ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Public Health Assessment for

K-25 and S-50 Uranium and Fluoride Releases

Oak Ridge Reservation (USDOE)
Oak Ridge, Roane County, Tennessee
EPA FACILITY ID: TN1890090003
September 13, 2010

U.S. DEPARTMENT OF HEALTH AND HUMAN SERVICES
PUBLIC HEALTH SERVICE
Agency for Toxic Substances and Disease Registry

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6)), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate.

In addition, this document has previously been provided to EPA and the affected states in an initial release, as required by CERCLA section 104 (i)(6)(H) for their information and review. The revised document was released for a 30-day public comment period. Subsequent to the public comment period, ATSDR addressed all public comments and revised or appended the document as appropriate. The public health assessment has now been reissued. This concludes the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

Additional copies of this report are available from:
National Technical Information Service, Springfield, Virginia
(703) 605-6000

You May Contact ATSDR Toll Free at
1-800-CDC-INFO
or
Visit our Home Page at: http://www.atsdr.cdc.gov

PUBLIC HEALTH ASSESSMENT

K-25 and S-50 Uranium and Fluoride Releases
OAK RIDGE RESERVATION (USDOE)

OAK RIDGE, ROANE COUNTY, TENNESSEE

EPA FACILITY ID: TN1890090003

Prepared by:

Site and Radiological Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

FOREWORD

The Agency for Toxic Substances and Disease Registry, ATSDR, was established by Congress in 1980 under the Comprehensive Environmental Response, Compensation, and Liability Act, also known as the *Superfund* law. This law set up a fund to identify and clean up our country's hazardous waste sites. The Environmental Protection Agency, EPA, and the individual states regulate the investigation and clean up of the sites.

Since 1986, ATSDR has been required by law to conduct a public health assessment at each of the sites on the EPA National Priorities List. The aim of these evaluations is to find out if people are being exposed to hazardous substances and, if so, whether that exposure is harmful and should be stopped or reduced. If appropriate, ATSDR also conducts public health assessments when petitioned by concerned individuals. Public health assessments are carried out by environmental and health scientists from ATSDR and from the states with which ATSDR has cooperative agreements. The public health assessment program allows the scientists flexibility in the format or structure of their response to the public health issues at hazardous waste sites. For example, a public health assessment could be one document or it could be a compilation of several health consultations - the structure may vary from site to site. Nevertheless, the public health assessment process is not considered complete until the public health issues at the site are addressed.

Exposure: As the first step in the evaluation, ATSDR scientists review environmental data to see how much contamination is at a site, where it is, and how people might come into contact with it. Generally, ATSDR does not collect its own environmental sampling data but reviews information provided by EPA, other government agencies, businesses, and the public. When there is not enough environmental information available, the report will indicate what further sampling data is needed.

Health Effects: If the review of the environmental data shows that people have or could come into contact with hazardous substances, ATSDR scientists evaluate whether or not these contacts may result in harmful effects. ATSDR recognizes that children, because of their play activities and their growing bodies, may be more vulnerable to these effects. As a policy, unless data are available to suggest otherwise, ATSDR considers children to be more sensitive and vulnerable to hazardous substances. Thus, the health impact to the children is considered first when evaluating the health threat to a community. The health impacts to other high risk groups within the community (such as the elderly, chronically ill, and people engaging in high risk practices) also receive special attention during the evaluation.

ATSDR uses existing scientific information, which can include the results of medical, toxicologic and epidemiologic studies and the data collected in disease registries, to determine the health effects that may result from exposures. The science of environmental health is still developing, and sometimes scientific information on the health effects of certain substances is not available. When this is so, the report will suggest what further public health actions are needed.

Conclusions: The report presents conclusions about the public health threat, if any, posed by a site. When health threats have been determined for high risk groups (such as children, elderly, chronically ill, and people engaging in high risk practices), they will be summarized in the conclusion section of the report. Ways to stop or reduce exposure will then be recommended in the public health action plan.

ATSDR is primarily an advisory agency, so usually these reports identify what actions are appropriate to be undertaken by EPA, other responsible parties, or the research or education divisions of ATSDR. However, if there is an urgent health threat, ATSDR can issue a public health advisory warning people of the danger. ATSDR can also authorize health education or pilot studies of health effects, full-scale epidemiology studies, disease registries, surveillance studies or research on specific hazardous substances.

Community: ATSDR also needs to learn what people in the area know about the site and what concerns they may have about its impact on their health. Consequently, throughout the evaluation process, ATSDR actively gathers information and comments from the people who live or work near a site, including residents of the area, civic leaders, health professionals and community groups. To ensure that the report responds to the community's health concerns, an early version is also distributed to the public for their comments. All the comments received from the public are responded to in the final version of the report.

Comments: If, after reading this report, you have questions or comments, we encourage you to send them to us.

Letters should be addressed as follows:

Agency for Toxic Substances and Disease Registry
ATTN: Records Center
1600 Clifton Road, NE (Mail Stop F-09)
Atlanta, GA 30333

Table of Contents

List of Figures

List of Tables

Acronyms and Abbreviations

µg/L	micrograms per liter
ANL	Argonne National Laboratory
AOI	areas of interest
ATSDR	Agency for Toxic Substances and Disease Registry
CAP88-PC	Clean Air Act Assessment Package–1988
CDC	Centers for Disease Control and Prevention
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Ci	Curies
COC	contaminant of concern
CRM	Clinch River mile
CROET	Community Reuse Organization of East Tennessee
CV	comparison value
D&D	decontamination & decommissioning
DOE	U.S. Department of Energy
EE/CA	engineering evaluation/cost analysis
EEWG	Exposure Evaluation Work Group
EFPC	East Fork Poplar Creek
ERAMS	environmental radiation ambient monitoring system
ETTP	East Tennessee Technology Park
FACA	Federal Advisory Committee Act
FFA	Federal Facility Agreement
ft	feet
HF	hydrogen fluoride
IAG	Interagency Agreement
ICRP	International Commission on Radiological Protection
kg	kilogram
Kr-85	krypton 85
LEFPC	Lower East Fork Poplar Creek
LWBR	Lower Watts Bar Reservoir
m	meter
mg/kg/day	milligram per kilogram per day
mrem/year	millirem per year
MRL	minimal risk level
mSv	millisievert
NCEH	National Center for Environmental Health
NIOSH	National Institute for Occupational Safety and Health
Np-237	neptunium 237
NPL	National Priorities List
NRC	U.S. Nuclear Regulatory Commission
OREIS	Oak Ridge Environmental Information System
ORGDP	Oak Ridge Gaseous Diffusion Plant
ORHASP	Oak Ridge Health Agreement Steering Panel
ORNL	Oak Ridge National Laboratory
ORO	Oak Ridge Operations

ORR	Oak Ridge Reservation
ORRHES	Oak Ridge Reservation Health Effects Subcommittee
OSHA	Occupational Safety and Health Administration
OU	operable unit
PCB	polychlorinated biphenyl
pCi/L	picoCuries per liter
pCi/m^3	picoCuries per cubic meter
PCM	Poplar Creek mile
PHAWG	Public Health Assessment Work Group
ppb	parts per billion
ppm	parts per million
Pu-239	plutonium 239
RAR	remedial action report
RASCAL	Radiological Assessment System for Consequence Analysis
RCRA	Resource Conservation and Recovery Act
RER	remediation effectiveness report
RI	remedial investigation
RI/FS	remedial investigation/feasibility study
RmAR	removal action report
ROD	record of decision
SDWIS	Safe Drinking Water Information System
SVOC	semi-volatile organic compound
Tc-99	technetium 99
TDEC	Tennessee Department of Environment and Conservation
TDOH	Tennessee Department of Health
TDOT	Tennessee Department of Transportation
TRM	Tennessee River mile
TSCA	Toxic Substances Control Act
TVA	Tennessee Valley Authority
TWRA	Tennessee Wildlife Resources Agency
U-234	uranium 234
U-235	uranium 235
U-238	uranium 238
UF_4	uranium tetrafluoride
UF_6	uranium hexafluoride
UO_2	uranium dioxide
USACE	U.S. Army Corps of Engineers
USEPA	U.S. Environmental Protection Agency
VOC	volatile organic compound
WBRIWG	Watts Bar Reservoir Interagency Working Group

I. Summary

I.A. Introduction

A principal mission of the Agency for Toxic Substances and Disease Registry (ATSDR) is to evaluate the human health effects of hazardous substances released into the environment. ATSDR is a sister agency of the Centers for Disease Control and Prevention (CDC) and has for many years worked closely with the CDC's National Center for Environmental Health (NCEH) to address public health concerns and issues at the Oak Ridge Reservation (ORR) in Tennessee. ATSDR's principal mission at ORR is to provide persons living in nearby communities with the best possible information regarding their health.

I.B. Oak Ridge Reservation Background

In 1942, the federal government established ORR in Tennessee's Anderson and Roane counties to research, develop, and produce materials for nuclear weapons. Three facilities—the Y-12 plant, the K-25 site, and the S-50 site—enriched uranium. The fourth facility, the X-10 site, demonstrated processes for producing and separating plutonium. Since the end of World War II, the Y-12 plant, the K-25 site, and the X-10 site have broadened their scope to include a variety of nuclear research and production projects vital to national security.

The 1,700-acre K-25 site, which includes the former S-50 plant (37 acres), was previously known as the Oak Ridge Gaseous Diffusion Plant (ORGDP). In October 1944, the S-50 plant began separating uranium by liquid thermal diffusion, but closed less than 1 year later, in September 1945. In 1946, all of the buildings associated with the S-50 site were destroyed. The K-25 site remained operational from 1945 to 1964, enriching weapons-grade uranium through gaseous diffusion. From 1965 to 1985 at K-25, uranium hexafluoride subjected to the gaseous diffusion process became commercial-grade uranium. In 1985, all gaseous diffusion operations ceased at K-25, and in 1987, the site closed.

In its near-70 year history, the ORR generated a variety of radioactive and nonradioactive wastes. Some wastes have remained in unused sites on the reservation and consequently some waste-related pollutants have released into the environment. In 1989, the U.S. Environmental Protection Agency (USEPA) added Oak Ridge Reservation to its National Priorities List (NPL). Under a Federal Facility Agreement (FFA) between U.S. EPA and the Tennessee Department of Environment and Conservation (TDEC), DOE is removing wastes and is restoring ORR's environment.

In 1996, ORR began a program of reindustrialization. In 1997, the K-25 site became the East Tennessee Technology Park. As part of the site's ongoing decontamination and decommissioning project, most of the buildings at the renamed East Tennessee Technology Park either have been demolished or have been scheduled for demolition. Under the Reindustrialization Program, some remaining facilities will possibly transfer to private-sector organizations.

I.C. ATSDR's Public Health Activities at the Oak Ridge Reservation

Since 1991, ATSDR has responded to requests for investigation of possible ORR environmental releases. The requests have come from community members, civic organizations, and other government agencies. And the requests have not been limited to areas within the ORR boundaries. For several years, ATSDR has evaluated contaminant levels in areas off site from ORR to determine whether those contaminants pose health risks. In the 1990s, for example, ATSDR focused on evaluating potential human exposures to site contaminants that migrated off site. The evaluations included clean-up activities at off-site areas affected by Oak Ridge Reservation operations, such as the East Fork Poplar Creek area and the Watts Bar Reservoir area. For ATSDR, the public health issue at ORR has always been whether community members eating, drinking, breathing, or otherwise contacting off-site but site-related toxic substances could potentially be at risk of harm.

In 2001, ATSDR scientists conducted a review and a screening analysis of the Tennessee Department of Health's (TDOH) Oak Ridge Health Studies. The review evaluated whether off-site exposures to toxic substances in the *past* (1944–1990) could have caused adverse health effects in populations living off site. ATSDR consulted this review to identify contaminants of concern for further evaluation. ATSDR also expanded on the TDOH's efforts by conducting public health assessments on

- X-10 iodine-131 releases;
- Y-12 mercury releases;
- Y-12 uranium releases;
- Radionuclide releases from White Oak Creek;
- K-25 uranium and fluoride releases;
- PCB releases from X-10, Y-12, and K-25;
- Chemical screening of potential exposures in off-site areas; and
- Other topics such as the Toxic Substances Control Act (TSCA) Incinerator and off-site groundwater.

A public health assessment (sometimes referred to in this document as a "PHA") evaluates and analyzes data and findings from previous studies and investigations. Those data and findings are then used to assess the public health implications of *past, current, or future exposures*. For more information on ATSDR's public health activities related to the Oak Ridge Reservation, visit the agency's Oak Ridge Reservation Web site at: http://www.atsdr.cdc.gov/HAC/oakridge/.

I.D. Evaluation of Uranium and Fluoride Releases from the K-25/S-50 Site

This public health assessment evaluates uranium and fluoride releases from the ORR K-25/S-50 site and responds to community health concerns. The PHA evaluates the potential health effects of past K-25 and S-50 air releases involving radioactive and nonradioactive hazardous substances for people living in nearby, off-site communities. ATSDR evaluates here potential past short-term (acute) and long-term (chronic) off-site, 1944–1995 exposures

An ***acute exposure*** occurs over a short period (fewer than 14 days); a ***chronic exposure*** occurs over a long period (more than 1 year).

from K-25/S-50 air releases of ionizing radiation, uranium, hydrogen fluoride, and fluoride. ATSDR evaluates these potential health effects for three communities which, based on their proximity, had the highest potential exposures: Happy Valley, Sugar Grove, and Union/Lawnville. ATSDR also discusses potential current and future hazards, defined as any potential hazards that might be identified during ongoing remedial activities at the K-25 site. And ATSDR addresses community health concerns and issues associated with releases from the K-25 and S-50 facilities.

I.E. This Public Health Assessment's Scope

In this PHA, ATSDR does not address potential releases and exposures to surface water or groundwater, or air emissions from the TSCA Incinerator (located within the K-25 site boundaries). This PHA also does not address the release of other contaminants of concern such as mercury, iodine-131, and PCBs. ATSDR evaluated these potential exposures and contaminants in separate public health assessments, available at http://www.atsdr.cdc.gov/hac/oakridge/index.html. This PHA also does not address on-site exposures for Oak Ridge Reservation workers. Oak Ridge Reservation workers may have been exposed to hazardous substances at higher levels than have the public. Yet they were trained in the safe handling and use of hazardous substances. DOE or its predecessor agencies or contractors were responsible for the safety of their workers and for monitoring workers' potential exposures.

I.F. Sources and Emission Estimates from the K-25/S-50 Site

The primary airborne contaminant released from the K-25/S-50 sources was uranium hexafluoride (UF_6). At atmospheric temperatures and pressures, UF_6 is a dense or heavy gas—it is heavier than air. When released into the air, UF_6 reacts rapidly with atmospheric water to form hydrogen fluoride, uranyl fluoride, and uranium oxide particulates. The UF_6 fed into the gaseous diffusion cascades was initially derived from natural uranium. Beginning in 1952, however, UF_6 feed material included reprocessed, previously fissioned uranium (i.e., reactor tails). This spent reactor fuel contained fission products and transuranic radionuclides, including technetium 99 (Tc-99), neptunium 237 (Np-237), and very small quantities of plutonium 239 (Pu-239). Thus post-1952, K-25 facility airborne emissions also contained quantities of Tc-99 and Np-237, but these are accounted for in airborne emission estimates. And the small quantities of Pu-239 and other plutonium isotopes (e.g., plutonium 240 [Pu-240]) together with their decay products (e.g., americium 241 [Am-241]) in the reactor tails account for less than 1 percent of the total radiation dose. Consequently, Pu-239 and other plutonium isotopes and their decay products are not a public health hazard and are not included in subsequent radiological dose assessments.

To evaluate past uranium releases and potential off-site exposures to the surrounding communities, ATSDR used background information and data from portions of the TDOH's *Task 6 of the Reports of the Dose Reconstruction, Uranium Releases from the Oak Ridge Reservation—a Review of the Quality of Historical Effluent Monitoring Data and a Screening Evaluation of Potential Off-Site Exposures* (referred to as the "Task 6 report") (ChemRisk 1999a). The Task 6 report found that because estimated K-25 facility uranium doses for the Union/Lawnville exposure area were below screening indices, a more detailed dose reconstruction was not warranted (ChemRisk 1999a). After reviewing emissions data and a dose

estimation model, the Task 6 report concluded that uranium emissions from the K-25/S-50 facility did not pose a significant public health risk to the surrounding community. The report, however, did identify several issues regarding K-25/S-50 uranium releases that required further investigation. Recommendations included using environmental monitoring data and obtaining site-specific meteorological data to confirm the adequacy of the uranium emissions and dispersion estimates. Concerned residents also identified the need to evaluate fluoride releases and exposures and to assess potential, 1943–1947 exposures for former Happy Valley labor camp residents.

ATSDR obtained and analyzed DOE airborne uranium emissions data. To analyze the dispersion of the uranium isotopes and the resulting doses to the potentially exposed populations, ATSDR used the DOE estimate of total uranium activities—combined with the Task 6 estimate of uranium isotope proportions—and the Np-237 and Tc-99 release rates. The long-term or annual uranium release estimates represent the sum of individual release events for each year.

One of ATSDR's tasks is to determine whether any individual, short-term release event posed a public health hazard to communities living near the Oak Ridge Reservation. The largest documented UF_6 release of 1,184 kilograms occurred in September 1958. The available data are probably incomplete, but ATSDR nonetheless considers that because the records include the years of highest production and of the highest annual emissions, they likely represent the most significant individual release events. And those individual release events included "midnight negative" releases. That is, to support a planned opening of isolated process gas equipment, operators would use jets during nighttime hours to accelerate the attainment of an adequate UF_6 negative.

Thus for each of the three communities with the highest exposure potential, ATSDR has estimated potential short-term release exposure scenarios. To estimate chronic (i.e., annual) effective dose equivalents for airborne radionuclides, ATSDR used the Clean Air Act Assessment Package-1988 (CAP88-PC). To evaluate the off-site concentrations and potential uranium and hydrogen fluoride doses from short-term or episodic releases from the K-25/S-50 facility, ATSDR used the Radiological Assessment System for Consequence Analysis (RASCAL3) model. RASCAL3 develops 50-year committed, effective dose equivalents resulting from inhalation. Because the locations (and elevations) of the two DOE meteorological data towers K-1208 and K-1209 at the K-25 site approximately correspond to the locations of K-25 and S-50 sites, respectively, the CAP88-PC model used meteorological data from each of these locations to evaluate contaminant dispersion and historic exposures from each source. For the September 1958 accidental release, however, no specific meteorological data were available—thus ATSDR's analysis was based on presumed worst-case weather conditions.

Since ORR's 1942 establishment and at least since 1953, DOE or its precursor agencies and contractors in all likelihood have been collecting various environmental measurements. These measurements included ambient radiation activities in soil, water, and air. Since at least the mid-1960s, two stations adjacent to K-25/S-50 have been sampled for airborne, radioactive gross alpha particulates (HP-35 and HP-33). With some simplifying assumptions, agreement is reasonably uniform between the historic measured gross alpha concentrations and those predicted by the CAP88-PC air dispersion model for K-25/S-50 air release estimates. This agreement, especially during the period when measured gross alpha data are available, validates

the modeling procedure's estimates of off-site doses for 1961 and 1963—the earlier maximum release years.

Except as included in UF_6 releases, DOE has not compiled any estimates of annual airborne fluoride releases because there were no regulatory requirements for monitoring annual airborne releases of fluoride. From 1971 to 1985, DOE measured airborne fluoride concentrations at a number of locations around K-25; ATSDR used these data in this evaluation. But for the years with no measured concentrations, ATSDR had to estimate fluoride air concentrations by correlating fluoride releases with airborne uranium releases. Because of the increased distance from emission sources and the protective effects of topographic ridges between the emission sources and exposure areas, ATSDR based these estimated concentrations on conservative (i.e., protective) worst-case assumptions and modeled air data. Thus at areas of potential exposure along the site perimeter, the approximated concentrations overestimate fluoride and HF concentrations.

I.G. Estimated Doses and Concentrations

I.G.1. Ionizing Radiation

ATSDR estimated radiological doses from airborne releases for the communities closest to K-25/S-50. ATSDR estimated for the largest documented accidental release and for the largest estimated annual release. The highest estimated short-term, 50-year committed effective dose for off-site communities that ATSDR evaluated was the 34-mrem, 1958 K-25 accidental release for the Sugar Grove community. The highest annual radiological effective dose is the 30 mrem/year, 1945 S-50 annual release for the Union/Lawnville community. Yet even this release is approximately one-third of ATSDR's 100 mrem/year minimal risk level (MRL). It is also approximately one-third of the public radiation dose limit of 100 mrem/year as recommended by the International Commission on Radiological Protection (ICRP), the U.S. Nuclear Regulatory Commission (NRC), and the National Council on Radiation Protection and Measurements (NCRP). Moreover, 37 mrem/year for Sugar Grove is the highest cumulative radiation dose from summing potential short-term and long-term doses for a specific exposure area, and it is below these health comparison values. ATSDR also measured the highest, 37 mrem/year-cumulative dose from potential historic short-term and long-term exposures to airborne releases at the area of highest off-site exposure from K-25/S-50 radiological contaminants. This 37 mrem/year-cumulative dose includes uranium 234, 235, and 238 [U-234, U-235, and U-238, respectively], Np-237, and Tc-99. It is also below ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years (or 71 mrem per year). Thus, historic exposure to airborne releases of ionizing radiation from the K-25/S-50 facility is not expected to cause adverse health effects.

I.G.2. Uranium

The highest estimated short-term (i.e., 1-hour, acute) off-site uranium air concentration was approximately 51 $\mu g/m^3$. This was measured at the nearest off-site exposure area during an accidental hydrogen fluoride and particulate uranyl fluoride release. Although on-site air concentrations would have been even higher, Sugar Grove and Union/Lawnville residents would not have been exposed to similar, elevated air concentrations. ATSDR has not derived health-based guidelines for acute uranium inhalation exposure, which is an exposure occurring once or

for only a short time—up to 14 days. Workers exposed during accidental releases[1] to estimated levels of uranium ranging from 0.6 to 24 milligrams have succumbed to hydrogen fluoride toxicity (i.e., respiratory and irritant effects) without signs of uranium-induced kidney toxicity. And the National Research Council (2008) reviewed the estimated health risks the U.S. Army reported in its Capstone Report.[2] The Capstone Report evaluated toxicologic and radiologic risks associated with exposure to depleted uranium for U.S. military personnel during the Gulf War.

In general, the Council agreed with the Army's characterization of the carcinogenic and noncarcinogenic risks associated with depleted uranium exposure. The toxicological information used in this ATSDR document is also similar to a published report that discussed long-term health effects among Gulf War veterans with embedded uranium shrapnel (McDiarmid et al. 2004). Specifically, McDiarmid et al. (2004) report that chemical effects of uranium on the kidney occur following repeated exposures over a long period, rather than an acute exposure from an accidental release. The point here is that if during the K-25 accidental release people did not experience effects from hydrogen fluoride exposure, concurrent uranium exposure affecting the kidney is unlikely. Thus after its evaluation of the effects reported in these studies, ATSDR does not expect exposure to the estimated short-term concentration to result in adverse effects, including kidney effects.

Because of chronic operational emissions, long-term exposure to airborne uranium also occurred during the years 1944 to 1995. The highest annual uranium release (as UF_6) occurred in 1963. The maximum estimated annual uranium air concentration for that year in an area of potential off-site exposure (Union/Lawnville) is 0.04 $\mu g/m^3$—about 10 times lower than the chronic-duration inhalation MRL (0.3 $\mu g/m^3$) for soluble uranium compounds. Thus, even if people were exposed long term to this estimated maximum air concentration, the chemical toxicity of uranium would not have been expected to cause adverse health effects.

I.G.3. Fluoride and Hydrogen Fluoride (HF from normal operations, accidents, or controlled releases)

Historically, fluoride and hydrogen fluoride enter the environment as a result of normal operations, accidents, or controlled releases. Thus releases during normal ORR process operations could have resulted in chronic (i.e., long-term) exposures for people living around the K-25/S-50 facility. Accidents or controlled releases could have resulted in acute (short-term) hydrogen fluoride and fluoride exposures.

In August 2003, the California EPA (Cal-EPA; Office of Environmental Health Hazard Assessment) prepared a chronic toxicity summary for fluorides, including hydrogen fluoride. Skeletal fluorosis was the critical effect identified, with a chronic inhalation reference exposure level of 14 $\mu g/m^3$ for hydrogen fluoride and 13 $\mu g/m^3$ for fluoride. The estimated 6 $\mu g/m^3$ maximum annual exposure concentration for people living around the K-25/S-50 facility is well below Cal-EPA's reference levels. As such, the estimated long-term fluoride and hydrogen fluoride air concentrations and resulting exposures were not expected to harm the health of off-site residents.

[1] Such as the 31 workers exposed during the Gore, OK accident.

[2] Officially titled "Depleted Uranium Aerosol Doses and Risks: Summary of U.S. Assessments."

To estimate short-term (acute) exposure to hydrogen fluoride concentrations, ATSDR used short-term fluoride measurements and a dispersion estimate from the September 1, 1958 accidental UF_6 release. The highest measured short-term (24-hour) fluoride concentration was 26.3 ppb, which occurred at station F-2 in 1975. Similarly, ATSDR's modeled short-term (i.e., hourly) hydrogen fluoride concentrations of 156 and 27 ppb used that same September 1958 accidental release to estimate exposures for the Sugar Grove and Union/Lawnville communities, respectively. ATSDR's MRL for acute inhalation exposure to hydrogen fluoride and fluorine is 20 ppb and 10 ppb, respectively. Concentrations below these values are not expected to cause adverse health effects. That said, the 20-ppb MRL for hydrogen fluoride in air is 25 times lower than exposures that caused mild upper respiratory tract inflammation in human volunteers exposed for 1 hour (Lund et al. 1999). The highest average level (time-weighted average) allowed by the Occupational Safety and Health Administration (OSHA) for HF in air for a 40-hour work week made up of 8-hour work days is 2.5 mg/m^3 (3 ppm or 3,000 ppb). Thus, the 20-ppb MRL for hydrogen fluoride air concentrations is 150 times lower than OSHA's occupational level. Nevertheless, the largest documented accidental release from the K-25 facility may have produced temporary minor respiratory irritation in sensitive persons living in the Sugar Grove or Union/Lawnville communities. But because of the high degree of uncertainty in the modeled results and the lack of sufficient data for short-term (acute) hydrogen fluoride and fluoride exposures, a health hazard determination is not feasible.

I.G.4. Uranyl Fluoride and Hydrogen Fluoride (HF from UF_6 cylinders)

No past releases of uranyl fluoride and hydrogen fluoride were ever recorded from the UF_6 storage cylinders located at ETTP. Removal of all of the UF_6 cylinders was completed in December 2006 (Halen Philpot, ETTP UF_6 Cylinder Project Manager, Bechtel Jacobs Company LLC, personal communication, January 29, 2007).

I.H. Current and Future Exposure

Current and future exposures include any potential hazards that might be identified during ongoing remedial activities at the K-25 site. At this time, ATSDR's evaluation has not identified any potential current or future hazards to off-site residents.[3] ATSDR concurs with the selected ongoing remedial activities at ORR and recommends that during remediation, DOE continue its precautionary measures to prevent any off-site releases of any residual contaminants potentially remaining at the K-25 site.

I.I. CONCLUSIONS

I.I.1. Past Exposure (1944 to 1995)

ATSDR's evaluation of potential past exposures to K-25/S-50 releases for nearby off-site communities resulted in four important conclusions. ATSDR developed the conclusions based on an evaluation of available, historic air, soil, water, and biota monitoring data, contaminant release estimates, the physical setting of the site and surrounding area, multiple years of site-specific meteorological data, and data estimated using air-dispersion models developed and

[3] An explanation of ATSDR's public health assessment process and how it differs from a risk assessment is available at: http://www.atsdr.cdc.gov/publications/CitizensGuidetoRiskAssessments.html.

approved by U.S. EPA, DOE, and the U.S. Nuclear Regulatory Commission (NRC). Although each of these data sources is limited, the cumulative dataset provides adequately for this public health assessment's determinations.

Conclusion 1. Off-site residents' long-term (chronic) breathing of low levels of uranium, hydrogen fluoride, fluoride, and other radioactive materials from 1944 to 1995 is not expected to harm their health.

Conclusion 2. Off-site residents' short-term (acute) breathing of low levels of uranium and other radioactive materials from 1944 to 1995 is not expected to harm their health.

Conclusions Basis. The estimated levels of uranium, hydrogen fluoride, fluoride, and radioactive materials released from the K-25/S-50 site into nearby off-site community air are lower than generally accepted health-harmful levels.

Conclusion 3. ATSDR is unable to determine whether past short-term (acute) breathing of fluoride and hydrogen fluoride from the large, sudden UF_6 releases in the 1940s and 1950s during accidents and equipment maintenance at the K-25/S-50 site could harm people's health.

Conclusion Basis. During accidental and equipment maintenance releases of UF_6 in the 1940s and 1950s, the air sampling data ATSDR needed to make a health decision were never collected. In part to compensate for this lack of data, ATSDR used conservative worst-case assumptions and modeled air data to estimate past short-term air levels of hydrogen fluoride in nearby off-site areas. But relying on worst-case estimated air levels to arrive at health decisions is inappropriate—in this case, for example, the modeled results are uncertain and the actual occurrence of estimated worst-case levels is unlikely.

Conclusion 4. Current and future off-site exposure to potential air releases of uranium, radioactive materials, hydrogen fluoride, and fluoride from the K-25/S-50 site will not harm the health of those living near the site. People are not currently exposed to these contaminants nor are they expected to be so exposed in the future.

Conclusion Basis. In the late 1980s, all gaseous diffusion operations ceased. Today, DOE takes precautionary measures during on-site remedial activities to prevent off-site contaminant releases into ambient air. Remediation at the K-25 site is ongoing and will continue for the foreseeable future. ATSDR's assessment has identified no potential current or future exposures to site-related contaminants for nearby residents.

Next Steps. ATSDR recommends that during remediation DOE continues its precautionary measures to prevent any future off-site releases of contaminants potentially remaining at the K-25 site.

FOR MORE INFORMATION Contact your health care provider if you have concerns about your health. For more information on this document or ATSDR's site-related activities, please call ATSDR at 1-800-CDC-INFO and ask for information on the DOE Oak Ridge Reservation.

II. Background

II.A. Site Description

The U.S. government created the Oak Ridge Reservation (ORR) in 1942 as part of the Manhattan Project. ORR's Manhattan Project purpose was to develop fuel for nuclear weapons (ChemRisk 1993a; ORHASP 1999; TDOH 2000). Today the majority of the ORR is within the city limits of Oak Ridge, in eastern Tennessee (ChemRisk 1999a; EUWG 1998; ORNL 2002). The reservation comprises parts of Anderson and Roane Counties and is about 15 miles west of Knoxville, Tennessee (Bechtel Jacobs Company LLC et al. 1999; EUWG 1998; ORNL 2002; TDEC 2002). The Clinch River forms the reservation's southern and western borders (EUWG 1998). Figure 1 shows the ORR's location.

In the years following the 1942 acquisition of the 58,575-acre Oak Ridge Reservation (Bechtel Jacobs Company LLC et al. 1999; ORNL 2002), the federal government transferred 24,340 acres to other parties (e.g., the City of Oak Ridge, the Tennessee Valley Authority [TVA]); the U.S. Department of Energy (DOE) continues to control 34,235 acres of the original reservation (ORNL 2002). Figure 2 shows the original and current ORR boundaries. About 70 percent of the reservation is currently designated a National Environmental Research Park; these lands were a buffer zone and have never been used for nuclear weapons-related operations (ORNL 2002).

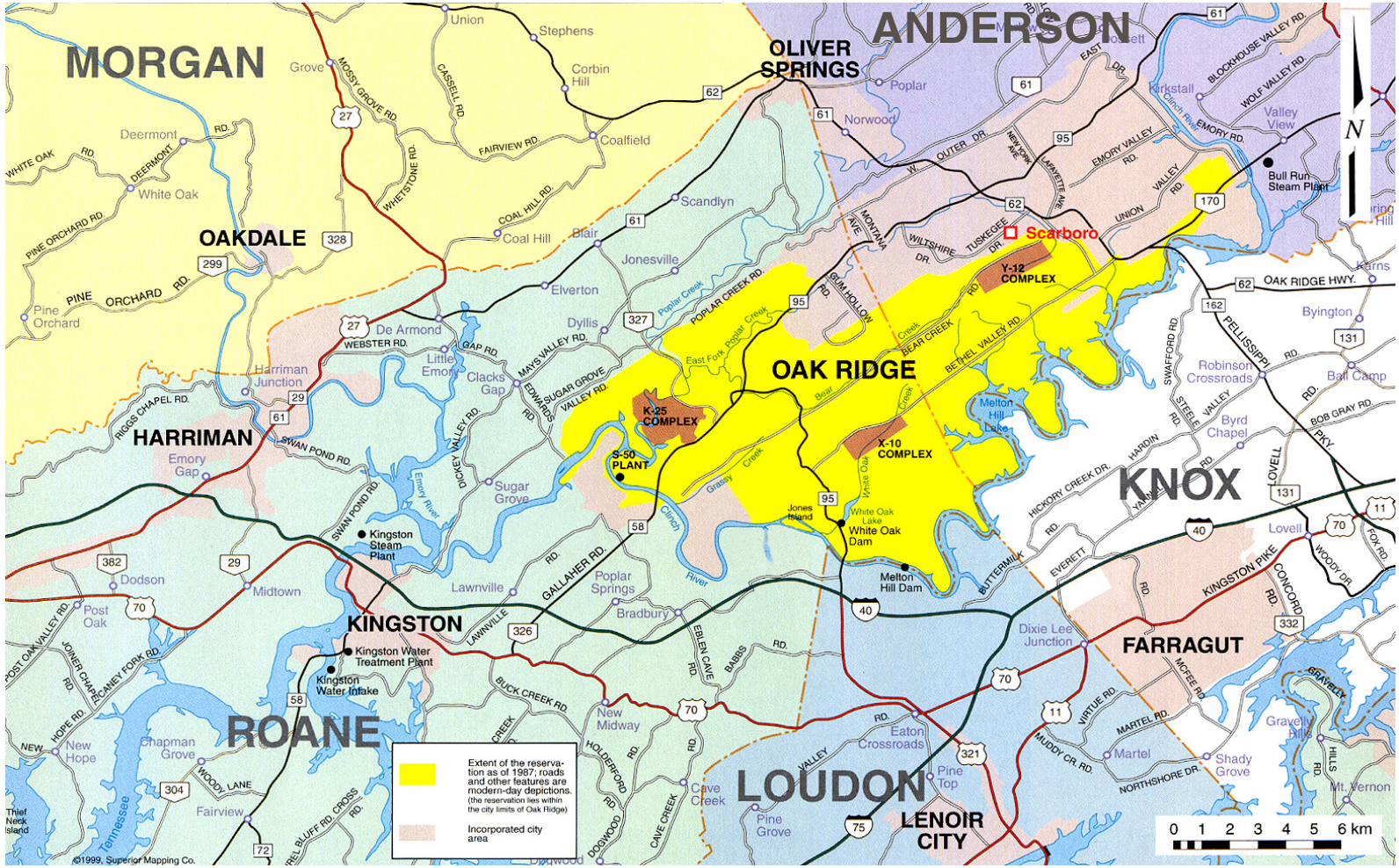
Approximately 30 percent of the reservation is made up of three major facility areas that the government constructed as part of the Manhattan Project:

K-25 and S-50. The K-25 site (formerly referred to as the Oak Ridge Gaseous Diffusion Plant [ORGDP]) and the former S-50 site, now collectively referred to as the East Tennessee Technology Park [ETTP]), were created to enrich uranium by gaseous diffusion (K-25) or liquid thermal diffusion (S-50).

Y-12. The Y-12 plant (now known as the Y-12 National Security Complex) was used to enrich uranium by an electromagnetic process.

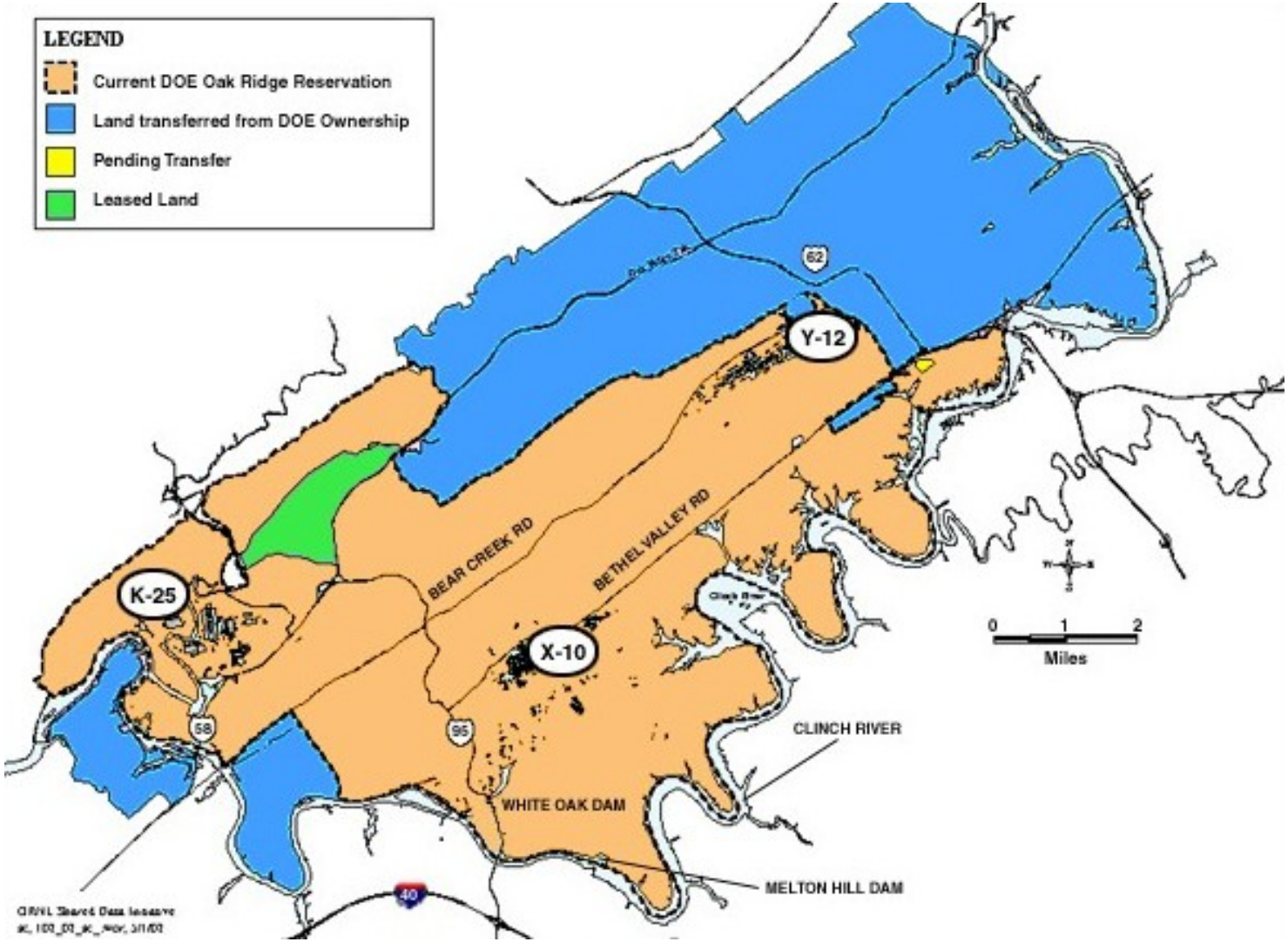
X-10. The X-10 site—formerly referred to as Clinton Laboratories and now part of the Oak Ridge National Laboratory [ORNL]—was designed to develop methods for the separation of plutonium from uranium reactor fuels (ChemRisk 1993a; ChemRisk 1999a; ORNL 2002; TDOH 2000).

Figure 1. Location of the Oak Ridge Reservation



Source: ChemRisk 1999a

Figure 2. Original and Current ORR Boundaries



Source: ORNL et al. 2002

II.A.1. The K-25/S-50 Site

The K-25/S-50 site is close to the ORR's western, Poplar Creek border, which in turn is near the creek's confluence with the Clinch River (ChemRisk 1999a; USDOE 1996). The site is within the Valley and Ridge Subregion of the Appalachian Highlands Province, close to the province's border with the Cumberland Plateau (USDOE 1995a). The 1,700-acre K-25/S-50 site is in Roane County, approximately 10 miles west of downtown Oak Ridge (ORHASP 1999; TDOH 2000; USDOE 2003a; USDOE 2003b; USEPA 1991). Figure 1 shows the location of the K-25 site. The 1998 End Use Working Group report noted over 500 area buildings with a total floor area in excess of 15 million square feet where gaseous diffusion processes occurred. The site also had more than 270 auxiliary facilities for support operations (e.g., testing, storage) with a combined floor area above 2.5 million square feet. The site also contained approximately 290 additional buildings and trailers with various uses, such as laboratories and offices (EUWG 1998).

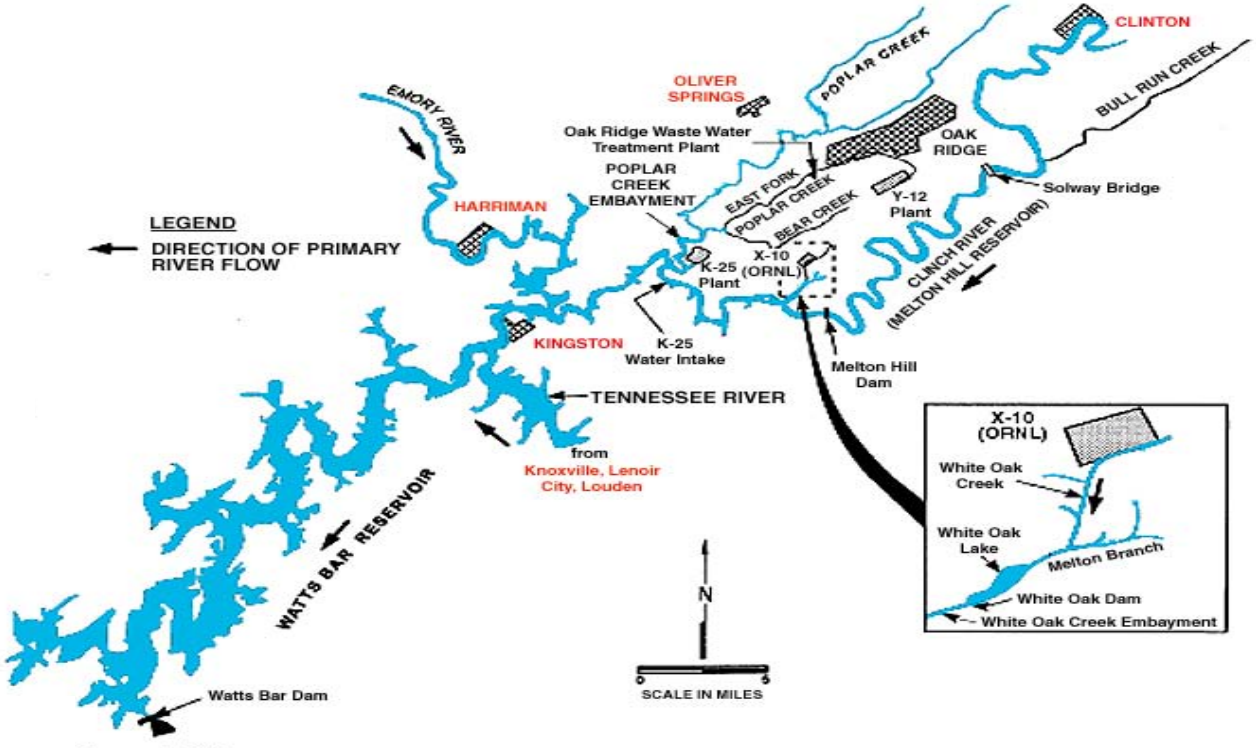
Most buildings at ETTP have either been demolished or scheduled for demolition as part of the ETTP Decontamination and Decommissioning Project. Remaining facilities are scheduled for possible transfer to private sector organizations under the Reindustrialization Program. Some of the notable structures that have been demolished include K-29 (one of the large gaseous diffusion buildings), several facilities in the laboratory and main plant area of ETTP, K-1002 (former cafeteria), K-1003 (former medical facility), "Group I Buildings," and "Group II Buildings." DOE has also completed the demolition of 18 facilities near the K-1064 peninsula. These consisted of pump houses, a cooling tower (K-801-H), old storage facilities (K-1025 A-E), and miscellaneous maintenance areas, Buildings K-1401 (former maintenance facility) and K-1501 (ETTP Steam Plant) have also been demolished (Bechtel Jacobs 2008; DOE 2008).

Additionally, the first stage of demolition activity on the K-25 building was completed in 2008. The K-25 building, the largest facility at ETTP, occupies about 40 acres. The northwest bridge that connected the west wing to the base of the u-shaped structure has been removed. The bridge housed pipes that transferred uranium between building wings as it was undergoing enrichment. The next step in the K-25 demolition process, which began in 2009, was to remove the west wing (Bechtel Jacobs 2008). As of October 2009, demolition of about two-thirds of the west wing had been completed (Munger 2009). Demolition of both wings of the building is scheduled for completion at the end of 2010 (Bechtel Jacobs 2008).

The S-50 site comprised approximately 37 acres southeast of the K-25 site, along the Clinch River. Figure 1 is a map showing the K-25 and S-50 areas, and Figure 3 shows the location of K-25 along the Clinch River. The S-50 site operated for less than 1 year and is now part of the K-25 site (ChemRisk 1999a). All of S-50's buildings were destroyed and buried in 1946—no physical evidence of the site remains (ChemRisk 1999a; TDEC 2002).

In 1943, J.A. Jones began construction of labor camps collectively referred to as "Happy Valley." The camps were intended to house construction workers and their families while the Oak Ridge Gaseous Diffusion Plant was under construction (Hewlett and Anderson 1962; Jacobs EM Team 1997a). Happy Valley was located in the lower reaches of East Fork Valley near the main K-25 gaseous diffusion plant. The westernmost portion of Happy Valley was between 1.0 and 1.5 miles farther southeast of the K-25 Power House area and the former S-50 plant (Prince 2003). By the end of 1944, an estimated 5,600 workers lived at Happy Valley. In the mid-

Figure 3. Map of Surface Water Bodies on and around the Oak Ridge Reservation



CFRF–consolidated fuel recycling facility; HFIR–high flux isotope reactor; TSF–tower shielding facility

Source: Lockheed Martin Energy Systems, Inc. 1998

summer of 1945, the total residential (worker and family) population peaked at over 8,700 (Keith and Baker 1946; Prince 2003). Small family units, barracks, hutments, and trailers housed the residents; shops, a school, a movie theatre, gas stations, and other facilities were also constructed (J.A. Jones Construction Company, date unknown; Keith and Baker 1946). Destruction of the site began in 1947, and by the mid-1950s all the Happy Valley buildings were razed (Jacobs EM Team 1997a).

II.A.1.1. The Sugar Grove community

The Sugar Grove community is near the K-25 site, about 1.6 miles north-northwest of the process buildings. Locally, Sugar Grove is referred to as the Blair Road community. Although residents of the community are nearest to the air emission sources on the K-25 facility, Black Oak Ridge, which trends northeast-southwest and has elevations as high as 380 feet (ft) (115 m) above the adjacent valleys, separates the community from K-25. Many of the homes near the K-25 site were constructed as early as 1953 (USGS 1953).

II.A.1.2. Union/Lawnville

Union/Lawnville is about 2.8 miles to the south-southwest of the K-25/S-50 site. The community's area is defined by the Union Church, which is on Lawnville Road about 0.6 miles north of Gallaher Road. The Clinch River is about 0.9 miles northeast of the Union Church and is the main surface water source for the community. In this public health assessment, the Union/Lawnville community is used as a reference location for releases from the K-25 site and the former S-50 plant (ChemRisk 1999a).

II.B. Operational History

II.B.1. 1943 to 1987

Beginning in the early 1940s, the ORR processed significant amounts of uranium. Methods such as gaseous diffusion and liquid thermal diffusion enriched the uranium into uranium 235 (U-235), the uranium isotope also used for various research and development projects (ChemRisk 1993a).

Although only begun in 1943, by January 1945 the K-25 uranium enrichment facility was operational. K-25 used a gaseous diffusion system of cascades to enrich uranium into the U- 235 component (see the text box) (ChemRisk 1999a; USEPA 2005). Between 1945 and 1954, four additional gaseous diffusion process buildings (K-27, K-29, K-31, K-33) were erected, and the K-25 site was renamed the Oak Ridge Gaseous Diffusion Plant (ORGDP) (ChemRisk 1993a; ORHASP 1999).

A cascade is a system of highly specialized pumps and filters specifically designed to separate uranium isotopes. Multiple cascades were required to purify adequately the nuclear weapons grade uranium. For a more detailed technical discussion, see ChemRisk (1999a).

The K-25 site operated as a weapons-grade uranium enrichment facility until 1964 (EUWG 1998). By then all military requirements had been fulfilled, and Buildings K-25 and K-27 were closed (ChemRisk 1993a). Between 1965 and 1985, the facility used uranium hexafluoride (UF_6) to manufacture commercial-grade uranium. From the 1960s until 1985, K-25 was used for

centrifuge enrichment (EUWG 1998). Activities at the remaining gaseous diffusion process buildings were discontinued in 1985, and the buildings were officially closed in 1987 (ChemRisk 1993a; ORHASP 1999; USDOE 2003b). The site name then reverted from ORGDP back to K-25 (ORHASP 1999).

The main processes and activities associated with uranium at the K-25 site include

- Hydrogen fluoride and fluorine disposal (1944–1952),
- Gaseous diffusion enrichment (1945–1985),
- UF_6 feed manufacturing (1952–1965),
- Product and tails withdrawal (1945–1985),
- Uranium recovery and decontamination (1944–1985)
- Feed vaporization (1945–1985),
- Research and development activities (1944–1985),
- K-25 laboratories (1944–1985),
- Toll enrichment (1969–1985), and
- Gas centrifuge program (1960s–1980s).

Building of the former S-50 liquid thermal diffusion plant began on June 6, 1944. By October 1944 the plant was fully operational. It housed processes designed to assess the financial and scientific feasibility of separating U-235 from uranium 238 (U-238) through liquid thermal diffusion. Because of constant equipment malfunctions and releases into the Clinch River and into the air, in September 1945 the plant was closed. The only documented process at the S-50 site was liquid thermal diffusion enrichment between 1944 and 1945 (ChemRisk 1999a).

II.B.2. Date: 1988 to Present

Since the 1987 cessation of K-25 operations, many clean-up activities have removed wastes and have restored the environment around the site. Reindustrialization at the site started in 1996. In 1997, the K-25 site was renamed the East Tennessee Technology Park (ETTP) (ORHASP 1999; TDOH 2000; USDOE 2003b). A 2002 status report described the ETTP site as containing two business centers: the Heritage Center and the Horizon Center. The Heritage Center includes 125 of the main buildings formerly used for gaseous diffusion processes, and the Horizon Center includes various buildings spread across 1,000 acres intended for high-technology companies (USDOE 2003a). The Toxic Substances Control Act (TSCA) incinerator also occupies part of the K-25 site. This incinerator is the only one in the United States permitted to incinerate radioactive materials and hazardous wastes that contain polychlorinated biphenyls (PCBs) (TDEC 2002).

In December 2006, DOE completed its removal of the UF_6 cylinders from the cylinder storage yards at the K-25 site. From March 2004 to December 2006, DOE shipped approximately 6,000 UF_6 cylinders collectively containing about 119 million pounds of UF_6 off site to DOE's Portsmouth Gaseous Diffusion Plant (PORTS) in Portsmouth, Ohio (Halen Philpot, ETTP UF_6 Cylinder Project Manager, Bechtel Jacobs Company LLC, personal communication, January 29, 2007).

As of July 2009, additional remedial activities at the site for groundwater and soil were scheduled, were ongoing, or were complete. A summary of some activities is presented here; for more information refer to the DOE's 2009 Oak Ridge Environmental Management Program fact sheet: http://www.bechteljacobs.com/pdf/factsheets/ettp_fact_sheet.pdf. In 2008, a time-critical removal action was completed to extract chromium-contaminated groundwater from Mitchell Branch. Also in 2008, soil excavation was conducted at contaminated areas at the K-1085 Old Firehouse Drum Site, with disposal of all excavated soil completed in 2009. In July 2009, a groundwater treatability study to assess feasibility of groundwater treatment was underway as well as a final site-wide record of decision to address sediment, groundwater, surface water, and ecological soil risk associated with the K-25 site (DOE 2009).

For additional details on historical operations at the K-25 site and the former S-50 site, see Section 1.5 and Appendix B of Task 6 of the Reports of the Dose Reconstruction, *Uranium Releases from the Oak Ridge Reservation—a Review of the Quality of Historical Effluent Monitoring Data and a Screening Evaluation of Potential Off-Site Exposures* (ChemRisk 1999a) and also Section 3.1 of *Oak Ridge Health Studies Phase I Report—Volume II—Part A—Dose Reconstruction Feasibility Study. Tasks 1 & 2: A Summary of Historical Activities on the Oak Ridge Reservation with Emphasis on Information Concerning Off-Site Emission of Hazardous Material* (ChemRisk 1993a). The final reports of the Oak Ridge Dose Reconstruction are available via the Internet at http://health.state.tn.us/CEDS/OakRidge/ORidge.html. A timeline (Figure 4) also provides details on historical K-25 and S-50 site activities.

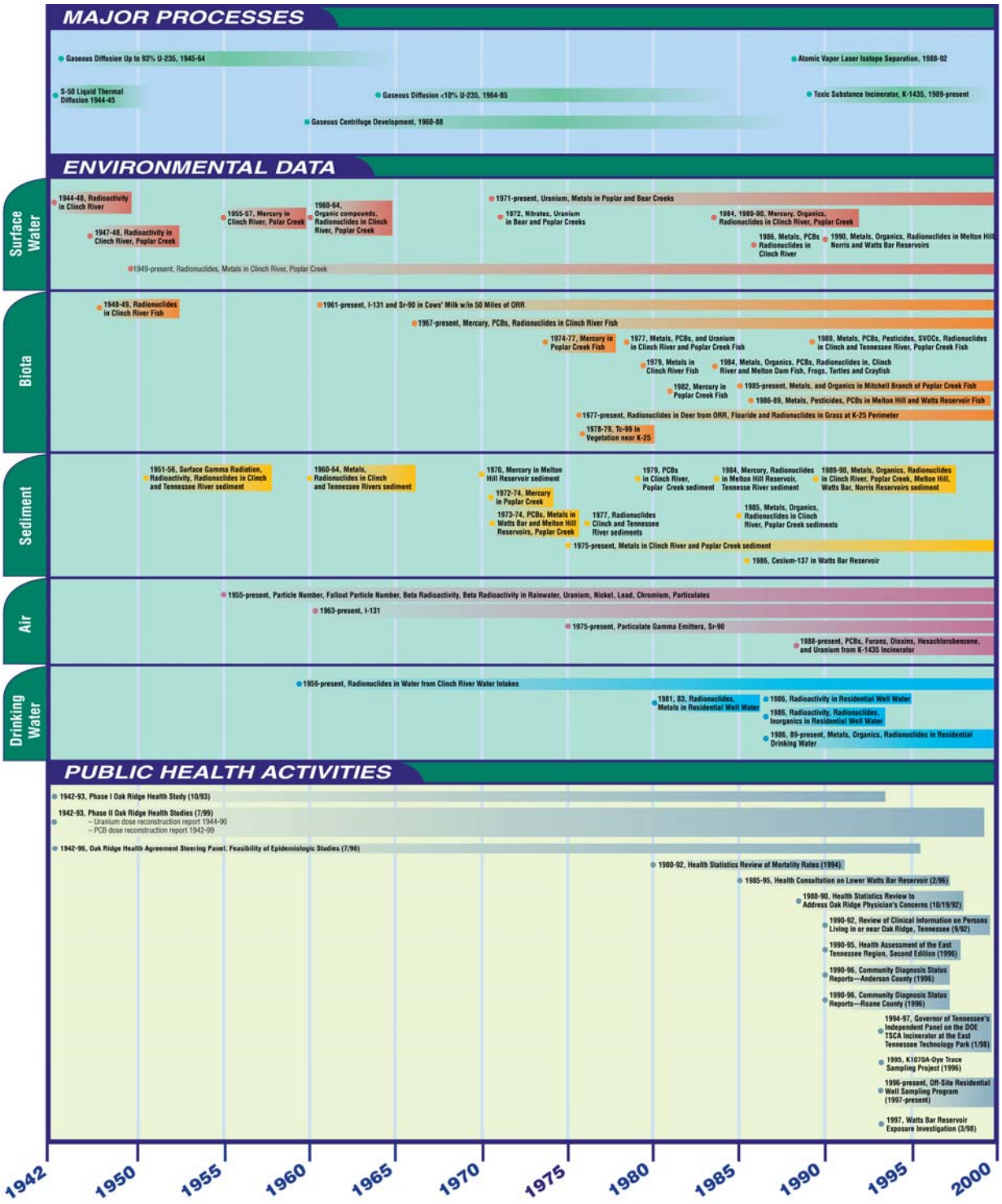
II.C. Remedial and Regulatory History

On November 21, 1989, because of many on-site operations that released radioactive and nonradioactive wastes, U.S. EPA placed the ORR on the final National Priorities List (NPL) (EUWG 1998; USEPA 2004c). Various contaminants (e.g., uranium) are present in old waste sites at the ORR. These waste sites constitute 5 to 10 percent of the reservation. Releases from these waste sites, as well as leaching caused by abundant rainfall and high water tables, have contributed to the radionuclide contamination of ORR surface water, groundwater, soil, and sediments (EUWG 1998).

The DOE is conducting remedial actions at the reservation under a Federal Facility Agreement (FFA). This is an interagency agreement between the DOE, the U.S. Environmental Protection Agency (USEPA), and the Tennessee Department of Environment and Conservation (TDEC). The U.S. EPA, TDEC, and the public assist DOE with ORR remedial activity details. The parties work together to ensure that clean-up actions are appropriate and to ensure that hazardous wastes associated with former and current ORR activities are adequately studied (USDOE 2003b). Given that ORR is on the National Priority List, the DOE's remediation activities are

On January 1, 1992, ORR implemented the legally binding Federal Facility Agreement, also referred to as the Interagency Agreement. The agreement establishes documentation, procedures, and schedules for remedial actions at the ORR (EUWG 1998; U.S. DOE 2003b). The Federal Facility Agreement is available online at http://www.bechteljacobs.com/pdf/ffa/ffa.pdf.

Figure 4. K-25 Facility Time Line (1942–2000)



In the timeline, "present" refers to the year 2000, when the timeline was developed.

under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), a federal statute that requires an FFA for all government-owned NPL sites (EUWG 1998; USDOE 2003b; USEPA 2004c). In addition, DOE is combining response measures from CERCLA with mandatory actions from the Resource Conservation and Recovery Act (RCRA) (USEPA 2004c). Figure 4 contains a timeline of air, biota, drinking water, sediment, soil, and surface water sampling data related to processes at the K-25 site from 1942 to 2000. In the timeline, "present" refers to the year 2000, when the timeline was developed.

Under a RCRA permit, DOE began conducting remedial actions at the reservation in 1986. Since then DOE has initiated about 50 response activities under the FFA that address on- and off-site contamination, as well as waste disposal issues related to the ORR (USEPA 2005). To ease the study and clean up of the ORR, the contaminated areas on the reservation were separated into five large tracts of land generally related to the reservation's major hydrologic watersheds (EUWG 1998).

For CERCLA purposes, K-25 environmental restoration was separated into three administrative zones as shown in Figure 5. Zone 1 encompasses the approximate 1,400-acre area outside the main plant fence (most disposal activities occurred in this area). Zone 2 includes the estimated 800-acre main plant area. The remaining zone is along the ridgelines surrounding Zones 1 and 2 and comprises the approximately 2,800-acre "balance of site" (SAIC 2005).

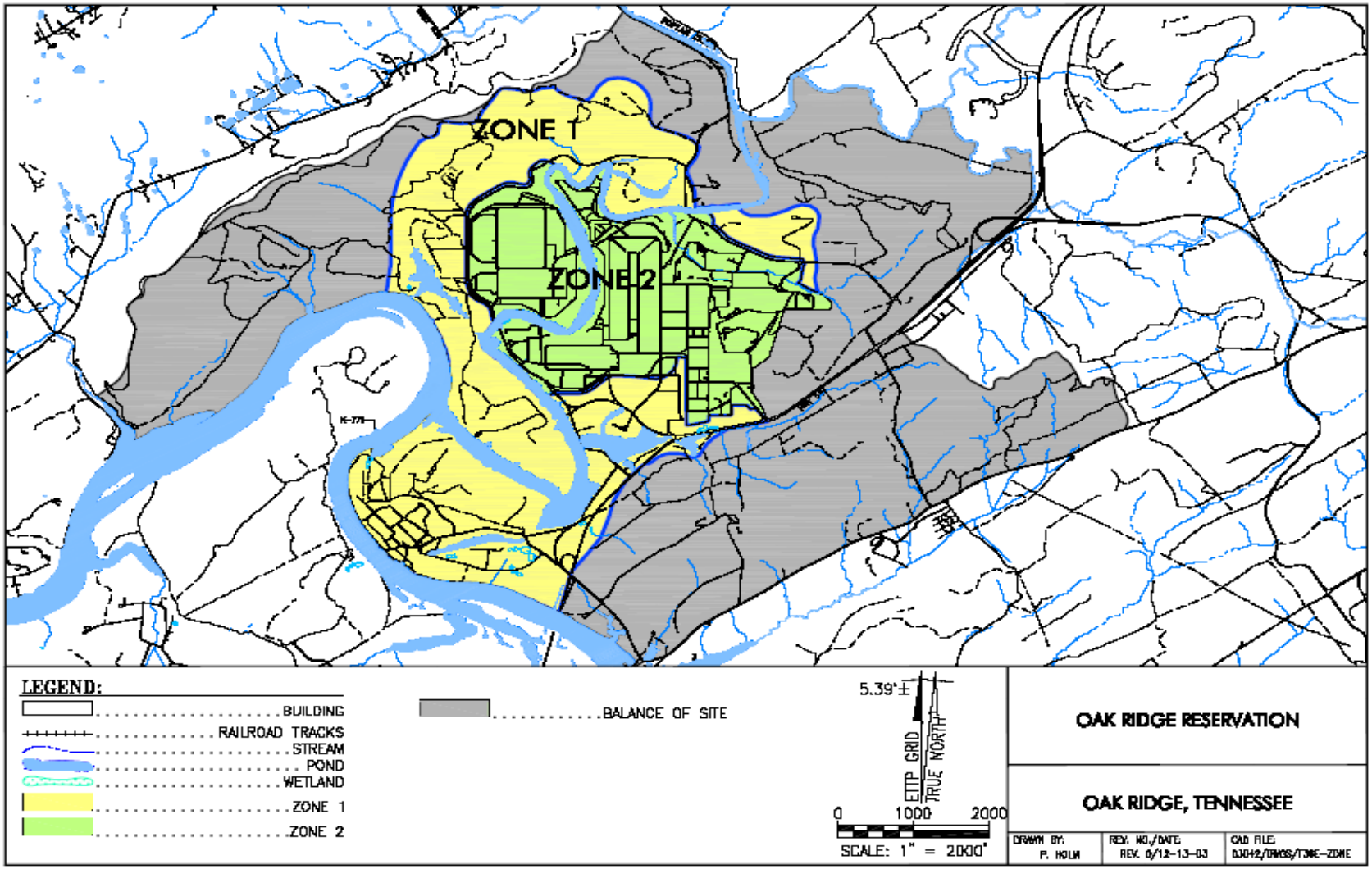
Some Zone 1 soils are contaminated with PCBs and radionuclides. By focusing on identified soil-contamination areas and known release sources, Zone 1 remedial actions protect against exposures to humans. Contaminated subsurface structures, soil, and buried waste permeate Zone 2, where remedial activities focus on protecting groundwater resources and also preventing exposures to humans (SAIC 2004). About 500 aboveground facilities in the remaining zone or "balance of site" could be contaminated with radiological and other hazardous substances (SAIC 2005). The major remedial actions associated with both on- and off-site areas affected by K-25 site-related contaminants are further detailed in Appendix C and shown in Figure 6.

II.D. Land Use and Natural Resources

At the time of its 1942 acquisition, the federal government reserved 14,000 of the 58,575-acre ORR acres to establish businesses, housing, and support services for reservation personnel (ChemRisk 1993c; ORNL 2002). In 1959, this section of land became the self-governing city of Oak Ridge with parks, homes, schools, offices, stores, and industrial areas (ChemRisk 1993c).

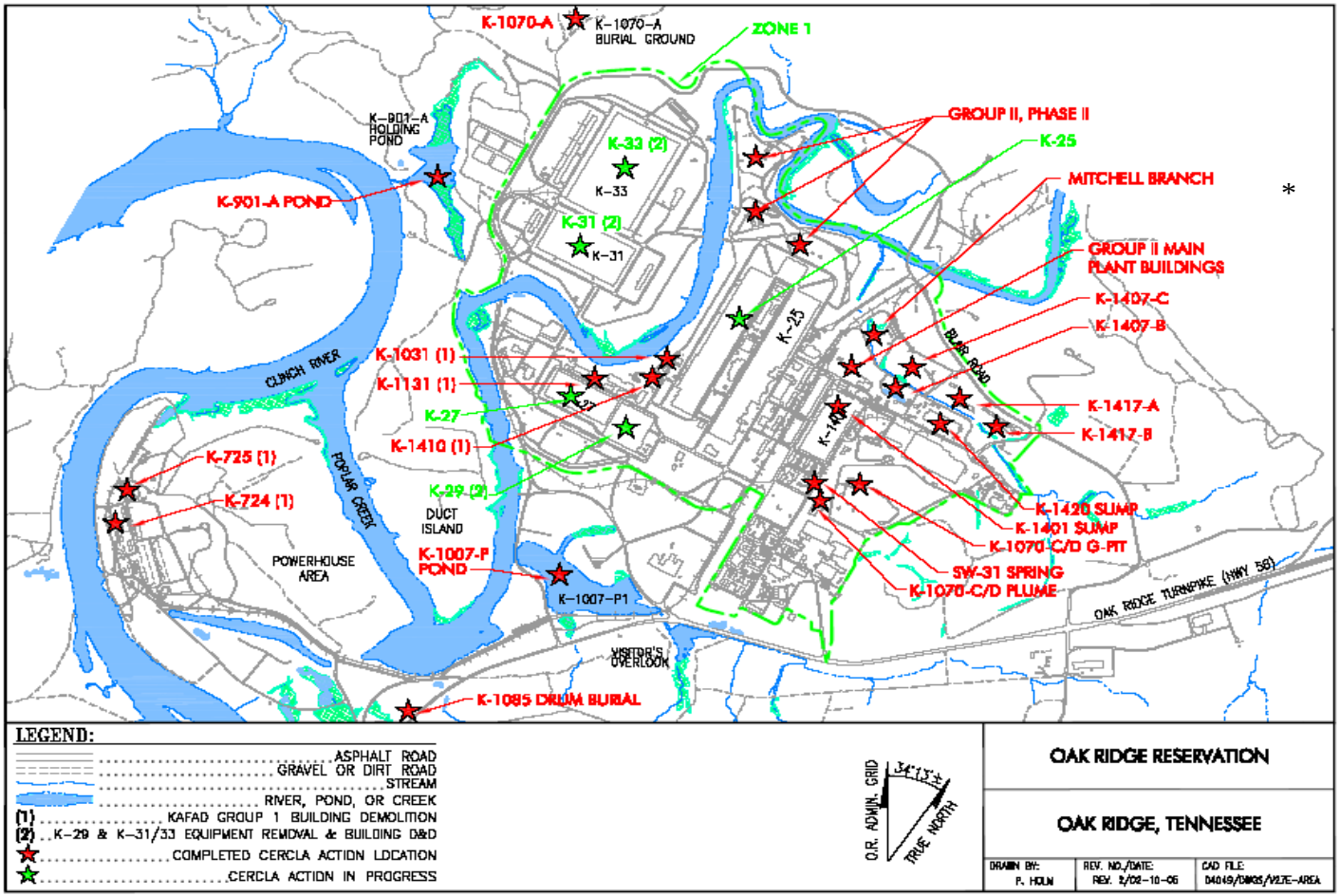
As stated, the ORR reservation is entirely within Anderson and Roane Counties and mostly within the Oak Ridge city limits (EUWG 1998). As of 2002, the ORR comprised 34,235 acres that included the three main DOE installations: K-25, Y-12, and X-10 (ORNL 2002). These three DOE facilities make up about 30 percent of the reservation. In 1980, the remaining 70 percent of the reservation became the National Environmental Research Park. The park designation protects land intended for environmental research and education and indicates that development of energy technology is compatible with a quality environment (EUWG 1998).

Figure 5. Administrative Zones for Environmental Restoration at the K-25 Site



Source: SAIC 2005

Figure 6. Map of the Major Remedial Activities at the K-25 Site



Source: SAIC 2005

* In 2005, the groundwater collection and treatment system was shut down because the system was not producing the desired results. The ETTP site-wide ROD is evaluating the need for future remedial actions. Therefore, it is not currently a "Completed CERCLA Action Location."

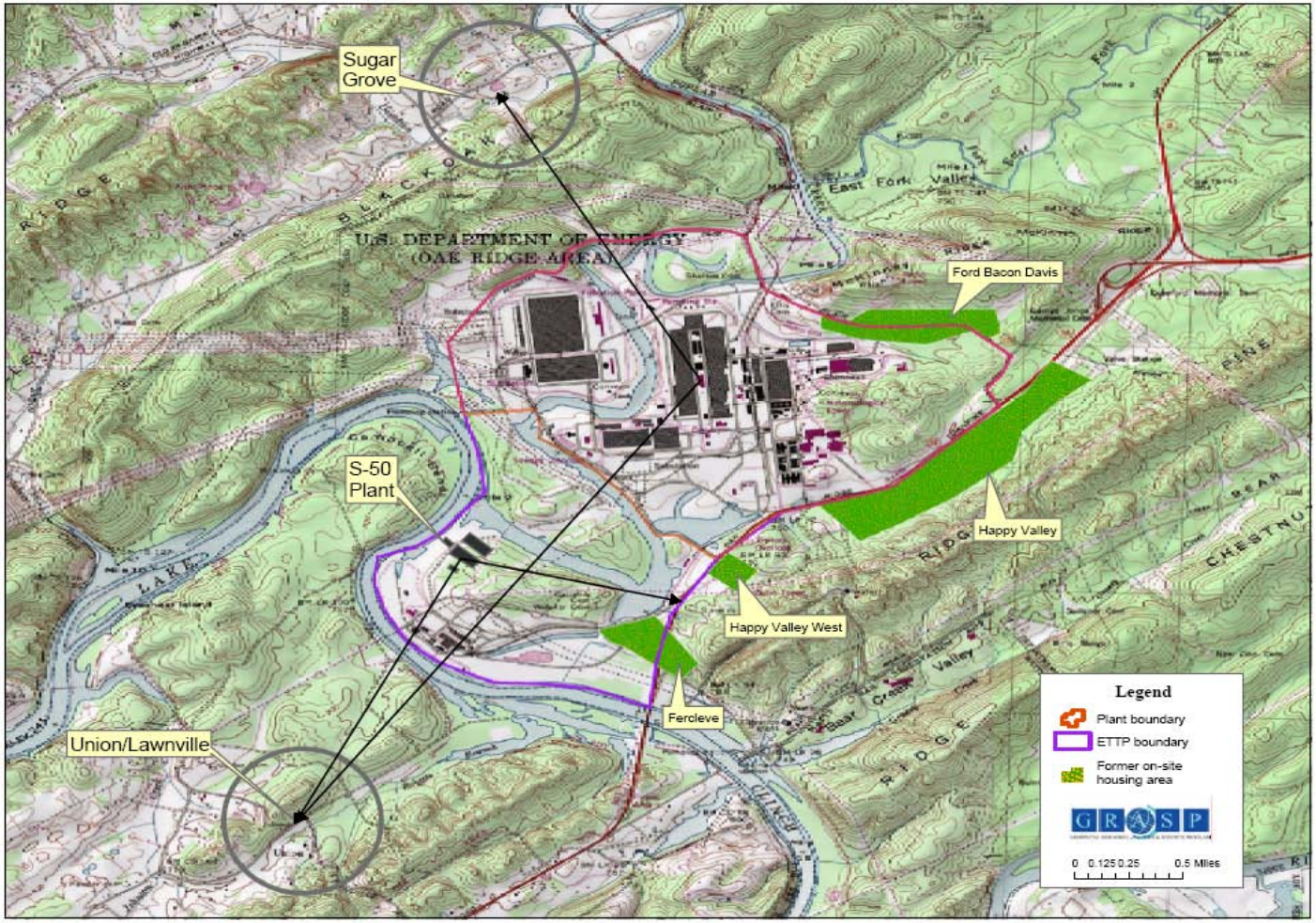
The majority of Oak Ridge residents live along the northern and eastern borders of the reservation (Bechtel Jacobs Company LLC et al. 1999; ORNL 2002). Since the 1950s, however, the urban population of Oak Ridge has expanded to the west. Because of this growth, several homes in the city's western section border the reservation (Faust 1993). Except for these urban areas, the land surrounding the ORR is primarily rural. In fact, approximately 40 percent of the land close to the ORR is currently undeveloped (Bechtel Jacobs Company LLC et al. 1999; ChemRisk 1993c).

Homes closest to the K-25 site are about three-quarters of a mile north of the site boundary and about 1.6 miles (about 2,600 meters [m]) north-northwest of both the process buildings and the contaminant release points (see Figure 7). Many of these homes were constructed as early as 1953 (USGS 1953). Although in subsequent analyses this area is referred to as the Sugar Grove community, it is known locally as the Blair Road community. Sugar Grove residents are nearest to the K-25 facility air emission sources. But Black Oak Ridge, which trends northeast-southwest and has elevations as high as 380 feet (ft) (115 m) above the adjacent valleys, separates the Sugar Grove residents from K-25. Other nearby communities include the Union/Lawnville community, approximately 2.8 miles (about 4,500 m) south-southwest of the K-25 site and 1.5 miles (about 2,300 m) south-southwest of the S-50 facility (ChemRisk 1999a), and the Happy Valley community, which housed workers and their dependents between approximately 1943 and 1947. Happy Valley was south of the K-25 gaseous diffusion plant and about 1 mile (approx. 1,600 m) east-southeast of the former S-50 plant (see Figure 7) (Prince 2003).

Current K-25 (ETTP) land use emphasizes reindustrialization. This includes the reuse of materials, equipment, buildings, and utilities formerly used for gaseous diffusion processes (USDOE 2003a). Of the 1,700-acre K-25 site, about 700 acres are within a secured fence (USEPA 1991). Only authorized personnel have access to the entire K-25 site (Radian Corporation 1993). The site includes former gaseous diffusion process buildings, testing facilities, maintenance operations, disposal areas, waste treatment plants, production areas, plating facilities, offices, laboratories, storage areas, change houses, and other buildings that aggregate over 17.5 million square feet (EUWG 1998). As stated, today two business centers operate at the K-25 site: the Horizon Center and the Heritage Center. The Horizon Center comprises about 1,000 acres of building sites. The Heritage Center encompasses 125 of the main facilities that were used for gaseous diffusion operations; the center leases these facilities to over 40 companies (USDOE 2003a).

Historically, commercial forestry and agriculture (e.g., beef and dairy cattle) were the primary land uses around the reservation, although in recent years both have declined. At one time, milk produced in the area was bottled for local distribution, but that appears no longer the case. Area crops include corn, tobacco, wheat, and soybeans (ChemRisk 1993c). The ORR area hosts seasonal waterfowl, small game, and deer hunting (ChemRisk 1993c), but all deer carcasses are subjected to radiological monitoring before they are released to hunters. Monitoring ensures that none of the animals contain quantities of radionuclides that could cause "significant internal exposure" to the consumer (Teasley 1995).

Figure 7. Residential Areas Closest to the K-25/S-50 Site



Note: The residential areas closest to K-25/S-50 emission sources (Sugar Grove, Union/Lawnville, and Happy Valley) represent areas of maximum potential exposure.

As shown in the various maps, the K-25 site is near the confluence of Poplar Creek and the Clinch River (USDOE 1979). Figure 3 shows the surface water features in the site vicinity. Poplar Creek begins in the Cumberland Mountains and enters the reservation from north of the K-25 site (Loar et al. 1981). Poplar Creek converges upstream with East Fork Poplar Creek (EFPC) at Poplar Creek Mile (PCM) 5.5 (Jacobs EM Team 1997b). Poplar Creek travels through the K-25 plant area before it enters the Clinch River at Clinch River Mile (CRM) 12.0—the Poplar Creek embayment (Jacobs EM Team 1997b; Loar et al. 1981).

The K-25 site comprises a chain of limited drainage basins. Small streams such as Poplar Creek cross through these basins and eventually flow into the Clinch River (USDOE 1979). Groundwater contamination at K-25 does not migrate off-site via the groundwater—it discharges into surface water. Because the local water table occurs just below the surface in the unconsolidated zone, groundwater flow is generally consistent with the surface topography. The groundwater predominantly discharges into surface water via seeps and springs. Most groundwater at the ORR ultimately flows into the Clinch River, serving as base flow for small streams and tributaries such as Mitchell Branch and Poplar Creek near the ETTP area. Surface water at the site also flows into Mitchell Branch, Poplar Creek, and the Clinch River. The Clinch River represents the most direct destination for K-25 discharges (Geraghty & Miller, Inc. 1989). Past gaseous diffusion operations have resulted in surface waters at the K-25 site receiving small quantities of uranium and fluoride compounds. K-25 surface water radiological monitoring establishes that levels are within the state of Tennessee's water quality standards; in most cases nonradiological constituents have also been below standard levels (USDOE 2003a). And for the communities near the K-25 site, on-site surface water (e.g., Poplar Creek, East Fork Poplar Creek, Bear Creek) is not a source of off-site drinking water (e.g., Sugar Grove, Union/Lawnville).

Because Poplar Creek (along with EFPC) drains the ORR northern and western boundaries, and because the Clinch River constitutes the ORR southern and eastern borders, all surface waters that leave the ORR travel through these water bodies and eventually reach the Lower Watts Bar Reservoir (LWBR) (Jacobs EM Team 1997b; SAIC 2002). Figure 3 shows the location of Poplar Creek, the Clinch River, and the Watts Bar Reservoir in relation to the ORR. Consequently, Poplar Creek, the Clinch River, and the Lower Watts Bar Reservoir have received several contaminants associated with ORR activities, including contaminants from White Oak Creek (Jacobs EM Team 1997b). For additional details on the relationship between White Oak Creek, the Clinch River, and the Watts Bar Reservoir, refer to ATSDR's *White Oak Creek Radionuclide Releases Public Health Assessment,* which evaluated radioactive contaminants released from the ORR to the Clinch River. This PHA is available at: http://www.atsdr.cdc.gov/HAC/oakridge/phact/white_oak/index.html.

The K-25 site has a water intake at CRM 14.4—the intake draws water from the Clinch River (ChemRisk 1999b). Figure 3 shows the K-25 water intake along the Clinch River, 2 miles upstream from the Poplar Creek confluence. Through community concerns, work group meetings held by ATSDR, and discussions with DOE, ATSDR learned that this water intake provided domestic water to the Happy Valley community (1943–1947). In the past and currently, the K-25 water intake provides potable water for the K-25 site (ChemRisk 1999b). U.S. EPA regulations mandate regular chemical, radiological, bacteriological, and chlorine sampling of

"finished water" from the treatment plant. After public concerns voiced at a July 31, 2000 meeting, DOE–Oak Ridge Operations (DOE–ORO) conducted a special sampling effort that included testing for metals, radionuclides, and chemicals in water directly from the tap. After collecting and analyzing more than 475 drinking water samples, DOE-ORO concluded that water at the K-25 site was "safe to drink." More information on this sampling effort is available at the DOE-ORO Reading Room at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee (DOE–ORO and CROET 2000). The drinking water quality report for this sampling effort is available at: http://www.state.tn.us/environment/doeo/pdf/PSBroch.pdf. ATSDR also evaluated past, current, and future potential exposures to drinking water via the K-25 water intake in the *White Oak Creek Radionuclide Release Public Health Assessment*. Copies of this assessment are available online at: http://www.atsdr.cdc.gov/HAC/oakridge/phact/white_oak/index.html or by calling ATSDR **toll-free at 1-800-232-4636**.

Also within the K-25 site, the Poplar Creek/Clinch River Operable Unit (OU) is a multiuse resource for drinking water, swimming, waterfowl hunting, shoreline recreation, and agriculture. The only unacceptable human health risk is fish caught and consumed from Poplar Creek and the Clinch River. Because of elevated mercury concentrations, all Poplar Creek fish, if eaten, pose a health risk (Jacobs EM Team 1997b). TDEC's fishing advisory warns the public not only against eating any fish from Poplar Creek but against even having any contact with the water (Jacobs EM Team 1997b; TDEC 2004). TDEC also advises the public to avoid consumption of striped bass from the Clinch River arm of the Watts Bar Reservoir, and, for children, pregnant women, and nursing mothers, not to consume catfish and sauger from this part of the Watts Bar Reservoir (TDEC 2004).

II.E. Demographics

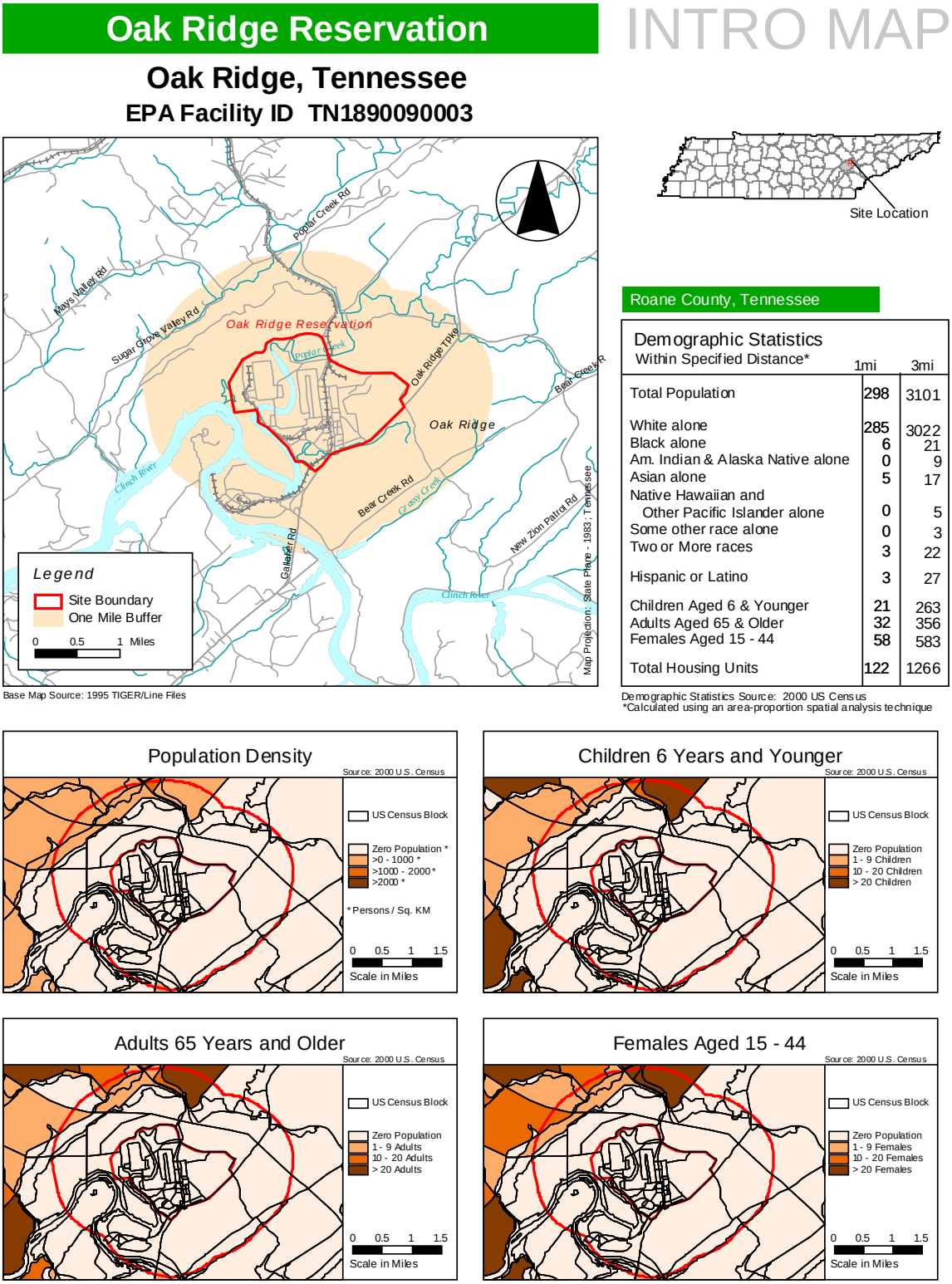
Again, in this health assessment ATSDR evaluates potential health effects from K-25 and S-50 fluoride and uranium releases for the three communities with the highest potential exposures: Happy Valley, Sugar Grove, and Union/Lawnville. ATSDR considered community concerns, public health assessment work group (PHAWG) meetings, discussions with DOE, previous TDOH assessments, and especially proximity to the K-25/S-50 facility. ATSDR then concluded that these communities would have been most affected by K-25/S-50 releases. Figure 8 shows recent population distributions for 1-mile and 3-mile radii around the K-25/S-50 site.

II.E.1. Happy Valley

At its 1945 peak, Happy Valley's population exceeded 8,700 residents: about 5,600 workers and over 3,100 dependents (Keith and Baker 1946; Prince 2003).

By the end of 1944, 5,600 workers lived at Happy Valley. Including families, by the mid-summer of 1945 residents peaked at over 8,700 (Keith and Baker 1946; Prince 2003). Happy Valley was a conglomeration of trailers, barracks, small family units, and hutments, as well as various facilities that included a movie theatre, a school, shops, and gasoline stations (J.A. Jones Construction Company, date unknown; Keith and Baker 1946). According to a recent review of the labor camp history, workers and families resided at Happy Valley between approximately 1943 and 1947, with destruction of the camp beginning in 1947. Anecdotal observations by an Oak Ridge community member suggest, however, that people lived in the labor camp as late as 1948. In any event, by the mid-1950s all of the Happy Valley structures had been destroyed (Jacobs EM Team 1997a).

Figure 8. 2000 Population Characteristics for the 1- and 3-Mile Areas around the K-25/S-50 Site



II.E.2. Sugar Grove

The Sugar Grove community (locally referred to as the Blair Road community) is about 1.6 miles north-northwest of the K-25 site process buildings. Many of the homes near the K-25 site were constructed as early as 1953 (USGS 1953). Although residents of the community are nearest to the air emission sources on the K-25 facility, Black Oak Ridge, which trends northeast-southwest and has elevations as much as 380 feet (ft) (115 m) above the adjacent valleys, separates the community from K-25.

Specific demographic information is not available for areas smaller than a census tract. Thus, the population estimate is derived from counting the buildings from photo-interpreted topographic maps and multiplying by the average number of people per household. These counts include all buildings such as garages, stores, and other nonresidential structures. This method will provide a conservative (i.e., overcounted) estimate of the total population. Using the 1980 aerial photo-based maps and 3.2 people per household, between 1953 and 1980 approximately 67 persons lived in the Sugar Grove community (see Figure 7). No specific census data were available for this community, but data were available for the total population of the Harriman District[4] in which Sugar Grove is located. Table 1 shows the demographic data for this district between 1940 and 2000, which includes Sugar Grove and other rural areas in this part of Roane County, minus the population for the city of Harriman area.

