PUBLIC HEALTH ASSESSMENT

White Oak Creek Radionuclide Releases

Oak Ridge Reservation (USDOE)

Oak Ridge, Roane County, Tennessee

EPA Facility ID: TN1890090003

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AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

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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 cleanup 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. Whatever the form of the public health assessment, the 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 than adults. 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 it touches on cases in which this is so, this report suggests what further public health actions are needed.

Conclusions

This report presents conclusions about the public health threat, if any, posed by a site. Any health threats that have been determined for high-risk groups (such as children, the elderly, chronically ill people, and people engaging in high-risk practices) are summarized in the Conclusions section of the report. Ways to stop or reduce exposure are recommended in the Public Health Action Plan section.

ATSDR is primarily an advisory agency, so its reports usually 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:

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Acronyms

ALS	amyotrophic lateral sclerosis
AOEC	Association of Occupational and Environmental Clinics
ATSDR	Agency for Toxic Substances and Disease Registry
BEIR	Biological Effects of Ionizing Radiation
Bq	becquerel
BSCP	Background Soil Characterization Project
CDC	Centers for Disease Control and Prevention
Ce 144	cerium 144
CEDR	Comprehensive Epidemiologic Data Resource
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CFRF	consolidated fuel recycling facility
Ci	curie
cm	centimeter
Co 60	cobalt 60
COC	contaminant of concern
COPD	chronic obstructive pulmonary disease
CRM	Clinch River Mile
Cs 137	cesium 137
D&D	decontaminating and decommissioning
DOE	U.S. Department of Energy
EE/CA	Engineering Evaluation/Cost Analysis
EEWG	Exposure Evaluation Work Group
EMWMF	Environmental Management Waste Management Facility
EFPC	East Fork Poplar Creek
EPA	U.S. Environmental Protection Agency
ERAMS	Environmental Radiation Ambient Monitoring System
ETTP	East Tennessee Technology Park
FACA	Federal Advisory Committee Act
FAMU	Florida Agriculture and Mechanical University
FFA	Federal Facility Agreement
GAAT	gunite and associated tanks
Gy	gray
H3	tritium
HF	hydrofracture facility
HFIR	high flux isotope reactor
Hg	mercury
HHS	U.S. Department of Health and Human Services
HRE	homogeneous reactor experiment
HRSA	Health Resources and Services Administration
IAG	interagency agreement
ICRP	International Commission on Radiological Protection
IHP	intermediate holding pond
IROD	Interim Record of Decision
I 131	iodine 131

Acronyms (continued)

ISG	in situ grouting
ISV	in situ vitrification
IWMF	interim waste management facility
LEFPC	Lower East Fork Poplar Creek
LLW	low-level waste
LLLW	liquid low-level waste
LWBR	Lower Watts Bar Reservoir
MCL	maximum contaminant level
MeV	million electron volts
mg/kg	milligrams per kilogram
mrem	millirem
μCi/mL	microcuries per milliliter
μR/hr	microroentgen per hour
MRL	minimal risk level
MS	multiple sclerosis
mSv	millisievert
MVST	Melton Valley storage tanks
Nb 95	niobium 95
NCEH	National Center for Environmental Health
NCRP	National Council on Radiation Protection and Measurements
NHF	new hydrofracture facility
NIOSH	National Institute for Occupational Safety and Health
NOAEL	no observed adverse effect level
NPDES	National Pollutant Discharge Elimination System
NPL	National Priorities List
NRC	U.S. Nuclear Regulatory Commission
OHF	Old Hydrofracture Facility
OREIS	Oak Ridge Environmental Information System
ORGDP	Oak Ridge Gaseous Diffusion Plant
ORHASP	Oak Ridge Health Agreement Steering Panel
ORNL	Oak Ridge National Laboratory
ORR	Oak Ridge Reservation
ORRHES	Oak Ridge Reservation Health Effects Subcommittee
OU	operable unit
P&A	plugging and abandonment
PCB	polychlorinated biphenyl
pCi	picocurie
PCM	Poplar Creek mile
PDF	portable document format
PHAP	Public Health Action Plan
PHAWG	Public Health Assessment Work Group
ppb	parts per billion
ppm	parts per million
PWSB	process waste sludge basin
PWTP	Process Waste Treatment Plant

Acronyms (continued)

rad	radiation absorbed dose
RaLa	radioactive lanthanum
RAR	Remedial Action Report
RCRA	Resource Conservation and Recovery Act
RER	remediation effectiveness report
RfD	reference dose
Rh	rhodium
RI/FS	Remedial Investigation/Feasibility Study
ROD	Record of Decision
Ru 106	ruthenium 106
SDWA	Safe Drinking Water Act
SDWIS	Safe Drinking Water Information System
SNF	spent nuclear fuel
SRS	sediment retention structure
Sr 90	strontium 90
Sv	sievert
SWSA	solid waste storage area
TDEC	Tennessee Department of Environment and Conservation
TDOH	Tennessee Department of Health
TRM	Tennessee River Mile
TRU	transuranic waste
TSCA	Toxic Substances Control Act
TSF	tower shielding facility
TVA	Tennessee Valley Authority
TWRA	Tennessee Wildlife Resources Agency
U 233	uranium 233
U.S.ACE	U.S. Army Corps of Engineers
WAC	waste acceptance criteria
WAG	waste area grouping
WBRIWG	Watts Bar Reservoir Interagency Work Group
WIPP	waste isolation pilot plant
WOC	White Oak Creek
WOCE	White Oak Creek Embayment
W_R	radiation weighting factor
W_T	tissue weighting factor
Zr 95	zirconium 95

I. Summary

ORR Background

In 1942, the federal government established the Oak Ridge Reservation (ORR) in Anderson and Roane Counties in Tennessee as part of the Manhattan Project to research, develop, and produce special radioactive materials for nuclear weapons. Four facilities were built at that time. The Y-12 plant, the K-25 site, and the S-50 site were created to enrich uranium. The X-10 site was created to demonstrate processes for producing and separating plutonium. Since the end of World War II, the role of the ORR (Y-12 plant, K-25 site, and X-10 site) has broadened widely to include a variety of nuclear research and production projects vital to national security.

Over the years, ORR operations have generated a variety of radioactive and nonradioactive wastes. A portion of these remain in old waste sites, and some pollutants have been released into the environment. Consequently, in 1989, the ORR was added to the U.S. Environmental Protection Agency's (EPA's) National Priorities List (NPL). Under a Federal Facility Agreement (FFA) with EPA and the Tennessee Department of Environment and Conservation (TDEC), the U.S. Department of Energy (DOE) is conducting cleanup activities at the ORR. These agencies are working together to investigate and to take remedial action on hazardous wastes generated from both past and present site activities.

ATSDR's Involvement and Other Health Activities at ORR

The Agency for Toxic Substances and Disease Registry (ATSDR), one of several agencies within the U.S. Department of Health and Human Services (HHS), is the principal federal public health agency charged with evaluating human health effects of exposure to hazardous substances in the environment. ATSDR, a sister agency to the Centers for Disease Control and Prevention (CDC), has for many years worked closely with the CDC's National Center for Environmental Health (NCEH). In December 2003, ATSDR and NCEH—both charged with controlling and preventing diseases related to environmental causes—consolidated their administrative and management functions and are now known as NCEH/ATSDR. For more information on these and other affiliated agencies, please refer to http://www.atsdr.cdc.gov/ and http://www.cdc.gov/.

Since 1991 ATSDR has responded to requests and addressed health concerns of community members, civic organizations, and other government agencies in the affected areas of the ORR by working extensively to determine whether levels of environmental contamination in off-site areas present a *public health hazard*, that is, a source of potential harm to human health as a result of past, current, or future exposures. During this time, ATSDR has identified and evaluated several public health issues and has worked closely with many parties. While the Tennessee Department of Health (TDOH) conducted the Oak Ridge Health Studies to evaluate whether off-site populations have been exposed in the *past*, ATSDR's activities focused on *current* public health issues related to Superfund cleanup activities at the site. Prior to this public health assessment, ATSDR addressed current public health issues related to off-site areas, including the East Fork Poplar Creek area and the Watts Bar Reservoir area. The agency's Oak Ridge Reservation Web site at http://www.atsdr.cdc.gov/HAC/oakridge/ contains additional information on ATSDR's ORR-related public health activities.

During Phase I and Phase II of the Oak Ridge Health Studies, the TDOH conducted extensive reviews and screening analyses of the available information and identified four hazardous substances related to past ORR operations that could have been responsible for adverse health effects: radioactive iodine, mercury, polychlorinated biphenyls (PCBs), and radionuclides from White Oak Creek. In addition to the dose reconstruction studies on these four substances, the TDOH conducted additional screening analyses for releases of uranium, radionuclides, and several other toxic substances.

To expand on TDOH efforts—but not duplicate them—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. Using this review, ATSDR scientists are conducting public health assessments on X-10 iodine 131 releases, Y-12 mercury releases, K-25 uranium and fluoride releases, PCB releases from X-10, Y-12, and K-25, and other topics such as the Toxic Substances Control Act (TSCA) incinerator and off-site groundwater. In spring 2004 ATSDR completed a public health assessment on Y-12 uranium releases and in this public health assessment evaluates radionuclides released from White Oak Creek. In conducting these public health assessments, ATSDR scientists are evaluating and analyzing the data and findings from previous studies and investigations to assess the public health implications of past, current, and future exposures.

ATSDR's Evaluation of Exposure to Radionuclide Releases From X-10

As stated, this public health assessment evaluates the releases of radionuclides to the Clinch River (and the Lower Watts Bar Reservoir, or LWBR) from the ORR via White Oak Creek, assesses past, current, and future exposure to radionuclide releases for people who use or live along the Clinch River (and within the White Oak Creek study area; that is, the area along the Clinch River from the Melton Hill Dam to the Watts Bar Dam), and addresses the community health concerns and issues associated with the radionuclide releases from White Oak Creek. This document does not address the release of other contaminants of concern such as mercury, radioactive iodine, PCBs, uranium from the K-25 facility, and fluorides, nor does it address exposures to those contaminants. ATSDR will evaluate these contaminants and other topics in separate public health assessments. Please note that this document only evaluates **off-site exposures** to White Oak Creek radionuclide releases for downstream residents and others who use or who live along these waterways. It does not evaluate any exposures potentially occurring on site at the reservation, including exposures to workers and other individuals who may contact contaminants while at the ORR.

Most of the radioactive contamination in White Oak Creek came from ORR's X-10 facility (formerly Clinton Laboratories and now known as the Oak Ridge National Laboratory [ORNL]). The entire ORNL site encompasses approximately 26,580 acres. The main operations at the laboratory take place on about 4,250 acres—the original X-10 site. The ORNL site is located in two valleys: Bethel Valley and Melton Valley. In 1943, the X-10 site was built as a "pilot plant" to demonstrate plutonium production and separation. The government had planned to run the X-10 site for 1 year, but this time frame was made indefinite as operations at the facility were broadened. Over time, operations at X-10 grew to include nuclear fission product separation, nuclear reactor safety and development, and radionuclide production for worldwide use in the medical, industrial, and research fields. Today, the ORNL site is globally recognized as a research and development laboratory.

White Oak Creek travels south along the X-10 border, flows through or past several contaminated sources in Melton Valley (e.g., solid waste storage areas), and ultimately empties into White Oak Lake. The government had anticipated using this man-made lake as a "settling basin" for radionuclides released from the X-10 site. Some of the contaminants, however, did not settle in White Oak Lake. Instead, they flowed over White Oak Dam into the White Oak Creek Embayment, and then entered the Clinch River. As contaminants in White Oak Creek surface water enter the Clinch River, their concentrations will dilute; and when the Clinch River meets the Tennessee River, the concentrations will dilute even further. The ORR-related surface water and sediment that traveled through the Clinch River eventually flowed into the LWBR. The LWBR, which is located downstream of the ORR, extends from the confluence of the Clinch River and the Tennessee River to the Watts Bar Dam. Between 1944 and 1991, approximately 200,000 curies of radioactive waste were discharged from X-10 into the Clinch River via White Oak Creek.

ATSDR concluded that past, current, and future exposures to radionuclides released from White Oak Creek to the Clinch River/Lower Watts Bar Reservoir are not a public health hazard.

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 X-10 radionuclides that entered the Clinch River or Lower Watts Bar Reservoir via White Oak Creek. However, 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.

Past Exposure (1944–1991)

ATSDR evaluated past exposure to radionuclides released into the Clinch River from the X-10 site via White Oak Creek. ATSDR's evaluation showed that the estimated external and internal radiation doses were not expected to cause harmful health effects. Therefore, ATSDR concluded that past off-site exposure to those radionuclides traveling from X-10 to the Clinch River via White Oak Creek was not a public health hazard.

To evaluate past exposure to radionuclide releases from the X-10 site via White Oak Creek, ATSDR primarily relied on data generated during Task 4 of the TDOH's *Reports of the Oak Ridge Dose Reconstruction, 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* (referred to as the "Task 4 report"). The Task 4 team conducted a screening process that allowed the team to estimate the dose and subsequent risk (to individuals and to target organs) associated with exposure to 24 radionuclides in Clinch River sediment, surface water, and biota. The team assumed that individuals would have been exposed between 1944 and 1991—a period of up to 48 years—and that exposure to radionuclides would have occurred during recreational activities or from the consumption of water, milk, fish, local meats, or local crops. The Task 4 team used conservative screening parameters with the intention of calculating estimates of risk that are not likely to underestimate the actual risk to any exposed individual. Meaning, for each radionuclide and exposure pathway evaluated, the Task 4 team expected these calculated estimates to overestimate the risk for most or all real individuals.

