in higher estimated intakes and doses than an individual would actually receive.

Dose Estimate

Once the oral daily intake of a chemical contaminant has been estimated, the dose can be determined. The chemical dose to humans is measured in mg/kg-day. In this case, "kilogram" refers to the body weight of an adult. When a chemical dose is calculated, the length of time an individual is exposed to a certain concentration is important. To assess off-site chemical doses, it is assumed that the exposure duration occurs over 30 years. These are known as chronic exposures, in contrast to short-term exposures, which are called acute exposures.

Calculation Method

Current risk assessment methodologies use the term "hazard quotient" to evaluate non-carcinogenic health effects. Because intakes are calculated in mg/kg-day using the hazard quotient methodology, they are expressed in terms of dose. Hazard quotient values less than 1 indicate an unlikely potential for adverse noncarcinogenic health effects; hazard quotient values greater than 1 indicate a concern for adverse health effects or the need for further study.

Risk methods evaluating carcinogenic risk use slope factors instead of reference doses. To estimate the potential carcinogenic risk from ingestion of water and fish, the estimated dose or intake is multiplied by the slope factor (risk per mg/kg-day). As mentioned earlier, acceptable risk levels for carcinogens range from 10^{-6} (risk of developing cancer over a human lifetime is 1 in 1,000,000) to 10^{-4} (risk of developing cancer over a human lifetime is 1 in 10,000). Carcinogenic risks greater than 10^{-4} indicate a concern for adverse health effects or the need for further study.

F.6. References

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G

Appendix G Radiological Airborne Emissions at Oak Ridge National Laboratory

This appendix presents annual radioactive airborne emissions for ORNL in 2020. All data were determined to be statistically different from zero at the 95 percent confidence level. Any number not statistically different from zero was not included in the emission calculation. Because measuring a radionuclide requires counting random radioactive emissions from a sample, the same result may not be obtained if the sample is analyzed repeatedly. This deviation is referred to as the "counting uncertainty." Statistical significance at the 95 percent confidence level means that there is a 5 percent chance that the results could be erroneous.

Table G.1. Radiological airborne emissions from all sources at ORNL, 2020 (Ci)[a]

Isotope	Inhalation form[b]	Chemical form	Stack								Total minor sources	ORNL total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{223}Ac	B	unspecified									3.97E-13	3.97E-13
^{225}Ac	M	particulate									2.18E-06	2.18E-06
^{226}Ac	M	particulate									1.07E-07	1.07E-07
^{227}Ac	M	particulate									1.86E-08	1.86E-08
^{228}Ac	M	particulate									1.64E-13	1.64E-13
^{106}Ag	M	particulate									2.8E-25	2.8E-25
^{108}Ag	B	unspecified									1.82E-18	1.82E-18
^{108m}Ag	M	particulate									2.48E-13	2.48E-13
^{109m}Ag	B	unspecified									5.5E-12	5.5E-12
^{110}Ag	B	unspecified									1.51E-07	1.51E-07
^{110m}Ag	M	particulate									1.13E-05	1.13E-05
^{111}Ag	M	particulate									4.23E-06	4.23E-06
^{112}Ag	M	particulate									5.62E-08	5.62E-08
^{26}Al	M	particulate									2.68E-17	2.68E-17
^{241}Am	M	particulate	2.82E-08	5.83E-07					3.69E-09		1.24E-05	1.3E-05
^{241}Am	F	particulate			1.07E-07		4.95E-09	2.41E-07			1.84E-09	3.55E-07
^{242}Am	M	particulate									5.77E-08	5.77E-08
^{242m}Am	M	particulate									6.25E-08	6.25E-08
^{243}Am	M	particulate									2.8E-07	2.8E-07
^{244}Am	M	particulate									3.03E-29	3.03E-29
^{245}Am	M	particulate									1.32E-18	1.32E-18
^{246}Am	M	particulate									1.59E-23	1.59E-23
^{37}Ar	B	unspecified									1.37E-04	1.37E-04
^{39}Ar	B	unspecified									5.97E-05	5.97E-05
^{41}Ar	B	unspecified							1.09E+03	2.90E+01		1.12E+03