Table 1. Population of Rural Areas around the City of Harriman from 1940 to 2000

County	1940	1950	1960	1970	1980	1990	2000
Rural Areas in the Harriman District (including Sugar Grove, but minus the city population of Harriman)	4,729	4,532	9,533	5,388	7,760	7,253	3,659

Source: U.S. Census Bureau 1940a, 1950a, 1960a, 1970a, 1980a, 1990a, 2000a

Table 1 shows that Sugar Grove and other rural populations surrounding Harriman have fluctuated over time. The smallest population was recorded most recently in 2000, with 3,659 residents. The largest population was in 1960, when these rural areas reached 9,533 residents (U.S. Census Bureau 1940a, 1950a, 1960a, 1970a, 1980a, 1990a, 2000a).

II.E.3. Union/Lawnville

Union/Lawnville is about 2.8 miles to the south-southwest of the K-25 site and 1.5 miles south-southwest of the former S-50 plant (see Figure 7). The Union Church on Lawnville Road defines the community area; the church is just over one-half mile north of Gallaher Road. The Clinch River, almost a mile northeast of the Union Church, is the community's main surface water source. During Phase II of the Oak Ridge Health Studies, TDOH determined that the Union/Lawnville community was "the most representative of maximum and typical exposures" for K-25 site and former S-50 plant releases. Thus, ATSDR uses the Union/Lawnville community as a reference location (ChemRisk 1999a).

[4] See Figure 1 for the location of the city of Harriman.

Because, again, specific demographic information is not available for areas smaller than a census tract, ATSDR calculated the population estimate using the method described above for Sugar Grove. A review of the 1980 aerial photo-based maps and an assumption of 3.2 persons per household means that between 1953 and 1980, approximately 58 persons lived in the immediate Union/Lawnville community (see Figure 7).

Union and Lawnville are in Roane County, Tennessee. As specific demographic information was not available for these areas, 1940–2000 data paint a 10-mile area, demographic picture around the city of Kingston (Figure 1). That picture includes the communities of Union and Lawnville as well as other rural communities within that area. Table 2 shows the total population of the communities in the 10-mile area, including Union and Lawnville.

Table 2. Population within 10 Miles of Kingston from 1940 to 2000

County	1940	1950	1960	1970	1980	1990	2000
Kingston and Surrounding Communities (including Union and Lawnville)	3,635	4,864	8,005	7,802	10,115	10,366	12,340

Source: U.S. Census Bureau 1940b, 1950b, 1960b, 1970b, 1980b, 1990b, 2000b

Table 2 shows that since 1940, Kingston and its surrounding communities have continued to grow from 3,635 to 12,340 residents. 1940 recorded the smallest population—3,635 residents. 2000 recorded the largest population, when the areas within 10 miles of Kingston reached a population of 12,340 residents. Between this 60-year timeframe, the population of communities around Kingston more than tripled in size (U.S. Census Bureau 1940b, 1950b, 1960b, 1970b, 1980b, 1990b, and 2000b).

II.F. Summary of Public Health Activities Pertaining to Uranium and Fluoride Releases from the K-25 Site and Former S-50 Plant

This section describes the public health activities that pertain to uranium and fluoride releases from the K-25 site and former S-50 plant (now part of the K-25 site). ATSDR, TDOH, and other agencies have conducted additional public health activities at the ORR, described in Appendix B. See Figure 4 for a timeline of public health activities related to the K-25 site from 1942 to the present.

II.F.1. ATSDR's ORR Activities

Since 1992, ATSDR has made a determined effort to establish whether levels of environmental contamination at and near the ORR present a public health hazard. ATSDR has identified and evaluated several public health issues and to address those issues has worked closely with many parties, including community members, physicians, and several federal, state, and local health and environmental agencies. While TDOH conducted the Oak Ridge Health Studies to evaluate whether off-site populations experienced exposures in the *past*, to avoid duplication of the state's efforts ATSDR's activities have focused on *current* public health issues. The following sections highlight major ATSDR public health activities that pertain to the Watts Bar Reservoir and K-25 uranium releases.

II.F.1.1. Health Consultation on the Lower Watts Bar Reservoir, February 1996.

In March 1995, DOE released a proposed plan to address the chemical and radiological contaminants in the Watts Bar Reservoir. Local residents were concerned about the contamination in the reservoir and expressed concern about the adequacy of DOE's proposed remedial actions and controls. The residents requested that ATSDR assess the health hazards associated with contaminants in the Lower Watts Bar Reservoir.

ATSDR uses a comparison value (CV) as a screening level during the public health assessment process. Substances found in amounts greater than their CVs are further evaluated. If a contaminant exceeds its comparison value, it does not necessarily mean that the contaminant will cause adverse health effects. Comparison values are used to help ATSDR determine which contaminants need to be evaluated more closely.

To evaluate present and recent-past exposures, ATSDR reviewed environmental sampling data from the 1980s and 1990s from DOE, TVA, and various consultants. In addition, ATSDR examined TVA's 1993 and 1994 Annual Radiological Environmental Reports for the Watts Bar nuclear plant. ATSDR initially screened the data to determine the presence of any contaminants at levels exceeding health-based comparison values. Then, to determine whether current chemical and radiological contaminant levels could potentially affect area residents, ATSDR used both worst-case and realistic exposure scenarios to estimate the doses for any contaminants above comparison values.

This methodology revealed that polychlorinated biphenyls (PCBs) in the Lower Watts Bar Reservoir were a public health concern. Frequent and long-term consumption of reservoir fish could moderately increase a person's risk of cancer, and reservoir turtles could also contain PCBs at health-concern levels. Nursing or pregnant mothers who regularly consumed these fish might increase their risk of delivering a developmentally affected child (ATSDR et al. 2000).

On the other hand, ATSDR found that other contaminant levels currently in reservoir sediment and surface water were not of public health concern. The reservoir was declared safe for recreational activities such as skiing, swimming, and boating, and the municipal water was found safe to drink. ATSDR also concluded that DOE's chosen remedial actions were protective of public health. These actions included ongoing environmental monitoring, continuing fish-consumption advisories, offering community and physician education concerning PCB contamination, and applying institutional controls to prevent resuspension, removal, disruption, or disposal of contaminated sediment (ATSDR et al. 2000).

After reviewing these findings, ATSDR made the following recommendations:

- To minimize exposure to PCBs, continue the Lower Watts Bar Reservoir fish advisory.
- ATSDR and the State of Tennessee should implement a community health education program regarding the Lower Watts Bar fish advisory and regarding the health effects of PCB exposure.

- Evaluate the likelihood of health effects from consumption of turtles in the Lower Watts Bar Reservoir. The evaluation should investigate turtle consumption patterns and PCB levels in edible portions of turtles.

- Do not disturb, remove, or dispose of surface and subsurface sediments without prior careful review from the interagency working group (see Section II.C.3. for a discussion of this group).

- Continue sampling of municipal drinking water at regular intervals. If a significant release of contaminants from the ORR is discharged into the Clinch River at any time, DOE should notify the municipal water systems and monitor surface water intakes.

II.F.1.2. Coordination with Other Parties.

From 1992 to the present ATSDR has consulted regularly with representatives of other, ORR-concerned parties. Specifically, ATSDR has coordinated with TDOH, TDEC, the National Center for Environmental Health (NCEH), the National Institute for Occupational Safety and Health (NIOSH), and DOE. In 1999, these coordinated efforts led to the establishment of the Public Health Working Group, which in turn led to the formation of the Oak Ridge Reservation Health Effects Subcommittee (ORRHES). ATSDR has provided some assistance to TDOH in its study of past public health issues (ATSDR et al. 2000) and has obtained and interpreted ORR-related studies prepared by academic institutions, consulting firms, community groups, and others.

II.F.1.3. Oak Ridge Reservation Health Effects Subcommittee.

ATSDR and the Centers for Disease Control and Prevention (CDC), under the authority of the Federal Advisory Committee Act (FACA), established ORRHES in 1999 as a subcommittee of the U.S. Department of Health and Human Services' Citizens Advisory Committee on Public Health Service Activities and Research at DOE sites. The subcommittee consisted of persons representing diverse interests, expertise, backgrounds, and communities, as well as liaison from federal and state agencies. It was a forum for communication and collaboration between citizens and agencies to evaluate public health issues and to conduct public health activities at the ORR. To help ensure citizen participation, the meetings of the subcommittee's work groups were open to the public—everyone was invited to attend and present his or her ideas and opinions. The subcommittee

- Served as a citizen advisory group to CDC and ATSDR and made recommendations on matters related to public health activities and research at the ORR.

- Allowed citizens to collaborate with agency staff members and to learn more about the public health assessment process and other public health activities.

- Helped to articulate and prioritize the public health issues and community concerns evaluated by ATSDR.

The ORRHES created various work groups to conduct in-depth exploration of specific issues and to present findings to the subcommittee for deliberation. Work group meetings were open to all

who wished to attend, and those who did attend were invited to participate. Figure 9 shows the organizational structure of the ORRHES. For more information on the ORRHES, visit the ORRHES Web site at www.atsdr.cdc.gov/HAC/oakridge/index.html (ATSDR et al. 2000).

II.F.1.4. ATSDR Field Office

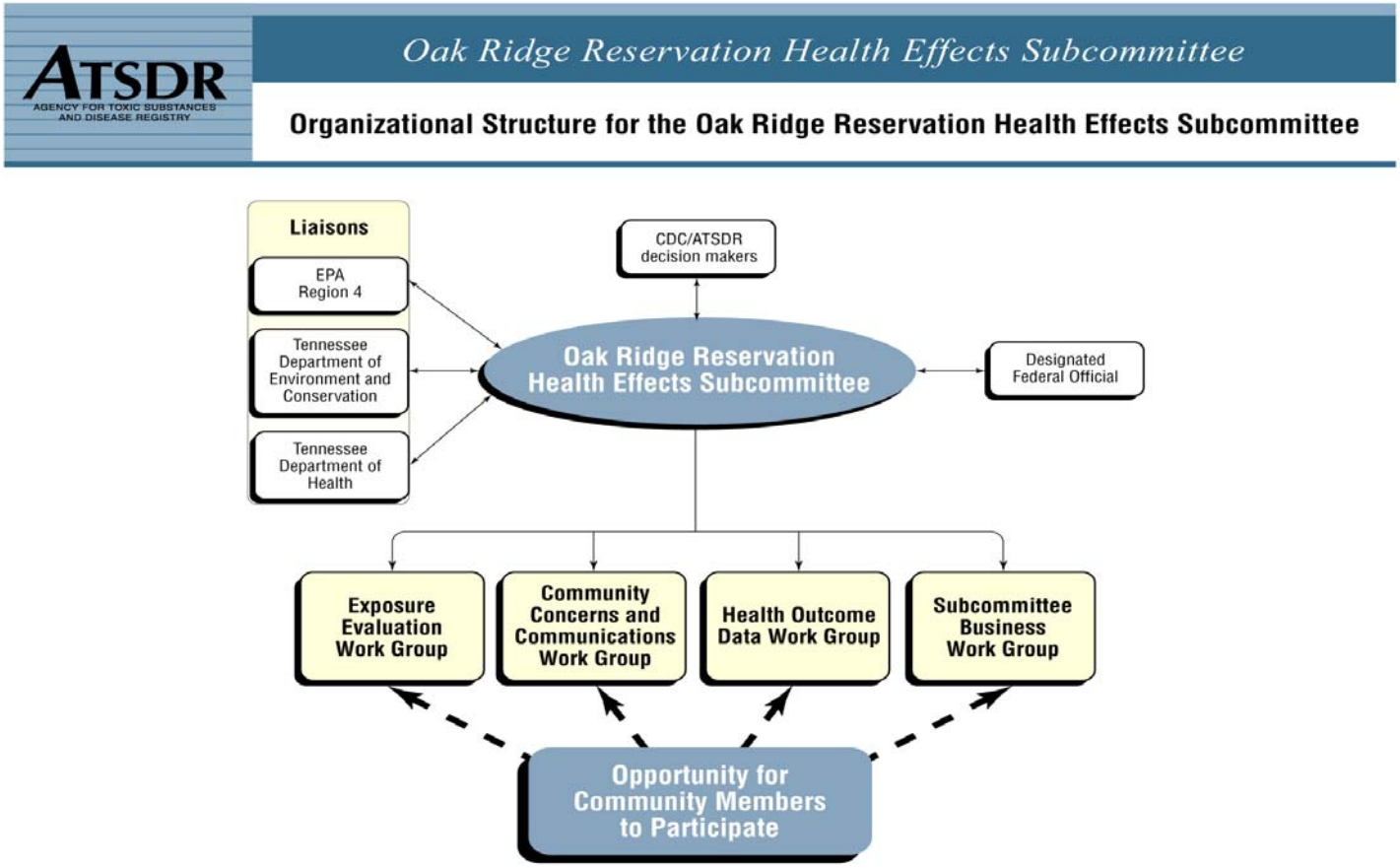
From 2001 to 2005, ATSDR maintained a field office in the city of Oak Ridge. The office promoted collaboration between ATSDR and the communities surrounding the ORR by providing community members with opportunities to become involved in ATSDR's ORR public health activities (ATSDR et al. 2000).

How to obtain more information on ATSDR's activities at Oak Ridge

ATSDR has conducted several additional analyses that are not documented here or in Appendix C, as have other agencies that have been involved with this site. Community members can find more information on ATSDR's past activities by

- *Visiting one of the records repositories.* Copies of ATSDR's publications on the ORR, along with publications from other agencies, can be viewed in records repositories at public libraries and the DOE Information Center in Oak Ridge. For directions to these repositories, please contact ATSDR at 1-800-CDC-INFO (or 1-800-232-4636).
- *Visiting the ATSDR or ORRHES Web sites.* These Web sites include our past publications, schedules of future events, and other information materials. ATSDR's Web site is at www.atsdr.cdc.gov and the ORRHES Web site is at www.atsdr.cdc.gov/HAC/oakridge. The most comprehensive summary of past activities can be found at http://www.atsdr.cdc.gov/HAC/oakridge/phact/index.html.
- *Contacting ATSDR directly.* Residents can contact representatives from ATSDR directly by dialing the agency's toll-free number, 1-800-CDC-INFO (or 1-800-232-4636), and requesting to speak with the ATSDR representative for the DOE Oak Ridge Reservation.

Figure 9. Organizational Structure for the Oak Ridge Reservation Health Effects Subcommittee



II.F.2. TDOH

II.F.2.1. Oak Ridge Health Studies.

The 1991 Tennessee Oversight Agreement between DOE and the State of Tennessee allowed TDOH to undertake the Oak Ridge Health Study—a two-phase, independent state research project to determine whether past environmental releases from ORR operations harmed nearby residents (ORHASP 1999).

II.F.2.1.1. Phase I

Phase I of the Oak Ridge Health Study was a Dose Reconstruction Feasibility Study; an evaluation of all known past ORR hazardous substances releases and operations. The study was to determine the quantity, quality, and potential usefulness of the available information and data on past releases and subsequent exposure pathways. Phase I began in May 1992 and was completed in September 1993 (ATSDR et al. 2000). Appendix H contains a brief summary of the Phase I Feasibility Study.

The feasibility study findings established that a significant amount of information was available to reconstruct past releases and potential off-site doses for four hazardous substances with the highest potential risk for adverse health effects. These four substances were

- Radioactive iodine releases associated with radioactive lanthanum processing at X-10 from 1944 through 1956;
- Mercury releases associated with lithium separation and enrichment operations at the Y-12 plant from 1955 through 1963;
- PCBs in fish from EFPC, the Clinch River, and the Watts Bar Reservoir; and
- Radionuclides from White Oak Creek associated with various chemical separation activities at X-10 from 1943 through the 1960s (ATSDR et al. 2000).

II.F.2.1.2. Phase II —also referred to as the Oak Ridge Dose Reconstruction

The health study's Phase II occurred at Oak Ridge from mid-1994 to early 1999. It was primarily a dose reconstruction study focusing on past releases of radioactive iodine, radionuclides from White Oak Creek, mercury, and PCBs. In addition to the full-dose reconstruction analyses, Phase II included additional detailed screening analyses for releases of uranium and several other toxic substances not fully characterized in Phase I. The following paragraphs describe the significant Dose Reconstruction findings. The final Oak Ridge Dose Reconstruction Phase II reports are available at http://health.state.tn.us/CEDS/OakRidge/ORidge.html.

X-10 radioactive lanthanum processing from 1944 through 1956 was apparently the source of the ORR-related radioactive iodine releases. Dose Reconstruction results indicate that area children born in the early 1950s who drank milk produced by cows or goats living in the family yard had a theoretical, increased thyroid cancer risk over background. The calculated risk of developing thyroid cancer for children living within a 25-mile radius of Oak Ridge was greater than 1 chance in 10,000. This is the Oak Ridge Health Agreement Steering Panel's (ORHASP's)

Decision Guide for cancer risk due to radiation or chemical exposure and the U.S. EPA's upper risk limit for some regulatory decisions.

The Dose Reconstruction also evaluated mercury releases associated with lithium separation and enrichment operations at the Y-12 plant from 1955 through 1963. Results indicate that depending on activities, persons living in the area during the years mercury releases were highest (i.e., mid-1950s to early 1960s) may have received annual average doses of mercury exceeding the U.S. EPA reference dose.

U.S. EPA's *reference dose* is an estimate of the largest amount of a substance that a person can take in on a daily basis over his or her lifetime without experiencing adverse health effects.

PCBs in fish from EFPC, the Clinch River, and the Watts Bar Reservoir was also a Dose Reconstruction subject. Preliminary results indicated that persons who consumed a large amount of fish from these waters might have received PCB doses exceeding the U.S. EPA reference dose.

From 1943 through the 1960s, radionuclides associated with various chemical separation activities at the X-10 site were released into White Oak Creek. Eight radionuclides deemed more likely to carry significant risks were studied: cesium 137, ruthenium 106, strontium 90, cobalt 60, cerium 144, zirconium 95, niobium 95, and iodine 131. Dose Reconstruction results showed that for persons who consumed fish from the Clinch River near the mouth of White Oak Creek, the releases resulted in small, over-background radiation dose increases. Dose reconstructionists estimated that a human male who ate up to 130 meals of fish from the mouth of White Oak Creek every year for 50 years (worst-case scenario) would face an excess cancer risk ranging from 4 to 350 in 100,000. For people who ate fewer fish and for people who ate fish caught farther downstream, the risk was significantly reduced.

Various large-scale operations released uranium—primarily uranium processing and machining operations at the Y-12 plant and K-25/S-50 uranium enrichment operations. Because uranium was not initially a high priority contaminant of concern, only a Level II screening assessment for all uranium releases was ever performed. Preliminary screening indices were slightly below the decision guide of one chance in 10,000, which indicated that more work may be needed to characterize better the uranium releases and any possible health risk. Appendix H provides a brief summary of the Task 6 report.

The *Screening-Level Evaluation of Additional Potential Materials of Concern* was conducted to determine whether contaminants other than those identified in the *Oak Ridge Dose Reconstruction Feasibility Study* warranted further assessment of their potential for health effects in off-site populations. Three methods—a qualitative screening, a quantitative screening, and a threshold quantity approach—were used to evaluate the potential for 25 materials or groups of materials to cause off-site health effects. Using the screening results, five materials employed at the K-25 plant and 14 materials at the Y-12 plant warranted no further study. Three materials used at the K-25 plant (copper powder, nickel, and technetium 99), three materials used at the Y-12 plant (beryllium compounds, lithium compounds, and technetium 99), and one material used at the ORR (chromium VI) were determined to be potential candidates for further study. High priority candidates for further study included one material used at the K-25 plant (arsenic) and

two materials used at the Y-12 plant (arsenic and lead). A brief summary of the Task 7 report is provided in Appendix H.

II.F.3. Tennessee Department of Environment and Conservation (TDEC)

II.F.3.1. Sampling of Public Drinking Water Systems in Tennessee.

In the 30-plus years since the passage of the Safe Drinking Water Act of 1974, the U.S. EPA has set health-based standards and has specified treatments for public drinking water systems. In 1977, U.S. EPA gave the state of Tennessee authority to operate its own Public Water System Supervision Program under the Tennessee Safe Drinking Water Act. TDEC's Division of Water Supply now regulates drinking water at all public water systems. All public water systems in Tennessee now individually monitor their water supply for U.S. EPA-regulated contaminants and report their monitoring results to TDEC (TDEC 2003a). The public water supplies in Tennessee are monitored for substances that include 15 inorganic contaminants, 51 synthetic and volatile organic contaminants, and 4 radionuclides. U.S. EPA's monitoring schedules for each contaminant are available at http://www.epa.gov/safewater/pws/pdfs/qrg_smonitoringframework.pdf (USEPA 2004a). TDEC submits individual water supply data quarterly to U.S. EPA's Safe Drinking Water Information System (SDWIS) (TDEC 2003a).

In 1996 TDEC's DOE Oversight Division began participation in U.S. EPA's Environmental Radiation Ambient Monitoring System (ERAMS) drinking water program. As part of the Oak Ridge ERAMS program, TDEC collects samples from five facilities from within ORR and from the ORR vicinity. These public water suppliers include the Kingston Water Treatment Plant (Tennessee River Mile [TRM] 568.4), DOE Water Treatment Plant at K-25 (Clinch River Mile [CRM] 14.5), West Knox Utility (CRM 36.6), DOE Water Treatment Plant at Y-12 (CRM 41.6), and Anderson County Utility District (CRM 52.5) (TDEC 2003b). Under the Oak Ridge ERAMS program, TDEC collects quarterly the finished drinking water samples from these five public water supplies and submits the samples to U.S. EPA for radiological analyses. The schedule and contaminants sampled at the supplies are available at http://www.state.tn.us/environment/doeo/pdf/EMP2006.pdf. More information related to drinking water supplies or additional water supplies in the area is available by calling U.S. EPA's Safe Drinking Water Hotline at 1-800-426-4791 or visiting U.S. EPA's Safe Drinking Water Web site at http://www.epa.gov/safewater.

U.S. EPA's ERAMS Program was established to provide radiological monitoring for public water supplies located near U.S. nuclear facilities.

II.F.3.2. Off-Site Residential Well Sampling.

Since 1993, TDEC (DOE Oversight Division) has conducted off-site residential well monitoring for wells outside the ORR. In 1996 and 1997, TDEC conducted a house-to-house survey to identify off-site residential wells located near the K-25, X-10, and Y-12 facilities. TDEC monitors the residential wells to determine whether ORR operations have contaminated off-site groundwater sources. During the survey 60 residential wells were identified. Investigators did not find any contaminants in the wells that could have originated from DOE activities on the Oak Ridge Reservation (ATSDR et al. 2000).

II.F.3.3. K1070-A Dye-Trace Sampling.

In 1995, TDEC initiated a dye-trace sampling study at the K1070-A waste burial ground on the K-25 site (ATSDR et al. 2000). This was part of a cooperative effort with DOE and its contractors, who were themselves conducting a DOE-initiated dye trace study. The TDEC study, conducted between 1995 and January 1996, was to identify groundwater exit pathways along the Clinch River and across the western ORR boundaries at the K1070-A burial ground. State laboratories analyzed TDEC-collected data and samples. That sampling detected the same volatile organic compounds (VOCs) at spring 21-002 that were found in the K1070-A burial ground. Fluorescent dye was placed into wells at the burial ground, and the dye later appeared in spring 21-002. The dye was also found off site in a spring on the Clinch River (ATSDR et al. 2000).

TDEC uses dye trace studies at the reservation to link contaminants in off-site springs with contaminants at the ORR (Benfield 2002).

II.F.4. DOE

II.F.4.1. Watts Bar Interagency Agreement, February 1991.

DOE, EPA, TVA, TDEC, and USACE comprise the Watts Bar Reservoir Interagency Working Group (WBRIWG). The group works collaboratively through the Watts Bar Interagency Agreement, which established guidelines related to any dredging in Watts Bar Reservoir. These agencies now review permitting and all other activities that could possibly disturb Watts Bar Reservoir sediment, such as erecting a pier or building a dock (ATSDR 1996; Jacobs EM Team 1997b; USDOE 2003c). The agreement also establishes guidelines for reviewing potential sediment-disturbing activities in the Clinch River below Melton Hill Dam, including Poplar Creek (Jacobs EM Team 1997b). Under the interagency agreement DOE must take action if an institutional control is ineffective or if a sediment-disturbing activity could cause harm (USDOE 2003c).

Permit coordination under the Watts Bar Interagency Agreement was established to allow TVA, USACE, and TDEC—the agencies with permit authority over actions taken in Watts Bar Reservoir—to discuss proposed sediment-disturbing activities with DOE and U.S. EPA before beginning the normal permit review process. This affords an opportunity to determine the presence of any ORR-related contaminants in the sediments. The coordination follows a series of defined processes as outlined in the agreement.

The basic permitting process is the same for any organization or individual (Jacobs EM Team 1997b). If dredging is necessary in an area with contaminated sediments, DOE will assume financial and waste management responsibility over and above normally incurred costs (Jacobs EM Team 1997b). For more details, please see the Clinch River/Poplar Creek OU ROD at http://www.epa.gov/superfund/sites/rods/fulltext/r0497075.pdf and page 3-5 of the Lower Watts Bar Reservoir ROD at http://www.epa.gov/superfund/sites/rods/fulltext/r0495249.pdf (Jacobs EM Team 1997b; USDOE 1995b).

II.F.4.2. Independent Medical Evaluation of K-25 Workers

In the fall of 1995, K-25 workers and persons living near K-25 reported several illnesses. The workers and others believed the illnesses resulted from exposure to K-25-related contaminants. Lockheed Martin Energy Systems, Inc., an employer of the workers under a DOE contract, requested medical evaluations of whether workplace factors contributed to these reported illnesses. Three physicians—Richard Bird from the JSI Center for Environmental Health Studies and the Beth Israel Deaconess Medical Center at the Bowdoin Street Health Center in Boston, Massachusetts, and James Lockey and Andrew Freeman from the University of Cincinnati College of Medicine in Cincinnati, Ohio—conducted medical evaluations of 53 past and current workers at the ORR's K-25 facility. The evaluations, which included self-selected participants, started in the fall of 1996 and continued over a 4-year period. The physicians reviewed historical and current medical records and visited workplaces. The workers underwent physical examinations, diagnostic testing, interviews to evaluate work history, and evaluations by medical specialists (ATSDR et al. 2000; Parson 2000).

The findings indicated that "several workers in the study group have one or more conditions that … have been exacerbated, aggravated, or directly caused by historical exposures in the K-25 work environment." The investigators stated, however, that some conditions were common to other industrial settings, such as acute and chronic bronchitis and occupational asthma. Still, certain symptoms were more specific to work at the K-25 site, including possible beryllium sensitization (two workers), definite peripheral beryllium sensitization (five workers), chronic beryllium disease (one worker), peripheral neuropathies, toxic encephalopathy, and autonomic neuropathy with postural hypotension and cardiac arrhythmia. Also, some workers had neuropsychological changes consistent with significant depression and anxiety, toxic encephalopathy due to solvent and heavy metal exposures, and cerebrovascular problems. Yet in some instances the physicians could not assess whether the changes were caused by exposures in the workplace or from nonwork-related physical conditions (ATSDR et al. 2000; Parson 2000).

The physicians reported they had identified "several unique aspects and complicating factors" associated with workers' exposures to hazardous materials at the K-25 site. For instance, work was exchanged between the K-25 facility and the Y-12 plant, where beryllium was widely used. K-25 workers with longer periods of occupational exposures had higher serum PCB levels than did workers without prolonged exposures. The study nonetheless determined that the detected levels would not definitely cause adverse health effects (ATSDR et al. 2000; Parson 2000).

The study findings were released on July 31, 2000, in the "Summary Report of Findings of K-25 Worker Evaluations." They were presented at a public meeting on the same day. Each of the 53 workers was provided with an individual, final medical report. The reports included physician-prepared summaries that detailed the most likely workplace-related medical conditions. The reports also identified the conditions that could not be related to workplace factors "within a reasonable degree of medical probability and certainty." For workers who were believed to have a medical condition directly related to exposures at the workplace or a condition that was considerably aggravated by exposures in the workplace, the physicians prepared a separate "Work Related Abnormalities as Determined to Date." Following this study's August 1, 2000 release, DOE stated that it would work with DOE–Oak Ridge Operations and its contractors to assist those identified with work-related illnesses to enter claims for Tennessee workers

compensation benefits. In addition, DOE stated that it would examine the study's results and by August 31, 2000 would recommend follow-up actions to DOE's Office of Health, Safety and Security (ATSDR et al. 2000).

II.F.4.3. Aerial Radiological Surveys and ORR Off-Site Background.

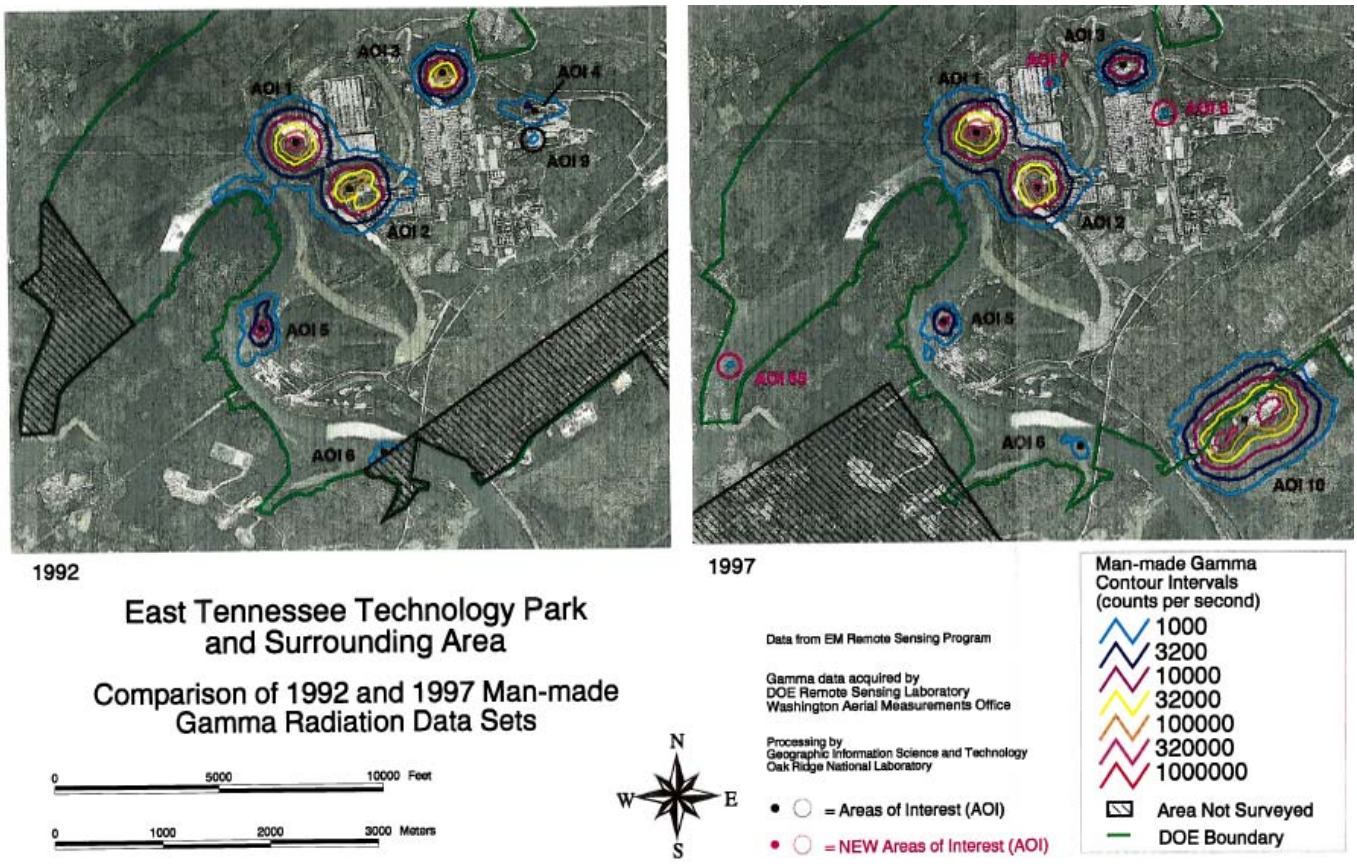
From 1959 through 1997, DOE and its predecessors performed aerial radiological surveys on the ORR site and its surrounding areas. This was part of a project to assist in characterizing and defining contamination resulting from past ORR operations (Carden and Joseph 1998; USDOE 1997). Helicopters equipped with highly sensitive monitoring equipment capable of detecting the presence of anthropogenic and natural radioactivity aerially surveyed the entire area (USDOE 1997). Aircraft-mounted instruments calibrated during flight against a known radiation source surveyed the intended target area at a constant airspeed and altitude. Aerial surveys are sufficiently sensitive to detect radiation sources that might or might not constitute a hazard. Any detected radiation sources are then investigated on the ground using standard survey techniques.

The most recent aerial radiological surveys were from June 10 through June 27, 1997. They included flyovers of the Oak Ridge Reservation and areas approximately 1 mile beyond the reservation's boundary. These off-site areas included residential and industrial areas in Anderson, Knox, and Roane Counties. The data collected during the surveys were entered into a DOE-maintained database of ORR radiological data (USDOE 1997). The aerial surveys included 11 areas of interest (AOI) associated with the K-25 site, shown in Figure 10. Six of the 11 AOIs (1, 2, 3, 5, 6, and 10) were also identified in a previous 1992 survey. AOI 1 is primarily within ETTP, with the main portion of the anomaly showing no noticeable change from 1992 to 1997. AOI 2 exhibited a slight increase in gamma emissions, AOI 5 showed a slight reduction in the extent of gamma emissions, and, compared with the 1992 survey, AOI 3 showed a significant reduction in both spatial extent and relative gamma emissions. Three additional AOIs (7, 8, and 65) were newly identified in 1997; whereas two AOIs (4 and 9) were identified before 1997, but in 1997 notable gamma radiation activity was not observed in these two AOIs (Lockheed Martin Energy Research Corporation 1998). Section III of this PHA, "Evaluation of Environmental Contamination and Potential Exposure Pathways," contains more information on aerial radiological surveys.

II.F.4.4. ORR Annual Monitoring.

Since ORR's establishment, DOE, its precursor agencies, or its contractors have been collecting various environmental measurements. These include ambient radiation activities in soil, water, and air (see Figure 4). Since at least 1959, records of these monitoring programs have been published as quarterly, semi-annual, or annual reports. From 1959 to 1970, these reports were titled *Environmental Levels of Radioactivity for the Oak Ridge Area* and were compiled and published by the Health Physics Division of the Oak Ridge National Laboratory (Abee 1960a–c, 1961; ORNL, date unknown 1-20). Beginning in 1971, the scope was expanded to include nonradiological monitoring data; the reports were then titled *Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities* (Union Carbide Corporation Nuclear Division 1972-1983; Martin Marietta Energy Systems 1984–1995). After 1995, DOE began including data from the environmental monitoring reports in the Oak Ridge Environmental Information System (OREIS, described below).

Figure 10. Areas of Interest at the K-25 Site Included in Aerial Surveys



Source: Lockheed Martin Energy Research Corporation 1998

II.F.4.5. Oak Ridge Environmental Information System (OREIS).

An abundance of ORR-related environmental data is available. DOE created an electronic data management system to integrate all of the data into a single database. This assists public and governmental access to operations-related ORR environmental data and maintains data quality. DOE wanted to ensure that the database had long-term retention of environmental data and had user-friendly data access. The OREIS database contains data related to compliance, environmental restoration, and surveillance activities. OREIS collects information from all key surveillance activities and environmental monitoring efforts. This information includes but is not limited to studies of the Clinch River embayment and the Lower Watts Bar, as well as annual site summary reports. As new studies are completed, those environmental data are entered into the database as well (ATSDR et al. 2000).

II.F.4.6. Comprehensive Epidemiologic Data Resource (CEDR).

CEDR is a public-use database. Its data are pertinent to health-related studies performed at the Oak Ridge Reservation and at other DOE sites. This easily accessible, easy-to-use repository of data—without personal identifiers—has been collected from occupational and environmental health studies of workers at DOE facilities and from nearby community residents. It organizes the electronic files of data and documentation collected during these studies and makes them accessible on the Internet at https://www.orau.gov/cedr/. Most of CEDR's large data collection pertains to about 50 epidemiologic studies of workers at various DOE sites. Of particular interest to Tennessee residents is an additional feature of CEDR that provides searchable text for about 1,800 original government documents (now declassified) used by TDOH for the Oak Ridge Dose Reconstruction. Also available through CEDR at https://www.orau.gov/cedr/ are all of the technical and summary reports produced by this study.

For the first time, this complex information is concise, uncluttered, comprehensible, and accessible. CEDR now provides slideshow-format images that estimate concentrations, doses, and risk values for three contaminants (iodine, mercury, and uranium) in air at locations studied in TDOH's Dose Reconstruction, compliance, environmental restoration, and surveillance activities. Information from all key surveillance activities and environmental monitoring efforts is entered into OREIS. This includes but is not limited to studies of the Clinch River embayment and the Lower Watts Bar, as well as annual site summary reports. As new studies are completed, those environmental data are entered as well (ATSDR et al. 2000).

III. Evaluation of Uranium and Fluoride Releases, Exposure Pathways, and Environmental Contamination

III.A. Introduction

In 2001, ATSDR reviewed and analyzed TDOH's Oak Ridge Health Studies Phase I and Phase II screening evaluation. ATSDR's purpose was to identify contaminants that might require further evaluation. TDOH had extensively reviewed available information and had conducted qualitative and quantitative analyses of past (1944–1990) releases from the entire ORR as well as off-site exposures to hazardous substances. After its review and analysis of the TDOH data, ATSDR determined that past releases of uranium, mercury, iodine 131, fluorides, radionuclides from White Oak Creek, and PCBs required further evaluation.

Again, for ATSDR, the vehicle to evaluate these contaminants further is the public health assessment (PHA). ATSDR has released, or is conducting ORR-related PHAs on

- Y-12 mercury releases,
- X-10 iodine 131 releases,
- White Oak Creek radionuclide releases, and
- PCB releases from X-10, Y-12, and K-25.

ATSDR previously prepared ORR PHAs on uranium releases from Y-12 and contaminant releases from the Toxic Substances Control Act (TSCA) Incinerator, and addressed current public health issues related to the East Fork Poplar Creek and the Lower Watts Bar Reservoir (LWBR). ORR PHAs have been conducted on other issues of concern, such as contaminated off-site groundwater and a screening of current (1990–2003) environmental data to identify any other chemicals that require further evaluation.

In this "K-25/S-50 uranium and fluoride releases" PHA, ATSDR evaluated the data and findings of previous studies and investigations to

- Identify sources of uranium and fluoride releases,
- Assess the amounts of uranium and fluoride released,
- Evaluate past and current off-site exposure pathways,
- Estimate radiological doses and uranium and fluoride concentrations, and
- Determine the health implications of past, current, and future uranium and fluoride exposures for residents near the ORR, specifically the communities of Sugar Grove, Union/Lawnville, and Happy Valley.

This PHA section discusses

- Sources, emissions, and concentrations of uranium, fluoride, and radioactive materials released from the K-25/S-50 site;
- Means by which residents near the site might come into contact with these contaminants;
- Evaluation of potential doses and concentrations associated with potential exposures to these contaminants; and
- Criteria for identifying and evaluating exposures for potentially affected populations.

Worth repeating is that this PHA primarily evaluates the *short-term (acute)* and *long-term (chronic)* airborne releases of uranium hexafluoride and other associated radiological materials from many of ORR's K-25 and S-50 buildings—the facilities involved in past gaseous diffusion operations. The PHA's goal is to estimate off-site concentrations and doses for people living in the communities of Sugar Grove, Union/Lawnville, and Happy Valley. Airborne uranium hexafluoride and other radiological materials are the primary contaminants of concern that require further evaluation; previous studies indicate that past releases of these contaminants may have resulted in off-site exposures at levels of health concern.

This PHA includes an evaluation of on-site soil samples collected on or adjacent to the K-25/S-50 site. Many of the soil samples were collected within the ORR boundary, between the K-25/S-50 site and any off-site populations. The contaminant releases to groundwater at the ORR—including the K-25 site—as well as off-site radionuclide releases to surface waters, are evaluated in separate PHAs. For copies of these assessments, please contact ATSDR **toll-free at 1-800-232-4636.**

For the purposes of this document, the terms "on-site releases" and "on-site contamination" describe releases of hazardous substances and the resulting contamination of material within ORR's fenced security area (i.e., areas to which public access is restricted) controlled by DOE. This PHA considers on-site releases and contamination primarily in terms of sources for off-site contamination. This PHA also considers on-site releases as means by which to evaluate their potential effect on nearby, off-site communities. "Off-site contamination" describes environmental media (e.g., soil, sediment, surface water, groundwater, air, or food chain entities) contaminated as a result of nonradioactive or radioactive contaminants that have traveled off site from the ORR. Specifically, this PHA focuses on human exposure to off-site air contaminants in areas surrounding the Oak Ridge Reservation. For ATSDR's public health assessments that evaluate potential human exposure to ORR-related contaminants in other off-site media, go to http://www.atsdr.cdc.gov/HAC/oakridge/phact/index.html. Also important to note is that this PHA does not evaluate the impact of potential exposures for DOE workers to on-site contaminants—this is outside ATSDR's legislative mandate and is the responsibility of other organizations such as the National Institute for Occupational Safety and Health (NIOSH) (see the agency's Occupational Energy Research Program Web site for more information at http://www.cdc.gov/niosh/oerp/).

III.B. Exposure Evaluation Process

Hazardous substances (e.g., chemicals or radioactive materials) released into the environment do not always result in human exposure. People are only exposed to a chemical contaminant if they come into contact with it. If no one comes into contact with a contaminant, no exposure occurs, and thus no health effects occur. Often the public does not have access to the source area of contamination or to areas where contaminants move through the environment. Such lack of access becomes important in determining whether people could come into contact with the contaminants or with radiological emissions from the contaminants.

The *exposure pathway* is a contaminant's route from the release source to the people exposed in off-site areas. For an exposure to occur, an exposure pathway must be completed. A *completed exposure pathway* must include the following five elements:

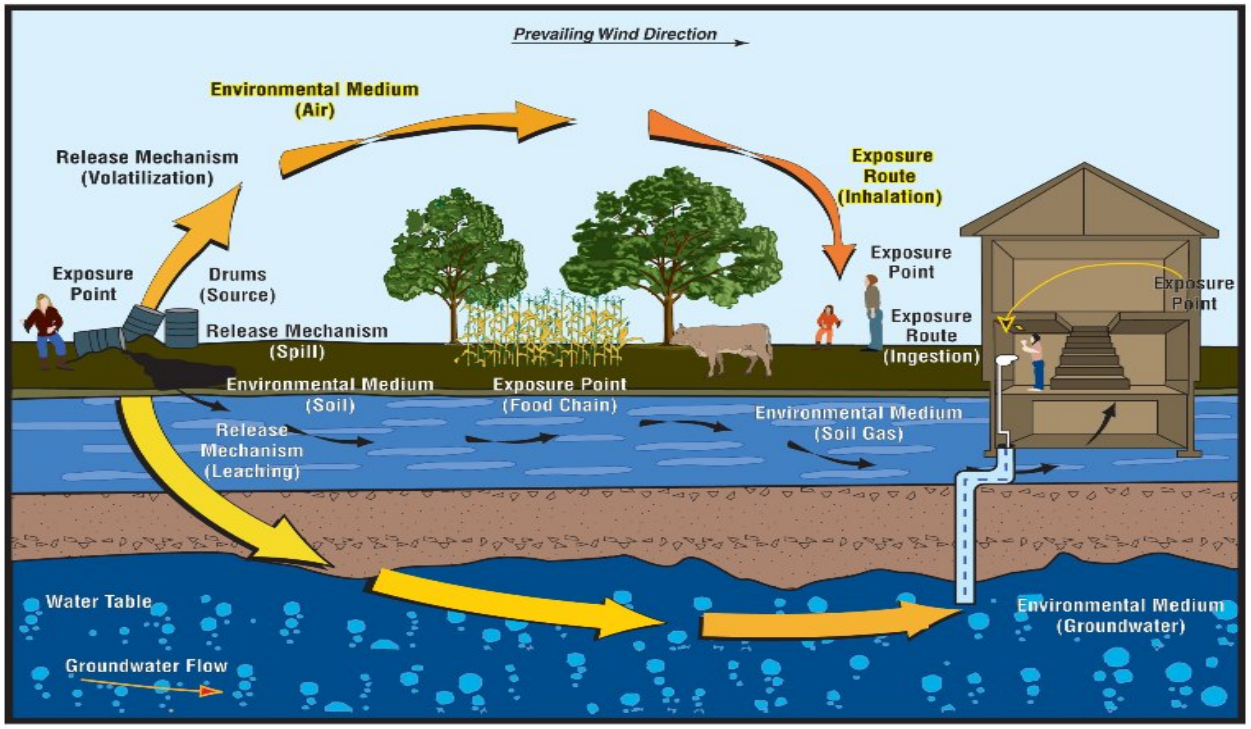
1. A source of contamination,
2. An environmental medium through which the contaminant is transported,
3. A point of human exposure,
4. A route of human exposure, and
5. An exposed population.

A *potential exposure pathway* is present when one or more of the elements is missing, but available information indicates that human exposure is likely to occur. A pathway is also considered potential when modeled data are used to predict human exposure. When one or more of the elements is missing and available information indicates that human exposure is unlikely, a site is categorized as *No exposure pathway* (ATSDR 2005). Figure 11 illustrates the pathways of exposure to contaminants. The exposure medium (i.e., air) and route (i.e., inhalation) of interest for this PHA are both highlighted in the figure.

Here ATSDR identifies and evaluates exposure pathways by considering how people might come into contact with a chemical or radiological contaminant—in this case, uranium or fluoride airborne releases. An exposure pathway could involve air, surface water, groundwater, soil, dust, or plants and animals. Exposure to any chemical can occur by breathing, eating, drinking, or by skin contact with a substance containing that chemical or a radioactive contaminant. Exposure specifically to radiation can occur just by proximity to the radioactive material; direct contact is unnecessary.

If an exposure route is established, ATSDR then considers whether environmental contamination is present at levels that might affect public health. ATSDR evaluates environmental contamination using available environmental sampling data and, in some cases, modeling studies. Contaminants are selected for further evaluation by matching environmental contaminant concentrations with health-based comparison values. Comparison values are developed from available scientific literature on subjects such as exposure and health effects. Comparison values are then derived for each medium. The values reflect an estimated concentration that is not expected to cause harmful health effects for a given contaminant, assuming a standard daily contact rate (e.g., the amount of water or soil consumed or the amount of air breathed) and representative body weight.

Figure 11. Pathways of Exposure for Site-Specific Contamination



Source: ATSDR 2005

Notes:

The environmental medium (air) and exposure route (inhalation) are highlighted because the inhalation pathway is the main focus of this PHA.

The concentrations and distributions of hazardous substances in each of the pathways are evaluated in this section.

This assessment does not include ingestion of drinking water from surface water or groundwater sources because these are evaluated by ATSDR in other PHAs.

Note, however, that comparison values are not thresholds for harmful health effects. ATSDR comparison values represent contaminant concentrations many times lower than levels at which no effects were observed in studies on experimental animals or in human epidemiologic studies. If specific contaminant concentrations are above comparison values, ATSDR further analyzes exposure variables (such as site-specific exposure, duration, and frequency) for health effects, including the toxicology of the contaminant, other epidemiology studies, and the weight of evidence.

More information about the ATSDR evaluation process can be found in ATSDR's Public Health Assessment Guidance Manual at http://www.atsdr.cdc.gov/HAC/PHAManual/index.html or by contacting ATSDR at 1-800-CDC-INFO. An interactive program that provides an overview of the public health assessment process ATSDR uses to evaluate whether people will be harmed by hazardous materials is available at: http://www.atsdr.cdc.gov/training/public-health-assessment-overview/html/index.html.

III.B.1. Chemical Evaluation

ATSDR screened available ORR-related chemical data for uranium and fluoride/HF to determine whether concentrations were above ATSDR's comparison values (see description below). To understand more completely the public health implications of exposure, ATSDR also reviewed relevant toxicologic and epidemiologic data to obtain information about the chemicals' toxicity.

ATSDR uses comparison values to screen chemicals that require additional evaluation.

ATSDR selects chemicals for further evaluation by comparing the maximum environmental concentrations against media-specific, health-based comparison values. At this step of the screening process, the maximum concentrations serve as a conservative measure. That people are exposed to a range of concentrations, not just the maximum reported levels, is well established. Because comparison values reflect concentrations much lower than those actually observed to cause adverse health effects, the values are public health-protective in essentially all exposure situations. Comparison values are derived for soil/sediment, water, and air: they reflect a concentration that is not expected to cause harmful health effects for a given contaminant, assuming a standard daily contact rate (e.g., the amount of water or soil consumed or the amount of air breathed) and representative child or adult body weight. Thus exposure to chemical concentrations detected at or below ATSDR's comparison values is not expected to cause health effects in people. Levels below media-specific comparison values do not pose a public health hazard and, for a given media, are not further evaluated.

While concentrations at or below the respective comparison value can be considered safe, that any environmental concentration exceeding a comparison value would produce adverse health effects does not automatically follow; comparison values are not health-effect thresholds. ATSDR comparison values represent concentrations that are many times lower than levels at which, in studies on experimental animals or in human epidemiologic studies, no effects were observed. The likelihood that adverse health outcomes will actually occur depends on site-specific conditions, individual differences, and factors that affect the route, magnitude, and duration of actual exposure. If contaminant concentrations are above comparison values or if no comparison values exist for particular contaminants, ATSDR further analyzes exposure variables

(such as site-specific exposure duration and frequency) for health effects, including the toxicity of the chemical, epidemiology studies, and the weight-of-evidence.

Weight-of-evidence is the extent to which the available scientific information supports the hypothesis that a substance causes an adverse effect in humans. For example, factors that determine the weight-of-evidence that a chemical poses a hazard to humans include

- The number of tissue sites affected by the agent;
- The number of animal species, strains, sexes, and number of experiments and doses showing a response;
- The dose-response relationship;
- Statistical significance in the occurrence of the adverse effect in treated subjects compared with untreated controls; and
- The timing of the adverse-effect occurrence.

For some public health assessments, however, critical data are simply unavailable. A professional judgment about the level of health hazard thus becomes impossible. In these instances, ATSDR must determine whether the needed data can be obtained elsewhere. In preparing this PHA for instance, evidence showed that fluoride and hydrogen fluoride were released as UF_6 at the K-25 site during accidents or during equipment maintenance. But with regard to these releases ATSDR was unable to locate environmental sampling data related to historic short-term exposure. Although ATSDR used worst-case assumptions and modeled air data to estimate exposures, the necessary and sufficient sampling data are nowhere to be found. Thus ATSDR cannot draw a conclusion about any past true health hazard. In all likelihood sufficient data will never be available to form a professional judgment about the level of health hazard from exposure to historic short-term fluoride and hydrogen fluoride released from the K-25 site.

III.B.2. Radiological Evaluation

The two broad classes of radiation exposure are *external radiation* and *internal radiation*. Internal exposures result from radioactive materials taken into the body through the process of inhalation or ingestion of radioactive materials such as contaminated food. External exposure results from radiation sources outside the body, such as radiation emitted from contaminated sediment. External-source radiation can sometimes penetrate human skin. Whether an exposure contributes to a person's external or internal exposure depends primarily on the type of radiation—alpha and beta particles or gamma rays—to which a person was exposed (see text box).

Beta particles can penetrate human skin and tissues and deliver a dose both internally and externally. *Gamma rays* can travel long distances and easily penetrate body tissues, and are therefore the primary type of radiation resulting in external radiation exposures. *Alpha particles* cannot penetrate skin, so they pose a minimal external exposure concern. Alpha particles, however, can inflict biological damage if the body takes them in, for example by breathing or swallowing radioactive material in air or food (ATSDR 1999b).

ATSDR calculates the radiation dose by using the concentration of the radionuclide in the environment and, if available, site-specific exposure factors such as time spent outdoors and amount of water and food ingested. If these site-specific factors are unavailable, ATSDR either uses default values or derives region-specific values. Once these inputs are derived, the dose coefficient converts the amount of radioactive material taken into the body to the radiation dose. ATSDR might use worst-case exposure factors to determine whether adverse health effects are *possible*. Because of this approach, the estimated radiation doses are usually much higher (i.e., more conservative) than the levels to which people are actually exposed. Note that the radiation dose concept is not as simple as related here. A number of other factors (e.g., how radionuclides decay, the organ most sensitive to the radiation, particle size distribution, the chemical form) might affect "dose" and therefore must factor into the dose derivation.

The *radiation dose* is the amount of energy from radiation that the body actually absorbs.

Most radioactive elements such as uranium have more than one radioactive species or isotope. The radiation dose delivered by a radioactive element to the body is a function of the element's chemical form, the specific isotope's radioactive half-life, and the energy of its decay. Uranium has three naturally occurring radioactive isotopes indicated by the mass numbers 234, 235, and 238, each with a different half-life and decay energy. The dose to the body is different for each isotope. The doses from each isotope are evaluated separately. The doses are then added together to yield the total uranium dose.

Even after the initial radioactive material has been taken into the body, internal radiation exposure from a radionuclide continues. And this occurs even if no additional radionuclides are ingested or inhaled. In other words, internal radiation exposure from radioactive material commits the exposed person to receiving a radiation dose for a period of time. That period typically depends on the radionuclide's half-life and its rate of elimination from the body. (See the glossary in Appendix A for a description of half-life.) For an organ-specific dose this is known as the *committed equivalent dose*, and for a whole-body dose, the *committed effective dose*. Exposure to external radiation sources, however, stops when the source is removed or when a person moves away from the source. The doses are further defined as follows:

III.B.2.1. Committed Equivalent Dose

The International Commission of Radiological Protection's (ICRP's) term (starting with ICRP Publication 60) for the dose to organs and tissues of reference that a person will receive from an intake of radioactive material:

- For workers or adults, over a 50-year period following the intake, and
- For children, up to a 70-year period following the intake.

III.B.2.2. Committed Effective Dose

ICRP's term for the sum of the products of 1) the weighting factors applicable to each body organ or tissue that is irradiated, and 2) the committed equivalent dose to the appropriate organ or tissue integrated over time (in years) following the intake, with the assumption that the entire dose is delivered in the first year following the intake. The integrated time for an adult is 50 years; for children, it is from the time of intake to 70 years. The *committed effective dose* is used

in radiation safety because it implicitly includes the relative carcinogenic sensitivity of the various tissues.

III.B.3. Weighting Factors

The ICRP developed weighting factors to address the variable effectiveness of different types of radiation and the variation of the radiation's effect on specific tissues. Depending on the type of radiation, the weighting factor can be 1.0, 5.0, or 20. For example, alpha radiation is 20 times more damaging than gamma radiation. Hence the radiation-weighting factor for alpha radiation is 20. In the case of tissues, the weighting factors are determined by a relative contribution to adverse health effects resulting from irradiation of the entire body.

III.B.3.1. Effective Dose

ICRP's term (starting with ICRP Publication 60) for the sum of the products of 1) the weighting factors applicable to each body organ or tissue that is irradiated, and 2) the mean equivalent dose in the tissue or organ following exposure to external radiation.

III.B.4. Past, Current, and Future Exposure Pathways Evaluated

ATSDR evaluated potential inhalation exposure for radionuclides (uranium 234, 235, and 238, technetium 99, and neptunium 237), fluorides (in both fluoride and fluorine forms), and hydrogen fluoride from K-25 and S-50 site air emissions. This PHA does not evaluate other potential exposures, such as ingestion of drinking water from surface water or groundwater; these were evaluated by ATSDR in other PHAs (see all other PHAs completed by ATSDR at: http://www.atsdr.cdc.gov/HAC/oakridge/phact/index.html). ATSDR's exposure pathway analysis in these other PHAs did not identify past off-site exposure pathways for uranium and fluoride via the groundwater or surface water bodies at the K-25 site. Additional evaluation of past ingestion exposure to uranium and fluoride via drinking water is therefore unwarranted. Table 3 contains the sources, timeframes, contaminants, and exposure areas evaluated in this PHA for past (1944–2006) exposures. Current and future exposures include any potential hazards that might be identified during ongoing remedial activities at the site. Using ATSDR's evaluation, no potential current or future hazards to off-site residents have been identified at this time, but remediation continues at the site. Figure 12 contains the locations of the significant emission sources at the K-25 site relative to the points of historic exposure and the locations of the former cylinder storage yards. Section II.E, Demographics, in this PHA discusses information on population estimates and residential histories for the respective exposure areas.

With respect to the K-25/S-50 site evaluated in this PHA, ATSDR assumed that uncontrolled releases of uranium and fluoride compounds would be transported in the atmosphere to off-site areas. Consequently, ATSDR also assumed that exposure pathways have been completed for historic air releases for uranium and fluoride compounds. The remainder of this section will evaluate the doses and concentrations of uranium and fluoride compounds at the areas of highest exposure (Happy Valley, Sugar Grove, and Union/Lawnville). Section IV, Public Health Implications, explores whether these estimated doses and concentrations are or were a public health hazard.

Table 3. Exposure Sources, Timeframes, Contaminants, and Exposure Areas for the Evaluation of Past Exposures to K-25/S-50 Air Emissions

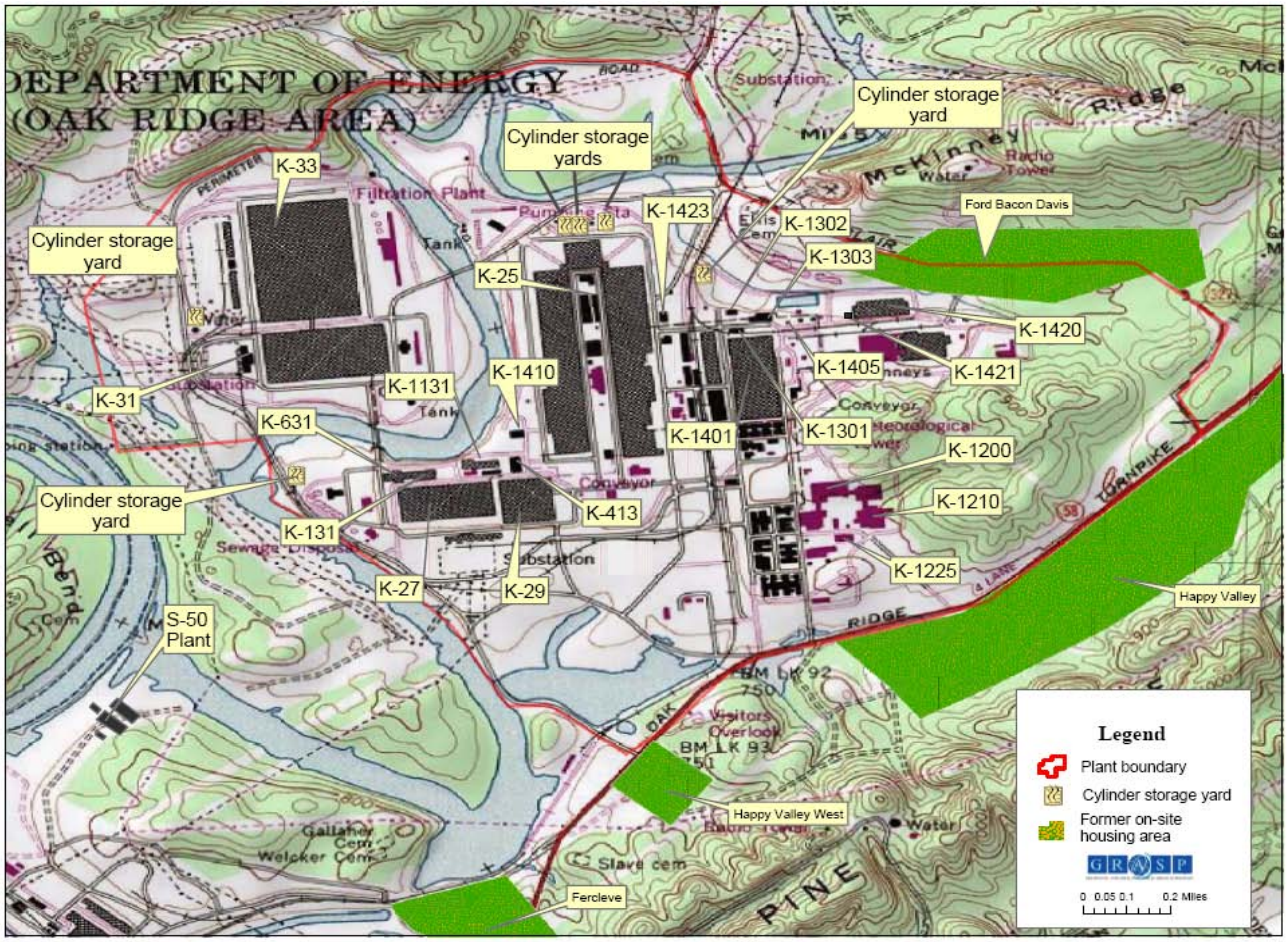
Source	Timeframe	Contaminant (Exposure Duration)	Exposure Area
Past Exposures			
K-25	1945 to 1995 1963 (maximum release year)	Radionuclides (acute/chronic) Fluorides (acute/chronic) Hydrogen Fluoride (acute/chronic)	Union/Lawnville
	1960 to 1995 1963 (maximum release year)	Radionuclides (acute/chronic) Fluorides (acute/chronic) Hydrogen Fluoride (acute/chronic)	Sugar Grove
S-50	1944 to 1945	Radionuclides (acute/chronic) Fluorides (acute/chronic) Hydrogen Fluoride (acute/chronic)	Happy Valley
		Radionuclides (acute/chronic) Fluorides (acute/chronic) Hydrogen Fluoride (acute/chronic)	Union/Lawnville

Notes:

Radionuclides include uranium (234, 235, and 238), technetium 99, and neptunium 237.

This PHA does not evaluate potential exposures other than inhalation (e.g., drinking water or groundwater ingestion). ATSDR evaluated these in other PHAs.

Figure 12. Locations of Primary Historic Air Emission Sources from the K-25/S-50 Site



Notes:

Descriptions of the past primary sources (specific buildings) including type of air releases, contaminants, and timeframes are listed in Table 4.

Cylinder yard locations are approximate.

Additionally, Appendix A provides a glossary of environmental and health terms presented in the discussion. Additional background information is provided in appendices as follows:

- Appendix B summarizes other public health activities at the ORR;
- Appendix C summarizes remedial activities related to the study area;
- Appendix D provides a description of the CAP88-PC Model and presents the output data from the model;
- Appendix E presents the model output for K-25 releases from the RASCAL3 model;
- Appendix F contains K-25 meteorological data;

- Appendix G details the measured versus predicted gross alpha concentrations at monitoring locations; and

- Appendix H contains summaries of ATSDR and TDOH studies.

- Appendix I provides toxicological data on specific contaminants evaluated in this public health assessment.

- Appendix J includes public comments received on this document during the public comment period (December 23, 2008, through February 20, 2009) and ATSDR's responses to those comments.

- Appendix K presents peer reviewer comments provided on this document and ATSDR's responses to those comments.

III.C. Past Releases from the K-25/S-50 Site (1944 to 2006)

III.C.1. Sources and Emissions Estimates of Airborne Uranium, Fluoride, Hydrogen Fluoride, and Other Radiological Contaminants

III.C.1.1. Sources

The primary airborne contaminant released from the K-25 and S-50 facilities was uranium hexafluoride (UF_6). The primary mission of the K-25 and S-50 facilities was the enrichment of U-235 via gaseous diffusion of uranium hexafluoride. From 1945 to 1963 the K-25 facility produced UF_6 that was highly enriched with the U-235 isotope (up to 93% U-235). From 1964 to 1985, the K-25 facility produced low enrichment UF_6 (up to 5% U-235). The S-50 facility, which operated for only about 12 months from 1944 to 1945, produced and released UF_6 with an enrichment of less than 1 percent U-235 (ChemRisk 1999a). These changes in relative UF_6 enrichment are reflected in the proportions of U-234, U-235, and U-238 released to the atmosphere. At atmospheric temperature and pressure, UF_6 is a dense or heavy gas (heavier than air). When released in the air, UF_6 reacts rapidly with atmospheric water to form hydrogen fluoride and uranyl fluoride and uranium oxide particulates (ATSDR 2003).

In the area where gaseous diffusion processes occurred, the K-25 site had more than 500 buildings, over 270 auxiliary facilities for support services, and about 290 more buildings and trailers used for various purposes. Figure 12 shows the locations of the process buildings on the K-25/S-50 site that were the primary sources of historic air emissions. Note that the process buildings—the specific release sources—were widely distributed across the K-25 site. Releases from these buildings occurred from a number of vents and stacks, many of which included some type of effluent treatment or trap to capture the uranium before it was released to the environment (ChemRisk 1999a). The specific contaminants and timeframe for releases from each building are described in Table 4 (ChemRisk 1999a; Lay and Rogers 1986).

Initially, all of the UF_6 fed into the gaseous diffusion cascades was made from natural uranium. Beginning in 1952, however, uranium reprocessed from previously fissioned material (reactor tails) was introduced as UF_6 feed material. The UF_6 from spent reactor fuel contained fission products and transuranic radionuclides including technetium 99 (Tc-99), neptunium 237 (Np-

237), and very small quantities of plutonium 239 (Pu-239). Consequently, after 1952, airborne emissions from the K-25 facility also contained quantities of Tc-99, Np-237, and Pu-239. The proportion of spent reactor tails to natural uranium in the feed material varied significantly from 1952 to 1985, but must be accounted for in airborne emission estimates.

From 1976 to 1980, airborne releases from the K-25 facility also included significant quantities of krypton 85 (Kr-85) (Lay and Rogers 1986). Krypton was apparently added to the UF_6 feed material as part of an Oak Ridge National Laboratory (ORNL) experiment. Available information is limited and does not indicate the part of the feed material production and processing where krypton 85 was introduced or released. A Lay and Rogers (1986) summary of K-25 radionuclide emissions, however, indicates that the experiment lasted 5 years and a total of 106.5 curies (Ci) of Kr-85 were released into the atmosphere. Annual Kr-85 releases varied from 6.5 Ci in 1976 to 41.5 Ci in 1978 and have been included in subsequent dispersion and dose calculations.[5]

Beginning in the 1950s, DOE and its predecessors accumulated approximately 6,000 UF_6 cylinders[6] in six storage yards at the K-25 site. As of December 2006, however, DOE completed removal of all UF_6 cylinders from the cylinder storage yards at the K-25 site. Uranium hexafluoride, or UF_6, is a solid, vacuum-stored in steel cylinders (Fricke 1996). When stored at temperatures below 134^{o}F (57^{o}C) at atmospheric pressure, depleted UF_6 is a white, crystalline solid (USDOE 1999).The cylinders were of several dimensions (the most common were 12 feet [about 3 ½ meters] long and 4 feet [about 1 meter] in diameter), had a nominal wall thickness of 3/16 inch (about 5 millimeters), and when full contained about 14 tons of UF_6. Figure 12 shows the location of the six former cylinder storage yards. If one of the cylinders had leaked, the UF_6 would have reacted with moisture in the atmosphere to form hydrogen fluoride (HF) gas and uranium reaction products such as solid uranyl fluoride. The solid would have sealed small leaks or cracks, preventing the escape of radioactive and chemical materials from the cylinders (Fricke 1996). No cylinders remain on site—removal was complete by December 2006.

[5] Kr-85 is not cited in the CAP88-PC model in Appendix D—no Kr-85 releases occurred in 1963, the release year included in the CAP88-PC model. Also, Kr-85 is an inert, nonreactive gas. The ICRP by definition does not calculate internal doses from inert gases as they do not bind to or react with any body tissue.

[6] The cylinders collectively contained about 119 million pounds of UF_6.

Table 4. Descriptions of the Past Primary Sources Contributing to Airborne Releases From the K-25 and S-50 Facilities

Process	Buildings	Type of Air Releases	Contaminants	Timeframe
S-50 Site				
Liquid thermal diffusion	S-50	-Routine releases from equipment conditioning exhausts -Accidental equipment failures and process errors	UF_6 (with subsequent atmospheric conversion to uranium oxides and hydrogen fluoride)	October 1944 to September 1945
K-25 Site				
Hydrogen fluoride and fluorine disposal (fluorine/hydrogen fluoride converted to sodium fluoride then released to air)	K-1405	-Routine releases from disposal tower -Accidental equipment failures -Process errors	-UF_6 -Sodium urinate -Uranyl fluoride	1944 to 1952
Gaseous diffusion enrichment	K-25, K-27, K-29, K-31, and K-33	-Routine monitored purging of cascades -Unmonitored evacuations for maintenance -Accidental equipment failures and process errors	UF_6 (with subsequent atmospheric conversion to uranium oxides and hydrogen fluoride)	1945 to1964 (highly enriched UF_6) 1945 to 1985 (low enrichment UF_6)
Feed vaporization and toll enrichment (cylinders heated to vaporize UF_6 for transfer to cascades)	K-131, K-1131, and K-1423	-Accidental equipment failures and process errors (e.g., faulty cylinder connections, valve failures, and overfilling)	UF_6 (enriched, natural, or depleted)	1945 to 1985
Product and tails transfers (gaseous UF_6 compressed/condensed into liquid and transferred to cylinders)	K-413, K-631, and K-1131	-Accidental equipment failures (including cylinder explosions and ruptures) -Process errors (faulty cylinder connections and valve failures)	UF_6 (enriched, natural, or depleted)	1945 to 1985
Uranium decontamination and recovery (process equipment cleaned with water, steam, acid, etc.; other waste material incinerated and ash recycled)	K-131, K-1301, K-1302, K-1303, K-1401, K-1410, and K-1421	-Routine releases from incinerator and cylinder purging/evacuation -Accidental equipment failures -Process errors	-UF_6 -Other uranium compounds	1945 to 1985
UF_6 feed manufacturing (production of UF_6 from uranium dioxide [UO_2] and hydrogen fluoride [HF]	K-1131	-Accidental equipment failures -Material transfer losses -Process errors	UF_6 (with subsequent atmospheric conversion to uranium oxides and hydrogen fluoride); UO_2; UF_4; HF	1952 to 1961 1962 to 1965

Table 4 (continued). Descriptions of the Past Primary Sources Contributing to Airborne Releases from the K-25 and S-50 Facilities

Process	Buildings	Type of Air Releases	Contaminants	Timeframe
K-25 Site				
Gas centrifuge program (a developmental program to prototype and test high speed centrifuges used to enrich UF_6)	K-1423, K-1200, K-1210, and K-1225	-Accidental equipment failures -Process errors	UF_6 (with subsequent atmospheric conversion to uranium oxides and hydrogen fluoride)	Early 1960s to late 1980s

Source: ChemRisk 1999a; Fricke 1996; Lay and Rogers 1986; USDOE 2003a

Notes:

UO_2 is uranium dioxide.

UF_4 is uranium tetrafluoride.

UF_6 is uranium hexafluoride.

III.C.1.2. Annual Airborne Emission Estimates (1944 to 1995)

ATSDR used DOE and ChemRisk estimates to evaluate total airborne uranium releases for the K-25/S-50 site. The DOE uranium release estimates are taken from quarterly, semi-annual, or annual environmental reports for the years 1959–1995 and from a Lay and Rogers (1986) historical summary. The ChemRisk estimates from the Task 6 report are based on more than 40 sources documenting over 1,200 uranium release events for the years 1944 to 1995 (ChemRisk 1999a); ChemRisk data were provided to ATSDR. Table 5 and Figure 13 show the total uranium releases, in Curies, to the atmosphere as estimated by DOE and by ChemRisk in its Task 6 report.

Although independently derived, the uranium release estimates are based on the same underlying monitoring and incident release reports. Additionally, S-50 facility emissions were not included in original DOE K-25 facility release estimates. In the Task 6 report ChemRisk adds the S-50 facility releases for 1944 and 1945 to the DOE estimate. ChemRisk did not independently estimate 1989 to 1995 releases in the Task 6 report, which were taken directly from DOE release estimates. As shown in Table 5 and Figure 13, these two semi-independent estimates of total airborne uranium releases are very similar.

ATSDR uses the term *conservative* to refer to values protective of public health in essentially all situations. Thus for public health purposes, overestimated values are considered conservative values.

That said, in two important attributes the DOE estimates of total airborne uranium releases are more conservative than are the Task 6 report estimates. First, when the S-50 facility emissions are added to the DOE release estimates, the cumulative activity of airborne uranium release, as estimated by DOE, is about 8 percent larger than the Task 6 report estimate. Second, and more important, the highest annual releases (1961 and 1963) as estimated by DOE for those years are more than 30 percent larger than the Task 6 report estimates.

Although the DOE estimate of total airborne uranium releases is more conservative than is the Task 6 report estimate, the Task 6 report emissions data are more complete. They include the relative composition of the uranium isotopes U-234, U-235, and U-238 for each of the release years. ATSDR's analyses of uranium isotope dispersion and of the resulting effective dose to the potentially exposed population uses the DOE estimate of total uranium activities and the Task 6 report estimate of uranium isotope proportions. Table 5 shows the estimated annual airborne radionuclide releases (total uranium, technetium 99, and neptunium 237) from the K-25/S-50 facilities and the relative abundance of uranium isotopes. As mentioned previously, the very small quantities of Pu-239 included in the reactor tails account for less than one percent of the total radiation and therefore are not included in radiological dose assessments.

Table 5. Estimated Annual Airborne Radionuclide Releases from K-25/S-50

	Total Uranium (Curies)		Relative Abundance (weight percent) Uranium Isotope Task 6 Report			Task 6 Report (Curies)	
Year	DOE	Task 6 Report	Uranium 234	Uranium 238	Uranium 235	Technetium 99	Neptunium 237
1944	0.04	0.04	48.05	49.67	2.29	—	—
1945	2.05	2.05	48.06	49.65	2.29	—	—
1946	0.01	0.05	95.83	0.46	3.71	—	—
1947	0.01	0.05	96.52	0.18	3.30	—	—
1948	0.01	0.00	56.58	41.00	2.42	—	—
1949	0.01	0.05	40.73	57.50	1.76	—	—
1950	0.10	0.09	48.13	49.59	2.28	—	—
1951	0.02	0.13	46.29	51.55	2.16	—	—
1952	0.23	0.78	46.26	51.59	2.15	—	—
1953	1.60	1.41	66.40	30.65	2.96	2.9	0.110
1954	0.26	0.79	93.92	2.99	3.09	2.9	0.050
1955	0.26	0.26	62.95	34.49	2.57	2.9	0.050
1956	0.81	0.16	43.42	54.62	1.96	2.9	0.023
1957	0.15	0.21	48.53	49.28	2.20	2.9	0.024
1958	1.80	1.82	48.01	49.71	2.28	2.9	0.130
1959	1.10	0.59	66.66	30.52	2.82	2.9	0.039
1960	1.50	0.99	48.23	49.48	2.29	2.9	0.072
1961	3.10	0.60	54.39	43.32	2.28	2.9	0.054
1962	0.24	0.17	87.28	8.85	3.87	2.9	0.013
1963	3.10	2.02	79.58	16.03	4.39	2.5	0.049
1964	0.01	0.01	71.79	24.82	3.39	2.5	0.002
1965	0.14	0.67	83.20	12.96	3.84	2.5	0.013
1966	0.01	0.00	73.01	23.00	3.99	2.5	0.002
1967	0.01	0.00	68.25	28.07	3.68	2.5	0.002
1968	0.01	0.00	39.41	58.95	1.65	2.5	0.002
1969	0.01	0.01	50.96	46.54	2.49	2.5	0.003
1970	0.01	0.01	66.92	29.49	3.59	2.5	0.003
1971	0.02	0.09	77.87	17.87	4.26	2.5	0.003
1972	0.03	0.05	63.13	33.55	3.32	2.5	0.004
1973	0.44	0.44	74.80	21.09	4.11	2.5	0.006
1974	0.13	1.18	78.64	17.01	4.34	0.27	0.014
1975	0.27	0.65	77.27	18.47	4.26	0.30	0.001
1976	0.05	0.25	80.60	15.00	4.40	6.79	0.002
1977	0.03	0.06	80.15	15.43	4.42	0.00	0.002
1978	0.02	0.04	81.76	14.73	3.51	0.29	0.002

Table 5 (continued). Estimated Annual Airborne Radionuclide Releases from K-25/S-50

	Total Uranium (Curies)		Relative Abundance (weight percent) Uranium Isotope Task 6 Report			Task 6 Report (Curies)	
Year	DOE	Task 6 Report	Uranium 234	Uranium 238	Uranium 235	Technetium 99	Neptunium 237
1979	0.04	0.11	82.08	13.39	4.53	1.34	0.002
1980	0.03	0.20	76.13	19.82	4.04	0.88	0.002
1981	0.01	0.13	78.62	17.08	4.30	0.04	0.002
1982	0.01	0.11	74.03	21.91	4.06	0.03	0.002
1983	0.01	0.00	76.68	19.10	4.22	0.02	0.002
1984	0.01	0.00	77.55	18.17	4.28	0.02	0.002
1985	0.01	0.00	78.35	17.34	4.32	—	0.002
1986	0.01	0.00	89.39	5.85	4.76	—	0.002
1987	0.01	0.00	52.96	44.41	2.63	—	0.002
1988	0.31	0.31	48.05	49.67	2.29	—	0.002
1989	0.00	0.00	47.67	50.02	2.30	—	0.002
1990	0.00	0.00	37.29	61.18	1.53	—	0.002
1991	0.02	0.02	42.10	56.04	1.87	—	0.002
1992	0.06	0.06	39.55	58.76	1.69	—	0.002
1993	0.01	0.01	47.66	50.20	2.14	—	0.002
1994	0.01	0.01	55.61	41.58	2.82	—	0.002
1995	0.01	0.01	18.43	81.39	0.18	—	0.002
Totals	18.15	16.70	63.76	33.15	3.08	66.48	0.700

Notes:

Technetium 99 (Tc-99) and neptunium 237 (Np-237) were not released during these years.

DOE uranium estimates are from Lay and Rogers (1986) and environmental monitoring reports.

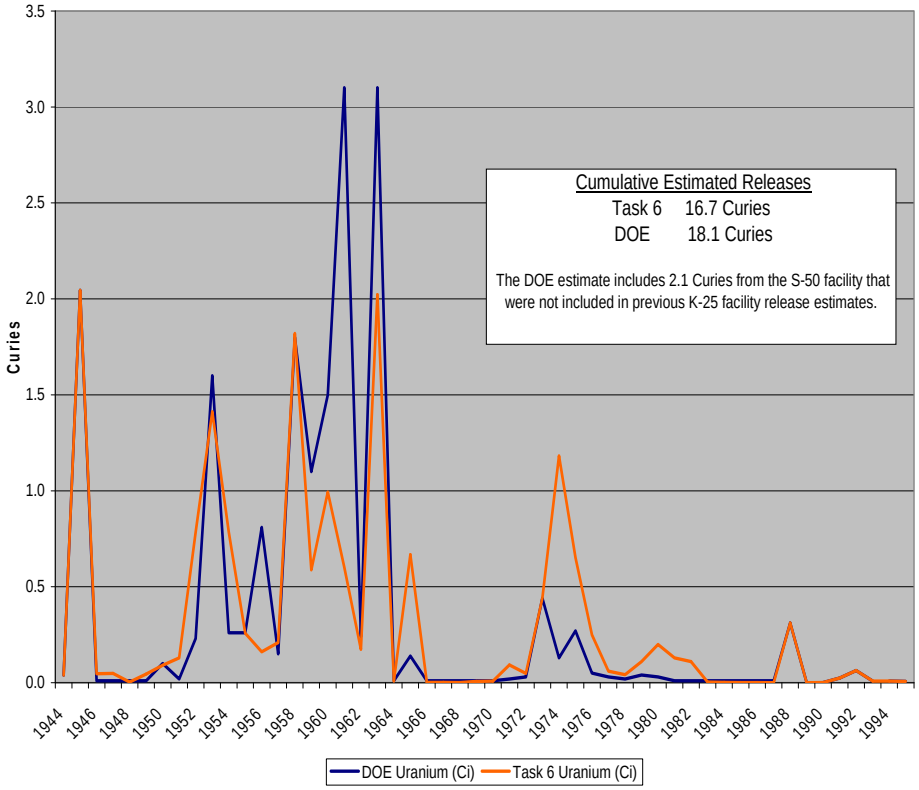
S-50 facility emissions were not included in the original DOE K-25 facility release estimates; ChemRisk added the 1944 and 1945 S-50 facility release estimates (shown in blue) to DOE's estimates. Thus, DOE uranium estimates include 1944–1945 S-50 releases from the Task 6 report.

Task 6 report uranium estimates are from ChemRisk in the Task 6 report (ChemRisk 1999a).

ChemRisk did not independently evaluate estimates for 1988 to 1995; the Task 6 report uranium estimates (shown in blue) were taken directly from DOE release estimates for 1988 to 1995.

Note that when the S-50 facility emissions are added to the DOE release estimates: 1) the cumulative DOE release estimate is greater than the Task 6 report estimate, and 2) during the maximum release years (1961 and 1963), DOE's estimates are much greater than the Task 6 report estimates.

Figure 13. Total Estimated Airborne Uranium Releases (in Curies) from the K-25/S-50 Facility



Notes:

DOE uranium estimates are from Lay and Rogers (1986) and environmental monitoring reports

S-50 facility emissions were not included in the original DOE K-25 facility release estimates; ChemRisk added the 1944 and 1945 S-50 facility release estimates to DOE's estimates. Thus, DOE uranium estimates include 1944–1945 S-50 releases from the Task 6 report.

Task 6 report uranium estimates are from ChemRisk in the Task 6 report (ChemRisk 1999a).

ChemRisk did not independently evaluate estimates for 1988 to 1995; the Task 6 report uranium estimates were taken directly from DOE release estimates for 1988 to 1995.

Note that when the S-50 facility emissions are added to the DOE release estimates: 1) the cumulative DOE release estimate is greater than the Task 6 report estimate, and 2) during the maximum release years (1961 and 1963), DOE's estimates are much greater than the Task 6 report estimates.

III.C.1.3. Historic Accidental or Short-Term Release Estimates (1944 to 1995)

The long-term or annual uranium release estimates, as shown in Table 5, represent the sum of individual release events for each year from 1944 to 1995. One of this PHA's specific tasks is to determine whether any of these historic short-term release events represented an acute public health hazard to the adjacent communities. Table 6 shows the four largest accidental releases that ChemRisk specifically identified in its Task 6 report (ChemRisk 1999a) or that ATSDR obtained via accident report records (Union Carbide Nuclear Company 1952–1955, 1957–1958, 1958, 1958–1961). Although the available data are probably incomplete, these records include the years of highest production and annual emissions, and are likely representative of the most significant individual release events.

Table 6 also includes an estimate of the maximum magnitude of UF_6 releases by the jetting or venting of process gas during routine maintenance processes. Jetting is also described as *midnight negative* releases (see text box). An evaluation of the gaseous diffusion at the K-25 facilities noted that if the maintenance procedures were followed, less than a pound of UF_6 would be released from the cascade component undergoing maintenance (DOE 2000). But the DOE report also noted that under certain conditions during the Cascade Improvement or Cascade Updating programs, significant quantities of UF_6 could have been available for release to the environment. The Task 6 report stated UF_6 releases occurred from K-25, but information describing the quantities of uranium released could not be found. A Bechtel Jacobs Company LLC evaluation of releases from the Paducah Gaseous Diffusion Plant states that "…up to several thousand pounds of UF_6 could still have been available for release to the environment from a single cascade cell…" (Bechtel Jacobs Company LLC 2000). As use of jetting and venting has also been reported for the K-25 facility, this PHA will assume that the K-25 jettings were of a similar magnitude as the Paducah Gaseous Diffusion Plant jetting negatives. The maximum estimated UF_6 release of 907 kilograms (kg) (1,995 lbs) is a conservative estimate based on the maximum amount of UF_6 in a cascade cell assuming a 10 percent reduction in pressure by purging and evacuation (DOE 2000). Although ATSDR has no information on the relative enrichment of material released during jetting negatives, that significant amounts of enriched material were released to the environment via this process is unlikely. Enriched product was too valuable to discharge.

> *Midnight Negatives* refers to using the jets at night to accelerate the attainment of an adequate UF_6 negative to support a planned opening of isolated process gas equipment (Bechtel Jacobs Company LLC 2000).

Although Table 6 does not include any records of specific accidental releases from the S-50 facility, ATSDR did review a letter that discussed the frequency and causes of material losses from typical individual release events during a 2-month period in 1945 (Blackwood 1945). This summary does not list specific release events. It does indicate, however, that four "open tit breaks" resulted in the release of 597 pounds of material and that 35 "column breaks" resulted in the loss of 1031.4 pounds of material. These records suggest that the individual, ongoing, operational releases from the S-50 facility were smaller than the specific releases listed in Table 6.

Table 6. Significant Historic Short-Term UF_6 Release Estimates from the K-25 Facility

Date	Building/Source	Amount	U-235 Weight Percentage	Comments
9/1/58	K-1131	1,184 kg 0.55 Ci	0.71%	Ruptured filter in hydrogen reduction system
12/30/52	K-402-1	1,138 kg <0.53 Ci	0.6%	Valve failure; most UF_6 retained in building
9/19/52	K-1131	454 kg 0.21 Ci	0.7%	Release occurred over 10-hour period
2/27/60	K-1131	681 kg 0.32 Ci	0.7%	Ruptured tube in cold trap
Various	Midnight negatives	907 kg maximum ~0.42 Ci	Unknown	Maximum amount of UF_6 in cascade cell assuming 10% reduction in pressure by purging and evacuation

Notes:

Kg – kilogram

Ci – curie

Building K-402-1 is located within Building K-27, presented in Figure 12.

See Figure 12 for the location of Building K-1131.

Also worth noting is that for many of the specific, documented release events, the reports state or infer that much of the material was not dispersed outside the buildings. Most likely, the majority of the released material was retained within the buildings and then recovered. Nevertheless, because ATSDR cannot verify recovery for all accidental releases, this public health assessment will assume that all of the released material was dispersed to the ambient air. Thus, our estimated releases will be higher—that is, more conservative—than the levels to which people were actually exposed.

III.C.2. Historical Environmental Monitoring Data

III.C.2.1. Ambient Environmental Monitoring

Since the establishment of the ORR, DOE or its predecessors or contractors have been collecting various environmental measurements, including ambient radiation activities in soil, water, and air (see Figure 4). Since at least 1959, records of these monitoring programs have been published as quarterly, semi-annual, or annual reports. Although some monitoring data have been collected over most of the operational history of the K-25/S-50 facility, the specific parameters have undergone extensive changes, analytical methods, and sample locations. The changes primarily involve measuring more parameters, improving analytical techniques, and using a larger number of sampling locations. Yet over the years and even in the face of such changes, some of the station locations have remained fairly consistent. This is important: understanding of long-term trends depends on maintenance of consistent sampling parameters, methods, and locations.

Table 7 lists the ambient monitoring data available for evaluation of historic uranium and fluoride air emissions released from the K-25/S-50 facility. Since as early as the mid-1950s, two specific locations (HP-35 and HP-33) adjacent to the K-25/S-50 facility have been sampled for airborne radioactive particulates. A review of environmental monitoring reports shows that only gross beta measurements were collected until 1966, when gross alpha measurements were initiated. The sample station locations are shown in Figure 14. In the next section of this public health assessment, the gross alpha measurement data (presented in Table 8) are used to evaluate the ability of the CAP88-PC modeling procedures to estimate off-site radiological effective dose equivalents.

Table 7. Ambient Monitoring Data Adjacent to the K-25/S-50 Facility Used to Evaluate Historical Uranium and Fluoride Releases

Media Sampled	Parameters	Stations*	Time Period
Air†	Gross Beta	HP-33/HP-35 (13/15)	1959 to 1983
	Alpha activity	HP-33/HP-35 (13/15)	1966 to 1983
	Uranium isotopes	Perimeter/remote station	1975 to 1995
	Fluorides	F1-F6	1971 to 1985
Soil‡	Gross Alpha	HP-33/HP-35	1971 to 1975
	Uranium isotopes	HP-33/HP-35	1976 to 1984
Biota‡ (Pine needles/grass)	Uranium (total)	VS1-VS9	1974 to 1985
	Fluorides	VS1-VS9	1974 to 1985

Notes:

* Sampling also occurred at many other locations; these are the stations of interest for this PHA.