Through its screening process, the Task 4 team concluded that 16 out of 24 radionuclides released from White Oak Creek to the Clinch River did not need further evaluation because the estimated screening indices, (i.e., the calculated probabilities of developing cancer), were below the minimal level of concern. The Task 4 team further studied the following radionuclides: cobalt 60 (Co 60), strontium 90 (Sr 90), niobium 95 (Nb 95), ruthenium 106 (Ru 106), zirconium 95 (Zr 95), iodine 131 (I 131), cesium (Cs 137), and cerium 144 (Ce 144). In addition, the team eliminated the following pathways from further analysis:

- swimming,
- irrigation,
- produce ingestion, and
- contact with dredged sediment.

The pathways requiring additional evaluation included drinking water, fish consumption, external radiation from contaminants in shoreline sediments, and ingestion of milk and meat from cattle that grazed near the river.

For this public health assessment, ATSDR used the Task 4 report results to re-evaluate past radionuclide exposures. ATSDR also used the report to estimate doses to community members who consumed local livestock or milk, or who used the Clinch River downstream from the mouth of White Oak Creek for recreation or for drinking water. These estimated doses for past radionuclide exposures to community members varied by critical organ, by pathway of exposure, and by gender.

ATSDR's evaluation indicated that people who ate fish taken from that part of the Clinch River near Jones Island received the highest estimated doses of radiation. Doses from fish consumption exceeded dose estimates for all exposure pathways by at least a factor of 6. Primarily, the dose depended on how often people ate fish and on the area of the Clinch River where the fish were collected. The highest cumulative organ doses (1944–1991) were for individuals who consumed fish frequently (1 to 2.5 fish meals per week) and caught their fish near Jones Island, close to the mouth of White Oak Creek. For people consuming fish from the Jones Island area of the Clinch River, estimated organ doses were higher than doses received by people who walked along the shore or who ingested water, milk, meat, and fish at locations downstream of Jones Island.

The Task 4 authors predicted that from any of the exposure pathways, human bone surface received the highest radiation dose. The higher doses to the bone reflect the additional contribution from Sr 90. Still, the maximum annual dose of radiation to the whole body received by people who lived on or used the Clinch River (4 mrem per year) is well below (25 times less than) the 100 mrem per year dose recommended for the public by ATSDR, by the International Commission on Radiological Protection (ICRP), by the U.S. Nuclear Regulatory Commission (NRC), and by the National Council on Radiation Protection and Measurements (NCRP). Furthermore, the estimated annual whole-body dose of 4 mrem is about 2% of the 360 mrem that the average U.S. citizen receives each year from background radiation (i.e., levels typically found in the environment and in sources from human activities and products, such as medical x-rays).

The maximum dose to the whole body over a lifetime (estimated committed effective dose of 278 mrem over 70 years) from all water and sediment exposure pathways is well below (18 times less than) ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years. Doses below this value are not expected to result in observable health effects. Radiation lifetime doses to critical organs (e.g., bone, lower large intestine, red bone marrow, breast, and skin) are also less than ATSDR's comparison values. ATSDR also conducted a separate analysis of possible exposures to radionuclides for Happy Valley residents who relied on the K-25 water intake along the Clinch River for their drinking water. ATSDR's estimated annual whole-body dose of 14 mrem from drinking water at Happy Valley in the past is at least 7 times lower than ATSDR's MRL of 100 mrem/year and the ICRP, NRC, and NCRP recommended maximum dose for the public of 100 mrem/year. Therefore, people who lived along or used the Clinch River and who in the past were exposed to levels of radionuclides from White Oak Creek were exposed at levels that are not considered to be a public health hazard.

Current and Future Exposure (1988–Present and Future)

ATSDR evaluated current and future exposure to radionuclides released from the X-10 site to the Clinch River and the LWBR via White Oak Creek. ATSDR evaluated current exposure to radionuclides via consumption of surface water, dermal contact with surface water and sediment, and consumption of fish and game. ATSDR's review of environmental data collected in and around the Clinch River and LWBR areas shows that the following practices

- *annual environmental monitoring,*
- *institutional controls intended to prevent disruption of sediment,*
- *on-site engineering controls to prevent off-site contaminant releases, and*
- *DOE continuing its expected appropriate and comprehensive system of monitoring (e.g., of remedial activities and contaminant levels in media), maintenance, and institutional and engineering controls,*

have limited exposure to the current levels of radionuclides in surface water, sediment, fish, and game to the point that radionuclides are not expected to cause any current or future harmful health effects. Given this evaluation, ATSDR concludes that current and future off-site exposure to radionuclides in the Clinch River and the LWBR via White Oak Creek is not a public health hazard.

In its evaluation of current exposures and doses related to releases from White Oak Creek, ATSDR used, for data from 1989 to 2003, DOE's Oak Ridge Environmental Information System (OREIS). OREIS contains data related to compliance, environmental restoration, annual site summary reports, and surveillance activities, which include but are not limited to studies of the Clinch River embayment and the Lower Watts Bar Reservoir. ATSDR also obtained 1989–1994 data from ATSDR's 1996 health consultation entitled *Health Consultation for U.S. DOE Oak Ridge Reservation: Lower Watts Bar Reservoir Operable Unit. Oak Ridge, Anderson County, Tennessee. Atlanta, Georgia: U.S. Department of Health and Human Services. February 1996.* These data include environmental sampling from the 1980s and 1990s that DOE, TVA, and various consultants had collected and assembled, as well as data from TVA's 1993 and 1994 annual radiological environmental reports for the Watts Bar Nuclear Plant. ATSDR prepared the 1996 health consultation to respond to community members' concerns about possible exposures to contaminants left in place in LWBR sediment. As part of this process, ATSDR evaluated potential hazards from exposure to either undisturbed or dredged LWBR contaminated sediment and reviewed institutional controls intended to prevent disruption of the contaminated sediment as outlined by the 1991 Watts Bar Interagency Agreement.

ATSDR evaluated *current* exposures to radionuclides via consumption of surface water, dermal contact with surface water and sediment (i.e., shoreline and dredged channel sediment), and consumption of fish and game. ATSDR based its evaluation of *future* exposures on current doses and exposures related to

- releases from White Oak Creek,
- data on current contaminant levels in the LWBR and the Clinch River,
- data on radionuclide concentrations in White Oak Creek,[1]
- institutional controls now in place to monitor contaminants in the LWBR and in the Clinch River, and
- consideration of the possibility that remedial activities could release radionuclides to White Oak Creek.

The cities of Kingston, Spring City, and Rockwood draw drinking water from the Tennessee River system. TDEC's Division of Water Supply regulates drinking water at all public water systems in Tennessee under EPA's Safe Drinking Water Act. As a requirement of this program, TDEC ensures that all public water systems in the state meet safe drinking water standards for a variety of chemical contaminants and radionuclides. TDEC's monitoring of the Kingston, Spring City, and Rockwood public water supplies indicates that the drinking water consistently meets safe drinking water standards. Using these results, ATSDR considers this water safe for consumption and for other household uses.

[1] These data show that the radionuclide releases as well as the concentrations in the water and along the shoreline have decreased over time because of remedial actions and preventive measures at X-10, physical movement of sediments from the area, and radiological decay.

Lower Watts Bar Reservoir (1988–Present and Future)

ATSDR estimated committed effective doses—that is, doses to the whole body that occur over a lifetime—for persons who have been exposed to radionuclides by

- contacting shoreline or dredged sediment,
- swimming in or showering with surface water,
- ingesting surface water, or
- eating fish from the LWBR.

In deriving exposure doses for LWBR, ATSDR scientists used worst-case hypothetical exposure scenarios with conservative (i.e., protective) assumptions that produce doses much higher (i.e., overestimate exposure) than the levels to which people are actually exposed. ATSDR's estimated doses vary by potential pathway of exposure to radionuclides, ranging from 3.5 mrem from swimming in or showering with Lower Watts Bar Reservoir surface water over a period of 70 years to 1,400 mrem over a period of 70 years from walking on and handling contaminated sediments dredged from the LWBR deep river channels. Nonetheless, ATSDR's conservatively derived, committed effective dose to the whole body for all pathways combined is less than 1,900 mrem—2.5 times below ATSDR's radiogenic CV of 5,000 mrem. ATSDR derived the *radiogenic comparison value* of 5,000 mrem over 70 years after reviewing the peer-reviewed literature and other documents developed to review the health effects of ionizing radiation. Doses below this value are not expected to result in observable health effects. Furthermore, the estimated annual whole-body dose is less than 30 mrem, which is below (3 times less than) the dose of 100 mrem per year recommended for the public by ATSDR, ICRP, NCRP, and NRC. Therefore, ATSDR considers that the current exposures associated with the detected level of radionuclides in sediment, surface water, and fish of the LWBR pose no threat to public health.

Clinch River (1989–Present and Future)

ATSDR's estimated committed effective dose to the whole body for all exposure pathways along the Clinch River combined is, for persons to 70 years of age, less than 240 mrem—over 20 times below ATSDR's radiogenic CV of 5,000 mrem over 70 years. The estimated annual whole-body dose is less than 3.4 mrem—nearly 30 times below ATSDR's screening comparison value (see text box) and about 30 times below ICRP's, NCRP's, and NRC's recommended value for the public of 100 mrem/year. The current radiation doses from exposure to radionuclides along the Clinch River varied by organ. ATSDR's estimates show that the *bone* receives the highest total committed equivalent dose over an average (to age 70) lifetime of exposure to radionuclides detected along the Clinch River. The highest committed equivalent doses to the bone were associated with a 15-year-old ingesting goose muscle or liver (230 mrem) and fish (114 mrem) over a period of 55 years. Much lower bone doses were associated with ingestion of Clinch River water (2.8 mrem) and external exposures from walking on sediment (13 mrem) and swimming (1.2 mrem) in the study area. That said, however, the bone dose estimate from all pathways combined, based on exposures for adults occurring over a 50-year period, is less than 218 mrem over 50 years. This is at least 1,788 times lower than the doses of 390,000 to 620,000 mrem associated with bone cancers in radium dial workers. For all pathways combined for adults following 50 years of exposure, the committed equivalent dose of 270 mrem to the lower large intestine was about 18 times less than ATSDR's radiogenic comparison value of 5,000 mrem over 70 years. For adults, the committed equivalent dose to the skin over a 50-year exposure is less than 6 mrem—1,500 times below the 9,000 mrem value based on the Biological Effects of Ionizing Radiation (BEIR) V report of patients irradiated for the treatment of ringworm. Therefore, ATSDR considers that current exposures to detected levels of radionuclides in sediment, surface water, fish, geese, and turtles of the Clinch River pose no threat to public health.

> Comparison values (CVs) are doses (health guidelines) or substance concentrations (environmental guidelines) set well below levels known or anticipated to result in adverse health effects. *Health guidelines* are derived based on data drawn from the epidemiologic and toxicologic literature with many uncertainty or safety factors applied to ensure that they are amply protective of human health. *Environmental guidelines* are derived from the health guidelines and represent concentrations of a substance (e.g., in water, soil, and air) to which humans may be exposed via a particular exposure route during a specified period of time without experiencing adverse health effects.
>
> During the public health assessment process, ATSDR uses CVs as screening levels. Substances detected at concentrations or doses above CVs might be selected for further evaluation.

Given its evaluation, ATSDR concludes that the levels of radionuclides released from White Oak Creek to the Clinch River and to the LWBR would not be expected to result in harmful health effects for either adults or children who have used or who might continue to use the waterways for recreation, food, or drinking water. **ATSDR therefore concludes that past, current, and future uses of these watersheds do not pose a health hazard**.

II. Background

II.A. Site Description

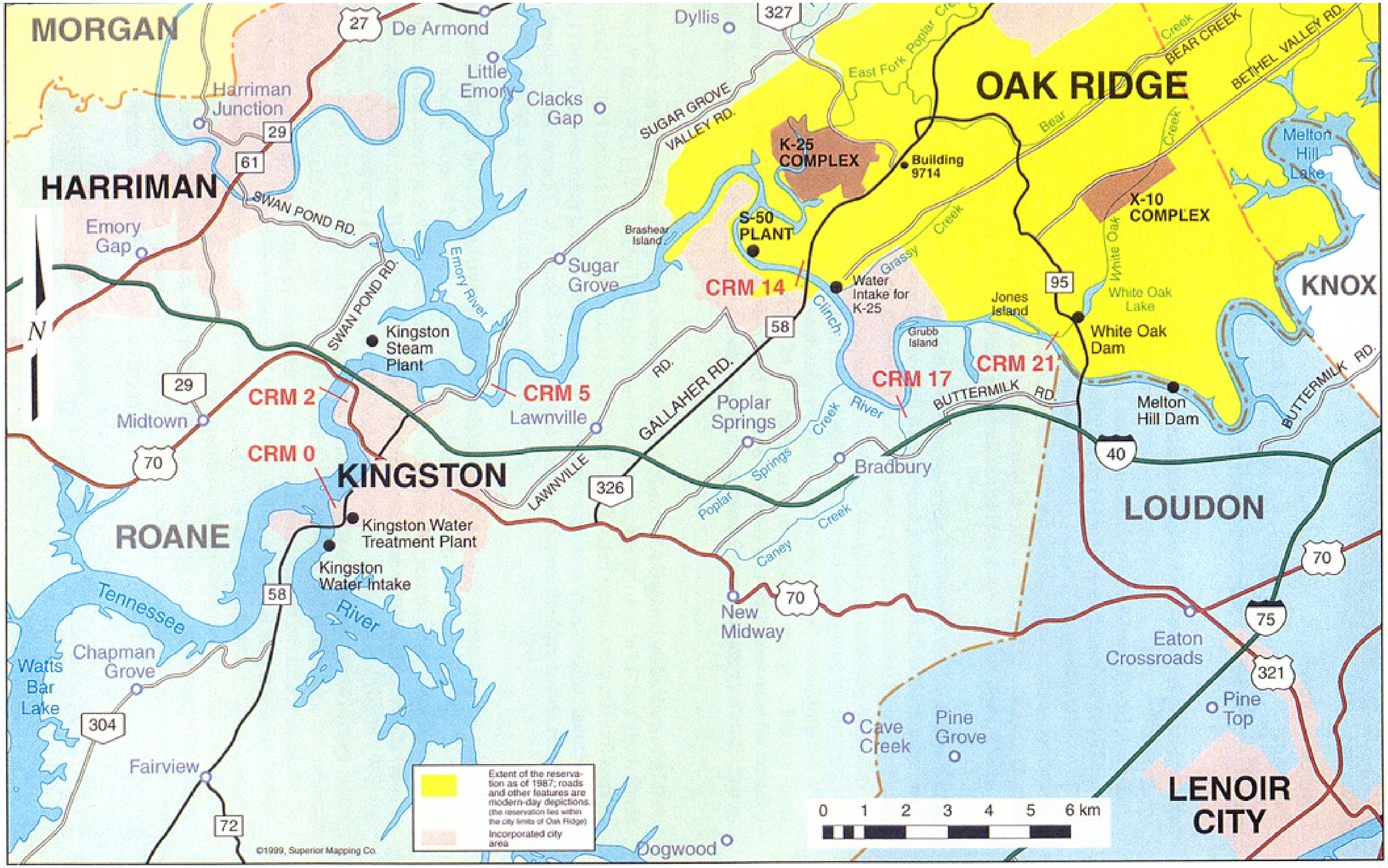
In 1942, during World War II, the U.S. government, under the Manhattan Project initiative, developed the Oak Ridge Reservation (ORR) to produce and study nuclear material needed to make nuclear weapons (ChemRisk 1993b; ORHASP 1999; TDOH 2000). The ORR is located in eastern Tennessee, approximately 15 miles west of Knoxville, and is situated in both Roane and Anderson Counties (ChemRisk 1993b; Jacobs Engineering Group Inc. 1996; ORNL et al. 2002). The southern and western borders of the ORR are formed by the Clinch River, and most of the reservation lies within the Oak Ridge city limits (EUWG 1998). The ORR plants are isolated from the city's populated areas. Figure 1 shows the location of the ORR.