Table G.1. Radiological airborne emissions from all sources at ORNL, 2020 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack								Total minor sources	ORNL total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{74}As	M	particulate									3.63E-33	3.63E-33
^{199}Au	M	particulate									1.14E-10	1.14E-10
^{131}Ba	M	particulate									2.15E-06	2.15E-06
^{133}Ba	M	particulate									2.65E-05	2.65E-05
^{137m}Ba	B	unspecified									3.63E-07	3.63E-07
^{139}Ba	M	particulate							2.91E-01			2.91E-01
^{140}Ba	M	particulate							6.80E-04		7.26E-07	6.81E-04
^{10}Be	M	particulate									7.33E-13	7.33E-13
^{7}Be	M	particulate	2.07E-07	1.32E-07		4.77E-08			4.99E-07		6.41E-06	7.3E-06
^{7}Be	S	particulate			3.61E-06						1.19E-06	4.8E-06
^{206}Bi	M	particulate									3.21E-07	3.21E-07
^{207}Bi	M	particulate									6.0E-16	6.0E-16
^{208}Bi	B	unspecified									8.67E-17	8.67E-17
^{210}Bi	M	particulate									3.12E-16	3.12E-16
^{210m}Bi	M	particulate									4.04E-17	4.04E-17
^{211}Bi	B	unspecified									5.82E-11	5.82E-11
^{212}Bi	M	particulate									4.14E-07	4.14E-07
^{213}Bi	M	particulate									3.62E-15	3.62E-15
^{214}Bi	M	particulate									5.19E-15	5.19E-15
^{249}Bk	M	particulate									7.01E-11	7.01E-11
^{250}Bk	M	particulate									3.5E-20	3.5E-20
^{82}Br	M	particulate									6.58E-08	6.58E-08
^{11}C	G	dioxide								2.0E+04		2.0E+04
^{14}C	M	particulate									1.36E-07	1.36E-07
^{41}Ca	M	particulate									7.04E-09	7.04E-09
^{45}Ca	M	particulate									4.34E-06	4.34E-06
^{47}Ca	M	particulate									1.08E-10	1.08E-10
^{109}Cd	M	particulate									5.26E-11	5.26E-11

Table G.1. Radiological airborne emissions from all sources at ORNL, 2020 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack								Total minor sources	ORNL total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{113}Cd	M	particulate									1.27E-21	1.27E-21
^{113m}Cd	M	particulate									1.21E-06	1.21E-06
^{115}Cd	M	particulate									1.16E-06	1.16E-06
^{115m}Cd	M	particulate									3.53E-08	3.53E-08
^{134}Ce	M	particulate									2.77E-09	2.77E-09
^{139}Ce	M	particulate									3.98E-08	3.98E-08
^{141}Ce	M	particulate							9.69E-07		1.26E-05	1.35E-05
^{143}Ce	M	particulate									8.38E-08	8.38E-08
^{144}Ce	M	particulate									1.17E-02	1.17E-02
^{249}Cf	M	particulate									7.13E-16	7.13E-16
^{250}Cf	M	particulate									3.13E-15	3.13E-15
^{251}Cf	M	particulate									1.25E-17	1.25E-17
^{252}Cf	M	particulate					5.45E-10				1.85E-08	1.9E-08
^{253}Cf	M	particulate									9.69E-24	9.69E-24
^{254}Cf	M	particulate									1.48E-21	1.48E-21
^{36}Cl	M	particulate									1.26E-10	1.26E-10
^{241}Cm	M	particulate									6.3E-14	6.3E-14
^{242}Cm	M	particulate									1.23E-04	1.23E-04
^{243}Cm	F	particulate					1.80E-08	9.70E-09			3.88E-10	2.81E-08
^{243}Cm	M	particulate	8.50E-08	5.20E-09		8.95E-11			1.95E-09		7.98E-07	8.91E-07
^{244}Cm	M	particulate	8.50E-08	5.20E-09		8.95E-11			1.95E-09		3.28E-05	3.29E-05
^{244}Cm	F	particulate					1.80E-08	9.70E-09			3.88E-10	2.81E-08
^{245}Cm	M	particulate									9.37E-09	9.37E-09
^{246}Cm	M	particulate									8.05E-09	8.05E-09
^{247}Cm	M	particulate									2.29E-12	2.29E-12
^{248}Cm	M	particulate									2.82E-09	2.82E-09
^{249}Cm	M	particulate									3.01E-26	3.01E-26
^{57}Co	M	particulate									2.01E-07	2.01E-07