† Most of the air samples were collected and analyzed weekly and then averaged; this PHA uses annual averages.

‡These data are included in doses modeled using CAP88-PC (see Appendix D). The CAP88-PC program computes radionuclide concentrations in air, rates of deposition on ground surfaces, radionuclide concentrations in food, and intake rates for people ingesting food produced in the assessment area. The doses calculated by CAP88-PC are annual effective doses.

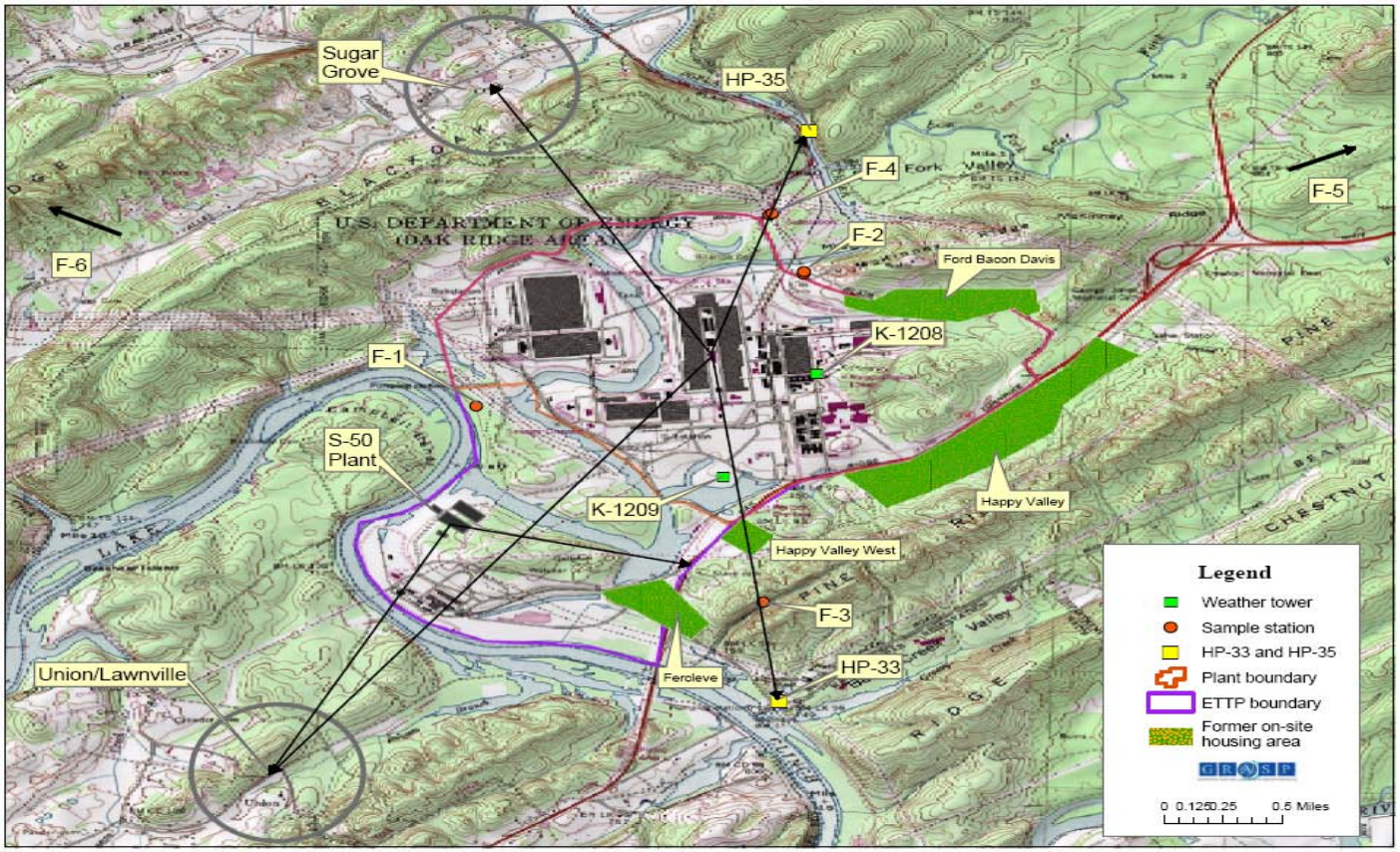
Although some of the station names have changed over time, the locations were apparently constant.

Locations of sample stations are shown in Figure 14.

Note that these monitoring data are not intended as a comprehensive list of all ambient monitoring data available from the K-25/S-50 facility.

ATSDR acknowledges larger HF and fluoride releases occurred before 1971 (DOE 2000). But these releases were not measured. Thus in the absence of actual air concentration data, ATSDR estimated off-site air concentrations. Despite the uncertainties that inhere in the pre-1971measurements, ATSDR's assumptions can estimate the potential worst-case exposures that could have occurred during this timeframe.

Figure 14. Locations of Emission Sources, Exposure Areas, Meteorological Towers, and Monitoring Stations



Notes:

Sugar Grove is 2,570 m NNW of K-25; Union/Lawnville is 4,323 m SSW of K-25 and 2,335 m SSW of S-50; and Happy Valley is 1,447 m ESE of S-50.

HP-33 and HP-35 are DOE monitoring stations; K-1209 and K-1208 are weather stations.

Distances and directions of exposure areas and HP-35/HP-33 monitoring stations (relative to K-25/S-50 emission sources) were used as reference locations for estimating doses and concentrations.

Fluoride monitoring stations are F-1, F-2, F-3, F-4, F-5, and F-6.

Station F-5 is approximately 6.4 kilometers (4 miles) northeast of K-25; Station F-6 is approximately 8 kilometers (5 miles) northwest of K-25.

Table 8. Average Annual Airborne Alpha Activity in Curies at Monitoring Stations HP-33 and HP-35 (1966–1983)

Year	Station HP-33	Station HP-35
1966	5	7
1967	3	5
1968	1.5	2
1969	1.5	2
1970	1	1
1971	1	1
1972	2	3
1973	1.6	2.3
1974	1.5	1.6
1975	1.4	1.6
1976	1.7	3.1
1977	1.6	1.3
1978	1.1	2.2
1979	1.2	1.5
1980	1.1	1.5
1981	0.85	0.89
1982	1.1	1
1983	1.3	1

A review of the available documents and emission reports reveals no record of long-term fluoride emissions. From 1971 to 1985, measurements of airborne fluoride, however, were collected at six locations around the K-25 perimeter. Figure 14 shows monitoring station locations (F-1 to F-6). These records measured actual airborne fluoride concentrations over the sampling duration of either 24-hour or 6- to 7-day collection periods. For each station, the reported results include annual averages and maximum 7-day concentrations. All of the monitoring results are reported in the annual environmental monitoring reports for the respective years. These reports provide limited information on analytical methods—but whether the methods are uniform for all years is not known. Table 9 shows the 1971–1985 measured annual average fluoride concentrations for monitoring stations F-1 to F-6.

Table 9. Annual Average Fluoride Air Concentration (in ppb) Measured at Monitoring Stations F-1 to F-6 (1971–1985)

Year	F-1	F-2	F-3	F-4	F-5	F-6
1971	0.9	0.8	0.8	1	0.7	0.5
1972	1.2	1.1	1.3	1.2	1	0.9
1973	0.9	0.8	0.8	0.7	0.7	0.7
1974	0.9	1.3	1.3	1.3	1.1	1.3
1975	1.1	1.7	1.2	1	1.1	1
1976	0.9	1	0.9	1.2	0.7	0.9

Table 9 (continued). Annual Average Fluoride Air Concentration (in ppb) Measured at Monitoring Stations F-1 to F-6 (1971–1985)

Year	F-1	F-2	F-3	F-4	F-5	F-6
1977	1	0.9	0.6	0.8	0.6	0.6
1978	0.3108	0.6216	0.3108	0.12432	0.10878	0.12432
1979	0.3108	0.6216	0.3108	0.3108	0.09324	0.0777
1980	0.1554	0.4662	0.3108	0.1554	0.1554	0.1554
1981	0.1554	0.1554	0.1554	0.1554	0.1554	0.1554
1982	0.1554	0.1554	0.1554	0.1554	0.1554	0.1554
1983	0.1554	0.1554	0.1554	0.1554	0.1554	0.1554
1984	0.6216	0.777	—*	0.777	0.6216	0.6216
1985	0.06216	0.0777	0.06216	0.06216	0.427869	0.06216

*Because of mechanical problems with air samplers, in 1984 no samples were collected at monitoring station F-3.

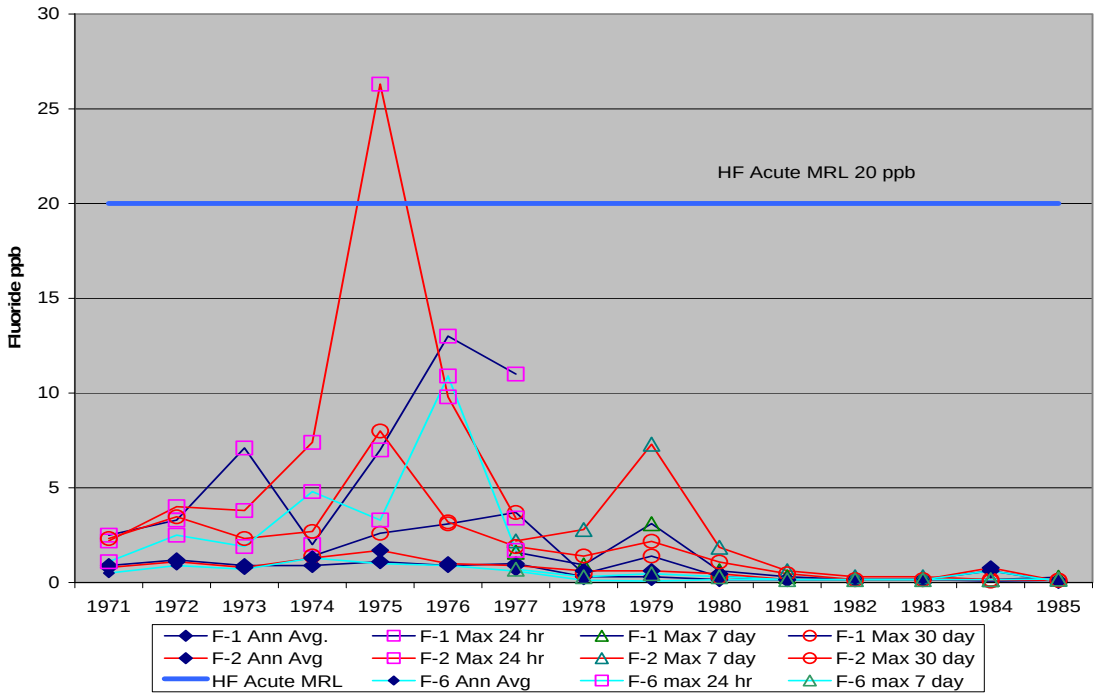
Figure 15 shows the 16-year (1971 to 1985) measured airborne fluoride concentrations (in parts per billion, or ppb) for three stations (F-1, F-2, and F-6). For the different years all of the annually averaged fluoride concentrations are less than 2 ppb and are relatively uniform. For each year the shorter duration values represent the maximum 24-hour, 7-day, or 30-day concentrations. The highest recorded value of 26.3 ppb for a 24-hour sample at station F-2 is the highest measured air fluoride concentration for any station and for any time period—it is about two times higher than any other measured value. Station F-2 is on the site perimeter, approximately 800 m (0.5 miles) downwind (NE) of the K-25 facility. It represents the perimeter location of maximum airborne fluoride concentration. In the next section of the public health assessment, ATSDR will use these measured fluoride air concentrations to estimate the annual average fluoride air concentrations for the years before and after fluoride was measured.

III.C.2.2. Aerial Radiological Surveys of ORR and Surrounding Areas

Since 1959 and through to 1997, DOE and its predecessors have used aircraft-mounted instruments to perform aerial gamma radiation surveys on the ORR site and its surrounding areas. As the methodology and detection capabilities have improved, so has the sophistication of the surveys. Today, aerial surveys will readily detect sources that constitute a hazard. Any detected radiation sources are then investigated on the ground by standard survey techniques.

Around the ORR, including the Union/Lawnville and Happy Valley areas, the single-contour anomalies show no elevated ground-level gamma readings (Figure 16). A single contour is defined as radiation limited in its area; that is, only a spot of radiation with no additional radiation detected at decreasing levels radiating from the central spot. If readings within this single contour are elevated, the source of the radiation is identified. By this method, an inventory of known “off-site” radiation sources has been established and maintained. The published radiation contour maps of the Oak Ridge area identify these source locations as “regions of interest.” They include such sites as the Atomic City Auto Parts, the CSX Railroad bed, and other places related to past or current nuclear operations, as well as the Bull Run Steam plant where fly ash from operations is stored (Maurer 1992).

Figure 15. Measured Airborne Fluoride Concentrations at Stations F-1, F-2, and F-6



Notes:

Measured airborne fluoride concentrations (in parts per billion, or ppb) at stations F-1, F-2, and F-6 are from the annual environmental monitoring reports.

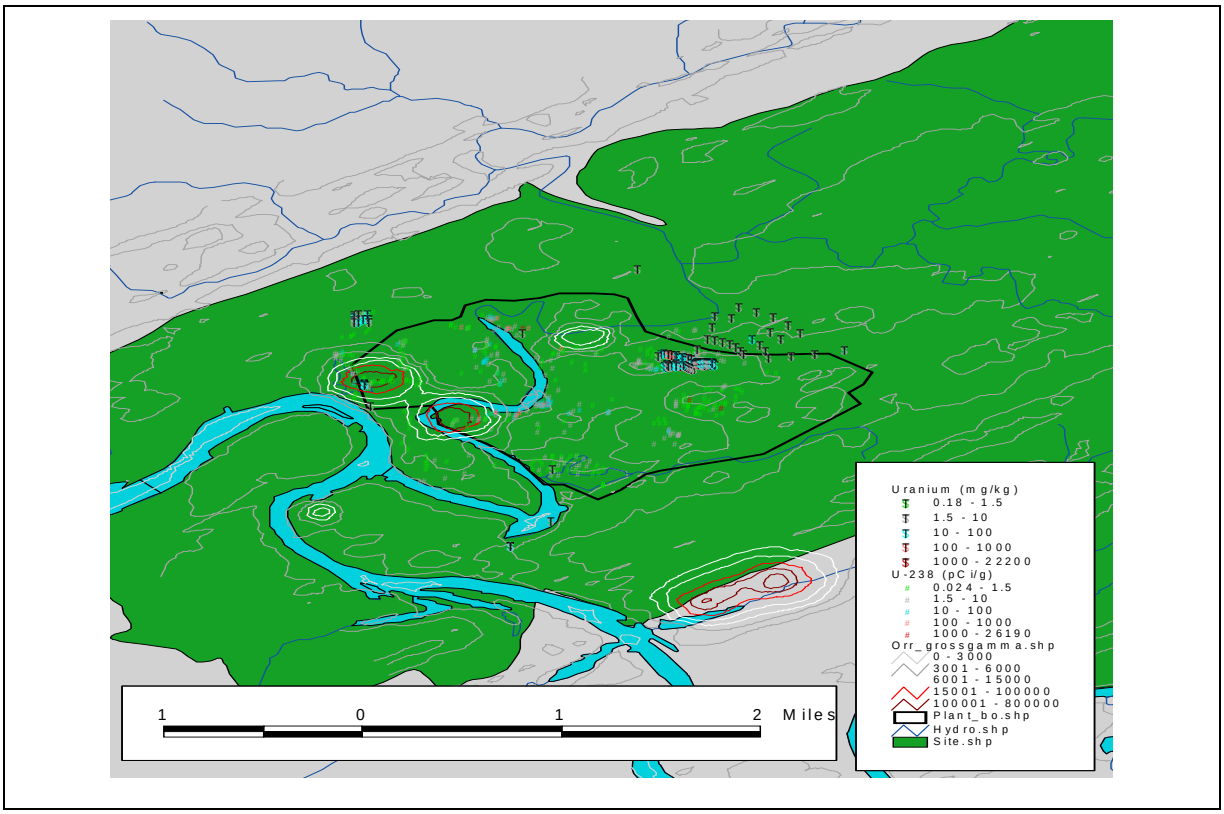
Twenty-four hour, 7-day, and 30-day values are maximum short-term concentrations for each year and are not reported for all years that fluorides were measured.

The minimal risk level (MRL) of 20 parts per billion (ppb) is for fluoride as hydrogen fluoride (HF). Although environmental measurements were fluoride, releases were most likely as HF. Fluorine is very reactive, and thus it will persist in the atmosphere in elemental form. Therefore, the MRL for HF is the most appropriate comparison value.

An aerial survey has detected both 1) the Chattanooga shale outcroppings on East Fork Ridge, which contain elevated concentrations of uranium and its decay products, and 2) a few small cesium-137 deposits along the Clinch River, detectible during low-water levels. TDEC/Oak Ridge Operations (ORO) has studied the Clinch River deposits and has deemed them a nonhazard (Storms and Rector 1997). Because the aerial surveys are sufficiently sensitive to detect sources that do not constitute a hazard, by implication they will readily detect gamma sources that do constitute a hazard. Except for a few known locations due to past or present operations, the off-site areas surrounding the ORR do not indicate areas of above-background gamma radiation.

Yet the uranium isotopes released from K-25/S-50 operations are mixed-emitting radionuclides. The emissions comprise mostly alpha particles with some gamma contribution. Although some gamma-emitting radionuclides were present in the recycled feed material (1952–1963 timeframe), the recycled uranium feed material was a relatively small proportion of the total uranium processed (Bechtel Jacobs Company LLC 2000). Consequently, K-25/S-50 air releases are an unlikely source of significant gamma radiation.

Figure 16. Contours of Aerial Gamma Survey and Uranium Soil Concentrations



Notes:

Areas of elevated gamma contour uranium soil concentrations are known disposal/remediation sites.

Total uranium is in mg/kg; U-238 is in pCi/g.

III.C.2.3. Uranium Soil Samples

Data from the Oak Ridge Environmental Information System (OREIS) has been electronically transferred to ATSDR. Relevant records from this dataset, including soil, air, and biota analyses, were for this assessment reviewed and evaluated relative to other data. More details on the OREIS data are contained in Section II.F.4.5. in this PHA.

On-site ORR soil samples collected on or adjacent to the K-25/S-50 facility include both chemical and radioactive uranium analyses. Figure 16 shows total uranium concentrations and U-238 activities in soil samples collected from 1983 to 2001 at specific locations. Nonradioactive total uranium concentrations (in mg/kg) are shown as triangular data points; U-238 activities (in pCi/g) are shown as circular data points. Although both elevated uranium concentrations and activities are found around the K-25/S-50 facility, most of the values represent background levels of uranium. Elevated uranium levels are primarily found at known waste disposal locations and are also found in some of the samples collected downwind (northeast) of the site boundary. Figure 16 shows the contours of aerial gamma survey and uranium soil sample concentrations.

III.C.3. Estimated Annual (Chronic) and Short-term (Acute) Doses and Concentrations (1944 to 2006)

III.C.3.1. Estimated Annual Radiological Doses and Concentrations

Past chronic (or annual) radiological doses and past air concentrations of uranium and fluoride were estimated using the Clean Air Act Assessment Package—1988 (CAP88-PC), an air dispersion/dose assessment model developed by the U.S. EPA and the DOE (Parks 1997) (see Table 10). Specific off-site air concentrations and annual radiological doses are calculated for the 1945 airborne releases from S-50 and for the 1963 airborne releases from K-25—the years with the highest annual airborne radionuclide emissions (see Table 5). This assessment is based on the assumption that if the year with the highest annual emissions (i.e., 1945 and 1963) did not represent a public health hazard, then neither did any other year with lower emissions. The estimated annual radiological doses to people residing in the vicinity of the K-25/S-50 site, labeled as "Individual Effective Equivalent Dose Rate" in mrem/year in Table 10, include all the air exposure pathways and all radionuclides (uranium 234, uranium 235, uranium 238, technetium 99, and neptunium 237) as shown in Table 3.[7] Doses in CAP88-PC are calculated as 50-year effective equivalent doses integrated over a 70-year lifetime such that ongoing exposures to long-lived radionuclides are included in the dose assessments. The doses are tabulated as annual effective doses.

Table 10. Estimated Annual Radiological Doses for the Maximum Release Years (K-25–1963; S-50–1945)

Source	Exposure Area	Release Year	Individual Effective Equivalent Dose Rate (mrem/year)	Total U Annual Air Concentration* µg/m³	Fluoride Annual Air Concentration** ppb
K-25	Sugar Grove	1963	3	0.0011	<5
	Union/Lawnville	1963	1	0.0003	<5
S-50	Happy Valley	1945	14	0.02	<5
	Union/Lawnville	1945	30	0.04	<5

Notes:

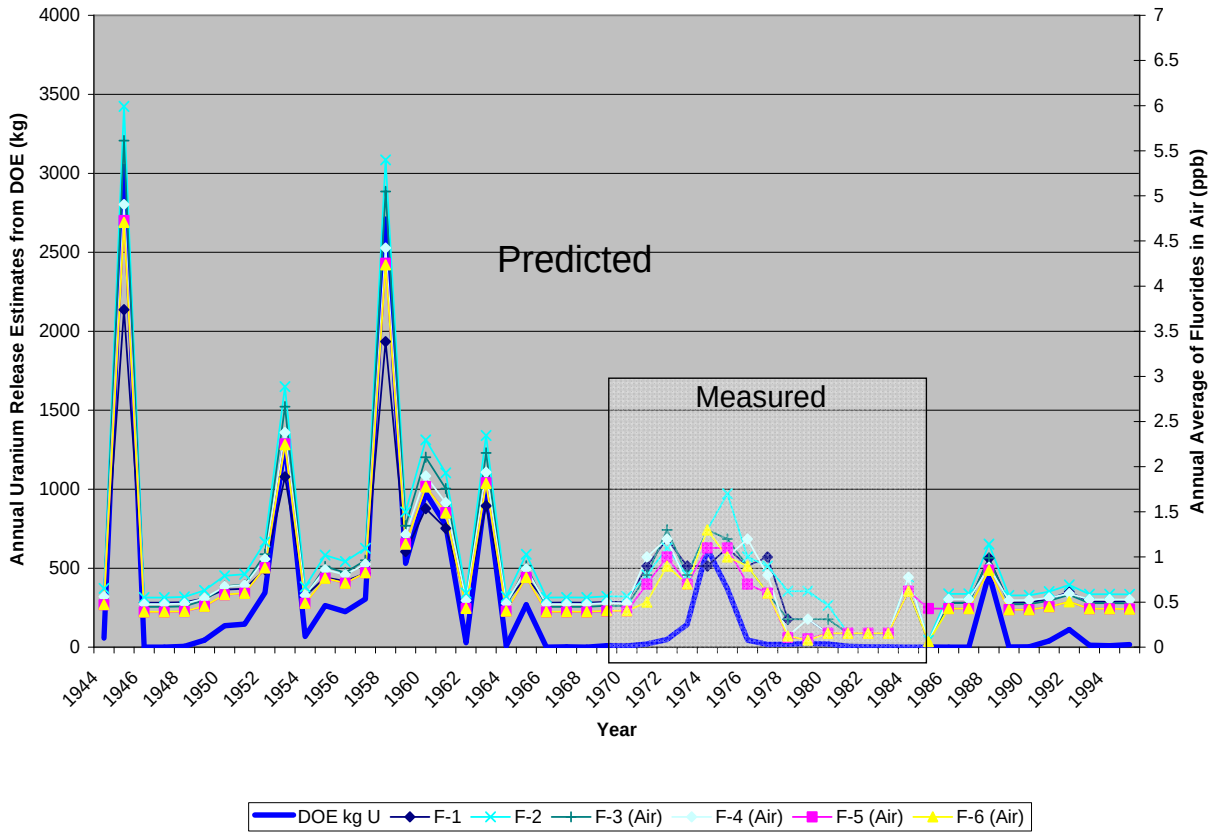
*CAP88-PC model output is pCi/m3 for each uranium isotope at each location; those results are divided by specific activity for each isotope and summed (U-234, U-235, and U-238) for a total U air concentration.

**Fluoride annual air concentration is from Figure 17.

The past chronic (annual) radiological doses and air concentrations of uranium and fluoride at discrete areas such as Union/Lawnville, Sugar Grove, and Happy Valley were modeled as specific distances and directions from the plume origin. Figure 14 shows these locations with their respective distances and directions from K-25 and S-50. The Happy Valley exposure area, however, was not affected by K-25 site releases, and the Sugar Grove exposure area was not affected by S-50 site releases. By the time of significant releases from the K-25 facility (around 1952 to 1953), the Happy Valley labor camp was abandoned (see Table 5). Similarly, during the S-50 facility's 1944–1945 operating period, the Sugar Grove community had not yet appeared.

[7] As previously mentioned, the very small quantities of Pu-239 included in the reactor tails account for less than one percent of the total radiation and therefore are not included in the radiological dose assessments.

Figure 17. Measured and Predicted Fluorides in Air at Selected Stations: Annual Averages



Notes:

Measured and predicted annual average fluoride air concentrations (ppb) at various locations around K-25.

Predicted concentrations are calculated using linear regression of measured fluoride concentrations with annual uranium emissions (in kg).

Correlation coefficients of these relationships vary from 0.5 to 0.7.

Fluoride air concentrations were measured from 1971 to 1985.

Although based on higher annual emissions, the doses from the K-25 release are lower than the doses from the S-50 release. The exposure areas for the K-25 release are approximately crosswind of the source area. By contrast, the Happy Valley exposure area is much closer to the S-50 source than to other areas, and the Union Valley/Lawnville area is downwind of a relatively strong south-southwest component (Figure F-2; K-1209 tower).

Furthermore, exposures to the Sugar Grove area are overestimated. This is because steep-sided Black Oak Ridge rises some 100 meters (330 feet) to separate the K-25 emission source from the Sugar Grove exposure area. Because dispersion from the CAP88-PC model does not accommodate this type of complex topography, the doses in the table below are a health-protective overestimate of likely doses to the Sugar Grove community. Section IV, Public Health Implications, discusses the public health implications of exposure to these estimated radiological doses, total uranium air concentrations, and fluoride air concentrations.

CAP88-PC uses site-specific annual weather data. These data include a frequency distribution of wind directions, velocities, and atmospheric stabilities. For the K-25 and S-50 facilities evaluation, ATSDR used hourly meteorological data from two on-site K-25 weather tower stations. Site-specific meteorological data for 1945 or 1963 are not available; thus, 2002 data from the L-1209 meteorological tower and 1999 data from the K-1208 meteorological tower were used as an historic release conditions proxy at S-50 and K-25, respectively (Figure 14). The dose assessment portion of the CAP88-PC model assumes a "rural default" for food consumption, and population estimates in this evaluation are the 1980 census data provided with the CAP88-PC model. See Appendix D for additional details of the CAP88-PC system, limitations, conservative assumptions, and the system's output for K-25/S-50 facility releases.

III.C.3.2. Agreement between Measured and Predicted Concentrations

To validate that the CAP88-PC modeling procedures could estimate off-site doses for the maximum release years of 1945 for S-50 and 1963 for K-25, ATSDR compared measured-and-modeled gross alpha concentrations during 1966–1993. This is the timeframe for which measured gross alpha data are available. The measured annual average gross alpha concentrations from monitoring locations HP-33 and HP-35 (see Table 7 and Figure 14) were compared with the estimated annual average gross alpha concentrations predicted using CAP88-PC and with the DOE and Task 6 K-25/S-50 emission estimates (see Table 5). Although the agreement between measured and predicted gross alpha concentrations was not exact, the overall trends showed that the CAP88-PC modeling procedures and the estimated emissions rates adequately predicted the environmental concentrations of radionuclides released from the facility. This agreement between measured and modeled gross alpha concentrations during the period when measured data are available confirms that the CAP88-PC modeling procedure may be used to estimate off-site doses for the earlier maximum release years. Appendix G contains further details on the measured-versus-predicted gross alpha concentrations for 1966 to 1983 at the HP-35 and HP-33 monitoring locations.

III.C.3.3. Estimated Fluoride Concentrations

Figure 17 shows the measured and predicted annual average fluoride air concentration (in ppb) at the six K-25 perimeter-monitoring stations. The annual average 1971–1985 air concentrations of fluoride are shown relative to the estimated annual uranium air emissions (in kg) measured at each of the six monitoring stations. The relationship between the estimated uranium emissions and measured fluoride air concentrations for the 1971–1985 timeframe can predict the annual average fluoride air concentrations for those years before and after fluoride was measured.[8] The correlation coefficients for those relationships vary from about 0.5 to 0.7. This indicates moderate agreement between estimated annual uranium emissions and annual airborne fluoride concentrations measured at the monitoring stations. To acknowledge that larger HF and fluoride releases occurred before 1971 is important (DOE 2000). But these releases were not measured; thus in the absence of actual air concentration data, ATSDR had to estimate off-site air concentrations. Consequently, uncertainties inhere in the pre-1971 measurements. Still,

[8] The predicted fluoride concentrations were estimated using the FORECAST function in an EXCEL spreadsheet. The relationship is a linear regression between known fluoride air concentrations and known uranium emissions in kg (DOE estimate).

ATSDR's worst-case assumptions account for those uncertainties by estimating the potential worst-case exposures that could have occurred during that period.

As shown in Figure 17, in 1945 the highest predicted yearly fluoride air concentration was about 6 ppb (7.2 $\mu g/m^3$). Note that the maximum uranium emission in kg at S-50 was in 1945, and that the correlations are based on emissions and measurements from the K-25 facility. Nonetheless, predicted, historic long-term airborne fluoride concentrations at the K-25 perimeter locations for the maximum K-25 release year are fewer than 6 ppb (1958; 2,711 kilograms of uranium). Also, as with the measured short-term fluoride concentrations in Figure 15, station F-2's downwind location meant that it had the highest predicted annual average fluoride concentrations. The fluoride monitoring location with the best correlation coefficient (0.74) was station F-6—considered by DOE as a background location (Union Carbide Corporation Nuclear Division 1974). In 1976, the maximum, measured short-term fluoride concentration (24-hour) was 10.9 ppb at the F-6 station, located about 8 km (~5 miles) upwind (northwest) of the K-25 facility.

For both the short-term (24-hour, 7-day, and 30-day) and annual average fluoride air concentrations, measured and predicted values at the six monitoring stations will be higher than the values in areas of potential off-site exposure. The accidental releases of UF_6 evaluated in the next section of the public health assessment use the RASCAL3 air dispersion model to evaluate further predicted HF concentrations at off-site areas.

III.C.3.4. Estimated Short-Term (Acute) Exposures (1944 to 1945)—Accidental or Episodic Releases

Past short-term (or acute) off-site concentrations and potential doses to uranium and HF from past accidental or episodic releases from the K-25/S-50 facility were estimated using the Radiological Assessment System for Consequence AnaLysis (RASCAL) 3.0. The NRC designed and developed this computer model specifically for radiological accident assessment. In this assessment of short-term releases and potential acute exposures, worst-case meteorological and exposure assumptions for the September 1, 1958 accidental UF_6 release were used to calculate radiological doses, uranium doses, and hydrogen fluoride concentrations in Sugar Grove and Union/Lawnville (see Table 11). The 1958 accidental UF_6 release represents the largest single release event (1,184 kilograms of UF_6) included in the available documents (Table 6). The radiological doses calculated using the RASCAL3 model are lung-specific equivalent doses in mrem.

This worst-case UF_6 release scenario assumes emission from the 23m-high roof vents and assumes that 100 percent of the UF_6 released was emitted to the atmosphere. As ATSDR does not have specific meteorological data for the time of this accidental release, the scenario assumes conditions that result in minimum plume dispersion and maximum off-site exposure (e.g., light winds, a stable atmosphere, no precipitation). And as the wind direction is similarly unknown, the assumption is that the wind could be toward either Sugar Grove (NNW) or Union/Lawnville (SSW). Also, these results ignore the effect of topography on plume dispersion; due to the effect of the 100m-Black Oak Ridge, doses/concentrations at Sugar Grove are likely to be much lower (Figure 7). This PHA's Public Health Implications section discusses the possible consequences of exposure to these estimated short-term concentrations and doses of uranium and UF_6.

Table 11. Maximum Potential Uranium Dose to Lung and Concentrations from the September 1, 1958 Accidental UF_6 Release (Plume Centerline)*

Distance (km)	Uranium Dose† (mrem)	Uranium Inhaled‡ (mg)	Uranium Concentration§ (µg/m³)	Hydrogen Fluoride Concentration¶ (ppb)
0.5	942	9.7	1,340	1,310
1.0	569	5.9	833	2,680
1.5	67	0.7	97	461
2.0	48	0.5	69	267
2.57 (Sugar Grove)	34	0.4	51	156
3.0	27	0.3	38	108
4.32 (Union/Lawnville)	12	0.1	17	27
5.0	8	0.1	11	14

Notes:

* Doses/concentrations are estimated using the RASCAL3 model and assume worst-case release conditions and meteorological and exposure assumptions. Note that effects could be toward either Sugar Grove or Union/ Lawnville, but for the same release event, not toward both.

† Acute inhaled lung dose equivalent (acute exposure equals 1 hour) based on a one time intake.

‡ Assumes inhalation rate of 1.2 m^3/hr.

§ Inhaled uranium dose in milligrams/inhalation volume m^3.

¶ Maximum 1-hour hydrogen fluoride concentration in parts per billion.

The RASCAL3 model was also designed to assess short-term or episodic emissions from gaseous diffusion plants and other nuclear facilities. Subprograms specifically evaluate the dispersion and atmospheric transformation of UF_6 to uranium oxides and HF in accidental release scenarios. For this analysis, the RASCAL model's relevant components use Gaussian models to describe the atmospheric dispersion of radioactive effluents from nuclear facilities. The RASCAL user's guide contains theoretical descriptions of the model components (NRC 2001). Appendix E includes additional details about the RASCAL3 model, the case summary, and analysis of this model's output.

III.D. Current and Future Releases from the East Tennessee Technology Park

Current and future exposures include any potential hazards that might be identified during ongoing remedial activities at the K-25 site. ATSDR's public health evaluation notes that no potential hazards—current or future—to off-site residents have been identified at this time, but site remediation continues. ATSDR recommends that DOE continue to take precautionary measures to prevent any off-site releases of contaminants potentially remaining at the K-25 site.

IV. Public Health Implications

IV.A. Introduction

This public health assessment (PHA) first addresses potential off-site (community) exposures to radioactive and nonradioactive hazardous substances. The substances were released to the atmosphere either from the Oak Ridge Gaseous Diffusion Plant (K-25) or from the former S-50 liquid thermal diffusion plant. This PHA then evaluates the potential for off-site community exposures to and potential health effects from atmospheric releases of K-25/S-50 hazardous substances. Table 12 is a summary of the public health implications from ATSDR's evaluation of past exposures.

This PHA's preceding sections have also defined and evaluated the periods, populations, and likely exposure scenarios for evaluating historic K-25/S-50 air emissions. Doses and concentrations have been conservatively estimated for both *short-term (acute)* and *long-term (chronic)* exposures to the communities most likely affected. Calculations of these potential doses and concentrations have been estimated and validated by site-specific environmental monitoring and meteorological data. Concerns and recommendations from community members have helped to formulate this PHA's specific questions and a means of answering them.

ATSDR defines an *acute exposure* as contact with a substance that occurs once or for only a short time (14 days or less). An *intermediate exposure* is defined as contact with a substance occurring for more than 14 days and less than 1 year (15–364 days). *Chronic exposure* occurs over a long time (365 days or more). See Appendix A for additional information.

The **Public Health Implications** section addresses the potential health effects associated with exposure to the estimated radiological doses and uranium and fluoride/HF concentrations. Section discussions compare the estimated doses and concentrations to levels at which potential adverse health effects have been observed. Section IV.D., Adequacy of Available Data for Public Health Determination, discusses how ATSDR uses health-protective exposure and modeling assumptions to accommodate uncertainties related to the available data and dose estimation processes. For detailed toxicological information on the substances discussed in the section below, please refer to ATSDR's toxicological profiles available at http://www.atsdr.cdc.gov/toxprofiles/index.asp.

Table 12. Summary of Public Health Implications from ATSDR's Evaluation of Past Exposures to K-25/S-50 Releases

Timeframe	Source	Date of Highest Release	Contaminant	Maximum Exposure Area	Exposure Duration	Estimated Dose/ Concentration	Comparison Value	Is the Dose/ Concentration Above or Below the Comparison Value?	Conclusion
Past (1944 to 2006)	S-50	1945	Radiological material	Union/ Lawnville	Chronic	30 mrem/year (effective dose)	100 mrem/year	Below	Past chronic exposure to K-25/S-50 site radioactive releases are not expected to result in adverse health effects.
	K-25	1958	Radiological material	Sugar Grove	Acute	34 mrem (equivalent dose to the lung only)	100 mrem/year	Below	Past acute exposure to K-25/S-50 site radioactive releases are not expected to result in adverse health effects.
	K-25	1963	Uranium	Union/ Lawnville	Chronic	0.04 µg/m^3	0.3 µg/m^3	Below	Past chronic exposure to airborne uranium releases from the K-25/ S-50 site are not expected to result in adverse health effects.
	K-25	1958	Uranium	Sugar Grove	Acute	51 µg/m^3	ATSDR has not derived health-based guidelines for acute uranium inhalation exposure	NA	Exposure to the estimated short-term exposure concentration is not expected to result in adverse effects, including kidney effects.
	K-25	1945	Fluoride*	Sugar Grove and Union/ Lawnville	Chronic	Fewer than 6 ppb (7.2 µg/m^3)	10.8 ppb (13 µg/m^3)	Below	Past chronic releases of fluoride were below levels associated with adverse health effects.
	K-25	1945	Hydrogen fluoride	Sugar Grove and Union/ Lawnville	Chronic	Fewer than 6 ppb (7.2 µg/m^3)	11.7 ppb (14 µg/m^3)	Below	Past chronic releases of hydrogen fluoride were below levels associated with adverse health effects.

Table 12 (continued). Summary of Public Health Implications from ATSDR's Evaluation of Past Exposures to K-25/S-50 Releases

Timeframe	Source	Date of Highest Release	Contaminant	Maximum Exposure Area	Exposure Duration	Estimated Dose/ Concentration	Comparison Value	Is the Dose/ Concentration Above or Below the Comparison Value?	Conclusion
	K-25	1975	Fluoride	Sugar Grove and Union/ Lawnville	Acute	26.3 ppb	20 ppb	Above	ATSDR cannot determine whether acute off-site exposure to fluoride could harm the public's health. Sufficient data will never be available to make a professional judgment about the level of health hazard from this exposure. The highest recorded short-term (24-hour) fluoride concentration was measured at monitoring station F-2, which is located along the northeast perimeter of K-25 about 0.5 miles from the release point. The closest residents are located more than 1 mile north-northwest from monitoring station F-2.

Table 12 (continued). Summary of Public Health Implications from ATSDR's Evaluation of Past Exposures to K-25/S-50 Releases

Timeframe	Source	Date of Highest Release	Contaminant	Maximum Exposure Area	Exposure Duration	Estimated Dose/ Concentration	Comparison Value	Is the Dose/ Concentration Above or Below the Comparison Value?	Conclusion
	K-25	1958	Hydrogen fluoride	Sugar Grove	Acute	156 ppb	20 ppb	Above	ATSDR cannot determine whether acute off-site exposure to hydrogen fluoride could harm the public's health. Sufficient data are not available to make a professional judgment about the level of health hazard from this exposure. The estimated worst-case hydrogen fluoride air concentrations are based on mathematical dispersion modeling that used conservative worst-case assumptions and modeled air data. To use these estimated worst-case concentrations is not appropriate as a basis for a health hazard category. The estimated concentrations are highly unlikely to have actually occurred and because of the high uncertainty in the modeled results.

Notes:

*Short- and long-term fluoride exposure was evaluated as hydrogen fluoride, which is the most likely form present and is a highly reactive respiratory irritant.

NA–not applicable

IV.B. Past Exposure (1944 to 2006)

ATSDR evaluated past chronic (annual) and acute (short-term) exposures to K-25/S-50 releases for nearby off-site communities (see text box). Both short-term and long-term exposures were assessed for ionizing radiation, uranium, hydrogen fluoride, and fluoride. The estimated concentrations and doses are presented below, and for each contaminant of concern are compared with health-protective comparison values.

Note particularly the many uncertainties involved in determining estimated doses for all potential historic exposures. The uncertainties include quantities released, release duration, and various persons' exact locations at the time of the September 1958 accident. To account for these uncertainties, ATSDR has relied on health-protective assumptions regarding contaminant dispersion and dose estimation. Section IV.D, Adequacy of Available Data for Public Health Determination, discusses limitations of the available data and of the dose estimation processes and explains why the resulting doses overestimate historical doses to the off-site communities.

ATSDR defines an *acute exposure* as contact with a substance that occurs once or for only a short time (14 days or less). An *intermediate exposure* is defined as contact with a substance occurring for more than 14 days and less than 1 year (15–364 days). *Chronic exposure* occurs over a long time (365 days or more). See Appendix A for additional information.

IV.B.1. Chronic (Annual) and Acute (Short-Term) Health Implications

IV.B.1.1. Ionizing Radiation

For the communities closest to the facilities, ATSDR estimated historical radiological doses from K-25/S-50 airborne releases for 1) the September 1958 largest documented accidental release, and 2) the largest estimated annual release. ATSDR also estimated a cumulative total dose by combining the highest short- and long-term doses for the community potentially receiving the highest off-site releases. Because all the estimated radiological doses were below relevant health comparison values, adverse health effects would not be expected.

IV.B.1.1.1. Chronic

For the year of maximum emissions, ATSDR estimated the highest annual radiological dose (fewer than 30 mrem/year) for the Union/Lawnville community. The 1945 S-50 off-site radiation exposure resulted in airborne releases of UF_6 and associated radionuclides (Np-237 and Tc-99). Doses will be commensurately less for years with smaller annual emissions. For annual, committed effective doses to the general population, the International Commission on Radiological Protection (ICRP) recommends a limit of 100 mrem/year (1 mSv) above background (ICRP 1991). This highest annual radiological dose of fewer than 30 mrem/year is also less than one third of

- U.S. Nuclear Regulatory Commission's (NRC) radiation dose limit,
- ATSDR's minimal risk level (MRL) of 100 mrem/year, and

- National Council on Radiation Protection and Measurements' (NCRP) recommended limit for the public (i.e., 100 mrem/year whole body dose equivalent for continuous exposure to external radiation, not including exposure from natural background and medical procedures).

No adverse health effects have been seen at the estimated chronic dose levels from ionizing radiation from the K-25/S-50 site, and no increased cancer risk would be expected (ICRP 1991; USEPA 1999).

IV.B.1.1.2. Acute

ATSDR evaluated potential radiological doses from the largest documented accidental or short-term releases. Following a 1958 accidental release from the K-25 facility, the largest estimated short-term dose (calculated as an inhaled lung dose equivalent) was fewer than 34 mrem to the Sugar Grove community. This estimated dose is approximately one-third of the 100 mrem/year dose limit recommended for the public by the ICRP, NRC, and NCRP, as well as ATSDR's MRL. Historic acute exposure to airborne releases of ionizing radiation from the K-25/S-50 facility is not expected to cause any adverse health effects.

IV.B.2. Chronic and Acute Cumulative Dose

The highest cumulative radiation dose from summing potential short-term and long-term doses for a specific exposure area (37 mrem/year for Sugar Grove) is below all relevant health comparison values.[9] ATSDR added the largest annual dose (whole-body effective dose) for the Sugar Grove community (3 mrem) to the largest short-term dose (34 mrem) to yield an annual cumulative dose to airborne releases from K-25/S-50 radiological contaminants (including U-234, U-235, U-238, Np-237, and Tc-99) at the area of highest off-site exposure. The highest cumulative dose from historic short- and long-term exposure is approximately 7.1 mrem/year—about one-tenth of the 71-mrem/year screening value (or 5,000 mrem over 70 years).[10] Estimated cumulative doses to other potentially exposed communities are also below the 71 mrem/year screening value and the 100 mrem/year dose limit recommended for the public by the ICRP, NRC, and NCRP, as well as ATSDR's MRL. Therefore, historic exposure to airborne releases of ionizing radiation from the K-25/S-50 facility is not expected to cause any adverse health effects.

ATSDR concludes that past acute and chronic exposure to radioactive materials in off-site media from K-25/S-50 airborne releases is not expected to result in adverse health effects.

IV.B.2.1. Uranium

ATSDR estimated historical uranium airborne releases from the K-25/S-50 site for the largest documented accidental release and for the largest estimated annual release for the communities

[9] The estimated annual radiological dose for the maximum release year (3 mrem/year) from K-25 (see Table 11) is added to the maximum dose from the September 1, 1958 accidental UF_6 release (34 mrem; see Table 11) from the K-25 site for the Sugar Grove community. Because the S-50 plant was no longer operational during the K-25 accidental release, the doses presented in Table 11 for the S-50 plant were not included in this summation.

[10] To sum the equivalent lung dose (short-term exposure) with the whole-body effective dose (long-term exposure), the lung dose is multiplied by the tissue-weighting factor of 0.12 and then added to the annual dose (ICRP 1977; 34 mrem x 0.12 = 4.1 mrem + 3 mrem= ~7 mrem/year).

closest to the facilities. ATSDR determined that historic airborne releases of UF_6 from the K-25 and S-50 facilities were not a hazard with respect to uranium's chemical toxicity. The highest estimated airborne uranium releases for both long- and short-term exposures were below levels at which, due to the chemical toxicity of uranium, adverse health effects have been shown to occur.

IV.B.2.1.1. Chronic

Elevated operational emissions from 1944 to 1995 resulted in long-term exposure to airborne uranium. The highest annual uranium release (as UF_6) from K-25 occurred in 1963. The maximum estimated annual uranium air concentrations for 1963 in an area of potential off-site exposure (Union/Lawnville) is 0.04 $\mu g/m^3$—about 10 times lower than the chronic-duration inhalation MRL (0.3 $\mu g/m^3$) for soluble uranium compounds. This MRL is averaged over a period of 1 year or longer. But exposure to an estimated uranium air concentration of 0.04 $\mu g/m^3$ over 1 year or longer is still unlikely to result in any adverse health effects attributable to uranium's chemical toxicity.

IV.B.2.1.2. Acute

The highest estimated short-term (1-hour, acute) off-site uranium air concentration at the nearest off-site exposure area was approximately 51 $\mu g/m^3$ (see Table 11). The exposure occurred in 1958, during an accidental release of hydrogen fluoride and particulate uranyl fluoride. On-site air concentrations could have exceeded 51 $\mu g/m^3$, although Sugar Grove and Union/Lawnville residents would not have been exposed to such elevated air concentrations. ATSDR has not derived health-based guidelines for acute uranium inhalation exposure—that is, an exposure occurring once or for only a short time (up to 14 days). Workers exposed during accidental releases (31 workers exposed during the Gore, OK accident) have succumbed to hydrogen fluoride toxicity (respiratory and irritant effects) without signs of uranium-induced kidney toxicity (exposures of these workers were estimated to range from 0.6 to 24 milligrams of uranium). Similar studies on Gulf War veterans with embedded uranium shrapnel show that even more than 10 years after exposure, kidney function is normal (McDiarmid et al. 2004). Thus, chemical effects of uranium on the kidney may occur from repeated exposures over a longer period of time and not from an acute exposure during an accidental release. And if people did not experience effects from hydrogen fluoride exposure during the accidental release, any concurrent uranium exposure affecting the kidney is unlikely. Exposure to the estimated short-term exposure concentration is not expected to result in adverse effects, including kidney effects.

In the past, to reduce the UF_6 concentration in the process gas system and to perform maintenance and inspection on process gas equipment, UF_6 was reportedly released at night through jets on top of the process buildings. These "midnight negative" releases potentially contained significant quantities of uranium and hydrogen fluoride. Still, the quantities released are likely to have been less than the 1958 accident and therefore are not considered a public health hazard.

ATSDR concludes that with respect to the chemical toxicity of uranium, historic airborne releases of UF_6 from the K-25 and S-50 facilities were not and are not a public health hazard. Further, because the conservative assumptions used in the modeling process likely overestimate

the real past concentrations, ATSDR has determined that both short- and long-term exposures to airborne uranium from K-25 and S-50 site releases would not be expected to result in adverse health effects.

IV.B.2.2. Fluoride and Hydrogen Fluoride (HF) from Normal K-25 Operations

Past, normal process operations could have exposed people living near the K-25/S-50 site to chronic (long-term) fluoride and hydrogen fluoride (HF) releases. From 1971 to 1985, airborne fluoride concentrations were measured at six stations around the K-25 site perimeter. ATSDR reviewed these measurements and concluded that people living in the communities closest to the K-25/S-50 site might have been exposed to long-term fluoride and HF released into the air during normal operations from the K-25/S-50 facility. But these exposures would have been at levels not expected to result in adverse health effects.

By contrast, acute (short-term) fluoride and HF exposure could only have resulted from accidents or controlled releases. (Appendix E contains details on an estimation of the HF accidental releases.) With regard to fluoride and HF released as UF_6 during historical accidents or equipment maintenance at the K-25 site, ATSDR scientists are not able to make a professional judgment about the level of health hazard from potential acute fluoride and HF exposure for people living near the K-25/S-50 site. ATSDR's worst-case estimate of off-site acute hydrogen fluoride concentrations is highly uncertain. ATSDR was also unable to locate sufficient environmental sampling data to estimate adequately any short-term, off-site (community) exposure.

IV.B.2.2.1. Chronic

Long-term HF air releases also occurred at the K-25/S-50 site. Uranium releases and ambient air fluoride concentrations are reasonably correlated at this site. Thus, for the years before monitoring data were available, ATSDR used the correlation between annual uranium releases and measured fluoride concentrations at the site perimeter to estimate concentrations from long-term fluoride exposure. Because of the increased distance from emission sources and the effects of topographic ridges between the emission sources and exposure areas, estimated concentrations at the site perimeter will overestimate concentrations at areas of potential exposure. ATSDR assumed that the highest annual HF release coincided with the highest annual uranium release. The highest estimated annual average fluoride concentration in air (fewer than 6 ppb in 1945) was at the F-2 station.

In August 2003, the California EPA (Cal-EPA; Office of Environmental Health Hazard Assessment) prepared a chronic toxicity summary for fluorides, including hydrogen fluoride. The critical effect identified was skeletal fluorosis, with a chronic inhalation reference exposure level of 14 $\mu g/m^3$ for hydrogen fluoride and 13 $\mu g/m^3$ for fluoride (Cal-EPA 2003). The estimated maximum annual exposure concentration of fewer than 6 ppb (7.2 $\mu g/m^3$) for people living around the K-25/S-50 facility is well below Cal-EPA's reference levels. As such, the fewer-than-6 $\mu g/m^3$ estimated long-term fluoride and hydrogen fluoride air concentrations and resulting exposures are not expected to result in adverse health effects.

IV.B.2.2.2. Acute

The highest recorded short-term (24-hour) fluoride concentration of 26.3 ppb was measured in 1975 at monitoring station F-2, located along the northeast perimeter of the K-25 site about 0.5 miles from the release point. At that time, the closest residents were more than 1 mile north-northwest from monitoring station F-2 and were separated from K-25 and monitoring station F-2 by Black Oak Ridge. ATSDR's MRL for acute inhalation exposure to hydrogen fluoride and fluorine is 20 ppb and 10 ppb, respectively. Concentrations below these values are not expected to cause adverse health effects. The 20-ppb MRL for HF in air is 25 times lower than exposures that caused mild upper respiratory tract inflammation in human volunteers exposed for 1 hour (Lund et al. 1999). The highest average level (time-weighted average) allowed by the Occupational Safety and Health Administration (OSHA) for HF in air for a 40-hour work week made up of 8-hour work days is 2.5 mg/m^3 (3 ppm or 3,000 ppb). The 20-ppb MRL for air concentrations of HF is 150 times lower than OSHA's occupational level.

ATSDR was unable to locate sufficient historical environmental monitoring data on fluoride and HF released as UF_6 during accidents or equipment maintenance at the K-25 site. Therefore, ATSDR estimated historic off-site acute hydrogen fluoride concentrations using accident records and mathematical dispersion modeling. To calculate acute exposure concentrations to HF, ATSDR used the short-term fluoride measurements, worst-case assumptions, and modeled dispersion estimates from the September 1, 1958, accidental release. The highest measured short-term (24-hour) fluoride concentration of 26.3 ppb occurred in 1975 at station F-2. The modeled short-term (hourly) HF concentrations of 156 and 27 ppb were estimated for the Sugar Grove and Union/Lawnville communities, respectively, for the September 1958 accidental UF_6 release (Table 11). Note too that because these estimated worst-case HF concentrations are based on health-protective assumptions, they are overestimated concentrations that for several reasons are unlikely to have actually occurred. First, the fate and transport mathematical model does not account for the complex topography of the K-25 site. Second, ATSDR does not have any record of the specific meteorological conditions at the time of this release, so the most conservative meteorological conditions were used to estimate concentrations. Third, ATSDR assumed that off-site exposure occurred outside, at the point of maximum HF concentration. Finally, ATSDR assumed that all of the UF_6 released was discharged to the atmosphere with no retention in the K-1131 building. Yet the high uncertainty in these estimated HF concentrations means use of such estimated concentrations as a basis for a health hazard category is inappropriate. Therefore, ATSDR cannot make a professional judgment about the level of health hazard from potential acute fluoride and HF exposures for people living near the K-25/S-50 site.

Insofar as other accidental releases are concerned, they involved smaller quantities and probably did not affect the off-site communities. For instance, smaller, short-term accidental or process releases such as "midnight negatives" and equipment purging are unlikely to have resulted in any adverse health effects to community residents.

Given this evaluation, ATSDR concludes that long-term fluoride and HF released during the normal operations of the K-25/S-50 facility did not pose a public health hazard for communities living near the K-25/S-50 site. ATSDR also concludes it is unable to determine whether short-term, off-site (community) exposure to fluoride and HF released during accidents or equipment maintenance at the K-25 site could harm the public's health—sufficient environmental sampling

data are not available to make a professional judgment about the level of health hazard from this exposure. ATSDR also modeled air data and estimated off-site acute hydrogen fluoride concentrations using conservative, worst-case assumptions. But because of the high uncertainty in these modeled estimates, using them to estimate worst-case concentrations as a basis for a professional judgment about the health hazard level is inappropriate.

IV.B.2.3. Uranyl Fluoride and Hydrogen Fluoride—Potential UF_6 Cylinder Releases

In December 2006, the UF_6 cylinders stored at ETTP were completely removed (Halen Philpot, ETTP UF_6 Cylinder Project Manager, Bechtel Jacobs Company LLC, personal communication, January 29, 2007). Before removal, no uranyl fluoride or hydrogen fluoride was released from the tanks.

IV.C. Current and Future Exposure

Current and future exposures include any potential hazards possibly identified during ongoing remedial activities at the K-25 site. ATSDR's public health evaluation has not identified potential current or future hazards to off-site residents, but site remediation continues. ATSDR recommends that DOE continue its precautionary measures to prevent any off-site releases of contaminants potentially remaining at the K-25 site.

IV.D. Adequacy of Available Data for Public Health Determinations

The public health evaluation in this PHA specifically addresses recommendations from a previous assessment of ORR uranium releases (*Uranium Releases from the Oak Ridge Reservation—a Review of the Quality of Historical Effluent Monitoring Data and a Screening Evaluation of Potential Off-Site Exposures*, referred to as the Task 6 report) and community health concerns related to the K-25 and S-50 facilities. Table 13 identifies the recommendations and concerns, the actions taken by ATSDR, and the findings associated with these issues.

The Task 6 report determined that K-25/S-50 uranium releases did not present a significant public health hazard to the Union/Lawnville community—the reference community in the Task 6 report. This determination, however, was based on estimated uranium release data and nonsite-specific meteorological data. The Task 6 report recommendations thus were directed toward 1) additional quantification of the uranium release estimates, 2) improvement of the atmospheric dispersion modeling through use of site-specific meteorological data, and 3) an evaluation of the uranium dispersion model's validity by comparing its findings with direct environmental monitoring data. The Task 6 report also included several recommendations to address the uncertainty inherent in this type of dose estimation process.

Table 13. Task 6 Public Health Issues, Actions, and Findings Addressed in this PHA

Recommendation or Concern	Action	Finding
Additional records research and data evaluation regarding S-50 plant operations and potential releases.	A reevaluation of S-50 releases was conducted using multiple years of site-specific meteorological data.	Health-protective dose estimates for S-50 releases are below levels constituting a public health hazard.
Review of additional data regarding unmonitored K-25 uranium releases.	Long-term analysis of estimated K-25 releases was compared with measured ambient gross alpha concentrations to assess adequacy of estimated emissions.	Measured gross alpha air concentrations are adequately predicted using estimated emissions and the CAP88-PC air dispersion model. Consequently, unmonitored releases are unlikely to represent a significant additional source component.
Refinement of the approach used to evaluate surface water and soil-based exposure concentrations. This refined approach could possibly involve shifting to a source term-based approach and use of additional measurement data.	Measured radionuclide concentrations compared with estimated concentrations predicted from air dispersion models. Radionuclides released to off-site surface waters are addressed in the *White Oak Creek Radionuclide Releases Public Health Assessment*. For copies of this assessment, please contact ATSDR toll-free at 1-800-232-4636.	Measured soil radionuclide concentrations are about 10 times less than the value used for Task 6 report calculations. Soil/ingestion concentrations in this PHA are based on the CAP88-PC deposition velocity (0.18 cm/sec).
Improved atmospheric modeling for K-25/S-50 by using wind data from multiple stations and years. Evaluation of the uncertainty associated with the air concentrations would provide upper and lower bounds of confidence in the estimates.	Improved atmospheric modeling conducted using site-specific stations and multiple years.	Doses/concentrations varied by about 20 percent over a 5-year period. Estimated doses predicted using worst-case meteorological conditions.
Improvement of the exposure assessment to include region-specific consumption habits and lifestyles, identification of likely exposure scenarios instead of hypothetical upper bound and typical assessments, and inclusion of uncertainty analysis to provide statistical bounds for the evaluations of risk.	Worst-case exposure factors used in estimating exposure doses at specific locations. Rural default consumption/exposure factors are health-protective.	Predicted, health-protective doses are below levels constituting a public health hazard. Consequently, there is no public health basis for further, probability-based analyses.
Refinement of the chemical toxicity evaluation, possibly to include other approaches/models and an uncertainty analysis.	Potential exposures/doses to uranium and fluoride/HF evaluated with respect to chemical toxicity.	Conservative, estimated doses/concentrations are below levels constituting a public health hazard. There is no public health basis for further, probability-based analyses.
The potential public health hazard posed by K-25/S-50 fluoride and hydrogen fluoride emissions.	Health-protective fluoride/HF concentrations estimated for areas of potential off-site exposure.	Fluoride and HF was released as UF_6 during accidents or equipment maintenance. ATSDR concluded that historic short-term exposures to the maximum estimated fluoride and HF concentrations released were unlikely, but possible. Yet because ATSDR does not have specific information to rule out these maximum calculated exposures, it is unable to determine whether this exposure could harm the public's health.

Table 13 (continued). Task 6 Public Health Issues, Actions, and Findings Addressed in this PHA

Recommendation or Concern	Action	Finding
Assessment of potential exposures from K-25 and S-50 emissions for the residents of the Happy Valley labor camp (circa 1944-47).	Potential doses to residents of Happy Valley estimated for S-50 releases.	Health-protective estimates of radiological and fluoride/HF doses or concentrations are below levels constituting a public health hazard.

In addition to the Task 6 report recommendations, the Oak Ridge community identified several other public health issues for this PHA to address. They include identification of a potentially exposed population that lived adjacent to the K-25/S-50 site at the Happy Valley labor camp, and potential exposures to fluorides/hydrogen fluoride released—together with uranium—from the K-25/S-50 site. ATSDR further believes that a complete public health assessment of historic, current, and future K-25/S-50 emissions must include potential exposures to the Sugar Grove community and evaluations of short-term incidental releases to all potentially exposed communities.

ATSDR has chosen to address the uncertainty in the emission estimates by determining whether the existing release estimates can predict adequately the measured air concentrations of uranium (as gross alpha). Using site-specific meteorological data, the CAP88-PC air dispersion model (see Appendix D) predicted with reasonable accuracy gross alpha concentrations at several monitoring locations, especially when those modeled predictions were compared with previous uranium release estimates. This agreement between the measured and predicted gross alpha air concentrations indicates both that the air dispersion model (using site-specific meteorological data) is a valid tool for assessing atmospheric dispersion, and that the emission estimates are reliable indicators of past emissions.

That said, this approach is limited; historical monitoring data are only available for a portion of the K-25/S-50 operating history. Yet the 18-year period for which gross alpha ambient air monitoring data are available appears adequate for determining both annual and long-term trends between measured and predicted air concentrations. Similarly, meteorological data are not available for all years. But again, a multi-year data comparison indicates reasonable agreement between years, and use of the most conservative weather year ensures the evaluation procedure is health-protective.

Information on the specific sampling and analytical methods used for historical monitoring (before about 1971) is likewise limited. Fluorides in air may be present in the gas phase (generally hydrogen fluoride) or in a particulate phase (ATSDR 2003). According to the 1975 environmental monitoring report (Union Carbide Corporation Nuclear Division 1976), airborne fluoride concentrations in the ppb range were collected for 24-hour periods with an 8-day frequency. Samples were collected in a caustic solution and analyzed with an ion-specific electrode. Although this method should capture both the HF and particulate fluoride compounds, it cannot discriminate the relative proportions. Whether this sampling and analytical methodology was consistent over the entire sampling period (1971–1985) is unknown. Because 24-hour samples were reported for 1971–1977 and 7-day samples were reported for 1978–1985, the duration of sample collection most likely changed. Annual averages, however, were reported for all periods.

Weekly airborne radionuclide samples for both gross alpha and gross beta were collected on filter paper, and radioactive decays were counted using “gross beta and gross alpha counting techniques” (Union Carbide Corporation Nuclear Division 1976). Although uranium releases from the K-25/S-50 facility would have been predominately gaseous UF_6, this compound is not stable in the atmosphere and would transform rapidly into uranium oxide particulates. The particulate filter sampling method then should provide adequate collection of airborne uranium.

If the gross alpha counting technique included decays in an appropriate energy range, this method will provide a reasonable estimate of airborne uranium particulates.

Both of the air dispersion models have another limitation: they do not consider the effect of topography on plume transport. But this is partially overcome by site-specific meteorological data, which reflect the influence of topography on measured wind directions and velocities. Also, because the net effect of the ridges surrounding the K-25/S-50 facility reduces contaminant transport to exposure areas on both slopes of the ridges, the resulting doses are health-protective overestimates. A related limitation of the measured monitoring data is that no sample stations are in the areas of potential exposure (Figure 14). The HP-35 station, however, is in the predominant downwind direction and should record maximum long-term concentrations. Again, because exposure areas are mostly isolated from K-25/S-50 air releases by ridges, the measured concentrations are potential exposure overestimates.

But while the estimated short-term and annual doses listed in Tables 8 and 9 are likely overestimates,[11] the estimated short-term doses from the largest accidental release are higher than the estimated doses from the largest annual release. This apparent discrepancy is because the short-term doses are lung-specific dose equivalents, while the annual doses are whole-body effective doses. To compare directly these doses, the short-term dose equivalents must be multiplied by a tissue-weighting factor. For lung doses this factor is 0.12 (ICRP 1977). Also, differences appeared in the particle deposition velocities used in the two dispersion models. The RASCAL3 model assumes a deposition velocity of 0.3 meter/second (m/s), while CAP88-PC uses a deposition velocity of 0.18 m/s. The higher deposition velocity will result in higher doses at close-in distances and lower doses at more distant locations.[12]

ATSDR has not attempted in this PHA to calculate any type of probability-based assessment of historical contaminant concentrations or doses. The health-protective assumptions used for estimating historical exposures render unlikely the detection of potentially adverse health effects by any other means. And even if effects were to occur, ATSDR's employed assumptions would mean that at worst, those effects would be relatively minor and temporary. In a recent analysis titled *Comparative Bias Associated with Various Estimates of Dose to Maximally Exposed Individuals*, the use of deterministic, health-protective screening assessments is supported as long as the estimated doses do not exceed the target criterion (Wilson and Hinton 2003). Similarly, the National Council on Radiation Protection and Measurements (NCRP) says that uncertainty analysis is unnecessary and, for environmental radiological doses of fewer than 2 rem (2,000 mrem), may even be misleading (NCRP 1996).

The 18-year relationship between estimated uranium emissions and measured gross alpha concentrations at the HP-35 location reveals several years in which estimated emissions overpredicted measured gross alpha concentrations (Figure G-1; 1973–1976 timeframe). Any probability-based assessment would then have to include the possibility that emissions were

[11] Specific accident reports indicate that large proportions (up to 90%) of released UF_6 were retained in the respective buildings and subsequently recovered. This evaluation of historic accidental releases assumes that 100% of material was emitted to the atmosphere.

[12] Deposition velocities for both RASCAL3 and CAP88-PC are fixed values and cannot be adjusted in the respective models.

lower than estimated (as well as higher). Every other assumed parameter would also have to include factors leading to higher atmospheric dispersion and lower overall exposures. And any probability-based analysis would only produce a wide range of lower doses than those estimated in this PHA—a further evaluation showing that historic exposures to K-25/S-50 air releases are without public health basis.

V. Health Outcome Data Evaluation

Health outcome data measure disease occurrence in a population. Common health outcome data sources are existing databases (e.g., cancer registries, birth defects registries, death certificates) that measure morbidity (disease) or mortality (death). Health outcome data can provide information on the general health status of a community—where, when, and what types of diseases occur and to whom they occur. By comparing disease occurrences in different populations over periods of years, public health officials can use health outcome data to look for unusual patterns or trends in disease occurrence. Health outcome data evaluations are descriptive epidemiologic analyses. They are exploratory, given that they might provide additional information about human health effects. They are useful, given that they might help identify the need for public health interventions (e.g., community health education). But health outcome data cannot—and are not meant to—establish cause and effect between environmental exposures to hazardous materials and adverse health effects in a community.

ATSDR generally considers a health outcome data evaluation when a plausible, reasonable expectation of adverse health effects is associated with observed levels of contaminant exposure. In this public health assessment on ORR fluoride and uranium releases, ATSDR determined that past radioactive and nonradioactive substances released from the K-25/S-50 site could have resulted in potential off-site exposures.

V.A. Criteria for Conducting a Health Outcome Data Evaluation

To determine how to use or analyze health outcome data in the public health assessment process, or even whether to use it at all, ATSDR solicits and receives input from epidemiologists, toxicologists, environmental scientists, and community involvement specialists. They consider the following criteria, based only on site-specific exposure considerations, to determine whether to include a health outcome data evaluation in a public health assessment:

- Is the exposure period determinable?
- Is the population that was or is now exposed quantifiable?
- Are the estimated exposure doses(s) and the duration(s) of exposure sufficient for a plausible, reasonable expectation of health effects?
- Are health outcome data available at a geographic level or with enough specificity for correlation with the exposed population?
- Do the validated data sources or databases have information on the specific health outcome(s) or disease(s) of interest? For example, are the outcome(s) or disease(s) likely to occur from exposure to the site contaminants, and are those data accessible?
- Does the site contain at least one current (or past) potential or completed exposure pathway?

Using the findings of this PHA's exposure evaluation, ATSDR has sufficiently documented completed past exposure pathways to airborne radioactive and nonradioactive hazardous substances. That documentation covered the years 1944 to 1995 and included people living in off-site communities—Union/Lawnville, Happy Valley, and Sugar Grove—near the K-25/S-50 site. The documented evidence of off-site acute and chronic exposure to uranium and ionizing

radiation indicates that estimates of past doses are below those associated with health effects (see Section IV, Public Health Implications). Acute exposure to hydrogen fluoride for the Sugar Grove and Union/Lawnville communities following the largest short-term or accidental UF_6 releases could have caused temporary respiratory irritation to sensitive persons living in these off-site areas. Historic concentrations, however, were probably much lower than those estimated here.

Past chronic and acute exposures to uranium and ionizing radiation are not expected to cause health effects. Past acute exposures to hydrogen fluoride for the Sugar Grove and Union/Lawnville communities are likely much lower than estimated. Thus, no further analysis of health outcome data is appropriate. Unless the level of estimated exposure is likely to result in an observable number of health effects, analysis of site-related health outcome data is not scientifically reasonable. And because such an estimate of exposure is not reasonable, the requirement to consider analysis of site-related health outcome data based on exposure is complete.

Responding to community health concerns is an essential part of ATSDR's overall mission and commitment to public health. Community concerns are important, and the public health assessment process must address them. The individual community health concerns addressed in the Community Health Concerns section (Section VI) of this public health assessment are concerns from the ATSDR Community Health Concerns Database related to issues associated with K-25/S-50 releases.

Area residents have voiced concerns about cancer. Citizens living in the communities surrounding the ORR have expressed many concerns to the ORRHES about a perceived increase in cancer in areas surrounding the ORR. A 1993 TDOH survey of eight counties adjacent to the ORR indicated that cancer was mentioned more than twice as often as any other health problem. The survey also showed that 83 percent of the surveyed population in the surrounding counties believed it was important to examine the actual occurrence of disease among residents in the Oak Ridge area.

To address these concerns, ORRHES requested that ATSDR assess health outcome data (cancer incidence) in the eight counties surrounding the ORR. ATSDR used data already collected by the Tennessee Cancer Registry. This assessment of cancer incidence is a descriptive epidemiologic analysis that provides a general picture of the occurrence of cancer in each of the eight counties. The purpose of this evaluation was to inform citizens living near the Oak Ridge Reservation area regarding cancer rates in their counties compared with the State of Tennessee. Note, however, that this evaluation only examines cancer rates at the population level—not at the individual level. The evaluation is not designed for specific associations between adverse health outcomes and documented human exposures, and it does not—and cannot—establish cause and effect.

A cancer incidence assessment evaluates the number of new cancer cases in a particular geographic area, such as a county, in a given timeframe. It provides information about the cancer rates in a community and is used to determine whether any unusual pattern or higher frequency of a disease is occurring within the community relative to a reference population, usually the state.

The results of the cancer incidence assessment released in 2006 showed that when compared with cancer incidence rates for the State of Tennessee, both higher and lower rates of certain cancers occurred in some of the counties examined. Most of the cancers in the eight-county area occurred at expected levels, and no consistent pattern of cancer occurrence was identified. The reasons for the increases and decreases of certain cancers are unknown. The document is available online at http://www.atsdr.cdc.gov/HAC/oakridge/phact/cancer_oakridge/index.html.

In addition, over the last 20 years, local, state, and federal health agencies have conducted public health activities to address and evaluate public health issues and concerns related to chemical and radioactive substances released from the Oak Ridge Reservation. For more information, see the Compendium of Public Health Activities at http://www.atsdr.cdc.gov/HAC/oakridge/phact/c_toc.html.

VI. Community Health Concerns

To address ORR health concerns raised by community members, ATSDR actively gathered comments and other information from people who live or work near the reservation. ATSDR is particularly interested in hearing from area residents and from civic leaders, health professionals, and community groups. In the appropriate ORR public health assessments, ATSDR will address their specific health concerns.

To improve the documentation and organization of community health concerns at the ORR, ATSDR developed a **Community Health Concerns Database** specifically designed to compile and track site-related community health concerns. The database allows ATSDR to record, to track, and to respond appropriately to all community concerns and to document ATSDR's responses to these concerns.

From 2001 to 2005, ATSDR compiled more than 3,000 community health concerns obtained from the ATSDR/ORRHES community health concerns comment sheets, written correspondence, phone calls, newspapers, comments made at public meetings (ORRHES and work group meetings), and surveys conducted by other agencies and organizations. After organizing these concerns in a consistent and uniform format, ATSDR imported them into the database.

Community health concerns addressed are those in the ATSDR Community Health Concerns Database regarding releases from the K-25 site and the former S-50 site. The following table contains summarized concerns and issues together with ATSDR's responses. The concerns and responses categories are

- Geographic areas of concern,
- Exposure pathway concerns,
- Health concerns,
- Concerns related to workers, and
- Concerns about fluoride [fluorine], hydrogen fluoride, uranium hexafluoride, uranium, and uranyl fluoride.

Community Health Concerns From the Oak Ridge Reservation Community Health Concerns Database

#	Summarized Concern/Issue	ATSDR's Response
Geographic Areas of Concern		
1	A community member's parents lived in Happy Valley from 1943 through 1948, and his sister and brother were born while his parents lived there. Both of his parents, who were now deceased, had suffered from cancer. He said that most of the people who lived in Happy Valley are dead now and some of the surviving former residents he had spoken with had some kind of cancer or their spouse had died with cancer. Have there been any studies such as dose reconstruction on this area and the people who lived at Happy Valley? He is concerned that his parents and others who lived in the Happy Valley area just east of DOE's K-25 Gaseous Diffusion Plant from 1943 through 1948 were at a high risk of developing illnesses due to exposures to chemicals released into the air and water from this plant. This community (comprised of DOE workers, DOE subcontract workers, and their families) was downwind from the K-25 plant and the community's water came from a treatment facility downstream from the plant. Will ATSDR be looking at water sources related to Happy Valley? What dangerous environmental exposures were his family members exposed to while living in Happy Valley?	To respond to concerns about possible past exposures for former residents of Happy Valley, ATSDR evaluated potential exposures to this community in this PHA. The State of Tennessee's Oak Ridge Dose Reconstruction did not include an evaluation of the Happy Valley community. Through, however, work group meetings and ATSDR's community health concerns database, ATSDR learned about the Happy Valley, Happy Valley West, Ford Bacon Davis, and Fercleve labor camps (see Figure 7)—established to house workers constructing the Oak Ridge Gaseous Diffusion Plant at K-25. Over 8,700 residents, including 5,600 workers and 3,100 dependents, lived at Happy Valley during its existence (about 1943–1947; but a community member's anecdotal observations suggest that Happy Valley may have been occupied as late as 1948.) Happy Valley was located in the lower reaches of East Fork Valley, near the main Gaseous Diffusion Plant at K-25. The westernmost portion of Happy Valley was between 1.0 and 1.5 miles further southeast of the K-25 Power House area and the former S-50 plant. Possible past exposures via the K-25 drinking water intake were evaluated in a separate public health assessment titled *White Oak Creek Radionuclide Releases*. ATSDR conservatively assumed that Happy Valley residents could have been exposed over a 7-year period (from 1944 to 1950). ATSDR did not identify any Clinch River monitoring data for radionuclides covering the period when Happy Valley was used as a housing area. In the absence of historical monitoring data, ATSDR used the 50th percentile of the modeled radioactivity concentrations in the Grassy Creek area of Clinch River as reported in the Oak Ridge Dose Reconstruction Task 4 report (available online at http://health.state.tn.us/CEDS/OakRidge/WOak1.pdf). ATSDR estimated an annual whole-body dose of 14 mrem for drinking water at Happy Valley in the past. That estimate is at least seven times lower than ATSDR's minimal risk level (MRL) for ionizing radiation of 100 mrem/year and the maximum dose limit recommended for the public of 100 mrem/year by the International Commission on Radiological Protection (ICRP), the U.S. Nuclear Regulatory Commission (NRC), and the National Council on Radiation Protection and Measurements (NCRP). Therefore, adverse health effects would not be expected to result from past exposures to drinking water at K-25 for Happy Valley residents. You can obtain copies of this PHA at http://www.atsdr.cdc.gov/HAC/oakridge/phact/white_oak/index.html or by calling ATSDR toll-free at 1-800-232-4636.

#	Summarized Concern/Issue	ATSDR's Response
1	*Continued* He is asking ATSDR to investigate this matter to determine the risks that his family members and other residents of Happy Valley were subjected to during 1943 through 1948. Dose reconstructions are based on historical events, performed to address public concerns about the cause of cancer among individuals. To achieve this goal in Oak Ridge, historical exposures will need to be traced to the initial establishment of ORR. If ORRHES attempts to determine whether past events during the years of maximum exposure in the community resulted in cancer or other diseases with a long latency period, another community member agreed, efforts should be made to locate persons who lived in the area at that time. These individuals should serve as the study population. A community member was initially unable to locate data about Happy Valley, but PHAWG assisted him in this effort. However, he needs more assistance in locating additional data to address his concerns about cancer-causing agents. Identifying a potential correlation between his parents' cancers and the environment is important due to his concerns about historical health effects, future generations, and a potential predisposition to the disease.	In this PHA, ATSDR evaluates historical air releases and examines possible exposures to contaminants released to the air from the former S-50 plant for Happy Valley residents. It is important to note that ATSDR only evaluated potential exposures to airborne releases from the former S-50 plant—not releases associated with the K-25 facility—for Happy Valley residents because the Happy Valley labor camp was abandoned before significant releases occurred from the K-25 facility (about 1952–1953). ATSDR used a worst-case scenario to evaluate potential off-site exposures, which used the maximum releases that occurred and assumed that all released material was dispersed to the outside atmosphere, in addition to many other conservative (protective) assumptions. Please see Tables 4 and 5, as well as Figure 13, for more information on this evaluation. ATSDR concluded based on estimated concentrations and doses, that historic chronic exposure to ionizing radiation, uranium, fluoride, and hydrogen fluoride, as well as acute exposure to ionizing radiation and uranium in airborne releases from the S-50 plant, would not be expected to result in adverse health effects. ATSDR concluded that acute exposures to the maximum estimated fluoride and hydrogen fluoride concentrations were unlikely but possible. ATSDR determined that sufficient data will never be available to make a professional judgment about the level of health hazard. In addition, ATSDR's estimated historic off-site acute hydrogen fluoride concentrations are not appropriate to use as a basis for a health hazard category—they are estimated worst-case concentrations, and they are highly unlikely to have actually occurred, given that they are based on modeled results with a high degree of uncertainty. Nonetheless, even based on these worst-case assumptions, exposures would have only been expected to possibly cause minor, temporary respiratory irritation in sensitive individuals. Furthermore, this evaluation of acute exposures is based on estimated releases occurring after Happy Valley had already closed. For more information on ATSDR's findings and public health evaluation of the Happy Valley community, please see Section III and Section IV, respectively, in this PHA.

#	Summarized Concern/Issue	ATSDR's Response
1	*Continued* In conducting the health statistics review (HSR), the community member urged ATSDR to research historic records to the extent possible. Due to TDOH's data gaps, he acknowledged that a wealth of information will be missing. For instance, the Tennessee Cancer Registry will not contain information regarding the 1940s transients. In a personal effort, he has been attempting to locate residents who lived in Happy Valley at the same time as his parents. In addition to conducting the HSR and other formal studies, he encouraged ATSDR to also collect qualitative data by interviewing persons. This approach can assist in identifying health effects among current and future residents in the communities of concern. He also asked ATSDR to refrain from limiting the HSR to 1990 census data.	ATSDR uses the public health assessment process to evaluate the public health implications of exposure to environmental contamination and to identify the appropriate public health actions or a study for particular communities. In public health assessments, ATSDR conducts a health effects evaluation. Scientists • Carefully examine site-specific exposure conditions about actual or likely exposures; • Conduct a critical review of available toxicological, medical, and epidemiologic information to ascertain the substance-specific toxicity characteristics (levels of significant human exposure); and • Compare an estimate of the amount of exposure (i.e., dose) to which people might frequently encounter at a site to situations that have been associated with disease and injury. This health effects evaluation involves a balanced review and integration of site-related environmental data, site-specific exposure factors, and toxicological, radiological, epidemiologic, medical, and health outcome data to help determine whether exposure to contaminant levels might result in harmful outcomes. The goal of the health effects evaluation is to decide whether harmful outcomes might be possible in the exposed population by weighing the scientific evidence and by keeping site-specific doses and concentrations in perspective. The output is a qualitative description of whether site exposure doses and concentrations are of sufficient nature and magnitude to trigger a public health action to limit, eliminate, or further study any potential harmful exposures. In addition, ATSDR will consider evaluating health outcome data if a plausible, reasonable expectation of adverse health effects is associated with the observed levels of exposure to contaminants. The PHA report presents conclusions about the actual existence and level of the health threat (if any) posed by a site. It also recommends ways to stop or reduce exposures. An overview of the PHA process is available at: http://www.atsdr.cdc.gov/training/public-health-assessment-overview/html/index.html. In this and all other public health assessments, during the public health assessment process ATSDR uses comparison values as screening tools. As explained above, the levels of contaminants associated with potential past exposures for Happy Valley residents are below levels where adverse health effects would be expected to occur. If the public health evaluation indicates that past doses are high enough for a plausible and reasonable expectation of adverse health effects, we would then conduct further in-depth health evaluations and consider a follow-up study, including an evaluation of health outcome data. Health outcome data are measures of disease occurrence in a population that can provide information on the general health status of a community. Common sources of health outcome data are existing databases (cancer registries, birth defects registries, death certificates) that measure morbidity or mortality. Public health officials use health outcome data to look for unusual patterns or trends in disease occurrence by comparing disease occurrences in different populations over periods of years. These health outcome data evaluations are descriptive epidemiologic analyses.

#	Summarized Concern/Issue	ATSDR's Response
1	*Continued*	ATSDR scientists generally consider health outcome data evaluation when there is a plausible, reasonable expectation of adverse health effects associated with the observed levels of exposure. Using the findings of the exposure evaluation in this PHA, ATSDR sufficiently documented completed exposure pathways to ionizing radiation, uranium, fluoride, and hydrogen fluoride for former Happy Valley residents. The documented evidence of off-site exposure to these contaminants indicates, however, that estimated doses and concentrations are below levels associated with health effects (see Section IV. Public Health Implications). Because past chronic and acute exposures to uranium and ionizing radiation were not expected to cause health effects, past acute exposures to hydrogen fluoride for the Sugar Grove and Union/Lawnville communities were likely much lower than estimated, and past exposures for off-site communities never occurred, no further analysis of health outcome data is appropriate. Analysis of site-related health outcome data is not scientifically reasonable unless the level of estimated exposure is likely to result in an observable number of health effects. And because such an estimate of exposure cannot be made, the requirement to consider analysis of site-related health outcome data based on exposure is complete (see Section V. Health Outcome Data Evaluation). Please see the response to the following concern for information on cancer and the statistics review conducted by ATSDR.

#	Summarized Concern/Issue	ATSDR's Response
2	There is a high incidence of cancer in the Union and Lawnville areas. How can a person get agencies to perform studies in a geographic area of concern?	Area residents living in the communities surrounding the Oak Ridge Reservation have expressed concerns to ATSDR and to the Oak Ridge Reservation Health Effects Subcommittee (ORRHES) about a perceived increase in cancer in areas surrounding the ORR. In 1993, the Tennessee Department of Health (TDOH) conducted a study of the eight-county area surrounding the reservation. According to the study, people mentioned cancer as a health problem more than twice as much as they did any other health problem. In addition, 83 percent of the population surveyed in the surrounding counties believed it was very important to examine the actual occurrence of disease among residents in the Oak Ridge area. To address these concerns, ORRHES requested that ATSDR assess health outcome data (cancer incidence) in the eight-county area (Anderson, Blount, Knox, Loudon, Meigs, Morgan, Rhea, and Roane) surrounding the reservation, which includes the Union and Lawnville areas. Therefore, ATSDR assessed *cancer incidence* (newly diagnosed cases of cancer) using cancer incidence data already collected by the Tennessee Cancer Registry for 1991–2000. This assessment of cancer incidence is a descriptive epidemiologic analysis that provides a general picture of the occurrence of cancer in each of the eight counties. The purpose of conducting this evaluation was to provide citizens living in the Oak Ridge Reservation area with information regarding cancer rates in their county compared with the state of Tennessee. This evaluation only examines cancer rates at the population level—not at the individual level. It is not designed to evaluate specific associations between adverse health outcomes and documented human exposures, and it does not—and cannot—establish cause and effect. The results indicated both higher and lower rates of certain cancers in some of the counties examined when compared with cancer incidence rates for the state of Tennessee. Yet no consistent pattern of cancer occurrence was identified. The reasons for the increases and decreases of certain cancers are unknown. The document is available online at http://www.atsdr.cdc.gov/HAC/oakridge/phact/cancer_oakridge/index.html. In addition to the eight-county area, ORRHES requested that ATSDR evaluate the cancer incidence rates for 49 specific census tract areas around the Oak Ridge Reservation. ATSDR was unable to conduct this analysis, however, because a high percentage of the addresses for several of the areas were either for post office boxes or rural routes, which did not allow the data to be incorporated into certain geographic areas. For further inquiries about cancer rates in your area of Tennessee, please contact the Tennessee Cancer Registry by phone at 1-800-547-3558 or by email at tncancer.registry@state.tn.us. If you are concerned about your risk of developing cancer, you should discuss this with your physician. For more information about cancer, visit the American Cancer Society's Web site at http://www.cancer.org or call the agency directly at 1-800-227-2345. You can also visit the National Cancer Institute's Web site at http://www.cancer.gov/ or call the agency directly at 1-800-422-6237.

#	Summarized Concern/Issue	ATSDR's Response
3	Members of the public want ATSDR to perform additional off-site sampling from the Gallaher Valley area and incorporate the data from the Roane County Gallaher Valley area (where the TSCA Incinerator is located) with the other data.	Regarding sampling at the Toxic Substances Control Act (TSCA) Incinerator, please refer to ATSDR's public health assessment on the TSCA Incinerator at http://www.atsdr.cdc.gov/HAC/oakridge/phact/tsca/index.html or contact ATSDR toll-free at 1-800-232-4636 to obtain a copy of the document. ATSDR is using the public health assessment process to evaluate previous studies and environmental data to determine whether releases of hazardous substances from the Oak Ridge Reservation could have affected the health of people in communities near the reservation. The public health assessment is the primary public health process ATSDR uses to • Identify populations off the site who could have been exposed to hazardous substances • Determine the potential health effects of exposure • Address the site-specific health concerns of people in the community • Recommend any needed follow up public health actions to address exposure • Communicate ATSDR's findings to the public ATSDR is conducting nine public health assessments to evaluate potential exposures to chemical and radiological off-site releases from the K-25, Y-12, and X-10 facilities. ATSDR uses conservative (protective) exposure assumptions to consider the closest populations to the sources and the highest possible contaminant concentrations. ATSDR uses these worst-case exposure scenarios so that potential exposures are not underestimated and to evaluate the populations that would be most affected by potential exposures. If ATSDR identified data gaps in sampling during the preparation of its public assessments at the Oak Ridge Reservation, then the agency would notify the U.S. Environmental Protection Agency (USEPA), the U.S. Department of Energy (DOE)—or both—and request the collection of additional data to fill those data needs. Thus, if ATSDR believed that additional sampling was necessary for any areas, then it would recommend that sampling be conducted. Given the agency's findings in this public health assessment, however, additional sampling is not necessary.