When in 1942 the federal government acquired the ORR, the reservation consisted of 58,575 acres (91.5 square miles). Since that time the federal government has transferred 24,340 (38.0 square miles) of the original 58,575 acres to other parties (e.g., City of Oak Ridge, Tennessee Valley Authority [TVA]), with the U.S. Department of Energy (DOE) maintaining control of the remaining 34,235 acres (53.5 square miles) (Jacobs Engineering Group Inc. 1996; ORNL et al. 2002). Please see Figure 2 for the original and current ORR boundaries.

Under the Manhattan Project, the government constructed four facilities at the ORR. The X-10 site (formerly known as the Clinton Laboratories and now part of what is referred to as the Oak Ridge National Laboratory [ORNL]) was built to produce and separate plutonium. The K-25 site (formerly known as the Oak Ridge Gaseous Diffusion Plant [ORGDP] and now referred to as the East Tennessee Technology Park [ETTP]), the Y-12 plant (now known as the Y-12 National Security Complex), and the former S-50 site (now part of the ETTP) were developed to manufacture enriched uranium (ChemRisk 1993b; Jacobs Engineering Group Inc. 1996; TDEC 2002; TDOH 2000).[2]

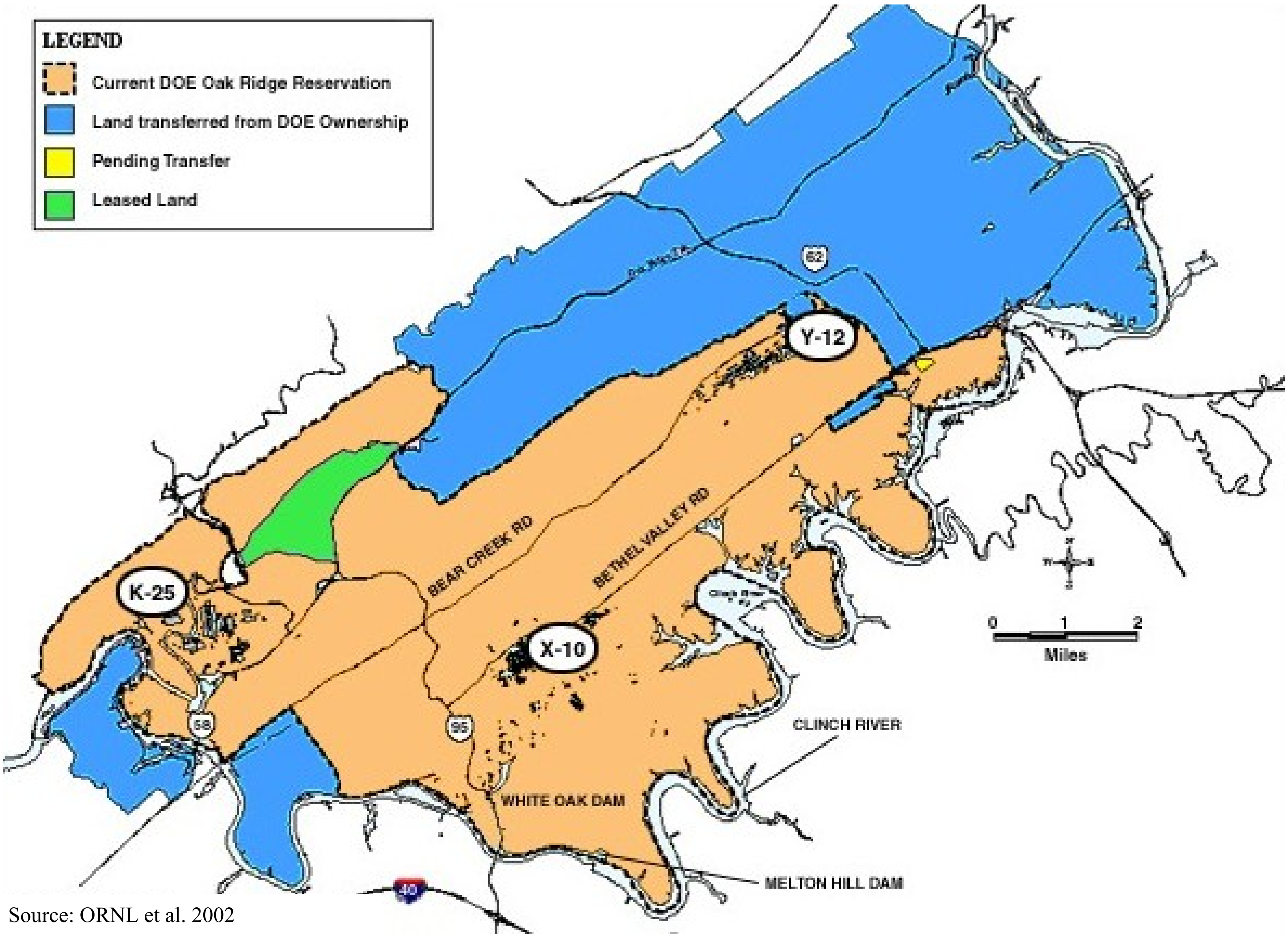
[2] Since this health assessment focuses on radionuclide releases from X-10 to the Clinch River via White Oak Creek, the other main facilities on the ORR are not discussed in detail.

Figure 1. Location of the Oak Ridge Reservation



Source: ChemRisk 1999a

Figure 2. Original and Current ORR Boundaries



Source: ORNL et al. 2002

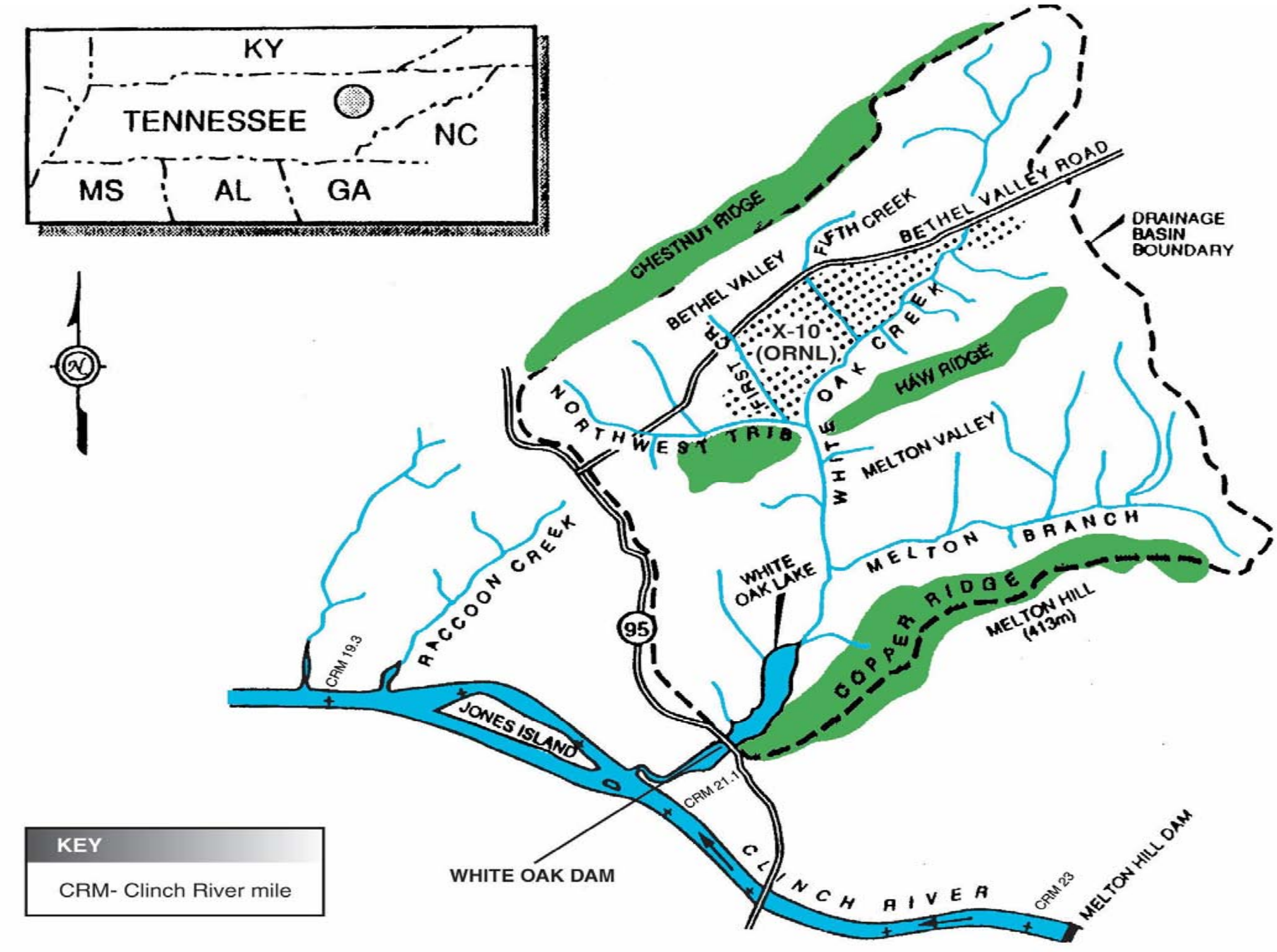
X-10 is now known as the Oak Ridge National Laboratory (ORNL). The entire ORNL site encompasses approximately 26,580 acres and is located in Roane County. The main operations at the laboratory take place on about 4,250 acres—the original X-10 site (Bechtel Jacobs Company LLC et al. 1999; ORNL et al. 1999; TDEC 2002).

The X-10 site is about 10 miles southwest of the city center of Oak Ridge, and is surrounded by heavily forested ridges including Chestnut Ridge, Haw Ridge, and Copper Ridge (ChemRisk 1999a; TDOH 2000). The X-10 site is situated within two watersheds: Bethel Valley and Melton Valley (ORNL et al. 1999). Please see Figure 3 for the location of X-10 in relation to Bethel Valley and Melton Valley. The main laboratory at X-10 is located along Bethel Valley Road, within Bethel Valley (ChemRisk 1999a; ORNL et al. 1999). The X-10 site also contains remote facilities and waste storage areas in Melton Valley (ORNL et al. 1999). White Oak Creek, which begins in Bethel Valley, flows in a southerly direction along the eastern border of the plant and travels through a gap in Haw Ridge before entering Melton Valley (ChemRisk 1993b, 1999a). From Melton Valley, White Oak Creek joins the Clinch River at Clinch River Mile (CRM) 20.8 below Melton Hill Dam (ChemRisk 1999a). See Figure 4 for the location of White Oak Creek and the relationship between X-10, White Oak Creek, White Oak Dam, the Clinch River, and the Watts Bar Reservoir.

Before 1963, the Clinch River close to CRM 20.8 was characteristic of a riverine system. Near the mouth of Grassy Creek, at about CRM 14, the Clinch River "becomes wider, the flow decreases, and Watts Bar Reservoir has a greater influence on the water conditions" (Blaylock 2004). Also before 1963, except during floods on the Clinch River, little backflow entered the White Oak Creek Embayment (Hoffman 2005).