Table G.1. Radiological airborne emissions from all sources at ORNL, 2020 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack								Total minor sources	ORNL total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{58}Co	M	particulate									4.2E-05	4.2E-05
^{60}Co	M	particulate									2.05E-04	2.05E-04
^{60}Co	S	particulate			2.43E-07			2.29E-07				4.72E-07
^{60m}Co	M	particulate									3.15E-13	3.15E-13
^{51}Cr	M	particulate									7.25E-04	7.25E-04
^{131}Cs	F	particulate									2.2E-06	2.2E-06
^{132}Cs	F	particulate									1.04E-07	1.04E-07
^{134}Cs	F	particulate									3.32E-03	3.32E-03
^{134}Cs	S	particulate						5.07E-07				5.07E-07
^{135}Cs	F	particulate									1.26E-08	1.26E-08
^{136}Cs	F	particulate									8.93E-07	8.93E-07
^{137}Cs	F	particulate	5.53E-07	2.77E-06					4.48E-06		5.68E-03	5.69E-03
^{137}Cs	S	particulate			2.43E-05		1.38E-08				4.38E-07	2.48E-05
^{138}Cs	F	particulate							1.07E+03			1.07E+03
^{64}Cu	M	particulate									3.0E-05	3.0E-05
^{67}Cu	M	particulate									1.06E-08	1.06E-08
^{159}Dy	M	particulate									7.33E-16	7.33E-16
^{169}Er	M	particulate									5.96E-08	5.96E-08
^{253}Es	M	particulate									3.76E-22	3.76E-22
^{254}Es	M	particulate									3.49E-20	3.49E-20
^{150}Eu	M	particulate									2.8E-13	2.8E-13
^{152}Eu	M	particulate									5.27E-07	5.27E-07
^{154}Eu	M	particulate									1.96E-04	1.96E-04
^{155}Eu	M	particulate									1.23E-04	1.23E-04
^{156}Eu	M	particulate									2.28E-09	2.28E-09
^{55}Fe	M	particulate									5.35E-04	5.35E-04
^{59}Fe	M	particulate									1.53E-05	1.53E-05
^{60}Fe	M	particulate									2.24E-14	2.24E-14

Table G.1. Radiological airborne emissions from all sources at ORNL, 2020 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack								Total minor sources	ORNL total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{223}Fr	M	particulate									1.18E-15	1.18E-15
^{68}Ga	M	particulate									7.37E-12	7.37E-12
^{72}Ga	M	particulate									1.13E-11	1.13E-11
^{151}Gd	M	particulate									5.9E-12	5.9E-12
^{152}Gd	M	particulate									7.67E-21	7.67E-21
^{153}Gd	M	particulate									7.94E-06	7.94E-06
^{159}Gd	M	particulate									2.56E-15	2.56E-15
^{68}Ge	M	particulate									7.37E-12	7.37E-12
^{71}Ge	M	particulate									1.1E-09	1.1E-09
^{3}H	V	vapor	3.24E-03		2.16E+00	3.49E-03	7.27E-01		6.07E+01	9.59E+02	2.25E-01	1.02E+03
^{175}Hf	M	particulate									4.17E-06	4.17E-06
^{178m}Hf	M	particulate									4.17E-08	4.17E-08
^{179m}Hf	M	particulate									1.47E-08	1.47E-08
^{181}Hf	M	particulate									1.06E-04	1.06E-04
^{182}Hf	M	particulate									2.77E-12	2.77E-12
^{203}Hg	M	inorganic									2.29E-09	2.29E-09
^{163}Ho	B	unspecified									6.41E-14	6.41E-14
^{166m}Ho	M	particulate									2.6E-11	2.6E-11
^{126}I	F	particulate									1.57E-07	1.57E-07
^{129}I	F	particulate									1.24E-05	1.24E-05
^{131}I	F	particulate			1.43E-02	1.70E-02			4.15E-02		2.68E-06	7.28E-02
^{132}I	M	particulate			6.85E-03							6.85E-03
^{132}I	F	particulate				3.08E-02			3.64E-01			3.95E-01
^{133}I	F	particulate							1.72E-01			1.72E-01
^{134}I	F	particulate							3.33E-01			3.33E-01
^{135}I	F	particulate							6.50E-01			6.5E-01
^{113m}In	M	particulate									2.62E-06	2.62E-06
^{114}In	B	unspecified									3.04E-07	3.04E-07