#	Summarized Concern/Issue	ATSDR's Response
Exposure Pathway Concerns		
4	Some water monitoring data indicate that tritium is present in East Tennessee Technology Park water samples. However, previous water sampling efforts did not include analysis for tritium.	Tritium is very difficult to extract from water samples because it is present in water form. Nonetheless, the measured tritium levels detected at ETTP are well below the regulatory limit (H Crabtree, TDEC Radiological Monitoring Program, ORRHES meeting minutes, October 22, 2002). The K-25 site has a water intake that withdraws water from the Clinch River, which is located at CRM 14.4 (ChemRisk 1999b). Please see Figure 3 for the location of the K-25 water intake. Although this intake is located on site at the reservation, through community concerns, Exposure Evaluation Work Group (EEWG, formerly referred to as the Public Health Assessment Work Group [PHAWG]) meetings, and discussions with DOE, ATSDR learned that this water intake provided domestic water to the Happy Valley community during its existence (1943–1947). The K-25 water intake also continues to be used today for potable water (non-domestic) on site at the Oak Ridge Reservation by the K-25 site, Beer Creek Industrial Park, and Building 9714 (ChemRisk 1999b). ATSDR evaluated off-site groundwater in its public health assessment titled *Evaluation of Potential Exposures to Contaminated Off-Site Groundwater from the Oak Ridge Reservation* (available at http://www.atsdr.cdc.gov/hac/pha/pha.asp?docid=1371&pg=0). In this document, ATSDR evaluated tritium and other contaminants of concern in on-site groundwater. ATSDR concluded that because of the close interaction between groundwater in the aquitard formations of Melton Valley and surface water, tritium detected in on-site groundwater migrates off the reservation via surface water—it does not leave the reservation via groundwater. For ATSDR's evaluation of exposures to off-site surface water releases of tritium and other radiological contaminants, please see the *White Oak Creek Radionuclide Releases Public Health Assessment.* You can obtain copies of this assessment by calling ATSDR toll-free at 1-800-232-4636 or from http://www.atsdr.cdc.gov/HAC/oakridge/phact/white_oak/index.html. For past exposures, ATSDR concluded that exposures to radionuclides, including tritium, released off site via surface water were not expected to result in adverse health effects. For current exposures, of the seven radionuclides detected in surface water released off site from White Oak Creek to the Lower Watts Bar Reservoir, hydrogen 3 (H 3, also known as tritium) reached the highest concentration (853 pCi/L) in the collected surface water samples. ATSDR concluded that the likelihood of adverse health effects from H 3 is extremely low; the concentrations were well below the EPA's current maximum contaminant level (MCL) for drinking water of 20,000 pCi/L of tritium.

#	Summarized Concern/Issue	ATSDR's Response
4	*Continued*	Also in the *White Oak Creek Radionuclide Releases Public Health Assessment,* ATSDR evaluated past potential exposures to drinking water via the K-25 water intake. For past exposures, ATSDR used conservative assumptions assuming that Happy Valley residents could have been exposed over a 7-year period (from 1944 to 1950). ATSDR estimated a past annual whole-body dose of 14 mrem for drinking water at Happy Valley. This is at least seven times lower than ATSDR's minimal risk level for ionizing radiation of 100 mrem/year and the maximum dose recommended for the public of 100 mrem/year by the International Commission on Radiological Protection (ICRP), the U.S. Nuclear Regulatory Commission (NRC), and the National Council on Radiation Protection and Measurements (NCRP). Therefore, adverse health effects would not be expected to result from past exposures to drinking water at K-25 for Happy Valley residents. The K-25 water intake continues to be used today for potable water by the K-25 site, Beer Creek Industrial Park, and Building 9714—all located on site at the Oak Ridge Reservation (ChemRisk 1999b). Chemical, radiological, bacteriological, and chlorine sampling of "finished water" from the treatment plant is regularly conducted pursuant to the state and EPA requirements. Because of public concerns voiced at a July 31, 2000, meeting, DOE–Oak Ridge Operations (DOE–ORO) conducted a special sampling effort that included testing for metals, radionuclides, and chemicals in water directly from the tap. More than 475 drinking water samples were taken and analyzed, and DOE-ORO concluded that drinking water at the K-25 site was "safe to drink." More information on this sampling effort is available at the DOE-ORO Reading Room at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee (DOE–ORO and CROET 2000). To view the drinking water quality report for this sampling effort, go to http://www.state.tn.us/environment/doeo/pdf/PSBroch.pdf. In addition, for 30 years under the Safe Drinking Water Act of 1974, the EPA has set health-based standards and specified treatments for substances in public drinking water systems. In 1977, EPA gave the state of Tennessee authority to operate its own Public Water System Supervision Program under the Tennessee Safe Drinking Water Act. Through this program, TDEC's Division of Water Supply regulates drinking water at all public water systems. As a requirement of this program, all public water systems in Tennessee individually monitor their water supply for EPA-regulated contaminants and report their monitoring results to TDEC (TDEC 2003a). The public water supplies in Tennessee are monitored for substances that include 15 inorganic contaminants, 51 synthetic and volatile organic contaminants, and 4 radionuclides. For EPA's monitoring schedules for each contaminant, go to http://www.epa.gov/safewater/pws/pdfs/qrg_smonitoringframework.pdf (USEPA 2004a). On a quarterly basis, TDEC submits the individual water supply data to EPA's Safe Drinking Water Information System (SDWIS) (TDEC 2003a). To look up information and sampling results for public water supplies in Tennessee, go to EPA's Local Drinking Water Information Web Site at http://www.epa.gov/safewater/dwinfo/tn.htm (USEPA 2004b).

#	Summarized Concern/Issue	ATSDR's Response
4	*Continued*	In addition, in 1996 TDEC's DOE Oversight Division started to participate in EPA's Environmental Radiation Ambient Monitoring System (ERAMS) drinking water program. As part of the Oak Ridge ERAMS program, TDEC collects samples from five facilities on the ORR and in its vicinity. These public water suppliers include the Kingston Water Treatment Plant (Tennessee River Mile [TRM] 568.4), DOE Water Treatment Plant at K-25 (Clinch River Mile [CRM] 14.5), West Knox Utility (CRM 36.6), DOE Water Treatment Plant at Y-12 (CRM 41.6), and Anderson County Utility District (CRM 52.5) (TDEC 2003b). Under the ERAMS program, TDEC collects finished drinking water samples from these five public water supplies on a quarterly basis and submits the samples to EPA for radiological analyses. In addition to tritium, samples are analyzed for other radionuclides including gross alpha, gross beta, gamma, radium, strontium, plutonium, uranium, and iodine. Monitoring has indicated that concentrations of radiological contaminants are below regulatory criteria. The schedule and contaminants sampled at the supplies are available at http://www.state.tn.us/environment/doeo/pdf/EMP2006.pdf. To find more information related to your drinking water supply or additional water supplies in the area, please call EPA's Safe Drinking Water Hotline at 1-800-426-4791 or visit EPA's Safe Drinking Water Web site at http://www.epa.gov/safewater.
5	The community needs the data from the secret well-monitoring done since the 1980s, including the surface and groundwater studies at Y-12 and K-25 as this data directly impacts the surrounding residents. Has the porosity of the limestone bedrock below K-25, Y-12, and X-10 been quantified?	ATSDR evaluated surface water and groundwater associated with off-site releases from the ORR in the Evaluation of Potential Exposures to Contaminated Off-Site Groundwater from the Oak Ridge Reservation. In this PHA, ATSDR evaluated contaminants released from the Oak Ridge facilities that have been detected in off-site groundwater. Available data indicate that off-site contamination has only occurred in monitoring wells and seeps/springs near Y-12 in Union Valley, and residential wells have been unaffected by ORR-related activities. Because nearly all groundwater beneath the ORR ends up as surface water before leaving the site, community exposure to contamination via off-site groundwater is unlikely. ATSDR scientists concluded that on-site groundwater does not pose a public health hazard because there is no completed exposure pathway for ingestion or direct contact with contaminated groundwater emanating from the ORR. Sufficient evidence supports that no human exposure to off-site contaminated groundwater has occurred, no exposures are currently occurring, and exposures are not likely to occur in the future. For specific information regarding the geology and hydrology of the ORR, please refer to Appendix B in the groundwater PHA (available at http://www.atsdr.cdc.gov/hac/pha/pha.asp?docid=1371&pg=0).

#	Summarized Concern/Issue	ATSDR's Response
6	Will the uranium releases to water and sediments be looked at?	Yes, ATSDR evaluated potential exposures to uranium via off-site releases of surface water and sediments In the *White Oak Creek Radionuclide Releases Public Health Assessment*. ATSDR evaluated potential off-site exposures for radionuclide releases, including uranium, from the Oak Ridge Reservation to the Clinch River and the Lower Watts Bar Reservoir. ATSDR concluded that adverse health effects would not be expected from potential past, current, or future exposures to uranium detected in off-site surface water or sediments. You can obtain copies of this assessment online at http://www.atsdr.cdc.gov/HAC/oakridge/phact/white_oak/index.html or by calling ATSDR toll-free at 1-800-232-4636.
7	I recall during the CIP-CUP upgrading program when converters (the huge pieces of equipment used in the gaseous diffusion process that contained the barrier materials that separated the uranium gasses) were removed from the system, taken to the K-1420 Decontamination Facility and cut open. All of the internal parts were removed to be replaced by new parts. Some of the parts were huge bowl-shaped aluminum pieces that riggers loaded onto flat-bed trailers and hauled to the peninsula at the K770 Salvage Yard. Bulldozers pushed the contaminated parts off the trailers onto the ground and later into huge piles. We saw large quantities of yellowish green product (enriched uranium) on and in these parts. Often the pieces were covered with uranium dust and sediments around the periphery and any rough parts or projections on them. We wondered and discussed among ourselves what happened to this enriched uranium when the rains washed it into Poplar Creek, which flowed into the Clinch River.	In the *White Oak Creek Radionuclide Releases Public Health Assessment*, ATSDR evaluated whether radionuclides, including uranium, released from the Oak Ridge Reservation could be harmful to people living along and using the Clinch River and the Lower Watts Bar Reservoir. ATSDR concluded that people who used or lived along the Clinch River or Lower Watts Bar Reservoir in the past, or who currently do so or will in the future, might have or might yet come in contact with radionuclides, including uranium, that entered the Clinch River or Lower Watts Bar Reservoir via White Oak Creek. ATSDR's evaluation of data and exposure situations for users of these waterways indicates that the levels of radionuclides in the sediment, surface water, and biota are—and have been in the past—too low to cause observable health effects. You can obtain copies of this assessment online at http://www.atsdr.cdc.gov/HAC/oakridge/phact/white_oak/index.html or by calling ATSDR toll-free at 1-800-232-4636.

#	Summarized Concern/Issue	ATSDR's Response
Health Concerns		
8	Members of the community who are not presently sick still worry that they will become sick in the future as a result of the very shortsighted approach to reindustrialization at the K-25 site.	Reindustrialization is the method being used at the former K-25 site, now known as the East Tennessee Technology Park (ETTP), to decontaminate and decommission buildings and transfer reusable buildings to the private sector. Initially, buildings containing too much contamination were scheduled to be demolished (TDEC 2000, 2004). Under the accelerated reindustrialization cleanup, however, all buildings that are not transferred to new owners will be demolished (TDEC 2004). As a result of reindustrialization at ETTP, there are workers employed at the ORR who are not associated with DOE operations. Thus, accessible contaminated areas become an issue because members of the public (not only DOE employees) who work at the reservation now have access to and are present at the ORR (TDEC 2004). ATSDR understands that there are concerns about exposures to contaminants remaining at ETTP for people working on site, such as radiation from buildings (Ledwidge 1999; TDEC 2004). Although worker health issues are a concern to ATSDR, the agency is only evaluating potential exposures related to ORR contaminants released off site to nearby communities from the main ORR facilities (K-25, Y-12, and X-10) in its public health assessments. Worker-related issues are under the purview of the National Institute for Occupational Safety and Health (NIOSH), a federal agency of the Department of Health and Human Services (DHHS) and part of the Centers for Disease Control and Prevention (CDC) that is responsible for conducting research and making recommendations to prevent work-related illness and injury. If you are concerned about exposures that might be occurring on site at ETTP, please contact NIOSH at 1-800-35-NIOSH (1-800-356-4674). Also, please visit DOE's Safety and Health Web site at http://www.energy.gov/safetyhealth/index.htm for information about various programs and contacts regarding the safety and health of DOE workers.
9	Treatment and testing needs to be provided to sick workers and residents at independent hospitals and by physicians who are not affiliated with DOE. Treatment and testing must be provided for workers who should not be working at the ORR's X-10, Y-12 and K-25 facilities because this is a Superfund site that is being cleaned up. One recommendation was to set up a cutting-edge treatment center for affected Oak Ridge residents.	ATSDR uses the public health assessment process to evaluate previous studies and environmental data to determine whether releases of hazardous substances from the Oak Ridge Reservation could have affected the health of people in communities near the reservation. The public health assessment is the primary public health process ATSDR uses to • Identify populations off the site who could have been exposed to hazardous substances, • Determine the potential health effects of exposure, • Address the site-specific health concerns of people in the community, • Recommend any needed follow up public health actions to address exposure, and • Communicate ATSDR's findings to the public.

#	Summarized Concern/Issue	ATSDR's Response
9	*Continued* A common place should be available where both workers and residents can go for help if they have the same types of exposures, such as nickel poisoning. A clinic is needed because DOE is not supporting the process of treating sick workers and physicians in Oak Ridge do not want to become involved in worker exposure controversies. I am a victim of K-25. If we help the people who live here now, then new residents and industry might come to Oak Ridge. However, the problems will continue to escalate if help is not provided to those who are here.	ATSDR worked with the Oak Ridge Reservation Health Effects Subcommittee (ORRHES) to ensure that the public health questions of people living in the Oak Ridge Reservation area will be answered. In response to community concerns regarding a clinic, the ORRHES Needs Assessment Work Group conducted a comprehensive program review of the various federal agencies to determine whether it is possible to establish an occupational/environmental clinic or another form of clinical intervention near the Oak Ridge Reservation. On August 27, 2002, the ORRHES made the following recommendation to ATSDR. "The Oak Ridge Reservation Health Effects Subcommittee (ORRHES) has determined that discussion of public health activities related to the establishment of a clinic, clinical evaluations, medical monitoring, health surveillance, health studies, and/or biological monitoring is premature. Thus, the ORRHES recommends that formal consideration of these issues be postponed until the ATSDR public health assessment (PHA) process identifies and characterizes an exposure of an off-site population at levels of health concern. If this exposure warrants follow-up public health activities, the ORRHES will then consider these issues in making its recommendations to ATSDR." This ORRHES recommendation is based on the review, evaluation, and understanding of the comprehensive program review presented by the Needs Assessment Work Group at the August 27, 2002, ORRHES meeting. The August 27, 2002, ORRHES meeting minutes are available on ATSDR's Web site at http://www.atsdr.cdc.gov/HAC/oakridge/meet/orr/m8_27.html. Also, please refer to the Environmental and Occupational Medical Resources Fact Sheet (at http://www.atsdr.cdc.gov/HAC/oakridge/factsheets/env_med_res.html) developed by the former ORRHES to provide guidance to persons seeking medical assistance for an environmentally- or occupationally-related illness or injury. This fact sheet provides information on the Association of Occupational and Environmental Clinics (AOEC) for persons who think something in the environment is causing an illness. To request assistance from AOEC, please call 1-888-347-2632 or access the AOEC Web site at http://www.aoec.org. Further, the U.S. Department of Labor is the lead agency in administering the Energy Employees Occupational Illness Compensation Program for former and current workers. You can obtain more information on this program at http://www.dol.gov/owcp/energy/.

#	Summarized Concern/Issue	ATSDR's Response
10	In addition to iodine 131 exposures from the RaLa process, what is the extent that thyroids of residents and workers could have been adversely affected by exposures to other contaminants (e.g., cumulative impacts from other radionuclides via the RaLa process; X-10 radionuclides released via other processes, thyroid-impacting contaminants at the three major facilities, and non-local exposures)? Fluoride and certain mixed chemicals possibly affect the thyroid in the same way as iodine. Thus, fluoride from K-25 could be a contributing factor to some of the thyroid problems. HF effects were quickly connected to the high rates of thyroid illness seen in the work force due to accumulation of mercury in the thyroid gland leading to thyroid cancer like problems normally associated with radiation damage.	Exposure to fluoride does not affect the thyroid in the same way as iodine. Exposure to radioactive iodine (Iodine 131 or I 131) can result in cancer to the thyroid, but exposure to fluoride has never been shown to result in thyroid cancer. Inhalation would have been the primary route of exposure for off-site residents to any fluoride released in the past from the K-25 site. According to ATSDR's 2003 *Toxicological Profile for Fluorides, Hydrogen Fluoride, and Fluorine* (available at http://www.atsdr.cdc.gov/toxprofiles/tp11.pdf), most scientific investigators do not consider it likely that cancer can result from fluoride inhalation. When ATSDR published its toxicological profile in 2003, no studies were located regarding cancer in animals, or endocrine effects in animals or humans, after inhalation exposure to fluoride, hydrogen fluoride, or fluorine. Since ATSDR published its toxicological profile, the National Research Council released a report in 2006 that evaluated potential health effects associated with fluoride exposure. Based on a review of several fluoride ingestion studies, the report stated that "several lines of information indicate an effect of fluoride exposure on thyroid function." However, the report noted that because of several complex factors (e.g., peripheral effects on thyroid function, difficulties related to exposure estimation in human studies), "it is difficult to predict exactly what effects on thyroid function are likely at what concentration of fluoride exposure and under what circumstances" (National Research Council 2006). The National Research Council recommended that studies of exposure to fluoride and endocrine effects be conducted on U.S. populations exposed to varying levels of fluoride. The National Research Council (2006) also looked at a potential association between cancer and fluoride exposure via inhalation, ingestion, and other routes, and determined that the "results are mixed, with some studies reporting a positive association and others no association." Specifically, based on data from studies on humans, genotoxicity assays, and in vitro bone cells, the evidence that fluoride could attribute to cancer is "tentative and mixed" (National Research Council 2006). In other words, the National Research Council (2006) report stated that the scientific literature "does not clearly indicate that fluoride either is or is not carcinogenic to humans."

#	Summarized Concern/Issue	ATSDR's Response
11	What health effect does depleted uranium have on the general public?	Natural uranium is actually a mixture of three types (or isotopes) of uranium: uranium 234 (U-234), uranium 235 (U-235), and uranium 238 (U-238). Chemically, these three types of uranium behave the same, but they are differing radioactive materials exhibiting different radioactive properties. Human activities, such as industrial processing of uranium, can change the ratios of the isotopes. Enriched uranium refers to when the fraction of U-235 is increased, whereas depleted uranium refers to when the portion of U-235 is decreased. Enrichment is an industrial process used to increase the amount of U-234 and U-235 and decrease the amount of U-238 in natural uranium. The product of this process is enriched uranium, and the leftover is depleted uranium. Enriched uranium is more radioactive than natural uranium, and natural uranium is about twice as radioactive as depleted uranium (ATSDR 1999a). Scientists have observed chemical effects from uranium in humans, such as signs of kidney disease and adverse effects on bodily tissues. Depleted uranium, however, is a weak radioactive substance not likely to cause cancer. In fact, no human cancer of any type has been observed as a result of exposure to depleted uranium. Nonetheless, there is a chance of developing cancer from any radioactive material like uranium, and uranium can also decay into other radioactive substances (e.g., radium) that can cause cancer in people who are exposed over long enough time periods. Still, according to ATSDR's *Toxicological Profile for Uranium*, "because the specific activities of … depleted uranium are low, no radiological health hazard is expected from exposure to … depleted uranium." Further, "there are no unequivocal studies that show that intake of … depleted uranium can induce radiation effects in humans or animals. The available information on humans and animals suggests that intake of uranium at the low concentrations usually ingested by humans or at levels found at or near hazardous waste sites is not likely to cause cancer" (ATSDR 1999a). Just like adults, children are also exposed to small amounts of uranium in their drinking water, food, and air. It is possible that children could have the same types of health effects as adults following exposure to large concentrations of uranium, such as kidney damage. We do not know, however, if children's susceptibility to uranium exposure is different from adults. Further, we do not know for sure if uranium exposure can adversely affect the human fetus, but animal studies have shown birth defects and an increase in fetal deaths following exposure to high uranium doses in drinking water (ATSDR 1999a). For more information on uranium, please see ATSDR's *Toxicological Profile for Uranium* available at http://www.atsdr.cdc.gov/toxprofiles/tp150.pdf. ATSDR's evaluation in this PHA shows that exposures to airborne uranium releases from the K-25 site are not expected to cause adverse chemical or radiological health effects in off-site communities. Please see Section III and Section IV of this public health assessment for more information on ATSDR's health evaluation of potential uranium exposures.

#	Summarized Concern/Issue	ATSDR's Response
12	It is a waste of resources to study uranium if there is no evidence that it is carcinogenic. Has cancer been observed as a result of exposure to uranium?	ATSDR does not agree that substances should only be studied if they are carcinogenic. In exposed persons, many substances can cause health effects other than cancer, and it is as important to use resources to study these substances as it is to study compounds found to cause cancer. Regarding uranium, it is a chemical compound that is also radioactive. Uranium mixtures include depleted, natural, and enriched uranium, all of which have the same chemical effect on the human body. Depleted uranium is less radioactive than natural uranium, and enriched uranium is more radioactive than natural uranium. Scientists have observed chemical effects from uranium in humans, such as signs of kidney disease and adverse effects on bodily tissues. Scientists have not, however, detected harmful radiation effects resulting from exposure to natural uranium, but some effects might be possible. Natural and depleted uranium are weak radioactive substances and are not likely to cause cancer from exposure to their radiation. In fact, no human cancer of any type has been observed as a result of exposure to natural or depleted uranium. However, there is a chance of developing cancer from any radioactive material like uranium, and uranium can also decay into other radioactive substances (e.g., radium) that can cause cancer in people who are exposed over long enough time periods. Just like adults, children are also exposed to small amounts of uranium in their drinking water, food, and air. It is possible that children could have the same types of health effects as adults following exposure to large concentrations of uranium, such as kidney damage. We do not know, however, if children's susceptibility to uranium exposure is different from adults. Further, we do not know for sure if uranium exposure can adversely affect the human fetus, but animal studies have shown birth defects and an increase in fetal deaths following exposure to high uranium doses in drinking water (ATSDR 1999a). For more information on uranium, please see ATSDR's *Toxicological Profile for Uranium* available at http://www.atsdr.cdc.gov/toxprofiles/tp150.pdf.

#	Summarized Concern/Issue	ATSDR's Response
13	What is the long-term effect on the community from 50-60 years of exposure to small concentrations of uranium, considering DOE operated multiple sites over the years with multiple emission sources?	Uranium was released from various large-scale operations, primarily uranium processing and machining operations at the Y-12 plant and uranium enrichment operations at the K-25 and S-50 plants. Phase I of the Tennessee Department of Health's (TDOH) Oak Ridge Health Study evaluated all past releases of hazardous substances and operations at the ORR. The study indicated that four substances had the largest potential risk for adverse health effects—uranium was not one of them. A brief summary of the Phase I Feasibility Study is provided in Appendix H of this PHA. Phase II of the health studies primarily consisted of a dose reconstruction study focusing on past releases of radioactive iodine, radionuclides from White Oak Creek, mercury, and PCBs. In addition to the full dose reconstruction analyses, the Phase II effort included further detailed screening analyses for releases of uranium and other toxic materials that had not been fully characterized in Phase I (a brief in Appendix H summarizes the *Screening-Level Evaluation of Additional Potential Materials of Concern, Task 7*). Because uranium was not initially given high priority as a contaminant of concern, a Level II screening assessment for all uranium releases was performed. Preliminary screening indices for Y-12 and K-25 were below the Oak Ridge Health Agreement Steering Panel (ORHASP) decision guide of one chance in 10,000. The ORHASP final report is available at http://health.state.tn.us/CEDS/OakRidge/ORHASP.pdf. To expand upon the efforts of the TDOH—but not to duplicate them—ATSDR conducted a review and a screening analysis of the department's Phase I and Phase II screening-level evaluation of past exposure (1944–1990) to identify contaminants of concern for further evaluation. Using this review and addressing community concerns about uranium, ATSDR conducted a public health assessment on Y-12 uranium releases (released in January 2004) and prepared this public health assessment on K-25 uranium (and fluoride) releases. ATSDR concluded, based on the TDOH's estimated doses for past exposures and ATSDR's evaluations in both of these public health assessments, that no adverse health effects would be expected from past off-site exposures to uranium released from the Y-12 plant or the K-25 site. In the Y-12 PHA, ATSDR evaluated both radiation and chemical aspects of long-term (chronic) past and current uranium exposure, and concluded that past and current off-site exposure to uranium from the Y-12 plant would not cause harmful health effects.Obtain copies of this public health assessment on the Internet at http://www.atsdr.cdc.gov/HAC/PHA/oakridgey12/oak_toc.html or by calling ATSDR toll-free at 1-800-232-4636. In this public health assessment, ATSDR evaluated historical exposures to chemical and radiation effects of airborne uranium releases from the K-25/S-50 site for the largest estimated annual releases for the communities located closest to the facilities. ATSDR determined that long-term exposure to the highest estimated airborne uranium releases would not be expected to result in adverse health effects. Please see Section III and Section IV in this public health assessment for more information on ATSDR's assessment of chronic exposures to uranium releases from the K-25/S-50 site.

#	Summarized Concern/Issue	ATSDR's Response
14	Because there is not much margin of safety between the RfD and a level at which severe effects can occur, it is likely that the reference dose for fluoride is not protective of all individuals.	ATSDR did not use the U.S. Environmental Protection Agency's (USEPA) reference dose (RfD) for fluoride in this public health assessment. The oral RfD is based on a cosmetic effect on teeth called dental fluorosis that develops because of excess fluoride exposure. The RfD of 0.06 mg/kg/day is based on a study on children consuming fluoride in their drinking water that found no observable adverse effect from consuming fluoride levels of 0.1–1.0 ppm in drinking water. Although there is much controversy over whether dental fluorosis is a toxic and/or adverse health effect, the EPA has determined that it is a cosmetic effect—not a toxic and/or adverse health effect. It is important to note that ATSDR would not use this RfD as a comparison value in this public health assessment because it is based on a cosmetic effect—not an adverse health effect—and it is based on oral exposure to drinking water. This PHA is evaluating adverse health effects resulting primarily from off-site inhalation exposures. Here ATSDR evaluated potential adverse health effects resulting from past chronic and acute off-site exposure to fluoride released from the K-25 site. ATSDR had not derived a chronic duration minimal risk level (MRL) for inhalation to fluoride or hydrogen fluoride because no chronic duration studies have been located. Thus for chronic exposures, ATSDR compared the maximum estimated annual exposure concentration of less than 6 ppb to the California EPA's (Cal-EPA) reference exposure level (REL) of 10.8 ppb (13 $\mu g/m^3$), a level at which the critical effect identified from chronic inhalation was skeletal fluorosis. Cal-EPA derived the chronic REL based on occupational exposure from a study (Derryberry et al. 1963) that found skeletal fluorosis (increased bone density) as the critical effect, with a lowest-observed-adverse-effect-level (LOAEL) of 1.89 mg/m^3 and a no-observed-adverse-effect-level (NOAEL) of 1.07 mg/m^3. After adjusting for exposure continuity and utilizing an intraspecies uncertainty factor of 10, the resulting REL was 13 $\mu g/m^3$. Please see http://www.oehha.ca.gov/air/chronic_rels/HyFluoCREL.html for more information on this Cal-EPA reference exposure level. To evaluate acute exposures, ATSDR compared the highest estimated acute fluoride concentration released from the K-25 site of 26.3 ppb to the MRL of 20 ppb for acute inhalation exposure to hydrogen fluoride. The MRL is based on a minimal LOAEL of 0.5 ppm (500 ppb) fluoride for upper respiratory irritation as reported in Lund et al. (1997). The 20 ppb MRL is 25 times lower than exposures that caused mild upper respiratory tract inflammation in human volunteers exposed for 1 hour (Lund et al. 1999). In addition, the MRL is 150 times lower than the highest average level allowed by the Occupational Safety and Health Administration (OSHA) for hydrogen fluoride in air for a 40-hour work week (8-hour work days) of 3,000 ppb. For more information on this MRL, please ATSDR's Toxicological Profile for Fluorides, Hydrogen Fluoride, and Fluorine (available at http://www.atsdr.cdc.gov/toxprofiles/tp11.pdf). For more information on these values, please see Section IV in this public health assessment. The values are based on health effects and are used to evaluate the public health implications of exposure to fluorides and related compounds released from the K-25/S-50 site.

#	Summarized Concern/Issue	ATSDR's Response
15	The true magnitude of the HF releases and long-term health effects are linked to asthma and lung damage, arthritis and bone/joint damage, neurological and foggy thinking effects, thyroid and parathyroid damage, birth defects, white and phage cell suppression, extreme fatigue, AND perpetuating DOE's entire "mysterious illness" cover up. It is deceptive for DOE public relations persons to list only the prompt symptoms of HF inhalation and leave off the other effects directly linked to K-25's mysterious illnesses.	According to ATSDR's Toxicological Profile for Fluorides, Hydrogen Fluoride, and Fluorine (available at http://www.atsdr.cdc.gov/toxprofiles/tp11.pdf) and the California Environmental Protection Agency's (Cal-EPA) Chronic Toxicity Summary: Fluorides Including Hydrogen Fluoride (available at http://www.oehha.ca.gov/air/chronic_rels/HyFluoCREL.html#download), no studies on chronic human inhalation exposure to pure hydrogen fluoride are available (ATSDR 2003; Cal-EPA 2003). In addition, no specific data are available regarding possible effects on human developmental or reproductive systems following inhalation of hydrogen fluoride (ATSDR 2003; Chemical Substances Bureau 1999). ATSDR welcomes the commenter to provide ATSDR with peer-reviewed, scientific literature that supports the health effects being mentioned as associated with long-term exposure to hydrogen fluoride to enable the agency to investigate this issue further. If nearby off-site communities were exposed to hydrogen fluoride released from the K-25/S-50 site, exposures would have likely occurred via inhalation. Chronic human exposure to low doses of hydrogen fluoride via inhalation has resulted in irritation and congestion of the nose, throat, and bronchi of lungs. In addition, there have been reports of increased bone density among workers who had long-term inhalation exposures to hydrogen fluoride (USEPA 1989). Though asthma and related respiratory effects have been reported in some worker studies, multiple exposures to respiratory irritants and other compounds make it difficult to determine whether these symptoms are the result of inhaled HF (Cal-EPA 2003). Nonetheless, given the evaluation in this public health assessment, adverse health effects were not expected to result in off-site communities, based on the estimated hydrogen fluoride concentrations released. In this public health assessment, ATSDR evaluated potential chronic exposures to fluoride and hydrogen fluoride (HF) released as a result of normal process operations from the K-25/S-50 site. ATSDR used a correlation between annual uranium releases and measured fluoride concentrations at the site perimeter to estimate concentrations from long-term exposure to fluoride for years before monitoring data were available. Estimated concentrations at the site perimeter will overestimate concentrations at areas of potential exposure due to the increased distance from emission sources and the effects of topographic ridges between the emission sources and exposure areas. ATSDR assumed that the largest annual HF release coincided with the highest annual uranium release. The highest estimated annual average fluoride concentration in air (less than 6 ppb in 1945) was at the F-2 station. A chronic toxicity summary prepared by the California EPA in 2003 for fluorides (including hydrogen fluoride) identified skeletal fluorosis as a critical effect with a chronic inhalation reference exposure level of 14 µg/m^3 for hydrogen fluoride and 13 µg/m3 for fluoride (Cal-EPA 2003). The estimated maximum annual exposure concentration, fewer than 6 ppb (7.2 µg/m^3) for people living around the K-25/S-50 facility, is well below Cal-EPA's reference levels. As such, ATSDR concluded that the estimated long-term fluoride and hydrogen fluoride air concentrations and resulting exposures are not expected to result in adverse health effects.

#	Summarized Concern/Issue	ATSDR's Response
16	HF is highly reactive and is cumulative in the body. Hydrogen fluoride retains in the body and less than one quarter is excreted. It accumulates over time of exposure and even low doses matter.	If nearby off-site communities were exposed to hydrogen fluoride released from the K-25/S-50 site, exposures would have likely occurred via inhalation. According to ATSDR's *Toxicological Profile for Fluorides, Hydrogen Fluoride, and Fluorine* (available at http://www.atsdr.cdc.gov/toxprofiles/tp11.pdf), when you breathe in air containing hydrogen fluoride, it enters your bloodstream quickly through your lungs. Contrary to the commenter's statement that "less than one quarter [of hydrogen fluoride] is excreted," almost all of the substance that enters your body via inhalation is quickly removed from the body in the urine. Some, however, is stored in bones and teeth. Human studies (Collings et al. 1951; Rye 1961) indicate that fluoride absorbed from inhaled hydrogen fluoride and fluoride dusts over an 8-hour work shift is excreted even during exposure, with urinary excretion peaking approximately 2–4 hours after cessation of exposure (about 10 hours following beginning of exposure) (ATSDR 2003).
17	Selenium-based glutathione (GSH) and the copper-zinc-based superoxide dimutase (SOD) are affected by hydrogen fluoride and fluorine ion effects. Glutathione is the main enzyme that clears toxic metals from the body and without it being at full potential toxic metals concentrations rise in the body leading to increases in free radical damage to cells via reactive oxygen damage (ROS). SOD is responsible for repair of the ROS damage to the cells. So, the main problem is both the loss of the mechanism that clears the toxic material and the loss of the mechanism that repairs the damage due to rise in the toxic materials driving high rates of ROS damage. There is a direct connection with the toxic releases from the DOE plants and damage to these two enzymes. The largest driver for the damage to these two enzymes turned out to be the high amounts of hydrogen fluoride emitted from the K-25 plant and the TVA coal power plants that were used to supply the coal power to run this plant. In the mid 1980s the news was clear that Oak Ridge plant operations were causing all kinds of excess illnesses in the workers and local population, as this is when the glutathione toxic metals clearance mechanism was discovered. The fluoride toxic effect and the other pollution that damaged the GSH levels raised the levels of toxic metals in person's bodies leading to levels of free radical damage and DNA damage seen in much older people.	ATSDR is not aware of any peer-reviewed scientific studies regarding the "damage or loss of the mechanism that clears the toxic material and the loss of the mechanism that repairs the damage due to rise in the toxic materials driving high rates of ROS damage" from exposure to hydrogen fluoride. ATSDR however welcomes the commenter to provide copies of or references to the studies. Glutathione (GSH) is known as a substrate in both conjugation reactions and reduction reactions, catalyzed by glutathione S-transferase enzymes in cytosol, microsomes, and mitochondria. Metals, including fluoride, react with GSH as part of the normal detoxification process. This can lead to a depletion of the available GSH pool. Oxidative stress is caused by an imbalance between the production of reactive oxygen and a biological system's ability to readily detoxify the reactive intermediates or easily repair the resulting damage. All forms of life maintain a reducing environment within their cells. The cellular redox environment is preserved by enzymes that maintain the reduced state through a constant input of metabolic energy. In chemical terms, oxidative stress is a large increase (becoming less negative) in the cellular reduction potential, or a large decrease in the reducing capacity of the cellular redox couples, such as GSH. The effects of oxidative stress depend upon the size of these changes, with a cell being able to overcome small changes and regain its original state. A particularly destructive aspect of oxidative stress is the production of reactive oxygen species, which include free radicals and peroxides. Most of these oxygen-derived species are produced at low levels by normal aerobic metabolism and the damage they cause to cells is constantly repaired. The best studied cellular antioxidants are the enzymes superoxide dismutase (SOD), catalase, and glutathione peroxidase. As previously mentioned, ATSDR is not familiar with any peer-reviewed scientific studies that evaluate the "damage or loss of the mechanism that clears the toxic material and the loss of the mechanism that repairs the damage due to rise in the toxic materials driving high rates of ROS damage" from exposure to hydrogen fluoride. ATSDR however invites the commenter to provide ATSDR with any scientific documents and/or references of these studies.

#	Summarized Concern/Issue	ATSDR's Response
Concerns Related to Workers		
18	Can the K-25 study on cyanide be re-done?	In the fall of 1995, employees at the K-25 site (now known as East Tennessee Technology Park, or ETTP) on the U.S. Department of Energy (DOE) Oak Ridge Reservation (employees of Lockheed Martin Energy Systems, Inc.) reported numerous health problems. These included suffering from sleeplessness, headaches, muscle aches, fatigue, muscle tremors, and depression. The employees requested that the National Institute for Occupational Safety and Health (NIOSH) investigate these problems in relation to possible cyanide exposure. Although worker health issues are a concern to ATSDR, worker-related issues are under the purview of NIOSH, a federal agency of the Department of Health and Human Services (DHHS) and part of the Centers for Disease Control and Prevention (CDC) that is responsible for conducting research and making recommendations to prevent work-related illness and injury. The study began in the fall of 1996 and took place over a 4-year period. Twenty-two employees were interviewed. Sensitive techniques, using the minimum detectable concentrations for long-term samples on the order of 1/5,000 of the most restrictive occupational exposure criteria, were used to collect air samples for cyanide. Even using these techniques, no cyanides (gaseous or particulate-borne) were detected in the air samples. The air sampling results show that the employees currently are not experiencing occupational inhalation exposures of hydrogen cyanide, cyanide salts, or any of a wide variety of gaseous or particulate-borne compounds containing the cyanide ion. Further, no evidence of any occupational exposures to these compounds by routes other than inhalation was found. A review of routine water sampling records indicates that cyanide is not a contaminant in the K-25 water supply nor is it a contaminant of concern for direct skin contact or ingestion because most of the concerned employees work in offices or similar "finished" indoor spaces. NIOSH concluded, based on the results of this evaluation, that no relationship could be established between the health problems reported by employees and chronic, occupational cyanide intoxication from exposures to those compounds or any other related substances. The findings of this investigation were presented during a public meeting held July 11, 1996, and were published in the following report (released in July 2000): *Blade LM and Worthington KA. Health Hazard Evaluation Report No. HETA-96-0071-2584, Lockheed Martin Energy Systems, Inc., U.S. Department of Energy Oak Ridge K-25 Site, Oak Ridge, Tennessee.* If NIOSH had concluded that workers were in fact being exposed to harmful levels of cyanide at the ETTP site, then additional study would be warranted. Based on the findings of the investigation, however, occupational exposures to cyanide were not identified. Therefore, an additional study would not be justified. For information on NIOSH's occupational energy research program, see NIOSH's Web site at http://www.cdc.gov/niosh/oerp/. For more information on workers studies, see ATSDR's Compendium of Public Health Activities at the ORR at http://www.atsdr.cdc.gov/HAC/oakridge/phact/c_toc.html.

#	Summarized Concern/Issue	ATSDR's Response
19	Unlike Y-12, information on people who were contaminated at K-25 and ORNL is being kept a secret. It seems nearly impossible for DOE to oversee 130 different contractors and to make sure that the health, safety, and environment is secure at all facilities. There have been recent worker injuries at Y-12, which were avoidable, and a release of fluorine from K-25. Supervision and oversight is needed of all of the contractors working at the ORR. Why are only K-25 workers being included for uranium screening in DOE's Worker Surveillance Program? Program eligibility criteria is needed to determine cancers that could be caused by radiation and cancers that could be caused by other types of exposures.	Although worker health issues are a concern to ATSDR, the agency is only evaluating potential exposures related to ORR contaminants released off site to nearby communities from the main ORR facilities (K-25, Y-12, and X-10) in its public health assessments. Worker-related issues are under the purview of the National Institute for Occupational Safety and Health (NIOSH), a federal agency of the Department of Health and Human Services (DHHS) and part of the Centers for Disease Control and Prevention (CDC) that is responsible for conducting research and making recommendations to prevent work-related illness and injury. NIOSH has an occupational energy research program to handle these worker-related issues. For information on this program, see NIOSH's Web site at http://www.cdc.gov/niosh/oerp/. If you are concerned about worker-related exposures occurring on the ORR, please contact NIOSH directly at 1-800-35-NIOSH (1-800-356-4674). In addition, specific federal regulations establish requirements for a radiological protection program, including monitoring requirements for personnel. A DOE Order delineates requirements to ensure worker protection in all environment, safety, and health disciplines. DOE's Office of Health has many responsibilities, including developing programs to protect the safety and health of workers at DOE facilities, conducting studies to determine potential health effects from exposure to hazardous substances, and developing regulations to address specific workplace hazards at DOE facilities. If you are concerned about these and other types of worker-related issues associated with the Oak Ridge Reservation, please contact DOE's Environment, Safety, & Health National Energy Policy Act (NEPA) Hotline at 1-800-472-2756.

#	Summarized Concern/Issue	ATSDR's Response
20	Fluorides cause health effects similar to pesticides. In fact, HF makes rat poison, calcium fluoride, in the body and is related to an insecticide used on fruits, cryolite. Workers are full of this poison. It would be fully expected to see long-term pesticide like illnesses for workers slowly poisoned with the same poison.	Calcium fluoride (CaF_2) or fluorite, commonly called fluorspar, is a mineral that is an important natural starting material for the production of fluorine chemicals, including fluorine, hydrogen fluoride, and sodium fluoride (ATSDR 2003). Cryolite, an insecticide, is used on many vegetables, fruits, and ornamental crops (USEPA 1996). Fluoride can enter the atmosphere in dusts and aerosols from the manufacture and use of pesticides, such as sodium fluoride, sodium fluorosilicate, barium fluorosilicate, and cryolite (NAS 1971a). Most occupational exposure to fluoride occurs because of inhalation of hydrofluoric acid fumes or dust from cryolite or fluorspar. Skeletal fluorosis is associated with long-term exposure to very high oral doses of fluoride or occupational exposure to cryolite ($A_1F_6Na_2$) dust, which would involve inhalation and oral exposure to fluoride (ATSDR 2003). Poorly soluble fluoride compounds, such as calcium fluoride, do not appear to be well absorbed. Studies have shown that very little (<10%) fluoride was absorbed in fasting subjects injected with calcium fluoride (Afseth et al. 1987; Trautner and Einwag 1987). Although worker health issues are a concern to ATSDR, the agency is only evaluating potential exposures related to ORR contaminants released off site to nearby communities from the main ORR facilities (K-25, Y-12, and X-10) in its public health assessments. ATSDR is not familiar with any scientific documentation supporting K-25 workers having high levels of cryolite in their bodies. ATSDR suggests that the commenter forward this information directly to the National Institute for Occupational Safety and Health (NIOSH) at 1-800-35-NIOSH (1-800-356-4674) or the Department of Energy's (DOE's) Environment, Safety, & Health National Energy Policy Act (NEPA) Hotline at 1-800-472-2756. If fluorides entered the atmosphere from the use of calcium fluoride and/or cryolite at the K-25 site, these concentrations would have been included in ATSDR's public health evaluation of off-site releases presented in Section III of this public health assessment. Please see that portion of the document for more information.

#	Summarized Concern/Issue	ATSDR's Response
21	There are some people who worked at the ORR facilities (X-10, K-25, and Y-12) and also live in the community. How do we separate exposures that could have occurred at the workplace from exposures that could have occurred from living in the community?	ATSDR is using the public health assessment process to evaluate previous studies and environmental data to determine whether releases of hazardous substances from the Oak Ridge Reservation could have affected the health of people in communities near the reservation. The public health assessment is the primary public health process ATSDR uses to • Identify populations off the site who could have been exposed to hazardous substances, • Determine the potential health effects of exposure, • Address the site-specific health concerns of people in the community, • Recommend any needed follow up public health actions to address exposure, and • Communicate ATSDR's findings to the public. As mentioned on several occasions, ATSDR does not evaluate workplace exposures and does not evaluate exposures on an individual, person-by-person basis. During the public health assessment process, ATSDR scientists review environmental data to determine whether people could have been or could be exposed to contaminants off the site. ATSDR assesses site-specific factors to determine if off-site exposure to contaminants in various media (air, biota, foodstuffs, sediment, and water) could have occurred or is occurring and evaluates if there is a completed exposure pathway for people to contact substances in these media. Because ATSDR's evaluations are based on contaminant concentrations in media and potential exposures to these media in the environment—not on actual detected levels of contaminants in a person's body—the site-specific exposure evaluations provide estimated doses to off-site releases that could have occurred in the community only. These evaluations do not take into account exposures potentially occurring in the workplace, which are under the purview of other agencies such as NIOSH and DOE.

#	Summarized Concern/Issue	ATSDR's Response
Concerns about Fluoride (Fluorine), Hydrogen Fluoride, Uranium Hexafluoride, Uranium, and Uranyl Fluoride		
22	A 2000 DOE report on K-25 states that fluorine/fluoride was used/released in massive amounts, but the report did not quantify the fluoride/fluorine releases or reference sources of information.	Even after a review of available documents and emission reports, DOE has not compiled any estimates of annual airborne fluoride releases (except as included in UF_6 releases). Thus no record of long-term fluoride emissions is available. Measurements of airborne fluoride concentrations, however, were collected at six sampling locations around the perimeter of K-25 from 1971 to 1985. To estimate concentrations from long-term exposure to fluoride for years before monitoring data were available, ATSDR used a correlation between annual uranium releases and measured fluoride concentrations at the site perimeter. The relationship between the estimated uranium emissions and measured fluoride air concentration for the 1971–1985 timeframe is used to predict the annual average fluoride air concentrations for years before and after fluoride was measured (see Table 9 and Figure 17). Estimated concentrations at the perimeter (Station F-2, at the perimeter of the K-25 site about 0.5 miles downwind or northeast of the K-25 facility) represent the point of maximum airborne fluoride concentrations. These estimates actually overestimate concentrations at areas of potential exposure due to increased distance from emission sources and the effects of topographic ridges between the emission sources and exposures areas. Locations of monitoring stations (F-1 to F-6) are presented in Figure 14 of the PHA. These records measured actual airborne fluoride concentrations over the sampling duration of either 24-hour or 6- to 7-day collection periods and the reported results include annual averages and maximum 7-day concentrations for each station. All of the monitoring results are reported in the annual environmental monitoring reports for the respective years. Figure 15 presents the measured airborne fluoride concentrations (in parts per billion, or ppb) for three stations (F-1, F-2, and F6) over a 16-year period (1971 to 1985). All of the annually averaged fluoride concentrations are less than 2 ppb and relatively uniform for the different years. The highest recorded value of 26.3 ppb for a 24-hour sample in 1975 at station F-2 is the highest measured air fluoride concentration for any station during any time, and it is about two times higher than any other measured value. As shown in Figure 17 of the PHA, the highest predicted yearly fluoride air concentration was about 6 ppb in 1945 at the K-25 perimeter locations. Also, as with the measured short-term fluoride concentrations, station F-2 had the highest predicted annual average fluoride concentrations due to its downwind location. The maximum measured short-term fluoride concentration (24-hour) at the F-6 station, located about 5 miles upwind (northwest) of the K-25 facility, was 10.9 ppb in 1976. ATSDR evaluated the potential past exposure pathways for fluorides (in both fluoride and fluorine forms) to reach off-site communities from the K-25/S-50 site. Fluoride exposures were evaluated for Union/Lawnville from the K-25 site for 1945 to 1995 and for the Sugar Grove community from the K-25 site for 1960 to 1995. Fluoride exposures from the S-50 plant from 1944 to 1945 were evaluated for both Happy Valley and Union/Lawnville. ATSDR also evaluated potential fluoride exposures for ETTP workers and the nearest off-site communities in the event that a natural disaster or an accident resulted in releases from the UF_6 cylinder storage yards. See Sections III and IV in the PHA for more information on this public health evaluation.

#	Summarized Concern/Issue	ATSDR's Response
23	Oak Ridge scientists have not reported some issues occurring in Oak Ridge, such as those involving depleted uranium. Depleted uranium shows up in soldiers; it is in their lymphatic systems and in their bones.	Natural uranium, enriched uranium, and depleted uranium are mixtures of primarily three uranium isotopes (U-238, U-235, and U-234; chemically similar but with a different number of neutrons). Natural uranium is, by weight, more than 99% U-238, 0.72% U-235, and 0.005% U-234. Enriched uranium is more than 0.72% U-235 by weight, and depleted uranium is less than 0.72% U-235 by weight. All three isotopes are radioactive but have different specific activities (that is, radioactivity per gram of material). U-238 has the lowest specific activity, and U-234 has the highest. The K-25 site no longer contains UF_6 cylinders holding depleted uranium hexafluoride. In December 2006, DOE completed its removal of the UF_6 cylinders from the six former cylinder storage yards (see Figure 12 in this PHA for the approximate location of the storage yards). From March 2004 to December 2006, DOE shipped approximately 6,000 UF_6 cylinders collectively containing about 119 million pounds of UF_6 off site to DOE's Portsmouth Gaseous Diffusion Plant (PORTS) in Portsmouth, Ohio (Halen Philpot, ETTP UF_6 Cylinder Project Manager, Bechtel Jacobs Company LLC, personal communication, January 29, 2007). Regarding on-site uses and exposures to depleted uranium, ATSDR's public health assessments will not be investigating these issues. Although worker health issues are a concern to ATSDR, the agency is only evaluating potential exposures related to ORR contaminants released off site to nearby communities from the main ORR facilities (K-25, Y-12, and X-10) in its public health assessments. Worker-related issues are under the purview of the National Institute for Occupational Safety and Health (NIOSH), a federal agency of the Department of Health and Human Services (DHHS) and part of the Centers for Disease Control and Prevention (CDC) that is responsible for conducting research and making recommendations to prevent work-related illness and injury. NIOSH has an occupational energy research program to handle these worker-related issues. For information on this program, see NIOSH's Web site at http://www.cdc.gov/niosh/oerp/. If you are concerned about worker-related exposures occurring on the ORR, please contact NIOSH directly at 1-800-35-NIOSH (1-800-356-4674). Federal regulations establish requirements for a radiological protection program, including monitoring requirements for personnel. A DOE Order delineates requirements to ensure worker protection in all environment, safety, and health disciplines. DOE's Office of Health has many responsibilities, including developing programs to protect the safety and health of workers at DOE facilities, conducting studies to determine potential health effects from exposure to hazardous substances, and developing regulations to address specific workplace hazards at DOE facilities. If you are concerned about these and other types of worker-related issues associated with the Oak Ridge Reservation, please contact DOE's Environment, Safety, & Health National Energy Policy Act (NEPA) Hotline at 1-800-472-2756.

#	Summarized Concern/Issue	ATSDR's Response
24	An undocumented release that occurred was the purge of the cascades at K-25, which occurred on a weekly basis. The purge of the cascade resulted in large and presumably undocumented releases of UF6. One massive release happened in the purge cascade that went on for days and dumped nearly a foot of UO_2F_2 on the floors, and HF vapors rained down clear to Ohio.	"A cascade is a system of gaseous diffusion process components arranged so as to enrich uranium in its U-235 component." During the gaseous diffusion process, uranium hexafluoride (UF_6) gas was put into a sequence of vessels that formed the "gaseous diffusion cascade." The "purge cascade" was part of the equipment used in the gaseous diffusion process. In the purge cascade, light gases (e.g., fluorine and air) were separated from the UF_6 that was being enriched. These light gases were removed so that they would not build up at the top of the cascade and prevent the flow of enriched UF_6 (ChemRisk 1999a). In the Task 6 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 6 report), the Task 6 team conducted an independent evaluation of airborne uranium releases from the K-25/S-50 site by reconstructing releases for certain time periods. As part of its evaluation, the Task 6 team analyzed actual monitoring data obtained from the purge cascade system to calculate purge cascade releases. In fact, according to the Task 6 report, purge cascade releases "…were the only airborne releases…historically monitored on a routine basis" from the K-25 site. Although the releases from the purge cascade constituted a small portion of the total uranium releases from the K-25 site, in fact, based on the Task 6 report's analysis, "…historical releases from the purge cascade were less than 1 percent of the total airborne uranium releases from K-25" (ChemRisk 1999a). More information on the Task 6 team's release estimates for the purge cascades is available in Section 2.2.3 of the Task 6 report available online at http://health.state.tn.us/CEDS/OakRidge/Uranium.pdf.
25	The K-29 incident resulted in large and presumably undocumented releases of UF_6.	On May 27, 1981, low-level radioactive uranium hexafluoride leaked from a compression cell at the K-29 facility. According to the Task 6 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 6 report) (at http://health.state.tn.us/CEDS/OakRidge/Uranium.pdf), the release from the cell following the high temperature reaction resulted in the atmospheric release of a total of 3.3E-03 curies of radioactivity and 2,000 grams of uranium (64 grams of uranium 235 and 1,936 grams of uranium 238). The same exact amounts were also released to the atmosphere during this incident because of a ruptured breached converter. Thus, a total of 4,000 grams of uranium were released to the atmosphere due to this compression cell leak at the K-25 facility. When preparing its 1999 report, the Task 6 team developed a database to track airborne uranium releases from the K-25 site for 1944 to 1995. Data were obtained from the K-25 Uranium Accountability Group, which was responsible for keeping track of uranium moving throughout the plant. The Task 6 team obtained material release reports that kept record of accidental and chronic environmental releases. These accidental atmospheric releases from the K-29 facility were recorded and the uranium release amounts were incorporated into the past release estimates in the Task 6 report (see Table E-1 on page E-32 of the report). In this public health assessment, ATSDR used the Task 6 report's estimates to assess potential past exposure for off-site communities to releases of UF_6 from the K-25 site. Thus, the estimated atmospheric releases from this 1981 accident are incorporated into the evaluations conducted by both the Task 6 team in its dose reconstruction and by ATSDR in this PHA. Please see the Task 6 report and Sections III and IV in this PHA for ATSDR's evaluation of these releases.

#	Summarized Concern/Issue	ATSDR's Response
26	There are places on the reservation that are unmarked burial grounds that contain uranium.	On November 21, 1989, the ORR was listed on the U.S. Environmental Protection Agency's (USEPA) final National Priorities List (NPL) because of many on-site operations that produced radioactive and nonradioactive wastes (EUWG 1998; USEPA 2004c). Various contaminants including uranium are present in old waste sites at the ORR. These waste sites constitute 5% to 10% of the reservation. Releases from these waste sites, as well as leaching caused by abundant rainfall and high water tables, have contributed to the radionuclide contamination of surface water, groundwater, soil, and sediments at the ORR (EUWG 1998). DOE is conducting remedial actions at the reservation under a Federal Facility Agreement (FFA) to ensure that appropriate clean up actions are selected, and to make sure that hazardous wastes associated with former and current ORR activities are adequately studied (USDOE 2003b). Remedial activities associated with wastes from K-25/S-50 activities are detailed in this public health assessment in Section II.C., and in Appendix C. To expand upon the efforts of the Tennessee Department of Health's (TDOH) Oak Ridge Health Studies, ATSDR scientists conducted a review and a screening analysis of the department's Phase I and Phase II screening-level evaluation of past exposure (1944-1990) to identify contaminants of concern for off-site exposure that required further evaluation. Pursuant to this review and its addressing of community concerns about uranium, ATSDR scientists conducted a public health assessment on off-site Y-12 uranium releases (released in January 2004; available at http://www.atsdr.cdc.gov/HAC/PHA/oakridgey12/oak_toc.html) and prepared this public health assessment to evaluate off-site K-25 uranium (and fluoride) releases. In addition, ATSDR evaluated off-site releases of radioactive uranium in its *White Oak Creek Radionuclide Releases Public Health Assessment* (available at http://www.atsdr.cdc.gov/HAC/oakridge/phact/white_oak/index.html) and the potential for off-site uranium releases via groundwater (available at http://www.atsdr.cdc.gov/HAC/oakridge/phact/groundwater/index.html) in a PHA titled *Contaminated Off-Site Groundwater from the Oak Ridge Reservation*. For copies of these other assessments, please contact ATSDR toll-free at 1-800-232-4636. It is important to note that although uranium is present on the reservation, the public does not have access to these areas. ATSDR is evaluating releases that could potentially leave the reservation and affect off-site communities—not contaminants that remain on site. DOE has and continues to conduct remedial activities to remove and/or contain the wastes in these areas to prevent off-site contaminant migration. In our public health assessments for the Oak Ridge Reservation, ATSDR assesses remedial activities that have occurred at the reservation and evaluates any on-site wastes (remaining in burial grounds and other areas) that could travel off the reservation to off-site communities.

#	Summarized Concern/Issue	ATSDR's Response
27	There are millions of tons of uranium kept in UF_6 storage tanks at the ORR.	The K-25 site no longer contains UF_6 cylinders holding depleted uranium hexafluoride. In December 2006, DOE completed its removal of the UF_6 cylinders from the six former cylinder storage yards (see Figure 12 in this PHA for the approximate location of the storage yards). From March 2004 to December 2006, DOE shipped approximately 6,000 UF_6 cylinders collectively containing about 119 million pounds of UF_6 off site to DOE's Portsmouth Gaseous Diffusion Plant (PORTS) in Portsmouth, Ohio (Halen Philpot, ETTP UF_6 Cylinder Project Manager, Bechtel Jacobs Company LLC, personal communication, January 29, 2007).
28	You need to recognize and accurately report that the fluoride component is one of the biggest industrial problems here today in Oak Ridge.	In conducting public health assessments, ATSDR scientists are evaluating and analyzing the information, data, and findings from previous studies and investigations to assess the public health implications of past, current, and future exposures. For our work at the Oak Ridge Reservation, ATSDR's role is to evaluate potential exposures to fluoride and other contaminants potentially released from the reservation, to assess the possible public health impacts of potential exposures on off-site residents, and respond to community concerns regarding the releases and health effects associated with these contaminants. Our mission is not, however, to investigate and report industrial issues concerning the Oak Ridge Reservation. Instead, our assessments are health-based and our goal is to investigate potential public health hazards that might exist from possible releases from the ORR to off-site areas. ATSDR uses the public health assessment process to • Identify populations (groups of people) off the site who could have been exposed to hazardous substances at levels of health concern, • Determine the public health implications of exposure, • Address the site-specific health concerns of people in the community, • Recommend any needed follow-up public health actions to address exposure, and • Communicate ATSDR's findings to the public.
29	In addition to Oak Ridge residents, there are quite a few people living in surrounding areas who are concerned about fluoride and fluorine products.	Many community members, from Oak Ridge and other surrounding areas, notified ATSDR of concerns about potential fluoride and fluorine products released from the Oak Ridge Reservation. Fluoride and fluorine products were not evaluated previously by the state in its 1993 *Phase I of the Oak Ridge Health Study—Dose Reconstruction Feasibility Study* because there is no evidence these products cause cancer or other chronic health effects. These substances are primarily associated with acute (short-term) health effects, which was not the focus of the state's evaluations. To address these community concerns, in this public health assessment ATSDR evaluates the public health implications for off-site exposures to fluorides and related compounds (including hydrogen fluoride and uranyl fluoride) released from the K-25/S-50 site in the past. Please see Sections III and IV in this public health assessment for ATSDR's evaluation of potential exposures to these substances released from the K-25/S-50 site.

#	Summarized Concern/Issue	ATSDR's Response
30	Why did the State not specifically look at fluorine, fluoride and UF_6? He felt that the State of Tennessee's screening process for past exposures was wrong, noting that fluoride gas converts to HF, which penetrates through the skin to the bone. Reports used for the state's feasibility study and dose reconstruction did not qualify fluorine or fluoride releases or reference sources of information. Fluorides should have received more attention during the Dose Reconstruction. No systematic effort was made during the Oak Ridge Dose Reconstruction or since the effort was completed to go back with additional information and make sure that nothing was missed or not assessed quantitatively. Fluorine/fluorides definitely need further attention based on the amount now known to have been released. There was avoidance in putting hydrogen fluoride from the screening process into the deeper ORHASP investigations and this then keeping the biggest of Oak Ridge problems out of public sight.	In its 1993 *Phase I of the Oak Ridge Health Study—Dose Reconstruction Feasibility Study*, the state identified fluorine and fluoride compounds as substances released from the K-25 site and considered the potential of these releases to impact the health of people living near the reservation. According to the feasibility study, the state did not evaluate fluorine and fluoride compounds further because these substances are primarily associated with acute exposures—they are not generally associated with cancer or other chronic, long-term health effects, which the state was investigating. Please see Appendix H for the brief on the 1993 Phase I feasibility study. Copies of the Tennessee Department of Health reports are available at the DOE Information Center located at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee (telephone number: 1-865-241-4780). Nonetheless, ATSDR added these substances to its list of contaminants to investigate further, and as a result, ATSDR evaluates the public health implications for off-site exposures in the past to fluorides and related compounds (including hydrogen fluoride and uranyl fluoride) released from the K-25/S-50 site in this public health assessment. ATSDR added these substances to its list of public health assessments because of the agency's experience at the Paducah Gaseous Diffusion Plant in Kentucky that had many of the same applications of fluoride products as K-25 and because individuals in the community expressed concern to ATSDR about potential exposures to these substances. ATSDR discussed these issues with the state, and subsequently decided to evaluate fluoride and related substances. Please see Sections III and IV in this public health assessment for ATSDR's evaluation of potential exposures to these substances released from the K-25/S-50 site.

#	Summarized Concern/Issue	ATSDR's Response
31	Most people had been under the impression that only uranium was released from the K-25 facility, but then they later found out that this was not the case. There was recycling and other elements that were blended at the facility. Would this change the sampling data used in the K-25 public health assessment or was this taken into account?	Phase I of the Tennessee Department of Health's (TDOH) Oak Ridge Health Study evaluated all past releases of hazardous substances and operations at the ORR. The study indicated that four substances had the largest potential risk for adverse health effects—radioactive iodine, radionuclides from White Oak Creek, mercury, and PCBs. A brief summary of the Phase I Feasibility Study is provided in Appendix H. In addition to conducting a full dose reconstruction analyses in Phase II, the state included further detailed screening analyses for releases of uranium, radionuclides, and other toxic materials from Y-12 and K-25 that had not been fully characterized in Phase I (a brief in Appendix H summarizes the *Screening-Level Evaluation of Additional Potential Materials of Concern, Task 7*). By 2000, many contaminants used at the K-25 facility were unclassified and these were considered in the state's supplementary evaluation. [Please note, however, that the sampling data for this PHA did not change because ATSDR already had the original data.] During this supplementary analysis, the state took into account additional contaminants as well as the recycling and blending of substances associated with the K-25 site. Preliminary screening indices for these additional contaminants from K-25 were below the Oak Ridge Health Agreement Steering Panel (ORHASP) decision guide of one chance in 10,000. The ORHASP final report is available at http://health.state.tn.us/CEDS/OakRidge/ORHASP.pdf. In addition, ORHASP noted the following: "With even the most conservative assumptions concerning potential material losses, none of the formerly classified substances at either Y-12 or K-25 qualified for additional evaluations." ATSDR scientists conducted a review and a screening analysis of the department's Phase I and Phase II screening-level evaluation of past exposure (1944–1990) to identify contaminants of concern for further evaluation. ATSDR also had reviewers analyze the screenings to evaluate whether the findings were scientifically appropriate and suitable for making public health decisions. Uranium emissions represented the primary releases from the K-25 facility, which were evaluated by the state, but fluoride was not previously evaluated. Using ATSDR's past evaluations of gaseous diffusion plants and because of community concerns received on this issue, ATSDR recognized that fluoride could be a potential problem and wanted to evaluate it. In addition, other radiological by-products released when uranium was released were evaluated in the state's screening assessments. ATSDR also considers these in its PHA when estimating radiological doses. As a result, this public health assessment evaluates potential exposures to uranium, fluoride, hydrogen fluoride, and radiological by-products released from the K-25 facility. Please see Sections III and IV in this PHA for more information on ATSDR's public health evaluation of potential exposures to these contaminants released from the K-25 site.

#	Summarized Concern/Issue	ATSDR's Response
32	Oak Ridge also burned uranyl fluoride compounds (UO_2F_2) in the incinerator (4 million pounds per year) and the elemental toxic effects of fluoride are not mutable.	Without additional information, ATSDR is unable to determine whether the commenter is referring to the Toxic Substances Control Act (TSCA) Incinerator or an incinerator that might have operated historically at the K-25 site. If the commenter is referring to the TSCA Incinerator, ATSDR evaluated the amount of waste burned each year at this facility in the *Toxic Substances Control Act Incinerator (TSCA) Public Health Assessment* (released in December 2005; available at http://www.atsdr.cdc.gov/HAC/oakridge/phact/tsca/index.html). From 1991 to 2002, the total amount of waste burned per year at the TSCA Incinerator was almost always less than 2,000 tons per year (or less than 4,000,000 pounds per year), including a variety of wastes. For reference, please see Figure 5 in the TSCA PHA that details the annual treatment statistics for the incinerator. ATSDR's evaluation of wastes treated at the TSCA Incinerator indicates that it is unlikely that the amount of one substance noted by the commenter—uranyl fluoride—could have been released in the amount of 4,000,000 pounds per year as the total amount of all waste burned per year was almost always less than this amount. Thus, the available data do not indicate that such quantities of waste were ever treated at the TSCA Incinerator. ATSDR welcomes any additional information from the commenter on these statistics to enable further investigation.

#	Summarized Concern/Issue	ATSDR's Response
33	K-25 routinely released huge amounts of HF gas to the air both during its operation and now during dismantlement from many trapped deposits. Oak Ridge's management rather than truthfully report the problem designed a carefully crafted plan to attempt to cover it up and also to make the local doctors rich in supporting the cover up. Oak Ridge shut down the K-25 gas diffusion plant and this stopped part of the larger hydrogen fluoride releases in the area and it also cut some 3,000 megawatts of load from the TVA coal plants, which reduced hydrogen fluoride emissions more. This put the emissions from the plants into a sudden nose-dive to help conceal the rising health problem from the local townships. Oak Ridge also pulled out its old scientists to deny the huge losses of HF from the K-25 plant. Thousands of tons of HF were released from K-25, which lost around 10% of the UF6 it processed. The danger of K-25 was hydrogen fluoride systemic chemical poisoning. The releases of huge amounts of a systemic poison called hydrogen fluoride became a quadruple effect on the community closest to the nuclear bomb factory of Oak Ridge. DOE admits that thousands of inadvertent UF6 and HF K-25 releases occurred, but the real order of magnitude is more a thousand-thousand releases.	Historically, people living in communities around the K-25/S-50 site could have received chronic exposures to fluoride and hydrogen fluoride (HF) from releases during normal process operations. In this PHA (sections III and IV), ATSDR used a correlation between annual uranium releases and measured fluoride concentrations at the site perimeter to estimate concentrations from long-term exposure to fluoride for years before monitoring data were available. Estimated concentrations at the site perimeter will overestimate concentrations at areas of potential exposure due to the increased distance from emission sources and the effects of topographic ridges between the emission sources and exposure areas. ATSDR assumed that the largest annual HF release coincided with the highest annual uranium release. The highest estimated annual average fluoride concentration in air (fewer than 6 ppb in 1945) was at the F-2 station. California EPA's 2003 chronic toxicity summary for fluorides (including hydrogen fluoride) identified skeletal fluorosis as a critical effect with a chronic inhalation reference exposure level of 14 µg/m^3 for hydrogen fluoride and 13 µg/m^3 for fluoride (Cal-EPA 2003). The estimated maximum annual exposure concentration, less than 6 ppb (7.2 µg/m^3) for people living around the K-25/S-50 facility, is well below Cal-EPA's reference levels. As such, ATSDR concluded that the estimated long-term fluoride and hydrogen fluoride air concentrations and resulting exposures are not expected to result in adverse health effects. Acute HF and fluoride exposures could have resulted from accidents or controlled releases. ATSDR estimated historic acute HF concentrations using accident records and air dispersion modeling. ATSDR used short-term fluoride measurements, worst-case assumptions, and a modeled dispersion estimate from the September 1, 1958, accidental release to calculate acute exposure concentrations to HF. The highest measured short-term (24-hour) fluoride concentration of 26.3 ppb occurred in 1975. Similarly, modeled short-term (hourly) HF concentrations of 156 and 27 ppb were estimated for the Sugar Grove and Union/Lawnville communities, respectively, for the September 1958 accidental UF_6 release (Table 11). Note that because these estimated worst-case modeled concentrations are based on health-protective assumptions, the concentrations are likely overestimated for several reasons: 1) the fate and transport mathematical model does not account for the complex topography of the K-25 site; 2) ATSDR does not have any record of the specific meteorological conditions at the time of this release so the most health-protective meteorological conditions were used to estimate concentrations; 3) ATSDR assumed that off-site exposure occurred outside at the point of maximum HF concentration; and 4) ATSDR assumed that all of the UF6 released was discharged to the atmosphere with no retention in the K-1131 building. ATSDR's minimal risk level (MRL) for acute inhalation exposure to HF and fluorine is 20 ppb and 10 ppb, respectively. The 20 ppb MRL for HF in air is 25 times lower than exposures that caused mild upper respiratory tract inflammation in human volunteers exposed for 1 hour (Lund et al. 1999). The highest average level (time weighted average) allowed by the Occupational Safety and Health Administration (OSHA) for HF in air for a 40-hour work week made up of 8-hour work days is 2.5 mg/m^3 (3 ppm or 3,000 ppb). The 20 ppb MRL for air concentrations of HF is 150 times lower than OSHA's occupational level.

#	Summarized Concern/Issue	ATSDR's Response
33	*Continued*	If sensitive people in nearby communities were exposed at these acute (short-term) levels, minor temporary adverse health effects such as nose, throat, and eye irritation could have occurred. However, because there is so much uncertainty associated with historical events, ATSDR cannot determine whether past acute exposure to the maximum air concentrations of fluoride and hydrogen fluoride could harm the public's health because sufficient data are not available to make a professional judgment about the level of health hazard.
34	It is hard to imagine that DOE could not pinpoint a fluorine leak in an old building that made several guards sick, closed down a portal, evacuated an "at risk" part of the plant, and went on for a week or longer. How much was emitted to air? This shows continued disregard for environment, health, and safety to allow such releases to continue as they are cumulative and linked to long-term health damage.	ATSDR believes the commenter is referring to a fluorine leak that occurred at the K-1302 building at the K-25 site in December 2000. Regarding the worker health issue part of this comment, though worker health issues are a concern to ATSDR the agency is only evaluating potential exposures related to ORR contaminants released off site to nearby communities from the main ORR facilities (K-25, Y-12, and X-10) in its public health assessments. Worker-related issues are under the purview of the National Institute for Occupational Safety and Health (NIOSH), a federal agency of the Department of Health and Human Services (DHHS) and part of the Centers for Disease Control and Prevention (CDC) that is responsible for conducting research and making recommendations to prevent work-related illness and injury. NIOSH has an occupational energy research program to handle these worker-related issues. For information on this program, see NIOSH's Web site at http://www.cdc.gov/niosh/oerp/. If you are concerned about worker-related exposures occurring on the ORR, please contact NIOSH directly at 1-800-35-NIOSH (1-800-356-4674). If you are concerned about worker-related issues associated with the Oak Ridge Reservation, you can also contact DOE's Environment, Safety, & Health National Energy Policy Act (NEPA) Hotline at 1-800-472-2756.

#	Summarized Concern/Issue	ATSDR's Response
35	The salt reactor is not being decontaminated but being decommissioned.	The Molten Salt Reactor Experiment (MSRE) is located not at the K-25 site but south of the former X-10 site, now known as the Oak Ridge National Laboratory (ORNL). From June 1965 to December 1969, ORNL ran the MSRE to demonstrate the positive aspects of the concept of molten uranium fluoride salt reactors. After the reactor was shut down, fuel salt from the MSRE circuit was drained to two drain tanks. The molten salt was comprised of a mixture of zirconium fluoride, lithium fluoride, uranium fluoride, and beryllium fluoride, as well as a small portion of plutonium fluoride that was added to the molten salt. For the purposes of decontamination, circulating of a "clean" salt was used and released into a third drain tank. Surveillance and maintenance activities of the facility began when it was closed in 1969 and have continued since that time (Haghighi et al. 2002; SAIC 2005). Surveillance activities conducted after the MSRE closed suggested that the facility posed a risk to human health and the environment because of elevated levels of gaseous uranium hexafluoride (UF_6) and fluorine in the off-gas lines connected to the three drain tanks and because of uranium deposits in the auxiliary charcoal bed cell. Following the detection of these gases and uranium deposits, activities were initiated to manage the fuel and flush salts safely and to remove the uranium deposits (SAIC 2005). In July 1998, an interim action record of decision (ROD) signed to remove the flush salts and fuel from the MSRE called for chemically treating the salt, separating the uranium and converting it to a stable oxide, and transferring the uranium to the ORNL uranium 233 repository. In fiscal year 2003, many actions associated with salt processing were finished, such as startup testing on fuel salt removal equipment and discussions of off-site disposal to the Waste Isolation Pilot Plant in New Mexico. In fiscal year 2004, DOE issued a Notification to Proceed with Fuel Salt Disposition (FSD) actions. In December 2004, remedial activities began at the first of three tanks. The purpose of the remedial interim action, according to the ROD, is to mitigate current on- and off-site potential risks resulting from the salts within the drain tanks. As of fiscal year 2005, remedial actions for the fuel and flush salt removal at the MSRE were still in progress (SAIC 2005). In 1998, activities began to remove the uranium deposits from the MSRE. As of fiscal year 2005, the uranium-laden charcoal was being kept in interim storage at the MSRE, where it will possibly remain for 2 years until it is either shipped off site to the Nevada Test Site for disposal or processed for storage at the Melton Valley Storage Tanks (MVSTs). Further characterization of the auxiliary charcoal bed indicated that the remaining uranium 233 in the charcoal bed (about 350 grams to 550 grams) exceeds the goal for this action (250 grams). Alternative approaches to remove the uranium deposited in the upper section of the auxiliary charcoal bed are currently being evaluated (SAIC 2005). Therefore, as detailed above, actions to decontaminate the MSRE have been and are being taken to eliminate potential risks to human health and the environment (SAIC 2005).

VII. Children's Health Considerations

Contaminants in the environment may sometimes act differently on women and children compared with the way those same contaminants affect the general population. Children are smaller than the population average and as a result may be susceptible to small quantities of contaminants that would have no effect on others. Hormonal variations, pregnancy, and lactation can all change the way a woman's body responds to some substances. Through the placenta or in the mother's milk, past exposures experienced by the mother, as well as exposure during pregnancy and lactation, can expose a fetus or preborn infant to chemicals. Depending on the stage of pregnancy, the nature of the chemical involved, and the dose of that chemical, fetal exposure can result in problems such as miscarriage, stillbirth, and birth defects.

ATSDR recognizes that fast-developing young people—whether fetuses, infants, or children—have unique vulnerabilities. Children are more vulnerable than are adults for many reasons, beginning with the fact that children are not simply small adults. Children drink more fluids, eat more food, breathe more air per kilogram of body weight, and have a larger skin surface area in proportion to their body volume. Behavior and lifestyle also influence exposure. Children crawl on floors, put things in their mouths, play close to the ground, and spend more time outdoors.

In addition to physical and behavioral differences, children's metabolic pathways, especially in the first months after birth, are less developed than are those of adults. In some instances, children are better able to deal with environmental toxins. In others, they are less able and more vulnerable; some chemicals that are not toxins to adults are highly toxic to infants.

In the first months and years of life, children grow and develop rapidly. If during this period some organ systems—especially the nervous and respiratory systems—are exposed to high concentrations of certain contaminants, permanent damage may occur. Because of their lack of knowledge and their dependence on adults for decisions, young children have less ability to avoid those hazards, which may affect them but might not affect adults.

In this PHA, the special susceptibilities of children are factored into the health comparison values we use to determine whether environmental concentrations of uranium and HF are likely to cause adverse health effects. Here we use minimal risk levels (MRLs), as derived by ATSDR, to assess the potential for adverse nonradiological health effects. MRLs are designed to be protective of persons who are particularly susceptible to the toxicologic effects of each chemical (ATSDR 1999a, 2003). Consequently, the estimated exposure calculations and resulting health determinations for nonradiological contaminants are protective for all sensitive persons, including women and children.

For radiological considerations, the dose calculations include age-specific factors to account for the special susceptibilities of children. The ICRP dose coefficients, which underlie the dose calculations in this PHA, apply to several age groups (age at time of intake): 3 months, 1 year, 5 years, 10 years, 15 years, and adults. The ICRP does not specifically evaluate the different sexes. The organ-specific dose coefficients, however, do account for the susceptibilities of the reproductive organs—the testis and uterus. Thus for both men and women, the dose assessment process factors reproductive susceptibility into radiological exposures.

VIII. Conclusions

In this public health assessment, ATSDR addressed historic off-site community exposures to radioactive and nonradioactive hazardous substances released to the atmosphere from the Oak Ridge Gaseous Diffusion Plant (K-25) and the S-50 Liquid Thermal Diffusion Plant. ATSDR also assessed possible current and future exposures associated with potential releases from ongoing remedial activities at the K-25 site, now known as the East Tennessee Technology Park. ATSDR evaluated potential exposures for three residential areas closest to the K-25/S-50 site: the Union/Lawnville community (about 4 km southwest of K-25), the Sugar Grove community (about 1.4 km north of K-25), and the Happy Valley labor camp (about 1.5 km south of K-25).

Historic emissions of uranium hexafluoride (UF_6) from the K-25/S-50 facility resulted in potential exposures to uranium and fluoride (primarily as hydrogen fluoride [HF]) for people living near the site. ATSDR evaluated the possibility of public health effects resulting from potential exposures to K-25-released contaminants by examining acute (short-term) and chronic (long-term) airborne releases of uranium, associated radionuclides (Np-237 and Tc-99), and fluoride (as HF). Specifically, ATSDR evaluated short-term (1 to 24 hours) and long-term (annual) exposures for these off-site areas using the maximum estimated short-term and long-term UF_6 emission rates and air dispersion and dose assessment models.

These evaluations have led ATSDR to several important conclusions:

1. Breathing in the estimated levels of uranium and radioactive material released from the site to nearby communities over short (24-hour) and long (more than 1 year) periods, as well as breathing in the levels of fluoride and hydrogen fluoride for long periods, would not be expected to harm people's health.

2. Historic off-site acute exposure was unlikely—but possible—to fluoride and to HF released as UF_6 during accidents or equipment maintenance at the K-25 site. Although ATSDR used worst-case assumptions and modeled air data to evaluate these releases, environmental air monitoring data are insufficient to determine the actual concentrations of fluoride and HF released. ATSDR consequently was unable to reach a conclusion regarding whether short-term (fewer than 24 hours) breathing of fluoride and hydrogen fluoride released as uranium hexafluoride (UF_6) during accidents or equipment maintenance at the K-25/S-50 site in the 1940s and 1950s could harm the health of residents in off-site communities.

3. ATSDR considered current and future exposures, which included any potential hazards that might be identified during remedial activities at the site. Although site remediation is ongoing, as of this PHA's completion ATSDR had not identified any potential current or future hazards to off-site residents.

IX. Recommendations

Having evaluated past, current, and future public health activities and available environmental information, ATSDR recommends that DOE continue its precautionary measures to prevent any future off-site releases of contaminants potentially remaining on the K-25 site.

X. Public Health Action Plan

The Public Health Action Plan (PHAP) for K-25/S-50 site releases describes actions to be taken at and near the site by ATSDR and other government agencies after the completion of this public health assessment. The PHAP purpose is to ensure that this public health assessment not only identifies public health hazards, but that it also provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to hazardous substances in the environment. If additional information about K-25/S-50 releases becomes available, that information could change any conclusion or conclusions of this public health assessment. Human exposure pathways would be reevaluated, and these conclusions and recommendations would be amended, as necessary, to protect public health.

1. ORR staff will notify ATSDR if environmental monitoring data indicate that because of ongoing remedial activities at the site, a release has occurred. On receipt of such notification, ATSDR will determine appropriate public health actions.

2. ATSDR will develop and implement additional environmental health education materials as necessary to help community members understand this public health assessment's findings and public health implications.

XI. Report Authors

Mark W. Evans, Ph.D.
Environmental Geologist
Site and Radiological Assessment Branch
Division of Health Assessment and Consultation

Paul A. Charp, Ph.D.
Senior Health Physicist
Site and Radiological Assessment Branch
Division of Health Assessment and Consultation

Jack Hanley, M.P.H.
Environmental Health Scientist
Site and Radiological Assessment Branch
Division of Health Assessment and Consultation

This document was prepared with the assistance of Eastern Research Group, Inc. (ERG)

Report Reviewers

Burt J. Cooper, M.S.
Environmental Health Scientist
Site and Radiological Assessment Branch
Division of Health Assessment and Consultation

Sandra G. Isaacs
Chief, Site and Radiological Assessment Branch
Division of Health Assessment and Consultation

Regional Representative

Robert Safay
Senior Regional Representative
Regional Services, Region IV
Office of Regional Operations

XII. References

Abee HH. 1960a. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for 1959; 1960 May 28.

Abee HH. 1960b. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for first quarter 1960; 1960 May 28.

Abee HH. 1960c. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for third quarter 1960; 1960 November 14.

Abee HH. 1961. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for fourth quarter 1960; 1961 March 14.

[ANL] Argonne National Laboratory. 1997. FIREPLUME model for plume dispersion from fires: application to uranium hexafluoride cylinder fires. Document no. ANL/EAD/TM-69. Argonne, Illinois: Argonne National Laboratory; 1997 June.

[ATSDR] Agency for Toxic Substances and Disease Registry. 1996. Health consultation for U.S. DOE Oak Ridge Reservation: Lower Watts Bar Reservoir Operable Unit. Oak Ridge, Anderson County, Tennessee. Atlanta, GA: U.S. Department of Health and Human Services; 1996 February.

[ATSDR] Agency for Toxic Substances and Disease Registry. 1999a. Toxicological profile for uranium. Atlanta, GA: U.S. Department of Health and Human Services; September. Available from: http://www.atsdr.cdc.gov/toxprofiles/tp150.pdf. Last accessed 2010 July 14.

[ATSDR] Agency for Toxic Substances and Disease Registry. 1999b. Toxicological profile for ionizing radiation. Atlanta, GA: U.S. Department of Health and Human Services; September. Available from: http://www.atsdr.cdc.gov/toxprofiles/tp149.pdf. Last accessed 2010 July 14.

[ATSDR] National Center for Environmental Health, National Institute for Occupational Safety and Health, Tennessee Department of Health, Tennessee Department of Environment and Conservation, and U.S. Department of Energy. 2000. Oak Ridge Reservation: compendium of public health activities at the U.S. Department of Energy; November. Available from: http://www.atsdr.cdc.gov/HAC/oakridge/phact/c_toc.html. Last accessed 2010 July 14.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2003. Toxicological profile for fluorides, hydrogen fluoride, and fluorine. Atlanta, GA: U.S. Department of Health and Human Services; September. Available from: http://www.atsdr.cdc.gov/toxprofiles/tp11.pdf. Last accessed 2010 July 14.

[ATSDR] Agency for Toxic Substances and Disease Registry. 2005. Public health assessment guidance manual. Atlanta, GA: U.S. Department of Health and Human Services. Available from: http://www.atsdr.cdc.gov/HAC/PHAManual/toc.html. Last accessed 2010 July 14.

Bechtel Jacobs Company LLC, Lockheed Martin Energy Research Corporation, and Lockheed Martin Energy Systems, Inc. 1999. Comprehensive integrated planning process for the Oak Ridge operations sites. For: U.S. Department of Energy; September.

Bechtel Jacobs Company LLC. 2000. Phase II—Independent Investigation of the Paducah Gaseous Diffusion Plant. Prepared by U.S. Department of Energy, Office of Oversight, Office of Environment, Safety, and Health. Previously available from: https://reports.eh.doe.gov/independent_oversight/gdps/0002paducah/paducah.pdf. Last accessed 2007 September 11.

Bechtel Jacobs Company LLC. 2008. FY2008 cleanup progress: Annual report to the Oak Ridge community. Available from: http://www.bechteljacobs.com/pdf/CleanProg2008.pdf. Last accessed 2010 July 14.

Benfield R. 2002. Oak Ridge Reservation Health Effects Subcommittee (ORRHES) meeting minutes. Tennessee Department of Environment and Conservation (TDEC) groundwater geologist presentation; 22 October. Available from: http://www.atsdr.cdc.gov/HAC/oakridge/meet/orr/m10_02.pdf. Last accessed 2010 July 14.

Benson M, Lyons W, and Scheb JM. 1994. Report of knowledge, attitudes and beliefs survey of residents of an eight-county area surrounding Oak Ridge, Tennessee. For: Tennessee Department of Health, Division of Epidemiology, the Oak Ridge Health Agreement Steering Panel (ORHASP), and the Oak Ridge Reservation Local Oversight Committee (LOC). University of Tennessee, Knoxville; August 12.

Blackwood JC. Frequency and causes of material losses. Inter-department letter to Dr. Barnett F. Dodge. Fercleve Corporation; May 17. Cited in Martin Marietta Energy Systems, Inc. Appendix B. Investigation of uranium hexafluoride (UF_6) losses.

[Cal-EPA] California Environmental Protection Agency. 2003. Chronic toxicity summary: fluorides including hydrogen fluoride. Sacramento, CA: Office of Environmental Health Hazard Assessment; August. Available from: http://www.oehha.ca.gov/air/chronic_rels/HyFluoCREL.html#download. Last accessed 2010 July 14.

Carden D, Joseph T. 1998. Aerial radiological surveys of the Scarboro community. Oak Ridge, TN: U.S. Department of Energy, Oak Ridge Operations; May.

Chemical Substances Bureau. 1999. Risk assessment: hydrogen fluoride. Final report. The Netherlands; 2 December. Available from: http://ecb.jrc.it/documents/Existing-Chemicals/RISK_ASSESSMENT/DRAFT/R002_9912_env_hh.pdf. Last accessed 2010 July 14.

ChemRisk. 1993a. Oak Ridge health studies, phase I report. Volume II—part A—dose reconstruction feasibility study. Tasks 1 & 2: A summary of historical activities on the Oak Ridge Reservation with emphasis on information concerning off-site emissions of hazardous materials. For: Oak Ridge Health Agreement Steering Panel and Tennessee Department of Health. Alameda, CA; September.

ChemRisk. 1993b. Oak Ridge health studies, phase I report. Volume II—part B—dose reconstruction feasibility study. Tasks 3 & 4: Identification of important environmental pathways for materials released from Oak Ridge Reservation. For: Oak Ridge Health Agreement Steering Panel and Tennessee Department of Health. Alameda, CA; September.

ChemRisk. 1993c. Oak Ridge health studies, phase 1 report. Volume II—part C—dose reconstruction feasibility study. Task 5: A summary of information concerning

historical locations and activities of populations potentially affected by releases from the Oak Ridge Reservation. For: Tennessee Department of Health and the Oak Ridge Health Agreement Steering Panel. Alameda, CA; September.

ChemRisk. 1999a. Uranium releases from the Oak Ridge Reservation—a review of the quality of historical effluent monitoring data and a screening evaluation of potential off-site exposures, Task 6. Reports of the Oak Ridge dose reconstruction, volume 5. For: Tennessee Department of Health. Alameda, CA; July. Available from: http://health.state.tn.us/CEDS/OakRidge/Uranium.pdf. Last accessed 2010 July 14.

ChemRisk. 1999b. Radionuclide releases to the Clinch River from White Oak Creek on the Oak Ridge Reservation—an assessment of historical quantities released, off-site radiation doses, and health risks, task 4. Reports of the Oak Ridge dose reconstruction, volume 4. For: Tennessee Department of Health. Alameda, CA; July. Available from: http://health.state.tn.us/CEDS/OakRidge/WOak1.pdf. Last accessed 2010 July 14.

Collings GH, Fleming RBL, May R. 1951. Absorption and excretion of inhaled fluorides. ANA Arch Ind Hyg Occup Med 4:585–590. [cited by [ATSDR] Agency for Toxic Substances and Disease Registry. 2003. Toxicological profile for fluorides, hydrogen fluoride, and fluorine. Atlanta, GA: U.S. Department of Health and Human Services; September. Available from: http://www.atsdr.cdc.gov/toxprofiles/tp11.pdf. Last accessed 2010 July 14.]

Daniels RC. 2002. K-25 cleanup pact signed. *The Oak Ridger* [Online]. November 12. Available from: http://nl.newsbank.com/nl-search/we/Archives?p_action=doc&p_docid=1110ECC6BACD0E08&p_docnum=3&p_theme=gatehouse&s_site=TORB&p_product=TORB. Last accessed 2010 July 14.

DOE see U.S. Department of Energy

Environmental Sciences Division, Oak Ridge National Laboratory, and Jacobs Engineering Group. 1995. Remedial investigation/feasibility study report for Lower Watts Bar Reservoir operable unit. For: U.S. Department of Energy, Office of Environmental Management. Oak Ridge, TN; March.

EPA see U.S. Environmental Protection Agency

[EUWG] End Use Working Group. 1998. Final report of the Oak Ridge Reservation. Oak Ridge, TN.

[FAMU] Florida Agricultural and Mechanical University. 1998. Scarboro community environmental study.