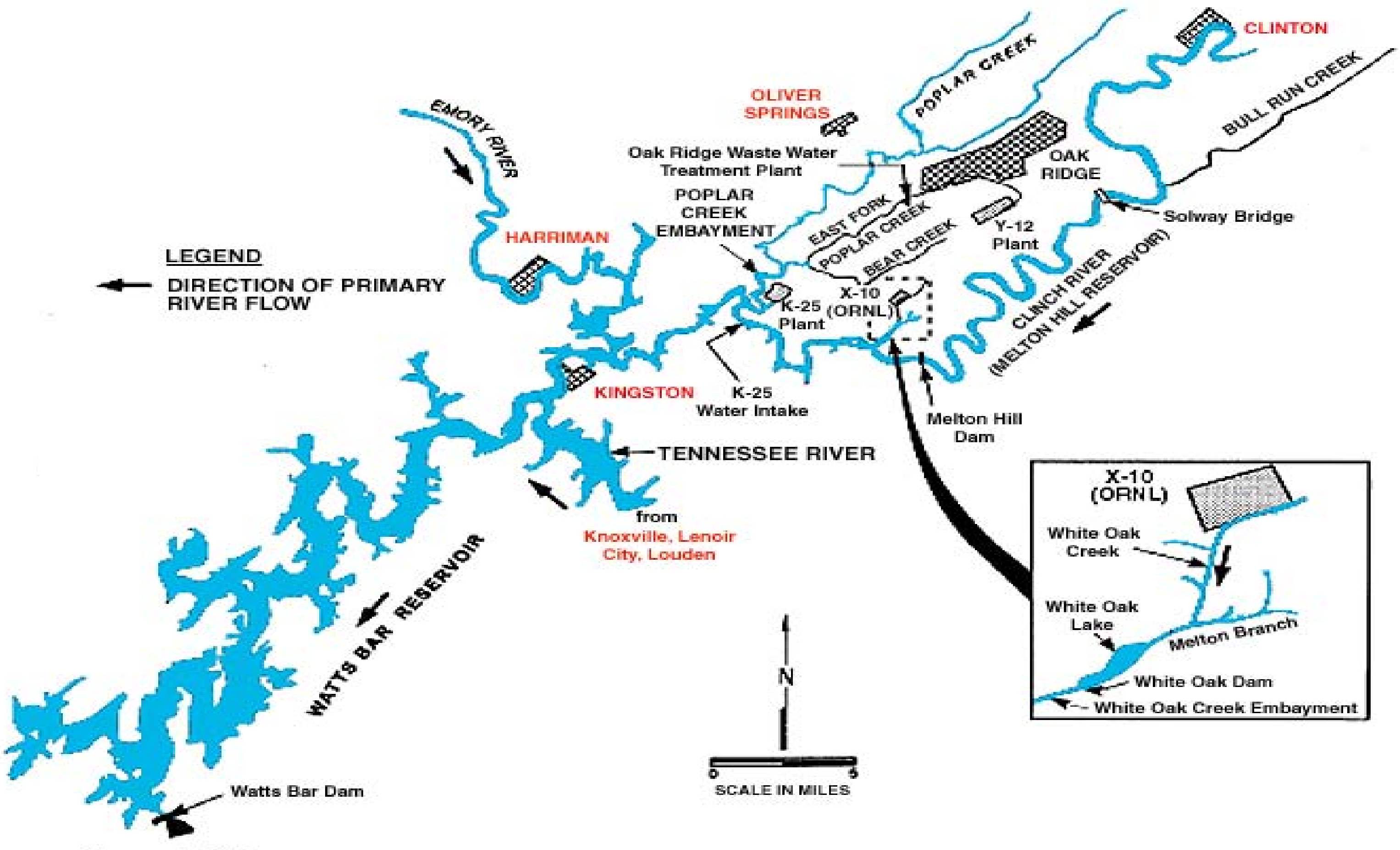
After the construction of the Melton Hill Dam was completed in 1963, the flow of the Clinch River changed. In the morning and evening, Melton Hill Dam releases water when power demands are being met. During remaining times of the day, flow past the mouth of White Oak Creek is extremely minimal. The volume of water released on a daily basis during peak periods is about the same as the quantity of releases prior to Melton Hill Dam's construction, although during peak operations the flow past the mouth of White Oak Creek is significantly higher (Blaylock 2004). The water surge into and out of the embayment, caused by daily releases of

Figure 3. Location of X-10 in Relation to Bethel Valley and Melton Valley



Source: ChemRisk 1999a

Figure 4. Location of White Oak Creek and the Relationship Between X-10, White Oak Lake, White Oak Dam, the Clinch River, and the Watts Bar Reservoir



Source: ChemRisk 1993b

water from Melton Hill Dam and flood flows in White Oak Creek, eroded sediments containing cesium 137 and other contaminants (SAIC 2005). This large volume of water released from Melton Hill Dam caused a backflow up White Oak Creek Embayment and scoured the embayment sediment (Hoffman 2005). "This increased flow can influence the distribution of radionuclides released from White Oak Creek and the deposition of the radionuclides in the Clinch River" (Blaylock 2004). See Figure 1 for the locations of CRM 20.8 and 14, Melton Hill Dam, Watts Bar Reservoir, Clinch River, and White Oak Creek.

II.B. Operational History

Beginning in the early 1940s, the ORR used radioactive material for various processes, such as uranium enrichment, plutonium production, plutonium separation, and the development of separation processes for additional radionuclides (ChemRisk 1993b; Jacobs Engineering Group Inc. 1996).

The X-10 site was built in 1943 as a "pilot plant" to demonstrate plutonium production and chemical separation. The government had intended to operate the facility for only 1 year. This initial time period was, however, extended indefinitely as operations were continued and expanded at X-10 (ChemRisk 1993b; ChemRisk 1999a; TDOH 2000). Because X-10 was developed to produce and separate plutonium, the main plant contained two parts that were both built in 1943: 1) a plutonium production plant called the "Clinton Pile" and later referred to as the ORNL graphite reactor, and 2) a chemical pilot plant developed to separate and purify plutonium. The chemical pilot plant focused on recovering small amounts of plutonium from fuel that was irradiated in the Clinton Pile (ChemRisk 1993b).

After World War II, the facility broadened its focus to include non-weapons related activities, such as the physical and chemical separation of nuclear fission products, the creation and assessment of nuclear reactors, and the production of a range of radionuclides for global use in the medicinal, industrial, and research disciplines (ChemRisk 1993b; U.S.DOE 1994a). In the 1950s and 1960s, the X-10 site became a worldwide research center to study nuclear energy and to investigate the physical and life sciences that are related to nuclear energy. From 1958 to 1987, the Oak Ridge Research Reactor operated to support various scientific experiments at X-10. For a long period of time, this reactor was the main radionuclide supplier to the "free world" for medical, research, and industrial purposes (Johnson and Schaffer 1992; Stapleton 1992; Thompson 1963).

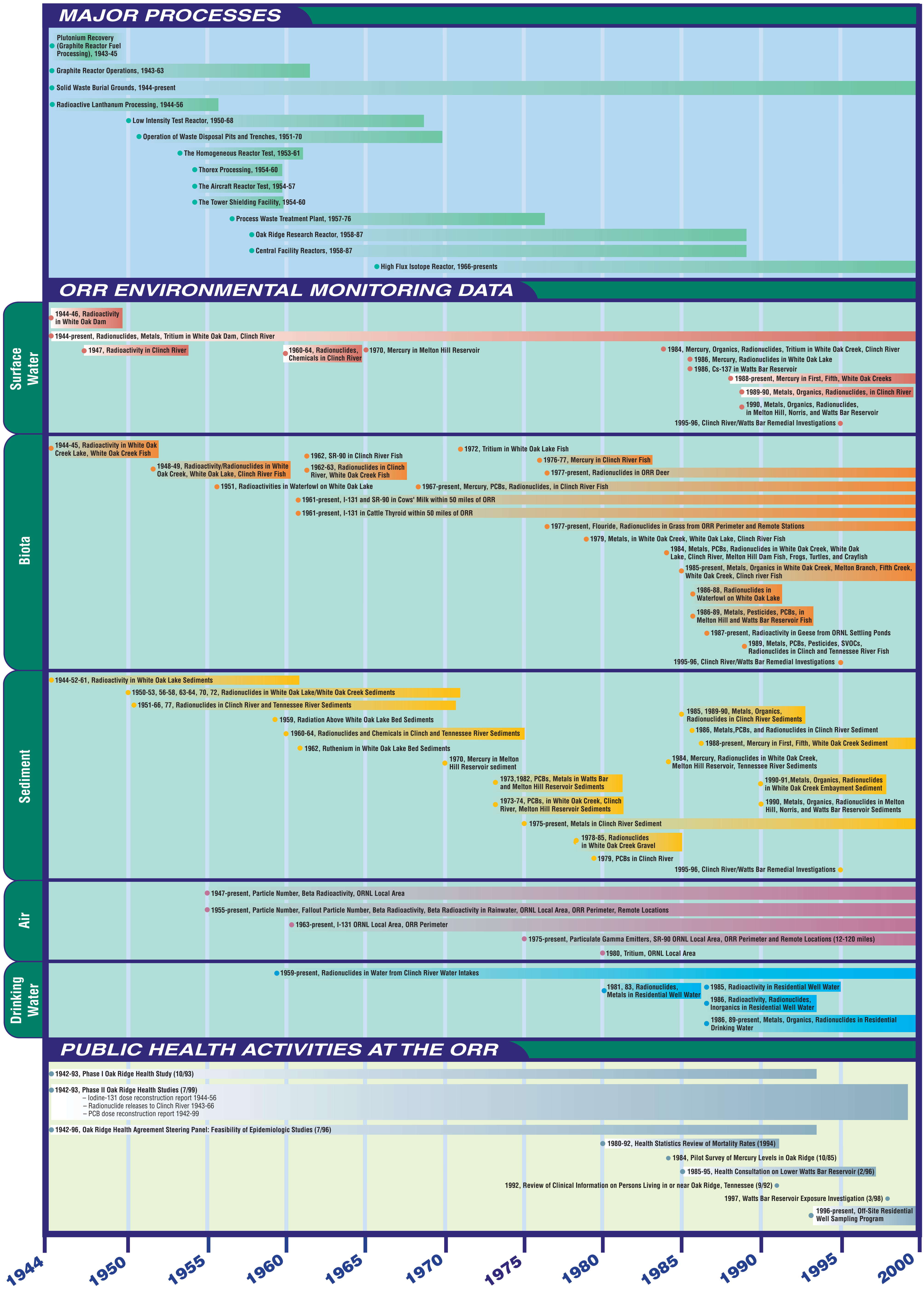
Following the establishment of the U.S. DOE in the 1970s, the research focus at X-10 was extended to include the study of energy transmission, conservation, and production (UT-Battelle 2003). For more than 50 years, the ORR has been the site for extensive scientific investigation by scores of ecologists and environmental scientists. The ORR is a natural haven for wildlife and plants with many rare and endangered species. Today, the X-10 site receives worldwide recognition as a facility for extensive research and development in several areas of science and technology. In addition, the X-10 site produces numerous radioactive isotopes that have significant uses in medicine and research (TDEC 2002). See Figure 5 for a time line of the major processes at the X-10 site.

The operational history of X-10 is described in greater detail in the 1993 Dose Reconstruction Feasibility Study (ChemRisk 1993b). The main processes and activities that are associated with off-site releases of contaminants from X-10 include: 1) production of radioactive lanthanum (RaLa processing) (1944–1956), 2) Thorex processing of short-decay irradiated thorium (approximately 1954–1960), 3) graphite reactor operations (1943–1963), 4) processing of graphite reactor fuel for plutonium recovery (1943–1945), and 5) waterborne and airborne waste disposal (1943–present). For additional details, please see Section 2.1 and 2.3 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 1993b).

Because the government had planned to run the X-10 site for only 1 year, minimal waste had been expected from the facility's chemical separation processes (ChemRisk 1993b; ChemRisk 1999a; Jacobs Engineering Group Inc. 1996). As a result, the intended waste disposal practices quickly proved insufficient for the amount of wastes generated at X-10. When X-10 began operating in 1943, liquid wastes were put into several underground "gunite" tanks[3] (ChemRisk 1999a; Jacobs Engineering Group Inc. 1996; ORHASP 1999; Spalding and Boegly 1985). These

[3] Tanks were constructed of a water, concrete, and sand mixture called "gunite," which was sprayed over a wire mesh and steel reinforcing rod frame (USDOE 2000).