Table G.1. Radiological airborne emissions from all sources at ORNL, 2020 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack								Total minor sources	ORNL total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{114m}In	M	particulate									2.86E-07	2.86E-07
^{115}In	M	particulate									6.11E-19	6.11E-19
^{115m}In	M	particulate									2.38E-12	2.38E-12
^{191m}Ir	B	unspecified									3.8E-10	3.8E-10
^{192}Ir	M	particulate									9.0E-08	9.0E-08
^{192n}Ir	B	unspecified									2.36E-17	2.36E-17
^{194}Ir	M	particulate									1.05E-10	1.05E-10
^{194m}Ir	M	particulate									7.2E-10	7.2E-10
^{40}K	M	particulate									3.33E-07	3.33E-07
^{42}K	M	particulate									1.03E-11	1.03E-11
^{81}Kr	B	unspecified									7.72E-10	7.72E-10
^{83m}Kr	B	unspecified									4.47E-19	4.47E-19
^{85}Kr	B	unspecified							1.61E+02		1.81E+02	3.42E+02
^{85m}Kr	B	unspecified							1.18E+01			1.18E+01
^{87}Kr	B	unspecified							5.59E+01	4.30E+01		9.89E+01
^{88}Kr	B	unspecified							5.62E+01	1.44E+02		2.0E+02
^{89}Kr	B	unspecified							2.92E+01			2.92E+01
^{137}La	M	particulate									1.16E-19	1.16E-19
^{138}La	M	particulate									1.18E-17	1.18E-17
^{140}La	M	particulate							1.09E-02		7.4E-07	1.09E-02
^{173}Lu	M	particulate									2.21E-11	2.21E-11
^{174}Lu	M	particulate									7.82E-11	7.82E-11
^{174m}Lu	M	particulate									2.16E-11	2.16E-11
^{176}Lu	M	particulate									1.2E-13	1.2E-13
^{176m}Lu	M	particulate									3.39E-13	3.39E-13
^{177}Lu	M	particulate									6.67E-05	6.67E-05
^{177m}Lu	M	particulate									8.63E-09	8.63E-09
^{53}Mn	M	particulate									1.07E-17	1.07E-17

Table G.1. Radiological airborne emissions from all sources at ORNL, 2020 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack								Total minor sources	ORNL total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{54}Mn	M	particulate									3.76E-05	3.76E-05
^{56}Mn	M	particulate									5.33E-12	5.33E-12
^{93}Mo	M	particulate									1.75E-06	1.75E-06
^{99}Mo	M	particulate									2.01E-06	2.01E-06
^{13}N	B	unspecified								4.31E+02		4.31E+02
^{22}Na	M	particulate									9.98E-10	9.98E-10
^{24}Na	M	particulate									3.95E-06	3.95E-06
^{91}Nb	B	unspecified									9.3E-08	9.3E-08
^{91m}Nb	B	unspecified									1.12E-06	1.12E-06
^{92}Nb	B	unspecified									4.66E-15	4.66E-15
^{92m}Nb	B	unspecified									1.79E-08	1.79E-08
^{93m}Nb	M	particulate									1.76E-06	1.76E-06
^{94}Nb	M	particulate									6.45E-08	6.45E-08
^{95}Nb	M	particulate									1.23E-03	1.23E-03
^{95m}Nb	M	particulate									5.25E-06	5.25E-06
^{96}Nb	M	particulate									9.67E-09	9.67E-09
^{97}Nb	M	particulate									5.95E-09	5.95E-09
^{147}Nd	M	particulate									2.12E-07	2.12E-07
^{59}Ni	M	particulate									3.01E-07	3.01E-07
^{63}Ni	M	particulate									3.43E-03	3.43E-03
^{235}Np	M	particulate									4.56E-16	4.56E-16
^{236}Np	M	particulate									1.06E-18	1.06E-18
^{237}Np	M	particulate									1.38E-07	1.38E-07
^{238}Np	M	particulate									3.23E-15	3.23E-15
^{239}Np	M	particulate									1.69E-09	1.69E-09
^{240}Np	M	particulate									2.32E-26	2.32E-26
^{240m}Np	B	unspecified									1.93E-23	1.93E-23
^{185}Os	M	particulate									2.13E-09	2.13E-09