Faust L. 1993. Personal communications with Lucian Faust, City Planner, city of Oak Ridge. August 6. [cited by ChemRisk 1993c. Oak Ridge health studies, phase 1 report. Volume II—part C—dose reconstruction feasibility study. Task 5: A summary of information concerning historical locations and activities of populations potentially affected by releases from the Oak Ridge Reservation. For: Tennessee Department of Health and the Oak Ridge Health Agreement Steering Panel. Alameda, CA; September.]

Fricke KE. 1996. Natural phenomena evaluations of the K-25 site UF_6 cylinder storage yards. Prepared by Oak Ridge K-25 Site. Managed by Lockheed Martin Energy Systems, Inc. Prepared for the U.S. Department of Energy; September. Available from:

www.osti.gov/bridge/servlets/purl/383583-C7riSB/webviewable/. Last accessed 2010 July 14.

Friday JC and Turner RL. 2001. Scarboro community assessment report. Washington, DC: Joint Center for Political and Economic Studies; August.

Geraghty & Miller, Inc. 1989. Hydrogeology of the Oak Ridge gaseous diffusion plant. Revised draft report. Oak Ridge, TN; December. [cited by USDOE. 2003a. Draft environmental impact statement for construction and operation of a depleted uranium hexafluoride conversion facility at the Portsmouth, Ohio, site. Office of Oak Ridge Operations, Office of Environmental Management; December. Available from: http://nepa.energy.gov/draft-eis0360.htm. Last accessed 2010 July 14.]

Haghighi MH, Kring CT, McGehee JT, Jugan MR, Chapman J, and Meyer KE. 2002. In situ NDA [nondestructive assay] conformation measurements performed at auxiliary charcoal bed and other main charcoal beds after uranium removal from molten salt reactor experiment at ACB [auxiliary charcoal bed] at Oak Ridge National Laboratory. Tucson, AZ: waste management conference; February 24–28. Available from: http://www.wmsym.org/archives/2002/Proceedings/28B/329.pdf. Last accessed 2010 July 14.

Hewlett RG and Anderson OE, Jr. 1962. The new world, 1939-1946. Volume I, a history of the United States Atomic Energy Commission. University Park, PA: Pennsylvania State University Press. [cited by Prince RP. 2003. The Happy Valley Settlement of the K-25 Plant—dates of initial construction, occupancy, and removal of buildings. Oak Ridge, TN; 20 May.]

[ICRP] International Commission on Radiological Protection. 1977. Recommendations of the International Commission on Radiological Protection. New York: Pergamon Press; ICRP Publication 26.

[ICRP] International Commission on Radiological Protection. 1991. 1990 recommendations of the International Commission on Radiological Protection. New York: Pergamon Press; ICRP Publication 60.

J.A. Jones Construction Company. Date unknown. General layout of the K-25 area, drawing 20024. [cited by Prince RP. 2003. The Happy Valley Settlement of the K-25 Plant—dates of initial construction, occupancy, and removal of buildings. Oak Ridge, TN; 20 May.]

Jacobs Engineering Group Inc. 1996. Remedial investigation/feasibility study of the Clinch River/Poplar Creek operable unit. For: U.S. Department of Energy, Office of Environmental Management; March. Available from: http://www.osti.gov/energycitations/product.biblio.jsp?query_id=1&page=0&osti_id=226399. Last accessed 2010 July 14.

Jacobs EM Team. 1997a. Remedial site evaluation report for the Happy Valley Campsite at the Oak Ridge Reservation, Oak Ridge, Tennessee. For: U.S. Department of Energy, Office of Environmental Management; October.

Jacobs EM Team. 1997b. Record of decision for the Clinch River/Poplar Creek operable unit, Oak Ridge, Tennessee. For: U.S. Department of Energy, Office of Environmental Management; September. Available from:

http://www.epa.gov/superfund/sites/rods/fulltext/r0497075.pdf. Last accessed 2010 July 14.

Johnson CA, Erwin PC, Redd SC, Robinson AJ, Ball L, and Moore W. 2000. Scarboro Community Environmental Justice Council, National Center for Health, Tennessee Department of Health—East Tennessee Regional Office (Knoxville), and Tennessee Department of Health (Nashville). An analysis of respiratory illnesses among children in the Scarboro community; July.

Keith PC and Baker AL. 1946. Completion report on the K-25 gas diffusion plant. The M.W. Kellogg Company and the Kellex Corporation. Volume IV. p. 947. January. [cited by Prince RP. 2003. The Happy Valley Settlement of the K-25 Plant—dates of initial construction, occupancy, and removal of buildings. Oak Ridge, TN; 20 May.]

Lay AC and Rogers JG. 1986. Oak Ridge Gaseous Diffusion Plant historical uranium and radionuclide release report. Martin Marietta Energy Systems, Inc., Environmental Management Department. Document K/HS-95. Oak Ridge, TN. 1986 February 28.

Ledwidge L. 1999. Rush to rent: DOE's leasing of contaminated facilities is putting workers at risk. Takoma Park, MD: Institute for Energy and Environmental Research; May. Available from: http://www.ieer.org/sdafiles/vol_7/7-3/rush.html. Last accessed 2010 July 14.

Loar JM, Burkhart FA, Cada GF, Huckabee JW, Kitchings JT, Kumar KD, et al. 1981. Ecological studies in the biotic communities in the vicinity of the Oak Ridge gaseous diffusion plant. Environmental Sciences Division. Report ORNL/TM-6714. ChemRisk Repository No. 250; October. [cited by ChemRisk. 1993b. Oak Ridge health studies, phase I report. Volume II—part B—dose reconstruction feasibility study. Tasks 3 & 4: Identification of important environmental pathways for materials released from Oak Ridge Reservation. For: Oak Ridge Health Agreement Steering Panel and Tennessee Department of Health. Alameda, CA; September.]

Lockheed Martin Energy Research Corporation. 1998. Qualitative change analysis of aerial radiological data of the Oak Ridge Reservation, Oak Ridge, Tennessee. For: U.S. Department of Energy, Office of Environmental Management. BJC/OR-106. Oak Ridge, TN; September.

Lockheed Martin Energy Systems, Inc. 1998. Accelerating cleanup: paths to closure. Draft. DOE/EM0342. For: U.S. Department of Energy, Office of Environmental Management; February.

Lund K, Refsnes M, Sandstrom T, Sostrand P, Schwarze P, Boe J, and Kongerud J. 1999. Increased CD3 positive cells in bronchoalveolar lavage fluid after hydrogen fluoride inhalation. Scand J Work Environ Health 25(4):326–334. [cited by: Agency for Toxic Substances and Disease Registry. 2003. Toxicological profile for fluorides, hydrogen fluoride, and fluorine. Atlanta, GA: U.S. Department of Health and Human Services. September 2003. Available from: http://www.atsdr.cdc.gov/toxprofiles/tp11.pdf. Last accessed 2010 July 14.]

Maurer RJ. 1992. An aerial radiological survey of the Oak Ridge Reservation and surrounding area, Oak Ridge, Tennessee. Date of survey: 1989. EGG-10617-1123. Las Vegas, Nevada: EG&G Energy Measurements.

McDiarmid M, Engelhardt S, Oliver M, Gucer P, Wilson PD, Kane R, et al. 2004. Health effects of depleted uranium on exposed Gulf War veterans: A 10-year follow-up. Journal of Toxicology and Environmental Health, Part A 67:277–296.

[MMES] Martin Marietta Energy Systems, Inc. 1984. Environmental monitoring report. United States Department of Energy, Oak Ridge facilities. Calendar year 1983. Y/UB-19. Oak Ridge, TN; June 15.

[MMES] Martin Marietta Energy Systems, Inc. 1985. Environmental monitoring report. United States Department of Energy, Oak Ridge facilities. Calendar year 1984. ORNL-6209. Oak Ridge, TN; August.

[MMES] Martin Marietta Energy Systems, Inc. 1986. Environmental surveillance of the Oak Ridge Reservation and surrounding environs during 1985. ORNL-6271. Oak Ridge, TN; May.

[MMES] Martin Marietta Energy Systems, Inc. 1987. Environmental surveillance of the Oak Ridge Reservation and surrounding environs during 1986. ES/ESH-1. Oak Ridge, TN; 1 April.

[MMES] Martin Marietta Energy Systems, Inc. 1988. Environmental surveillance of the Oak Ridge Reservation and surrounding environs during 1987. ES/ESH-4/V1. Oak Ridge, TN.

[MMES] Martin Marietta Energy Systems, Inc. 1989. Environmental surveillance of the Oak Ridge Reservation and surrounding environs during 1988. ES/ESH-8/V1. Oak Ridge, TN.

[MMES] Martin Marietta Energy Systems, Inc. 1990. Oak Ridge Reservation environmental report for 1989. ES/ESH-13/V2. Oak Ridge, Tennessee: Oak Ridge National Laboratory; October.

[MMES] Martin Marietta Energy Systems, Inc. 1991. Oak Ridge Reservation environmental report. ES/ESH-22/VI. Oak Ridge, TN.

[MMES] Martin Marietta Energy Systems, Inc. 1992. Oak Ridge Reservation environmental report. ES/ESH-31/VI. Oak Ridge, TN.

[MMES] Martin Marietta Energy Systems, Inc. 1993. Oak Ridge Reservation environmental report for 1992. ES/ESH-47. Oak Ridge, TN.

[MMES] Martin Marietta Energy Systems, Inc. 1994. Oak Ridge Reservation environmental report for 1993. ES/ESH-57. Oak Ridge, TN.

[MMES] Martin Marietta Energy Systems, Inc. 1995. Environmental monitoring on the Oak Ridge Reservation: 1994 results. ES/ESH-59. Oak Ridge, TN.

Munger F. 2009. The latest look at K-25 demolition. Knoxnews.com; 19 October. Available from: http://blogs.knoxnews.com/munger/2009/10/the_latest_look_at_k-25_demoli.html. Last accessed 2010 July 14.

[NCRP] National Council on Radiation Protection and Measurements. 1996. A guide for uncertainty analysis in dose and risk assessments related to environmental contamination. NCRP Commentary 14. Bethesda, MD: National Council on Radiation Protection and Measurements; May 10.

[NIOSH] National Institute for Occupational Safety and Health. 1997. NIOSH pocket guide to chemical hazards. Centers for Disease Control and National Institute for Occupational Safety and Health. Document no. 97-140. Washington, DC: U.S. Department of Health and Human Services; June.

[NLM] U.S. National Library of Medicine. 2000. Toxicology data network (TOXNET): hazardous substances database. Available from: http://toxnet.nlm.nih.gov/cgi-bin/sis/htmlgen?HSDB. Last accessed 2010 July 14.

National Research Council. 2006. Fluoride in drinking water: A scientific review of EPA's standards. Committee on Fluoride in Drinking Water, Board on Environmental Studies and Toxicology, Division on Earth and Life Studies. Washington, DC: National Academies of Sciences.

National Research Council. 2008. Review of the toxicologic and radiologic risks to military personnel from exposures to depleted uranium during and after combat. Washington, DC: National Academies Press.

[NRC] U.S. Nuclear Regulatory Commission. 2001. RASCAL version 3.0 radiological assessment system for consequence analysis, incident response operations. Rockville, MD: Nuclear Regulatory Commission; March.

[ORHASP] Oak Ridge Health Agreement Steering Panel. 1999. Releases of contaminants from Oak Ridge facilities and risks to public health. Final report of the ORHASP; December. Available from: http://health.state.tn.us/CEDS/OakRidge/ORHASP.pdf. Last accessed 2010 July 14.

[ORNL] Oak Ridge National Laboratory. Date unknown [1]. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for first quarter, 1961. Applied Health Physics Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[ORNL] Oak Ridge National Laboratory. Date unknown [2]. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for second quarter, 1961. Applied Health Physics Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[ORNL] Oak Ridge National Laboratory. Date unknown [3]. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for third quarter, 1961. Applied Health Physics Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[ORNL] Oak Ridge National Laboratory. Date unknown [4]. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for fourth quarter, 1961. Applied Health Physics Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[ORNL] Oak Ridge National Laboratory. Date unknown [5]. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for January to June, 1962. Applied Health Physics Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[ORNL] Oak Ridge National Laboratory. Date unknown [6]. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental

monitoring report for July to December, 1962. Applied Health Physics Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[ORNL] Oak Ridge National Laboratory. Date unknown [7]. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for July to December, 1963. Applied Health Physics Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[ORNL] Oak Ridge National Laboratory. Date unknown [8]. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for January to June, 1964. Applied Health Physics Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[ORNL] Oak Ridge National Laboratory. Date unknown [9]. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for July to December, 1964. Applied Health Physics Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[ORNL] Oak Ridge National Laboratory. Date unknown [10]. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for July to December, 1965. Applied Health Physics Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[ORNL] Oak Ridge National Laboratory. Date unknown [11]. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for January to June, 1966. Applied Health Physics Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[ORNL] Oak Ridge National Laboratory. Date unknown [12]. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for July to December, 1966. Applied Health Physics Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[ORNL] Oak Ridge National Laboratory. Date unknown [13]. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for January to June, 1967. Applied Health Physics Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[ORNL] Oak Ridge National Laboratory. Date unknown [14]. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for July to December, 1967. Applied Health Physics Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[ORNL] Oak Ridge National Laboratory. Date unknown [15]. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for January to June, 1968. Applied Health Physics Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[ORNL] Oak Ridge National Laboratory. Date unknown [16]. Environmental levels of radioactivity for the Oak Ridge area. Report for July to December, 1968. Applied Health Physics Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[ORNL] Oak Ridge National Laboratory. Date unknown [17]. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for January to June, 1969. Applied Health Physics Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[ORNL] Oak Ridge National Laboratory. Date unknown [18]. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for July to December, 1969. Applied Health Physics Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[ORNL] Oak Ridge National Laboratory. Date unknown [19]. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for January to June, 1970. Applied Health Physics Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[ORNL] Oak Ridge National Laboratory. Date unknown [20]. Environmental levels of radioactivity for the Oak Ridge area. Oak Ridge Reservation environmental monitoring report for July to December, 1970. Applied Health Physics Section, Health Physics Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee.

[ORNL] Oak Ridge National Laboratory. 2002. Oak Ridge National Laboratory land and facilities plan. For: U.S. Department of Energy. Oak Ridge, TN; August.

Parks BS. 1997. CAP88-PC version 2.0 user's guide. Germantown, MD: U.S. Department of Energy. ER-8/GTN.

Parson P. 2000. Study suggests a K-25, sick-worker connection. *The Oak Ridger* [Online]. 1 August. Available from: http://nl.newsbank.com/nl-search/we/Archives?p_action=doc&p_docid=110EACF4BB30C178&p_docnum=1&p_theme=gatehouse&s_site=TORB&p_product=TORB. Last accessed 2010 July 14.

Prince RP. 2003. The Happy Valley Settlement of the K-25 Plant—dates of initial construction, occupancy, and removal of buildings. Oak Ridge, TN; May 20.

Radian Corporation. 1993. Record of decision for the K-1407-B/C ponds at the Oak Ridge K-25 site, Oak Ridge, Tennessee. For: U.S. Department of Energy, Office of Environmental Restoration and Waste Management. Oak Ridge, TN; September. Available from: http://www.epa.gov/superfund/sites/rods/fulltext/r0493166.pdf. Last accessed 2010 July 14.

Rothstein A. 1949. Pharmacology and toxicology of uranium compounds. In: Voegtlin C and Hodge HC, editors. Pharmacology and Toxicology of Uranium Compounds, Vol. 1/2: 548-648. New York: McGraw-Hill.

Rye WA. 1961. Fluorides and phosphates—clinical observations of employees in phosphate operation. International Congress on Occupational Health, July 25–29, 1960, 361–364. [cited by [ATSDR] Agency for Toxic Substances and Disease Registry. 2003. Toxicological profile for fluorides, hydrogen fluoride, and fluorine. Atlanta, GA: U.S. Department of Health and Human Services; September. Available from: http://www.atsdr.cdc.gov/toxprofiles/tp11.pdf. Last accessed 2010 July 14.]

[SAIC] Science Applications International Corporation. 2002. 2002 remediation effectiveness report for the U.S. Department of Energy, Oak Ridge Reservation, Oak Ridge,

Tennessee. For: U.S. Department of Energy, Office of Environmental Management; March.

[SAIC] Science Applications International Corporation. 2004. 2004 remediation effectiveness report for the U.S. Department of Energy, Oak Ridge Reservation, Oak Ridge, Tennessee. For: U.S. Department of Energy, Office of Environmental Management; March.

[SAIC] Science Applications International Corporation. 2005. 2005 remediation effectiveness report for the U.S. Department of Energy, Oak Ridge Reservation, Oak Ridge, Tennessee. For: U.S. Department of Energy, Office of Environmental Management; March.

Stokinger HE, Baxter RC, Dygert HP, et al. 1953. Toxicity following inhalation for 1 and 2 years. In: Voegtlin C and Hodge HC, editors. Pharmacology and Toxicology of Uranium Compounds, Vol. 3/4: 1370-1778. New York: McGraw-Hill.

Storms R and Rector D. 1997. Radiological survey of Clinch River public parks and recreational areas from Melton Hill Dam to Kingston. TDEC/ORO3/20/97.

[TDEC] Tennessee Department of Environment and Conservation. 2000. Status report to the public. TDEC, DOE Oversight Division. Nashville, TN; December. Previously available from: http://www.local-oversight.org/TDEC2000.pdf. Last accessed 2007 September 11.

[TDEC] Tennessee Department of Environment and Conservation. 2002. Status report to the public; fiscal year 2001. TDEC, DOE Oversight Division. Nashville, TN; March. Previously available from: http://www.local-oversight.org/TDEC2001.pdf. Last accessed 2007 September 11.

[TDEC] Tennessee Department of Environment and Conservation. 2003a. Annual report of violations of the federal safe drinking water act—January 1, 2002 through December 31, 2002. Division of water supply. Nashville, TN; July. Available from: http://www.state.tn.us/environment/dws/pdf/2002ACR.pdf. Last accessed 2010 July 14.

[TDEC] Tennessee Department of Environment and Conservation. 2003b. On-line search of the state's drinking water program. Oak Ridge, TN. Previously available from: http://www.state.tn.us/environment/doeo/99empdw.pdf. Last accessed 2006 April 28.

[TDEC] Tennessee Department of Environment and Conservation. 2004. Status report to the public; fiscal year 2003. TDEC, DOE Oversight Division. Nashville, TN; September. Available from: http://www.tennessee.gov/environment/doeo/pdf/TDEC%20status%20report%202003.pdf. Last accessed 2010 July 14.

[TDOH] Tennessee Department of Health. 2000. Contaminant releases and public health risks: results of the Oak Ridge health agreement studies. Knoxville, TN; July.

Teasley N. 1995. Deer hunt radiation monitoring guidelines. Oak Ridge National Laboratory Chemical Sciences Division. Oak Ridge, TN; January. Available from: http://www.ornl.gov/sci/rmal/deer_hunt_procedure.pdf. Last accessed 2010 July 14.

Union Carbide Corporation Nuclear Division. 1972. Environmental monitoring report, calendar year 1971. United States Atomic Energy Commission, Oak Ridge Facilities, Office of

Safety and Environmental Protection, Oak Ridge, Tennessee. UCC-ND-221. Oak Ridge, TN; June 30.

Union Carbide Corporation Nuclear Division. 1973. Environmental monitoring report, calendar year 1972. United States Atomic Energy Commission, Oak Ridge Facilities, Office of Safety and Environmental Protection, Oak Ridge, Tennessee. UCC-ND-244. Oak Ridge, TN; March 26.

Union Carbide Corporation Nuclear Division. 1974. Environmental monitoring report, calendar year 1973. United States Atomic Energy Commission, Oak Ridge Facilities, Office of Safety and Environmental Protection, Oak Ridge, Tennessee. UCC-ND-280. Oak Ridge, TN; May 2.

Union Carbide Corporation Nuclear Division. 1975. Environmental monitoring report, calendar year 1974. United States Energy Research and Development Administration, Oak Ridge Facilities, Office of Safety and Environmental Protection, Oak Ridge, Tennessee. UCC-ND-302. Oak Ridge, TN; May 1.

Union Carbide Corporation Nuclear Division. 1976. Environmental monitoring report, calendar year 1975. United States Energy Research and Development Administration, Oak Ridge Facilities, Office of Safety and Environmental Protection, Oak Ridge, Tennessee. Y/UB-4. Oak Ridge, TN; May 1.

Union Carbide Corporation Nuclear Division. 1977. Environmental monitoring report, calendar year 1976. United States Energy Research and Development Administration, Oak Ridge Facilities, Office of Safety and Environmental Protection, Oak Ridge, Tennessee. Y/UB-6. Oak Ridge, TN; May 1.

Union Carbide Corporation Nuclear Division. 1978. Environmental monitoring report, calendar year 1977. United States Department of Energy, Oak Ridge Facilities, Office of Safety and Environmental Protection, Oak Ridge, Tennessee. Y/UB-8. Oak Ridge, TN; June 21.

Union Carbide Corporation Nuclear Division. 1979. Environmental monitoring report, calendar year 1978. United States Department of Energy, Oak Ridge Facilities, Office of Safety and Environmental Protection, Oak Ridge, Tennessee. Y/UB-10. Oak Ridge, TN; June 1.

Union Carbide Corporation Nuclear Division. 1980. Environmental monitoring report, calendar year 1979. United States Department of Energy, Oak Ridge Facilities, Office of Safety and Environmental Protection, Oak Ridge, Tennessee. Y/UB-13. Oak Ridge, TN; June 2.

Union Carbide Corporation Nuclear Division. 1981. Environmental monitoring report, calendar year 1980. United States Department of Energy, Oak Ridge Facilities, Office of Safety and Environmental Protection, Oak Ridge, Tennessee. Y/UB-15. Oak Ridge, TN; June 10.

Union Carbide Corporation Nuclear Division. 1982. Environmental monitoring report, calendar year 1981. United States Department of Energy, Oak Ridge Facilities, Office of Safety and Environmental Protection, Oak Ridge, Tennessee. Y/UB-16. Oak Ridge, TN; May 1.

Union Carbide Corporation Nuclear Division. 1983. Environmental monitoring report, calendar year 1982. United States Department of Energy, Oak Ridge Facilities, Office of Safety and Environmental Protection, Oak Ridge, Tennessee. Y/UB-18. Oak Ridge, TN; May 1.

Union Carbide Nuclear Company. 1952–1955. Material release report 81 through 187. K-25 plant. KP-303 combined. Oak Ridge, TN.

Union Carbide Nuclear Company. 1957–1958. Material release report nos. 252–260. Oak Ridge Gaseous Diffusion Plant. KP-1069/PT29-37. Oak Ridge, TN.

Union Carbide Nuclear Company. 1958. Material release report nos. 262–268. Oak Ridge Gaseous Diffusion Plant. KP-1069/PT39-45. Oak Ridge, TN.

Union Carbide Nuclear Company. 1958–1961. Material release report nos. 270–344. Oak Ridge Gaseous Diffusion Plant. KP-1069/PT47-121. Oak Ridge, TN.

U.S. Census Bureau. 1940a. Census of 1940. Available from the Tennessee State Library and Archives, Nashville, TN. Washington, DC: U.S. Department of Commerce.

U.S. Census Bureau. 1940b. 1940 decennial census report. Available from the Tennessee State Library and Archives, Nashville, TN. Washington, DC: U.S. Department of Commerce.

U.S. Census Bureau. 1950a. Census of 1950. Available from the Tennessee State Library and Archives, Nashville, TN. Washington, DC: U.S. Department of Commerce. U.S. Census Bureau. 1950b. 1950 decennial census report.

U.S. Census Bureau. 1950b. 1950 decennial census report. Available from the Tennessee State Library and Archives, Nashville, TN. Washington, DC: U.S. Department of Commerce.

U.S. Census Bureau. 1960a. Census of 1960. Available from the Tennessee State Library and Archives, Nashville, TN. Washington, DC: U.S. Department of Commerce.

U.S. Census Bureau. 1960b. 1960 decennial census report. Available from the Tennessee State Library and Archives, Nashville, TN. Washington, DC: U.S. Department of Commerce.

U.S. Census Bureau. 1970a. Census of 1970. Available from the Tennessee State Library and Archives, Nashville, TN. Washington, DC: U.S. Department of Commerce.

U.S. Census Bureau. 1970b. 1970 decennial census report. Available from the Tennessee State Library and Archives, Nashville, TN. Washington, DC: U.S. Department of Commerce.

U.S. Census Bureau. 1980a. Census of 1980. Available from the Tennessee State Library and Archives, Nashville, TN. Washington, DC: U.S. Department of Commerce.

U.S. Census Bureau. 1980b. 1980 decennial census report. Available from the Tennessee State Library and Archives, Nashville, TN. Washington, DC: U.S. Department of Commerce.

U.S. Census Bureau. 1990a. Census of 1990. Available from the Tennessee State Library and Archives, Nashville, TN. Washington, DC: U.S. Department of Commerce.

U.S. Census Bureau. 1990b. 1990 decennial census report. Available from the Tennessee State Library and Archives, Nashville, TN. Washington, DC: U.S. Department of Commerce.

U.S. Census Bureau. 2000a. Census of 2000. Available from the Tennessee State Library and Archives, Nashville, TN. Washington, DC: U.S. Department of Commerce.

U.S. Census Bureau. 2000b. 2000 decennial census report. Available from the Tennessee State Library and Archives, Nashville, TN. Washington, DC: U.S. Department of Commerce.

[USDOE] U.S. Department of Energy. 1979. Environmental assessment of the Oak Ridge gaseous diffusion plant site. DOE/EA-0106. Oak Ridge, TN; December. [cited by U.S. Department of Energy. 2003a. Draft environmental impact statement for construction and operation of a depleted uranium hexafluoride conversion facility at the Portsmouth, Ohio, site. Office of Oak Ridge Operations, Office of Environmental Management. DOE/EIS-0360. Oak Ridge, TN; December. Available from: http://nepa.energy.gov/draft-eis0360.htm. Last accessed 2010 July 14.]

[USDOE] U.S. Department of Energy. 1994. Defense Nuclear Facilities Safety Board technical review of UF_6 cylinder management, Oak Ridge K-25 Site. Washington, DC: U.S. Department of Energy; December.

[USDOE] U.S. Department of Energy. 1995a. Department of Energy programmatic spent nuclear fuel management and Idaho National Engineering Laboratory environmental restoration and waste management program final environmental impact statement. DOE/EIS-0203-F. Idaho Falls, ID: Office of Environmental Management, Idaho Operations Office; April. [cited by U.S. Department of Energy. 2003a. Draft environmental impact statement for construction and operation of a depleted uranium hexafluoride conversion facility at the Portsmouth, Ohio, site. Office of Oak Ridge Operations, Office of Environmental Management. DOE/EIS-0360. Oak Ridge, TN; December. Available from: http://nepa.energy.gov/draft-eis0360.htm. Last accessed 2010 July 14.]

[USDOE] U.S. Department of Energy. 1995b. Record of decision for Lower Watts Bar Reservoir, Oak Ridge, Tennessee. DOE/OR/02-1373&D3. 18 September. Available from: http://epa.gov/superfund/sites/rods/fulltext/r0495249.pdf. Last accessed 2010 July 14.

[USDOE] U.S. Department of Energy. 1996. 1996 Baseline environmental management report. U.S. Department of Energy, Office of Environmental Management. Last updated 4 November 1999. Available from: http://www.em.doe.gov/bemr/BEMRPages/toc.aspx. Last accessed 2010 July 14.

[USDOE] U.S. Department of Energy. 1997. DOE to perform aerial survey of Oak Ridge Reservation. Oak Ridge, TN; June 9. Available from: http://www.oakridge.doe.gov/media_releases/1997/r-97-011.htm. Last accessed 2010 July 14.

[USDOE] U.S. Department of Energy. 1999. Final programmatic environmental impact statement for alternative strategies for the long-term management and use of depleted

uranium hexafluoride. DOE/EIS-0269. Germantown, MD: Office of Nuclear Energy, Science and Technology; April.

[USDOE] U.S. Department of Energy. 2000. Independent investigation of the East Tennessee Technology Park. Volume I: Past environment, safety, and health practices. Washington, DC: Office of Oversight Environment Safety and Health; October.

[USDOE] U.S. Department of Energy. 2001a. ETTP auxiliary facilities demolition project: group 1 buildings.

[USDOE] U.S. Department of Energy. 2001b. Overview of CERCLA actions at off-site locations. Environmental management program fact sheet; September.

[USDOE] U.S. Department of Energy. 2002a. K-1070-A burial ground project. Environmental management program fact sheet; October.

[USDOE] U.S. Department of Energy. 2002b. K-1070 C/D G-pit and concrete pad project. Environmental management program fact sheet; October.

[USDOE] U.S. Department of Energy. 2003a. Draft environmental impact statement for construction and operation of a depleted uranium hexafluoride conversion facility at the Portsmouth, Ohio, site. Office of Oak Ridge Operations, Office of Environmental Management. DOE/EIS-0360. Oak Ridge, TN; December. Available from: http://nepa.energy.gov/draft-eis0360.htm. Last accessed 2010 July 14.

[USDOE] U.S. Department of Energy. 2003b. Quick facts—East Tennessee Technology Park. Oak Ridge Environmental Management Program; March.

[USDOE] U.S. Department of Energy. 2003c. Federal facility agreement. Environmental management program fact sheet; February.

[USDOE] U.S. Department of Energy. 2003d. ETTP zone 1 record of decision. Environmental management program fact sheet; March.

[USDOE] U.S. Department of Energy. 2003e. Decontaminating and decommissioning ETTP gaseous diffusion buildings. Environmental management program fact sheet; March.

[USDOE] U.S. Department of Energy. 2003f. K-25/K-27 buildings demolition project. Environmental management program fact sheet; March.

[USDOE] U.S. Department of Energy. 2003g. ETTP auxiliary facilities demolition project: group 2 buildings. Environmental management program fact sheet; April.

[USDOE] U.S. Department of Energy. 2003h. Lower Watts Bar Reservoir remedial action. Environmental management program fact sheet; April.

[USDOE] U.S. Department of Energy. 2003i. Comprehensive waste disposition plan for the DOE Oak Ridge Reservation. Approved for public release March 6.

[USDOE] U.S. Department of Energy. 2003j. Cleanup progress fiscal year 2003. Annual report to the Oak Ridge community. Environmental Management, Oak Ridge Operations. Available from: http://www.bechteljacobs.com/pdf/CleanProg2003.pdf. Last accessed 2010 July 14.

[USDOE] U.S. Department of Energy. 2005a. East Tennessee Technology Park fact sheet. DOE Oak Ridge Environmental Management Program. Oak Ridge, TN; September. Available from: http://www.bechteljacobs.com/pdf/factsheets/ettp_fact_sheet.pdf. Last accessed 2010 July 14.

[USDOE] U.S. Department of Energy. 2005b. Oak Ridge Reservation annual site environmental report for 2004. Prepared by Oak Ridge National Laboratory, Y-12 National Security Complex, and East Tennessee Technology Park. Oak Ridge, TN; September. Available from: http://www.ornl.gov/sci/env_rpt/aser2004/aser2004.htm. Last accessed 2010 July 14.

[USDOE] U.S. Department of Energy. 2006. DOE Oak Ridge Environmental Management Program: East Tennessee Technology Park; September.

[USDOE] U.S. Department of Energy. 2008. DOE Oak Ridge Environmental Management Program: History of the Oak Ridge EM Program; March.

[USDOE] U.S. Department of Energy. 2009. DOE Oak Ridge Environmental Management Program: East Tennessee Technology Park; July. Available from: http://www.bechteljacobs.com/pdf/factsheets/ettp_fact_sheet.pdf. Last accessed 2010 July 14.

[USDOE–ORO and CROET] U.S. Department of Energy Oak Ridge Operations and Community Reuse Organization of East Tennessee. 2000. Special drinking water quality report, East Tennessee Technology Park. Oak Ridge, TN; 20 September. Available from: http://www.state.tn.us/environment/doeo/pdf/PSBroch.pdf. Last accessed 2010 July 14.

[USEPA] U.S. Environmental Protection Agency. 1989. Health issue assessment: Summary review of health effects associated with hydrogen fluoride and related compounds. EPA/600/8-89/002F. Cincinnati, OH: Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, Office of Research and Development. [cited by USEPA 2000. Hydrofluoric acid hazard summary. Created 1992 April; revised 2000 January. Available from: http://epa.gov/ttn/atw/hlthef/hydrogen.html. Last accessed 2010 July 14.]

[USEPA] U.S. Environmental Protection Agency. 1991. Superfund record of decision: Oak Ridge Reservation, OU4, Oak Ridge, TN. EPA/ROD/R04-91/096. 19 September. Available from: http://www.epa.gov/superfund/sites/rods/fulltext/r0491096.pdf. Last accessed 2010 July 14.

[USEPA] U.S. Environmental Protection Agency. 1999. Federal guidance report no. 13. Cancer risk coefficients for environmental exposure to radionuclides. EPA 402-R-99-001. For: U.S. Environmental Protection Agency, Office of Radiation and Indoor Air. Oak Ridge, TN: Oak Ridge National Laboratory; September. Available from: http://www.epa.gov/radiation/docs/federal/402-r-99-001.pdf. Last accessed 2010 July 14.

[USEPA] U.S. Environmental Protection Agency. 2003. Final report. September 2001 sampling report for the Scarboro community, Oak Ridge, Tennessee. Science and Ecosystem Support Division. Athens, GA; April. Previously available from: http://www.epa.gov/region4/waste/fedfac/scarborofinal.pdf. Last accessed 2007 September 11.

[USEPA] U.S. Environmental Protection Agency. 2004a. The standardized monitoring framework: A quick reference guide. Washington, DC: Office of Water; March. Available from:

http://www.epa.gov/safewater/pws/pdfs/qrg_smonitoringframework.pdf. Last accessed 2010 July 14.

[USEPA] U.S. Environmental Protection Agency. 2004b. Local drinking water information, Tennessee drinking water. Available from: http://www.epa.gov/safewater/dwinfo/tn.htm. Last accessed 2010 July 14.

[USEPA] U.S. Environmental Protection Agency. 2004c. NPL site narrative for Oak Ridge Reservation (USDOE). Oak Ridge Reservation, Oak Ridge, Tennessee. Available from: http://www.epa.gov/superfund/sites/npl/nar1239.htm. Last accessed 2010 July 14.

[USEPA] U.S. Environmental Protection Agency. 2005. Tennessee NPL/NPL caliber cleanup site summaries. USDOE Oak Ridge Reservation, Oak Ridge, Anderson County, Tennessee. Available from: http://www.epa.gov/region4/waste/npl/npltn/oakridtn.htm. Last accessed 2010 July 14.

[USGS] U.S. Geological Survey. 1953. Elverton, TENN (N3552.5-W8422.5/7.5), 7.5 Minute Quadrangle Map. Washington, DC: U.S. Geological Survey.

Wilson MD and Hinton TG. 2003. Comparative bias associated with various estimates of dose to maximally exposed individuals. Health Physics 85(5):585–93; November.

Appendix A. ATSDR Glossary of Terms

The Agency for Toxic Substances and Disease Registry (ATSDR) is a federal public health agency with headquarters in Atlanta, Georgia, and 10 regional offices in the United States. ATSDR's mission is to serve the public by using the best science, taking responsive public health actions, and providing trusted health information to prevent harmful exposures and diseases related to toxic substances. ATSDR is not a regulatory agency, unlike the U.S. Environmental Protection Agency (USEPA), which is the federal agency that develops and enforces environmental laws to protect the environment and human health. This glossary defines words used by ATSDR in communications with the public. It is not a complete dictionary of environmental health terms. If you have questions or comments, call ATSDR's toll-free telephone number, 1-800-CDC-INFO (1-800-232-4636).

Absorption
The process of taking in. For a person or an animal, absorption is the process of a substance getting into the body through the eyes, skin, stomach, intestines, or lungs.

Acute
Occurring over a short time [compare with chronic].

Acute exposure
Contact with a substance that occurs once or for only a short time (up to 14 days) [compare with intermediate duration exposure and chronic exposure].

Additive effect
A biologic response to exposure to multiple substances that equals the sum of responses of all the individual substances added together [compare with antagonistic effect and synergistic effect].

Adverse health effect
A change in body function or cell structure that might lead to disease or health problems

Aerobic
Requiring oxygen [compare with anaerobic].

Ambient
Surrounding (for example, ambient air).

Anaerobic
Requiring the absence of oxygen [compare with aerobic].

Analyte
A substance measured in the laboratory. A chemical for which a sample (such as water, air, or blood) is tested in a laboratory. For example, if the analyte is mercury, the laboratory test will determine the amount of mercury in the sample.

Analytic epidemiologic study
A study that evaluates the association between exposure to hazardous substances and disease by testing scientific hypotheses.

Antagonistic effect
A biologic response to exposure to multiple substances that is less than would be expected if the known effects of the individual substances were added together [compare with additive effect and synergistic effect].

Background level
An average or expected amount of a substance or radioactive material in a specific environment, or typical amounts of substances that occur naturally in an environment.

Biodegradation
Decomposition or breakdown of a substance through the action of microorganisms (such as bacteria or fungi) or other natural physical processes (such as sunlight).

Biologic indicators of exposure study
A study that uses (a) biomedical testing or (b) the measurement of a substance [an analyte], its metabolite, or another marker of exposure in human body fluids or tissues to confirm human exposure to a hazardous substance [also see exposure investigation].

Biologic monitoring
Measuring hazardous substances in biologic materials (such as blood, hair, urine, or breath) to determine whether exposure has occurred. A blood test for lead is an example of biologic monitoring.

Biologic uptake
The transfer of substances from the environment to plants, animals, and humans.

Biomedical testing
Testing of persons to find out whether a change in a body function might have occurred because of exposure to a hazardous substance.

Biota
Plants and animals in an environment. Some of these plants and animals might be sources of food, clothing, or medicines for people.

Body burden
The total amount of a substance in the body. Some substances build up in the body because they are stored in fat or bone or because they leave the body very slowly.

CAP [see Community Assistance Panel.]

Cancer
Any one of a group of diseases that occur when cells in the body become abnormal and grow or multiply out of control.

Cancer risk
A theoretical risk for getting cancer if exposed to a substance every day for 70 years (a lifetime exposure). The true risk might be lower.

Carcinogen
A substance that causes cancer.

Case study
A medical or epidemiologic evaluation of one person or a small group of people to gather information about specific health conditions and past exposures.

Case-control study
A study that compares exposures of people who have a disease or condition (cases) with people who do not have the disease or condition (controls). Exposures that are more common among the cases may be considered as possible risk factors for the disease.

CAS registry number
A unique number assigned to a substance or mixture by the American Chemical Society Abstracts Service.

Central nervous system
The part of the nervous system that consists of the brain and the spinal cord.

CERCLA [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980]

Chronic
Occurring over a long time [compare with acute].

Chronic exposure
Contact with a substance that occurs over a long time (more than 1 year) [compare with acute exposure and intermediate duration exposure]

Cluster investigation
A review of an unusual number, real or perceived, of health events (for example, reports of cancer) grouped together in time and location. Cluster investigations are designed to confirm case reports; determine whether they represent an unusual disease occurrence; and, if possible, explore possible causes and contributing environmental factors.

Community Assistance Panel (CAP)
A group of people from a community and from health and environmental agencies who work with ATSDR to resolve issues and problems related to hazardous substances in the community. CAP members work with ATSDR to gather and review community health concerns, provide information on how people might have been or might now be exposed to hazardous substances, and inform ATSDR on ways to involve the community in its activities.

Comparison value (CV)
Calculated concentration of a substance in air, water, food, or soil that is unlikely to cause harmful (adverse) health effects in exposed people. The CV is used as a screening level during the public health assessment process. Substances found in amounts greater than their CVs might be selected for further evaluation in the public health assessment process.

Completed exposure pathway [see exposure pathway].

Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA)
CERCLA, also known as Superfund, is the federal law that concerns the removal or cleanup of hazardous substances in the environment and at hazardous waste sites. ATSDR, which was created by CERCLA, is responsible for assessing health issues and supporting public health activities related to hazardous waste sites or other environmental releases of hazardous substances. This law was later amended by the Superfund Amendments and Reauthorization Act (SARA).

Concentration
The amount of a substance present in a certain amount of soil, water, air, food, blood, hair, urine, breath, or any other media.

Contaminant
A substance that is either present in an environment where it does not belong or is present at levels that might cause harmful (adverse) health effects.

Delayed health effect
A disease or an injury that happens as a result of exposures that might have occurred in the past.

Dermal
Referring to the skin. For example, dermal absorption means passing through the skin.

Dermal contact
Contact with (touching) the skin [see route of exposure].

Descriptive epidemiology
The study of the amount and distribution of a disease in a specified population by person, place, and time.

Detection limit
The lowest concentration of a chemical that can reliably be distinguished from a zero concentration.

Disease prevention
Measures used to prevent a disease or reduce its severity.

Disease registry
A system of ongoing registration of all cases of a particular disease or health condition in a defined population.

DOD
United States Department of Defense.

DOE
United States Department of Energy.

Dose (for chemicals that are not radioactive)
The amount of a substance to which a person is exposed over some time period. Dose is a measurement of exposure. Dose is often expressed as milligram (amount) per kilogram (a measure of body weight) per day (a measure of time) when people eat or drink contaminated water, food, or soil. In general, the greater the dose, the greater the likelihood of an effect. An "exposure dose" is how much of a substance is encountered in the environment. An "absorbed dose" is the amount of a substance that actually got into the body through the eyes, skin, stomach, intestines, or lungs.

Dose (for radioactive chemicals)
The radiation dose is the amount of energy from radiation that is actually absorbed by the body. This is not the same as measurements of the amount of radiation in the environment.

Dose-response relationship
The relationship between the amount of exposure [dose] to a substance and the resulting changes in body function or health (response).

Environmental media
Soil, water, air, biota (plants and animals), or any other parts of the environment that can contain contaminants.

Environmental media and transport mechanism
Environmental media include water, air, soil, and biota (plants and animals). Transport mechanisms move contaminants from the source to points where human exposure can occur. The environmental media and transport mechanism is the second part of an exposure pathway.

Epidemiologic surveillance [see Public health surveillance].

Epidemiology
The study of the distribution and determinants of disease or health status in a population; the study of the occurrence and causes of health effects in humans.

Exposure
Contact with a substance by swallowing, breathing, or touching the skin or eyes. Exposure may be short-term [acute exposure], of intermediate duration, or long-term [chronic exposure].

Exposure assessment
The process of finding out how people come into contact with a hazardous substance, how often and for how long they are in contact with the substance, and how much of the substance they are in contact with.

Exposure-dose reconstruction
A method of estimating the amount of people's past exposure to hazardous substances. Computer and approximation methods are used when past information is limited, not available, or missing.

Exposure investigation
The collection and analysis of site-specific information and biologic tests (when appropriate) to determine whether people have been exposed to hazardous substances.

Exposure pathway
The route a substance takes from its source (where it began) to its end point (where it ends), and how people can come into contact with (or get exposed to) it. An exposure pathway has five parts: a source of contamination (such as an abandoned business); an environmental media and transport mechanism (such as movement through groundwater); a point of exposure (such as a private well); a route of exposure (eating, drinking, breathing, or touching), and a receptor population (people potentially or actually exposed). When all five parts are present, the exposure pathway is termed a completed exposure pathway.

Exposure registry
A system of ongoing follow up of people who have had documented environmental exposures.

Feasibility study
A study by EPA to determine the best way to clean up environmental contamination. A number of factors are considered, including health risk, costs, and what methods will work well.

Geographic information system (GIS)
A mapping system that uses computers to collect, store, manipulate, analyze, and display data. For example, GIS can show the concentration of a contaminant within a community in relation to points of reference such as streets and homes.

Grand rounds
Training sessions for physicians and other health care providers about health topics.

Groundwater
Water beneath the earth's surface in the spaces between soil particles and between rock surfaces [compare with surface water].

Half-life ($t_{½}$)
The time it takes for half the original amount of a substance to disappear. In the environment, the half-life is the time it takes for half the original amount of a substance to disappear when it is changed to another chemical by bacteria, fungi, sunlight, or other chemical processes. In the human body, the half-life is the time it takes for half the original amount of the substance to disappear, either by being changed to another substance or by leaving the body. In the case of radioactive material, the half life is the amount of time necessary for one half the initial number of radioactive atoms to change or transform into another atom (that is normally not radioactive). After two half lives, 25% of the original number of radioactive atoms remain.

Hazard
A source of potential harm from past, current, or future exposures.

Hazardous Substance Release and Health Effects Database (HazDat)
The scientific and administrative database system developed by ATSDR to manage data collection, retrieval, and analysis of site-specific information on hazardous substances, community health concerns, and public health activities.

Hazardous waste
Potentially harmful substances that have been released or discarded into the environment.

Health consultation
A review of available information or collection of new data to respond to a specific health question or request for information about a potential environmental hazard. Health consultations are focused on a specific exposure issue. Health consultations are therefore more limited than a public health assessment, which reviews the exposure potential of each pathway and chemical [compare with public health assessment].

Health education
Programs designed with a community to help it know about health risks and how to reduce these risks.

Health investigation
The collection and evaluation of information about the health of community residents. This information is used to describe or count the occurrence of a disease, symptom, or clinical measure and to evaluate the possible association between the occurrence and exposure to hazardous substances.

Health promotion
The process of enabling people to increase control over, and to improve, their health.

Health statistics review
The analysis of existing health information (i.e., from death certificates, birth defects registries, and cancer registries) to determine if there is excess disease in a specific population, geographic area, and time period. A health statistics review is a descriptive epidemiologic study.

Incidence
The number of new cases of disease in a defined population over a specific time period [contrast with prevalence].

Ingestion
The act of swallowing something through eating, drinking, or mouthing objects. A hazardous substance can enter the body this way [see route of exposure].

Inhalation
The act of breathing. A hazardous substance can enter the body this way [see route of exposure].

Intermediate duration exposure
Contact with a substance that occurs for more than 14 days and less than a year [compare with acute exposure and chronic exposure].

In vitro
In an artificial environment outside a living organism or body. For example, some toxicity testing is done on cell cultures or slices of tissue grown in the laboratory, rather than on a living animal [compare with in vivo].

In vivo
Within a living organism or body. For example, some toxicity testing is done on whole animals, such as rats or mice [compare with in vitro].

Lowest-observed-adverse-effect level (LOAEL)
The lowest tested dose of a substance that has been reported to cause harmful (adverse) health effects in people or animals.

Medical monitoring
A set of medical tests and physical exams specifically designed to evaluate whether an individual's exposure could negatively affect that person's health.

Metabolism
The conversion or breakdown of a substance from one form to another by a living organism.

Metabolite
Any product of metabolism.

mg/kg
Milligram per kilogram.

mg/cm^2
Milligram per square centimeter (of a surface).

mg/m^3
Milligram per cubic meter; a measure of the concentration of a chemical in a known volume (a cubic meter) of air, soil, or water.

Migration
Moving from one location to another.

Minimal risk level (MRL)
An ATSDR estimate of daily human exposure to a hazardous substance at or below which that substance is unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. MRLs are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). MRLs should not be used as predictors of harmful (adverse) health effects [see reference dose].

Morbidity
State of being ill or diseased. Morbidity is the occurrence of a disease or condition that alters health and quality of life.

Mortality
Death. Usually the cause (a specific disease, a condition, or an injury) is stated.

Mutagen
A substance that causes mutations (genetic damage).

Mutation
A change (damage) to the DNA, genes, or chromosomes of living organisms.

National Priorities List for Uncontrolled Hazardous Waste Sites (National Priorities List or NPL)
EPA's list of the most serious uncontrolled or abandoned hazardous waste sites in the United States. The NPL is updated on a regular basis.

National Toxicology Program (NTP)
Part of the Department of Health and Human Services. NTP develops and carries out tests to predict whether a chemical will cause harm to humans.

No-observed-adverse-effect level (NOAEL)
The highest tested dose of a substance that has been reported to have no harmful (adverse) health effects on people or animals.

NPL [see National Priorities List for Uncontrolled Hazardous Waste Sites]

Physiologically based pharmacokinetic model (PBPK model)
A computer model that describes what happens to a chemical in the body. This model describes how the chemical gets into the body, where it goes in the body, how it is changed by the body, and how it leaves the body.

Pica
A craving to eat nonfood items, such as dirt, paint chips, and clay. Some children exhibit pica-related behavior.

Plume
A volume of a substance that moves from its source to places farther away from the source. Plumes can be described by the volume of air or water they occupy and the direction they move. For example, a plume can be a column of smoke from a chimney or a substance moving with groundwater.

Point of exposure
The place where someone can come into contact with a substance present in the environment [see exposure pathway].

Population
A group or number of people living within a specified area or sharing similar characteristics (such as occupation or age).

Potentially responsible party (PRP)
A company, government, or person legally responsible for cleaning up the pollution at a hazardous waste site under Superfund. There may be more than one PRP for a particular site.

ppb
Parts per billion.

ppm
Parts per million.

Prevalence
The number of existing disease cases in a defined population during a specific time period [contrast with incidence].

Prevalence survey
The measure of the current level of disease(s) or symptoms and exposures through a questionnaire that collects self-reported information from a defined population.

Prevention
Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

Public availability session
An informal, drop-by meeting at which community members can meet one-on-one with ATSDR staff members to discuss health and site-related concerns.

Public comment period
An opportunity for the public to comment on agency findings or proposed activities contained in draft reports or documents. The public comment period is a limited time period during which comments will be accepted.

Public health action
A list of steps to protect public health.

Public health advisory
A statement made by ATSDR to EPA or a state regulatory agency that a release of hazardous substances poses an immediate threat to human health. The advisory includes recommended measures to reduce exposure and reduce the threat to human health.

Public health assessment (PHA)
An ATSDR document that examines hazardous substances, health outcomes, and community concerns at a hazardous waste site to determine whether people could be harmed from coming into contact with those substances. The PHA also lists actions that need to be taken to protect public health [compare with health consultation].

Public health statement
The first chapter of an ATSDR toxicological profile. The public health statement is a summary written in words that are easy to understand. The public health statement explains how people might be exposed to a specific substance and describes the known health effects of that substance.

Public health surveillance
The ongoing, systematic collection, analysis, and interpretation of health data. This activity also involves timely dissemination of the data and use for public health programs.

Public meeting
A public forum with community members for communication about a site.

Radioisotope
An unstable or radioactive isotope (form) of an element that can change into another element by giving off radiation.

Radionuclide
Any radioactive isotope (form) of any element.

RCRA [see Resource Conservation and Recovery Act (1976, 1984)]

Receptor population
People who could come into contact with hazardous substances [see exposure pathway].

Reference dose (RfD)
An EPA estimate, with uncertainty or safety factors built in, of the daily lifetime dose of a substance that is unlikely to cause harm in humans.

Registry
A systematic collection of information on persons exposed to a specific substance or having specific diseases [see exposure registry and disease registry].

Remedial investigation
The CERCLA process of determining the type and extent of hazardous material contamination at a site.

Resource Conservation and Recovery Act (1976, 1984) (RCRA)
This Act regulates management and disposal of hazardous wastes currently generated, treated, stored, disposed of, or distributed.

RFA
RCRA Facility Assessment. An assessment required by RCRA to identify potential and actual releases of hazardous chemicals.

RfD [see reference dose]

Risk
The probability that something will cause injury or harm.

Risk reduction
Actions that can decrease the likelihood that individuals, groups, or communities will experience disease or other health conditions.

Risk communication
The exchange of information to increase understanding of health risks.

Route of exposure
The way people come into contact with a hazardous substance. Three routes of exposure are breathing [inhalation], eating or drinking [ingestion], or contact with the skin [dermal contact].

Safety factor [see uncertainty factor]

SARA [see Superfund Amendments and Reauthorization Act]

Sample
A portion or piece of a whole. A selected subset of a population or subset of whatever is being studied. For example, in a study of people the sample is a number of people chosen from a larger population [see population]. An environmental sample (for example, a small amount of soil or water) might be collected to measure contamination in the environment at a specific location.

Sample size
The number of units chosen from a population or an environment.

Solvent
A liquid capable of dissolving or dispersing another substance (for example, acetone or mineral spirits).

Source of contamination
The place where a hazardous substance comes from, such as a landfill, waste pond, incinerator, storage tank, or drum. A source of contamination is the first part of an exposure pathway.

Special populations
People who might be more sensitive or susceptible to exposure to hazardous substances because of factors such as age, occupation, sex, or behaviors (for example, cigarette smoking). Children, pregnant women, and older people are often considered special populations.

Stakeholder
A person, group, or community who has an interest in activities at a hazardous waste site.

Statistics
A branch of mathematics that deals with collecting, reviewing, summarizing, and interpreting data or information. Statistics are used to determine whether differences between study groups are meaningful.

Substance
A chemical.

Substance-specific applied research
A program of research designed to fill important data needs for specific hazardous substances identified in ATSDR's toxicological profiles. Filling these data needs would allow more accurate assessment of human risks from specific substances contaminating the environment. This research might include human studies or laboratory experiments to determine health effects resulting from exposure to a given hazardous substance.

Superfund [see Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and Superfund Amendments and Reauthorization Act (SARA)]

Superfund Amendments and Reauthorization Act (SARA)
In 1986, SARA amended the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) and expanded the health-related responsibilities of ATSDR. CERCLA and SARA direct ATSDR to look into the health effects from substance exposures at hazardous waste sites and to perform activities including health education, health studies, surveillance, health consultations, and toxicological profiles.

Surface water
Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with groundwater].

Surveillance [see public health surveillance]

Survey
A systematic collection of information or data. A survey can be conducted to collect information from a group of people or from the environment. Surveys of a group of people can be conducted by telephone, by mail, or in person. Some surveys are done by interviewing a group of people [see prevalence survey].

Synergistic effect
A biologic response to multiple substances where one substance worsens the effect of another substance. The combined effect of the substances acting together is greater than the sum of the effects of the substances acting by themselves [see additive effect and antagonistic effect].

Teratogen
A substance that causes defects in development between conception and birth. A teratogen is a substance that causes a structural or functional birth defect.

Toxic agent
Chemical or physical (for example, radiation, heat, cold, microwaves) agents that, under certain circumstances of exposure, can cause harmful effects to living organisms.

Toxicological profile
An ATSDR document that examines, summarizes, and interprets information about a hazardous substance to determine harmful levels of exposure and associated health effects. A toxicological profile also identifies significant gaps in knowledge on the substance and describes areas where further research is needed.

Toxicology
The study of the harmful effects of substances on humans or animals.

Tumor
An abnormal mass of tissue that results from excessive cell division that is uncontrolled and progressive. Tumors perform no useful body function. Tumors can be either benign (not cancer) or malignant (cancer).

Uncertainty factor
Mathematical adjustments for reasons of safety when knowledge is incomplete. For example, factors used in the calculation of doses that are not harmful (adverse) to people. These factors are applied to the lowest-observed-adverse-effect-level (LOAEL) or the no-observed-adverse-effect-level (NOAEL) to derive a minimal risk level (MRL). Uncertainty factors are used to account for variations in people's sensitivity, for differences between animals and humans, and for differences between a LOAEL and a NOAEL. Scientists use uncertainty factors when they have some, but not all, the information from animal or human studies to decide whether an exposure will cause harm to people [also sometimes called a safety factor].

U.S. EPA
United States Environmental Protection Agency.

Volatile organic compounds (VOCs)
Organic compounds that evaporate readily into the air. VOCs include substances such as benzene, toluene, methylene chloride, and methyl chloroform.

Other glossaries and dictionaries:
Environmental Protection Agency (http://www.epa.gov/ocepaterms/)
National Library of Medicine (NIH)
(http://www.nlm.nih.gov/medlineplus/mplusdictionary.html)

For more information on the work of ATSDR, please contact:
Office of Policy and External Affairs
Agency for Toxic Substances and Disease Registry
1600 Clifton Road, N.E. (MS E-60)
Atlanta, GA 30333
Telephone: (404) 498-0080

Appendix B. Summary of Other Public Health Activities

Summary of ATSDR Activities

Exposure investigations, health consultations, and other scientific evaluations. ATSDR health scientists have addressed current public health issues and community health concerns related to two areas affected by Oak Ridge Reservation (ORR) operations—the East Fork Poplar Creek (EFPC) area and the Watts Bar Reservoir area. Section II.F.1 of this document summarizes principal ATSDR public health activities at the Watts Bar Reservoir area.

Following are summaries of other ATSDR public health activities related to the Oak Ridge Reservation.

ATSDR science panel meeting on the bioavailability of mercury in soil, August 1995. Using an evaluation of the DOE studies conducted on mercury, ATSDR concluded that outside expertise was needed to assess technical details related to mercury. As a result, a science panel was created that consisted of experts from various government agencies (e.g., U.S. EPA), private consultants, and others with experience in metal bioavailability research. The panel's goal was to select procedures and strategies that could be used by health assessors to create site-specific and data-supported estimates with regard to the bioavailability of inorganic mercury and other metals (e.g., lead) from soils. ATSDR applied the data from the panel to its assessment of the mercury clean-up level in the EFPC soil. In 1997, the International Journal of Risk Analysis (Volume 17:5) published three technical papers and an ATSDR overview paper that detailed this meeting's results (ATSDR et al. 2000).

Health consultation on proposed mercury clean up levels, January 1996. Following a request from community members and the city of Oak Ridge, ATSDR prepared a health consultation to assess DOE's clean-up levels for mercury in the EFPC floodplain soil. The final health consultation, which was released in January 1996, concluded that DOE's clean-up levels of 180 milligrams per kilogram (mg/kg) and 400 mg/kg of mercury in the soil of the EFPC floodplain would protect public health and did not present a health risk to adults or to children (ATSDR et al. 2000).

Community and physician education on PCBs in fish, September 1996. As a follow-up to the recommendations in the Lower Watts Bar Reservoir Health Consultation, ATSDR created a program to educate the community and various physicians on PCBs in the Watts Bar Reservoir. On September 11, 1996, Daniel Hryhorczuk, MD, MPH, ABMT, from the Great Lakes Center at the University of Illinois at Chicago, presented information on the health risks related to the consumption of PCBs in fish. Dr. Hryhorczuk made his presentation to about 40 area residents at the community health education meeting that was held in Spring City, Tennessee. In addition, on September 12, 1996, an educational meeting for health care providers in the Watts Bar Reservoir area was held at the Methodist Medical Center in Oak Ridge, Tennessee. Furthermore, ATSDR collaborated with local residents, associations, and state officials to create a brochure informing the public about TDEC's fish consumption advisories for the Watts Bar Reservoir (ATSDR et al. 2000).

Watts Bar Reservoir exposure investigation, March 1998. This exposure investigation was conducted as a follow-up to the February 1996 Health Consultation on the Lower Watts Bar Reservoir. Prior to this investigation, studies on the Watts Bar Reservoir and the Clinch River had reviewed several contaminants, but the only contaminant found to be of current public health concern was PCBs in reservoir fish. ATSDR conducted this exposure investigation primarily because of the uncertainties associated with estimating doses and increases in cancer likelihood from ingestion of reservoir fish and turtles. ATSDR believed that before any agency conducted extensive investigations, it should determine if mercury and PCBs were actually elevated in persons who consumed large amounts of fish and turtles from the reservoir.

Exposure investigations are one of the methods ATSDR uses to develop a better characterization of past, present, or possible future human exposure to hazardous substances in the environment. These investigations, however, only evaluate exposures—they do not assess whether exposure levels resulted in adverse health effects.

The exposure investigation evaluated exposures at one point in time. Because serum PCBs and mercury blood levels are, however, indicators of chronic exposure, the investigation results provide information on both past and present exposure. Participants were recruited through newspaper, radio, and television announcements, as well as through posters and flyers placed at various fishing-related locations. ATSDR interviewed over 550 volunteers; 116 of these had consumed enough fish or turtles to be included in the investigation. ATSDR concluded that the participants' serum PCB levels and blood mercury levels were consistent with those seen in the general population. ATSDR had three major findings (ATSDR et al. 2000; ORHASP 1999):

1. The investigation participants' serum PCB levels and blood mercury levels were very close to levels seen in the general population.
2. Of the 116 persons tested, only 5 (4%) had serum PCB levels above 20 micrograms per liter (μg/L) or parts per billion (ppb), which is the level regarded as elevated for total PCBs. Four of the five participants who exceeded 20 μg/L had levels between 20 and 30 μg/L. The remaining participant had a serum PCB level that measured 103.8 μg/L, which is above the distribution seen in the general population. Follow-up counseling was given to study participants with elevated PCB blood levels.
3. One investigation participant had a total blood mercury level above 10 μg/L, which is regarded as elevated. The other participants had mercury blood levels that varied up to 10 μg/L, which would be likely in the general population. Follow-up counseling was also given to this person.

Clinical laboratory analysis. In June 1992, William Reid, M.D., an Oak Ridge physician, notified ORHASP and TDOH that he believed that about 60 of his patients had been exposed to numerous heavy metals through their occupation or through the environment. Dr. Reid believed these exposures had caused a number of adverse health outcomes,

including immunosuppression, increased cancer incidence, neurologic diseases, bone marrow damage, chronic fatigue syndrome, autoimmune disease, and abnormal blot clots. Howard Frumkin, M.D., Dr.PH., then of the Emory University School of Public Health, requested clinical laboratory support to evaluate the patients referred by Dr. Reid. As a result of Dr. Frumkin's request, ATSDR and the CDC's NCEH facilitated this laboratory support from 1992 to 1993 through the NCEH Environmental Health Laboratory (ATSDR et al. 2000; ORHASP 1999).

Because of the confidentiality among physicians, as well as the confidentiality between physicians and their patients, the findings of these clinical analyses have not been provided to public health agencies (ATSDR et al. 2000). In an April 26, 1995, letter to the Commissioner of the Tennessee Department of Health, Dr. Frumkin suggested, however, that one should

> ". . . not evaluate the patients seen at Emory as if they were a cohort for whom group statistics would be meaningful. This was a self-selected group of patients, most with difficult to answer medical questions (hence their trips to Emory), and cannot in any way be taken to typify the population of Oak Ridge. For that reason, I have consistently urged Dr. Reid, each of the patients, and officials of the CDC and the Tennessee Health Department, not to attempt group analyses of these patients."

Review of clinical information on persons living in or near Oak Ridge. Following a request by William Reid, M.D., ATSDR evaluated the medical histories and clinical data associated with 45 of Dr. Reid's patients. The objective of this review was to assess the clinical data for patients who were tested for heavy metals, and to establish whether exposure to metals was related to these patients' various illnesses. ATSDR determined that the case data were not sufficient to support an association between these diseases and low levels of metals. The TDOH, which also evaluated the information, developed the same conclusion as ATSDR. In September 1992, ATSDR provided a copy of its review to Dr. Reid (ATSDR et al. 2000).

Health consultation on the assessment of cancer incidence in counties adjacent to the Oak Ridge Reservation, March 2006. Some area residents expressed concerns about the number of cancer cases in communities around the Oak Ridge Reservation. To address these concerns, the Oak Ridge Reservation Health Effects Subcommittee requested that ATSDR conduct an assessment of cancer incidence to evaluate cancer rates in these communities. For the consultation, ATSDR obtained cancer incidence data—data on newly diagnosed cases of cancer—from the Tennessee Cancer Registry for 42 different cancer types. Data from 1991–2000 were obtained for the eight-county area surrounding the Oak Ridge Reservation, including Anderson, Blount, Knox, Loudon, Meigs, Morgan, Rhea, and Roane Counties. To analyze the data and determine any increases of cancer incidence, ATSDR compared the number of observed cases in each of the eight counties with the expected number of cases in the state of Tennessee. The findings indicated both higher and lower rates of certain cancers in some of the counties examined when compared with the cancer incidence rates in the state. No consistent pattern of cancer occurrence was, however, identified, and the reasons for the increases and decreases of

cancer occurrence are unknown. For more information, the assessment of cancer incidence (released for public comment in 2006) is available at http://www.atsdr.cdc.gov/HAC/oakridge/phact/cancer_oakridge/index.html.

Health education. Another essential part of the public health assessment process is designing and implementing activities that promote health and provide information about hazardous substances in the environment.

Health professional education on cyanide. In January 1996, an employee from ETTP (formerly the K-25 facility) requested ATSDR's assistance with occupational cyanide exposure. As a result, in August 1996, ATSDR held a physician health education program in Oak Ridge to teach physicians about health effects that could result from potential cyanide intoxication. The purpose of the education program was to help community health care providers respond to concerns from ETTP employees. ATSDR gave the following materials to the concerned employee and to the area physicians: the ATSDR public health statement for cyanide, the NIOSH final health hazard evaluation, and the ATSDR Case Studies in Environmental Medicine publication entitled *Cyanide Toxicity*. ATSDR led the environmental health education workshop for physicians at the Methodist Medical Center in Oak Ridge, Tennessee. The session focused on supplying area physicians and other health care providers with information to assist with the diagnosis of acute and chronic cyanide intoxication, and also to assist with answering patient's questions. In addition, ATSDR established a system that area physicians could use to make patient referrals directly to the Association of Occupational and Environmental Clinics (AOEC) (ATSDR et al. 2000).

Workshops on epidemiology. Following requests from ORRHES members, ATSDR conducted two epidemiology workshops for the subcommittee. The first session took place at the ORRHES meeting on June 2001. During this meeting, Ms. Sherri Berger and Dr. Lucy Peipins of ATSDR's Division of Health Studies presented an overview of the science of epidemiology. Dr. Peipins also presented at the second epidemiology workshop, which was held at the ORRHES meeting on December 2001. The purpose of this second session was to help the ORRHES members build the skills that are required for analyzing scientific reports (ATSDR et al. 2000). In addition, at the PHAWG meeting on August 28, 2001, Dr. Peipins demonstrated the systematic and scientific approach of epidemiology by guiding the group as they critiqued a report by Joseph Mangano entitled *Cancer Mortality near Oak Ridge, Tennessee* (International Journal of Health Services, Volume 24: 3, 1994, page 521). Using the PHAWG critique, the ORRHES made the following conclusions and recommendations to ATSDR:

- The Mangano paper is not an adequate, science-based explanation of any alleged anomalies in cancer mortality rates of the off-site public.
- The Mangano paper fails to establish that radiation exposure from the ORR is the cause of any such alleged anomalies of cancer mortality rates in the public.
- The ORRHES recommends to ATSDR that the Mangano paper be excluded from consideration in the ORR public health assessment process (ATSDR et al. 2000).

Coordination with other parties. Since 1992 and continuing to the present, ATSDR has consulted regularly with representatives of other parties involved with the ORR. Specifically, ATSDR has coordinated its efforts with TDOH, TDEC, NCEH, NIOSH, and DOE. These coordinated efforts led to the establishment of the Public Health Working Group in 1999, which then led to the formation of the ORRHES. In addition, ATSDR provided some assistance to TDOH in its study of past public health issues. ATSDR has also obtained and interpreted studies prepared by academic institutions, consulting firms, community groups, and other parties.

Establishment of the ORR Public Health Working Group and the ORRHES. In 1998, under a collaborative effort with the DOE Office of Health Studies, ATSDR and CDC embarked on a process to develop credible, coherent, and coordinated agendas for public health activities and for health studies at each DOE site. In February 1999, ATSDR was given the responsibility to lead the interagency group's efforts to improve communication at the ORR. In cooperation with other agencies, ATSDR established the ORR Public Health Working Group to gather input from local organizations and from persons regarding the creation of a public health forum. After careful consideration of the input collected from community members, ATSDR and CDC determined that the most suitable approach to meet the community's needs was to establish the ORRHES.

Site visits. Since 1992, ATSDR scientists have conducted numerous site visits to the ORR and to the areas surrounding the reservation. These visits have enabled ATSDR to understand better the site-specific exposure conditions that exist with the ORR and with neighboring areas. The site visits have included guided tours of the ORR operation areas, as well as tours of the local communities. As a result of these site visits, ATSDR has been able to identify how community members might come into contact with environmental contamination.

Summary of U.S. Department of Health and Human Services Activities

U.S. Department of Health and Human Services' Evaluation of Data in The Tennessean Article From September 29, 1998. In a November 2, 1998 letter, the Honorable William H. Frist, M.D., then a United States Senator, requested that Donna E. Shalala, Secretary of the Department of Health and Human Services (DHHS), have the CDC, ATSDR, and the National Institutes of Health (NIH) evaluate the data that *The Tennessean* article described as reporting a pattern of illnesses among residents living near nuclear plants, including the DOE ORR.

In particular, Senator Frist requested the following:

- Assess the quality and usefulness of the data on which the report is based.
- Examine the data for any patterns of illness and assess whether there is sufficient data to establish a relationship to the nuclear plants.
- Summarize the current DHHS studies that are currently underway at the 11 sites.

- Estimate how the key questions raised by the newspaper article could be addressed in a potential study.

- Describe any existing programs at the three agencies that may help address the medical needs of people living near nuclear plants.

In a letter dated February 22, 1999, then-DHHS Secretary Donna E. Shalala responded to Senator Frist's request. The DHHS evaluated *The Tennessean* article and responded to Senator Frist's five specific issues. DHHS concluded the following:

1. The data in *The Tennessean* article were not compiled from an epidemiologic study and thus have many limitations. It is impossible to calculate rates for the reported illnesses or to determine whether rates of the illnesses were abnormal. It is also difficult to relate excess illnesses to specific nuclear plants because primary exposures differ among the plants.
2. Epidemiologically, tabulation of data collected in an unstandardized manner is unacceptable, as is assessment of illnesses and symptoms based on limited diagnostic information. Thus, if data in this report represent a new or unusual occurrence of symptoms in this population, determination is not possible.
3. DHHS has a significant number of ongoing studies that seek to analyze environmental exposure at each of the 11 sites rather than focusing on general medical evaluations of the populations near the sites. Clinical data from the Fernald Medical Monitoring Program and the Scarboro, Tennessee, survey focus, however, on respiratory illnesses in children and, although quite limited, are most relevant to the issues raised by the report.
4. Sound data using standardized information are essential to establish increased prevalence of a disease and linkage to the nuclear plants.
   - First, the occurrence of a single, definable illness would have to be assessed.
   - Second, studies including structured population surveys would need to be developed for general health and illness data in well-defined population groups near the nuclear sites. The finding would then be compared to results from other well-defined populations living elsewhere.
   - Third, any attempt to determine a causal relationship between disease or illness rates in these populations and exposures to hazards would be difficult, given that historic exposures themselves are difficult to identify and measure.
5. CDC, ATSDR, and NIH are working with DOE to plan appropriate public health follow-up activities to address the concerns of communities and workers regarding the nuclear weapons complexes. Embarking on such a comprehensive program will require considerable resource, planning, and evaluation. Please note that CDC, ATSDR, and NIH do not provide direct primary medical services to communities. Where possible, however, CDC, ATSDR, and NIH will continue to support community leaders and existing medical care systems to address public health concerns of communities that are near nuclear plants.

Summary of TDOH Activities

Pilot survey. In the fall of 1983, TDOH established an interim soil mercury level to use for environmental management decisions. CDC evaluated the methodology for this mercury level and advised the TDOH to conduct a pilot survey to determine whether populations with the greatest risk for mercury exposure had elevated mercury body burdens. Between June and July 1984, TDOH and CDC conducted a pilot survey to record the inorganic mercury levels of Oak Ridge residents who had the greatest risk of being exposed to mercury-contaminated fish and soil. In addition, the survey assessed if exposure to mercury through contaminated fish and soil represented an immediate health hazard for the Oak Ridge community. In October 1985, the findings of the pilot study were released. These results indicated that people who lived and worked in Oak Ridge, Tennessee, were unlikely to have a greater risk for significantly high mercury levels. Concentrations of mercury detected in hair and urine samples were lower than levels associated with known health effects (ATSDR et al. 2000).

Health statistics review. As referred to earlier, in June 1992, William Reid, M.D., an Oak Ridge physician, informed the ORHASP and the TDOH that he believed that about 60 of his patients had been exposed to numerous heavy metals through their occupation or through the environment. Dr. Reid felt that these exposures had caused a number of adverse health outcomes including immunosuppression, increased cancer incidence, neurologic diseases, bone marrow damage, chronic fatigue syndrome, autoimmune disease, and abnormal blot clots. In 1992, TDOH conducted a health statistics review that evaluated the cancer incidence rates for the counties around the reservation between 1988 and 1990, and compared these rates with the state rates for Tennessee. The health statistics review determined that when compared with state rates, some of the county rates were low and some were high. But the review was unable to distinguish any patterns associated with the site. More detailed findings of the review can be found in a TDOH memorandum dated October 19, 1992, from Mary Layne Van Cleave to Dr. Mary Yarbrough. In addition, the handouts and minutes from Ms. Van Cleave's presentation at the ORHASP meeting on December 14, 1994, are available through TDOH (ATSDR et al. 2000).

Health statistics review. In 1994, area residents reported several community members had amyotrophic lateral sclerosis (ALS) and multiple sclerosis (MS). TDOH consulted with Peru Thapa, M.D., M.P.H., from the Vanderbilt University School of Medicine, to perform a health statistics review of mortality rates for ALS and MS within certain counties in Tennessee. TDOH also received technical support for the health statistics review from ATSDR (ATSDR et al. 2000).

Because ALS and MS are not reportable diseases, TDOH determined that to calculate reliable incidence rates for these diseases was impossible. Mortality rates for counties surrounding the ORR were analyzed for the time period between 1980 and 1992, and then compared with mortality rates for the state of Tennessee. The review found that the mortality rates did not differ significantly from the rates in the rest of Tennessee (ATSDR et al. 2000). The following results were reported by TDOH at the ORHASP public meeting on August 18, 1994:

- In comparison with the rest of the state, no significant differences in ALS mortality appeared in any of the counties.

- For Anderson County, the rate of age-adjusted deaths from chronic obstructive pulmonary disease (COPD) was significantly higher than were rates in the rest of the state, but rates for total deaths, deaths from stroke, deaths from congenital anomalies, and deaths from heart disease were significantly lower for the period from 1979 to 1988.

- No significant differences were found in the rates of deaths due to cancer, for all sites, or in comparison with rates in the rest of the state. Although rates of deaths from uterine and ovarian cancer were significantly higher than the rates in the rest of the state, the rate of deaths from liver cancer was significantly lower in comparison with the rest of the state.

- For Roane County, the rates of total deaths and deaths from heart disease were significantly lower than the rates in the rest of the state for the period from 1979 to 1988. Although the total cancer death rate was significantly lower than the rate in the rest of the state, the rate of deaths from lung cancer was significantly higher than the rate in the rest of the state. Rates of deaths from colon cancer, female breast cancer, and prostate cancer were also significantly lower than the rates in the rest of the state.

- For Knox County, the rates for total deaths and deaths from heart disease were significantly lower than the rates in the rest of the state. No significant difference appeared in the total cancer death rate in comparison to the rest of the state.

- No significant exceedances were found for any cause of mortality studied in Knox, Loudon, Rhea, and Union counties in comparison with the rest of the state.

- Rates of total deaths were significantly higher in Campbell, Claiborne, and Morgan counties in comparison with the rest of the state.

- Cancer mortality was significantly higher in Campbell County in comparison with the rest of the state. The excess in number of deaths from cancer appeared to be attributed to the earlier part of the time period (1980 to 1985); the rate of deaths from cancer was not higher in Campbell County in comparison with the rest of the state for the time periods from 1986 to 1988 and 1989 to 1992.

- Cancer mortality was significantly higher in Meigs County in comparison with the rest of the state from 1980 to 1982. This excess in cancer deaths did not persist from 1983 to 1992.

Knowledge, attitude, and beliefs study. TDOH coordinated a study to evaluate the attitudes, beliefs, and perceptions of residents living in eight counties around Oak Ridge, Tennessee. The purpose of the study was to 1) investigate public perceptions and

attitudes about environmental contamination and public health problems related to the ORR, 2) ascertain the public's level of awareness and assessment of the ORHASP, and 3) make recommendations for improving public outreach programs. The report was released in August 1994 (ATSDR et al. 2000; Benson et al. 1994). Following is a summary of the findings (Benson et al. 1994):

- A majority of the respondents regard their local environmental quality as better than the national environmental quality. Most rate the quality of the air and their drinking water as good or excellent. Almost half rate the local groundwater as good or excellent.

- A majority of the respondents think that activities at the ORR created some health problems for people living nearby and most think that activities at the ORR created health problems for people who work at the site. Most feel that researchers should examine the actual occurrence of disease among Oak Ridge residents. Twenty-five percent know of a specific local environmental condition that they believe has adversely affected public health, but many of these appear to be unrelated to the ORR. Less than 0.1% have personally experienced a health problem that they attribute to the ORR.

- About 25% have heard of the Oak Ridge Health Study and newspapers are the primary source of information about the study. Roughly 33% rate the performance of the study as good or excellent and 40% think the study will improve public health. Also, 25% feel that communication about the study has been good or excellent.

Health assessment. The East Tennessee Region of TDOH conducted a health assessment on the eastern region of Tennessee. The purpose of this health assessment was to review the health status of the population, to evaluate the accessibility and utilization of health services, and to develop priorities for resource allocation. The East Tennessee Region released its first edition of *A Health Assessment of the East Tennessee Region* in December 1991—this edition generally contained data from 1986 to 1990. The second edition, which was released in 1996, generally included data from 1990 to 1995. A copy of the document can be obtained from the East Tennessee Region of TDOH (ATSDR et al. 2000).

Presentation. On February 16, 1995, Dr. Joseph Lyon of the University of Utah gave a TDOH-sponsored presentation at an ORHASP public meeting. The purpose of the presentation was to inform the public and the ORHASP that several studies had been conducted on the fallout from the Nevada Test Site, including the study of thyroid disease and leukemia (ATSDR et al. 2000).

Summary of Activities by Other Agencies

Assessment reports, environmental studies, health investigations, remedial investigation/feasibility studies, and sampling validation studies. Other agencies have also addressed community health concerns and public health issues through studies and

investigations. Two areas that have been investigated by other agencies—Scarboro and Lower East Fork Poplar Creek (LEFPC)—are discussed below.

Following are summaries of investigations related to the Scarboro community:

Scarboro Community Assessment Report. Since 1998, the Joint Center for Political and Economic Studies (with the support of DOE's Oak Ridge Operations) has worked with the Scarboro community to help residents express their economic, environmental, health, and social needs. In 1999, the Joint Center for Political and Economic Studies conducted a survey of the Scarboro community to identify the residents' environmental and health concerns. Although the surveyors' goal was to elicit responses from the entire community, they did succeed in achieving an 82 percent response rate. Because Scarboro is a small community, the community assessment provided new information about the area and its residents that would not be available from sources that evaluate more populated areas, such as the U.S. Census Bureau. In addition, the assessment identified Scarboro's strengths and weaknesses, and illustrated, in comparison with other community concerns, the relative unimportance among residents of environmental and health issues. The assessment showed that environmental and health issues were not a priority among Scarboro residents; the community was more concerned about crime and security, children, and economic development. The Joint Center for Political and Economic Studies recommended an increase in active community involvement in city and community planning (Friday and Turner 2001).

Scarboro Community Environmental Study. In May 1998, soil, sediment, and surface water samples were taken in the Scarboro community to address residents' concerns about previous environmental monitoring in the Scarboro neighborhood (i.e., validity of past measurements). The study was designed to integrate input from the community while also fulfilling the requirements of an EPA-type evaluation. The Environmental Sciences Institute of Florida Agriculture and Mechanical University (FAMU) conducted the analytical element of this study, in collaboration with its contractual partners at the Environmental Radioactivity Measurement Facility at Florida State University and the Bureau of Laboratories of the Florida Department of Environmental Protection, as well as DOE subcontractors in the Neutron Activation Analysis Group at the ORNL. These results were compared with findings from an October 1993 report by DOE, entitled *Final Report on the Background Soil Characterization Project (BSCP) at the Oak Ridge Reservation, Oak Ridge, Tennessee*. In general, mercury was detected within the range that was seen in the BSCP, which was between 0.021 mg/kg and 0.30 mg/kg. The radionuclide findings were within the predicted ranges, including concentrations of total uranium. About 10% of the soil samples indicated, however, an enrichment of uranium 235. In one sample, alpha-chlordane, gamma-chlordane, heptachlor, and heptachlor epoxide exceeded the detection limits. This same sample also had concentrations of lead and zinc that were twice as high as those found in the BSCP. On September 22, 1998, the final Scarboro Community Environmental Study was released (ATSDR et al. 2000).

Scarboro Community Health Investigation. In November 1997, a Nashville newspaper published an article that described various illnesses seen among children who lived in the Scarboro community—a neighborhood located close to the ORR's nuclear weapons

facility. The article stated that the Scarboro residents had high rates of respiratory illness, and that 16 children repeatedly experienced "severe ear, nose, throat, stomach, and respiratory illnesses." The reported respiratory illnesses included asthma, sinus infections, hay fever, ear infections, and bronchitis. The article implied that these illnesses were caused by exposure to the ORR, especially because of the proximity of these children's homes to the ORR facilities (ATSDR et al. 2000; Johnson et al. 2000).

In response to this article, on November 20, 1997, the Commissioner of TDOH requested that the CDC assist the TDOH with an investigation of the Scarboro community. TDOH coordinated the *Scarboro Community Health Investigation* to examine the reported excess of pediatric respiratory illness within the Scarboro community. The investigation consisted of a community health survey of parents and guardians, and a follow-up medical examination for children younger than 18 years. Both of these components (survey and exam) were essentially designed to measure the rates of common respiratory illnesses among Scarboro children, compare these rates with national rates for pediatric respiratory illnesses, and determine whether these illnesses had any unusual characteristics. The investigation was not, however, designed to determine the cause of the illnesses (ATSDR et al. 2000; Johnson et al. 2000).

In 1998, CDC and TDOH were assisted by the Scarboro Community Environmental Justice Oversight Committee to develop a study protocol. After the protocol was created, a community health survey was administered to members of households in the Scarboro neighborhood. The purpose of the survey was to assess whether the rates of specific diseases were higher in Scarboro when compared with the rest of the United States, and to determine whether exposure to different factors increased the Scarboro residents' risk of health problems. In addition, the survey collected information from adults about their occupations, occupational exposures, and general health concerns. The health investigation survey had an 83% response rate, as 220 out of 264 households were interviewed; this included 119 questionnaires about children and 358 questionnaires about adults in these households (ATSDR et al. 2000; Johnson et al. 2000).

In September 1998, CDC released its initial findings from the survey. For children in Scarboro, the asthma rate was 13%; this was compared with nationally estimated rates of 7% for children between the ages of 0 and 18, and 9% for African American children between the ages of 0 and 18. Still, the Scarboro rate fell within the range of rates (6% to 16%) found in comparable studies across the United States. The wheezing rate was 35% for children in Scarboro, as compared with international estimates that fell between 1.6% and 36.8%. With the exception of unvented gas stoves, the study did not find any statistically significant link between exposure to typical environmental asthma triggers (e.g., pests, environmental tobacco smoke) or possible occupational exposures (i.e., living with an adult who works at the ORR) and asthma or wheezing illness (ATSDR et al. 2000; Johnson et al. 2000).

A review of the information obtained in the health investigation survey showed that 36 children were invited to have a physical examination; this number included the children who were discussed in the November 1997 newspaper article. In November and December 1998, these medical examinations were conducted to verify the community

survey results, to evaluate whether the children with respiratory illnesses were receiving necessary medical care, and to confirm that the children detailed in the newspaper actually had those reported respiratory medical problems. The children who were invited to have medical examinations had one or more of the following conditions: 1) severe asthma, which was defined as more than three wheezing episodes or going to an emergency room as a result of these symptoms; 2) severe undiagnosed respiratory illness, which was defined as more than three wheezing episodes and going to an emergency room as a result of these symptoms; 3) respiratory illness and no source for regular medical care; or 4) identified in newspaper reports as having respiratory illness. Of the 36 children invited, 23 participated in the physical examination. A portion of the eligible children had moved away from Scarboro, whereas others were unavailable or opted not to participate (ATSDR et al. 2000; Johnson et al. 2000).

During the physical examinations, nurses asked the participating children and their parents a series of questions about the health of the children; volunteer physicians evaluated the findings from the nurse interviews and examined the children. In addition to these physical examinations, the children were given blood tests and a special breathing test. The examining physician sometimes took an x-ray of the child, but this was determined on a case-by-case basis. All of the tests, examinations, and transportation to and from the examinations were provided without charge (Johnson et al. 2000).

As soon as the examinations were completed, the results were evaluated to determine whether any children required immediate intervention—none of the children needed urgent care. Several laboratory tests revealed levels that were either above or below the normal range, which included blood hemoglobin level, blood calcium level, or breathing test abnormality. After a preliminary review of the findings, laboratory results were conveyed by letter or telephone to the parents of the children and to their doctors. If the parents did not want their child's results sent to a physician, then the parents received the results over the telephone. The parents of children who had any health concern identified from the physical examination were sent a personal letter from Paul Erwin, M.D., of the East Tennessee Regional Office of the TDOH that informed the parents that follow-up was needed with their medical provider. If the children did not have a medical provider, the parents were told to contact Brenda Vowell, R.N.C., a Public Health Nurse with the East Tennessee Regional Office of the TDOH, for help locating a provider and about possibly receiving TennCare or Children's Special Service (ATSDR et al. 2000; Johnson et al. 2000).

On January 5, 1999, a group of physicians from the CDC, TDOH, the Oak Ridge medical community, and the Morehouse School of Medicine, conducted a thorough review of the findings from the community health survey, the physical examinations, the laboratory tests, and the nurse interviews. From the 23 children who were physically examined, 22 of these children had evidence of some type of respiratory illness, which was discovered during the nurse interviews or during the doctor's physical examinations. Overall, the children seemed to be healthy, and no problems requiring immediate assistance were identified. Many of the children had mild respiratory illnesses at the time of their examination, but only one child was found to have a lung abnormality. In addition, none

of the children experienced wheezing at the time of their examination. The examinations did not indicate an unusual illness pattern among children in the Scarboro community. The illnesses that were identified from these examinations were no more severe than would be expected, and they were characteristic of illnesses that could be found in any community. Basically, the results of these examinations validated the results from the community health survey. On January 7, 1999, the results from this team review were presented at a Scarboro community meeting. In July 2000, the final report was released (ATSDR et al. 2000; Johnson et al. 2000).

Three months after the letters had been sent to the parents and to the physicians about the results, efforts were made to telephone the parents of the children who had been examined. Eight of the parents were contacted successfully. Because some of the parents had more than 1 child who participated in the examination, the questions for the 8 parents were applied to 14 children. Despite many attempts on different days, the parents of 9 children could not be contacted by telephone (Johnson et al. 2000).

Out of the 14 children whose parents had been contacted, 7 of the children had been to a doctor since the examinations. For the most part, the health of the children was about the same. Nevertheless, since the examinations one child had been in the hospital because of asthma and another child whose condition worsened had the asthma medication strengthened. In addition, several parents reported that their children had nasal allergies, and many parents noted problems with obtaining medicines because of the expense and the lack of coverage by TennCare for the specific medicines. Subsequently, TDOH nurses have helped these parents obtain the needed medicines (Johnson et al. 2000).