X-10 Facility Time Line

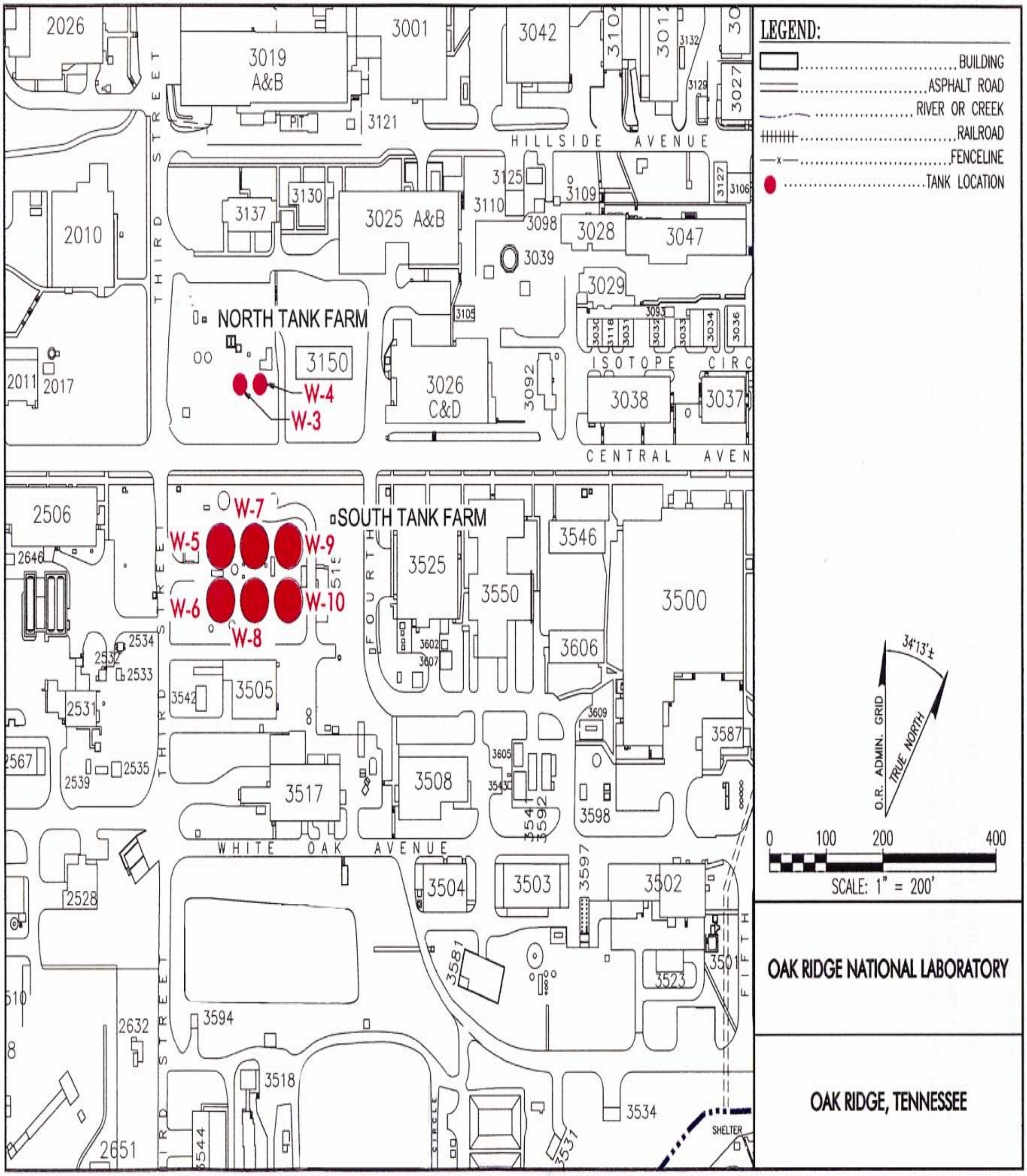


tanks, which are divided into the North Tank Farm and the South Tank Farm, are located in Bethel Valley within the center of X-10's main facility area (SAIC 2002). Please see Figure 6 for the location of the tanks.

Each gunite tank held 170,000 gallons, but the amount of liquid wastes and sludges quickly filled up the tanks. The sludges were kept in the gunite tanks; however, the liquid wastes were held until enough radioactivity was lost through decay before the liquid waste (combined with diluting water) could be released to White Oak Creek (ChemRisk 1999a; Jacobs Engineering Group Inc. 1996; ORHASP 1999; Spalding and Boegly 1985; USDOE 1996a). The creek received the liquid wastes from the tanks and storm water drainage as it flowed through the X-10 facilities. In June 1944, the 3513 Pond was created as a supplementary settling basin for gunite tank liquids and as a basin where short-lived radionuclides could further decay before being released to White Oak Creek (Jacobs Engineering Group Inc. 1996; Spalding and Boegly 1985).

Prior to emptying into the Clinch River, White Oak Creek flows through several contaminated areas in Melton Valley (for example, the old hydrofracture facility) before it runs into White Oak Lake (on-site) (TDOH 2000). This lake was used as a final "settling basin" since 1943 for radionuclides released from X-10 (Blaylock et al. 1993; ChemRisk 1999a; TDOH 2000; USDOE 2002a). See Figure 7 for a photograph (1991) of the X-10 site, White Oak Lake, the X-10 disposal area, and the Clinch River. White Oak Lake was made when White Oak Dam was built across White Oak Creek in 1943. This dam was used as a basin for further settling of the solids that remained (Jacobs Engineering Group Inc. 1996). Please see Figure 4 for the location of White Oak Dam. But some waste products did not settle into the 3513 Pond or White Oak Lake; instead, some of the flow spilled over White Oak Dam into the White Oak Creek Embayment and then reached the Clinch River (TDOH 2000; USDOE 2002a). Most of the wastes released to White Oak Creek are associated with former operations at X-10. This waste includes but is not limited to radionuclides. The X-10 site began discharging radioactive waste to the Clinch River via White Oak Creek in 1943. Thus, the Tennessee Department of Health (TDOH) conducted Task 4 of the *Reports of the Oak Ridge Dose Reconstruction, 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* to evaluate whether off-site

Figure 6. Location of the Gunite Tanks at the X-10 Site



Source: SAIC 2002

Figure 7. Photograph (1991) of the X-10 Site, White Oak Creek, White Oak Lake, White Oak Dam, X-10 Disposal Areas, White Oak Creek Embayment, Sediment Retention Dam, and the Clinch River

Source: TDOH 2000

populations have been exposed to radioactive waste from X-10 between 1944 and 1991 (the Task 4 dose reconstruction is used to examine past exposures in this public health assessment).

Since 1944, solid wastes generated by X-10 were disposed of at six solid waste storage areas (SWSAs) (USDOE 1994a). The first three SWSAs (1-3) are located in Bethel Valley and the remaining three SWSAs (4-6) are located in Melton Valley (ChemRisk 1993b, 1999a). For a map of these solid waste storage areas, please see Figure 8. Between 1955 and 1963, these waste storage areas were allocated as the Southern Regional Burial Ground by the Atomic Energy Commission. Throughout this time period, the X-10 site functioned as a main disposal location for wastes from more than 50 off-site installations (e.g., Knolls Atomic Power Laboratory, Battelle Memorial Institute), various research facilities, small contractors, several isotope consumers, and Atomic Energy Commission installations (EUWG 1998; Lockheed Martin Energy Systems, Inc. 1998). Please see Table 1 for more information on these disposal areas.

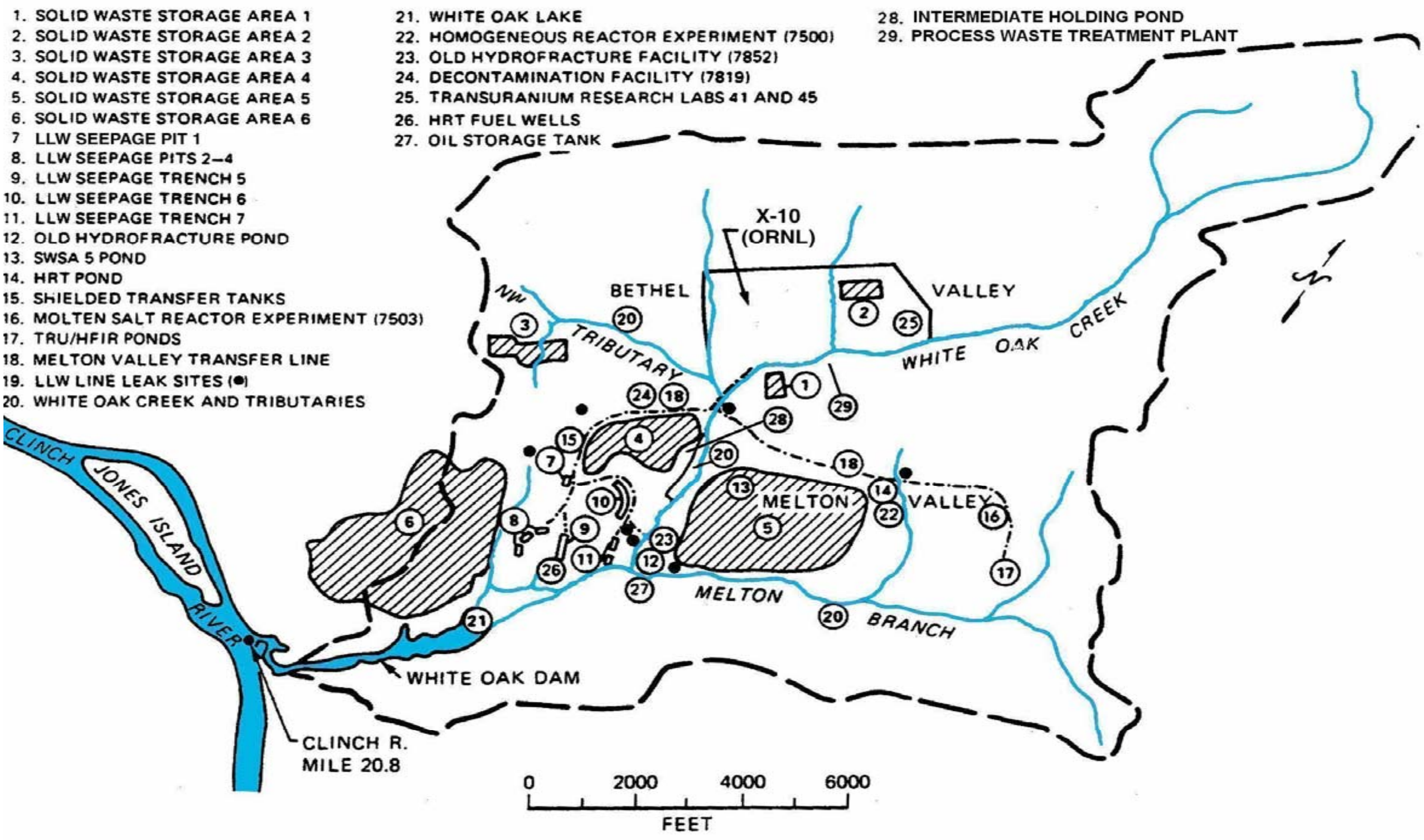
Table 1. Solid Waste Disposal Areas at the X-10 Site

Disposal Area	*Period of Operation*	*Status*	*Acreage*
1	1943–1944	Closed	1
2	1944–1946	Closed	4
3	1946–1951	Closed	6
4	1951–1959	Closed	23
5	1959–1973	Closed	50
6	1969–Unknown	Closed	68 (14.5 acres are usable)

Source: Bates 1983; TDEC 2006a

While X-10's operations continued, the amount of wastes generated at the site continued to increase. During X-10's early years of operation, after liquid radioactive wastes were initially treated they were pumped into an Intermediate Holding Pond (IHP) adjacent to the east side of SWSA 4 (see Figure 8 for the general location of the IHP next to SWSA 4 and Section II.C.2. for IHP-related remedial activities). The "hottest" radioactive substances decayed in the pond; the radionuclides that did not settle into the pond flowed downstream to the Clinch River (TDEC 2003a). In addition, between 1951 and 1976 the facility alternately used seven unlined "earthen pits" for liquid waste disposal (Spalding and Boegly 1985). A process waste treatment plant (PWTP), shown on Figure 8, was built in 1957 to retrieve fission products from these (and

Figure 8. Location of Solid Waste Storage Areas (SWSAs) at the X-10 Site



KEY
HFIR- high flux isotope reactor; HRT- homogenous reactor test; LLW- low-level waste; SWSA- solid waste storage area; TRU- transuranic

Source: ChemRisk 1999a

additional) liquid wastes before their disposal (a more advanced facility replaced this in 1976) (USDOE 1994a). In 1960, the "earthen pit" (also known as a low-level waste [LLW] seepage pit) was changed to an "earth-covered trench" (also called a LLW seepage trench) to reduce inadvertent radiation exposure and rainwater buildup.[4] Over time, leaks occurred at several of these pits, which resulted in the releases of various radionuclides (Spalding and Boegly 1985).

Trenches were used until 1966, when "hydrofracture technology"[5] was initiated for liquid waste disposal (Spaulding and Boegly 1985). The first hydrofracture facility operated between 1964 and 1979; 26 injections were made during this time period. A newer facility started performing injections in June 1982, but this operation was discontinued in 1984 because of uncertainties related to potential leaching into deep groundwater (Boyle et al. 1982; Ohnesorge 1986). ATSDR evaluates hydrofracture technology in its public health assessment on groundwater (available at http://www.atsdr.cdc.gov/HAC/PHA/region_4.html#groundwater).

In addition to releases from disposal areas, radioactive substances were discharged when White Oak Lake was partially drained in October 1955. The lake was drained to give X-10 a greater capacity to handle large discharges and to lessen the chance that ducks would live in the contaminated water (Blaylock et al. 1993). Before it could revegetate, severe rains in 1956 caused a flood that eroded the bottom sediment of White Oak Lake (Blaylock et al. 1993; ChemRisk 1999a). This resulted in the largest discharge of Cs 137 at the lake and also caused radionuclides in particulate form to deposit in the White Oak Creek Embayment. Sedimentation had covered this large amount of released cesium. Eventually, however, with the backflow of water from Melton Hill Dam into the Clinch River, the cesium gradually became uncovered (Hoffman 2005). In the early 1990s, a coffer cell dam was built at the mouth of White Oak Creek to prohibit water backflow to the White Oak Creek Embayment. After this dam was completed, the natural scouring of sediment at the embayment was prevented (ChemRisk 1999a).

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[4] These trenches operated hydraulically in a manner similar to a septic tank drain field, but with the waste being retained closely downstream rather than upstream; in this case, by virtue of the electrostatically polar nature of the clay and shale particles surrounding the trenches. These particles attracted and held a large fraction of the radioisotopes seeping out of the trenches. The trenches were also originally known as "intermediate level" liquid waste disposal trenches.

[5] Hydrofracture technology uses hydraulic pressure to create cracks in the shale bedrock layers that are below the disposal area. Low-level waste alkaline solutions are combined with cement and infused with pressure into the fracture zone. This grout mixture seals the cracks and stagnates wastes that are in the deep shale formation.