Table G.1. Radiological airborne emissions from all sources at ORNL, 2020 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack								Total minor sources	ORNL total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{191}Os	M	particulate				9.09E-01			1.11E-07		9.86E-10	9.09E-01
^{194}Os	M	particulate									1.1E-10	1.1E-10
^{32}P	M	particulate									1.51E-06	1.51E-06
^{33}P	M	particulate									4.7E-09	4.7E-09
^{228}Pa	M	particulate									5.5E-09	5.5E-09
^{230}Pa	M	particulate									3.72E-07	3.72E-07
^{231}Pa	M	particulate									1.01E-12	1.01E-12
^{232}Pa	M	particulate									1.4E-08	1.4E-08
^{233}Pa	M	particulate									3.81E-06	3.81E-06
^{234}Pa	M	particulate									5.65E-12	5.65E-12
^{234m}Pa	B	unspecified									4.38E-13	4.38E-13
^{205}Pb	M	particulate									1.83E-17	1.83E-17
^{209}Pb	M	particulate									3.67E-15	3.67E-15
^{210}Pb	M	particulate									3.13E-16	3.13E-16
^{211}Pb	M	particulate									8.66E-14	8.66E-14
^{212}Pb	M	particulate	3.77E-01	3.68E-01		2.16E-02			2.92E-02		4.14E-07	7.96E-01
^{212}Pb	S	particulate			1.28E+01		2.46E-01				6.56E-02	1.31E+01
^{214}Pb	S	particulate			7.81E-01							7.81E-01
^{214}Pb	M	particulate				2.65E-03					5.19E-15	2.65E-03
^{103}Pd	M	particulate									2.77E-32	2.77E-32
^{107}Pd	M	particulate									3.56E-09	3.56E-09
^{146}Pm	M	particulate									8.09E-08	8.09E-08
^{147}Pm	M	particulate									5.42E-03	5.42E-03
^{148}Pm	M	particulate									5.11E-08	5.11E-08
^{148m}Pm	M	particulate									9.3E-07	9.3E-07
^{209}Po	B	unspecified									9.3E-10	9.3E-10
^{210}Po	B	inorganic									4.6E-10	4.6E-10
^{143}Pr	M	particulate									3.22E-07	3.22E-07

Table G.1. Radiological airborne emissions from all sources at ORNL, 2020 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack								Total minor sources	ORNL total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{144}Pr	M	particulate									1.17E-02	1.17E-02
^{144m}Pr	B	unspecified									1.02E-10	1.02E-10
^{193}Pt	M	particulate									2.19E-09	2.19E-09
^{236}Pu	M	particulate									9.15E-14	9.15E-14
^{237}Pu	M	particulate									1.06E-19	1.06E-19
^{238}Pu	M	particulate	8.64E-09	3.40E-08					8.57E-10		1.04E-06	1.09E-06
^{238}Pu	F	particulate			1.16E-08		2.20E-09	8.87E-08				1.03E-07
^{239}Pu	M	particulate	1.79E-08	2.26E-07							2.17E-07	4.61E-07
^{239}Pu	F	particulate			2.94E-07		4.22E-09	3.20E-08			3.13E-08	3.62E-07
^{240}Pu	F	particulate			2.94E-07		4.22E-09	3.20E-08			2.77E-13	3.3E-07
^{240}Pu	M	particulate	1.79E-08	2.26E-07							1.21E-07	3.65E-07
^{241}Pu	M	particulate									3.36E-06	3.36E-06
^{242}Pu	M	particulate									6.26E-09	6.26E-09
^{243}Pu	M	particulate									1.66E-24	1.66E-24
^{244}Pu	M	particulate									8.72E-15	8.72E-15
^{223}Ra	M	particulate									2.34E-06	2.34E-06
^{224}Ra	M	particulate									9.13E-07	9.13E-07
^{225}Ra	M	particulate									1.09E-07	1.09E-07
^{226}Ra	M	particulate									1.0E-07	1.0E-07
^{228}Ra	M	particulate									6.01E-10	6.01E-10
^{83}Rb	M	particulate									5.6E-19	5.6E-19
^{84}Rb	M	particulate									8.09E-14	8.09E-14
^{86}Rb	M	particulate									1.46E-09	1.46E-09
^{87}Rb	M	particulate									1.35E-12	1.35E-12
^{183}Re	B	unspecified									3.32E-11	3.32E-11
^{184}Re	M	particulate									3.36E-09	3.36E-09
^{184m}Re	M	particulate									3.27E-09	3.27E-09
^{186}Re	M	particulate									3.39E-05	3.39E-05