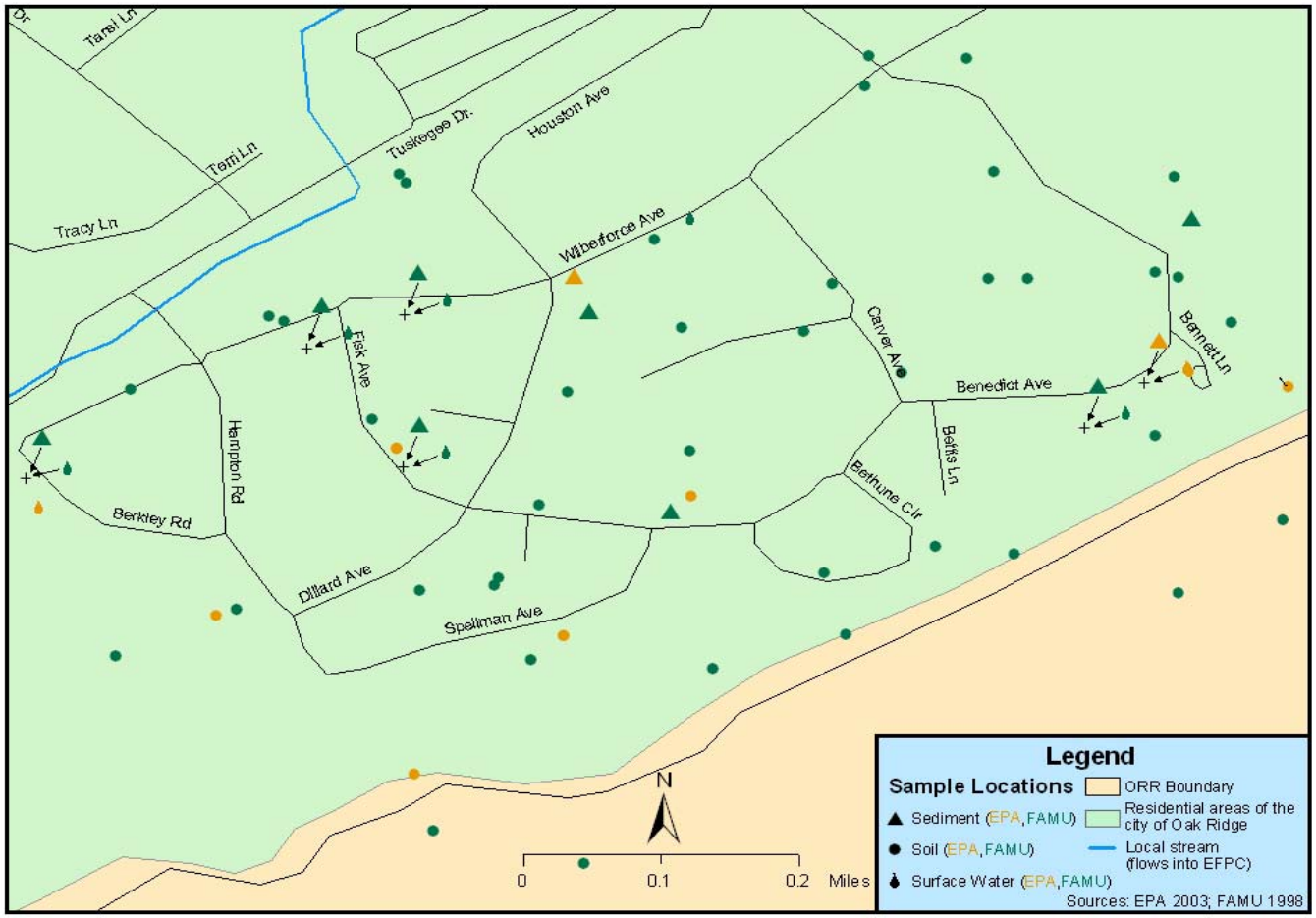
Scarboro Community Environmental Sampling Validation Study. In 2001, U.S. EPA's Science and Ecosystem Division Enforcement Investigation Branch collected soil, sediment, and surface water samples from the Scarboro community to respond to community concerns, identify data gaps, and validate the sampling performed by FAMU in 1998 (FAMU 1998) (see Figure B-1 for sample locations). All samples were subjected to a full analytical scan, including inorganic metals, volatile organic compounds, semi-volatile organic compounds, radiochemicals, organochlorine pesticides, and PCBs. In addition, EPA collected uranium core samples from two locations in Scarboro and conducted a radiation walkover of the areas selected for sampling to determine whether radiation existed above background levels (USEPA 2003).

The level of radiation was below background levels and the radionuclide analytical values did not indicate a level of health concern. Uranium levels in the core soil samples were also below background levels. EPA concluded that the results support the sampling performed by FAMU in 1998, and chemical, metal, or radionuclides have not elevated above a regulatory health level of concern. The residents of Scarboro are not currently being exposed to harmful levels of substances from the Y-12 plant. The report stated that "based on EPA's results, the Scarboro community is safe. Therefore, additional sampling to determine current exposure is not warranted." A final report was released in April 2003 (USEPA 2003).

Following is a summary of a remedial investigation/feasibility study (RI/FS) for LEFPC:

Lower East Fork Poplar Creek Remedial Investigation/Feasibility Study. Under the Federal Facility Agreement, DOE, EPA, and TDEC performed an RI/FS at Lower East Fork Poplar Creek (LEFPC) that was completed in 1994. The study was conducted to evaluate the floodplain soil contamination in LEFPC, which has resulted from Y-12 plant discharges since 1950. The goals of the study were to 1) establish the degree of floodplain contamination, 2) prepare a baseline risk analysis according to the level of contaminants, and 3) determine whether remedial action was necessary. The findings of the investigation suggested that sections of the floodplain were contaminated with mercury, and that floodplain soil with mercury concentrations above 400 parts per million (ppm) represented an unacceptable risk to human health and to the environment. As a result of this conclusion, a ROD was approved in September 1995 that requested remedial action at LEFPC. Remedial activities began in June 1996 and were completed in October 1997. The activities consisted of 1) excavating four sections of floodplain soil that had mercury concentrations above 400 ppm, 2) recording the removal by taking confirmatory samples during excavation, 3) disposing of contaminated soil at a Y-12 plant landfill, 4) refilling the excavated areas with soil, and 5) providing a new vegetative cover over the excavated areas (ATSDR et al. 2000).

Figure B-1. FAMU and U.S. EPA Sample Locations in Scarboro



Appendix C. Summary of Remedial and Regulatory Activities

The following remedial activities relate to Zone 1 at the K-25 site (see Figure 5 and Figure 6):

East Tennessee Technology Park, Zone 1 comprises about 1,400 acres outside of the main plant (see Figure 5). Areas within Zone 1 include a scrap yard, former cylinder destruction facility, dry quarry, and a sewage treatment facility. The majority of disposal activities at the site occurred within Zone 1, and as a result, this area contains buried waste, debris, and contaminated soils related to former K-25 operations. In August 2001, an interim remedial action plan was issued to address the site contamination, remaining debris, and the quarry. A draft record of decision (ROD) released in November 2001 chose excavation as the remedial alternative to address Zone 1 contamination sources. The plan is to make Zone 1 suitable for industrial uses, which will require the excavation and removal of 84,000 cubic yards of contaminated metal and all other wastes at the site. The ROD was signed in November 2002 and approved by DOE, EPA, and TDEC in November 2003. This ROD represented one of the initial steps to accelerate the entire K-25 site to a completed clean up by 2008 (Daniels 2002; USDOE 2003d, 2003j; USEPA 2005).

K-1070-A Burial Ground, an approximate 3-acre area in the northwest corner of the K-25 site, was opened in the 1950s and closed in the mid-1970s (see Figure 6). Primarily, the burial ground contained uranium-contaminated waste buried among 62 on-site pits and 26 unlined trenches that was associated with past operations at K-25 and other facilities. Radionuclides and chlorinated solvents were identified as the primary contaminants of concern at the burial ground. Field investigations were finished in 1996. The 1998 remedial investigation (RI) indicated that, although groundwater from the burial ground flows to the K-901-A holding pond (which subsequently discharges to the Clinch River), contamination still remained in the pits and trenches. After discussions at a public meeting, the selected cleanup-up alternative included waste removal and disposal as well as establishing institutional controls (for example, fencing and security patrols). A ROD was approved in January 2000, and in September 2000 a subcontract was initiated to plan activities needed for site remediation. During site restoration activities, which began in August 2001, about 23,000 cubic yards of debris and soil were excavated. The excavated soil was disposed of at the ORR's Environmental Management Waste Management Facility and the excavated areas were filled with clean soil. Restoration of the site was completed in June 2003 (SAIC 2002, 2005; USDOE 2002a).

K-1085 Old Firehouse Burn Area Drum Burial Site is situated outside of the site perimeter fence, and is bordered by Bear Creek Road, Powerhouse Road, and State Highway 58 (see Figure 6). According to site investigations, the drum burial site measures about 12,000 square feet. While working on a construction project on State Highway 58 in October 2000, the Tennessee Department of Transportation (TDOT) found three buried drums and accidentally punctured two of them. Geophysical surveys suggested that the site contained five drum burial areas. A sixth drum area was added when a highway contractor found black-colored soil containing radiological contamination above background levels. Because the drums contained unknown and possibly hazardous substances, a time-critical removal began on October 11, 2000 to

eliminate any potential hazards to human health and the environment. The soil-contaminated area was flagged and an impermeable cover was placed over the contaminated soil. In March 2001, an action memorandum was approved. During excavation at all six sites, about 98 cubic yards of debris and soil were sampled and removed and the excavated areas were restored. Waste characterized as LLW was shipped to the ORR's Environmental Management Waste Management Facility for disposal, whereas mixed waste was sent to the TSCA Incinerator for treatment and disposal. The waste removal and disposal has been completed and a removal action report (RmAR) was approved in February 2003 (SAIC 2002, 2004, 2005; USEPA 2005).

The following remedial activities are associated with Zone 2 at the K-25 site (see Figure 5 and Figure 6):

East Tennessee Technology Park, Zone 2 measures about 800 acres and contains the main plant area. In April 2005, a ROD was signed to address contamination in Zone 2, including soil, subsurface structures, buried debris, and slabs. The purpose of the ROD is to remediate Zone 2 to protect future industrial workers and the underlying groundwater from contamination. Remedial activities are expected to be completed in 2008 as part of the accelerated closure of ETTP (USDOE 2005a; USEPA 2005).

K-1417-A and K-1417-B Drum Storage Yards are situated in the eastern portion of the K-25 site (see Figure 6). After the K-1407-B/C Ponds were closed, between February 1987 and June 1989 raw sludges from these ponds were either treated or put into drums and placed into these storage yards. Because DOE had planned to dispose of the sludges as nonhazardous, low-level radioactive waste, these storage yards were established only to store the sludges temporarily (for about 1 to 2 years). In September 1991, TDEC issued a Commissioner's Order that mandated the execution of the "Plan for the Management of K-1407-B and K-1407-C Pond Waste at the Oak Ridge K-25 Site." The plan required: 1) taking water out of sludges and repacking sludges in appropriate containers, 2) using existent facilities to treat all liquids, and 3) storing all receptacles in present or new indoor facilities (SAIC 2002).

Also in September 1991, an interim record of decision associated with the treatment and repackaging of waste sludges was issued to prohibit the release of contaminants from deteriorating drums. An additional Commissioner's Order was issued by TDEC in June 1994 because DOE did not repackage the drums by the June 1993 deadline. The required activities specified in TDEC's order were finished in December 1994 and a remedial action report was released in February 1995. Remedial actions included the treatment, repackaging, storage, and removal of the drummed wastes. Following the completion of remedial activities, the drum storage yards were closed under RCRA (SAIC 2002).

K-1407-B and K-1407-C Ponds are settling and holdings ponds located on the eastern portion of the K-25 site (see Figure 6). Mainly, the ponds were used for the secondary treatment of metal hydroxide and additional wastes generated at the K-25 facility. As part of a RCRA closure action, sludges were removed from the ponds from February 1987 to August 1989. In September 1993, a ROD was issued to address possible risks related to wastes and soils remaining in the ponds. The purpose of the remedial action was to

"reduce potential threats to human health and the environment posed by residual metal, radiological, and VOC [volatile organic compound] contamination…" Between July 1994 and January 1995, clean-up activities included 1) putting clean soil in excavated areas and covering the surface with rockfill, 2) monitoring groundwater, and 3) maintaining institutional controls (for example, fencing and signage) that limit access and activity in the pond areas. A remedial action report was completed in August 1995 and the ponds were closed under RCRA. Groundwater and surface water have been monitored semiannually since 1996 (except for 1999 and 2000 when a formal submittal request was pending before TDEC to cease monitoring). The 2005 remediation effectiveness report (RER) noted that monitoring of metals, radionuclides, and VOCs in surface water and groundwater in the Mitchell Branch area would continue in fiscal year 2005 (SAIC 2002, 2005). In 2005, the groundwater collection and treatment system was shut down because the system was not producing the desired results. Therefore, it is not currently a "Completed CERCLA Action Location." Further evaluation and subsequent remedial action at Mitchell Branch will be included in the Final Site-wide Record of Decision for ETTP (formerly the K-25 site) (DOE 2006).

Buildings K-29, K-31, and K-33, situated inside the security fence on the western section of the K-25 site (see Figure 6), were built to store the low-enrichment part of the gaseous diffusion cascade. The buildings have not operated since 1985 and were deactivated in 1987. As a result of former operations, several sections of the buildings were contaminated with hazardous and radiological substances. Although the contaminants (for example, uranium and PCBs) remain in the buildings, a future release potential remains. An action memorandum was completed in September 1997. The chosen remedial alternative is to remove equipment and decontaminate the buildings. As of fiscal year 2005, over 155,700 tons of material had been removed. Remedial actions to remove equipment and decontaminate the buildings were still in progress as of 2005, but the removal activities were about 96% complete (SAIC 2002, 2005; USDOE 2003e).

K-1070-C/D G-Pit and Concrete Pad are situated in the eastern section of the K-25 site (see Figure 6). Disposal practices took place at the K-1070-C/D area between 1975 and 1989. The G-Pit, which was used as an organic solvent disposal pit, is the main source of organic contaminant discharges to the K-1070-C/D area. Chlorinated hydrocarbons, VOCs, semi-volatile organic compounds (SVOCs), uranium hexafluoride, solvents, and radionuclides are the main contaminants of concern at the G-Pit. The Concrete Pad is located in the southeastern part of the K-1070-C/D area. Because of radiological contaminant levels in soil, the Concrete Pad presents an "unacceptable health risk to workers" for future exposures (SAIC 2002; USDOE 2002a).

As a result of a January 1998 ROD, in April 1999, 2 feet of soil cover was used to cap the Concrete Pad to protect workers from ionizing radiation exposure. From December 1999 to January 2000, about 230 cubic yards of soil (containing VOCs and low-level PCBs and technetium 99) was excavated from the pit. The soil was thermally treated by June 2001 and a remedial action report was completed in July 2001. All of the treated soil was disposed at the Y-12 Industrial Landfill by April 2002. As of fiscal year 2005, about 60 cubic yards of construction debris was scheduled for incineration at the TSCA Incinerator at the K-25 site. The ROD required the following: 1) periodic radiological surveys,

2) institutional controls (e.g., controls to restrict site access), and 3) maintenance of soil covering the Concrete Pad. Use of institutional controls will continue as long as waste remains buried at the site. Radiological walkover surveys conducted since remedial activities were conducted at the concrete pad have detected no readings above background levels (SAIC 2002, 2005; USDOE 2002b; USEPA 2005).

K-25/K-27 Buildings are located close to the center of the site (see Figure 6). The K-25 building, located on about 40 acres, contains 54 different units. The K-27 building, which is southwest of the K-25 building, occupies nearly 9 acres and includes nine units. Uranium enrichment operations took place at both buildings from 1945 to the early 1960s, when operations ceased entirely. The buildings continue to deteriorate, and as a result hazardous substances and radioactive contamination contained within the buildings could potentially release to the environment. To prevent possible exposures to on-site personnel and the release of hazardous substances, a three-phased demolition was proposed for K-25 and K-27. In 2001, an engineering evaluation/cost analysis (EE/CA) was prepared for building demolition. In February 2002, Phase 1—hazardous materials characterization and removal—began at the site. Phase 1 was about 85 percent completed by the end of fiscal year 2004: over 550,000 cubic feet of waste had been removed and disposed of at the ORR's Environmental Management Waste Management Facility. Phase 2 addresses the process equipment removal and Phase 3 addresses the building demolition. DOE anticipates building demolition to begin in fiscal year 2005. In addition, DOE and other affiliated parties will incorporate public input into a final memorandum of agreement established to preserve these facilities' histories (SAIC 2005; USDOE 2003f; USEPA 2005).

Group II Buildings—Main Plant Demolition refers to 10 main plant buildings at the K-25 site that were torn down as part of the Group II Buildings Phase I project (see Figure 6). In August 2000, an action memorandum was approved to remove the 10 main plant buildings. The remedial alternative for these Group II Buildings is "near-term demolition to slab," which entails removing unneeded equipment, demolishing buildings to the concrete slab, and removing all of the related wastes. The remedial plan was chosen to eliminate hazards to on-site personnel from the deteriorating contaminated structures and to reduce potential exposures to radiation and hazardous materials via uncontrolled releases from equipment, building materials, and dust. Demolition of these main buildings started in the fall of 2000 and was finished by January 2003. A removal action report was approved in September 2004 (SAIC 2002, 2005; USDOE 2003g, 2005a).

Group II Buildings—Phase II Demolition Project refers to 18 facilities located near the K-1064 Peninsula area, which is bordered on three sides by Poplar Creek in the north section of the K-25 site; one facility to the west of the K-1064 Peninsula is also included in this demolition project. The facilities include pump houses, a water treatment facility, old storage facilities, a salvage material yard, various maintenance areas, and other facilities. The Phase II project consists of waste characterization, removal of hazardous materials, physical removal of structures, radiological decontamination of exposed soil surfaces and concrete slabs (or application of additional cover material as needed), packaging debris for disposal, treatment of debris prior to disposal (as necessary), and

proper transport of wastes for disposal. An action memorandum to demolish the facilities and remove scrap materials was signed in July 2002. Decontamination and demolition, which began on the 18 facilities in the K-1064 Peninsula area in March 2004, were completed in 2005. A remedial action report is scheduled for submission in September 2006 (SAIC 2005; USDOE 2005a, 2005b; USEPA 2005).

The following remedial activities relate to areas located in both Zone 1 and Zone 2 at the K-25 site (see Figure 5 and Figure 6):

ETTP Sitewide Record of Decision pertains to areas located in Zone 1 and Zone 2. As of 2005, this ROD project was in progress to address contamination in surface water, sediment, and groundwater, and to assess whether further soil remediation was necessary. To support ongoing investigations and to supplement existing data necessary for the ROD or an action memorandum, more field data were collected in 2004 and 2005. EPA, TDEC, and DOE have created a detailed schedule of future activities to enable the signing of the ROD in early 2007 (USDOE 2005a, 2005b).

Group I Buildings refers to a collective group of five buildings at the K-25 site: K-724 (Storage Building), K-725 (Beryllium Building), K-1031, (Warehouse), K-1131 (Feed and Tails Facility), and K-1410 (Plating Facility). K-1031, K-1131, and K-1410 are located in the central portion of the site near K-25 and K-27 in Zone 2; K-724 and K-725 are situated southwest of these buildings in Zone 1 (see Figure 5 and Figure 6). The facilities were used for various purposes, such as uranium hexafluoride production, cascade maintenance, and machine shop operations. Contaminants in the buildings included beryllium dust, uranium, PCBs, radionuclides, asbestos, and lead-painted surfaces. In January 1997, an action memorandum required the dismantlement and disposal of the five buildings because the buildings were in poor condition, the buildings were close to surface water and additional structures, or because of the cost of maintenance and surveillance activities. Following building removal, the concrete slabs were cleaned. Because the contamination that remained on slabs from buildings K-1031, K-1131, and K-1410 could not be reduced to acceptable levels, they were covered with a 2-inch layer of soil to decrease future dispersion of radioactive contamination. Demolition was finished in June 1999 and a removal action report was issued in August 1999 (SAIC 2002; USDOE 2001a, 2005a).

The following remedial activities relate to the remaining areas of ETTP or “balance of site” (see Figure 5 and Figure 6):

Balance of Site refers to an estimated 500 aboveground facilities remaining at ETTP that are located outside of Zone 1 and Zone 2. These facilities, consisting of tanks, buildings, sheds, and other structures, either have or potentially have been contaminated with radiological or other hazardous substances resulting from past operations. In August 2003, to prevent future releases of contaminants into the environment, an action memorandum was issued for the demolition and removal of facilities not previously addressed under any environmental decision documents. Remedial activities will include facility and waste characterization, hazardous material and equipment removal, structure demolition down to concrete slabs, radiological decontamination of any exposed slabs (or

application of cover material if decontamination cannot be achieved), preparation of demolition debris for disposal, waste treatment (as necessary), and proper transport and disposal of all wastes generated during these activities. In 2004, demolition began on 169 primarily uncontaminated facilities and on the Balance of Site—Laboratories Group facilities. Demolition and field activities continued in 2005, mainly focusing on the Laboratories Group facilities and K-1008 areas (SAIC 2005; USDOE 2005a, 2005b).

The following remedial activities relate to off-site areas affected by contaminants from the K-25 site (see Figure 3):

Clinch River/Poplar Creek is defined as the operable unit (OU) that consists of biota and sediments in the Melton Hill Reservoir and the Watts Bar Reservoir from Clinch River Mile (CRM) 0.0 (where the Tennessee and Clinch Rivers join) to CRM 43.7, upstream of Melton Hill Dam (see Figure 3). In addition, the OU contains the Poplar Creek embayment from the mouth of Poplar Creek along the Clinch River (at CRM 12.0) to its joining with East Fork Poplar Creek (at Poplar Creek mile [PCM] 5.5). All of the Poplar Creek sections of the OU are within ORR borders of the (SAIC 2002; USDOE 2001b).

In 1996, a remedial investigation/feasibility study (RI/FS) examined past and present releases to off-site surface water and determined whether remedial action was necessary (ATSDR et al. 2000). The RI/FS concluded that the Clinch River/Poplar Creek OU presented two main risks by exposure to 1) fish tissue that contained chlordane, mercury, PCBs, and arsenic, and 2) deep sediments in the primary river channel that contained arsenic, mercury, cesium 137, and chromium (Jacobs EM Team 1997b; Jacobs Engineering Group Inc. 1996; SAIC 2002; USDOE 2001b). The largest detected radionuclide concentrations are buried between 8 and 32 inches in the deep sediments; radionuclide contamination has *not* been detected in the shoreline sediment (Jacobs EM Team 1997b).

A baseline risk assessment suggested that consumption of certain PCB-contaminated fish posed the greatest risk to public health. In addition, fish contaminated with chlordane, mercury, and arsenic presented a possible chance of causing health effects. The assessment determined that consumption of any type of fish in Poplar Creek posed a health risk, as well as bass from the Clinch River below Melton Hill Dam. Furthermore, the risk assessment determined that contaminants in deep-water sediments would only present a health risk if they were dredged; no exposure pathway currently exists to the deep-water sediments (Jacobs EM Team 1997b).

In September 1997, a ROD determined that the following remedial actions were needed at the OU: 1) yearly monitoring to assess fluctuations in concentration levels and contaminant dispersion, 2) fish consumption advisories, 3) surveys to gauge the usefulness of the fish advisories, and 4) institutional controls to restrict activities that could unsettle the sediment (Jacobs EM Team 1997b; SAIC 2002; USDOE 2001b; USEPA 2005). These institutional controls were developed under an interagency agreement (IAG) established by DOE, EPA, TVA, TDEC, and the U.S. Army Corps of Engineers (USACE) in February 1991. The IAG allows these agencies to cooperatively work through the Watts Bar Interagency Agreement to review permitting and all other

activities that could result in disturbing sediment (for example, building a dock or erecting a pier) (ATSDR 1996; Jacobs EM Team 1997b; USDOE 2003c). Please see page 3–12 of the ROD at http://www.epa.gov/superfund/sites/rods/fulltext/r0497075.pdf for more details. For additional information on institutional controls to prevent sediment-disturbing activities, please see Rules of the Tennessee Department of Environment and Conservation, Chapter 1200-4-7, Aquatic Resource Alteration Permit Process; Section 26A of the Tennessee Valley Authority Act of 1933; and Section 10 of the Rivers and Harbors Act of 1910 (USACE) (Jacobs EM Team 1997b).

In February 1991, DOE, EPA, TVA, TDEC, and USACE established an interagency agreement. Under this agreement, these agencies collaboratively work through the Watts Bar Interagency Agreement to review permitting and other activities that could possibly disturb sediment, such as erecting a pier or building a dock (ATSDR 1996; Jacobs EM Team 1997b; U.S. DOE 2003c). For more details, see the ROD at http://www.epa.gov/superfund/sites/rods/fulltext/r0497075.pdf.

In February 1998, an approved remedial action report (RAR) recommended surface water, fish, sediment, and turtle monitoring in the Clinch River/Poplar Creek OU (ATSDR et al. 2000). Beginning in 1998, annual surface water sampling, sediment monitoring, and fish and turtle sampling were conducted at the OU (SAIC 2002; USDOE 2001b). Institutional controls are also used to examine activities that could result in movement of the sediments, and the Tennessee Wildlife Resources Agency (TWRA) prints fish consumption advisories in its *Tennessee Fish Regulations* (SAIC 2002).

Lower Watts Bar Reservoir operable unit stretches from the confluence of the Tennessee River and the Clinch River downstream to the Watts Bar Dam (see Figure 3). All surface water and sediment released from the ORR enter the Lower Watts Bar Reservoir OU (SAIC 2002; USDOE 2001b; USDOE 2003h). In 1995, a RI/FS assessed the level of contamination in the Watts Bar Reservoir, created a baseline risk analysis based on the contaminant levels, and determined whether remedial action was necessary (ATSDR et al. 2000). The RI/FS found that radioactive, inorganic, and organic pollutant discharges from the ORR contributed to biota, water, and sediment contamination in the Lower Watts Bar Reservoir (ATSDR et al. 2000; SAIC 2002; USDOE 2001b, 2003i). The baseline risk analysis indicated that standards for environmental and human health would not be reached if deep channel sediments with cesium 137 were dredged and placed in a residential area, and if people consumed moderate to high quantities of specific fish that contained increased levels of PCBs (ATSDR et al. 2000; Environmental Sciences Division et al. 1995).

In September 1995, a ROD identified the following contaminants of concern (COCs): 1) mercury, arsenic, PCBs, chlordane, and aldrin in fish, 2) mercury, chromium, zinc, and cadmium in dredged sediments and sediments used for growing food products, and 3) manganese through ingestion of surface water (ATSDR et al. 2000; SAIC 2002; USDOE 2001b, 2003i). The largest threat to public health from the Lower Watts Bar Reservoir is related to the consumption of PCB-contaminated fish (SAIC 2002; USDOE 2001b, 2003i). The ROD concluded that if the deep sediments were kept in place, then

"…these sediments do not pose a risk to human health because no exposure pathway exists" (USDOE 1995b).

The remedial activities selected for the Lower Watts Bar Reservoir included 1) using preexisting institutional controls to decrease contact with contaminated sediment, 2) fish consumption advisories printed in the *Tennessee Fish Regulations*, and 3) yearly monitoring of biota, sediment, and surface water (ATSDR et al. 2000; SAIC 2002; USDOE 1995b, 2001b, 2003i; USEPA 2005). The institutional controls are developed through the Watts Bar Interagency Agreement under the IAG to restrict sediment-disturbing activities. For example, people are required to obtain a permit before building a pier or constructing a dock (ATSDR 1996; Jacobs EM Team 1997b). According to the IAG, DOE is required to take action if an institutional control is not effective or if a sediment-disturbing activity could cause harm (USDOE 2003c). For more details, please see page 3-5 of the ROD at http://www.epa.gov/superfund/sites/rods/fulltext/r0495249.pdf. For additional information on institutional controls to prevent sediment-disturbing activities, please see *Rules of the Tennessee Department of Environment and Conservation, Chapter 1200-4-7, Aquatic Resource Alteration Permit Process; Section 26A of the Tennessee Valley Authority Act of 1933; and Section 10 of the Rivers and Harbors Act of 1910 (USACE)* (Jacobs EM Team 1997b).

Clinch River/Poplar Creek and Lower Watts Bar Reservoir in September 1999, operable units were combined by DOE for monitoring purposes because these surface water bodies comprise a hydrologically connected system through which ORR contaminants could be transported. Using sampling data collected until 2004, no chemical or radiological contaminants in surface water or near-shore sediments posed an unacceptable risk to humans. Because of these findings, the previously established, long-term monitoring program was modified in fiscal year 2004. The new program, scheduled to commence in fiscal year 2005, requires sediment, surface water, and turtle sampling every 5 years (instead of annually) and fish sampling to continue annually. As appropriate, DOE will use sediment and surface water sampling data collected by TVA, TDEC, and the Tennessee Wildlife Resources Agency (TWRA) to supplement data collected under the revised monitoring program (SAIC 2005).

Appendix D. Description and Output from the CAP88-PC Model

The Clean Air Act Assessment Package-1988 (CAP88-PC) is a set of computer programs, databases, and associated utility programs for estimation of dose and risk from radionuclide emissions to air. The EPA has approved the use of CAP88-PC for "…determining compliance with Clean Air Act National Emission Standards for Hazardous Air Pollutants radionuclide standards at Department of Energy facilities" (USEPA 1999). The following description of the CAP88-PC software is from the 1997 version (Version 2.0) of the CAP88-PC User's Guide (Parks 1997). The User's Guide for the most recent version (Version 3.0) is available at http://www.epa.gov/radiation/docs/cap88/userguide_120907.pdf.

CAP88-PC is a personal computer software system used for calculating both dose and risk from radionuclide emissions to air. CAP88-PC is an approved system for demonstrating compliance with 40 CFR 61 Subpart H, the Clean Air Act standard that applies to U.S. Department of Energy (DOE) facilities that emit radionuclides to air.

CAP88-PC uses a modified Gaussian plume equation to estimate the average dispersion of radionuclides released from up to six sources. The sources may be either elevated stacks, such as a smokestack, or uniform area sources, such as a pile of uranium mill tailings. Plume rise can be calculated assuming either a momentum or buoyancy-driven plume. Assessments are done for a circular grid of distances and directions with a radius of 80 kilometers (50 miles) around the facility. The program computes radionuclide concentrations in air, rates of deposition on ground surfaces, concentrations in food and intake rates to people from ingestion of food produced in the assessment area. Estimates of the radionuclide concentrations in produce, leafy vegetables, milk, and meat consumed by humans are made by coupling the output of the atmospheric transport models with the U.S. Nuclear Regulatory Commission Regulatory Guide 1.109 terrestrial food chain models. Given that the health effects and dosimetric data are based on low-level radionuclide intakes, dose and risk estimates from CAP88-PC are applicable only to low-level chronic exposures.

In this public health assessment, ATSDR used CAP88-PC to estimate past chronic (or annual) radiological doses from airborne uranium, technetium 99, and neptunium 237, as well as air concentrations of uranium and fluoride. Because the health effects and dosimetric data are based on low-level radionuclide intakes, radiological dose estimates from CAP88-PC are applicable only to low-level chronic exposures (Parks 1997). In this assessment, estimated annual airborne radionuclide releases from the K-25/S-50 site (see Table 5) were used to estimate off-site concentrations and doses. CAP88-PC uses site-specific annual weather data in the form of a frequency distribution of wind directions, velocities, and atmospheric stabilities. To evaluate releases from the K-25 and S-50 facilities, ATSDR obtained hourly records of meteorological data from on-site K-25 weather stations (see Appendix F). Because no site-specific meteorological data are available for 1961 or 1963, ATSDR used data from the 1999 weather year as a proxy for historic release conditions. The population estimates used in this evaluation are from the 1980 U.S. Census data provided with the CAP88-PC model.

Here, CAP88-PC estimated historic off-site concentrations and annual doses for the year with the highest annual radionuclide emissions. This assessment is based on the assumption that if the year with the highest annual emissions (1961 and 1963) did not represent a public health hazard,

then any other year with lower emissions would also not represent a public health hazard. CAP88-PC calculates doses as 50-year effective dose equivalents integrated over a 70-year lifetime, such that ongoing exposures to long-lived radionuclides are included in the dose assessments.

It is important to note that the CAP88-PC system has several significant limitations. Because of these limitations, protective assumptions are used to estimate conservative chronic (or annual) doses to airborne radionuclides—resulting in *overestimates* of the doses that people would have actually received. One limitation of the system is that all emission sources or release points are co-located at the middle of a site. The model can accommodate up to six sources with varying emission parameters (e.g., stack height and emission rates), but all sources will be located at a single location. Site-specific exposures at discrete areas such as Union/Lawnville, Sugar Grove, or Happy Valley must be modeled as specific distances and directions from the plume origin. These locations, with their respective distances and directions, are shown in Figure 14. Specification of these locations assumes that the approximate center of the K-25 building, which is at the approximate center of the K-25 site, is the point of origin for K-25 releases. Similarly, the center of the S-50 footprint (see Figure 14) serves as the point of origin for S-50 releases. The net result of this co-located source assumption is that it minimizes plume dispersion and maximizes plume concentrations in discrete exposure areas.

Another CAP88-PC limitation is that all sources use the same plume rise mechanism. For this assessment, ATSDR used the stack parameters (within rounding error) from the Task 6 report for air modeling of K-25/S-50 releases: a plume rise (exit velocity) based on a release momentum of 10 meters/second, a stack height of 23 meters, a stack diameter of 2 meters, and an exit temperature of 293 Kelvin.

The dose assessment portion of the CAP88-PC assessment assumes a “rural default” for food consumption. This default conservatively assumes that 70% of vegetables, 40% of milk, and 45% of meat are homegrown (at each exposure location) and the remainder (30% of vegetables, 60% of milk, and 55% of meat) is grown in the local area. The model assumes that no food items are imported from outside the local area.

CAP88-PC assessments are done for a circular grid of distances and directions with a radius of 4,800 meters (3 miles) around the facility; however, the CAP88-PC model does not accommodate for the effect of complex topography on air dispersion. Consequently, dispersion to areas such as Sugar Grove and Union/Lawnville, which are separated from K-25 by significant topographic features (see Figure 7), will be overestimated. The potential overestimation of doses in exposure areas may be particularly important for consideration of UF_6 dispersion. UF_6 is a dense gas (heavier than air) that does not rise through the atmosphere like lighter gases. Also, to the extent that the ridge and valley topography have influenced the site-specific weather data, the effect of topography may be moot.

The remainder of this appendix contains the input and output data for the CAP88-PC model run for the 1963 annual releases from K-25 using the 1999 meteorological data.

Effective Dose Equivalent (mrem/year)
5.28E+01

At This Location: 1600 Meters Northeast
Dataset Name: K25_1999
Dataset Date: 9/27/2004 12:55:00 PM
Wind File: C:\Program Files\CAP88-PC21\k-25\120899.WND

MAXIMALLY EXPOSED INDIVIDUAL

Location of the Individual: 1600 Meters Northeast
Lifetime Fatal Cancer Risk: 6.68E-04

ORGAN DOSE EQUIVALENT SUMMARY

Organ	Dose Equivalent (mrem/y)
GONADS	5.76E-01
BREAST	3.46E-01
R MAR	6.05E+00
LUNGS	3.93E+02
THYROID	1.28E+00
ENDOST	8.54E+01
RMNDR	7.08E+00
EFFEC	5.28E+01

RADIONUCLIDE EMISSIONS DURING THE YEAR 1963

Nuclide	Class	Size	Source #1 Ci/y	TOTAL Ci/y
U-235	Y	1.00	1.4E-01	1.4E-01
U-238	Y	1.00	5.0E-01	5.0E-01
U-234	Y	1.00	2.5E+00	2.5E+00
NP-237	Y	1.00	5.0E-02	5.0E-02
TC-99	W	1.00	2.5E+00	2.5E+00

SITE INFORMATION

Temperature:	10	degrees C
Precipitation:	100	cm/y
Humidity:	8	g/cu m
Mixing Height:	1000	m

SOURCE INFORMATION

Source Number: 1

Stack Height (m): 23.00
Diameter (m): 2.00

Plume Rise
Momentum (m/s): 10.00
(Exit Velocity)

D O S E A N D R I S K E Q U I V A L E N T S U M M A R I E S

ORGAN DOSE EQUIVALENT SUMMARY

Organ	Selected Individual (mrem/y)
GONADS	5.76E-01
BREAST	3.46E-01
R MAR	6.05E+00
LUNGS	3.93E+02
THYROID	1.28E+00
ENDOST	8.54E+01
RMNDR	7.08E+00
EFFEC	5.28E+01

PATHWAY EFFECTIVE DOSE EQUIVALENT SUMMARY

Pathway	Selected Individual (mrem/y)
INGESTION	4.42E+00
INHALATION	4.84E+01
AIR IMMERSION	1.62E-06
GROUND SURFACE	7.99E-02
INTERNAL	5.28E+01
EXTERNAL	7.99E-02
TOTAL	5.29E+01

NUCLIDE EFFECTIVE DOSE EQUIVALENT SUMMARY

Nuclide	Selected Individual (mrem/y)
U-235	2.22E+00
U-238	7.37E+00
U-234	4.09E+01
NP-237	2.10E+00
TC-99	2.50E-01
TOTAL	5.29E+01

CANCER RISK SUMMARY

Cancer	Selected Individual Total Lifetime Fatal Cancer Risk
LEUKEMIA	6.00E-06
BONE	4.27E-06
THYROID	5.32E-07
BREAST	8.98E-07
LUNG	6.32E-04
STOMACH	7.38E-06
BOWEL	1.03E-06
LIVER	3.84E-06
PANCREAS	3.59E-07
URINARY	1.17E-05
OTHER	4.40E-07
TOTAL	6.68E-04

PATHWAY RISK SUMMARY

Pathway	Selected Individual Total Lifetime Fatal Cancer Risk
INGESTION	3.02E-05
INHALATION	6.36E-04
AIR IMMERSION	3.77E-11
GROUND SURFACE	1.84E-06
INTERNAL	6.66E-04
EXTERNAL	1.84E-06
TOTAL	6.68E-04

NUCLIDE RISK SUMMARY

Nuclide	Selected Individual Total Lifetime Fatal Cancer Risk
U-235	2.90E-05
U-238	9.45E-05
U-234	5.19E-04
NP-237	1.63E-05
TC-99	9.13E-06
TOTAL	6.68E-04

INDIVIDUAL EFFECTIVE DOSE EQUIVALENT RATE (mrem/y)
(All Radionuclides and Pathways)

	Distance (m)				
Direction	1600	2000	2570	3000	4324
N	7.4E+00	5.8E+00	4.4E+00	3.7E+00	2.5E+00
NNW	4.0E+00	3.6E+00	3.0E+00	2.7E+00	2.0E+00
NW	4.0E+00	3.3E+00	2.6E+00	2.3E+00	1.6E+00
WNW	2.3E+00	1.7E+00	1.4E+00	1.3E+00	1.0E+00
W	6.4E+00	5.1E+00	4.0E+00	3.5E+00	2.4E+00
WSW	3.8E+00	3.4E+00	2.9E+00	2.6E+00	1.9E+00
SW	2.9E+00	2.4E+00	2.0E+00	1.9E+00	1.5E+00
SSW	2.8E+00	2.3E+00	1.8E+00	1.5E+00	1.1E+00
S	4.8E+00	4.3E+00	3.7E+00	3.3E+00	2.3E+00
SSE	1.5E+01	1.1E+01	8.2E+00	6.7E+00	4.3E+00
SE	3.6E+01	2.6E+01	1.8E+01	1.5E+01	8.9E+00
ESE	1.9E+01	1.4E+01	9.9E+00	8.0E+00	4.9E+00
E	3.4E+01	2.5E+01	1.7E+01	1.4E+01	8.5E+00
ENE	4.8E+01	3.5E+01	2.4E+01	1.9E+01	1.1E+01
NE	5.3E+01	3.7E+01	2.5E+01	2.0E+01	1.2E+01
NNE	4.0E+01	2.9E+01	2.0E+01	1.6E+01	9.5E+00

AGRICULTURAL DATA

	Vegetable	Milk	Meat
Fraction Home Produced:	0.700	0.400	0.440
Fraction From Assessment Area:	0.300	0.600	0.560
Fraction Imported:	0.000	0.000	0.000

Food Arrays were not generated for this run.
Default Values used.

DISTANCES (M) USED FOR MAXIMUM INDIVIDUAL ASSESSMENT

1600 2000 2570 3000 4324

INDIVIDUAL LIFETIME RISK (deaths)
(All Radionuclides and Pathways)

	Distance (m)				
Direction	1600	2000	2570	3000	4324
N	9.2E-05	7.1E-05	5.4E-05	4.5E-05	3.0E-05
NNW	4.8E-05	4.3E-05	3.6E-05	3.2E-05	2.3E-05
NW	4.8E-05	3.9E-05	3.1E-05	2.6E-05	1.8E-05
WNW	2.6E-05	1.9E-05	1.5E-05	1.3E-05	1.1E-05
W	7.8E-05	6.2E-05	4.8E-05	4.1E-05	2.8E-05
WSW	4.5E-05	4.0E-05	3.4E-05	3.0E-05	2.1E-05
SW	3.4E-05	2.8E-05	2.3E-05	2.1E-05	1.6E-05
SSW	3.3E-05	2.7E-05	2.1E-05	1.7E-05	1.2E-05
S	5.8E-05	5.2E-05	4.4E-05	3.9E-05	2.8E-05
SSE	1.9E-04	1.4E-04	1.0E-04	8.3E-05	5.2E-05

SE	4.5E-04	3.3E-04	2.3E-04	1.8E-04	1.1E-04
ESE	2.4E-04	1.8E-04	1.2E-04	9.9E-05	6.0E-05
E	4.3E-04	3.1E-04	2.2E-04	1.7E-04	1.1E-04
ENE	6.1E-04	4.4E-04	3.0E-04	2.4E-04	1.4E-04
NE	6.7E-04	4.7E-04	3.2E-04	2.5E-04	1.4E-04
NNE	5.0E-04	3.6E-04	2.5E-04	2.0E-04	1.2E-04

VALUES FOR RADIONUCLIDE-DEPENDENT PARAMETERS

Nuclide	Clearance Class	Particle Size (microns)	Scavenging Coefficient (per second)	Dry Deposition Velocity (m/s)
U-235	Y	1.0	1.00E-05	1.80E-03
U-238	Y	1.0	1.00E-05	1.80E-03
U-234	Y	1.0	1.00E-05	1.80E-03
NP-237	Y	1.0	1.00E-05	1.80E-03
TC-99	W	1.0	1.00E-05	1.80E-03

VALUES FOR RADIONUCLIDE-DEPENDENT PARAMETERS

	DECAY CONSTANT (PER DAY)			TRANSFER COEFFICIENT	
Nuclide	Radio-active (1)	Surface	Water	Milk (2)	Meat (3)
U-235	0.00E+00	5.48E-05	0.00E+00	6.00E-04	2.00E-04
U-238	0.00E+00	5.48E-05	0.00E+00	6.00E-04	2.00E-04
U-234	0.00E+00	5.48E-05	0.00E+00	6.00E-04	2.00E-04
NP-237	0.00E+00	5.48E-05	0.00E+00	5.00E-06	5.50E-05
TC-99	0.00E+00	5.48E-05	0.00E+00	1.00E-02	8.50E-03

FOOTNOTES: (1) Effective radioactive decay constant in plume; set to zero if less than 1.0E-2

(2) Fraction of animal's daily intake of nuclide which appears in each L of milk (days/L)

(3) Fraction of animal's daily intake of nuclide, which appears in each kg of meat (days/kg)

VALUES FOR RADIONUCLIDE-DEPENDENT PARAMETERS

	CONCENTRATION UPTAKE FACTOR		GI UPTAKE FRACTION	
Nuclide	Forage (1)	Edible (2)	Inhalation	Ingestion
U-235	8.50E-03	1.71E-03	2.00E-03	2.00E-01
U-238	8.50E-03	1.71E-03	2.00E-03	2.00E-01
U-234	8.50E-03	1.71E-03	2.00E-03	2.00E-01
NP-237	1.00E-01	4.28E-03	1.00E-03	1.00E-03
TC-99	9.50E+00	6.42E-01	8.00E-01	8.00E-01

FOOTNOTES: (1) Concentration factor for uptake of nuclide from soil for pasture and forage (in pCi/kg dry weight per pCi/kg dry soil)

(2) Concentration factor for uptake of nuclide from soil by edible parts of crops (in pCi/kg wet weight per pCi/kg dry soil)

VALUES FOR RADIONUCLIDE-INDEPENDENT PARAMETERS

HUMAN INHALATION RATE	
Cubic centimeters/hr	9.17E+05
SOIL PARAMETERS	
Effective surface density (kg/sq m, dry weight)	
(Assumes 15 cm plow layer)	2.15E+02

BUILDUP TIMES	
For activity in soil (years)	1.00E+02
For radionuclides deposited on ground/water (days)	3.65E+04
DELAY TIMES	
Ingestion of pasture grass by animals (hr)	0.00E+00
Ingestion of stored feed by animals (hr)	2.16E+03
Ingestion of leafy vegetables by man (hr)	3.36E+02
Ingestion of produce by man (hr)	3.36E+02
Transport time from animal feed-milk-man (day)	2.00E+00
Time from slaughter to consumption (day)	2.00E+01
WEATHERING	
Removal rate constant for physical loss (per hr)	2.90E-03

VALUES FOR RADIONUCLIDE-INDEPENDENT PARAMETERS

CROP EXPOSURE DURATION	
Pasture grass (hr)	7.20E+02
Crops/leafy vegetables (hr)	1.44E+03
AGRICULTURAL PRODUCTIVITY	
Grass-cow-milk-man pathway (kg/sq m)	2.80E-01
Produce/leafy veg for human consumption (kg/sq m)	7.16E-01
FALLOUT INTERCEPTION FRACTIONS	
Vegetables	2.00E-01
Pasture	5.70E-01

GRAZING PARAMETERS	
Fraction of year animals graze on pasture	4.00E-01
Fraction of daily feed that is pasture grass when animal grazes on pasture	4.30E-01
ANIMAL FEED CONSUMPTION FACTORS	
Contaminated feed/forage (kg/day, dry weight)	1.56E+01
DAIRY PRODUCTIVITY	
Milk production of cow (L/day)	1.10E+01
MEAT ANIMAL SLAUGHTER PARAMETERS	
Muscle mass of animal at slaughter (kg)	2.00E+02
Fraction of herd slaughtered (per day)	3.81E-03
DECONTAMINATION	
Fraction of radioactivity retained after washing for leafy vegetables and produce	5.00E-01
FRACTIONS GROWN IN GARDEN OF INTEREST	
Produce ingested	1.00E+00
Leafy vegetables ingested	1.00E+00
INGESTION RATIOS:	
IMMEDIATE SURROUNDING AREA/TOTAL WITHIN AREA	
Vegetables	7.00E-01
Meat	4.40E-01
Milk	4.00E-01

VALUES FOR RADIONUCLIDE-INDEPENDENT PARAMETERS

MINIMUM INGESTION FRACTIONS FROM OUTSIDE AREA
(Minimum fractions of food types from outside area listed below are actual fixed values.)

Vegetables	0.00E+00
Meat	0.00E+00
Milk	0.00E+00

HUMAN FOOD UTILIZATION FACTORS

Produce ingestion (kg/y)	1.76E+02
Milk ingestion (L/y)	1.12E+02
Meat ingestion (kg/y)	8.50E+01
Leafy vegetable ingestion (kg/y)	1.80E+01

SWIMMING PARAMETERS

Fraction of time spent swimming	0.00E+00
Dilution factor for water (cm)	1.00E+00

ESTIMATED RADIONUCLIDE CONCENTRATIONS AT VARIOUS LOCATIONS IN THE ENVIRONMENT

Wind Toward	Distance (meters)	Nuclide	Air Concentration (pCi/m3)	Dry Deposition Rate (pCi/cm2/s)	Wet Deposition Rate (pCi/cm2/s)	Ground Deposition Rate (pCi/cm2/s)
N	1600	U-235	2.7E-04	4.8E-11	4.5E-11	9.3E-11
N	1600	U-238	9.5E-04	1.7E-10	1.6E-10	3.3E-10
N	1600	U-234	4.7E-03	8.5E-10	8.0E-10	1.6E-09

N	1600	NP-237	9.5E-05	1.7E-11	1.6E-11	3.3E-11
N	1600	TC-99	4.8E-03	8.6E-10	8.1E-10	1.7E-09
N	2000	U-235	2.0E-04	3.7E-11	3.6E-11	7.3E-11
N	2000	U-238	7.3E-04	1.3E-10	1.3E-10	2.6E-10
N	2000	U-234	3.6E-03	6.5E-10	6.4E-10	1.3E-09
N	2000	NP-237	7.3E-05	1.3E-11	1.3E-11	2.6E-11
N	2000	TC-99	3.6E-03	6.6E-10	6.4E-10	1.3E-09
N	2570	U-235	1.5E-04	2.7E-11	2.8E-11	5.5E-11
N	2570	U-238	5.4E-04	9.7E-11	9.9E-11	2.0E-10
N	2570	U-234	2.7E-03	4.8E-10	4.9E-10	9.7E-10
N	2570	NP-237	5.4E-05	9.7E-12	9.9E-12	2.0E-11
N	2570	TC-99	2.7E-03	4.9E-10	5.0E-10	9.8E-10
N	3000	U-235	1.2E-04	2.2E-11	2.4E-11	4.6E-11
N	3000	U-238	4.5E-04	8.0E-11	8.5E-11	1.6E-10
N	3000	U-234	2.2E-03	4.0E-10	4.2E-10	8.1E-10
N	3000	NP-237	4.5E-05	8.0E-12	8.5E-12	1.6E-11
N	3000	TC-99	2.2E-03	4.0E-10	4.2E-10	8.2E-10
N	4324	U-235	7.9E-05	1.4E-11	1.6E-11	3.0E-11

ESTIMATED RADIONUCLIDE CONCENTRATIONS AT VARIOUS LOCATIONS IN THE ENVIRONMENT

Wind Toward	Distance (meters)	Nuclide	Air Concentration (pCi/m3)	Dry Deposition Rate (pCi/cm2/s)	Wet Deposition Rate (pCi/cm2/s)	Ground Deposition Rate (pCi/cm2/s)
N	4324	U-238	2.8E-04	5.1E-11	5.7E-11	1.1E-10
N	4324	U-234	1.4E-03	2.5E-10	2.8E-10	5.3E-10
N	4324	NP-237	2.8E-05	5.1E-12	5.7E-12	1.1E-11
N	4324	TC-99	1.4E-03	2.5E-10	2.9E-10	5.4E-10
NNW	1600	U-235	1.3E-04	2.4E-11	3.6E-11	6.0E-11
NNW	1600	U-238	4.7E-04	8.4E-11	1.3E-10	2.1E-10
NNW	1600	U-234	2.3E-03	4.2E-10	6.4E-10	1.1E-09
NNW	1600	NP-237	4.7E-05	8.4E-12	1.3E-11	2.1E-11
NNW	1600	TC-99	2.3E-03	4.2E-10	6.4E-10	1.1E-09
NNW	2000	U-235	1.2E-04	2.1E-11	2.9E-11	5.0E-11

NNW	2000	U-238	4.2E-04	7.6E-11	1.0E-10	1.8E-10
NNW	2000	U-234	2.1E-03	3.7E-10	5.0E-10	8.8E-10
NNW	2000	NP-237	4.2E-05	7.6E-12	1.0E-11	1.8E-11
NNW	2000	TC-99	2.1E-03	3.8E-10	5.1E-10	8.9E-10
NNW	2570	U-235	9.9E-05	1.8E-11	2.2E-11	4.0E-11
NNW	2570	U-238	3.5E-04	6.3E-11	7.8E-11	1.4E-10
NNW	2570	U-234	1.7E-03	3.1E-10	3.9E-10	7.0E-10
NNW	2570	NP-237	3.5E-05	6.3E-12	7.8E-12	1.4E-11
NNW	2570	TC-99	1.8E-03	3.2E-10	3.9E-10	7.1E-10
NNW	3000	U-235	8.6E-05	1.5E-11	1.9E-11	3.4E-11
NNW	3000	U-238	3.1E-04	5.5E-11	6.6E-11	1.2E-10
NNW	3000	U-234	1.5E-03	2.7E-10	3.3E-10	6.0E-10
NNW	3000	NP-237	3.1E-05	5.5E-12	6.6E-12	1.2E-11
NNW	3000	TC-99	1.5E-03	2.8E-10	3.3E-10	6.1E-10
NNW	4324	U-235	5.8E-05	1.0E-11	1.3E-11	2.3E-11
NNW	4324	U-238	2.1E-04	3.7E-11	4.5E-11	8.2E-11
NNW	4324	U-234	1.0E-03	1.8E-10	2.2E-10	4.0E-10
NNW	4324	NP-237	2.1E-05	3.7E-12	4.5E-12	8.2E-12
NNW	4324	TC-99	1.0E-03	1.8E-10	2.2E-10	4.1E-10
NW	1600	U-235	1.3E-04	2.4E-11	3.9E-11	6.3E-11
NW	1600	U-238	4.7E-04	8.5E-11	1.4E-10	2.3E-10
NW	1600	U-234	2.3E-03	4.2E-10	6.9E-10	1.1E-09
NW	1600	NP-237	4.7E-05	8.5E-12	1.4E-11	2.3E-11
NW	1600	TC-99	2.4E-03	4.3E-10	7.0E-10	1.1E-09
NW	2000	U-235	1.1E-04	1.9E-11	3.1E-11	5.0E-11
NW	2000	U-238	3.8E-04	6.8E-11	1.1E-10	1.8E-10
NW	2000	U-234	1.9E-03	3.3E-10	5.5E-10	8.9E-10
NW	2000	NP-237	3.8E-05	6.8E-12	1.1E-11	1.8E-11
NW	2000	TC-99	1.9E-03	3.4E-10	5.6E-10	9.0E-10
NW	2570	U-235	8.1E-05	1.5E-11	2.4E-11	3.9E-11
NW	2570	U-238	2.9E-04	5.2E-11	8.6E-11	1.4E-10
NW	2570	U-234	1.4E-03	2.6E-10	4.2E-10	6.8E-10
NW	2570	NP-237	2.9E-05	5.2E-12	8.6E-12	1.4E-11
NW	2570	TC-99	1.4E-03	2.6E-10	4.3E-10	6.9E-10
NW	3000	U-235	6.8E-05	1.2E-11	2.0E-11	3.3E-11
NW	3000	U-238	2.4E-04	4.4E-11	7.3E-11	1.2E-10
NW	3000	U-234	1.2E-03	2.2E-10	3.6E-10	5.8E-10

ESTIMATED RADIONUCLIDE CONCENTRATIONS AT VARIOUS LOCATIONS IN THE ENVIRONMENT

Wind Toward	Distance (meters)	Nuclide	Air Concentration (pCi/m3)	Dry Deposition Rate (pCi/cm2/s)	Wet Deposition Rate (pCi/cm2/s)	Ground Deposition Rate (pCi/cm2/s)
NW	3000	NP-237	2.4E-05	4.4E-12	7.3E-12	1.2E-11
NW	3000	TC-99	1.2E-03	2.2E-10	3.6E-10	5.8E-10
NW	4324	U-235	4.3E-05	7.8E-12	1.4E-11	2.2E-11
NW	4324	U-238	1.5E-04	2.8E-11	4.9E-11	7.7E-11
NW	4324	U-234	7.6E-04	1.4E-10	2.4E-10	3.8E-10
NW	4324	NP-237	1.5E-05	2.8E-12	4.9E-12	7.7E-12
NW	4324	TC-99	7.7E-04	1.4E-10	2.5E-10	3.8E-10
WNW	1600	U-235	6.4E-05	1.2E-11	3.8E-11	4.9E-11
WNW	1600	U-238	2.3E-04	4.1E-11	1.3E-10	1.8E-10
WNW	1600	U-234	1.1E-03	2.0E-10	6.6E-10	8.7E-10
WNW	1600	NP-237	2.3E-05	4.1E-12	1.3E-11	1.8E-11
WNW	1600	TC-99	1.1E-03	2.1E-10	6.7E-10	8.8E-10
WNW	2000	U-235	4.4E-05	7.8E-12	3.0E-11	3.8E-11
WNW	2000	U-238	1.6E-04	2.8E-11	1.1E-10	1.3E-10
WNW	2000	U-234	7.7E-04	1.4E-10	5.3E-10	6.7E-10
WNW	2000	NP-237	1.6E-05	2.8E-12	1.1E-11	1.3E-11
WNW	2000	TC-99	7.8E-04	1.4E-10	5.3E-10	6.7E-10
WNW	2570	U-235	3.2E-05	5.7E-12	2.3E-11	2.9E-11
WNW	2570	U-238	1.1E-04	2.0E-11	8.2E-11	1.0E-10
WNW	2570	U-234	5.6E-04	1.0E-10	4.1E-10	5.1E-10
WNW	2570	NP-237	1.1E-05	2.0E-12	8.2E-12	1.0E-11
WNW	2570	TC-99	5.6E-04	1.0E-10	4.1E-10	5.1E-10
WNW	3000	U-235	2.8E-05	5.1E-12	2.0E-11	2.5E-11
WNW	3000	U-238	1.0E-04	1.8E-11	7.0E-11	8.8E-11
WNW	3000	U-234	5.0E-04	8.9E-11	3.5E-10	4.4E-10
WNW	3000	NP-237	1.0E-05	1.8E-12	7.0E-12	8.8E-12
WNW	3000	TC-99	5.0E-04	9.0E-11	3.5E-10	4.4E-10
WNW	4324	U-235	2.0E-05	3.6E-12	1.3E-11	1.7E-11
WNW	4324	U-238	7.2E-05	1.3E-11	4.8E-11	6.1E-11
WNW	4324	U-234	3.6E-04	6.4E-11	2.4E-10	3.0E-10
WNW	4324	NP-237	7.2E-06	1.3E-12	4.8E-12	6.1E-12

WNW	4324	TC-99	3.6E-04	6.5E-11	2.4E-10	3.0E-10
W	1600	U-235	2.2E-04	4.0E-11	5.9E-11	9.9E-11
W	1600	U-238	7.9E-04	1.4E-10	2.1E-10	3.5E-10
W	1600	U-234	3.9E-03	7.0E-10	1.0E-09	1.7E-09
W	1600	NP-237	7.9E-05	1.4E-11	2.1E-11	3.5E-11
W	1600	TC-99	4.0E-03	7.1E-10	1.1E-09	1.8E-09
W	2000	U-235	1.7E-04	3.1E-11	4.7E-11	7.8E-11
W	2000	U-238	6.2E-04	1.1E-10	1.7E-10	2.8E-10
W	2000	U-234	3.1E-03	5.5E-10	8.3E-10	1.4E-09
W	2000	NP-237	6.2E-05	1.1E-11	1.7E-11	2.8E-11
W	2000	TC-99	3.1E-03	5.6E-10	8.4E-10	1.4E-09
W	2570	U-235	1.3E-04	2.4E-11	3.6E-11	6.0E-11
W	2570	U-238	4.7E-04	8.5E-11	1.3E-10	2.1E-10
W	2570	U-234	2.3E-03	4.2E-10	6.4E-10	1.1E-09
W	2570	NP-237	4.7E-05	8.5E-12	1.3E-11	2.1E-11

ESTIMATED RADIONUCLIDE CONCENTRATIONS AT VARIOUS LOCATIONS IN THE ENVIRONMENT

Wind Toward	Distance (meters)	Nuclide	Air Concentration (pCi/m3)	Dry Deposition Rate (pCi/cm2/s)	Wet Deposition Rate (pCi/cm2/s)	Ground Deposition Rate (pCi/cm2/s)
W	2570	TC-99	2.4E-03	4.3E-10	6.5E-10	1.1E-09
W	3000	U-235	1.1E-04	2.0E-11	3.1E-11	5.1E-11
W	3000	U-238	4.0E-04	7.2E-11	1.1E-10	1.8E-10
W	3000	U-234	2.0E-03	3.6E-10	5.4E-10	9.0E-10
W	3000	NP-237	4.0E-05	7.2E-12	1.1E-11	1.8E-11
W	3000	TC-99	2.0E-03	3.6E-10	5.5E-10	9.1E-10
W	4324	U-235	7.2E-05	1.3E-11	2.1E-11	3.4E-11
W	4324	U-238	2.6E-04	4.6E-11	7.5E-11	1.2E-10
W	4324	U-234	1.3E-03	2.3E-10	3.7E-10	6.0E-10
W	4324	NP-237	2.6E-05	4.6E-12	7.5E-12	1.2E-11
W	4324	TC-99	1.3E-03	2.3E-10	3.7E-10	6.1E-10
WSW	1600	U-235	1.2E-04	2.2E-11	3.5E-11	5.7E-11
WSW	1600	U-238	4.4E-04	8.0E-11	1.2E-10	2.0E-10
WSW	1600	U-234	2.2E-03	4.0E-10	6.2E-10	1.0E-09
WSW	1600	NP-237	4.4E-05	8.0E-12	1.2E-11	2.0E-11
WSW	1600	TC-99	2.2E-03	4.0E-10	6.2E-10	1.0E-09
WSW	2000	U-235	1.1E-04	2.0E-11	2.8E-11	4.8E-11
WSW	2000	U-238	3.9E-04	7.1E-11	9.9E-11	1.7E-10
WSW	2000	U-234	1.9E-03	3.5E-10	4.9E-10	8.4E-10
WSW	2000	NP-237	3.9E-05	7.1E-12	9.9E-12	1.7E-11
WSW	2000	TC-99	2.0E-03	3.5E-10	4.9E-10	8.5E-10
WSW	2570	U-235	9.2E-05	1.7E-11	2.1E-11	3.8E-11
WSW	2570	U-238	3.3E-04	5.9E-11	7.6E-11	1.4E-10
WSW	2570	U-234	1.6E-03	2.9E-10	3.8E-10	6.7E-10
WSW	2570	NP-237	3.3E-05	5.9E-12	7.6E-12	1.4E-11
WSW	2570	TC-99	1.6E-03	3.0E-10	3.8E-10	6.8E-10
WSW	3000	U-235	8.0E-05	1.4E-11	1.8E-11	3.3E-11
WSW	3000	U-238	2.9E-04	5.2E-11	6.4E-11	1.2E-10
WSW	3000	U-234	1.4E-03	2.6E-10	3.2E-10	5.7E-10

WSW	3000	NP-237	2.9E-05	5.2E-12	6.4E-12	1.2E-11
WSW	3000	TC-99	1.4E-03	2.6E-10	3.2E-10	5.8E-10
WSW	4324	U-235	5.4E-05	9.7E-12	1.2E-11	2.2E-11
WSW	4324	U-238	1.9E-04	3.5E-11	4.3E-11	7.8E-11
WSW	4324	U-234	9.5E-04	1.7E-10	2.1E-10	3.9E-10
WSW	4324	NP-237	1.9E-05	3.5E-12	4.3E-12	7.8E-12
WSW	4324	TC-99	9.6E-04	1.7E-10	2.2E-10	3.9E-10
SW	1600	U-235	8.8E-05	1.6E-11	4.6E-11	6.1E-11
SW	1600	U-238	3.1E-04	5.7E-11	1.6E-10	2.2E-10
SW	1600	U-234	1.6E-03	2.8E-10	8.0E-10	1.1E-09
SW	1600	NP-237	3.1E-05	5.7E-12	1.6E-11	2.2E-11
SW	1600	TC-99	1.6E-03	2.8E-10	8.1E-10	1.1E-09
SW	2000	U-235	6.9E-05	1.3E-11	3.6E-11	4.9E-11
SW	2000	U-238	2.5E-04	4.5E-11	1.3E-10	1.7E-10
SW	2000	U-234	1.2E-03	2.2E-10	6.4E-10	8.6E-10
SW	2000	NP-237	2.5E-05	4.5E-12	1.3E-11	1.7E-11
SW	2000	TC-99	1.2E-03	2.2E-10	6.5E-10	8.7E-10
SW	2570	U-235	5.6E-05	1.0E-11	2.8E-11	3.8E-11

ESTIMATED RADIONUCLIDE CONCENTRATIONS AT VARIOUS LOCATIONS IN THE ENVIRONMENT

Wind Toward	Distance (meters)	Nuclide	Air Concentration (pCi/m3)	Dry Deposition Rate (pCi/cm2/s)	Wet Deposition Rate (pCi/cm2/s)	Ground Deposition Rate (pCi/cm2/s)
SW	2570	U-238	2.0E-04	3.6E-11	1.0E-10	1.4E-10
SW	2570	U-234	9.9E-04	1.8E-10	4.9E-10	6.7E-10
SW	2570	NP-237	2.0E-05	3.6E-12	1.0E-11	1.4E-11
SW	2570	TC-99	1.0E-03	1.8E-10	5.0E-10	6.8E-10
SW	3000	U-235	5.1E-05	9.2E-12	2.4E-11	3.3E-11
SW	3000	U-238	1.8E-04	3.3E-11	8.5E-11	1.2E-10
SW	3000	U-234	9.0E-04	1.6E-10	4.2E-10	5.8E-10
SW	3000	NP-237	1.8E-05	3.3E-12	8.5E-12	1.2E-11
SW	3000	TC-99	9.1E-04	1.6E-10	4.2E-10	5.9E-10
SW	4324	U-235	3.7E-05	6.6E-12	1.6E-11	2.3E-11

SW	4324	U-238	1.3E-04	2.4E-11	5.7E-11	8.1E-11
SW	4324	U-234	6.5E-04	1.2E-10	2.8E-10	4.0E-10
SW	4324	NP-237	1.3E-05	2.4E-12	5.7E-12	8.1E-12
SW	4324	TC-99	6.6E-04	1.2E-10	2.9E-10	4.1E-10
SSW	1600	U-235	8.7E-05	1.6E-11	2.5E-11	4.1E-11
SSW	1600	U-238	3.1E-04	5.6E-11	9.1E-11	1.5E-10
SSW	1600	U-234	1.5E-03	2.8E-10	4.5E-10	7.2E-10
SSW	1600	NP-237	3.1E-05	5.6E-12	9.1E-12	1.5E-11
SSW	1600	TC-99	1.6E-03	2.8E-10	4.5E-10	7.3E-10
SSW	2000	U-235	6.9E-05	1.2E-11	2.0E-11	3.3E-11
SSW	2000	U-238	2.5E-04	4.5E-11	7.2E-11	1.2E-10
SSW	2000	U-234	1.2E-03	2.2E-10	3.6E-10	5.8E-10
SSW	2000	NP-237	2.5E-05	4.5E-12	7.2E-12	1.2E-11
SSW	2000	TC-99	1.2E-03	2.2E-10	3.6E-10	5.8E-10
SSW	2570	U-235	5.1E-05	9.2E-12	1.5E-11	2.5E-11
SSW	2570	U-238	1.8E-04	3.3E-11	5.5E-11	8.8E-11
SSW	2570	U-234	9.0E-04	1.6E-10	2.7E-10	4.4E-10
SSW	2570	NP-237	1.8E-05	3.3E-12	5.5E-12	8.8E-12
SSW	2570	TC-99	9.1E-04	1.6E-10	2.8E-10	4.4E-10
SSW	3000	U-235	4.1E-05	7.5E-12	1.3E-11	2.1E-11
SSW	3000	U-238	1.5E-04	2.7E-11	4.7E-11	7.4E-11
SSW	3000	U-234	7.3E-04	1.3E-10	2.3E-10	3.6E-10
SSW	3000	NP-237	1.5E-05	2.7E-12	4.7E-12	7.4E-12
SSW	3000	TC-99	7.4E-04	1.3E-10	2.3E-10	3.7E-10
SSW	4324	U-235	2.5E-05	4.4E-12	8.9E-12	1.3E-11
SSW	4324	U-238	8.8E-05	1.6E-11	3.2E-11	4.8E-11
SSW	4324	U-234	4.4E-04	7.8E-11	1.6E-10	2.4E-10
SSW	4324	NP-237	8.8E-06	1.6E-12	3.2E-12	4.8E-12
SSW	4324	TC-99	4.4E-04	7.9E-11	1.6E-10	2.4E-10
S	1600	U-235	1.6E-04	2.9E-11	4.2E-11	7.1E-11
S	1600	U-238	5.8E-04	1.0E-10	1.5E-10	2.5E-10
S	1600	U-234	2.9E-03	5.2E-10	7.4E-10	1.3E-09
S	1600	NP-237	5.8E-05	1.0E-11	1.5E-11	2.5E-11
S	1600	TC-99	2.9E-03	5.2E-10	7.5E-10	1.3E-09
S	2000	U-235	1.5E-04	2.6E-11	3.3E-11	6.0E-11
S	2000	U-238	5.2E-04	9.4E-11	1.2E-10	2.1E-10
S	2000	U-234	2.6E-03	4.6E-10	5.9E-10	1.1E-09

ESTIMATED RADIONUCLIDE CONCENTRATIONS AT VARIOUS LOCATIONS IN THE ENVIRONMENT

Wind Toward	Distance (meters)	Nuclide	Air Concentration (pCi/m3)	Dry Deposition Rate (pCi/cm2/s)	Wet Deposition Rate (pCi/cm2/s)	Ground Deposition Rate (pCi/cm2/s)
S	2000	NP-237	5.2E-05	9.4E-12	1.2E-11	2.1E-11
S	2000	TC-99	2.6E-03	4.7E-10	6.0E-10	1.1E-09
S	2570	U-235	1.2E-04	2.2E-11	2.6E-11	4.8E-11
S	2570	U-238	4.4E-04	7.8E-11	9.1E-11	1.7E-10
S	2570	U-234	2.1E-03	3.9E-10	4.5E-10	8.4E-10
S	2570	NP-237	4.4E-05	7.8E-12	9.1E-12	1.7E-11
S	2570	TC-99	2.2E-03	3.9E-10	4.6E-10	8.5E-10
S	3000	U-235	1.1E-04	1.9E-11	2.2E-11	4.1E-11
S	3000	U-238	3.8E-04	6.9E-11	7.8E-11	1.5E-10
S	3000	U-234	1.9E-03	3.4E-10	3.8E-10	7.2E-10
S	3000	NP-237	3.8E-05	6.9E-12	7.8E-12	1.5E-11
S	3000	TC-99	1.9E-03	3.4E-10	3.9E-10	7.3E-10
S	4324	U-235	7.2E-05	1.3E-11	1.5E-11	2.8E-11
S	4324	U-238	2.6E-04	4.6E-11	5.2E-11	9.9E-11
S	4324	U-234	1.3E-03	2.3E-10	2.6E-10	4.9E-10
S	4324	NP-237	2.6E-05	4.6E-12	5.2E-12	9.9E-12
S	4324	TC-99	1.3E-03	2.3E-10	2.6E-10	4.9E-10
SSE	1600	U-235	5.7E-04	1.0E-10	6.1E-11	1.6E-10
SSE	1600	U-238	2.0E-03	3.6E-10	2.2E-10	5.8E-10
SSE	1600	U-234	1.0E-02	1.8E-09	1.1E-09	2.9E-09
SSE	1600	NP-237	2.0E-04	3.6E-11	2.2E-11	5.8E-11
SSE	1600	TC-99	1.0E-02	1.8E-09	1.1E-09	2.9E-09
SSE	2000	U-235	4.2E-04	7.6E-11	4.8E-11	1.2E-10
SSE	2000	U-238	1.5E-03	2.7E-10	1.7E-10	4.4E-10
SSE	2000	U-234	7.5E-03	1.3E-09	8.5E-10	2.2E-09
SSE	2000	NP-237	1.5E-04	2.7E-11	1.7E-11	4.4E-11
SSE	2000	TC-99	7.5E-03	1.4E-09	8.7E-10	2.2E-09
SSE	2570	U-235	3.0E-04	5.4E-11	3.7E-11	9.2E-11
SSE	2570	U-238	1.1E-03	1.9E-10	1.3E-10	3.3E-10

SSE	2570	U-234	5.3E-03	9.5E-10	6.6E-10	1.6E-09
SSE	2570	NP-237	1.1E-04	1.9E-11	1.3E-11	3.3E-11
SSE	2570	TC-99	5.4E-03	9.7E-10	6.7E-10	1.6E-09
SSE	3000	U-235	2.4E-04	4.4E-11	3.2E-11	7.5E-11
SSE	3000	U-238	8.6E-04	1.6E-10	1.1E-10	2.7E-10
SSE	3000	U-234	4.3E-03	7.7E-10	5.6E-10	1.3E-09
SSE	3000	NP-237	8.6E-05	1.6E-11	1.1E-11	2.7E-11
SSE	3000	TC-99	4.3E-03	7.8E-10	5.7E-10	1.3E-09
SSE	4324	U-235	1.5E-04	2.6E-11	2.2E-11	4.8E-11
SSE	4324	U-238	5.3E-04	9.5E-11	7.8E-11	1.7E-10
SSE	4324	U-234	2.6E-03	4.7E-10	3.8E-10	8.5E-10
SSE	4324	NP-237	5.3E-05	9.5E-12	7.8E-12	1.7E-11
SSE	4324	TC-99	2.6E-03	4.7E-10	3.9E-10	8.6E-10
SE	1600	U-235	1.4E-03	2.4E-10	1.3E-10	3.7E-10
SE	1600	U-238	4.9E-03	8.7E-10	4.5E-10	1.3E-09
SE	1600	U-234	2.4E-02	4.3E-09	2.2E-09	6.5E-09
SE	1600	NP-237	4.9E-04	8.7E-11	4.5E-11	1.3E-10

ESTIMATED RADIONUCLIDE CONCENTRATIONS AT VARIOUS LOCATIONS IN THE ENVIRONMENT

Wind Toward	Distance (meters)	Nuclide	Air Concentration (pCi/m3)	Dry Deposition Rate (pCi/cm2/s)	Wet Deposition Rate (pCi/cm2/s)	Ground Deposition Rate (pCi/cm2/s)
SE	1600	TC-99	2.4E-02	4.4E-09	2.3E-09	6.6E-09
SE	2000	U-235	9.9E-04	1.8E-10	1.0E-10	2.8E-10
SE	2000	U-238	3.5E-03	6.4E-10	3.6E-10	1.0E-09
SE	2000	U-234	1.7E-02	3.1E-09	1.8E-09	4.9E-09
SE	2000	NP-237	3.5E-04	6.4E-11	3.6E-11	1.0E-10
SE	2000	TC-99	1.8E-02	3.2E-09	1.8E-09	5.0E-09
SE	2570	U-235	6.9E-04	1.2E-10	7.8E-11	2.0E-10
SE	2570	U-238	2.5E-03	4.4E-10	2.8E-10	7.2E-10
SE	2570	U-234	1.2E-02	2.2E-09	1.4E-09	3.6E-09
SE	2570	NP-237	2.5E-04	4.4E-11	2.8E-11	7.2E-11
SE	2570	TC-99	1.2E-02	2.2E-09	1.4E-09	3.6E-09

SE	3000	U-235	5.4E-04	9.8E-11	6.6E-11	1.6E-10
SE	3000	U-238	1.9E-03	3.5E-10	2.4E-10	5.9E-10
SE	3000	U-234	9.6E-03	1.7E-09	1.2E-09	2.9E-09
SE	3000	NP-237	1.9E-04	3.5E-11	2.4E-11	5.9E-11
SE	3000	TC-99	9.7E-03	1.8E-09	1.2E-09	2.9E-09
SE	4324	U-235	3.3E-04	5.9E-11	4.6E-11	1.0E-10
SE	4324	U-238	1.2E-03	2.1E-10	1.6E-10	3.7E-10
SE	4324	U-234	5.7E-03	1.0E-09	8.0E-10	1.8E-09
SE	4324	NP-237	1.2E-04	2.1E-11	1.6E-11	3.7E-11
SE	4324	TC-99	5.8E-03	1.0E-09	8.1E-10	1.9E-09
ESE	1600	U-235	7.2E-04	1.3E-10	1.1E-10	2.4E-10
ESE	1600	U-238	2.6E-03	4.6E-10	4.0E-10	8.6E-10
ESE	1600	U-234	1.3E-02	2.3E-09	2.0E-09	4.3E-09
ESE	1600	NP-237	2.6E-04	4.6E-11	4.0E-11	8.6E-11
ESE	1600	TC-99	1.3E-02	2.3E-09	2.0E-09	4.3E-09
ESE	2000	U-235	5.2E-04	9.3E-11	8.9E-11	1.8E-10
ESE	2000	U-238	1.8E-03	3.3E-10	3.2E-10	6.5E-10
ESE	2000	U-234	9.1E-03	1.6E-09	1.6E-09	3.2E-09
ESE	2000	NP-237	1.8E-04	3.3E-11	3.2E-11	6.5E-11
ESE	2000	TC-99	9.2E-03	1.7E-09	1.6E-09	3.3E-09
ESE	2570	U-235	3.6E-04	6.4E-11	6.9E-11	1.3E-10
ESE	2570	U-238	1.3E-03	2.3E-10	2.5E-10	4.8E-10
ESE	2570	U-234	6.3E-03	1.1E-09	1.2E-09	2.4E-09
ESE	2570	NP-237	1.3E-04	2.3E-11	2.5E-11	4.8E-11
ESE	2570	TC-99	6.4E-03	1.2E-09	1.2E-09	2.4E-09
ESE	3000	U-235	2.9E-04	5.1E-11	5.9E-11	1.1E-10
ESE	3000	U-238	1.0E-03	1.8E-10	2.1E-10	3.9E-10
ESE	3000	U-234	5.0E-03	9.1E-10	1.0E-09	1.9E-09
ESE	3000	NP-237	1.0E-04	1.8E-11	2.1E-11	3.9E-11
ESE	3000	TC-99	5.1E-03	9.2E-10	1.1E-09	2.0E-09
ESE	4324	U-235	1.7E-04	3.0E-11	4.0E-11	7.0E-11
ESE	4324	U-238	6.0E-04	1.1E-10	1.4E-10	2.5E-10
ESE	4324	U-234	3.0E-03	5.3E-10	7.1E-10	1.2E-09
ESE	4324	NP-237	6.0E-05	1.1E-11	1.4E-11	2.5E-11
ESE	4324	TC-99	3.0E-03	5.4E-10	7.2E-10	1.3E-09

ESTIMATED RADIONUCLIDE CONCENTRATIONS AT VARIOUS LOCATIONS IN THE ENVIRONMENT

Wind Toward	Distance (meters)	Nuclide	Air Concentration (pCi/m3)	Dry Deposition Rate (pCi/cm2/s)	Wet Deposition Rate (pCi/cm2/s)	Ground Deposition Rate (pCi/cm2/s)
E	1600	U-235	1.3E-03	2.3E-10	1.3E-10	3.6E-10
E	1600	U-238	4.7E-03	8.4E-10	4.6E-10	1.3E-09
E	1600	U-234	2.3E-02	4.1E-09	2.3E-09	6.4E-09
E	1600	NP-237	4.7E-04	8.4E-11	4.6E-11	1.3E-10
E	1600	TC-99	2.3E-02	4.2E-09	2.3E-09	6.5E-09
E	2000	U-235	9.4E-04	1.7E-10	1.0E-10	2.7E-10
E	2000	U-238	3.4E-03	6.1E-10	3.6E-10	9.7E-10
E	2000	U-234	1.7E-02	3.0E-09	1.8E-09	4.8E-09
E	2000	NP-237	3.4E-04	6.1E-11	3.6E-11	9.7E-11
E	2000	TC-99	1.7E-02	3.0E-09	1.8E-09	4.9E-09
E	2570	U-235	6.5E-04	1.2E-10	7.9E-11	2.0E-10
E	2570	U-238	2.3E-03	4.2E-10	2.8E-10	7.0E-10
E	2570	U-234	1.1E-02	2.1E-09	1.4E-09	3.5E-09
E	2570	NP-237	2.3E-04	4.2E-11	2.8E-11	7.0E-11
E	2570	TC-99	1.2E-02	2.1E-09	1.4E-09	3.5E-09
E	3000	U-235	5.2E-04	9.3E-11	6.7E-11	1.6E-10
E	3000	U-238	1.8E-03	3.3E-10	2.4E-10	5.7E-10
E	3000	U-234	9.1E-03	1.6E-09	1.2E-09	2.8E-09
E	3000	NP-237	1.8E-04	3.3E-11	2.4E-11	5.7E-11
E	3000	TC-99	9.2E-03	1.7E-09	1.2E-09	2.9E-09
E	4324	U-235	3.1E-04	5.5E-11	4.6E-11	1.0E-10
E	4324	U-238	1.1E-03	2.0E-10	1.7E-10	3.6E-10
E	4324	U-234	5.4E-03	9.8E-10	8.2E-10	1.8E-09
E	4324	NP-237	1.1E-04	2.0E-11	1.7E-11	3.6E-11
E	4324	TC-99	5.5E-03	9.9E-10	8.3E-10	1.8E-09
ENE	1600	U-235	1.9E-03	3.3E-10	1.8E-10	5.1E-10
ENE	1600	U-238	6.6E-03	1.2E-09	6.3E-10	1.8E-09
ENE	1600	U-234	3.3E-02	5.9E-09	3.1E-09	9.0E-09
ENE	1600	NP-237	6.6E-04	1.2E-10	6.3E-11	1.8E-10

ENE	1600	TC-99	3.3E-02	6.0E-09	3.1E-09	9.1E-09
ENE	2000	U-235	1.3E-03	2.4E-10	1.4E-10	3.8E-10
ENE	2000	U-238	4.8E-03	8.6E-10	5.0E-10	1.4E-09
ENE	2000	U-234	2.4E-02	4.2E-09	2.5E-09	6.7E-09
ENE	2000	NP-237	4.8E-04	8.6E-11	5.0E-11	1.4E-10
ENE	2000	TC-99	2.4E-02	4.3E-09	2.5E-09	6.8E-09
ENE	2570	U-235	9.1E-04	1.6E-10	1.1E-10	2.7E-10
ENE	2570	U-238	3.3E-03	5.9E-10	3.9E-10	9.7E-10
ENE	2570	U-234	1.6E-02	2.9E-09	1.9E-09	4.8E-09
ENE	2570	NP-237	3.3E-04	5.9E-11	3.9E-11	9.7E-11
ENE	2570	TC-99	1.6E-02	2.9E-09	1.9E-09	4.9E-09
ENE	3000	U-235	7.2E-04	1.3E-10	9.2E-11	2.2E-10
ENE	3000	U-238	2.6E-03	4.6E-10	3.3E-10	7.9E-10
ENE	3000	U-234	1.3E-02	2.3E-09	1.6E-09	3.9E-09
ENE	3000	NP-237	2.6E-04	4.6E-11	3.3E-11	7.9E-11
ENE	3000	TC-99	1.3E-02	2.3E-09	1.7E-09	4.0E-09
ENE	4324	U-235	4.2E-04	7.6E-11	6.4E-11	1.4E-10
ENE	4324	U-238	1.5E-03	2.7E-10	2.3E-10	5.0E-10

ESTIMATED RADIONUCLIDE CONCENTRATIONS AT VARIOUS LOCATIONS IN THE ENVIRONMENT

Wind Toward	Distance (meters)	Nuclide	Air Concentration (pCi/m3)	Dry Deposition Rate (pCi/cm2/s)	Wet Deposition Rate (pCi/cm2/s)	Ground Deposition Rate (pCi/cm2/s)
ENE	4324	U-234	7.4E-03	1.3E-09	1.1E-09	2.5E-09
ENE	4324	NP-237	1.5E-04	2.7E-11	2.3E-11	5.0E-11
ENE	4324	TC-99	7.5E-03	1.4E-09	1.1E-09	2.5E-09
NE	1600	U-235	2.0E-03	3.6E-10	2.4E-10	6.0E-10
NE	1600	U-238	7.2E-03	1.3E-09	8.5E-10	2.1E-09
NE	1600	U-234	3.6E-02	6.4E-09	4.2E-09	1.1E-08
NE	1600	NP-237	7.2E-04	1.3E-10	8.5E-11	2.1E-10
NE	1600	TC-99	3.6E-02	6.5E-09	4.3E-09	1.1E-08
NE	2000	U-235	1.4E-03	2.5E-10	1.9E-10	4.4E-10
NE	2000	U-238	5.0E-03	9.1E-10	6.8E-10	1.6E-09

NE	2000	U-234	2.5E-02	4.5E-09	3.4E-09	7.8E-09
NE	2000	NP-237	5.0E-04	9.1E-11	6.8E-11	1.6E-10
NE	2000	TC-99	2.5E-02	4.5E-09	3.4E-09	7.9E-09
NE	2570	U-235	9.4E-04	1.7E-10	1.5E-10	3.2E-10
NE	2570	U-238	3.4E-03	6.0E-10	5.3E-10	1.1E-09
NE	2570	U-234	1.7E-02	3.0E-09	2.6E-09	5.6E-09
NE	2570	NP-237	3.4E-04	6.0E-11	5.3E-11	1.1E-10
NE	2570	TC-99	1.7E-02	3.0E-09	2.6E-09	5.7E-09
NE	3000	U-235	7.3E-04	1.3E-10	1.3E-10	2.6E-10
NE	3000	U-238	2.6E-03	4.7E-10	4.5E-10	9.2E-10
NE	3000	U-234	1.3E-02	2.3E-09	2.2E-09	4.6E-09
NE	3000	NP-237	2.6E-04	4.7E-11	4.5E-11	9.2E-11
NE	3000	TC-99	1.3E-02	2.4E-09	2.3E-09	4.6E-09
NE	4324	U-235	4.2E-04	7.5E-11	8.7E-11	1.6E-10
NE	4324	U-238	1.5E-03	2.7E-10	3.1E-10	5.8E-10
NE	4324	U-234	7.4E-03	1.3E-09	1.5E-09	2.9E-09
NE	4324	NP-237	1.5E-04	2.7E-11	3.1E-11	5.8E-11
NE	4324	TC-99	7.4E-03	1.3E-09	1.6E-09	2.9E-09
NNE	1600	U-235	1.5E-03	2.7E-10	1.5E-10	4.2E-10
NNE	1600	U-238	5.4E-03	9.7E-10	5.4E-10	1.5E-09
NNE	1600	U-234	2.7E-02	4.8E-09	2.6E-09	7.5E-09
NNE	1600	NP-237	5.4E-04	9.7E-11	5.4E-11	1.5E-10
NNE	1600	TC-99	2.7E-02	4.9E-09	2.7E-09	7.5E-09
NNE	2000	U-235	1.1E-03	2.0E-10	1.2E-10	3.1E-10
NNE	2000	U-238	3.9E-03	7.0E-10	4.3E-10	1.1E-09
NNE	2000	U-234	1.9E-02	3.4E-09	2.1E-09	5.6E-09
NNE	2000	NP-237	3.9E-04	7.0E-11	4.3E-11	1.1E-10
NNE	2000	TC-99	1.9E-02	3.5E-09	2.1E-09	5.6E-09
NNE	2570	U-235	7.4E-04	1.3E-10	9.3E-11	2.3E-10
NNE	2570	U-238	2.6E-03	4.8E-10	3.3E-10	8.1E-10
NNE	2570	U-234	1.3E-02	2.4E-09	1.6E-09	4.0E-09
NNE	2570	NP-237	2.6E-04	4.8E-11	3.3E-11	8.1E-11
NNE	2570	TC-99	1.3E-02	2.4E-09	1.7E-09	4.0E-09
NNE	3000	U-235	5.8E-04	1.1E-10	7.9E-11	1.8E-10
NNE	3000	U-238	2.1E-03	3.8E-10	2.8E-10	6.6E-10
NNE	3000	U-234	1.0E-02	1.9E-09	1.4E-09	3.3E-09
NNE	3000	NP-237	2.1E-04	3.8E-11	2.8E-11	6.6E-11

ESTIMATED RADIONUCLIDE CONCENTRATIONS AT VARIOUS LOCATIONS IN THE ENVIRONMENT

Wind Toward	Distance (meters)	Nuclide	Air Concentration (pCi/m3)	Dry Deposition Rate (pCi/cm2/s)	Wet Deposition Rate (pCi/cm2/s)	Ground Deposition Rate (pCi/cm2/s)
NNE	3000	TC-99	1.0E-02	1.9E-09	1.4E-09	3.3E-09
NNE	4324	U-235	3.5E-04	6.2E-11	5.4E-11	1.2E-10
NNE	4324	U-238	1.2E-03	2.2E-10	1.9E-10	4.2E-10
NNE	4324	U-234	6.1E-03	1.1E-09	9.6E-10	2.1E-09
NNE	4324	NP-237	1.2E-04	2.2E-11	1.9E-11	4.2E-11
NNE	4324	TC-99	6.2E-03	1.1E-09	9.7E-10	2.1E-09

HARMONIC AVERAGE WIND SPEEDS (WIND TOWARDS)

	Pasquill Stability Class							
Dir	A	B	C	D	E	F	G	Wind Freq
N	0.773	2.572	2.577	2.873	0.772	0.772	0.772	0.009
NNW	0.775	0.772	2.572	0.773	0.772	0.772	0.772	0.004
NW	0.772	0.772	2.572	0.775	0.772	0.772	0.772	0.004
WNW	0.772	0.772	2.574	2.573	2.572	0.772	0.772	0.004
W	0.773	0.779	9.769	0.780	0.774	0.772	0.772	0.025
WSW	0.776	0.784	2.575	0.773	0.774	0.775	0.772	0.004
SW	0.778	0.773	2.572	0.788	0.776	0.772	0.772	0.005
SSW	2.572	0.773	2.572	0.775	2.572	2.572	0.772	0.003
S	0.772	2.579	2.576	0.775	0.772	0.772	0.772	0.005
SSE	0.772	0.774	2.586	8.134	0.772	2.572	0.772	0.043
SE	0.772	0.774	2.593	8.833	0.772	0.772	0.772	0.117
ESE	0.773	0.772	9.773	5.093	0.772	0.772	0.772	0.079
E	0.774	0.774	9.769	8.706	0.772	0.772	0.772	0.122
ENE	0.774	0.777	9.757	8.818	0.773	2.572	0.772	0.172
NE	0.774	0.792	9.774	8.405	0.781	0.772	0.772	0.260
NNE	0.773	0.774	9.768	8.740	0.775	0.772	0.772	0.143

ARITHMETIC AVERAGE WIND SPEEDS (WIND TOWARDS)

	Pasquill Stability Class						
Dir	A	B	C	D	E	F	G
N	0.774	2.572	2.581	7.913	0.774	0.772	0.772
NNW	0.782	0.774	2.572	0.775	0.773	0.772	0.772
NW	0.772	0.773	2.572	0.783	0.773	0.774	0.772
WNW	0.773	0.773	2.575	2.573	2.572	0.772	0.772
W	0.777	0.795	9.773	0.799	0.778	0.772	0.772
WSW	0.784	0.811	2.576	0.776	0.779	0.784	0.772
SW	0.794	0.778	2.572	0.826	0.787	0.774	0.772
SSW	2.572	0.776	2.572	0.782	2.572	2.572	0.772
S	0.772	2.584	2.579	0.781	0.774	0.773	0.772
SSE	0.772	0.779	2.596	9.618	0.774	2.572	0.772
SE	0.773	0.779	2.608	9.691	0.774	0.773	0.772
ESE	0.775	0.774	9.774	9.061	0.774	0.772	0.772
E	0.780	0.779	9.773	9.679	0.773	0.772	0.772
ENE	0.778	0.788	9.770	9.690	0.777	2.572	0.772
NE	0.780	0.838	9.774	9.648	0.803	0.774	0.772
NNE	0.776	0.778	9.773	9.683	0.783	0.773	0.772

FREQUENCIES OF STABILITY CLASSES (WIND TOWARDS)

	Pasquill Stability Class						
Dir	A	B	C	D	E	F	G
N	0.1454	0.0002	0.0001	0.6180	0.1272	0.0545	0.0545

NNW	0.0419	0.0833	0.0002	0.2918	0.2915	0.0832	0.2081
NW	0.2305	0.3076	0.0001	0.1160	0.1922	0.0769	0.0768
WNW	0.2398	0.2796	0.0003	0.0007	0.0004	0.3195	0.1597
W	0.0417	0.0141	0.7910	0.0282	0.0487	0.0416	0.0347
WSW	0.1737	0.1322	0.0019	0.1729	0.3463	0.0868	0.0862
SW	0.0336	0.2997	0.0006	0.0342	0.1004	0.2991	0.2323
SSW	0.0001	0.2347	0.0005	0.3533	0.0010	0.0005	0.4099
S	0.1782	0.0001	0.0004	0.3223	0.2852	0.1425	0.0712
SSE	0.0240	0.0080	0.0000	0.9279	0.0360	0.0000	0.0040
SE	0.0132	0.0044	0.0000	0.9634	0.0132	0.0029	0.0029
ESE	0.0108	0.0194	0.7369	0.1919	0.0194	0.0108	0.0108
E	0.0028	0.0099	0.1606	0.8056	0.0113	0.0056	0.0042
ENE	0.0080	0.0070	0.1134	0.8567	0.0070	0.0000	0.0080
NE	0.0060	0.0014	0.6014	0.3781	0.0013	0.0059	0.0059
NNE	0.0072	0.0084	0.1367	0.8297	0.0036	0.0096	0.0048
TOTAL	0.0141	0.0124	0.2931	0.6418	0.0158	0.0110	0.0118

ADDITIONAL WEATHER INFORMATION

Average Air Temperature: 9.8 degrees C
283.00 K
Precipitation: 100.0 cm/y
Humidity: 8.0 g/cu m
Lid Height: 1000 meters
Surface Roughness Length: 0.010 meters
Height Of Wind Measurements: 10.0 meters
Average Wind Speed: 9.054 m/s

Vertical Temperature Gradients:
STABILITY E 0.073 k/m
STABILITY F 0.109 k/m
STABILITY G 0.146 k/m

Appendix E. RASCAL3 Model Output for K-25 Releases

The Radiological Assessment System for Consequence AnaLysis (RASCAL) 3.0 is a software package developed by the U.S. Nuclear Regulatory Commission (NRC) for conducting assessments of radiological accidents (NRC 2001). RASCAL3 includes three sets of components for consequence analysis: STDose, FMDose, and DecayCalc. STDose estimates 1) source terms for radiological accidents at nuclear reactors, 2) atmospheric transport, diffusion, and deposition of effluents from accidental releases, and 3) doses from exposure to release effluents. FMDose calculates doses from environmental radiological measurements and DecayCalc calculates future activities of radionuclides due to decay and ingrowth. The STDose, however, is the only component of the model used in this public health assessment.