DOE predicted that 70% to 80% of radioactive substances released from X-10 to surface waters resulted from seepage at waste disposal areas (USDOE 1988). Mainly because of these disposal practices at X-10 and the heavy rains in 1956, approximately 200,000 curies of radioactive waste were discharged from White Oak Creek into the Clinch River between 1944 and 1991 (ATSDR et al. 2000; TDOH 2000). Please see Table 2 for the estimated discharges of radionuclide releases to the Clinch River via White Oak Creek (Jacobs Engineering Group Inc. 1996). Table 3 is a summary of peak annual releases from White Oak Dam for the eight "key" radionuclides—those that were identified for further evaluation based on a pathway and disease incidence analysis of 24 radionuclides (ChemRisk 2000). For additional details regarding the radioactive waste disposal history of the X-10 site, please see Section 2.1.5 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 1993b) and also Section 2.0 of Task 4 of the *Reports of the Oak Ridge Dose Reconstruction, 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* (ChemRisk 1999a). For information on current remedial activities, see Sections II.C.1. (Bethel Valley Watershed), II.C.2. (Melton Valley Watershed), and II.C.3. (Off-Site Locations) in this document.

Table 2. Estimated Discharges (in curies) of Radionuclides From White Oak Creek [a]

Year	Cs 137	Ru 106	Sr 90	TRE [b]	Ce 144	Zr 95	I 131	Co 60	H 3	TRU[c]
1949	77	110	150	77	18	180	77			0.04
1950	19	23	38	30		15	19			0.04
1951	20	18	29	11		5	18			0.08
1952	10	15	72	26	23	19	20			0.03
1953	6	26	130	110	7	8	2			0.08
1954	22	11	140	160	24	14	4			0.07
1955	63	31	93	150	85	5	7	7		0.25
1956	170	29	100	140	59	12	4	46		0.28
1957	89	60	83	110	13	23	1	5		0.15
1958	55	42	150	240	30	6	8	9		0.08
1959	76	520	60	94	48	27	1	77		0.68
1960	31	1,900	28	48	27	38	5	72		0.19
1961	15	2,000	22	24	4	20	4	31		0.07
1962	6	1,400	9	11	1	2	0.4	14		0.06
1963	4	430	8	9	2	0.3	0.4	14		0.17
1964	6	190	7	13	0.3	0.2	0.3	15	1,900	0.08
1965	2	69	3	6	0.1	0.3	0.2	12	1,200	0.50
1966	2	29	3	5	0.1	0.7	0.2	7	3,100	0.16
1967	3	17	5	9	0.2	0.5	0.9	3	13,300	1.03
1968	1	5	3	4	0.03	0.3	0.3	1	9,700	0.04
1969	1	2	3	5	0.02	0.2	0.5	1	12,200	0.20
1970	2	1	4	5	0.06	0.02	0.3	1	9,500	0.40
1971	1	0.5	3	3	0.05	0.01	0.2	1	8,900	0.05
1972	2	0.5	6	5	0.03	0.01	0.3	1	10,600	0.07
1973	2	0.7	7		0.02	0.05	0.5	1	15,000	0.08
1974	1	0.2	6		0.02	0.02	0.2	0.6	8,600	0.02
1975	0.6	0.3	7				0.3	0.5	11,000	0.02
1976	0.2	0.2	5				0.03	0.9	7,400	0.01
1977	0.2	0.2	3				0.03	0.4	6,200	0.03
1978	0.3	0.2	2				0.04	0.4	6,300	0.03
1979	0.2	0.1	2.4				0.04	0.4	7,700	0.03
1980	0.6	0	1.5				0.04	0.4	4,600	0.04
1981	0.2	0.1	1.5				0.04	0.7	2,900	0.04
1982	1.5	0.2	2.7				0.06	1.0	5,400	0.03
1983	1.2	0.2	2.1				0.004	0.3	5,600	0.05
1984	0.6	0.2	2.6				0.05	0.2	6,400	0.03
1985	0.4	0.007	3.0					0.6	3,700	0.008
1986	1.0	0	1.8					0.54	2,600	0.024
1987	0.6	0	1.2					0.12	2,500	0.006
1988	0.4	0	1.1					<0.07	1,700	
1989	1.2	0	2.9					0.13	4,100	
1990	1.1	0	3.1					0.12	3,100	
1991	1.7		2.7					0.12	2,100	
1992	0.6		2.1					0.04	1,900	
1993	0.5		2.1					0.04	1,700	
1994	0.5		2.8					0.07	2,200	
Total	**699.6**	**6,931.6**	**1,214.6**	**1,295**	**341.93**	**376.61**	**175.33**	**325.58**	**183,100**	**5.248**

Source: Blaylock et al. 1993; Martin Marietta Energy Systems, Inc. 1992, 1993; USDOE 1988

a All digits were carried through to avoid any errors from rounding numbers. Only the first two are significant.

b Total of rare earth elements, excluding cerium.

c Transuranic radionuclides.

Blank cells indicate that no data were reported.

The four radionuclides expected to be of most concern are highlighted in gray.

Table 3. Summary of Peak Annual Releases From White Oak Dam for the Eight Key Radionuclides (1944–1991)

Radionuclide	*Peak Annual Releases (curies)*			*Number of Years at 10% of Peak Release or More*
	Lower Bound	*Central Estimate*	*Upper Bound*	
Cesium 137	50	200	510	14
Ruthenium 106	1,600	2,100	2,700	5
Strontium 90	68	190	390	18
Cobalt 60	64	85	110	15
Cerium 144	70	94	120	13
Zirconium 95	72	210	440	9
Niobium 95	17	200	520	10
Iodine 131	10	68	190	10

Source: ChemRisk 2000

Annual estimates were based on data in log books, interviews with knowledgeable parties, and laboratory documents.

II.C. Remedial and Regulatory History

As a result of several on-site processes that produced nonradioactive and radioactive wastes, on November 21, 1989, EPA listed the ORR on the final National Priorities List (NPL) (EUWG 1998; USDOE 2001a; USEPA 2002a). The DOE is performing remediation activities at the reservation under a Federal Facility Agreement (FFA), which is an interagency agreement between the DOE, EPA, and TDEC. The EPA and TDEC, along with the public, help DOE select the details for remedial actions at the ORR (USDOE 2003a). These parties work collaboratively to ensure that adequate remediation activities are used, and to ensure that hazardous waste related to previous and current ORR activities is completely studied and appropriate remedial action is taken (USDOE 1996b, 2003a). DOE is conducting its investigations of the ORR under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), a program that requires an FFA be established for all NPL sites owned by the federal government (EUWG 1998; USEPA 2002b). In addition, DOE is incorporating response procedures designated by CERCLA, with mandatory actions from the Resource Conservation and Recovery Act (RCRA) (USEPA 2002b). See Figure 5 for a time line of major processes, environmental data, and public health activities associated with the X-10 site.

> The Federal Facility Agreement was implemented at the ORR on January 1, 1992. This is a legally binding agreement used to establish schedules, procedures, and documentation for remedial activities at the ORR (EUWG 1998). The Federal Facility Agreement is available online at http://www.bechteljacobs.com/pdf/ffa/ffa.pdf.

Radioactive waste material, such as Cs 137 and Sr 90, is 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). According to DOE, waste sites located in the Melton Valley Watershed "…are the primary contributors to off-site spread of contaminants" from the ORR and White Oak Creek flows through or past these areas (USDOE 2002b).

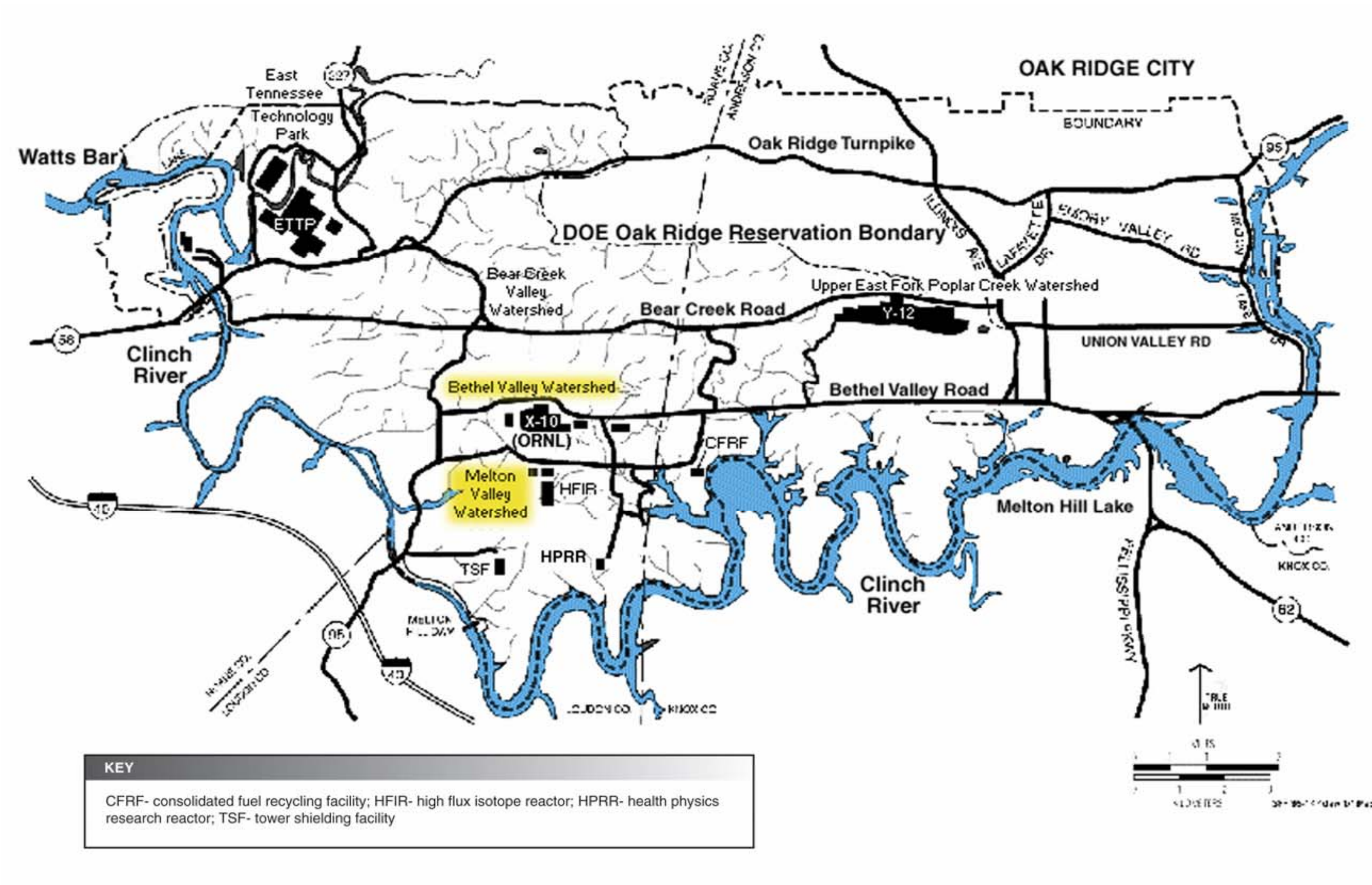
In 1986, DOE began remedial actions at the ORR under a RCRA permit. Since that time, DOE has started about 50 response activities under the FFA that address waste disposal and contamination issues on the reservation (USEPA 2002a). To facilitate the investigation and remediation of contamination related to the reservation, the contaminated areas on the ORR were separated into five large tracts of land that are typically associated with the major hydrologic watersheds (EUWG 1998). More specifically, the contaminated areas associated with X-10 are located in the Bethel Valley Watershed and the Melton Valley Watershed (USDOE 2001b). Please refer to Figure 9 for the locations of these two watersheds.

Although not current public health concerns, some of these former waste disposal sites are nonetheless subject to remediation. DOE is remediating these sites to ensure long-term safety and to prevent off-site releases. More information on DOE's environmental management program can be obtained at http://www.oakridge.doe.gov/External/Default.aspx?tabid=42.

II.C.1. Bethel Valley Watershed

The major operations at X-10 take place within the Bethel Valley Watershed. The main plant, key research facilities, primary administrative offices, as well as various forms of waste sites, are situated in Bethel Valley. Over the past 60 years, X-10 releases have contaminated the Bethel Valley Watershed. Mobile contaminants primarily leave the Bethel Valley Watershed via White Oak Creek. These contaminants travel from the Bethel Valley Watershed to the Melton Valley Watershed, where further contaminants enter White Oak Creek. Then, the contaminants that have been discharged to White Oak Creek are released over White Oak Dam and into the Clinch River (USDOE 2001b).