Table G.1. Radiological airborne emissions from all sources at ORNL, 2020 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack								Total minor sources	ORNL total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{186m}Re	M	particulate									2.48E-12	2.48E-12
^{187}Re	M	particulate									1.68E-18	1.68E-18
^{188}Re	M	particulate									1.74E-04	1.74E-04
^{102}Rh	M	particulate									1.06E-07	1.06E-07
^{102m}Rh	M	particulate									2.22E-15	2.22E-15
^{103m}Rh	M	particulate									3.09E-05	3.09E-05
^{105}Rh	M	particulate									5.44E-07	5.44E-07
^{106}Rh	B	unspecified									1.25E-08	1.25E-08
^{219}Rn	B	unspecified									3.8E-11	3.8E-11
^{220}Rn	B	unspecified									4.14E-07	4.14E-07
^{222}Rn	B	unspecified									4.62E-10	4.62E-10
^{103}Ru	M	particulate									3.51E-05	3.51E-05
^{106}Ru	M	particulate									4.72E-03	4.72E-03
^{35}S	M	particulate									5.46E-07	5.46E-07
^{120m}Sb	M	particulate									1.46E-07	1.46E-07
^{122}Sb	M	particulate				3.09E-03					3.01E-07	3.09E-03
^{124}Sb	M	particulate				9.50E-03					6.84E-07	9.5E-03
^{125}Sb	M	particulate				1.20E-03					2.6E-04	1.46E-03
^{126}Sb	M	particulate				1.98E-02					5.3E-07	1.98E-02
^{126m}Sb	M	particulate									2.74E-08	2.74E-08
^{127}Sb	M	particulate									4.53E-07	4.53E-07
^{46}Sc	M	particulate									3.91E-06	3.91E-06
^{47}Sc	M	particulate									7.45E-08	7.45E-08
^{48}Sc	M	particulate									2.36E-07	2.36E-07
^{75}Se	F	particulate									2.08E-05	2.08E-05
^{79}Se	F	particulate									4.98E-09	4.98E-09
^{32}Si	M	particulate									2.0E-12	2.0E-12
^{145}Sm	M	particulate									2.91E-10	2.91E-10