STDose is composed of five computational modules (STCALC, TADPLUME, TADPUFF, UF6PLUME, and METPROC). The technical basis for these components is presented in the RASCAL3 User Guide (NRC 2001). Of these components, only the UF6PLUME module is used in this PHA. UF_6 is initially a dense gas that reacts with atmospheric water to form hydrogen fluoride (HF) and uranyl fluoride (UO_2F_2). The UF6PLUME module is a version of TADPLUME that has been modified to treat the dense gas dispersion and chemical transformations associated with releases of UF_6 (NRC 2001).

The UF6PLUME module works in two stages. The first stage calculates the spread of UF_6, the conversion of UF_6 to HF and UO_2F_2, and the plume rise of HF and UO_2F_2. In the second stage, a straight-line Gaussian model is used to calculate airborne transport and deposition of the HF and UO_2F_2. The specific calculation procedures are presented in the user guide (NRC 2001).

The RASCAL3 model includes a database of UF_6 processing facilities that can be used for event analysis. The K-25 facility was shut down before the RASCAL3 model was developed, however, so it is not included in the database of UF_6 processing facilities. Though, the model does include information on the U.S. Department of Energy's Paducah Gaseous Diffusion Plant (located just outside Paducah, Kentucky)—a plant which is very similar to that of the former K-25 facility. Consequently, the September 1958 release from the K-1131 building at the K-25 site is modeled as a release from the C-331 building at the Paducah Gaseous Diffusion Plant. Due to the similar building designs and operations, this substitution is a reasonable approximation of historic conditions at K-25.[13]

Meteorological data used for evaluating a release can be input from site-specific weather conditions or for typical summer or winter weather conditions. Because historic releases from the K-25/S-50 facility could have occurred during any type of weather conditions, ATSDR used worst-case conditions that result in maximum transport and minimum dispersion of the release plume. RASCAL3 is only used to evaluate potential exposures from short-term accidental or episodic releases, thus site-specific meteorological data are not required. Results of this model will be used to evaluate worst-case conditions from the September 1, 1958 accidental UF_6 releases from the K-25 facility. The model will assume that plume dispersion was in the direction of maximum exposure at the time of the release and that worst-case meteorological conditions

[13] The assumed release height of 23 meters is the same as the CAP88-PC analyses and previous modeling presented in the Task 6 Report (ChemRisk 1999a).

were present. These worst-case conditions and other release parameters are presented below. As presented in the following case summary, the release of 1,184 kg of UF_6 (0.7% enrichment) is assumed to occur over a 1-hour time period from a 23-meter stack height. Doses are measured over a 6-hour period and meteorological conditions are constant over that period.

Case Summary

Event Type Fuel Cycle / UF_6 / Criticality

Location

Name:	K-25	
City, county, state:		Oak Ridge, Roane, TN
Elevation:	253 m	
Latitude, longitude:		35.5 N, 84.4 W
Time zone:	Eastern	

Source Term

Type:	UF_6 Cascade	
Building name:	K-1131	Cascade / Process
Amount released:		1,184 kg
Time of release:		09/01/1958 00:00
Release fraction:		1.00E+00
Release rate:	1.30E+02 lb/s	
UF_6 Enrichment:		0.7 percent

Release Pathway

Type:	UF_6 Release	
Building flow config:		Summer
Release timings		
To atmosphere start:		09/01/1958 00:00
To atmosphere stop:		09/01/1958 01:00

Meteorology

Type:	Predefined - Not site specific	
Data set name:	Summer - Night - Calm	
Data set desc:	F Stab 4 mph No Precip 55F 80% rh	

Summary of data	Temp	RH	Dir	Speed	Stability
at release point:		Type	deg	mph	class
Precip	°F	%			
00:00		Obs	270	4.0	F
None	55	80			

Calculations

Case description:	K-25 Accidental Release summer night calm
End of calculations:	09/01/1958 06:00
Distance of calculation:	Close-in only
Close-in distances:	0.5, 1.0, 1.5, 2.0, 2.57, 3.0, 4.32, 5.0 kilometers

Debug Mode Settings

Plume algorithms:	RASCAL 3
Puff algorithms:	RASCAL 3
Model time step:	5 minutes
Puff cleaning:	Off

Maximum Dose Values

Dist from release						
miles	0.311	0.621	0.932	1.243	1.597	1.864
	2.687	3.107				
(kilometers)	(0.5)	(1.)	(1.5)	(2.)	(2.57)	(3.)
	(4.32)	(5.)				
Avg HF Conc. (ppm)		6.1E+00	1.0E+01	1.5E+00	7.6E-01	4.0E-01
	2.6E-01	5.7E-02	2.9E-02			
1h Eq HF Conc. (ppm)		1.3E+00	2.7E+00	4.6E-01	2.7E-01	1.6E-01
	1.1E-01	2.7E-02	1.4E-02			
Deposited HF (g/m²)		9.3E-03	2.4E-02	4.8E-03	3.1E-03	2.0E-03
	1.5E-03	4.2E-04	2.4E-04			
U Exposure ((g-s)/m³)		2.9E+01	1.8E+01	2.1E+00	1.5E+00	1.1E+00
	8.3E-01	3.6E-01	2.4E-01			
U Inhaled (mg)	9.7E+00	5.9E+00	6.9E-01	4.9E-01	3.5E-01	2.8E-01
	1.2E-01	8.1E-02				
U Inhaled Dose (rem)		9.4E-01	5.7E-01	6.7E-02	4.8E-02	3.4E-02
	2.7E-02	1.2E-02	7.8E-03			
U Deposition (g/m²)		1.7E-02	4.4E-02	9.4E-03	6.6E-03	4.7E-03
	3.8E-03	1.6E-03	1.1E-03			

UF_6 Plume distance: 1,317.4 meters

Notes:

NRC action limit for intake of soluble uranium - 10 mg

HF limits - 30 ppm, possible death; 20 ppm, health effects

Appendix F. K-25 Meteorological Data

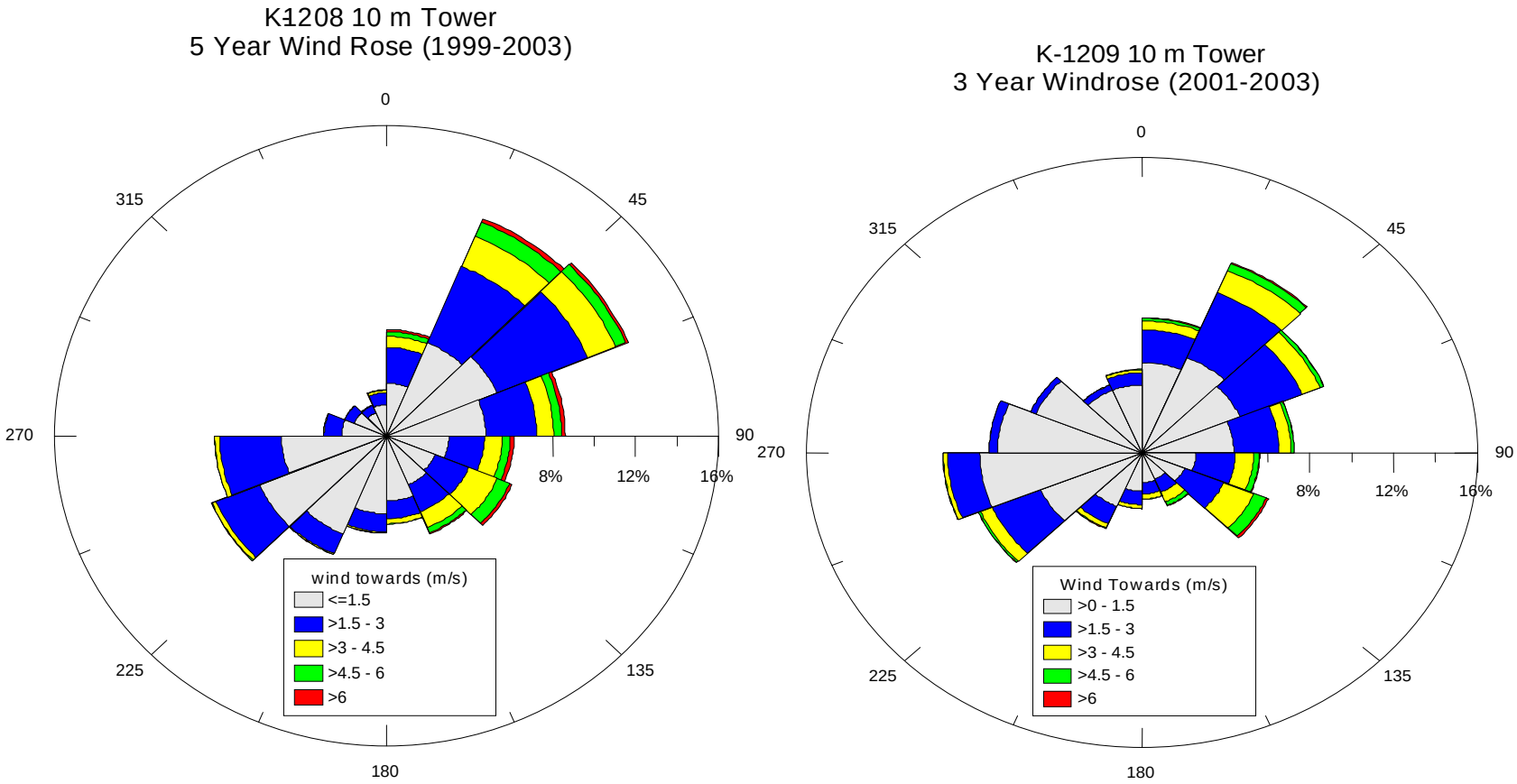
DOE operates two meteorological data towers on the K-25 site (K-1208 and K-1209) (see Figure 14). The K-1208 location includes 10-meter and 60-meter towers, which have been operational since about 1985. The K-1209 location has 10-meter and 30-meter towers that have operated since 1993. To evaluate releases from the K-25 and S-50 facilities, ATSDR obtained hourly and annual meteorological summary data sets from these on-site weather stations. ATSDR used data from the K-1208 10-meter tower in all air dispersion models because it is close to the center of the K-25/S-50 facility and very close to the buildings that are the primary release points for airborne emissions. The K-1209 tower is close to the site of the former S-50 facility.

Multi-year wind roses for each location are shown in Figures F-1 and F-2. These wind roses, based on hourly wind direction and velocity, show the percentage of time that wind of specified velocities and directions (blowing towards) occurred during these years. In general, the wind distribution for these years is very similar, with the most frequent and strongest winds blowing towards the northeast and a less frequent trend towards the southwest. This wind distribution pattern is a strong reflection of the orientation of the ridges and valleys. The overall distribution of wind directions is similar for the different towers. The distribution of wind velocities is different with the K-1209 tower, however, which shows a higher percentage of low velocity winds blowing towards the west.

Because the locations (and elevations) of the K-1208 and K-1209 towers approximately correspond with the locations of K-25 and S-50 (respectively), in the CAP88-PC model ATSDR uses meteorological data for each of these locations to evaluate contaminant dispersion and historic exposures from each source. Figure F-2 shows annual wind roses for the K-1208 tower. Overall, the variation in wind patterns between different years is minimal. ATSDR, however, will use additional CAP88-PC evaluations to determine any significant differences in dispersion and dose for different years.

ATSDR obtained 8 and 5 years of hourly data for the K-1208 and K-1209 locations, respectively. Several years of data for each location, however, are in formats unsuitable for use in the CAP88-PC model. In addition, 2002 data for the K-1208 location includes numerous missing values erroneously interpreted by the CAP88-PC model. Thus, the air dispersion results for the K-25 facility are based on the 1999, 2000, 2001, and 2003 meteorological data years from the K-1208 location. For the S-50 facility, the air dispersion results are based on the 2001, 2002, and 2003 meteorological data years from the K-1209 location.

Figure F-1. Multi-Year Wind Roses from K-1208 and K-1209 Meteorological Towers (10-Meter)



Notes:

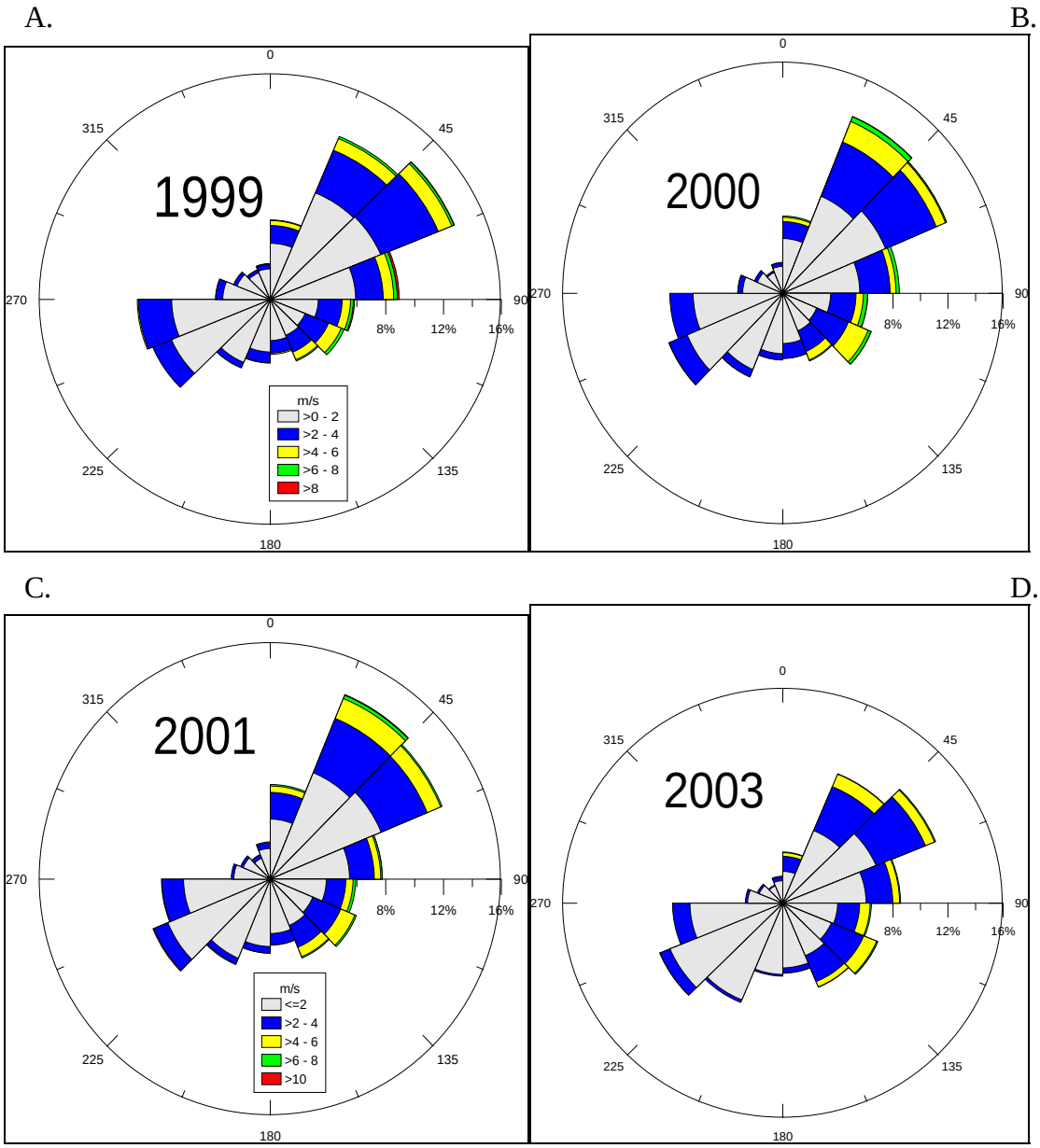
Meteorological tower locations are shown in Figure 14.

Wind directions are “towards” and speeds are in meters per second (m/s).

Although distribution of directions is similar, there is a difference in velocity distributions.

Individual annual wind roses for the towers are very similar.

Figure F-2. Wind Roses for 1999-2003 Meteorological Data



Notes:

Years based on hourly data from the K-1208 10-meter tower.

Wind speeds are in meters per second (m/s) and direction is shown as wind direction "towards."

The highest proportion of all winds, and especially the strongest winds, blows towards the northeast with a less frequent trend toward the southwest.

Although the yearly wind roses are similar, they produced slightly different estimated radionuclide concentrations and doses at the HP-35 and HP-33 locations.

Appendix G. Measured vs. Predicted Concentrations at Monitoring Locations

Measured vs. Predicted Gross Alpha Concentrations at Monitoring Locations

Figures G-1 and G-2 show the predicted vs. measured gross alpha concentrations at the HP-35 and HP-33 locations, respectively, for the 1966 to 1983 period. Each figure has three trend lines—the measured annual average gross alpha concentration at that location, the concentrations predicted using CAP88-PC with the DOE report release estimates (plus background), and the predicted concentrations using CAP88-PC with the Task 6 report release estimates (plus background). For the CAP88-PC predictions, the HP-35 location is assumed to be 2,000 meters northeast of the center of the site (point of release) and the HP-33 location is assumed to be 3,000 meters south-southeast of the center of the site. Background concentrations, taken as the annual average of the remote stations (located 12 to 70 miles from the ORR), are added to the CAP88-PC concentrations based on K-25/S-50 emissions.[14] Also, predicted gross alpha concentrations are the sum of the U-234, U-235, U-238, and Np-237 concentrations, and all of the CAP88-PC model concentrations were based on the 1999 meteorological data year.

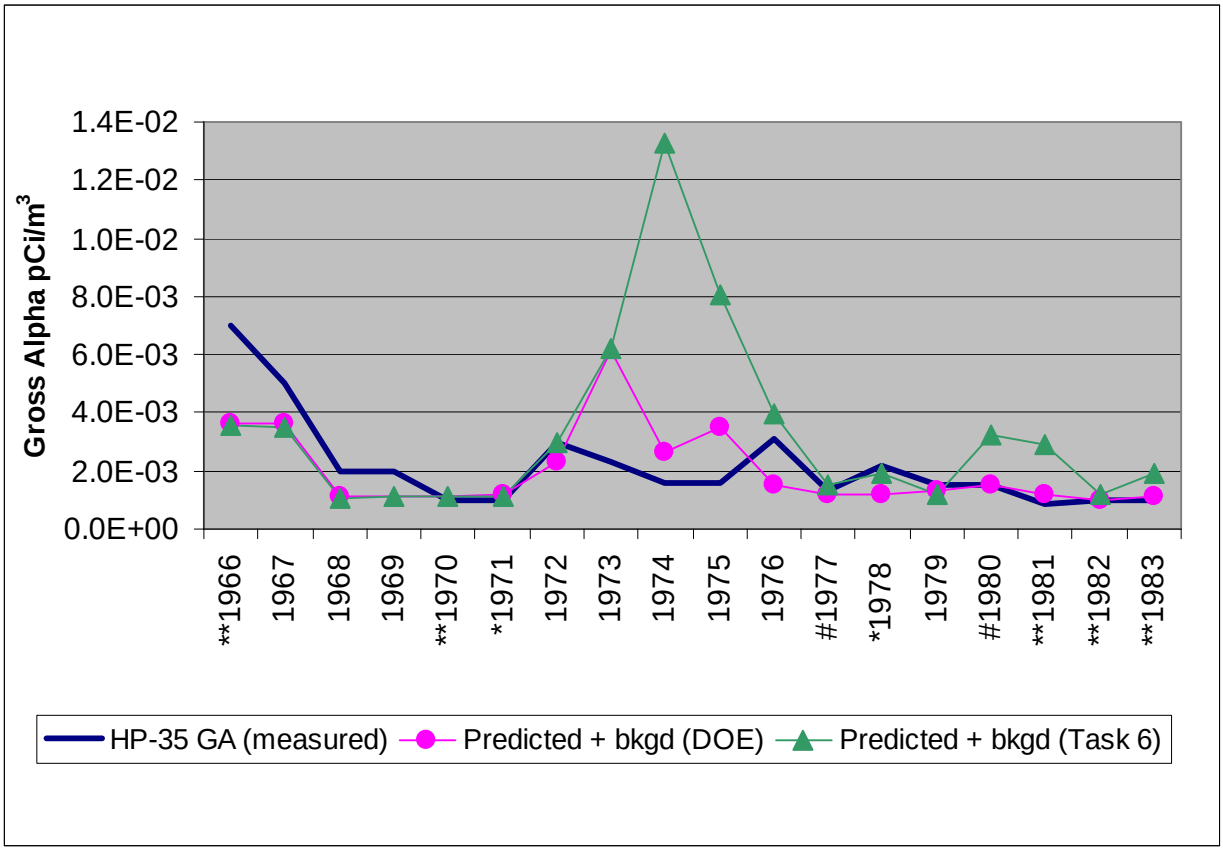
Even with the simplified assumptions noted above, these figures show substantial agreement between the historic measured gross alpha concentrations and those predicted using the CAP88-PC air dispersion model with K-25/S-50 air release estimates. For most years, the predicted concentrations are slightly higher than measured concentrations with the exception of 1966 and 1967. For those years, the measured concentrations are about 40% greater than the predicted values. There are several potential explanations for the apparent deviation between measured and predicted gross alpha concentrations for those years: a) the emissions were underestimated for those years, b) the 1999 meteorological data are not appropriate, or c) the measured concentrations may be in error. Although all of these potential explanations have some validity, it is interesting to note that background concentrations for 1966 and 1967 (from remote stations 12 to 70 miles from the ORR) were 2 to 3 times higher than subsequent years (from 1966 and 1967 monitoring reports).

Although the agreement between measured and predicted gross alpha concentrations is not perfect, the overall trends shown in Figures G-1 and G-2 indicate that CAP88-PC and the estimated emission rates adequately predict the environmental concentrations of radionuclides released from the K-25 facility. This agreement between measured and modeled gross alpha concentrations—during the period when measured gross alpha data are available—provides confidence that the modeling procedure may be used to estimate off-site doses for the earlier maximum release years (1961 and 1963).

Note that both predicted and measured gross alpha for the HP-35 location are about 1.5 to 2 times higher than for the HP-33 location. This is expected—HP-35 is in the dominant downwind direction relevant to releases from the K-25 sources. Also significant is that the concentrations

[14] The gross alpha monitoring data measure all ambient gross alpha decays. The CAP88-PC predicted data include only dispersed concentrations from K-25/S-50 sources. Consequently, measured background gross alpha concentrations from remote stations are added to the predicted concentrations to enable comparisons with monitored concentrations.

Figure G-1. Predicted vs. Measured Gross Alpha Concentrations at HP-35 Location Based on DOE and Task 6 Emission Estimates



Notes:

Bkgd equals background.

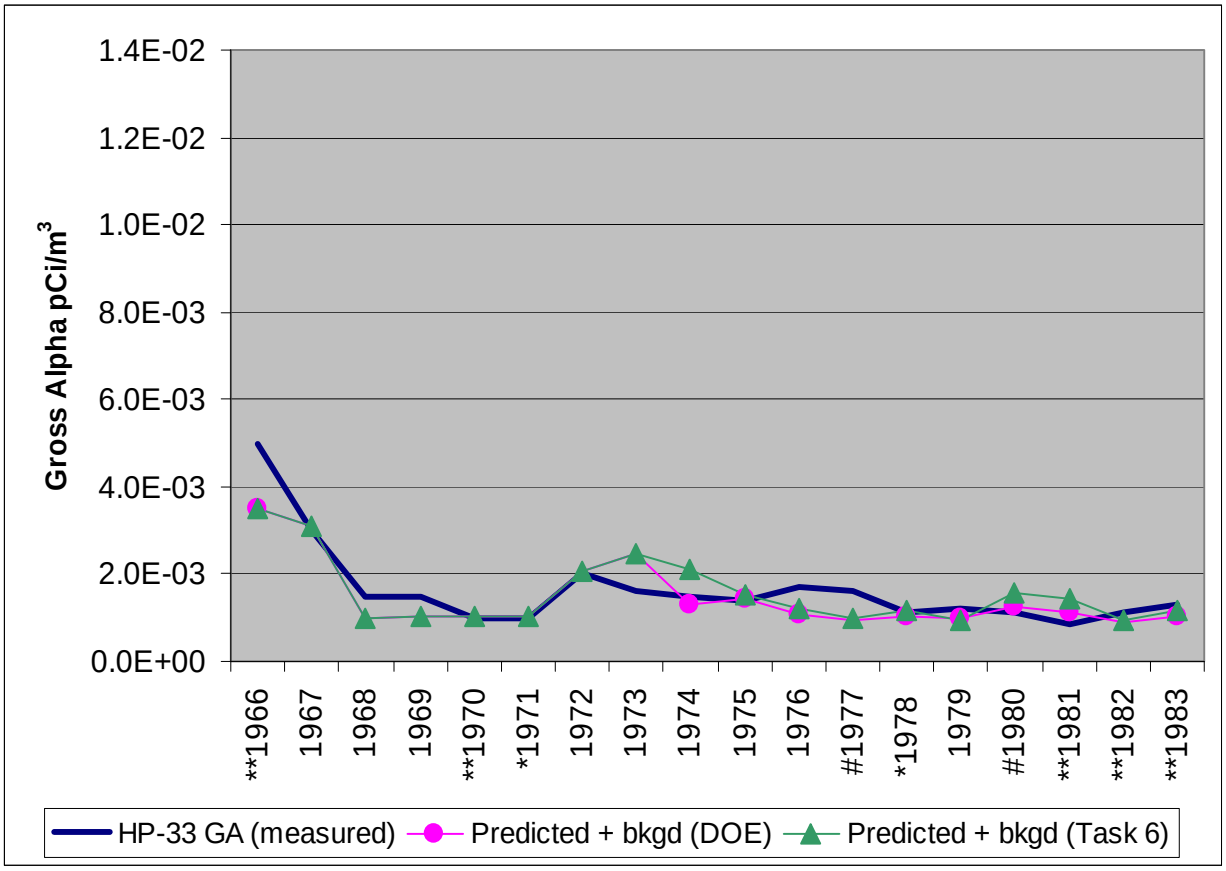
Measured annual average gross alpha concentration (pCi/m^3) from monitoring location HP-35 vs. annual average gross alpha concentrations predicted using CAP88-PC with the DOE and ChemRisk K-25/S-50 emission estimates. The HP-35 location is taken as 2,000 meters northeast of the plume origin or center of the K-25 facility.

The 1999 meteorological data set was used for all years.

Predicted gross alpha concentrations include measured background gross alpha concentrations from remote stations and are the sum of the U-234, U-235, U-238, and Np-237 concentrations.

*, **, and # symbols represent years with nearly identical emission estimates, such that independent analyses were not conducted.

Figure G-2. Predicted vs. Measured Gross Alpha Concentrations at HP-33 Location Based on DOE and Task 6 Emission Estimates



Notes:

Bkgd equals background.

Measured annual average gross alpha concentration (pCi/m^3) from monitoring location HP-33 vs. annual average gross alpha concentrations predicted using CAP88-PC with the DOE and ChemRisk K-25/S-50 emission estimates.

The HP-33 location is taken as 3,000 meters south-southeast of the plume origin or center of the K-25 facility.

The 1999 meteorological data set was used for all years.

Predicted gross alpha concentrations include measured background gross alpha concentrations from remote stations and are the sum of the U-234, U-235, U-238, and Np-237 concentrations.

*, **, and # symbols represent years with nearly identical emission estimates such that independent analyses were not conducted.

predicted for HP-35 from DOE-estimated emissions provide a somewhat better agreement with measured gross alpha concentrations than do the concentrations predicted with Task 6 report emissions.

The CAP88-PC predicted concentrations shown in Figures G-1 and G-2 all use the 1999 meteorological data (K-1209 tower; Figure 14) with different radionuclide emission estimates (Table 5). Table G-1 shows the predicted annual doses at the HP-35 and HP-33 locations using the 1963 emission estimates and meteorological data for four different years (1999, 2000, 2001, and 2003). The resulting doses from CAP88-PC (whole-body effective dose equivalent rates in millirem/year) show some expected variation, but are reasonably uniform. Subsequent dose estimates at the areas of maximum exposure (Union/Lawnville and Happy Valley) are based on the 1999 meteorological data, which produced the highest dose at the HP-35 location and the second highest dose at the HP-33 location.

Table G-1. Effect of Different Meteorological Data Years on K-25 Releases at the HP-35 and HP-33 Locations

Year	HP-35 (mrem/yr)	HP-33 (mrem/yr)
1999	37	6.7
2000	30	4.0
2001	29	7.4
2002	—	—
2003	36	2.4
	Avg. 33; Std. 4.1	Avg. 5.1; Std. 2.3

Notes:

Radionuclide emissions are based on 1963 DOE release estimates.

Doses are individual whole-body effective dose equivalent rate (mrem/year) from CAP88-PC.

The 2002 data included numerous missing values, which resulted in inaccurate input for the CAP88-PC model for that year.

Avg. equals numeric average.

Std. equals standard deviation.

Appendix H. Summary Briefs

1. TDOH's Phase I Dose Reconstruction Feasibility Study
2. TDOH's Task 7 Screening Level Evaluation of Additional Potential Materials of Concern
3. TDOH's Task 6 Uranium Releases from the Oak Ridge Reservation
4. ATSDR's Health Consultation on the Lower Watts Bar Reservoir

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

ORRHES Brief

Oak Ridge Reservation Health Effects Subcommittee

Dose Reconstruction Feasibility Study Oak Ridge Health Study Phase I Report

Site: Oak Ridge Reservation
Study area: Oak Ridge Area
Time period: 1942–1992
Conducted by: Tennessee Department of Health and the Oak Ridge Health Agreement Steering Panel

Purpose

The Dose Reconstruction Feasibility Study had two purposes: first, to identify past chemical and radionuclide releases from the Oak Ridge Reservation (ORR) that have the highest potential to impact the health of the people living near the ORR; and second, to determine whether sufficient information existed about these releases to estimate the exposure doses received by people living near the ORR.

Background

In July 1991, the Tennessee Department of Health initiated a Health Studies Agreement with the U.S. Department of Energy (DOE). This agreement provides funding for an independent state evaluation of adverse health effects that may have occurred in populations around the ORR. The Oak Ridge Health Agreement Steering Panel (ORHASP) was established to direct and oversee this state evaluation (hereafter called the Oak Ridge Health Studies) and to facilitate interaction and cooperation with the community. ORHASP was an independent panel of local citizens and nationally recognized scientists who provided direction, recommendations, and oversight for the Oak Ridge Health Studies. These health studies focused on the potential effects from off-site exposures to chemicals and radionuclides released at the reservation since 1942. The state conducted the Oak Ridge Health Studies in two phases. Phase 1 is the Dose Reconstruction Feasibility Study described in this summary.

Methods

The Dose Reconstruction Feasibility Study consisted of seven tasks. During Task 1, state investigators identified historical operations at the ORR that used and released chemicals and radionuclides. This involved interviewing both active and retired DOE staff members about past operations, as well as reviewing historical documents (such as purchase orders, laboratory records, and published operational reports). Task 1 documented past activities at each major facility, including routine operations, waste management practices, special projects, and accidents and incidents. Investigators then prioritized these activities for further study based on the likelihood that releases from these activities could have resulted in off-site exposures.

During Task 2, state investigators inventoried the available environmental sampling and research data that could be used to estimate the doses that local populations may have received from chemical and radionuclide releases from the ORR. These data, obtained from DOE and other federal and state agencies (such as the U.S. Environmental Protection Agency, Tennessee Valley

Authority, and the Tennessee Division of Radiological Health), were summarized by environmental media (such as surface water, sediment, air, drinking water, groundwater, and food items). As part of this task, investigators developed abstracts which summarize approximately 100 environmental monitoring and research projects that characterize the historical presence of contaminants in areas outside the ORR.

Based on the results of Tasks 1 and 2, investigators identified a number of historical facility processes and activities at ORR as having a high potential for releasing substantial quantities of contaminants to the off-site environment. These activities were recommended for further evaluation in Tasks 3 and 4.

Tasks 3 and 4 were designed to provide an initial, very rough evaluation of the large quantity of information and data identified in Tasks 1 and 2, and to determine the potential for the contaminant releases to impact the public's health. During Task 3, investigators sought to answer the question: How could contaminants released from the Oak Ridge Reservation have reached local populations? This involved identifying the exposure pathways that could have transported contaminants from the ORR site to residents.

Task 3 began with compiling a list of contaminants investigated during Task 1 and Task 2. These contaminants are listed in Table 1. The contaminants in the list were separated into four general groups: radionuclides, nonradioactive metals, acids/bases, and organic compounds. One of the first steps in Task 3 was to eliminate any chemicals on these lists that were judged unlikely to reach local populations in quantities that would pose a health concern. For example, acids and bases were not selected for further evaluation because these compounds rapidly dissociate in the environment and primarily cause acute health effects, such as irritation. Likewise, although chlorofluorocarbons (Freon) were used in significant quantities at each of the ORR facilities, they were judged unlikely to result in significant exposure because they also rapidly disassociate. Also, some other contaminants (see Table 2) were not selected for further evaluation because they were used in relatively small quantities or in processes that are not believed to be associated with significant releases. Investigators determined that only a portion of contaminants identified in Tasks 1 and 2 could have reached people in the Oak Ridge area and potentially impacted their health. These contaminants, listed in Table 3, were evaluated further in Tasks 3 and 4.

The next step in Task 3 was to determine, for each contaminant listed in Table 3, whether a complete exposure pathway existed. A complete exposure pathway means a plausible route by which the contaminant could have traveled from ORR to off-site populations. Only those contaminants with complete exposure pathways would have the potential to cause adverse health effects. In this feasibility study, an exposure pathway is considered complete if it has the following three elements:

- A source that released the contaminant into the environment;
- A transport medium (such as air, surface water, soil, or biota) or some combination of these media (e.g., air → pasture → livestock milk) that carried the contaminant off the site to a location where exposure could occur; and
- An exposure route (such as inhalation, ingestion, or—in the case of certain radionuclides that emit gamma or beta radiation—immersion) through which a person could come into contact with the contaminant.

In examining whether complete exposure pathways existed, investigators considered the characteristics of each contaminant and the environmental setting at the ORR. Contaminants that lacked a source, transport medium, or exposure route were eliminated from further consideration because they lacked a complete exposure pathway. Through this analysis, investigators identified a number of contaminants with complete exposure pathways.

During Task 4, investigators sought to determine qualitatively which of the contaminants with complete exposure pathways appeared to pose the greatest potential to impact off-site populations. They began by comparing the pathways for each contaminant individually. For each contaminant, they determined which pathway appeared to have the greatest potential for exposing off-site populations, and they compared the exposure potential of the contaminant's other pathways to its most significant pathway. They then divided contaminants into three categories—radionuclides, carcinogens, and noncarcinogens—and compared the contaminants within each category based on their exposure potential and on their potential to cause health effects. This analysis identified facilities, processes, contaminants, media, and exposure routes believed to have the greatest potential to impact off-site populations. The results are provided in Table 4.

The Task 4 analysis was intended to provide a preliminary framework to help focus and prioritize future quantitative studies of the potential health impacts of off-site contamination. These analyses are intended to provide an initial approach to studying an extremely complex site. However, care must be taken in attempting to make broad generalizations or draw conclusions about the potential health hazard posed by the releases from the ORR.

In Task 5, investigators described the historical locations and activities of populations most likely to have been affected by the releases identified in Task 4. During Task 6, investigators compiled a summary of the current toxicologic knowledge and hazardous properties of the key contaminants. Task 7 involved collecting, categorizing, summarizing, and indexing selected documents relevant to the feasibility study.

Study Group

A study group was not selected.

Exposures

Seven completed exposure pathways associated with air, six completed exposure pathways associated with surface water, and ten completed exposure pathways associated with soil/sediment were evaluated for radionuclides and chemical substances (metals, organic compounds, and polycyclic aromatic hydrocarbons) released at the ORR from 1942 to 1992.

Outcome Measures

No outcome measures were studied.

Conclusions

The feasibility study indicated that past releases of the following contaminants have the greatest potential to impact off-site populations.

- **Radioactive iodine**
  The largest identified releases of radioactive iodine were associated with radioactive lanthanum processing from 1944 through 1956 at the X-10 facility.

- **Radioactive cesium**
  The largest identified releases of radioactive cesium were associated with various chemical separation activities that took place from 1943 through the 1960s.

- **Mercury**
  The largest identified releases of mercury were associated with lithium separation and enrichment operations that were conducted at the Y-12 facility from 1955 through 1963.

- **Polychlorinated biphenyls**
  Concentrations of polychlorinated biphenyls (PCBs) found in fish taken from the East Fork Poplar Creek and the Clinch River have been high enough to warrant further study. These releases likely came from electrical transformers and machining operations at the K-25 and Y-12 plants.

State investigators determined that sufficient information was available to reconstruct past releases and potential off-site doses for these contaminants. The steering panel (ORHASP) recommended that dose reconstruction activities proceed for the releases of radioactive iodine, radioactive cesium, mercury, and PCBs. Specifically they recommended that the state should continue the tasks begun during the feasibility study, and should characterize the actual release history of these contaminants from the reservation; identify appropriate fate and transport models to predict historical off-site concentrations; and identify an exposure model to use in calculating doses to the exposed population.

The panel also recommended that a broader-based investigation of operations and contaminants be conducted to study the large number of ORR contaminants released that have lower potentials for off-site health effects, including the five contaminants (chromium VI; plutonium-239, -240, and -241; tritium; arsenic; and neptunium-237) that could not be qualitatively evaluated during Phase 1 due to a lack of available data. Such an investigation would help in modifying or reinforcing the recommendations for future health studies.

Additionally, the panel recommended that researchers explore opportunities to conduct epidemiologic studies investigating potential associations between exposure doses and adverse health effects in exposed populations.

TABLE 1

LIST OF CONTAMINANTS INVESTIGATED DURING TASK 1 AND TASK 2

X-10	K-25	Y-12
Radionuclides		
Americium-241 Argon-41 Barium-140 Berkelium Californium-252 Carbon-14 Cerium-144 Cesium-134,-137 Cobalt-57,-60 Curium-242,-243,-244 Einsteinium Europium-152,-154,-155 Fermium Iodine-129, -131, -133 Krypton-85 Lanthanum-140 Niobium-95 Phosphorus-32 Plutonium-238, -239, -240, -241 Protactinium-233 Ruthenium-103, -106 Selenium-75 Strontium-89, -90 Tritium Uranium-233,-234, -235, -238 Xenon-133 Zirconium-95	Neptunium-237 Plutonium-239 Technetium-99 Uranium-234, -235, -238	Neptunium-237 Plutonium-239, -239, -240, -241 Technetium-99 Thorium-232 Tritium Uranium-234, -235, -238
Nonradioactive Metals		
None initially identified	Beryllium Chromium (trivalent and hexavalent) Nickel	Arsenic Beryllium Chromium (trivalent and hexavalent) Lead Lithium Mercury
Acids/Bases		
Hydrochloric acid Hydrogen peroxide Nitric acid Sodium hydroxide Sulfuric acid	Acetic acid Chlorine trifluoride Fluorine and fluoride compounds Hydrofluoric acid Nitric acid Potassium hydroxide Sulfuric acid	Ammonium hydroxide Fluorine and various fluorides Hydrofluoric acid Nitric acid Phosgene
Organic Compounds		
None initially identified	Benzene Carbon tetrachloride Chloroform Chlorofluorocarbons (Freons) Methylene chloride Polychlorinated biphenyls 1,1,1-Trichloroethane Trichloroethylene	Carbon tetrachloride Chlorofluorocarbons (Freons) Methylene chloride Polychlorinated biphenyls Tetrachloroethylene 1,1,1-Trichloroethane Trichloroethylene

TABLE 2

CONTAMINANTS NOT WARRANTING FURTHER EVALUATION IN TASK 3 AND TASK 4

Radionuclides
Americium-241
Californium-252
Carbon-14
Cobalt-57
Cesium-134
Curium-242, -243, -244
Europium-152, -154, -155
Phosphorus-32
Selenium-75
Uranium-233
Berkelium
Einsteinium
Fermium
Nonradioactive Metals
Lithium
Organic Compounds
Benzene
Chlorofluorocarbons (Freons)
Chloroform
Acids/Bases
Acetic acid
Ammonium hydroxide
Chlorine trifluoride
Fluorine and various fluoride compounds
Hydrochloric acid
Hydrogen peroxide
Hydrofluoric acid
Nitric acid
Phosgene
Potassium hydroxide
Sulfuric acid
Sodium hydroxide

TABLE 3

CONTAMINANTS FURTHER EVALUATED IN TASK 3 AND TASK 4

Radionuclides	Nonradioactive Metals	Organic Compounds
Argon-41	Arsenic	Carbon tetrachloride
Barium-140	Beryllium	Methylene chloride
Cerium-144	Chromium (trivalent and hexavalent)	Polychlorinated biphenyls
Cesium-137	Lead	Tetrachloroethylene
Cobalt-60	Mercury	1,1,1-Trichloroethane
Iodine-129, -131, -133	Nickel	Trichloroethylene
Krypton-85		
Lanthanum-140		
Neptunium-237		
Niobium-95		
Plutonium-238, -239, -240, -241		
Protactinium-233		
Ruthenium-103, -106		
Strontium-89, 90		
Technetium-99		
Thorium-232		
Tritium		
Uranium-234 -235, -238		
Xenon-133		
Zirconium-95		

TABLE 4

HIGHEST PRIORITY CONTAMINANTS, SOURCES, TRANSPORT MEDIA, AND EXPOSURE ROUTES

Contaminant	Source	Transport Medium	Exposure Route
Iodine-131, -133	X-10 Radioactive lanthanon (RaLa) processing (1944-1956)	Air to vegetable to dairy cattle milk	Ingestion
Cesium-137	X-10 Various chemical separation processes (1944-1960s)	Surface water to fish Soil/sediment Soil/sediment to vegetables; livestock/game (beef); dairy cattle milk	Ingestion Ingestion Ingestion
Mercury	Y-12 Lithium separation and enrichment operations (1955-1963)	Air Air to vegetables; Livestock/game (beef); dairy cattle milk Surface water to fish Soil/sediment to livestock/game (beef); vegetables	Inhalation Ingestion Ingestion Ingestion
Polychlorinated biphenyls	K-25 and Y-12 Transformers and machining	Surface water to fish	Ingestion

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

ORRHES Brief

Oak Ridge Reservation Health Effects Subcommittee

Screening-Level Evaluation of Additional Potential Materials of Concern, July 1999—Task 7

Site: Oak Ridge Reservation
Study area: Oak Ridge Area
Time period: 1942–1990
Conducted by: Tennessee Department of Health and the Oak Ridge Health Agreement Steering Panel

Purpose

The purpose of this screening-level evaluation was to determine whether additional contaminants that existed at Oak Ridge Reservation (ORR), other than the five already identified in the Oak Ridge Dose Reconstruction Feasibility Study (iodine, mercury, polychlorinated biphenyls [PCBs], radionuclides, and uranium), warrant further evaluation of their potential for causing health effects in off-site populations.

Background

In July 1991, the Tennessee Department of Health in cooperation with the U.S. Department of Energy initiated a Health Studies Agreement to evaluate the potential for exposures to chemical and radiological releases from past operations at ORR. The Oak Ridge Dose Reconstruction Feasibility Study was conducted from 1992 to 1993 to identify those operations and materials that warranted detailed evaluation based on the risks posed to off-site populations. The feasibility study recommended that dose reconstructions be conducted for radioactive iodine releases from X-10 radioactive lanthanum processing (Task 1), mercury releases from Y-12 lithium enrichment (Task 2), PCBs in the environment near Oak Ridge (Task 3), and radionuclides released from White Oak Creek to the Clinch River (Task 4). In addition, the study called for a systematic search of historical records (Task 5), an evaluation of the quality of historical uranium effluent monitoring data (Task 6), and additional screening of materials that could not be evaluated during the feasibility study (Task 7).

The Oak Ridge Health Agreement Steering Panel (ORRHES) was established to direct and oversee the Oak Ridge Health Studies and to facilitate interaction and cooperation with the community. This group is composed of local citizens and nationally recognized scientists.

Methods

During the Task 7 Screening-Level Evaluation, three different methods (qualitative screening, the threshold quantity approach, and quantitative screening) were used to evaluate the importance of materials with respect to their potential for causing off-site health effects. Twenty-five materials or groups of materials were evaluated. Please see Table 1 for a summary of the methods used to evaluate each material/group of materials.

- *Qualitative screening*—All materials used on ORR were qualitatively screened for quantities used, forms used, and/or manners of use. If it was unlikely that off-site releases were sufficient to pose an off-site health hazard, then these materials were not evaluated quantitatively. If off-site exposures were likely to have occurred at harmful levels, then the materials were evaluated quantitatively.

- *Threshold quantity approach*—When information was insufficient to conduct quantitative screening, inventories of materials used at ORR were estimated based on historical records and interviews of workers. These estimated inventories of materials were

determined to be either above or below a conservatively calculated health-based threshold quantity. If the estimates for a material were below the calculated threshold quantity, then it was determined to be highly unlikely to have posed a risk to human health through off-site releases.

- *Quantitative screening*—The quantitative screening used a two-level screening approach to identify those materials that could produce health risks (i.e., doses) to exposed people that are clearly below minimum levels of health concern (Level I Screen) and above minimum levels of health concern (Refined Level I Screen). Health-based decision guides were established by the Oak Ridge Health Agreement Steering Panel and represent minimum levels of health concern.

  — The Level I Screening calculates a screening index for a maximally exposed reference individual who would have received the highest exposure. This conservative (protective) screening index is not expected to underestimate exposure to any real person in the population of interest. If the estimated Level I screening index was below the ORRHES decision guide, then the hazard to essentially all members of the population, including the maximally exposed individual, would be below the minimum level of health concern. In addition, the Level I screening index would be so low that further detailed study of exposures is not warranted because the screening index is below the threshold for consideration of more extensive health effects studies. However, if during the Level I Screening, the screening index was above the ORRHES decision guide, then the contaminant was further evaluated using Refined Level I Screening.

  — The Refined Level I Screen calculates a less conservative, more realistic screening index by using more reasonable exposure parameters than the Level I Screen. In addition, depending upon the contaminant, a less conservative environmental concentration was sometimes used. However, the transfer factors and toxicity values remained the same for both screening levels. The Refined Level I Screening maintains considerable conservatism because of these conservative transfer factors and toxicity values.

  If the Refined Level I screening index was below the ORRHES decision guide, then the hazard to most members of the population would be below minimum levels of health concern. In addition, the Refined Level I screening index would be so low that further detail study of exposure is not warranted because the screening index is below the threshold for consideration of more extensive health effects studies and was given a low priority for further study. However, if during the Refined Level I Screening, the screening index was above the ORRHES decision guide, then the contaminant was determined to be of high priority for a detail evaluation.

Study Group

The screening evaluation focuses on the potential for health effects to occur in off-site residents. The Level I Screen estimates a dose for the hypothetical maximally exposed individual who would have received the highest exposure and would have been the most at-risk. The Refined Level I Screen estimates a dose for a more typically exposed individual in the targeted population. The study group for exposure from lead were children because they are particularly sensitive to the neurological effects of lead.

Exposures

Quantitative screening used mathematical equations to calculate a screening index (theoretical estimates of risk or hazard) from multiple exposure pathways, including inhalation; ground exposure (for radionuclides); ingestion of soil or sediment; and ingestion of vegetables, meat, milk, and/or fish.

Outcome Measures

No outcome measures were studied.

Results

Screening-level analyses were performed for seven carcinogens. They were evaluated according to source, resulting in 10 separate analyses. Three of the Level I Screen analyses (Np-237 from K-25, Np-237 from Y-12, and tritium from Y-12) yielded results that were below the decision guides. Refined Level I Screens were performed on the other seven carcinogenic assessments. The results of five separate analyses (beryllium from Y-12, chromium VI from ORR, nickel from K-25, technetium-99 from K-25, and technetium-99 from Y-12) were below the decision guides, and two analyses (arsenic from K-25 and arsenic from Y-12) were above the decision guides.

Arsenic was released into the air from the burning of coal at several coal-fired steam plants located on the Oak Ridge Reservation and into the soil, sediment, and surface water from coal piles and disposal of fly ash from the steam plants. Lead was likely released into soil, sediment, and surface water from the disposal of liquid waste into the Y-12 storm sewers and may have been released into the air from process stacks and the plant ventilation system.

Screening-level analyses were performed for seven noncarcinogens. These, too, were evaluated according to source, resulting in eight separate analyses. One Level I Screen analysis (beryllium from Y-12) yielded results that were below the decision guide. Refined Level I Screens were performed on the other seven noncarcinogenic assessments. Four analyses (chromium VI from ORR, copper from K-25, lithium from Y-12, and nickel from K-25) were below the decision guides and three analyses (arsenic from K-25, arsenic from Y-12, and lead from Y-12) were above the decision guides.

Three materials (niobium, zirconium, and tetramethylammoniumborohydride [TMAB]) were evaluated using the threshold quantity approach because information was insufficient to perform quantitative screening. None of the three was determined to be present in high enough quantities at the Y-12 Plant to have posed off-site health hazards.

Conclusions

Based on the qualitative and quantitative screening, the materials were separated into three classes in terms of potential off-site health hazards: not candidates for further study, potential candidates for further study, and high priority candidates for further study. (as shown in Table 2).

- *Not candidates*—Five materials at the K-25 and 14 materials used at the Y-12 Plant were determined to not warrant further study. All of these chemicals were eliminated because either (1) quantitatively, they fell below Level I Screening decision guides; (2) not enough material was present to have posed an off-site health hazard according to the threshold quantity approach; or (3) qualitatively, the quantities used, forms used, and/or manners of usage were such that off-site releases would not have been sufficient to cause off-site health hazards.

- *Potential candidates*—Three materials at the K-25 (copper powder, nickel, and technetium-99), three materials used at the Y-12 Plant (beryllium compounds, lithium compounds, and technetium-99), and one material used at ORR (chromium VI) were determined to be potential candidates for further study. These materials were identified as potential candidates because (1) their Level I Screening indices exceeded the decision guides and (2) their Refined Level I Screening indices did not exceed the decision guides.

- *High priority candidates*—One material used at the K-25 (arsenic) and two at the Y-12 Plant (arsenic and lead) were determined to be high priority candidates for further study. They were chosen as high priority materials because their Refined Level I Screening indices exceeded the decision guides.

Two issues remaining from the Dose Reconstruction Feasibility Study were evaluated during Task 7: the possible off-site health risks associated with asbestos and the composition of plutonium formed and released to the environment.

- *Asbestos*—Asbestos could not be fully evaluated during the feasibility study; therefore, it was qualitatively evaluated during this task for the potential for off-site releases and community exposure. Available information on the use and disposal of asbestos, as well as off-site asbestos monitoring, was summarized. None of the investigations performed to date have identified any asbestos-related exposure events or activities associated with community exposure, making it very unlikely that asbestos from ORR has caused any significant off-site health risks.

- *Plutonium*—The records that documented the rate of plutonium release did not specify the isotopic composition of the product formed. As a result, during the feasibility study, the project team made the assumption that the plutonium that was formed and released was plutonium-239. If incorrect, this assumption could have significant ramifications on the screening of past airborne plutonium releases. Therefore, the composition of the plutonium formed and released was evaluated further during this task. Plutonium inventory from X-10 was calculated, and plutonium-239 was found to comprise at least 99.9% of the plutonium present in Clinton Pile fuel slugs. This result confirmed that the assumptions made in the feasibility study did not introduce significant inaccuracy into the screening evaluation that was conducted.

TABLE 1
Summary of Screening Methods Used for Each Material

Qualitative Screening		
Material	**Source**	**Notes**
Boron carbide, boron nitride, yttrium boride, titanium boride, rubidium nitrate, triplex coating, carbon fibers, glass fibers, and four-ring polyphenyl ether	ORR	Evaluated based on quantities used, forms used, and manners of usage.
Tellurium	Y-12	Evaluated based on quantities used, forms used, and manners of usage.

Threshold Quantity Approach			
Material	**Source**	**Media**	**Threshold Values**
Niobium	Y-12 Used in production of two alloys, mulberry and binary	Air Surface water	Evaluated using a reference dose derived from an LD50, an empirically derived dispersion factor for airborne releases from Y-12 to Scarboro, and estimated average East Fork Poplar Creek (EFPC) flow rates.
Tetramethylammoniumboro-hydride (TMAB)	Y-12	Air Surface water	Maximum allowable release rates were calculated to estimate threshold quantities.
Zirconium	Y-12 Used in production of an alloy, mulberry	Air Surface water	Evaluated using a reference dose derived from an ACGIH Threshold Limit Value for occupational exposure, an empirically derived dispersion factor for air released from Y-12 to Scarboro, and estimated average EFPC flow rates.

TABLE 1
Summary of Screening Methods Used for Each Material (continued)

Quantitative Screening			
Material	**Source**	**Media**	**Exposure Values**
Arsenic Level I Screen and Refined Level I Screen	K-25 Y-12 Released as a naturally occurring product in coal, which was used in coal-fired steam plants	Air	Based on coal use and dispersion modeling to Union/Lawnville (K-25) and Scarboro (Y-12).
		Surface water	Used maximum in Poplar Creek (K-25) and the 95% upper confidence limit (UCL) on the mean concentration in McCoy Branch (Y-12).
		Soil/sediment	Used sediment core concentration detected in Poplar Creek to represent the early 1960s (K-25) and the 95% UCL on the mean concentration in McCoy Branch (Y-12).
		Food items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.
Beryllium compounds Level I Screen and Refined Level I Screen	Y-12 Used in production	Air	Used Y-12 stack monitoring data and an empirical dispersion factor for releases to Scarboro.
		Surface water	Used maximum concentration measured in EFPC.
		Soil	Used maximum concentration measured in EFPC.
		Food items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.
Copper Level I Screen and Refined Level I Screen	K-25	Air	Based on airborne concentrations measured at the most-affected on-site air sampler that were adjusted according to the ratio of dispersion model results at that sampler to those at Union/Lawnville.
		Surface water	Used maximum concentration measured during the Clinch River Remedial Investigation.
		Soil/sediment	Used highest mean concentration in Clinch River.
		Food items	Based on concentrations in air, soil, and water and NCRP biotransfer factor and an ATSDR bioconcentration factor.

TABLE 1
Summary of Screening Methods Used for Each Material (continued)

Quantitative Screening (continued)			
Material	**Source**	**Media**	**Exposure Values**
Hexavalent chromium (Chromium VI) Level I Screen and Refined Level I Screen	ORR Used in cooling towers to control corrosion	Air	Based on modeling of emission and drift from K-25 cooling towers to Union/Lawnville.
		Surface water	Used maximum concentration measured in Poplar Creek before 1970.
		Soil	Used average concentration of total chromium measured during the EFPC Remedial Investigation; assumed to be 1/6 (16.7%) chromium VI.
		Food items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.
Lead EPA's Integrated Exposure Uptake Biokinetic model	Y-12 Used in production of components, in paints, and as radiation shielding	Air	Estimated from background concentrations of lead prior to mid-1970s.
		Surface water	Used maximum concentration measured in EFPC (a higher concentration was detected near Y-12; however it was considered to be anomalous).
		Soil/sediment	Used maximum concentration measured in the EFPC Remedial Investigation, the 95% UCL, and the 95% UCL multiplied by 3.5 for a higher past concentration.
		Food items	Based on concentrations in air, soil, and water and biotransfer and bio-concentration factors from literature.
Lithium Level I Screen and Refined Level I Screen	Y-12 Used in lithium isotope separation, chemical, and component fabrication	Air	Used stack sampling data from two lithium processing buildings and an empirical dispersion factor for releases to Scarboro.
		Surface water	Used highest quarterly average measured in EFPC.
		Soil/sediment	Used maximum concentration measured in the EFPC floodplain.
		Food items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.

TABLE 1
Summary of Screening Methods Used for Each Material (continued)

Quantitative Screening (continued)			
Material	**Source**	**Media**	**Exposure Values**
Neptunium-237 Level I Screen	K-25 Y-12 Found in recycled uranium	Air	Based on levels in recycled uranium, an estimated release fraction, and dispersion modeling to Union/Lawnville (K-25) and Scarboro (Y-12).
		Surface water	Based on reported releases to Clinch River (K-25) and EFPC (Y-12), corrected for dilution.
		Soil/sediment	Used maximum concentrations detected in Clinch River (K-25) and EFPC (Y-12).
		Food items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.
Nickel Level I Screen and Refined Level I Screen	K-25 Used in the production of barrier material for the gaseous diffusion process	Air	Based on the 95% UCL for the year of the highest measured concentrations in on-site air samplers and dispersion modeling to Union/Lawnville.
		Surface water	Used 95% UCL for the year of the highest concentrations in Clinch River.
		Soil/sediment	Used highest mean concentration in Clinch River.
		Food items	Based on concentrations in air, soil, and water and NCRP biotransfer and bioconcentration factors.
Technetium-99 Level I Screen and Refined Level I Screen	K-25 Y-12 Product of fission of uranium atoms and from neutron activation of stable molybdenum-98	Air	Used an average of concentrations modeled to Union/Lawnville (K-25) and Scarboro (Y-12).
		Surface water	Used maximum concentration detected in Clinch River (K-25) and EFPC (Y-12).
		Soil/sediment	Used maximum concentration from the K-25 perimeter and EFPC (Y-12).
		Food items	Based on concentrations in air, soil, and water and biotransfer and bioconcentration factors from literature.

TABLE 1
Summary of Screening Methods Used for Each Material (continued)

Quantitative Screening (continued)			
Material	**Source**	**Media**	**Exposure Values**
Tritium Level I Screen	Y-12 Used in deuterium gas production and lithium deuteride recovery operations	Surface water	Evaluated based on deuterium inventory differences and the peak tritium concentration in the deuterium that was processed at Y-12; the release estimate was used with the International Atomic Energy Agency method for tritium dose assessment, assuming all the tritium that escaped was released to EFPC.

TABLE 2
Categorization of Materials Based on Screening Results

Contaminant Source	Not Candidates for Further Study (Level I result was below the decision guide)	Potential Candidates for Further Study (Refined Level I result was below the decision guide)	High Priority Candidates for Further Study (Refined Level I result was above the decision guide)
K-25	Neptunium-237 (cancer) Evaluated qualitatively (quantities, forms, and manner of use were not sufficient): • Carbon fibers • Four-ring polyphenyl ether • Glass fibers • Triplex coating	• Copper powder (noncancer) • Nickel (cancer) • Nickel (noncancer) • Technetium-99 (cancer)	• Arsenic (cancer) • Arsenic (noncancer)
Y-12 Plant	• Beryllium compounds (noncancer) • Neptunium-237 (cancer) • Tritium (cancer) Evaluated using Threshold Quantity Approach (not enough material was present): • Niobium (noncancer) • TMAB • Zirconium (noncancer) Evaluated qualitatively (quantities, forms, and manner of use were not sufficient): • Boron carbide • Boron nitride • Rubidium nitrate • Rubidium bromide • Tellurium • Titanium boride • Yttrium boride • Zirconium	• Beryllium compounds (cancer) • Lithium compounds (noncancer) • Technetium-99 (cancer)	• Arsenic (cancer) • Arsenic (noncancer) • Lead (noncancer) Arsenic was released into the air from the burning of coal at several coal-fired steam plants located on the Oak Ridge Reservation and into the soil, sediment, and surface water from coal piles and disposal of fly ash from the steam plants. Lead was likely released into soil, sediment, and surface water from the disposal of liquid waste into the Y-12 storm sewers and may have been released into the air from process stacks and the plant ventilation system.
ORR (all complexes)		• Chromium VI (cancer) • Chromium VI (noncancer)	

ORRHES Brief
Oak Ridge Reservation Health Effects Subcommittee

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Uranium Releases from the Oak Ridge Reservation—a Review of the Quality of Historical Effluent Monitoring Data and a Screening Evaluation of Potential Off-Site Exposures, Report of the Oak Ridge Dose Reconstruction, Vol. 5 The Report of Project Task 6

Site: Oak Ridge Reservation

Conducted by: ChemRisk/ORHASP for the Tennessee Department of Health

Time Period: 1999

Location: Oak Ridge, Tennessee

Purpose

The purpose of the Task 6 study was to further evaluate the quality of historical uranium operations and effluent monitoring records, to confirm or modify previous uranium release estimates for the period from 1944 to 1995 for all three complexes on the Oak Ridge Reservation (ORR), and to determine if uranium releases from the ORR likely resulted in off-site doses that warrant further study. The main results of the study are revised uranium release estimates from the Y-12 plant, K-25 gaseous diffusion plant, and the S-50 liquid thermal diffusion plant and screening-level estimates of potential health effects to people living near the ORR. These results, which are called "screening indices," are conservative estimates of potential exposures and health impacts and are intended to be used with the decision guide established by Oak Ridge Health Agreement Steering Panel (ORHASP) to determine if further work is warranted to estimate the human health risks from past uranium releases.

Background

The 1993 Oak Ridge Health Studies, Phase I Dose Reconstruction Feasibility Study by the Tennessee Department of Health indicated that uranium was not among the list of contaminants that warranted highest priority for detailed dose reconstruction investigation of off-site health effects. After receiving comments from several long-term employees at the ORR uranium facilities, a number of ORHASP members recommended that past uranium emissions and potential resulting exposures receive closer examination. In 1994, the Task 6 uranium screening evaluation was included in the Oak Ridge Dose Reconstruction project.

The Oak Ridge Y-12 plant was built in 1945, as part of the Manhattan project. Located at the eastern end of Bear Creek Valley, the Y-12 complex is within the corporate limits of the city of Oak Ridge and is separated from the main residential areas of the city by Pine Ridge. The Y-12 plant housed many operations involving uranium, including the preparation, forming, machining, and recycling of uranium for Weapon Component Operations.

Construction of the K-25 uranium enrichment facility began in 1943, and the facility was operational by January 1945. The K-25 site is located near the western end of the ORR, along Poplar Creek near where it meets the Clinch River. The primary mission of K-25 was to enrich uranium by the gaseous diffusion process.

Located along the Clinch River near the K-25 site was a liquid thermal diffusion plant (the S-50 site) that operated from October 1944 to September 1945. Because of their close proximity, the K-25 and S-50 complexes were generally discussed together in the Task 6 report.

The X-10 facility, which conducted chemical processing of reactor fuel and other nuclear materials, was not a primary focus of the Task 6 study.

Methods

An extensive information gathering and review effort was undertaken by the project team in searching for information related to historical uranium operations at the Y-12, K-25, and S-50 sites. Thousands of documents were searched and many active and retired workers were interviewed.

The Task 6 investigation followed these basic steps:

- Information that described uranium uses and releases on the ORR was collected.
- Effluent monitoring data were evaluated for quality and consistency with previous U.S. Department of Energy (DOE) historical uranium release reports.
- Updated estimates of airborne uranium releases over time were generated using the more complete data available to the project team.
- Air dispersion models were used to estimate uranium air concentrations at selected reference locations near each ORR facility. The reference locations were:
  - — the Scarboro community (for Y-12),
  - — the Union/Lawnville community (for K-25/S-50), and
  - — Jones Island area along the Clinch River (for X-10).

  Because the terrain surrounding the Y-12 facility has complex topography, air dispersion modeling techniques were not employed. Instead, an empirical relative concentration (chi/Q) relationship was established between measured releases of uranium from Y-12 and measured airborne concentrations of uranium at Scarboro. The chi/Q relationship was then used to extrapolate airborne uranium concentrations for times in which it was not directly measured.
- The screening evaluation of potential offsite exposures to waterborne uranium was based on environmental measurements of uranium at local surface waters. The sampling sites were: White Oak Dam, downstream of New Hope Pond, and the confluence of Poplar Creek and the Clinch River.
- A screening-level evaluation of the potential for health effects was performed by calculating intakes and associated radiation doses. A two-tiered exposure assessment methodology was employed, which provided both upper bound and more typical results. Because of the scarcity of information regarding estimates of uranium concentrations in the environment over the period of interest, some conservatism was maintained in the uranium concentrations used in the Level II screening.
- Annual radiation doses from uranium intake and external exposure were calculated for the adult age group for each screening assessment and then converted to screening indices using a dose-to-risk coefficient of 7.3% Sv^{-1}.
- Estimates of annual-average intakes of uranium by inhalation and ingestion were also used to evaluate the potential for health effects due to the chemical toxicity of uranium compounds, specifically for damage to the kidneys. Uranium was assumed to be in its most soluble form and safety factors were included to minimize the potential for underestimation of the potential for toxic effects.

Study Subjects

The screening evaluation estimated potential off-site exposure and screening indices for hypothetical individuals in three reference locations (Scarboro, Union/Lawnville, and Jones Island). These reference locations represent residents who lived closest to the ORR facilities and would have received the highest exposures from past uranium releases. Thus, they are associated with the highest screening indices derived by the screening evaluation.

Exposures

The following potential air exposure pathways were evaluated:

1. Air to humans-direct inhalation of airborne particulates
2. Air to humans (immersion in contaminated air)
3. Air to livestock (via inhalation) to beef to humans
4. Air to dairy cattle (via inhalation) to milk to humans
5. Air to vegetables (deposition) to humans
6. Air to pasture (deposition) to cattle beef to humans
7. Air to pasture (deposition) to dairy cattle to milk to humans

The following potential water exposure pathways were evaluated:

1. Incidental ingestion by humans during recreation
2. Water to livestock (ingestion) to beef to humans
3. Water to dairy cattle (ingestion) to milk to humans
4. Water to fish to humans
5. Water to humans via immersion during recreation

The following potential soil exposure pathways were evaluated:

1. Soil to air (dust resuspension) to humans
2. Soil incidental ingestion
3. Soil to livestock (soil ingestion) to beef to humans
4. Soil to dairy cattle (soil ingestion) to milk to humans
5. Soil to vegetables (root uptake) to humans
6. Soil to pasture (root uptake) to livestock to beef to humans
7. Soil to pasture (root uptake) to dairy cattle to milk to humans
8. Soil to humans via external radiation

Outcome Measures

Health outcomes were not studied.

Results

Airborne uranium releases from the Y-12, K-25, and S-50 sites were found to be greater than previously reported. DOE estimated that the amount of uranium released from the Y-12 plant was 6,535 kilograms. The Task 6 team estimated that 50,000 kilograms of uranium was released to the air by the Y-12 plant. DOE estimated that the amount released from the K-25 and S-50 plants (combined) was 10,713 kilograms. The Task 6 team estimated that 16,000 kilograms were released to the air by the K-25/S-50 complex.

The Scarboro community was associated with the highest total screening index attributable to uranium releases from the Y-12 plant. The screening indices were 1.9×10^{-3} for the Level I assessment and 8.3×10^{-5} for the Level II assessment. While the overall Level I screening index for the Scarboro community is above the ORHASP decision guide of 1.0×10^{-4} (1 in 10,000), the Level II value is below that guide value. This indicates that the Y-12 uranium releases are candidates for further study, but that they are not high priority candidates for further study.

For the K-25/S-50 assessment, the total screening index for Union/Lawnville from the Level I assessment (2.7×10^{-4}) exceeded the ORHASP decision guide. The less conservative Level II screening result (4.0×10^{-5}) did not exceed the

guide. This indicates that the K-25/S-50 uranium releases are also candidates for further study, but that they are not high priority candidates for further study.

The X-10 Level I assessment yielded a screening index for Jones Island (7.6×10^{-5}) below the decision guide. This indicates that releases from the X-10 site warrant lower priority, especially given the pilot-plant nature and relatively short duration of most X-10 uranium operations.

The Scarboro community was selected for the initial chemical toxicity evaluation since its screening index for radiological exposures was the highest. Estimated kidney burdens resulting from simultaneous intake of uranium by ingestion and inhalation under the Scarboro assessment do not exceed an effects threshold criterion (1 microgram per gram of kidney tissue) proposed by some scientists, but they do exceed an effects threshold criterion (0.02 micrograms per gram of kidney tissue) proposed by other scientists. The Task 6 team also evaluated the average-annual intakes using a reference dose/Hazard Index approach and concluded that further study of chemical toxicity from past ORR uranium exposures did not warrant high priority.

Conclusions

The Task 6 team reached the following general conclusions:

- Estimates of uranium releases previously reported by DOE are incomplete and; therefore, were not used in the Task 6 screening evaluation.
- Historical uranium releases from the Y-12 plant are likely significantly higher (over seven times higher) than totals reported by DOE. There are several reasons why previous estimates were so much lower.
- Historical uranium releases from the K-25/S-50 complex are likely higher than totals reported by DOE.
- Operations at the S-50 plant are poorly documented.
- The Scarboro community had the highest total screening index from uranium releases at the ORR, specifically the Y-12 plant. Since the Level II screening index is just below the ORHASP decision criterion, with most of the conservative assumptions regarding source term and exposure parameters removed, potential exposure to uranium releases could have been of significance from a health standpoint and should; therefore, be considered for dose reconstruction.
- The Union/Lawnville community evaluation (releases from the K-25/S-50 complex) had a Level II screening index below the ORHASP criterion. However, without quantification of the uncertainties associated with the release estimates and the exposure assessment, it is not possible to say that these releases do not warrant further characterizations.
- The Level I screening index for the Jones Island area (releases from the X-10 site) are below the ORHASP decision criterion.
- Because Pine Ridge separates the Y-12 plant from Scarboro, an alternate approach (chi/Q) was used to estimate uranium air concentrations in Scarboro.
- The concentrations of uranium in soil are a major factor in the screening analyses. Because limited soil data are available for the reference locations, alternative approaches should be considered for future analyses.
- While the estimated uranium intake from ingestion and inhalation exceed one effects threshold criterion, they do no exceed another. Calculated hazard indices indicate that further study of chemical effects of the kidneys rank as a low priority.

If the evaluation of ORR uranium releases is to proceed beyond a conservative screening stage and on to a nonconservative screening with uncertainty and sensitivity analyses, activities that should be evaluated for possible follow-up work include:

- Additional records research and data evaluation regarding S-50 plant operations and potential releases.
- Additional searching for and review of effluent monitoring data for Y-12 electromagnetic enrichment operations from 1944 to 1947 and data relating to releases from unmonitored depleted uranium operations in the 1950s through the 1990s.
- Uncertainty analysis of the Y-12 uranium release estimates derived in this study.
- Review of additional data regarding unmonitored K-25 uranium releases.
- Refinement of the approach used to evaluate surface water and soil-based exposure concentrations.
- Evaluation of the effects of the ridges and valleys that dominate the local terrain surrounding Y-12 and Scarboro and investigation of alternative approaches to estimate air concentrations at Scarboro with an emphasis on identifying additional monitoring data.
- Performance of a bounding assessment of the amounts of uranium that were handled at the X-10 site.
- Improvement of the exposure assessment to include region-specific consumption habits and lifestyles, identification of likely exposure scenarios instead of hypothetical upper bound and typical assessments, and inclusion of uncertainty analysis to provide statistical bounds for the evaluation of risk.
- Refinement of the chemical toxicity evaluation, possibly to include other approaches and models, as well as an uncertainty analysis.

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

ORRHES Brief

Oak Ridge Reservation Health Effects Subcommittee

Health Consultation, U.S. DOE Oak Ridge Reservation, Lower Watts Bar Operable Unit, February 1996

Site: Oak Ridge Reservation
Study authors: Agency for Toxic Substances and Disease Registry
Time period: 1980s and 1990s
Target population: Lower Watts Bar Reservoir Area

Purpose

This health consultation was conducted to evaluate the public health implications of chemical and radiological contaminants in the Watts Bar Reservoir and the effectiveness of the Department of Energy's proposed remedial action plan for protecting public health.

Background

In March 1995, the Department of Energy (DOE) released a proposed plan for addressing contaminants in the Lower Watts Bar Reservoir. The plan presented the potential risk posed by contaminants and DOE's preferred remedial action alternative. DOE's risk assessment indicated that consumption of certain species of fish from the Lower Watts Bar Reservoir and the transfer of sediment from deeper areas of the reservoir to areas on land where crops were grown could result in unacceptable risk to human health.

The September 1995 Record of Decision for the Lower Watts Bar Reservoir presented DOE's remedial action plan for the reservoir. This remedial action included maintaining the fish consumption advisories of the Tennessee Department of Environment and Conservation (TDEC), continuing environmental monitoring, and implementing institutional controls to prevent disturbance, resuspension, removal, or disposal of contaminated sediment. The U.S. Environmental Protection Agency (EPA) and TDEC concurred with the remedial action plan.

Concerned about the sufficiency of DOE's plan, local residents asked the Agency for Toxic Substances and Disease Registry (ATSDR) to evaluate the health risk related to contaminants in the Lower Watts Bar Reservoir. These residents asked ATSDR to provide an independent opinion on whether DOE's selected remedial actions would adequately protect public health.

Methods

ATSDR agreed to provide a health consultation. A health consultation is conducted in response to a specific request for information about health risks related to a specific site, a specific chemical release, or the presence of other hazardous material. The response from ATSDR may be verbal or written.

To assess the current and recent past health hazards from the Lower Watts Bar Reservoir contamination, ATSDR evaluated environmental sampling data. ATSDR evaluated reservoir studies conducted by DOE and the Tennessee Valley Authority during the 1980s and 1990s. ATSDR also evaluated TVA's 1993 and 1994 Annual Radiological Environmental Reports for the Watts Bar nuclear plant. ATSDR first screened the voluminous environmental data to determine whether any contaminants were present at levels above health–based comparison values. ATSDR next estimated exposure doses for any contaminants exceeding comparison values. It is important to note that the fact that a contaminant exceeds comparison values does

not necessarily mean that the contaminant will cause adverse health effects. Comparison values simply help ATSDR determine which contaminants to evaluate more closely.

ATSDR estimated exposure doses, using both worst case and realistic exposure scenarios, to determine if current chemical and radiological contaminant levels could pose a health risk to area residents. The worst case scenarios assumed that the most sensitive population (young children) would be exposed to the highest concentration of each contaminant in each media by the most probable exposure routes.

Target population

Individuals living along the Watts Bar Reservoir and individuals visiting the area.

Exposures

The exposures investigated were those to metals, radionuclides, volatile organic compounds, polychlorinated biphenyls (PCBs), and pesticides in surface water, sediment, and fish.

Outcome measure

ATSDR did not review health outcome data.

Results

Reservoir Fish and Other Wildlife: Using a realistic exposure scenario for fish consumption that assumed an adult weighing 70 kilogram (kg) consumed one 8-ounce sport fish meal per week, or per month, for 30 years, ATSDR determined that PCB levels in reservoir fish were at levels of health concern. ATSDR estimated ranges of PCB exposure doses from 0.099 to 0.24 micrograms of PCBs per kilogram of human body weight every day (µg/kg/day) for the one fish meal a week scenario and 0.023 to 0.055 µg/kg/day for the one fish per month scenario.

At these exposure doses, ATSDR estimates that approximately one additional cancer case might develop in 1,000 people eating one fish meal a week for 30 years and three additional cancer cases might develop in 10,000 people eating one fish meal a month for 30 years.

At these exposure doses, ATSDR also determined that ingestion of reservoir fish by pregnant women and nursing mothers might cause adverse neurobehavioral effects in infants. Although the evidence that PCBs cause developmental defects in infants is difficult to evaluate and inconclusive, ATSDR's determination was made on the basis of the special vulnerability of developing fetuses and infants.

Using a worst case scenario that assumed adults and children consumed two 8-ounce fish meals a week, containing the maximum concentration of each radioactive contaminant, ATSDR determined that the potential level of radiological exposure, which was less than 6 millirem per year (mrem/yr), was not a public health hazard.

Reservoir Surface Water: Using a worst case exposure scenario that assumed a child would daily ingest a liter of unfiltered reservoir water containing the maximum level of contaminants, ATSDR determined that the levels of chemicals in the reservoir surface water were not a public health hazard.

Levels of radionuclides in surface water were well below the levels of the current and proposed EPA drinking water standards. In addition, the total radiation dose to children from waterborne radioactive contaminants would be less that 1 mrem/yr, which is well below background levels. The radiation dose was estimated using the conservative assumption that a 10-year-old child would drink and shower with unfiltered reservoir water and swim in the reservoir daily.

Reservoir Sediment: ATSDR determined that the maximum chemical and radioactive contaminant concentrations reported in the recent surface sediments data (mercury, Co-60, Sr–89/90, and Cs-137) would not present a public health hazard. The estimated dose from radioactive contaminants was less than 15 mrem/yr, which is below background levels.

ATSDR also evaluated the potential exposure a child might receive if the subsurface sediments were removed from the deep reservoir channels and used as surface soil in residential properties. Using a worst case exposure scenario that included ingestion, inhalation, external, and dermal contact exposure routes, ATSDR determined that the potential radiation dose to individuals living on these properties (less than 20 mrem/yr) would not pose a public health hazard.

Conclusions

ATSDR found that only PCBs in the reservoir fish were of potential public health concern. Other contaminants in the surface water, sediment, and fish were not found to be a public health hazard.

On the basis of current levels of contaminants in the water, sediment, and wildlife, ATSDR concluded the following.

- The levels of PCBs in the Lower Watts Bar Reservoir fish posed a public health concern. Frequent and long-term ingestion of fish from the reservoir posed a moderately increased risk of cancer in adults and increased the possibility of developmental effects in infants whose mothers consumed fish regularly during gestation and while nursing. Turtles in the reservoir might also contain PCBs at levels of public health concern.
- Current levels of contaminants in the reservoir surface water and sediment were not a public health hazard. The reservoir was safe for swimming, skiing, boating, and other recreational purposes. It is safe to drink water from the municipal water systems, which draw surface water from tributary embayments in the Lower Watts Bar Reservoir and the Tennessee River upstream from the Clinch River and Lower Watts Bar Reservoir.
- DOE's selected remedial action was protective of public health.

ATSDR made the following recommendations.

- The Lower Watts Bar Reservoir fish advisory should remain in effect to minimize exposure to PCBs.
- ATSDR should work with the state of Tennessee to implement a community health education program on the Lower Watts Bar fish advisory and the health effects of PCB exposure.
- The health risk from consumption of turtles in the Lower Watts Bar Reservoir should be evaluated. The evaluation should investigate turtle consumption patterns and PCB levels in edible portions of turtles.
- Surface and subsurface sediments should not be disturbed, removed, or disposed of without careful review by the interagency working group.
- Sampling of municipal drinking water at regular intervals should be continued. In addition, at any time a significant release of contaminants from the Oak Ridge Reservation is discharged into the Clinch River, DOE should notify municipal water systems and monitor surface water intakes.

Appendix I. Toxicological Data

Ionizing Radiation

As previously noted, radiation exposure divides into two broad classes: internal radiation and external radiation. Internal exposures result from radioactive sources taken into the body through the inhalation of radioactive particles or the ingestion of contaminated food. External exposure results from radiation sources originating outside the body, such as radiation emitted from contaminated sediment. These external sources can sometimes penetrate the human skin. Whether an exposure contributed to a person's internal or external exposure depends primarily on the type of radiation—that is, alpha and beta particles or gamma rays—to which that person was exposed.

Beta particles can penetrate human skin and tissues and deliver a dose both internally and externally. *Gamma rays* can travel long distances and easily penetrate body tissues, and are therefore the primary type of radiation that results in external radiation exposures. *Alpha particles* cannot penetrate skin, so they pose a minimal external exposure concern. Alpha particles can inflict biological damage if the body takes them in, for example by breathing or swallowing radioactive material in air or food.
Source: ATSDR 1999b

The following information is from ATSDR's *Toxicological Profile for Ionizing Radiation* (ATSDR 1999b). Radioactive material can be released to the air as particles or gases as a result of natural forces and from human industrial, medical, and scientific activities. Everyone, with no exception, is exposed to ionizing radiation. You are exposed to low levels of ionizing radiation from the sun, rocks, soil, natural sources in your body, fallout from past nuclear weapons tests, some consumer products, and radioactive materials released from hospitals and from nuclear and coal power plants. You are exposed to more if you work as a pilot, flight attendant, astronaut, industrial and nuclear power plant worker, or an x-ray or medical technician. You receive additional exposure with each x-ray exam and nuclear medicine test, and the amount depends on the type and number of tests.

How radiation affects your health depends on how much ionizing radiation you received and over what period of time, and personal factors such as sex, age at the time of exposure, and your health and nutritional status. Increasing the dose results in a more severe effect. Studies so far have not shown that the low dose of ionizing radiation we are exposed to every day causes us any harm. We do know that exposure to massive amounts of ionizing radiation can cause great harm, so it is wise to avoid exposure to any more ionizing radiation than necessary.

Exposure to high doses of ionizing radiation can result in skin burns, hair loss, nausea, birth defects, illness, and death. Increased psychological stress has been shown in large populations exposed to small doses of radiation from nuclear accidents. Mental function has been affected in people exposed before birth to high doses of ionizing radiation. Ionizing radiation is called a carcinogen because it may also increase your chance of getting cancer. Increasing the size of the dose increases your chance of getting cancer. Scientists base radiation safety standards on the assumption that any radiation dose, no matter how small, carries with it a corresponding probability of causing a cancer. This is called a "zero threshold" dose-response relationship. Cancers that are actually caused by radiation are indistinguishable from those from other causes, so we can never be certain whether any individual cancer was not caused by radiation.

We have seen health effects from very high doses of ionizing radiation, but not at normal everyday levels. As a precaution, scientists and regulating agencies assume some harmful effects at any dose, no matter how small. Because ionizing radiation has the potential to cause harmful health effects in overexposed people, regulations and guidelines have been established for ionizing radiation by state, national, and international agencies. The current federal and state regulation limit for the general public is 0.001 Sievert (Sv)/year (0.1 rem/year or 100 mrem/year). To give the public an extra margin of safety, the public dose limit is set at least 10 times lower than the occupational limit.

Uranium

Uranium is a radioactive metal that is naturally present in rocks, soil, groundwater, surface water, air, plants, and animals in small amounts. It contributes to a natural level of radiation in our environment, called background radiation. The amount of uranium in drinking water in the United States is generally less than 1 picoCurie per liter (pCi/L) or approximately 1.5 microgram per liter (µg/L) (ATSDR 1999a).

Natural uranium, enriched uranium, and depleted uranium are mixtures of primarily three uranium isotopes (U-238, U-235, and U-234) that are chemically similar but contain a different number of neutrons. By weight, natural uranium is more than 99% U-238, 0.72% U-235, and 0.005% U-234. Enriched uranium is more than 0.72% U-235 by weight, and depleted uranium is less than 0.72% U-235 by weight. All three isotopes are radioactive but have different specific activities (that is, radioactivity per gram of material). U-238 has the lowest specific activity, and U-234 has the highest.

Uranium can harm people in two ways: as a chemical toxin and as a radioactive substance. (That is, uranium's chemical and radioactive properties can both be harmful so they are considered separately.) Because natural uranium produces very little radioactivity, the chemical effects of uranium are generally more harmful than the radioactive effects. Due to the combined effects of chemical and radioactive properties, however, radioactive mixtures such as enriched uranium can harm the kidney or skeletal system more than natural uranium.