Figure 9. Map of the Bethel Valley Watershed and the Melton Valley Watershed



Source: Lockheed Martin Energy Systems, Inc. 1998

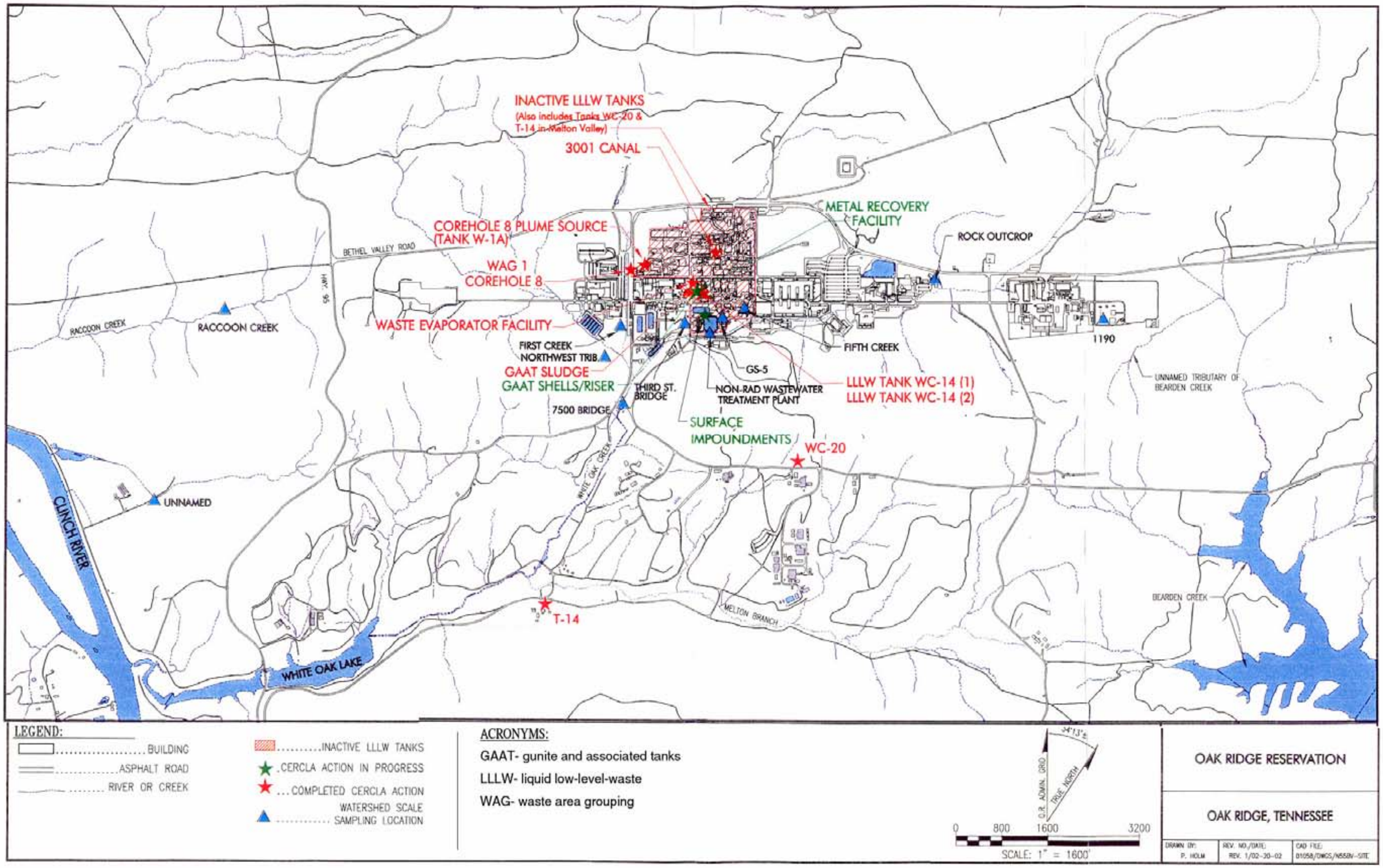
Many remedial activities have been conducted in Bethel Valley to protect human health and the environment in the present and future. These actions, which comply with federal and state requirements, have removed the most contaminated materials (including source and leaching materials) and reduced the amount of contaminants in Bethel Valley. Main remedial activities conducted in Bethel Valley associated with X-10 operations have included 1) groundwater treatment and extraction at the Corehole 8 Plume, 2) sludge and liquid waste removal at the Gunite and Associated Tanks (GAAT), 3) liquid and solid waste removal and treatment at the inactive liquid low-level waste tanks, and 4) contaminated sediment removal from the surface impoundments operable unit (SAIC 2002, 2004; USDOE 2001c). In addition, in May 2002 a Record of Decision (ROD) was signed to address several interim remedial actions in Bethel Valley. As of the 2004 fiscal year, ROD-initiated activities—including a groundwater study—had begun (SAIC 2005). Please see Figure 10 for a map of Bethel Valley that includes these areas. The main remedial activities conducted in Bethel Valley are detailed further in Appendix B.

II.C.2. Melton Valley Watershed

X-10 disposed of its radioactive wastes (liquid and solid) in Melton Valley, and also operated its experimental facilities within this watershed (USDOE 2002a, 2002b). Discharges from Melton Valley's waste areas have produced secondary contamination sources that include sediment, groundwater, and soil contamination. Furthermore, contaminants discharged from Melton Valley travel off the reservation through surface water and flow into the Clinch River (SAIC 2002). As a result, the waste sites in the Melton Valley Watershed "…are the primary contributors to off-site spread of contaminants" from the ORR (USDOE 2002b).

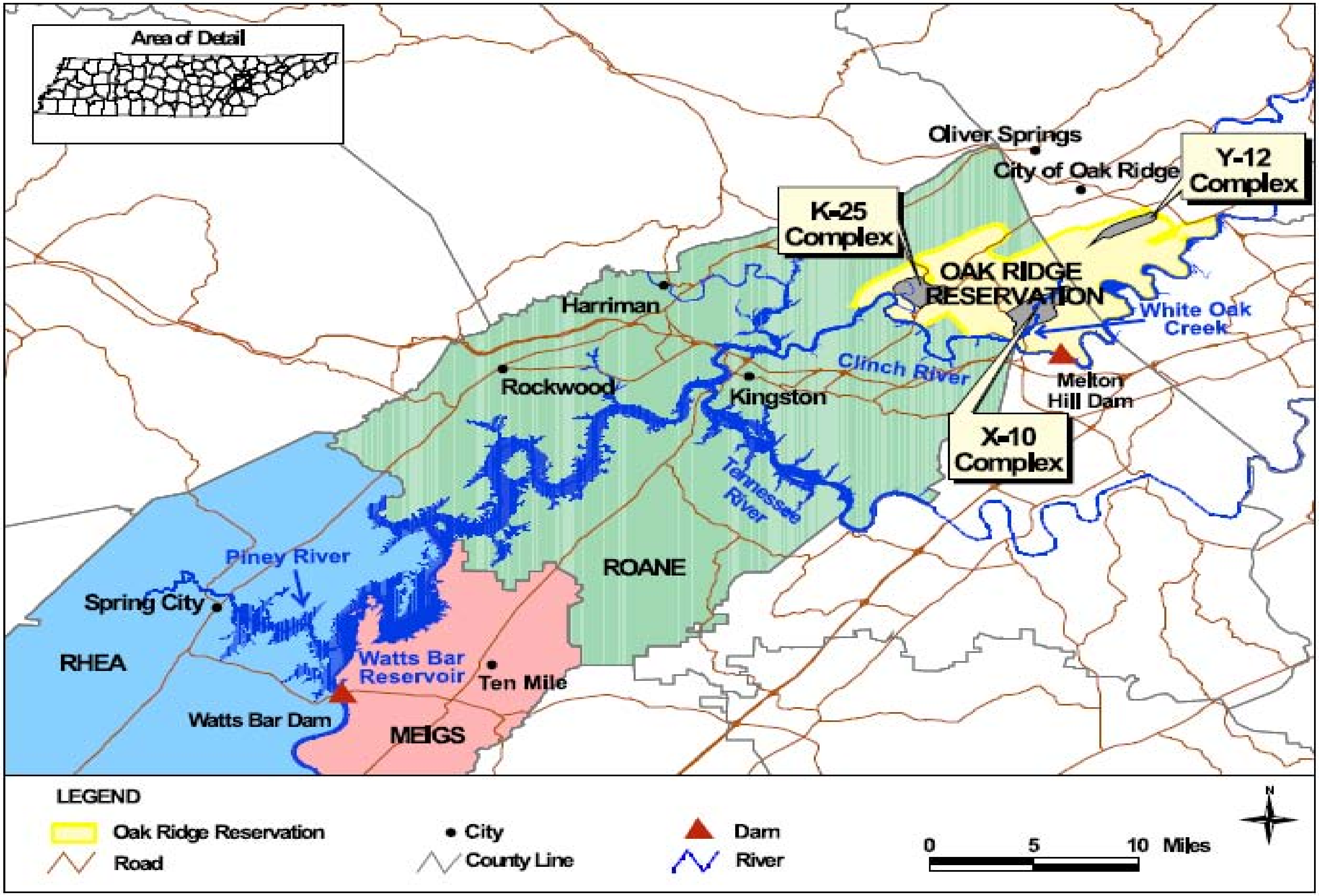
Many remedial activities, which comply with federal and state requirements, have been conducted in Melton Valley. These actions—undertaken to protect human health and the environment in the present and future—have removed the most contaminated materials and reduced the amount of contaminants in Melton Valley. Main remedial activities related to X-10 operations and the White Oak Creek study area (see Figure 11) have included 1) removing contaminated soil and restricting access to the Cesium Plots Research Facility, 2) building a

Figure 10. Map of the Major Remedial Activities in Bethel Valley



Source: SAIC 2002

Figure 11. Map of the White Oak Creek Study Area



sediment retention structure at the mouth of White Oak Creek to reduce off-site movement of sediments to the Watts Bar Reservoir and the Clinch River, 3) reducing releases of strontium 90 into White Oak Creek from waste area grouping (WAG) 4 trenches, 4) installing a groundwater treatment unit at WAG 5 to prevent strontium 90 from entering Melton Branch, and 5) injecting radioactive waste and grout below ground and removing liquid low-level waste (LLLW) underground storage tanks (USTs) from the Old Hydrofracture Facility (OHF) (SAIC 2002; USDOE 2002c; USEPA 2002a). A ROD signed in September 2000 focused on remedial activities to prevent contaminant releases into surface waters and groundwater in Melton Valley (SAIC 2002, 2004). Please see Figure 12 for a map of Melton Valley that includes these areas. The main remedial activities conducted in Melton Valley are further detailed in Appendix B.

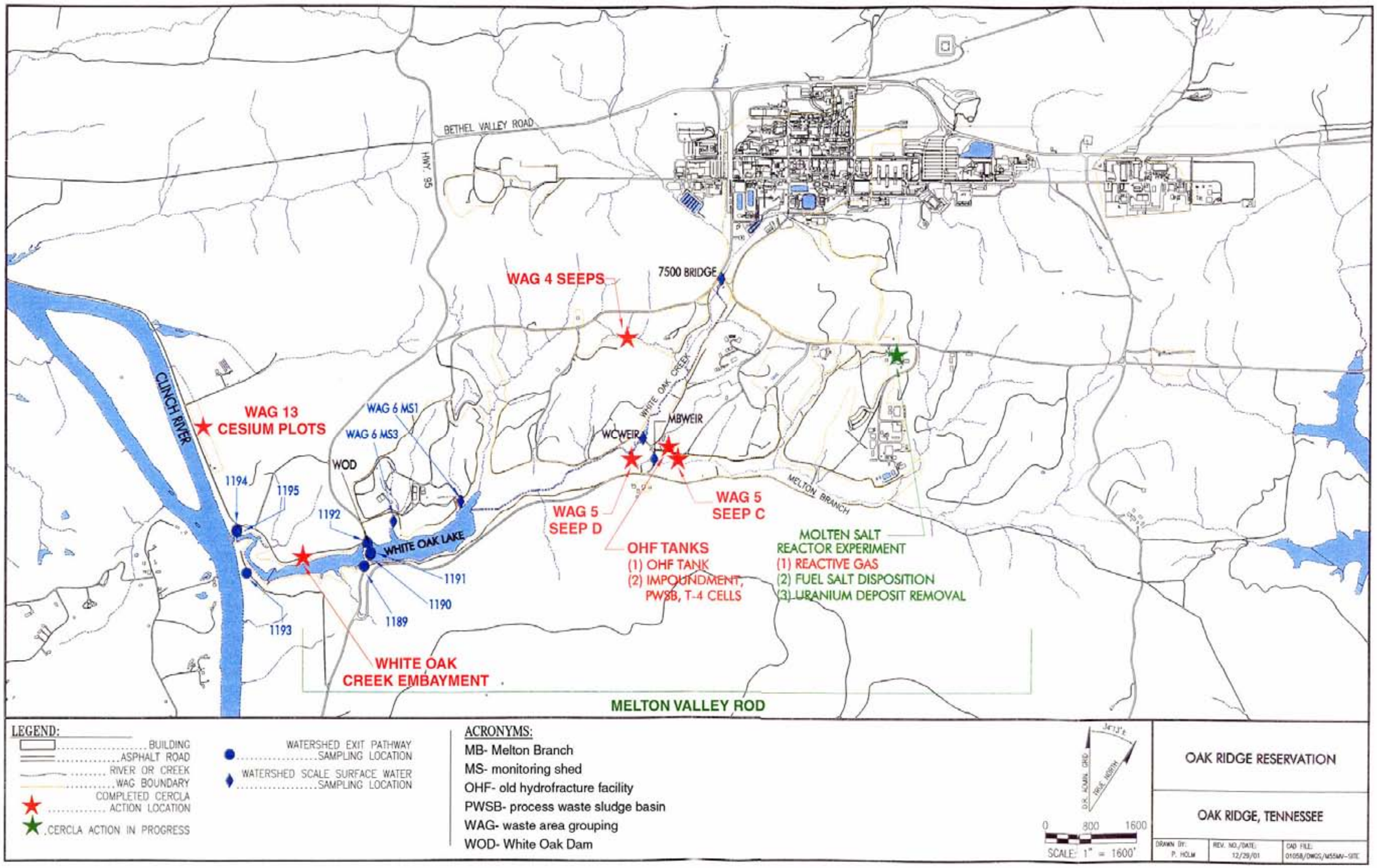
II.C.3. Off-Site Locations

This section discusses remedial activities that have been conducted at two off-site locations related to X-10 that are located within the White Oak Creek Public Health Assessment study area: the Clinch River/Poplar Creek Operable Unit (OU) and the Lower Watts Bar Reservoir OU (SAIC 2002). The White Oak Creek study area (see Figure 11) consists of the area along the Clinch River, from the Melton Hill Dam to the Watts Bar Dam. The Lower Watts Bar Reservoir is downstream of the ORR, extending from the confluence of the Clinch and Tennessee Rivers to the Watts Bar Dam (USDOE 1995a). As a result, the Clinch River and the Lower Watts Bar Reservoir have received contaminants related to X-10 operations (Jacobs EM Team 1997b; USDOE 1995a; USDOE 2001a). See Figure 1 and Figure 4 for these surface water locations.

Remedial actions at the Clinch River/Poplar Creek OU and the Lower Watts Bar Reservoir OU, which were undertaken to protect human health and the environment in the present and future, comply with federal and state guidelines (Jacobs EM Team 1997b; USDOE 1995a). Remedial activities at these OUs are summarized below.