Table G.1. Radiological airborne emissions from all sources at ORNL, 2020 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack								Total minor sources	ORNL total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{146}Sm	M	particulate									5.57E-15	5.57E-15
^{147}Sm	M	particulate									2.02E-13	2.02E-13
^{151}Sm	M	particulate									7.5E-06	7.5E-06
^{113}Sn	M	particulate									2.76E-06	2.76E-06
^{117m}Sn	M	particulate									1.76E-07	1.76E-07
^{119m}Sn	M	particulate									9.08E-07	9.08E-07
^{121}Sn	M	particulate									4.15E-09	4.15E-09
^{121m}Sn	M	particulate									1.43E-08	1.43E-08
^{123}Sn	M	particulate									4.23E-06	4.23E-06
^{123m}Sn	M	particulate									3.36E-12	3.36E-12
^{125}Sn	M	particulate									3.65E-07	3.65E-07
^{126}Sn	M	particulate									1.2E-08	1.2E-08
^{85}Sr	M	particulate									1.51E-07	1.51E-07
^{89}Sr	S	particulate			4.86E-06		1.96E-08				1.9E-07	5.07E-06
^{89}Sr	M	particulate	5.10E-08	1.18E-06		1.61E-08			7.50E-06		1.8E-04	1.89E-04
^{90}Sr	M	particulate	5.10E-08	1.18E-06		1.61E-08			7.50E-06		4.68E-03	4.69E-03
^{90}Sr	S	particulate			4.86E-06		1.96E-08	1.13E-06			6.94E-07	6.7E-06
^{91}Sr	M	particulate									1.19E-11	1.19E-11
^{179}Ta	M	particulate									3.79E-10	3.79E-10
^{182}Ta	M	particulate									1.69E-05	1.69E-05
^{182m}Ta	M	particulate									9.0E-11	9.0E-11
^{183}Ta	M	particulate									5.63E-06	5.63E-06
^{158}Tb	M	particulate									6.45E-13	6.45E-13
^{160}Tb	M	particulate									2.75E-07	2.75E-07
^{161}Tb	M	particulate									3.13E-09	3.13E-09
^{96}Tc	M	particulate									1.97E-08	1.97E-08
^{97m}Tc	M	particulate									1.99E-10	1.99E-10
^{98}Tc	M	particulate									1.61E-13	1.61E-13

Table G.1. Radiological airborne emissions from all sources at ORNL, 2020 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack								Total minor sources	ORNL total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{99}Tc	M	particulate									2.11E-05	2.11E-05
^{99}Tc	S	particulate						7.64E-07				7.64E-07
^{99m}Tc	M	particulate									1.95E-07	1.95E-07
^{121}Te	M	particulate									9.51E-05	9.51E-05
^{121m}Te	M	particulate									5.41E-09	5.41E-09
^{123}Te	M	particulate									2.26E-24	2.26E-24
^{123m}Te	M	particulate									2.63E-08	2.63E-08
^{125m}Te	M	particulate									6.39E-05	6.39E-05
^{127}Te	M	particulate									6.24E-06	6.24E-06
^{127m}Te	M	particulate									6.37E-06	6.37E-06
^{129}Te	M	particulate									1.91E-07	1.91E-07
^{129m}Te	M	particulate									2.94E-07	2.94E-07
^{131m}Te	M	particulate									9.13E-08	9.13E-08
^{132}Te	M	particulate									3.03E-07	3.03E-07
^{226}Th	S	particulate									2.59E-29	2.59E-29
^{227}Th	S	particulate									1.61E-06	1.61E-06
^{228}Th	S	particulate	4.71E-09	1.52E-08	2.10E-08	1.71E-09	6.78E-10		1.57E-08		5.88E-07	6.47E-07
^{229}Th	S	particulate									4.09E-08	4.09E-08
^{230}Th	S	particulate	8.84E-10	2.37E-09		6.76E-10			9.41E-09		1.42E-08	2.75E-08
^{230}Th	F	particulate			1.45E-08		4.72E-10				3.43E-10	1.53E-08
^{231}Th	S	particulate									1.39E-10	1.39E-10
^{232}Th	S	particulate	1.41E-09	2.66E-09		7.90E-10			1.19E-08		7.41E-08	9.08E-08
^{232}Th	F	particulate			9.70E-09		5.69E-10				4.46E-10	1.07E-08
^{234}Th	S	particulate									4.64E-12	4.64E-12
^{44}Ti	M	particulate									9.45E-11	9.45E-11
^{204}Tl	M	particulate									9.76E-15	9.76E-15
^{208}Tl	B	unspecified									4.14E-07	4.14E-07
^{168}Tm	B	unspecified									1.31E-14	1.31E-14