The kidney is the primary target organ for the chemical effects of ingested and inhaled uranium. The extent of toxicity is determined primarily by exposure route, type of uranium compound, and solubility of that compound. Ingested uranium compounds are generally less toxic to the kidneys than are inhaled uranium compounds, partly because uranium is poorly absorbed from the intestinal tract. Highly soluble uranium compounds are generally more toxic to the kidneys than are less-soluble compounds via ingestion; the more soluble compounds are more readily absorbed, thus they pose a greater potential dose to the kidney. Absorption of uranium is low by all (inhalation, ingestion, and dermal) exposure routes—less than 5%.

Studies using laboratory animals provide most of the evidence for kidney toxicity. ATSDR has established intermediate (15 to 364 days) exposure health guidelines for inhalation of both soluble and insoluble uranium compounds. The guideline for insoluble uranium is 8 $\mu g/m^3$. This guideline is based on structural changes (lesions) in kidneys of dogs exposed to uranium dioxide dust for a 5-week period, with exposure occurring over 6 days a week for 6 hours a day (Rothstein 1949). The health guideline for inhalation of soluble uranium of 0.4 $\mu g/m^3$ is based on

kidney lesions in dogs exposed to uranium chloride in air over a 1-year period, with exposure occurring over 6 days a weeks for 6 hours a day (Stokinger et al. 1953). Neither study provided information about the size of the uranium particles used, so ATSDR based its guideline on the conservative assumption that uranium particles were 2 microns or less in diameter.

Fluoride (Fluorine) and Hydrogen Fluoride

The following review is primarily from ATSDR's *Toxicological Profile for Fluorides, Hydrogen Fluoride, and Fluorine* (ATSDR 2003). Fluorides in air may be present in the gas phase (generally as HF) or in a particulate phase. Fluoride ions form stable colorless complexes with certain multivalent ions, such as $(AlF_6)^{3-}$, $(FeF_6)^{3-}$, and $(ZrF_6)^{3-}$. HF is a colorless fuming gas or liquid that is made up of a hydrogen ion and a fluoride ion. HF is used as a catalyst, as a fluorinating agent, in making fluorine and aluminum fluoride, as an additive in rocket fuel, and for the refining of uranium.

HF is an irritant that is soluble in water. It dissolves easily in any water in the air or other media, including the skin, upper respiratory tract, eyes, plants, and soil. When HF is dissolved in water, it is called hydrofluoric acid. Hydrofluoric acid is dangerous to humans because it can burn the skin and eyes. At first, exposure to hydrofluoric acid may not look like a chemical burn. Skin may only appear red and may not be painful at first. Damage to the skin can occur over several hours or days, and deep painful wounds can develop. When not treated properly, serious skin damage and tissue loss can occur. In the worst cases, people who get a large amount of hydrofluoric acid on their skin can die when the fluoride affects the lungs, the heart, or both.

Breathing in a large amount of HF can harm the lungs and heart and cause death. The human health effects for breathing moderate amounts of HF for several months are not well known, but rats that breathed HF for several months suffered kidney damage and nervous system changes, such as learning problems. If you breathe HF or fluoride-containing dust for several years, changes in your bones (called skeletal fluorosis) can occur.

HF is highly corrosive and produces adverse effects at the point of contact, which is usually the respiratory tract (nose, throat, trachea, and bronchi), eyes, and skin. Because HF is absorbed into the bloodstream, it can affect other organs in the body, such as the lungs, liver, kidney, and heart.

Short-term exposure to HF in air at concentrations as high as 20 ppm can be tolerated for 1 minute, although concentrations of 120 ppm irritate the nose, throat, eyes, and skin in humans (NLM 2000). Vapors can cause ulcers of the respiratory tract at concentrations of 50 to 250 ppm—these concentrations can be dangerous, even for brief exposures. Inhalation of HF at higher concentrations can cause severe throat irritation, cough, lung injury, and pulmonary edema (swelling) resulting in death.

The National Institute of Occupational Safety and Health (NIOSH) recommends that exposure to HF by workers not exceed 3 ppm (or 2.5 mg/m^3), with a 15-minute ceiling of 6 ppm (or 5 mg/m^3). The recommendations, based on studies of workers and laboratory animals, are intended to protect workers from effects on the respiratory tract, eyes, skin, and bones. One study of rabbits and guinea pigs exposed to HF, at concentrations of 24 to 8,000 ppm for 5 to 41 minutes, reported eye and respiratory tract irritation at all exposure concentrations. A significant number of animals died within 5 minutes when they inhaled air containing 1,800 ppm (or 1,500 mg/m^3)

of hydrogen fluoride. Weakness and appearance of illness were apparent in all animals at concentrations above 600 ppm (or 500 mg/m^3) for 15 minutes or longer. Rabbits that survived returned to normal within a few weeks, but guinea pigs showed a definite tendency to delayed response and death between the fifth and tenth week following exposure (NIOSH 1997).

HF readily penetrates the skin and can cause deep tissue destruction and burns following dermal exposure. Exposure to the eye can result in irritation to severe ocular damage and visual effects (ATSDR 2003). The National Research Council (2006) evaluated a potential association between cancer and fluoride exposure via inhalation, ingestion, and other routes, and determined that the "results are mixed, with some studies reporting a positive association and others no association." Specifically, based on data from studies on humans, genotoxicity assays, and in vitro bone cells, the evidence that fluoride could attribute to cancer is "tentative and mixed." In other words, the scientific literature "does not clearly indicate that fluoride either is or is not carcinogenic to humans" (National Research Council, 2006).

Uranyl Fluoride

Uranyl fluoride is water-soluble. Its toxicity is determined primarily by route of exposure; exposure concentration, duration, and frequency; and particle size. Ingestion generally produces less toxicity than inhaled uranium because uranium is poorly absorbed from the gastrointestinal tract following ingestion. Targets for inhaled uranium are respiratory and kidney toxicity.

Appendix J. Responses to Public Comments

ATSDR received the following comments from the public during the public comment period (December 23, 2008, through February 20, 2009) for the *K-25 and S-50 Uranium Releases: Oak Ridge Reservation (USDOE)* public health assessment. For comments that questioned the validity of statements made in the document, ATSDR verified or corrected the statements.

Comment #	Public Comment	ATSDR's Response
General comments		
1	This is one of 8 public health assessments of the Oak Ridge Reservation. ATSDR evaluated the potential past chronic and acute exposures for nearby offsite residents to ionizing radiation, uranium, hydrogen fluoride, and fluoride released from the K-25/S-50 site. Document is well written in laymen's terms and goes into detail about the process used in its evaluation.	Thank you for your comment.
2	A fact sheet was not provided with this Public Health Assessment for review.	According to need and available funding, ATSDR determined that a fact sheet was not needed to accompany this public health assessment. The agency will take this suggestion under advisement, however.
Currency of information		
3	Even though this has a 2008 date, many of the references are from 2000 or older.	ATSDR has reviewed some more recent documents, and updated the reference list accordingly.
4	Page 15, line 19: The reference provided is from 1998, currently eleven years old and potentially very outdated. Some buildings probably have been demolished in that intervening timeframe. This should either be updated or reworded to reflect that the information is as of 1998.	ATSDR revised the text to reflect that the information was from a 1998 report. ATSDR also revised the PHA to include information from recent DOE updates on site activity, including the current status (as of the end of 2008) of buildings on the K-25 site.
5	Page 19, line 20: remove the word "presently" and replace with a date. The reference used for this paragraph states 2002.	ATSDR revised the text to reflect that the information provided was from a 2002 report. Additional remedial activities were included based on the most current site documents.
6	Page 23, graphic- why does it stop at year 2000?	The graphic ends at 2000, when the timeline was developed. The dates represented in the timeline (i.e., 1942 to 2000) have been added to the title of the figure and into the text narrative.
7	Page 44, line 2: How can one state a "2003 as of" date using a year 2000 reference?	ATSDR reviewed the referenced source of information and revised the text to remove "as of 2003" and clarify the findings of the residential well survey conducted in 1996 and 1997.

Comment #	Public Comment	ATSDR's Response
8	Page 46, line 29 &30: DOE ES&H has been re-organized in to HSS (Health, Safety and Security). Current (2009) DOE points of contact should be identified.	ATSDR has revised the text to reflect the change in name. To keep the document timeless, however, DOE points of contact were not included.
9	Page 51, line 20: incorrectly states that 2003 is "current". Suggest deleting "current" and stating, "... environmental data (1990 to 2003)..."	ATSDR agrees and has modified the document accordingly.
10	Page 81, line 4: references 2006 timeframe but most data is still presented as 2000.	ATSDR removed the time period (i.e., "1946–2006") referenced in the heading. The specific time periods for data collected and for dose estimates are provided in the text.
Further explanation		
11	Past Exposure (1944 to 1995): Footnote 1: Although ATSDR was unable to locate environmental sampling data that pertained to fluoride and hydrogen fluoride releases, maintenance and "upset" records do exist for the K-25 building and have been used to assist in understanding the process knowledge associated with the K-25 Building operations in preparation for demolition. It is suggested that ATSDR access and review these maintenance records, if the agency has not already done so, to determine the relevance of these documents to this Public Health Assessment.	ATSDR used DOE and ChemRisk emission estimates from the Task 6 report and historical DOE environmental monitoring data to estimate fluoride concentrations at locations around K-25 by using correlations with annual airborne uranium releases. According to the *Independent Investigation of the East Tennessee Technology Park, Volume 1: Past Environment, Safety, and Health Practices* by the DOE Office of Oversight, Environment, Safety, and Health (2000), the "record reviews and interviews with former workers indicate that many releases were probably not formally documented" and that the ChemRisk Task 6 report represents "the most recent and most complete" study of historical uranium releases from the K-25/S-50 facility. As suggested, ATSDR conducted additional reviews to identify supplemental information that could help with our evaluation of fluoride exposures. Specifically, we reviewed the TDOH Oak Ridge Health Studies Project Database, which provides a list of all supporting documentation for the Oak Ridge Dose Reconstruction reports. A keyword search using the terms "maintenance" and "upset" was conducted to identify documents included in the Project Database, and the relevant sources were reviewed. No additional supporting documentation was identified from these reviews that would change the overall conclusions of the PHA.
12	Sources and Emission Estimates; Page 8, Line 15: The text states that DOE has not compiled any estimates of annual airborne releases of fluoride except for UF6. The text should include an explanation of the requirements for conducting these airborne releases so that the public can be assured that there were no regulatory omissions or deficiencies in the conduct of this monitoring activity. This will put the historic data and the ATSDR modeling in perspective for the reader.	In order to clarify the sentence, ATSDR modified the text to read "Except as included in UF_6 releases, DOE has not compiled any estimates of annual airborne fluoride releases because there were no regulatory requirements for monitoring annual airborne releases of fluoride."

Comment #	Public Comment	ATSDR's Response
13	Current and Future Exposure; Page 11, Line 20: This section discusses current and future exposure hazards using the ATSDR evaluation protocol and references ongoing remedial activities being conducted at the K-25 Site. It is suggested that the text describe the difference in the ATSDR calculation of the likelihood of adverse public health effect outcomes related to exposure compared to the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) risk characterization, exposure assessment and uncertainties related to cleanup of contaminated areas. The public would be better served and not be unintentionally misled to assume the approaches to evaluate risk to exposure are similar. This is also important as the requirements of the Federal Facility Agreement parties to assure hazardous wastes associated with former and current ORR activities are adequately studied as referenced at II.C, Remedial and Regulatory History on page 21 of this document.	ATSDR provides a detailed explanation of the difference between a risk assessment and a PHA in ATSDR's "A Citizens Guide to Risk Assessments and Public Health Assessments at Contaminated Sites." The link to this guide is: http://www.atsdr.cdc.gov/publications/CitizensGuidetoRiskAssessments.html. This link was added to the referenced section of the PHA for readers who are interested in obtaining additional information. In brief, this guide provides an overview of two different assessments commonly performed at hazardous waste sites. Both types of evaluations (i.e., risk assessment and the public health assessment) are required for all sites listed on the U.S. Environmental Protection Agency's (EPA's) National Priorities List (NPL). Risk assessments, prepared by EPA and other agencies are generally used to determine if levels of toxic substances at hazardous waste sites pose an unacceptable risk as defined by regulatory standards and requirements. The risk assessment helps regulatory officials determine hazardous site cleanup strategies that will ensure overall protection of human health and the environment. A risk assessment, however, does not attempt to measure the actual health effects that hazardous substances at a site have on people. Risk assessments often are conducted without considering actual or possible exposure. ATSDR's public health assessments, on the other hand, define likely exposure pathways, identify potentially exposed populations, and recommend actions to protect public health.
14	Figure 6, Map of the Major Remedial Activities at the K-25 Site; Page 25: Even though the Public Health Assessment does not "address potential releases and exposures to surface water or groundwater, the legend on page 25 indicates that Mitchell Branch is a completed "CERCLA Action Location." This CERCLA action did not achieve its remedial goal objective(s) and was terminated at the request of the Department of Energy. Terminating the removal action was approved by EPA with the understanding that a future decision would be made regarding the contamination. Further evaluation and subsequent remedial action at Mitchell Branch will be included in the Final Site-wide Record of Decision for the East Tennessee Technology Park (formerly the K-25 site). The text in this section should identify this critical piece of information pertaining to the completed CERCLA action as noted in the legend.	ATSDR modified Figure 6 by adding a footnote that explains the current status of Mitchell Branch, which was incorrectly characterized as a "Completed CERCLA Action Location." Additionally, updated information concerning the current status of the site was added to Appendix C, page C-4.
15	Section II.F.4, Aerial Radiological Surveys and ORR Off-Site Background; Page 4, Line 17: This section provides the areas of radiological interest identified by the 1997 aerial surveys and gives the number as 11. At this level,	ATSDR has provided additional descriptive information pertaining to the 11 areas of interest (AOI) identified.

Comment #	Public Comment	ATSDR's Response
	there is difficulty identifying these areas with distinction. Where possible, please identify the areas by text description and compare to information obtained as a result of the CERCLA investigations conducted pursuant to the ROD for the East Tennessee Technology Park.	
Release assumptions		
16	There is likely an inaccuracy in the releases assumptions. The evidence for the "midnight negative" releases described in the text is questionable. When this was shown to Bill Wilcox, former Technical Director at Oak Ridge Gaseous Diffusion Plant (and for 12 years at Y-12) for the years 1949 through 1985 (overseeing quality of product, health physics, laboratory operations, etc.) he said that there was no need to hide any releases from opening equipment, and he had never heard of any such "midnight negative" releases. Process gas equipment was taken off line and purged through the cold traps a few times with nitrogen prior to being opened for barrier removal or other maintenance. Such routine maintenance would have released no more than a gram of UF6, and this into the facility, not to the outside environment. At the time there was great concern for worker safety due to the acute danger of working with this compound.	ATSDR provided additional information to clarify the estimated maximum magnitude of UF_6 releases by the jetting or venting of process gas during routine maintenance processes. ATSDR acknowledges in the public health assessment that there are data gaps with respect to intentional and unintentional releases at the K-25 facility as well as limited information concerning the routine maintenance processes that would have involved releases referred to as "jetting" or "venting" that was required for equipment maintenance. Therefore, the statement that "there is likely an inaccuracy in the release assumptions" is not correct. The "jetting" releases were described in the DOE's (2000) *Independent Investigation of the Paducah Gaseous Diffusion Plant* as "midnight negative" releases. The maximum estimated ORR UF_6 release of 907 kilograms (kg) (1,995 lbs) is a conservative estimate. It is based on 1) the maximum amount of UF_6 in a cascade cell assuming a 10 percent reduction in pressure by purging and evacuation and 2) similar venting/jetting processes occurring at the Paducah Gaseous Diffusion Plant and at the ORR K-25 Gaseous Diffusion Plant. As stated in the public health assessment, the 907 kg UF_6 maximum release estimate is not likely, but it is the largest possible. The typical releases were probably on the order of 10 ppm or less of uranium hexafluoride. The public health assessment also uses another conservative assumption—that the released material was dispersed to the ambient air—because ATSDR cannot verify recovery for all accidental releases. However, the public health assessment noted that for many of the documented release events, the available reports state the majority of the UF_6 was retained within the building and recovered. Regarding the venting and jetting releases during the cascade maintenance at K-25, the Task 6 report by ChemRisk (page 2-35) states "The project team identified that many of these releases did occur, but could not find information that describes the quantities of uranium released." In the DOE's (2000) *Independent Investigation of the East Tennessee Technology Park,* investigators looked at numerous activities associated with the K-25 facility. In that report, the investigators indicated there were over 600 releases of UF_6 with 17 releases exceeding 100 pounds and

Comment #	Public Comment	ATSDR's Response
		over 100 releases of 10 pounds or more. They, however, were not able to determine what percentages of these releases escaped the buildings. In addition to these releases, hydrogen fluoride and fluorine gases were released from the S-50 facility, and other buildings that converted uranium oxides and other uranium compounds to UF_6. With respect to "negatives," the report noted that if the maintenance procedures were followed, less than a pound of uranium hexafluoride would be released from the cascade component undergoing maintenance. The report also noted that under certain conditions (e.g., during Cascade Improvement or Cascade Updating Programs), significant quantities of UF_6 could have been available for release to the environment. For example, in interviews with former workers, the investigators heard of many visible releases as the UF_6 would rapidly be hydrolyzed to a white powder and along with it, hydrogen fluoride (DOE 2000).
Fluoride		
17	In its responses to various public comments, the 2008 ATSDR report states that fluorine and fluoride compounds "are primarily associated with acute (short-term) health effects, whereas the state was interested in evaluating chronic exposures" (p. 138, response to comment 29) and "are primarily associated with acute exposures—they are not generally related to chronic, long-term health effects which the state was investigating" (p. 139, response to comment 30). These statements are not correct. In fact, the report from the Feasibility Study did not give a specific reason for the exclusion of fluorine or various fluoride compounds from any quantitative assessment. "Fluorine and fluoride compounds," "Hydrofluoric acid," Fluorine and various fluorides," and "Chlorine trifluoride" were categorized as "acids/bases" for which collectively it was stated that the primary health effect is irritation, commonly associated with acute exposure (ChemRisk 1993b). However, at least for fluorine and fluoride chemicals, this statement is not correct. While acute exposures to fluorine and fluoride are certainly a potential danger and deserve proper evaluation, fluorine and fluoride compounds are also associated with chronic, long-term effects from either inhalation or ingestion exposures. This was well known at the time of the K- 25 and Y-12 releases (1944-1995) and certainly by the time of Phase I of the Oak Ridge Dose Reconstruction (the Feasibility Study, 1992-1993). See for example a 1937 monograph on fluoride toxicity (Roholm 1937), the cold-war era literature on fluoride toxicity (e.g., Hodge and Smith 1965; various AEC studies), and an	The TDOH's Oak Ridge Health Studies Dose Reconstruction Feasibility Study did not provide a specific reason for the exclusion of fluorine or fluoride compounds from a quantitative assessment. However, based on a January 12, 2000, email sent from the ChemRisk Project Manager for the Oak Ridge Dose Reconstruction to members of the Oak Ridge Health Agreement Steering Panel (ORHASP), the following statement from community concern comment #29 is accurate. "Fluoride and fluorine products were not evaluated previously by the state in its 1993 Phase I of the Oak Ridge Health Study—Dose Reconstruction Feasibility Study because these substances are primarily associated with acute (short-term) health effects, whereas the state was interested in evaluating chronic exposures." To be more consistent with what was recorded in the original email from the ChemRisk Project Manager for the Oak Ridge Dose Reconstruction to members of the ORHASP concerning the evaluation of fluorine/fluorides (see text from original email below), ATSDR has modified slightly the information presented in our response to community concern comment #29 in the PHA. The January 12, 2000, e-mail from the ChemRisk Project Manager for the Oak Ridge Dose Reconstruction to members of the ORHASP stated the following: "Fluorine/fluorides were not evaluated quantitatively in Phase I or Phase II, mainly since there doesn't appear to be any evidence that it causes cancer or any really glaring chronic effects. Fluorine does have a USEPA reference dose (0.06 mg/kg-d based on 'objectionable dental fluorosis, a cosmetic effect.'). There is an ATSDR Toxicological Profile for it—the profile seems to talk mostly about the acute irritant

Comment #	Public Comment	ATSDR's Response
	EPA health effects summary for airborne fluorides (USEPA 1988). In addition, fluorine and fluoride compounds were released from both K-25 and Y-12 in massive quantities; the DOE (2000) states that the principal nonradionuclide emissions from the K-25 site included fluorine and HF. Even if the principal health effects for fluorine and fluorides were due solely to acute exposure, the magnitude of the releases should have suggested that further assessment was required. It is apparent from the annual environmental reports (1971-1985) that ATSDR cites and from material cited in the Feasibility Study report (ChemRisk 1993a) that the government considered fluorine/fluoride something important to monitor; this would not have been the case for a substance that was only an acute hazard or irritant. References ATSDR (Agency for Toxic Substances and Disease Registry). 2008. Public Health Assessment for K-25 and S-50 Uranium Fluoride Releases, Oak Ridge Reservation. U.S. Department of Health and Human Services, Public Health Service, Atlanta, GA. Draft for Public Comment, December 2008. ChemRisk. 1993a. Oak Ridge Health Studies, Phase I report. Volume II—part A—Dose reconstruction feasibility study. Tasks 1 & 2: A summary of historical activities on the Oak Ridge Reservation with emphasis on information concerning off-site emissions of hazardous materials. For: Oak Ridge Health Agreement Steering Panel and Tennessee Department of Health. Alameda, CA; September 1993. ChemRisk. 1993b. Oak Ridge Health Studies, Phase I report. Volume II—part B—Dose reconstruction feasibility study. Tasks 3 & 4: Identification of important environmental pathways for materials released from Oak Ridge Reservation. For: Oak Ridge Health Agreement Steering Panel and Tennessee Department of Health. Alameda, CA, September 1993. DOE (Department of Energy). 2000. Independent Investigation of the East Tennessee Technology Park. Volume 1: Past Environment, Safety, and Health Practices. Department of Energy, Office of Oversight, Environment, Safety and	effects of hydrogen fluoride, and again the dental fluorosis as well as skeletal fluorosis." ATSDR conducted this PHA on K-25 and S-50 Uranium and Fluoride Releases because there were community concerns about long-term exposure to fluoride compounds and these compounds were not quantitatively evaluated in the TDOH dose reconstruction reports. Furthermore, ATSDR addressed specific community concerns and public health implications pertaining to acute and chronic off-site exposures to fluorides and related compounds (including hydrogen fluoride and uranyl fluoride) released from the K-25/S-50 site in the past (refer to community concern #10 and #14 in the PHA, respectively).

Comment #	Public Comment	ATSDR's Response
	Health, October 2000. Hodge, H.C., and F.A. Smith. 1965. Fluorine Chemistry, Vol. 4, J.H. Simons, ed. New York: Academic Press. Roholm, K. 1937. Fluorine Intoxication: A Clinical-Hygienic Study, with a Review of the Literature and Some Experimental Investigations. London: H.K. Lewis & Co. USEPA (U.S. Environmental Protection Agency). 1988. Summary Review of Health Effects Associated with Hydrogen Fluoride and Related Compounds. Health Issue Assessment. EPA/600/8-89/002F. Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC. December 1988.	
18	In the 2008 report, ATSDR has considered only fluoride releases associated with uranium releases, a set of measured fluoride concentrations in air (1971-1985), and estimates of airborne fluoride concentrations based on the uranium fluoride releases. Also, the report considers fluoride losses only from K-25. There is additional information in existence that should be considered in assessing fluoride exposures from Oak Ridge-area facilities.	Please see ATSDR's responses below to each individual question or issue mentioned in the commenter's concern.
	First, fluoride in association with uranium was released from Y-12 as well as K-25. The ATSDR has assessed Y-12 uranium releases in a separate report, but has not addressed fluoride releases from Y-12. The estimated uranium releases from Y-12 over the entire period (1944-1995) were approximately 50,000 kg (ChemRisk 1999, p. D-5), as compared to about 16,000 kg of uranium released from K-25 over the same period (ChemRisk 1999, p. 2-27). Clearly, a considerable amount of fluoride could have been released from Y-12 as well as from K-25. In my 2001 letter, I provided a rough lower-bound estimate of 15,000 kg of F released from Y-12 and K-25 combined (from 1944-1995) as a part of the uranium fluoride releases, without considering releases of F_2, HF, or other fluoride compounds.	Y-12 fluoride releases: ATSDR agrees that fluorides were released as uranium hexafluoride (UF_6) from theY-12 Plant, as discussed in pages 2-2, 2-3, Appendix A (pages A-8, A-9, A-14, and A-15), and Appendix D (Tables D-1 and D-2) of the Task 6 report (Volume 5 of the Oak Ridge Dose Reconstruction). Your comments resulted in a re-review of the information and a determination that Y-12 air releases of fluoride and HF were not expected to harm people's health. From mid-1945 to 1947, Building 9212 at the Y-12 plant received approximately 4700 kg of partially enriched UF_6 from K-25 and S-50. For approximately 18 months, the hydrofluorination processes released UF_6 to the air through stacks and exhaust vents equipped with chemical scrubbers. From 1952 to 1964, chemical conversion of enriched UF_6 or the production of nuclear weapon components occurred in Buildings 9202, 9203, 9206, and 9212. The Task 6 report states that Building 9212 housed the largest chemical operations used for enriched uranium. Buildings 9206 housed additional chemical operations and Buildings 9202 and 9203 were used for pilot-scale uranium process design and

Comment #	Public Comment	ATSDR's Response
		improvements. Effluents from the processes in these four buildings were treated through cold traps, caustic/wet scrubber systems, and filtered exhaust systems to minimize releases of UF_6 and UO_2F_2. These effluents were routinely monitored for enriched uranium and periodically monitored for depleted uranium. In the Task 6 report, ChemRisk estimated the annual Y-12 releases of uranium to the air from 1944 to 1995. These estimated releases are based on the monitoring of uranium in effluent emissions. The maximum annual Y-12 airborne uranium release was 6200 kg in 1959 during the chemical conversion processing of enriched UF_6. Adjusting for the percentage of fluoride atoms based on the mole percent fluoride, we believe the maximum annual amount of fluoride released to the air from Y-12 was 2970 kg in 1959. This equates to an average air release 8.5 kg or less of fluoride per day from Y-12. Using these estimated average daily Y-12 fluoride releases in 1959—the year with the maximum annual fluoride release—the fluoride and HF in the air was unlikely to migrate off site at levels of public health concern. The fluoride and HF released into the air from Y-12 would not have reached potential off-site exposure areas at a level of concern because of the relatively small amounts of fluoride released per day and the extended distance from the Y-12 emission sources to the potential off-site exposure areas during that timeframe. In addition, the meteorological data and air dispersion modeling indicate that the predominate wind direction is generally up and down Bear Creek Valley with limited winds crossing over Pine Ridge into potential off-site exposure areas. Therefore, the fluoride and HF released from Y-12 into the air was not expected to harm people's health. ATSDR realizes that the release rate of UF_6 was variable; however, the Task 6 report does not include sufficient information to refine further the estimated daily releases of fluorides from Y-12. Moreover, as fluorine gas (F_2) is about 40% more dense than air, it would not, to a great degree, migrate up or down Bear Creek Valley nor would it easily cross Pine Ridge unless there were significant winds and this would result in a more dilute distribution.
	However, for K-25 in particular, it is known that large amounts of fluorine or fluoride (primarily as gaseous HF or F_2) were used and released apart from the uranium fluorides (DOE 2000). The Department of Energy describes the routine and accidental atmospheric releases of HF and F_2 from K-25 as having not been well documented, but with annual releases reaching 22,000 lb (10,000 kg) of F_2 in 1957 and 58,500 lb (27,000 kg) of HF in 1954 decreasing to 44,000 lb (20,000 kg) of HF in 1957 (DOE 2000, based on a 1957 study).	Estimated HF and F_2 Releases: We acknowledge and understand the limitations of the available data and have built in conservatism into our estimates to account for uncertainties. The DOE's (2000) *Independent Investigation of the East Tennessee Technology Park* clearly states that HF and F_2 releases at K-25, both routine and accidental, were not well documented. The DOE 2000 report (page 86) states that "uranium releases were probably the best documented of all historical releases" and that the ChemRisk Task 6 report contains "the most recent

Comment #	Public Comment	ATSDR's Response
	Bryson (2004) cites a 1955 document from the Oak Ridge DOE Public Reading Room that provides an estimated cost of deliberately vented fluorine of $400,000 per year if recovery of the fluorine were not implemented; at a cost per pound of $0.65, this corresponds to 280,000 kg of fluorine per year. Fluorine/fluoride emissions from K-25 were reduced in the early 1960s and again in the late 1960s (DOE 2000) due to changes in plant processes and emissions control.	and most complete" estimates of historical uranium releases. In addition, ATSDR evaluated fluoride and HF releases during the cascade operations (see response to public comment #16 for more information). Furthermore, the DOE 2000 report (page 86) indicates that "since HF is produced by hydrolysis of UF_6 during release to the atmosphere, some HF releases can be estimated based on historic UF_6 releases." This is consistent with how ATSDR evaluated potential exposures to HF in the public health assessment. ATSDR used scientifically defensible methods to estimate fluoride concentrations in the absence of actual air concentration measurements. We believe that using known correlations between uranium releases and fluoride concentrations provides a reasonable method of estimating past exposures to HF and F_2.
	Accidental releases of fluorine or fluorides include a release of 5000 lb (2300 kg) of HF in the 1974-1976 period (DOE 2000). The ATSDR (2008) does not mention the DOE report or the documentation cited by Bryson (2004) and does not seem to have followed up on these estimates or information sources. Nor has the ATSDR attempted to estimate the possible exposure of members of the public to fluoride releases of this magnitude. The ATSDR (p. 97) mentions a correlation between the annual uranium releases and measured fluoride concentrations at the site perimeter (based on the 1971-1985 monitoring data) and the use of this correlation to estimate fluoride concentrations prior to the monitoring data; given the known large releases of HF and F_2 during the pre-1971 period (especially prior to the 1960s) apart from uranium releases, this approach seriously underestimates the off-site fluoride concentrations for earlier years.	Accidental Release of 5,000 lbs of HF: The release of 5000 lb of HF mentioned by the commenter is already addressed in the PHA. DOE (2000) states that a very large (5,000-lb) accidental release of HF occurred in the 1974–1976 timeframe. This large release of HF occurred during the time when DOE was monitoring for airborne fluoride. The PHA states that airborne fluoride measurements (24-hour and 6 to 7 day periods) were collected at six K-25 perimeter locations from 1971 to 1985. The highest recorded 24-hour value of 26.3 ppb was measured at the F-2 perimeter station located 0.5 miles downwind (see Figure 15 and Table 12 in the PHA). The closest residents were more than 1 mile from F-2 and would have been exposed to concentrations much less than 26.3 ppb. ATSDR compared this measured concentration to the minimal risk level (MRL) of 20 parts per billion (ppb) for fluoride as hydrogen fluoride (HF). Although environmental measurements were fluoride, releases were most likely as HF. Fluorine is very reactive, and thus it will not persist in the atmosphere in elemental form. Therefore, the MRL for HF is the most appropriate comparison value. The 20 ppb MRL is 25 times less than exposures that caused mild upper respiratory tract inflammation in volunteers exposed for 1 hour. The MRL is also 150 times lower than the highest average level of 3,000 ppb (time weighted average) allowed by the Occupational Safety and Health Administration for HF in air for a 40-hour work week made up of 8-hour work days. Therefore, based on the toxicological evaluation conducted in this PHA, ATSDR does not expect exposure to 26.3 ppb to cause adverse health effects. Although the book by Christopher Bryson, an investigative reporter and television producer, provided noteworthy background information, ATSDR does not believe this information is appropriate to use as a basis for estimating the potential for human inhalation exposure to HF or F_2 released into the air from the K-25/S-50

Comment #	Public Comment	ATSDR's Response
		site. ATSDR acknowledges in the PHA that K-25 releases are not well documented and that there is a lack of historical monitoring data. In the PHA, ATSDR is upfront about recognizing and discussing the uncertainties involved with estimating fluoride concentrations in the absence of actual air concentration measurements. ATSDR's public health evaluation of HF and fluoride releases included scientifically defensible data and methods cited by DOE 2000. Additional text has been added to the PHA about uncertainties involving HF and F_2 estimates for the pre-1971 period. Please refer to the PHA for more information on how ATSDR used appropriate conservative assumptions because of these uncertainties.
	The same annual environmental reports for 1971-1985 from which ATSDR obtained airborne fluoride concentrations also provide some measurements of fluoride in surface waters near K-25 and Y-12 (UCC 1972-1983; MMES 1984-1986). It ought to be worthy of mention that a number of these measurements (well after the 1950s when the peak releases from K-25 probably occurred) reach or exceed the fluoride concentrations reached with deliberate fluoridation of drinking water (up to 3.5 mg/L, vs. 1 mg/L typical of fluoridated water in Tennessee) even though background fluoride concentrations in surface waters in the Oak Ridge area are routinely very low (< 0.3 mg/L; e.g., Morton 1962a; 1962b). While the surface waters near K-25 and Y-12 (Poplar Creek, East Fork Poplar Creek, Bear Creek) were not routinely used as drinking water sources for the population and thus might not have contributed significantly to off-site exposures of the public, fluoride concentrations in excess of 1 mg/L (up to 2.6 mg/L) were measured in the Clinch River in 1972 and 1973. Such measurements lend credence to the theories (e.g., Bryson 2004) that fluoridation of public water supplies was at least partially motivated, not for oral health benefits, but as an attempt to downplay the potential significance of fluoride releases to the environment from industrial and nuclear-related facilities. This issue therefore deserves discussion by the ATSDR.	Groundwater and Surface Water: This assessment does not include ingestion of drinking water from surface water or groundwater sources because these were evaluated by ATSDR in other PHAs. These PHAs are available at http://www.atsdr.cdc.gov/HAC/oakridge/phact/index.html. In the final version of this PHA, we have clarified in several sections that this PHA only focuses on the inhalation pathway associated with K-25 releases. Still, to address this concern, we will briefly summarize the findings of our groundwater and surface water PHAs here. ATSDR's exposure pathway analysis did not identify completed off-site exposure pathways for fluoride via the groundwater or surface water bodies at the K-25 site. Groundwater contamination at K-25 does not migrate off site via the groundwater; rather, it is discharged into surface water. Because the local water table occurs just below the surface in the unconsolidated zone, groundwater flow is generally consistent with the surface topography. The groundwater predominantly discharges into surface water via seeps and springs. Most groundwater at the ORR ultimately ends up in the Clinch River, serving as base flow for small streams and tributaries, including Mitchell Branch and Poplar Creek near the ETTP area. On-site surface water (e.g., Poplar Creek, East Fork Poplar Creek, Bear Creek) is not used as an off-site drinking water source for the communities near the K-25 site (e.g., Sugar Grove, Union/ Lawnville). In the PHA, ATSDR discusses current and past uses of Clinch River surface water from the K-25 water intake located upstream along the Clinch River from the confluence with Poplar Creek. The K-25 water intake provided domestic water to the Happy Valley community (1943–1947). Since 1947, the K-25 water intake has not provided water to any off-site communities. Since ATSDR's pathway analysis of potential exposure to fluoride indicates that the contaminated groundwater and surface water at the K-25 site is not used as a

Comment #	Public Comment	ATSDR's Response
		drinking water supply, additional scientific evaluation of ingestion exposure to fluoride via drinking water is not warranted. Please refer to Section 2.5.4 in ATSDR's Public Health Assessment Guidance Manual (PHAGM) for more information regarding identifying exposure pathways: http://www.atsdr.cdc.gov/HAC/PHAmanual/ch2.html#2.5.4. The Tennessee Department of Environment and Conservation (TDEC) monitors public drinking water supplies in Tennessee under the Safe Drinking Water Act for U.S. Environmental Protection Agency (EPA)-regulated contaminants, and TDEC's Department of Energy (DOE) Oversight Division conducts quarterly radiological monitoring of public water supplies on the Oak Ridge Reservation (ORR) and in its vicinity under the EPA's Environmental Radiation Ambient Monitoring System program.
	Other bits of information not included by ATSDR include a fluoride vegetation damage study performed in 1957 (DOE 2000) and employee reports of detectable or "overpowering" onsite concentrations of fluorine and HF (DOE 2000). The DOE (2000) also mentions ambient air sampling for HF and fluorine having begun at K-25 in 1959. Vegetation monitoring for fluoride was routinely done at least for the 1971-1985 period. "Elevated concentrations" of fluoride were found in vegetation and some animals on the Oak Ridge Reservation in a 1979 study, well after the fluoride releases at K-25 had substantially decreased (DOE 1979).	DOE's (2000) *Independent Investigation of the East Tennessee Technology Park* does not have a bibliography section that provides information for the references used and cited in the report. ATSDR contacted DOE Headquarters in an attempt to obtain the 1957 fluoride vegetation damage study cited by the commenter. DOE headquarters was unable to find this document or a reference to this document in DOE 2000. DOE (2000) noted that the fluoride vegetation damage study "attributed some of the damage that was found to an acute, massive release rather than chronic releases." Moreover, in 1957, DOE's focus was on monitoring on-site vegetation, and thus, even if we were able to obtain the study, it likely would not provide any indication of the impact on the off-site populations via inhalation of fluorine and HF. However, ATSDR did evaluate the perimeter air monitoring data. According to DOE (2000), fluorine and HF were also vented directly to the atmosphere during cascade and feed plant operations. Under certain conditions, significant releases occurred during the Cascade Improvement or Cascade Updating Programs. DOE (2000) reported that former workers confirmed these releases, which formed a visible and pungent cloud of gas. ATSDR evaluated releases during maintenance and modifications of cascade equipment.
	References ATSDR (Agency for Toxic Substances and Disease Registry). 2008. Public Health Assessment for K-25 and S-50 Uranium Fluoride Releases, Oak Ridge Reservation. U.S. Department of Health and Human Services, Public Health Service, Atlanta, GA. Draft for Public Comment, December 2008.	

Comment #	Public Comment	ATSDR's Response
	Bryson, C. 2004. *The Fluoride Deception.* New York, Seven Stories Press. ChemRisk. 1999. Uranium releases from the Oak Ridge Reservation—a review of the quality of historical effluent monitoring data and a screening evaluation of potential off-site exposures, Task 6. Reports of the Oak Ridge dose reconstruction, volume 5. For: Tennessee Department of Health. Alameda, CA; July. DOE (Department of Energy). 1979. Environmental Assessment of the Oak Ridge Gaseous Diffusion Plant Site. Department of Energy, DOE/EA-0106, December 1979. DOE (Department of Energy). 2000. Independent Investigation of the East Tennessee Technology Park. Volume 1: Past Environment, Safety, and Health Practices. Department of Energy, Office of Oversight, Environment, Safety and Health, October 2000. MMES (Martin Marietta Energy Systems, Inc.). 1984. Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calendar Year 1983. Y/UB-19. Oak Ridge, TN. June 1984. MMES (Martin Marietta Energy Systems, Inc.). 1985. Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calendar Year 1984. ORNL-6209. Oak Ridge, TN. August 1985. MMES (Martin Marietta Energy Systems, Inc.). 1986. Environmental Surveillance of the Oak Ridge Reservation and Surrounding Environs during 1985. ORNL-6271. Oak Ridge, TN. April 1986. Morton, R.J. (Ed.). 1962a. Status Report No. 2 on the Clinch River Study. ORNL-3202, Oak Ridge National Laboratory, Oak Ridge, TN. April 1962. Morton, R.J. (Ed.). 1962b. Status Report No. 3 on the Clinch River Study. ORNL-3370, Oak Ridge National Laboratory, Oak Ridge, TN. December 1962.	

Comment #	Public Comment	ATSDR's Response
	UCC (Union Carbide Corporation). 1972. Environmental Monitoring Report, United States Atomic Energy Commission, Oak Ridge Facilities, Calendar Year 1971. UCC-ND-221. Oak Ridge, TN. June 1972. UCC (Union Carbide Corporation). 1973. Environmental Monitoring Report, United States Atomic Energy Commission, Oak Ridge Facilities, Calendar Year 1972. UCC-ND-244. Oak Ridge, TN. March 1973. UCC (Union Carbide Corporation). 1974. Environmental Monitoring Report, United States Atomic Energy Commission, Oak Ridge Facilities, Calendar Year 1973. UCC-ND-280. Oak Ridge, TN. May 1974. UCC (Union Carbide Corporation). 1975. Environmental Monitoring Report, United States Energy Research and Development Administration, Oak Ridge Facilities, Calendar Year 1974. UCC-ND-302. Oak Ridge, TN. May 1975. UCC (Union Carbide Corporation). 1976. Environmental Monitoring Report, United States Energy Research and Development Administration, Oak Ridge Facilities, Calendar Year 1975. Y/UB-4. Oak Ridge, TN. May 1976. UCC (Union Carbide Corporation). 1977. Environmental Monitoring Report, United States Energy Research and Development Administration, Oak Ridge Facilities, Calendar Year 1976. Y/UB-6. Oak Ridge, TN. May 1977. UCC (Union Carbide Corporation). 1978. Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calendar Year 1977. Y/UB-8. Oak Ridge, TN. June 1978. UCC (Union Carbide Corporation). 1979. Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calendar Year 1978. Y/UB-10. Oak Ridge, TN. June 1979. UCC (Union Carbide Corporation). 1980. Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calendar Year	

Comment #	Public Comment	ATSDR's Response
	1979. Y/UB-13. Oak Ridge, TN. June 1980. UCC (Union Carbide Corporation). 1981. Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calendar Year 1980. Y/UB-15. Oak Ridge, TN. June 1981. UCC (Union Carbide Corporation). 1982. Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calendar Year 1981. Y/UB-16. Oak Ridge, TN. May 1982. UCC (Union Carbide Corporation). 1983. Environmental Monitoring Report, United States Department of Energy, Oak Ridge Facilities, Calendar Year 1982. Y/UB-18. Oak Ridge, TN. May 1983.	
19	In its assessment of the significance of the fluoride releases (ATSDR 2008, pp. 97-98), ATSDR compares estimated airborne fluoride concentrations to concentrations associated with specific health effects. This approach is acceptable if the airborne fluoride is the only source of fluoride exposure or (primarily for acute exposures) the overwhelmingly predominant source of fluoride exposure. However, for long-term exposures and health effects, the total fluoride exposure from all sources (airborne, drinking water, food, dentifrices, etc.) must be considered. This has been stated many times (e.g., Chester et al. 1979; USEPA 1988; NRC 2006). OEHHA (2003) states that fluoride exposures at an acceptable level when a single route of exposure is considered in isolation might be deleterious for individuals with substantial fluoride exposures from other sources. In general, except for direct effects of inhaled fluoride on the respiratory tract, the body does not distinguish between inhaled and ingested fluoride, and it is the total exposure from all routes and sources that drives the health effects. Therefore, it is also necessary to assess K-25 and Y-12 fluoride releases in terms of their contribution to total fluoride exposures of off-site individuals (mg/kg/day), and to compare the total fluoride exposures to an appropriate reference exposure. References ATSDR (Agency for Toxic Substances and Disease Registry). 2008. Public Health Assessment for K-25 and S-50 Uranium Fluoride Releases, Oak Ridge	K-25/S-50 Air Exposure: In this PHA, ATSDR focused its public health evaluation on assessing off-site exposure to fluoride via the inhalation exposure pathway because this is the most likely way that people living in nearby communities would be exposed to fluoride that was released from the K-25/S-50 facility during normal operations, accidents, or controlled releases. The predominant source of K-25 fluoride was the release of uranium hexafluoride (UF_6) to the atmosphere. ATSDR assumed that uncontrolled releases of uranium and fluoride compounds would be transported through the atmosphere to off-site areas. K-25/S-50 Surface Water and Groundwater: ATSDR's exposure pathway analysis in the PHA did not identify completed or potential exposure pathways for fluoride via the groundwater or surface water bodies at the K-25 site. Specifically, groundwater contamination at K-25 does not migrate off-site via the groundwater; rather, it is discharged into surface water. As a result of past gaseous diffusion operations, surface waters at the K-25 site have received small quantities of fluoride compounds. However, on-site surface water (e.g., Poplar Creek, East Fork Poplar Creek, Bear Creek) is not used as an off-site drinking water source for the communities near the K-25 site (e.g., Sugar Grove, Union/ Lawnville). Therefore, because ATSDR's pathway analysis of potential exposure to K-25 fluoride releases indicates that the contaminated groundwater and surface water at the K-25 site is not used as a drinking water supply, additional scientific evaluation of ingestion exposure to fluoride via drinking water is not warranted. Y-12 Fluoride Releases: ATSDR determined that based on the estimated average daily Y-12 fluoride releases in 1959—the year with the maximum annual fluoride release—the fluoride and HF in the air was unlikely to migrate off site at

Comment #	Public Comment	ATSDR's Response
	Reservation. U.S. Department of Health and Human Services, Public Health Service, Atlanta, GA. Draft for Public Comment, December 2008. Chester, R.O., K.A. Kirksey, and M.L. Randolph. 1979. Survey of Knowledge of Hazards of Chemicals Potentially Associated with the Advanced Isotope Separation Processes. Oak Ridge National Laboratory, ORNL/TM-6812, September 1979. NRC (National Research Council). 2006. *Fluoride in Drinking Water: A Scientific Review of EPA's Standards.* Washington, DC: The National Academies Press. [Available at http://www.nap.edu/catalog/11571.html] OEHHA (Office of Environmental Health Hazard Assessment). 2003. Fluorides including Hydrogen Fluoride. Chronic Toxicity Summary. Determination of Noncancer Chronic Reference Exposure Levels. USEPA (U.S. Environmental Protection Agency). 1988. Summary Review of Health Effects Associated with Hydrogen Fluoride and Related Compounds. Health Issue Assessment. EPA/600/8-89/002F. Environmental Criteria and Assessment Office, Office of Health and Environmental Assessment, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, NC. December 1988.	levels of public health concern. The fluoride and HF released into the air from Y-12 would not have reached potential off-site exposure areas near Y-12 at a level of concern because of the relatively small amounts of fluoride released per day and the extended distance from the Y-12 emission sources to the potential off-site exposure areas during that timeframe. In addition, the meteorological data and air dispersion modeling indicate that the predominate wind direction is generally up and down Bear Creek Valley with limited winds crossing over Pine Ridge into potential off-site exposure areas. Therefore, the fluoride and HF released from Y-12 into the air was not expected to contribute to the body burden of fluorides of individuals living in the communities of Sugar Grove and Union/Lawnville. Fluoride Exposure from All Sources: ATSDR is not able to estimate the total fluoride exposure from all sources for individuals living in Sugar Grove, Union/Lawnville, and Happy Valley in the past because we do not have historical exposure data for non-DOE fluoride sources (e.g., food, drinking water, toothpaste), which these individuals could have been exposed to. However, the National Research Council (2006) report stated that for most people in the United States the "major sources of exposure to fluoride are drinking water, food, dental products, and pesticides" (National Research Council 2006). The most significant contributor to fluoride exposure is drinking water, primarily "fluoridated municipal (community) drinking water, including water consumed directly, food and beverages prepared at home or in restaurants from municipal drinking water, and commercial beverages and processed foods originating from fluoridated municipalities" (National Research Council 2006). Based on the National Research Council's (2006) estimated aggregated total chronic fluoride exposures, drinking water is "the most significant source of exposure" (National Research Council 2006). The relative contributions from each of the nonwater sources of exposure (background food, air, toothpaste, and pesticides) are much less significant and are not considerable enough to add a significant body burden of fluorides to individuals potentially exposed to atmospheric fluoride releases from the K-25/S-50 site.
20	ATSDR's 2008 report considers skeletal fluorosis and dental fluorosis to be the effects of concern (e.g., pp. 122, 126-127), with skeletal fluorosis requiring very high intakes over many years and dental fluorosis being a cosmetic effect rather than a health effect. There are a number of additional effects of concern that should be considered, some of which can be expected at lower levels of fluoride exposure than either skeletal fluorosis or dental fluorosis.	In the PHA, ATSDR scientists evaluated the potential health effects from inhalation of fluoride released to the atmosphere from the K-25/S-50 facility. In the public health implications evaluation, ATSDR scientists compared an estimated maximum off-site annual average fluoride exposure concentration of 6 ppb (7.2 $\mu g/m^3$) to the California EPA's chronic inhalation reference exposure level of 14 $\mu g/m^3$ for hydrogen fluoride and 13 $\mu g/m^3$ for fluoride (Cal-EPA 2003). The California EPA's chronic inhalation reference exposure level is based on the

Comment #	Public Comment	ATSDR's Response
		results of the Derryberry et al. (1963) study on chronic inhalation exposure to fluorides in the workplace. The analysis of the study data by California's Office of Environmental Health Hazard Assessment (OEHHA) shows a statistically significant relationship between air fluoride and the minimal bone density increases. The California EPA states that "changes in bone density in association with fluoride exposure have been observed in several studies, and appear to be the most sensitive health effect for chronic exposure." California EPA stated that "the increased bone density observed was considered as indicating that adverse effects had occurred, based on the adverse effects associated with the increased density in the study, and on other research showing that increased bone density caused by fluoride exposure also leads to decreased bone strength and increased fragility (Riggs et al., 1990)." The California EPA also noted that "although dental fluorosis is a sensitive endpoint in many fluoride studies, the dental examinations of exposed workers in this study showed healthier teeth than in controls." California EPA states that "The major strengths of the key study (Derryberry et al., 1963) for fluoride are the observation of health effects in a large group of workers exposed over many years, the availability of individual exposure estimates for each worker, and the identification of a NOAEL."
	On p. 127, in a response to a member of the public, the ATSDR refers to the EPA's reference dose (0.06 mg/kg/day), which is intended to protect children from severe dental fluorosis, and dismisses its relevance for the K-25 assessment. ATSDR should be aware, first, that 0.06 mg/kg/day is not protective of dental fluorosis in general, and is not necessarily protective of severe dental fluorosis. Second, the National Research Council (2006) concluded that severe dental fluorosis is definitely an adverse health effect rather than merely a cosmetic effect, and even less severe forms of dental fluorosis should be avoided. Finally, the NRC (2006) cites a number of papers that show associations between the presence of dental fluorosis and an increased risk of other adverse health effects (e.g., reduced thyroid function, lowered IQ, increased fracture risk). It should be noted that the ATSDR's own Minimal Risk Level (MRL) for fluoride is also 0.06 mg/kg/day, based on an increased risk of bone fracture (ATSDR 2003). Both skeletal fluorosis and increased risk of bone fracture (from increased brittleness of bones due to incorporated fluoride) are relatively	The ATSDR's chronic oral Minimal Risk Level (MRL) is 0.05 mg/kg/day—not 0.06 mg/kg/day as specified by the commenter. This oral MRL dose is used to evaluate public health implications of ingestion of fluoride, not the inhalation exposure pathway. ATSDR did not use the ATSDR chronic oral MRL of 0.05 mg/kg/day to evaluate the public health implications of the K-25/S-50 fluoride releases because inhalation is the only potential off-site exposure pathway to fluoride released from K-25. ATSDR's pathway analysis of potential off-site exposure to K-25 fluoride releases indicates that the contaminated groundwater and surface water at the K-25 site is not used as a drinking water supply. No potential off-site exposure to K-25 fluoride via ingestion means that no additional scientific evaluation of ingestion exposure to fluoride is warranted.

Comment #	Public Comment	ATSDR's Response
	severe effects, requiring either high exposures or long exposure durations. The ATSDR should be evaluating more sensitive effects. For example, ATSDR's toxicological profile for fluoride (ATSDR 2003) refers to an animal study of thyroid function that would give a lower MRL (value not given) than the MRL derived for bone fracture risk.	
	On p. 122 in the K-25 assessment, in a response to a member of the public, the ATSDR (2008) states that "no evidence to date has suggested that fluoride is an endocrine disruptor, but some data from drinking water suggest that exposure to fluoride could potentially affect some endocrine glands" (citing ATSDR 2003). However, the National Research Council (2006) has concluded that fluoride is an endocrine disruptor, based on an extensive review, including studies not reviewed by ATSDR (2003). For many health endpoints, a lowest observed effect level (not a no-effect level) for fluoride appears to be around 0.05 mg/kg/day (estimated average fluoride intake for a study group); for some endpoints such as altered thyroid function in persons with iodine deficiency, it appears to be even lower. Several population subgroups (e.g., persons with renal impairment) have been identified that are at higher than usual risk of adverse effects from fluoride exposure (NRC 2006). The NRC (2006) states that fluoride appears to have the potential to initiate or promote cancer, and several occupational studies (Grandjean et al. 1992; Grandjean and Olsen 2004; Romundstad et al. 2000) are consistent with an association between exposure to inhaled fluoride and bladder cancer. Finally, a recent paper (Taiwo et al. 2006) discusses increased risk of asthma with chronic exposure to inhaled fluoride.	ATSDR thanks the commenter for noting additional information provided in the National Research Council's 2006 report. This report has been reviewed, added to the reference section of this document, and relevant findings from the report have been added to the public comment being referenced by the commenter (i.e., pertaining to studies that evaluated potential associations between fluoride exposure and health effects including endocrine effects and cancer). Moreover, the statement quoted by the commenter from ATSDR 2003 ("no evidence to date has suggested that fluoride is an endocrine disruptor, but some data from drinking water suggest that exposure to fluoride could potentially affect some endocrine glands") has been removed from the public comment response, and the reader is now directed to the ATSDR toxicological profile and the National Research Council's report for more information. Specifically, the National Research Council's report indicated that, based on a review of several fluoride ingestion studies "several lines of information indicate an effect of fluoride exposure on thyroid function." However, the report noted that because of several complex factors (e.g., peripheral effects on thyroid function, difficulties related to exposure estimation in human studies), "it is difficult to predict exactly what effects on thyroid function are likely at what concentration of fluoride exposure and under what circumstances" (National Research Council 2006). The National Research Council recommended that studies of exposure to fluoride and endocrine effects be conducted on U.S. populations exposed to varying levels of fluoride. The National Research Council (2006) also looked at a potential association between fluoride exposure and cancer by examining studies that considered ingestion, inhalation, and other exposure routes, and determined that the "results are mixed, with some studies reporting a positive association and others no association." Specifically, based on data from studies on humans, genotoxicity assays, and in vitro bone cells, the evidence that fluoride could attribute to cancer is "tentative and mixed" (National Research Council 2006). In other words, the National Research Council (2006) report states that the scientific literature "does not clearly indicate that fluoride either is or is not carcinogenic to humans."
	References ATSDR (Agency for Toxic Substances and Disease Registry). 2003.	

Comment #	Public Comment	ATSDR's Response
	Toxicological Profile for Fluorides, Hydrogen Fluoride, and Fluorine. U.S. Department of Health and Human Services, Public Health Service, Atlanta, GA. September 2003. ATSDR (Agency for Toxic Substances and Disease Registry). 2008. Public Health Assessment for K-25 and S-50 Uranium Fluoride Releases, Oak Ridge Reservation. U.S. Department of Health and Human Services, Public Health Service, Atlanta, GA. Draft for Public Comment, December 2008. Grandjean, P., and J.H. Olsen. 2004. Extended follow-up of cancer incidence in fluoride-exposed workers. J. National Cancer Institute 96(10):802-803. Grandjean, P., J.H. Olsen, O.M. Jensen, and K. Juel. 1992. Cancer incidence and mortality in workers exposed to fluoride. J. National Cancer Institute 84(24):1903-1909. NRC (National Research Council). 2006. *Fluoride in Drinking Water: A Scientific Review of EPA's Standards.* Washington, DC: The National Academies Press. [Available at http://www.nap.edu/catalog/11571.html] Romundstad, P., A. Andersen, and T. Haldorsen. 2000. Cancer incidence among workers in six Norwegian aluminum plants. Scand. J. Work Environ. Health 26(6):461-469. Taiwo, O.A., K.D. Sircar, M.D. Slade, L.F. Cantley, S.J. Vegso, P.M. Rabinowitz, M.G. Fiellin, and M.R. Cullen. 2006. Incidence of asthma among aluminum workers. JOEM 48(3):275-282.	
Conclusions		
21	The CAP is pleased to learn that all releases (except acute fluoride and hydrogen fluoride) from K-25 and S-50 constituted no apparent public health hazard. Although the public health hazard from acute fluoride and hydrogen fluoride releases is indeterminate, the CAP recognizes that worst-case assumptions were used for this evaluation, and that actual public health hazard was likely significantly less. The PHA should evaluate the likely range	As noted in the Public Health Implications section of the PHA, ATSDR used worst-case assumptions and modeled air data as sufficient historical environmental sampling data do not exist. Therefore, ATSDR determined that it will never be able to make a professional judgment about the level of health hazard from this exposure. Note that per agency policy change since the draft version of this document was released, the "indeterminate" and "no apparent" conclusion

Comment #	Public Comment	ATSDR's Response
	of possible releases to the environment and consequent exposures, not just the most conservative estimates.	categories are no longer used by ATSDR. These changes are reflected in the final version of this document.
Additional comments		
22	Page 7, line 16: clarify the time period over which this number was calculated (1945-2000?) I believe this release is described in different units later in the report.	ATSDR believes the commenter is referencing the following statement from the PHA: "The largest documented release of 1,184 kilogram of UF_6 occurred in September 1958." This estimate does not represent cumulative releases over a long time period, as suggested by the commenter, but rather represents a single release event that occurred on one day (i.e., September 1, 1958). Also, this release estimate is always presented using kilograms.
23	Page 8, line 9;:define the term "good". How well was the data correlated? What is the actual level of confidence?	ATSDR has replaced the term "good" with "reasonably uniform." Please refer to Figures G-1 and G-2 in the PHA for more information on the agreement between predicted and measured concentrations.
24	Figure 14, Locations of Emission Sources, Exposure Areas, Meteorological Towers, and Monitoring Stations; Page 76: It appears that the Plant boundary lines and ETTP boundary lines do not adequately depict the areas involved. From the graphic, the Plant boundary drawn near the northern portion of the K-33 building integrates the boundary defined by the Zone 2 ROD and does not incorporate the areas defined by Zone 1 ROD for acreage addressing what is termed the 901 area. This drawing transects a portion of Zone 1 and omits a portion of the K-901 Pond and also appears to omit the K-1070-A Burial Ground. Please correct the lines for both the DOE Plant and ETTP boundaries so that an accurate representation can be presented to the reader so that all of the current boundary that defines ETTP is referenced.	Thank you for your comment. This map was not created to depict CERCLA operable units, but rather was prepared to show the reader the locations of historical air releases, monitoring stations, emissions sources, and exposure areas relevant to the discussions in this PHA.
25	Page 98, lines 8-19: A graphic showing these relationships would help clarify the math.	Please refer to Table 12 in the PHA, which summarizes this information in tabular format.
Editorial comments		
26	Please review references pages identified in the Table of Contents, List of Tables, and List of Figures as the sequencing of the numbers does not progress.	Final crosscheck of these parts of the document was done.
27	Page i, line 13 through page v, line 5: Page numbers in table of contents are inaccurate: it is showing many items as being on page 36.	The page numbering appears to be correct.
28	Page 1, line 9; add comment that all S-50 buildings were destroyed in 1946 (per a comment on page 15)	ATSDR agrees: text was revised accordingly.

Comment #	Public Comment	ATSDR's Response
29	Page 3, line 27: It may be appropriate to list the web addresses of where these alternate studies may be found.	The link to ATSDR's Oak Ridge Reservation: Public Health home page was added: http://www.atsdr.cdc.gov/hac/oakridge/index.html This link provides additional links to all of ATSDR's PHAs for the ORR as well as other products and activities associated with the ORR.
30	ATSDR's Evaluation of Exposure to Uranium and Fluoride Releases from the K- 25/S-50 Site; Page 4, Line 2: Please provide the reference that supports 1,700 acres of the K-25 Site identified in this assessment. The main plant area (inside the security fence) is approximately 800 acres while Zone 1 (outside the security fence but within the DOE boundary fenced areas) is approximately 1,400 acres. Combined there are approximately 2,800 acres that are subject to Records of Decision (ROD) which includes the S-50 site. It is EPA's preference to reflect acreage that could have been impacted as disposal or impacted by DOE operations as these areas are currently under investigation.	ATSDR updated the information corresponding to the acreage of the K-25/S-50 site using the following reference: *Bechtel Jacobs Company LLC. 2008. FY2008 Cleanup Progress: Annual Report to the Oak Ridge Community. Available from:* http://www.bechteljacobs.com/pdf/CleanProg2008.pdf The information in this annual report is consistent with the information presented in this comment.
31	Page 4, line 6: identify that the site been called ETTP since 1997 (per page 19, line 19).	ATSDR revised as suggested.
32	Page 7, line 7: Add the years of operation (from 1942-1948 (reference on page 32 line 24)).	ATSDR revised as suggested.
33	Page 19, line 25: remove the word "indeed." Specify it is the TSCA incinerator at K-25 that is the only facility permitted.	ATSDR revised as suggested.
34	Pg. 79, Figure 16, graph is difficult to read and needs improvement.	The resolution of the figure has been improved.
35	Pg. 145, 1st paragraph. "Women and children are smaller than the population average…" The sentence is correct for children but not for women (adult).	ATSDR revised accordingly.
36	Pg. 147, 3rd paragraph, line 21, "…from the K-25 and S-10 sites,…" should read S-50 sites.	ATSDR corrected the text.
37	Page 148, line 21: suggest adding: "from evaluated contaminants" after the word residents.	ATSDR revised as suggested.
38	Page 149, line 3: suggest listing some of the DOE precautionary measures in this sentence.	ATSDR revised as suggested.

Appendix K. Responses to Peer Review Comments

ATSDR received the following comments from independent peer reviewers for the *K-25 and S-50 Uranium Releases: Oak Ridge Reservation (USDOE)* public health assessment. For comments that questioned the validity of statements made in the document, ATSDR verified or corrected the statements.

Comment #	Peer Reviewer Comment	ATSDR's Response
Does the public health assessment adequately describe the nature and extent of contamination?		
1	Yes, within the limitations of the data available and used and the specific concerns about overstating the appropriateness of the use of CAP-88PC (see peer reviewer comment # 16).	Thank you for your comment.
2	The release terms are based on available data for activities at K-25 and S-50. As in all historical data for the time period considered, there are some gaps in recorded data and information. The investigators have made an excellent effort to fill in any gaps and used reasonable and conservative assumptions. The isotopes and materials of interest were accounted for in the radiological source terms. The decision not to track the very small quantities of Pu-239 is a good decision.	Thank you for your comment.
3	Generally, the nature and extent of the contamination appear to be adequately characterized. An exception to this pertains to uranium isotopic composition or enrichment, which, although of importance from the standpoint of radiation dose and potential radiological effects is not well characterized nor is the significance of isotopic composition described, although some mention is made in Appendix I. Further, such isotopic data as are given are unclear; consider Table 5 (pp. 69-70) which gives the total activity of uranium in units of curies and the percent isotopic relative abundance but does not state whether the percent abundance is in terms of activity or weight percent.	Thank you for your comment. Based on information derived from the supporting documentation in the State of Tennessee Dose Reconstruction Task 6 reports, ATSDR determined that the isotopic abundance is based on the weight percentages of natural uranium.
Does the public health assessment adequately describe the existence of potential pathways of human exposure?		
4	Yes. Excellent discussion of the pathways to human exposure.	Thank you for your comment.

Comment #	Peer Reviewer Comment	ATSDR's Response
5	The potential pathways for human exposure were well though. In particular, Figure 11 is an excellent visualization of the exposure pathways. The descriptions of the selections of processes and parameters in the environmental transport was well covered in the document. I see nothing here that raises a question about the consideration of the appropriate pathways based on the released radionuclides and their form. The existing data at offsite locations agree with the computed concentrations at those locations within model limits. This would indicate that the model results should be of similar accuracy at other locations of interest.	Thank you for your comment.
6	The description of pathways is given in Section III and is quite superficial and brief; additional explanation of the pathways is indicated. For example, the notes to Figure 11 state that the inhalation pathway is the main focus of the PHA and that water ingestion pathways were excluded from consideration as these were evaluated in other unspecified PHA's. This is unsatisfactory; the explanation and choice of pathways needs to be characterized in the text. The pathway analysis also should include the route of entry into the body and such factors as solubility; for example, inhaled insoluble oxides of uranium deposit in the lungs and as such deliver a higher radiation dose and hence risk to that organ as compared with soluble uranium, which results in a much smaller lung dose and whose risk is primarily from its chemical nephrotoxicity.	Thank you for your comment. The text has been changed to clarify the results of the exposure pathway evaluation.
Are all relevant environmental, toxicological, and radiological data (i.e., hazard identification, exposure assessment) being appropriately used?		
7	Yes, except as noted in peer reviewer comment #1 and #16.	Thank you for your comment.
8	The use of the human exposure levels is explained well in terms of the use of available knowledge and contaminant levels, both chemical and radiological. The relevant data of this type is handled with care by the investigators.	Thank you for your comment.

Comment #	Peer Reviewer Comment	ATSDR's Response
9	Certainly a large amount of data is used, evaluated, and indeed are appropriately used. However, whether these data compromise the universe of "all relevant . . . data" is questionable and indeed impossible to determine from the PHA. Suffice to say it appears that the data used in the PHA are likely sufficient and appropriately used. Still, there is an absence of any reference to toxicological and related data published in the peer reviewed literature subsequent to the 1999 toxicological profiles for uranium and ionizing radiation, and the 2003 toxicologic profile for fluorides, HF, and fluorine. Not to detract in any way from these excellent toxicological profiles, which in and of themselves provide outstanding evaluations of the knowledge to the date of their publication, in the decade since the profiles on uranium and ionizing radiation have been published, there has been considerable research on the effects of depleted uranium on the Gulf War veterans, including two reports by the National Academies, which bear directly on the questions being examined by the PHA.	Thank you for your comment. ATSDR understands and agrees with your comment concerning the universe of all relevant data with respect to intentional and unintentional releases at the K-25 facility. In the PHA, ATSDR acknowledged that there are data gaps and limitations of the available data and have built in conservatism into our estimates to account for uncertainties. According to the *Independent Investigation of the East Tennessee Technology Park, Volume 1: Past Environment, Safety, and Health Practices* by the DOE Office of Oversight, Environment, Safety, and Health (2000), the "record reviews and interviews with former workers indicate that many releases were probably not formally documented" and that both routine and accidental releases were not well documented. However, the DOE 2000 report states that "uranium releases were probably the best documented of all historical releases" and that the ChemRisk Task 6 report contains "the most recent and most complete" estimates of historical uranium releases from the K-25/S-50 facility. ATSDR used DOE and ChemRisk emission estimates from the Task 6 report and historical DOE environmental monitoring data to estimate doses and concentrations at off-site locations around K-25. Furthermore, the DOE 2000 report indicates "since HF is produced by hydrolysis of UF_6 during release to the atmosphere, some HF releases can be estimated based on historic UF_6 releases." This is consistent with how ATSDR evaluated potential exposures to HF in the public health assessment. ATSDR used scientifically defensible methods to estimate fluoride concentrations in the absence of actual air concentration measurements. We believe that using known correlations between uranium releases and fluoride concentrations provides a reasonable method of estimating past exposures to HF and F_2. The National Research Council in 2008 reviewed the results of the U.S. Army Capstone Report on depleted uranium impacts on U.S. military personnel during the Gulf War. In essence, the Council agreed with the report on the toxicological implications as reported. The toxicological information used in the ATSDR document is similar to the Capstone Report.

Comment #	Peer Reviewer Comment	ATSDR's Response
Does the public health assessment accurately and clearly communicate the health threat posed by the site?		
10	This reviewer's only concern is that a casual reader may overlook the fact that accidental and unmonitored UF_6 releases constitute an indeterminate health hazard. (This reviewer can offer no suggestion as to how ATSDR might have made a clearer statement than on p.4, text box and p. 147, and elsewhere.)	The comment is noted. The text was changed in the public health assessment to communicate clearly and effectively the PHA conclusions. Also note that per agency policy change, ATSDR no longer uses the "indeterminate" public health hazard category. This change is reflected in the final version of the document.
11	The investigators were careful to interpret the health assessment results in light of the available knowledge and regulation concerning the contaminants. They were careful not to reach a conclusion if there were no available exposure limits.	Thank you for your comment.
12	In general, Yes. And, even reference to the more recent publications mentioned in peer reviewer comment #9 would not change but actually strengthen these conclusions.	Thank you for your comment.
Are the conclusions and recommendations appropriate in view of the site's condition as described in the public health assessment?		
13	P. 147, lines 18- 28, The ATSDR did perhaps the best job possible in communicating both the "…no apparent health hazard…" and the "…indeterminate public health hazard…" However, logically when one combines a "…no apparent…" with an "…indeterminate…," the "…indeterminate…" is the governing statement.	The comment is noted. Per agency policy change since this version of the document was released, ATSDR no longer uses these health hazard categories. The final version of the document was changed accordingly.
14	The conclusions seem appropriate in terms of the releases and downfield concentrations of the radiological and chemical contaminants computed. The conclusion of "an indeterminate public health hazard" for short-term exposure to fluoride and hydrogen fluoride released as UF6 during the accidents or maintenance due to the insufficient environmental sampling data is the correct decision. This is consistent with the great consideration with which the investigators have weighted their decisions.	Thank you for your comment. Per agency policy change since this version of the document was released, ATSDR no longer uses the "indeterminate" health hazard category. The final version of the document was changed accordingly.
15	The conclusions (Section VIII) and recommendations are succinct and clear and free of equivocation.	Thank you for your comment.

Comment #	Peer Reviewer Comment	ATSDR's Response
Are there any other comments about the public health assessment that you would like to make?		
16	Perhaps the key observation in the PHA is found on p.4 (text box) with the statement that "acute exposure to UF_6 is an indeterminate health hazard." This reviewer agrees totally. But more specifically, on p.4, lines 18-21 the PHA lumps the on "air dispersion models (l. 18) with "the cumulative data set provides adequate basis for the public health determination in this PHA" (l.20-21). This statement appears to give high credibility to the modeling (particularly with CAP-88, as discussed below) which this reviewer believes is not justified. Specifically on p. 8, lines 9-11, "with some simplifying assumptions agreement is good between the measured gross alpha and those predicted by CAP-88 PC for K 25/ S 50 air release estimates. The fact that gross alpha is in general agreement with CAP-88 is insufficient basis for the statement (p.8, lines 11- 14, and p. 102, lines 14- 17), "This agreement … provides confidence that the procedure may be used to estimate off-site exposure for the earlier period … 1961-1963," and also (p.8, lines 19-21) that "effects of topographic ridges … will overestimate the concentration at areas of potential exposure along the site perimeter." This reviewer does NOT agree that the use of CAP-88 (particularly retrospectively) is justified by agreement with measured gross alpha. This reviewer followed closely the development of the predecessor algorithms that continue to be used as the computational basis for CAP-88 PC. These algorithms were and are based on a "binning" procedure wherein hourly data are lumped into bins to construction joint frequency distributions of wind speed, wind direction and stability category. (This was done because of limited computing power at the time of development --- late 1970s and early 1980s.) This reviewer also had the opportunity to study the sensitivity (or lack thereof) of the algorithms based on joint frequency distributions. In short, when one applies hourly data into a joint frequency distribution with	Thank you for your comment. Note that per agency policy change since this draft version was released, ATSDR no longer uses the "indeterminate" health hazard category. This change has been reflected in the final version of the PHA. The agreement between actual measured historic data and model predictions is the only way to justify use of said models for estimating historic exposures. ATSDR might agree that the specific process by which the model parses hourly meteorological data into annual averages is of some concern relative to the annual concentrations except that measured concentrations and predictions show very good agreement over a 25-year time period. Similarly, in order for funneling to increase concentrations relative to model predictions, some sort of wind gap in ridgeline must be present. HP-35 is located in such a wind gap and again, measured concentrations at that location do not show significant increases relative to predicted concentrations. Actual concentrations at exposure areas downwind of the 100m ridges will necessarily be lower than the concentrations predicted assuming no such terrain obstruction (especially considering that UF-6 is a ground-hugging dense gas). Use of the predicted historic concentrations for exposure estimation is health-protective. The use of gross alpha measurements is not the ideal data to use for an isotope specific assessment. However, as appropriate data are lacking, ATSDR assumed that the gross alpha measurement was entirely uranium. Therefore the model results are biased toward being conservative. Other agencies and researchers have used similar approaches during the evaluation of fallout from the atmospheric nuclear testing.

Comment #	Peer Reviewer Comment	ATSDR's Response
	rather "wide bins" based on wind speed [say, for example, all data from wind speeds less than 5 mph or 2 m/s into one bin] one loses sensitivity when (as in the Southeastern U.S.) much of the hourly data falls into the low-wind-speed category, precisely when nighttime highly stable air produces the highest ground level concentrations. Consequently, one loses the effect of near –calm and highly stable air, precisely the times when one should calculate the highest ground level air concentration. In fact, the EPA was so concerned over the limitations of "binning" low wind speed data (in the procedures that used this approach) that EPA planned, but never implemented, a project to completely revise the methodology and algorithms. This work was lost in the rush to provide a computer code (later CAP-88 PC) for use in the radionuclide release analysis from DOE facilities. Unfortunately, the weaknesses of this conceptual basis have yet to be corrected. P.8, lines 18-21. *Flat earth assumption*. Although this reviewer is aware that some studies in the Oak Ridge valley do show that omitting terrain effects may be acceptable for nominal ground level concentration estimates, ATSDR should not state that "… these estimates will overestimate concentrations at areas of potential exposure along the site perimeter." In fact, the terrain features will funnel some concentrations and "block" or dilute others. This reviewer has not seen any conceptual or empirical evidence that would lead one to make such an overly broad statement.	
17	The report is rather lengthy, but as a result has a good depth of discussion on the modeling, decisions, etc. The work seems to have done a comprehensive review of other work related to the study. There some minor points that this reviewer would like to note:	Thank you for your comment.
	Figure 10 (page 50) should be closer to the first reference to it on page 47. Similarly Figure 12 is first mentioned on page 60 and several times on other pages before appearing in the text on page 64. There are a couple of others. This could be corrected rather easily in the WORD document.	The comment is noted. The figures were changed in the public health assessment.
	On page 60, maybe some discussion of the weighting factors, etc are needed. This page may not be very public friendly. It is acceptable for health physicists.	The comment is noted. The text was changed in the public health assessment.

Comment #	Peer Reviewer Comment	ATSDR's Response
	"midnight negatives" should be explained in the texts. I am not sure what it is – I can guess. From page 7 – "Individual release events also included "midnight negative" releases. The term refers to using the jets at night to accelerate the attainment of an adequate UF6 negative to support a planned opening of isolated process gas equipment." What is a UF6 negative – negative pressure or what?	The comment is noted. The text was changed in the public health assessment.
	On page 86, line 17 - is it UF6 or UF as written?	The comment is noted. The text was changed in the public health assessment.
	On page 89, Table 12 – is the contaminant ionizing radiation or radiological material. This is nit-picky comment and can be left as it is.	The comment is noted. The text was changed in the public health assessment.
	Page 114, comment #2 reply, third paragraph – It would seem that you could determine by looking at the cancer incidence rates in other counties if the eight-county numbers fluctuate within the differences seen between the state average and other counties.	ATSDR used the State of Tennessee as the reference population because the reported numbers of cases for each of the 42 different cancer types in the whole state are much larger than are any of the counties, which makes the State of Tennessee reference population rates more stable than county rates. In addition, the following limitations associated with the available data from the Tennessee Cancer Registry would likely result in less stable cancer incidence rates if the smaller number of cases from counties were used as a reference population instead of the State of Tennessee: (a) the data are only about 80% complete for the time period of study (1991–2000); (b) some of the reported numbers of specific cancer types are very small, making the rates unstable; c) for reasons of confidentiality, only cancer types with more than five observed cases in each county were evaluated; and (d) the data only contain an individual's address at the time a cancer case was diagnosed, which can result in over- or undercounting of cases because you cannot determine the length of time a person has lived in a county or if a person has moved out of a county prior to diagnosis.
	The inclusion of the code outputs in the appendix is a good idea and provides the data used in the modeling so an informed professional can check the values.	Thank you for your comment.
18	This is a rather lengthy PHA and sometimes difficult to follow. As a general statement, it is in serious need of technical editing, both to improve readability and to ensure correct and precise use of terminology and technical accuracy and to eliminate errors and ambiguities. There is a good deal of redundancy (see, for example, the first paragraph on p. 26; first paragraph on p. 32, which is redundant with p. 15). Following are some specific comments derived from my review of this draft PHA.	Thank you for your comment. The authors will review the text and make the appropriate changes and the document will be sent through editorial services prior to distribution.
	Page 1, line 5. It is a small point, but I do not believe that ORR's mission was	The comment is noted. The text was changed in the public health assessment.

Comment #	Peer Reviewer Comment	ATSDR's Response
	to ". . . produce special radioactive materials for nuclear weapons". It is the adjective 'radioactive' that I have trouble with and which I believe should be deleted.	
	Page 6, line 6. What is meant by "less than 1 percent of the total radiation"? Does this mean activity? Dose? Relative hazard or risk? Or what? And what about Pu-240 and Am-241? These need to be mentioned if only to point out that the doses from these are insignificant.	The comment is noted. The text was changed in the public health assessment.
	Page 8, line 20. Risk based on these estimates will also be overstated; should this be mentioned?	The comment is noted. The text was changed in the public health assessment.
	Page 9, lines 20ff. This is incorrect, not referenced and needs to be revised and properly referenced. For example, transitory signs of kidney toxicity were specifically reported in a worker exposed at Gore, OK, with an estimated intake of 24 mg (cf Fisher et a1 NUREG/CR 5566; 1990); other cases of transitory clinical signs of renal dysfunction have also been reported. These are summarized in Table 8-7 of the 2008 National Academies report *Review of the Toxicologic and Radiologic Risks to Military Personnel from Exposures to Depleted Uranium During and After Combat".*	The comment is noted. The text was changed in the public health assessment.
	Page 12. The last sentence beginning at the end of line 15 appears misleading; was there not a great deal of research done over the years with toxic and radioactive materials? And does the 70% refer to areas of land that were simply not used?	The comment is noted. The text was changed in the public health assessment.
	Page 18. Sidebar. The explanation of the cascade is poor in that it would not be easily understood by an average person.	The comment is noted. The text was changed in the public health assessment.
	Page 28, linel6. The reference cited is 16 years old. Have the primary crops been the same since the 1940's and after 1993?	Crops have not changed significantly.
	Page 40, line 8. The word 'known' should be inserted between 'all' and 'past'.	The comment is noted. The text was changed in the public health assessment.
	Page 41, line 8. Is what is meant less than 1 in 10,000?	One chance in 10,000, which is the Oak Ridge Health Agreement Steering Panel's (ORHASP's) Decision Guide for cancer risk due to radiation or chemical exposure and the upper risk limit used by EPA for some regulatory decisions. The text was changed in the public health assessment.

Comment #	Peer Reviewer Comment	ATSDR's Response
	Page 42, line 2. The word 'proportionately' has an exact scientific definition and is misused here. The risk is proportionate to the intake, which is a function not only of the amount of fish eaten but the concentration in the fish. Concentration is not constant, nor is it reduced linearly or proportionately with distance downstream. Suggest that the phrase 'goes down proportionately' be replaced by 'is significantly reduced'.	The comment is noted. The text was changed in the public health assessment.
	Page 45 ff. The discussion of the independent medical evaluation of K-25 workers deals primarily with beryllium and raises the question of why this PHA did not include consideration of beryllium exposures.	To identify contaminants of concern for further evaluation, in 2001, ATSDR scientists conducted a review and a screening analysis of the TDOH's Phase I Dose Reconstruction Feasibility Study and Phase II screening-level evaluation of past releases (1944–1990). Based on this evaluation, ATSDR determined beryllium was not a contaminant of concern to off-site residents living near the K-25 facility. Therefore, beryllium was not evaluated in this PHA.
	Page 47, line 6. What is 'fabricated' radioactivity? Is what is meant here 'artificially produced' or 'anthropogenic"?	The comment is noted. The text was changed in the public health assessment.
	Page 52. This sidebar is redundant with and not as complete as the one on p.88.	The comment is noted. The text was changed in the public health assessment.
	Page 53. This sidebar is confusing. The source of contamination is not necessarily where it is released to the environment, and should not be confused with the term 'source term' which appears throughout the literature (although not this PHA) and is widely used. And, this definition of 'source' does not seem to be entirely consistent with the later usage of the word 'source' as on p. 62.	The comment is noted. The text was changed in the public health assessment.
	Page 58, paragraph beginning on line 10. Well done and well written; kudos.	Thank you for your comment.
	16. Page 58, lines 27 ff. The first sentence, and indeed the following discussion as well as the sidebar on p. 59 are confusing and inaccurate in places. (Also the sidebar on page I-1). This section needs to be rewritten and clarified and precise and correct terminology used; looking at line 27, what is meant is not that the external sources that penetrate the human skin (although the sources themselves can theoretically at least do so) but that the radiations emitted by these sources can penetrate the superficial layers of the body and irradiate the deeper lying tissues and organs. The dosimetry definitions starting at the bottom of p. 59 are poorly done and in some cases incorrect or at best misleading; for example, line 29. Suffice to say again and at the risk of being redundant myself, this entire section needs to be rewritten.	The comment is noted. The text was changed in the public health assessment.

Comment #	Peer Reviewer Comment	ATSDR's Response
	17. Page 59. The same sidebar is used on p. 68 and hence one of these is redundant.	The comment is noted. The text was changed in the public health assessment.
	18. Page 60, lines 20 ff. The various isotopes of uranium are spelled out even though their pathways are identical and as has been pointed out above there is, regrettably, virtually no consideration or discussion of the importance of isotopic composition with respect to dose and risk.	The comment is noted. The text was changed in the public health assessment.
	19. Page 62, lines 17 ff. Interesting to suddenly come across 93% enriched uranium. This supports the earlier comments with respect to inclusion of consideration of the isotopic composition of uranium from the standpoint of radiation risk.	The comment is noted. The text was changed in the public health assessment. ATSDR agrees radiation from uranium is normally not an issue until U-235 approaches 15% enrichment.
	20. Page 63, last paragraph. This is repeated in the Summary; it also deals with other materials than uranium and fluoride, implying that these materials were ignored in the PHA.	Technetium 99 and neptunium 237 are evaluated in the subsequent sections of the PHA.
	21. Pages 68, line 20. Given that uranium is both radiotoxic and chemotoxic, it is important to specify what is meant by 8% larger. Does this mean by activity or mass?	The comment is noted. The text was changed in the public health assessment.
	22. Pages 69-70, Table 5. Is the relative abundance of uranium in terms of percent activity or weight percent. This is an important distinction, and although perhaps obvious to an expert from inspection of the numbers, still needs to be clearly stated. As is true for all tables and figures, Table 5 should stand alone without need to refer to the text for explanation.	The comment is noted. The text was changed in the public health assessment.
	23. Page 73, Figure 13. This figure raises many questions; why did not the DOE estimates include the years before 1947? Why is there such a large difference in the two estimates for the maximum release years 1961 and 1963? The footnote only repeats the obvious and the text is mute. If I attempt to add up all the values plotted, for the DOE, I get somewhat less than 18.1 Ci; maybe a table would be a superior way of presenting these data.	The DOE K-25 estimate did not include the S-50 facility estimates for 1944 and 1945. Similarly, the ChemRisk Task 6 K-25 estimates did not independently estimate 1989 to 1995 releases. This information is included in the PHA under Annual Airborne Emission Estimates (1944 to 1995) in Section III.B.1. Sources and Emissions Estimates of Airborne Uranium, Fluoride, Hydrogen Fluoride, and Other Radiological Contaminants. The data are presented in Table 5 and in Figure 13.
	24. Page 72, line 7 FF. and sidebar. These do not give me a clue as to what 'midnight negative' releases really were or the definition of 'negative' as used in this context.	The comment is noted. The text was changed in the public health assessment.
	25. Page 73, Table 6. The table heading should specify weight percentage (or enrichment) of U-235.	The comment is noted. The text was changed in the public health assessment.

Comment #	Peer Reviewer Comment	ATSDR's Response
	26. Page 75, Table 8. The heading is wrong; these are not gross alpha concentrations. Gross alpha concentrations are not measured in curies, but annual airborne alpha activity can be.	The comment is noted. The text was changed in the public health assessment.
	27. Page 77, Table 9. Concentrations in what? This table should stand alone; the concentrations are in air.	The comment is noted. The text was changed in the public health assessment.
	28. Page 80, line 24. What are nonradioactive total uranium concentrations; all isotopes of uranium are radioactive.	"Nonradioactive total uranium concentrations" means that the method used for uranium determination was based on chemical procedures, not radiochemical methods.
	29. Page 82, Table 10. Is this really effective equivalent dose rate? Or effective dose rate? I use this to illustrate how badly muddled the use of dose quantities and their associated units is throughout this report. Be specific; there is a difference and an important one between effective dose and equivalent dose. Every radiation dose should be precisely and accurately identified everywhere in this report.	CAP-88 calculated the "Individual Effective Equivalent Dose Rate." See the discussion in the PHA under Estimated Annual Radiological Doses and Concentrations in Section III.B.3. Estimated Annual (Chronic) and Short-term (Acute) Doses and Concentrations (1944 to 2006).
	30, Page 87, Table 11. Another dose specification problem. The table heading says uranium dose, the note says inhaled lung dose equivalent, and implies it is an acute dose. How confusing, especially when considered with the definition at the top of page 60. If I as an expert am confused, what about the lay persons - i.e. members of the general public who read this. Also, the peak HF concentrations listed: are they sufficient to produce lung irritation?	The comment is noted. The text was changed in the public health assessment.
	31. Page 89, Table 12. Estimated doses (actually dose rates) are lists, but what are these doses: committed effective doses? External radiation doses? Organ dose equivalents? Or what?	The comment is noted. The text was changed in the public health assessment.
	32. Page 93, line 24, Now we introduce millisieverts and so we change the units from mrem (without telling the general reader who likely is already thoroughly confused) and still don't specify the type of dose (actually the dose quantity - please note difference between a quantity and a unit).	The comment is noted. The text was changed in the public health assessment.
	33. Page 94, line 3. Would say 'less than one third the ICRP recommended dose limit". The ICRP recommends a limit, not a dose. And, I recommend throughout that values below a suggested limit be expressed as a fraction of that limit (e.g. one tenth or less than one tenth) rather than '10 times lower than' to avoid confusion.	The comment is noted. The text was changed in the public health assessment.

Comment #	Peer Reviewer Comment	ATSDR's Response
	34. Page 96, first paragraph. Much erroneous information here. See comment 5 above. Particularly egregious are lines 12-13; there is ample evidence from human and animal data that this sentence is untrue.	The comment is noted. The text was changed in the public health assessment.
	35. Page 97, lines 9 ff. Could not meteorological data have been used to provide estimates as was done for the unmonitored K-25 releases.	The comment is noted. The text was changed in the public health assessment.
	36. Page 104, lines 2-3. How could the doses from the largest accidental release be higher than the dose from the largest annual release? Is not the former a part of the latter?	The comment is noted. The text was changed in the public health assessment.
	37. Page 108. A question of report organization: why does the subsection "Responding to Community Concerns" precede the larger section "Community Health Concerns" beginning on page 110?	The comment is noted. The text was changed in the public health assessment.
	38. Page 108, Side bar. The definition of cancer incidence is wanting.	The comment is noted. The text was changed in the public health assessment.
	39. Appendix I. Page I-4, line 27. Is 'as high as' meant rather than 'as low as'?	The comment is noted. The text was changed in the public health assessment.
Are there any comments on ATSDR's peer review process?		
19	The ATSDR review process is appropriate in its format and content. This reviewer did this review primarily because of professional interest and the importance to our overall public understanding of the impact of these operations at the ORR. Having said that, the compensation to the reviewer does not comport with the importance and the investment of time required to do a reasonable review. The bulk and complexity of the materials to review speak for themselves. ATSDR should work toward increasing the stipend for conducting such reviews in the future.	Thank you for your comment.
20	None.	—
21	Excellent, and honest and transparent.	Thank you for your comment.