Table G.1. Radiological airborne emissions from all sources at ORNL, 2020 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack								Total minor sources	ORNL total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{170}Tm	M	particulate									5.89E-07	5.89E-07
^{171}Tm	M	particulate									6.63E-05	6.63E-05
^{172}Tm	M	particulate									4.86E-11	4.86E-11
^{230}U	M	particulate									2.55E-29	2.55E-29
^{232}U	M	particulate									1.7E-07	1.7E-07
^{233}U	S	particulate			4.51E-08		5.60E-09				3.53E-09	5.42E-08
^{233}U	M	particulate	2.85E-08	1.42E-07		1.30E-09			2.07E-08		4.56E-08	2.38E-07
^{234}U	M	particulate	2.85E-08	1.42E-07		1.30E-09			2.07E-08		3.37E-05	3.39E-05
^{234}U	S	particulate			4.51E-08		5.60E-09				3.53E-09	5.42E-08
^{235}U	M	particulate	1.22E-09	4.27E-09		1.23E-10			5.01E-09		1.53E-04	1.53E-04
^{235}U	S	particulate			4.23E-09						9.2E-10	5.15E-09
^{236}U	M	particulate									3.39E-11	3.39E-11
^{237}U	M	particulate									7.81E-13	7.81E-13
^{238}U	M	particulate	2.93E-09	2.48E-08		1.77E-09			1.92E-08		8.24E-03	8.24E-03
^{238}U	S	particulate			2.75E-08		1.34E-09				4.4E-09	3.32E-08
^{240}U	M	particulate									4.23E-23	4.23E-23
^{48}V	M	particulate									8.86E-11	8.86E-11
^{49}V	M	particulate									1.94E-07	1.94E-07
^{176}W	M	particulate									2.32E-06	2.32E-06
^{181}W	M	particulate									4.61E-05	4.61E-05
^{185}W	M	particulate									3.19E-03	3.19E-03
^{187}W	M	particulate									2.75E-09	2.75E-09
^{188}W	M	particulate									2.12E-04	2.12E-04
^{127}Xe	B	unspecified								9.20E+02	6.33E-08	9.2E+02
^{131m}Xe	B	unspecified							1.57E+02		1.71E-07	1.57E+02
^{133}Xe	B	unspecified				3.49E-04			8.17E+00			8.17E+00
^{133m}Xe	B	unspecified							2.58E+01			2.58E+01
^{135} Xe	B	unspecified							5.72E+01			5.72E+01

Table G.1. Radiological airborne emissions from all sources at ORNL, 2020 (Ci)[a] (continued)

Isotope	Inhalation form[b]	Chemical form	Stack								Total minor sources	ORNL total
			X-2026	X-3020	X-3039	X-4501	X-7503	X-7880	X-7911	X-8915		
^{135m}Xe	B	unspecified							3.83E+01			3.83E+01
^{137}Xe	B	unspecified							7.50E+01			7.5E+01
^{138}Xe	B	unspecified							1.90E+02			1.9E+02
^{88}Y	M	particulate									1.28E-07	1.28E-07
^{88}Y	F	particulate						3.38E-07				3.38E-07
^{89m}Y	B	unspecified									1.96E-17	1.96E-17
^{90}Y	M	particulate									4.54E-03	4.54E-03
^{91}Y	M	particulate									2.11E-04	2.11E-04
^{169}Yb	M	particulate									2.33E-08	2.33E-08
^{175}Yb	M	particulate									4.93E-06	4.93E-06
^{65}Zn	M	particulate									3.39E-05	3.39E-05
^{69}Zn	M	particulate									9.87E-07	9.87E-07
^{69m}Zn	M	particulate									9.2E-07	9.2E-07
^{88}Zr	M	particulate									1.24E-09	1.24E-09
^{89}Zr	M	particulate									6.29E-09	6.29E-09
^{93}Zr	M	particulate									1.24E-09	1.24E-09
^{95}Zr	M	particulate									2.33E-04	2.33E-04
^{97}Zr	M	particulate									3.72E-09	3.72E-09
Totals			**3.80E-01**	**3.68E-01**	**1.58E+01**	**1.02E+00**	**9.73E-01**	**3.38E-06**	**3.09E+03**	**2.25E+04**	**1.81E+02**	**2.58E+04**

[a] *Emissions given in curies (Ci). 1 Ci = 3.7E+10 Bq*

[b] *The designation of F, M, and S refers to the lung clearance type—fast (F), moderate (M), and slow (S) for the given radionuclide. G stands for gaseous, V stands for vapor, and B stands for blank, unspecified form.*

Acronym:

ORNL = Oak Ridge National Laboratory