- *Clinch River/Poplar Creek*. The Clinch River/Poplar Creek OU consists of the biota and sediments in the Melton Hill Reservoir and the Watts Bar Reservoir from CRM 0.0 (where the Tennessee and Clinch Rivers join) to CRM 43.7, which is upstream of Melton Hill Dam. 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 the borders of the ORR (SAIC 2002; USDOE 2001a).

Figure 12. Map of the Major Remedial Activities in Melton Valley



Source: SAIC 2002

In 1996, a remedial investigation/feasibility study (RI/FS) was conducted to examine the past and present releases to off-site surface water and to determine if 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 2001a). The largest concentrations of radionuclides that have been detected are buried between 8 and 32 inches into the deep sediments (Jacobs EM Team 1997b).

A baseline risk assessment was conducted. It suggested that consumption of certain fish contaminated with PCBs posed the greatest risk to public health. In addition, fish contaminated with chlordane, mercury, and arsenic presented the possible chance of causing health effects. The assessment also determined that because of PCB and mercury contamination, the consumption of any type of fish in Poplar Creek posed a health risk. Similarly, consumption of bass from the Clinch River below Melton Hill Dam posed a health risk due to PCB contamination. Still, no primary risks were associated with exposure to radionuclides in fish from the Clinch River or from Poplar Creek. Furthermore, the risk assessment determined that contaminants in deep-water sediments would present a health risk only if they were dredged; no exposure pathway currently exists to the deep-water sediments (Jacobs EM Team 1997b).

In September 1997, DOE issued a Record of Decision for the Clinch River/Poplar Creek OU. EPA and TDEC—supportive agencies for this response action—agree with the remedial actions selected for this OU. The chosen actions, which comply with federal and state requirements, were undertaken to protect human health and the environment in the present and future. The following remedial actions were selected for the OU:

1. yearly monitoring to assess fluctuations in concentration levels and contaminant dispersion,
2. advisories on fish consumption,
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 2001a; USEPA 2002a).

These institutional controls are 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 work cooperatively through the Watts Bar Interagency Agreement to review permitting and all other activities that could result in disturbing the sediment (for example,

> 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; USDOE 2003a). For more details, see the ROD at http://www.epa.gov/superfund/sites/rods/fulltext/r0497075.pdf.

building a dock or erecting a pier) (ATSDR 1996; Jacobs EM Team 1997b; USDOE 2003a). 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 (U.S.A.C.E.)* (Jacobs EM Team 1997b).

In February 1998, a Remedial Action Report (RAR) was approved. This report recommended that monitoring be conducted for surface water, fish, sediment, and turtles in the Clinch River/Poplar Creek OU (ATSDR et al. 2000). Since this time, annual surface water sampling, sediment monitoring, and fish and turtle sampling have been conducted at the Clinch River/Poplar Creek OU (SAIC 2002; USDOE 2001a). 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*. The Lower Watts Bar Reservoir OU stretches from the confluence of the Tennessee River and the Clinch River downstream to the Watts Bar Dam. All surface water and sediment released from the ORR enter the Lower Watts Bar Reservoir OU (SAIC 2002; USDOE 2001a; USDOE 2003c). In 1995, a RI/FS was conducted to assess the level of contamination in the Watts Bar Reservoir, to create a baseline risk assessment based on the contaminant levels, and to determine if remedial action was necessary (ATSDR et al. 2000). The RI/FS revealed that discharges of radioactive, inorganic, and organic pollutants from the ORR have contributed to biota, water, and sediment contamination in the Lower Watts Bar Reservoir (ATSDR et al. 2000; SAIC 2002; USDOE 2001a, 2003b). The baseline risk assessment 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, DOE issued a Record of Decision for the Lower Watts Bar Reservoir OU. EPA and TDEC, which are supportive agencies for this response action, agree with the remedial actions selected for this OU. The chosen actions were undertaken to protect human health and the environment in the present and future, and comply with federal and state requirements. The following contaminants of concern (COCs) were identified at the OU: 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 2001a, 2003b). The largest threat to public health from the Lower Watts Bar Reservoir is related to the consumption of PCB-contaminated fish (SAIC 2002; USDOE 2001a, 2003b). 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 1995a)."

  The remedial activities selected for the Lower Watts Bar Reservoir have included using preexisting institutional controls to decrease contact with contaminated sediment, fish consumption advisories printed in the *Tennessee Fish Regulations*, and yearly monitoring of biota, sediment, and surface water (ATSDR et al. 2000; SAIC 2002; USDOE 1995a, 2001a, 2003b; USEPA 2002a). The interagency agreement established by DOE, EPA, TVA, TDEC, and USACE in February 1991 allows these agencies to work cooperatively through the Watts Bar Interagency Agreement to review permitting and all other activities that could result in disturbing the sediment, such as building a dock or erecting a pier (ATSDR 1996; Jacobs EM Team 1997b; USDOE 2003a). According to the interagency agreement, DOE is required to take action if an institutional control is not effective or if a sediment-disturbing activity could cause harm (Jacobs EM Team 1997b; USDOE 2003a). For more details, please see page 3-5 of the Lower Watts Bar Reservoir ROD at http://www.epa.gov/superfund/sites/rods/fulltext/r0495249.pdf and the Clinch River/Poplar Creek OU ROD at http://www.epa.gov/superfund/sites/rods/fulltext/r0497075.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 (U.S.A.C.E.)* (Jacobs EM Team 1997b).

- In September 1999 DOE combined the *Clinch River/Poplar Creek and Lower Watts Bar Reservoir* operable units for monitoring purposes. These surface water bodies comprise a hydrologically connected system through which ORR contaminants could be transported. A review of sampling conducted to 2004 revealed that no chemical or radiological contaminants in surface water or near-shore sediments posed an unacceptable risk to humans. As a result of these findings, in fiscal year 2004 the previously established long-term monitoring program was modified. The new program, scheduled to commence in fiscal year 2005, requires sediment, surface water, and turtle sampling every 5 years (instead of annually); fish sampling will continue on an annual basis. As appropriate, DOE will supplement the data it collects under the revised monitoring program with sediment and surface water sampling data collected by TVA, TDEC, and TWRA (SAIC 2005).

II.D. Land Use and Natural Resources

When the government acquired the ORR in 1942, it reserved a section of the reservation (about 14,000 acres out of the total of approximately 58,575) for housing, businesses, and support services (ChemRisk 1993c; ORNL et al. 2002). In 1959, that section of the ORR was turned into the independently governed city of Oak Ridge. This self-governing area has parks, homes, stores, schools, offices, and industrial areas (ChemRisk 1993c).

The majority of residences in Oak Ridge are located along the northern and eastern borders of the ORR (Bechtel Jacobs Company LLC et al. 1999). Since the 1950s, however, the urban population of Oak Ridge has grown toward the west. As a result of this expansion, the property lines of many homes in the city's western section border the ORR property (Faust 1993). Apart from these urban sections, the areas close to the ORR continue to be mainly rural, as they have historically been (Bechtel Jacobs Company LLC et al. 1999; ChemRisk 1993c). The closest homes to X-10 are located near Jones Island, about 2.5 to 3.0 miles southwest of the main facility (ChemRisk 1993c).

In 2002, the ORR measured 34,235 acres, which includes the three main DOE facilities: Y-12, X-10, and K-25 (ORNL et al. 2002). The majority of the ORR is situated within the city limits of Oak Ridge. These DOE facilities constitute approximately 30% of the reservation; the remaining 70% of the reservation was turned into the National Environmental Research Park in 1980. This park was created so that protected land could be used for environmental education and research, and to show that the development of energy technology could be compatible with a quality environment (EUWG 1998). A large amount of land at the ORR that was formerly cleared for farmland has grown into full forests over the past several decades. Sections of this land contain areas called "deep forest" that include flora and fauna considered ecologically significant, and portions of the reservation are regarded as biologically rich (SAIC 2002).

Today, the entire ORNL site encompasses approximately 26,580 acres. The main operations at the ORNL take place on about 4,250 acres, which was formerly known as the X-10 site. The remaining acres are divided between the Oak Ridge National Environmental Research Park (21,980 acres) and the Solway Bend area that is used for environmental monitoring (350 acres) (ORNL et al. 1999). The X-10 site contains approximately 517 buildings, trailers, and additional facilities, which total over 3.4 million square feet. There are additional facilities related to X-10 operations, but these are situated at the Y-12 plant and at off-site locations. Of the X-10 facilities and those at the other locations, however, 156 are inactive or are expected to be inactive in the future (Bechtel Jacobs Company LLC et al. 1999).

Historically, forestry and agriculture (beef and dairy cattle) have constituted the primary uses of land in the area around the reservation; but these land uses are both declining. For several years, milk produced in the area was bottled for local distribution, whereas beef cattle from the area were sold, slaughtered, and nationally distributed. In addition, tobacco, soybeans, corn, and wheat were the primary crops grown in the area. Also, small game and waterfowl were hunted on a regular basis in the ORR area, but deer were hunted during specific time periods. Waterfowl and small game hunting regularly occurs within the ORR area, while deer hunting occurs annually on the ORR (ChemRisk 1993c). During the annual deer hunts, radiological monitoring is conducted on all deer prior to their release to the hunters. Monitoring is conducted to ensure that none of the animals contain quantities of radionuclides that could cause “significant internal exposure” to the consumer (Teasley 1995).

The southern and western boundaries of the ORR are formed by the Clinch River; Poplar Creek and East Fork Poplar Creek drain the ORR to the north and west (Jacobs EM Team 1997b). White Oak Creek, which travels south along the eastern border of the X-10 site, flows into White Oak Lake, over White Oak Dam, and into the White Oak Creek Embayment before meeting the Clinch River at CRM 20.8 (ChemRisk 1993b, 1999a; TDOH 2000; USDOE 2002a). Ultimately, every surface water system on the reservation drains into the Clinch River (ChemRisk 1993b). The Lower Watts Bar Reservoir is situated downstream of the ORR, extending from the confluence of the Clinch and Tennessee Rivers to the Watts Bar Dam (USDOE 1995a). As a result, the Clinch River and the Lower Watts Bar Reservoir have received contaminants associated with X-10 operations (Jacobs EM Team 1997b; USDOE 1995a; USDOE 2001a). Please see Figure 4 for these relative water systems.

The majority of land around the Clinch River and the Lower Watts Bar Reservoir is undeveloped and wooded. Other than activities at the ORR, there is minimal industrial development in these surrounding areas, and there is a fair amount of residential growth. The public has access to the Clinch River and to the Lower Watts Bar Reservoir, which it uses for recreational purposes such as boating, swimming, fishing, water skiing, and shoreline activities (USDOE 1996d, 2001b, 2003b).

Kingston, Spring City, and Rockwood maintain public water supplies in the vicinity of the Oak Ridge Reservation (Figures 13 and 14 show these water intake and city locations, respectively, that are all within the White Oak Creek study area). The Kingston water supply has two water intakes, but only one of the intakes—located upstream on the Tennessee River in Watts Bar Lake at Tennessee River Mile (TRM) 568.4—would potentially be affected by ORR contaminants (Hutson and Morris 1992; G. Mize, Tennessee Department of Environment and Conservation, Drinking Water Program, personal communication re: Kingston public water supply, 2004). Spring City obtains its water from an intake on the Piney River branch of Watts Bar Lake

(Hutson and Morris 1992). The city of Rockwood receives its water from an intake on the King Creek branch of Watts Bar Lake, located at TRM 552.5 (TDEC 2001, 2006b; TVA 1991). Still, only reverse flow conditions could potentially affect any of these three intakes (ATSDR 1996).

Under the Safe Drinking Water Act, the EPA has since 1974 set health-based standards for substances in drinking water and specified treatments for providing safe drinking water (USEPA 1999a). The public water supplies for Kingston, Spring City, and Rockwood are continually monitored for these regulated substances, which include 15 inorganic contaminants, 51 synthetic and volatile organic contaminants, and 4 radionuclides. For EPA's monitoring schedules, see http://www.epa.gov/safewater/pws/pdfs/qrg_smonitoringframework.pdf (EPA 2004a).

According to EPA's Safe Drinking Water Information System (SDWIS), the Kingston, Spring City, and Rockwood public water supply systems have not had any significant violations (USEPA 2004b). To look up information related to these and other public water supplies, go to EPA's Local Drinking Water Information Web Site at http://www.epa.gov/safewater/dwinfo.htm. In addition, in 1996 TDEC's DOE Oversight Division started to participate in EPA's Environmental Radiation Ambient Monitoring System (ERAMS). Under this program, TDEC collects finished drinking water samples from the Kingston Water Treatment Plant on a quarterly basis and then submits the samples to EPA for radiological analyses (TDEC 2002, 2003a). Please see the TDEC–DOE Oversight Division's annual report to the public at http://www.state.tn.us/environment/doeo/active.shtml for a summary of radiological drinking water sampling results. TDEC has also conducted filter backwash sludge sampling at Spring City because contaminants from the reservation could potentially move downstream into community drinking water supplies (TDEC 2003b). Additional information on TDEC's participation in the ERAMS program is provided in Section II.F.3. of this document.

> To ask specific questions related to your drinking water, please call TDEC's Environmental Assistance Center in Knoxville, Tennessee at 865-594-6035. To find additional information related to your water supply or other water supplies in the area, please call EPA's Safe Drinking Water Hotline at 800-426-4791 or visit EPA's Safe Drinking Water Web site at http://www.epa.gov/safewater.

II.E. Demographics

The White Oak Creek study area (see Figure 11) consists of the area along the Clinch River, from the Melton Hill Dam to the Watts Bar Dam. Four main cities fall within this area. Three of the cities—Harriman, Kingston, and Rockwood—are located in Roane County and one of the cities—Spring City—is located in Rhea County. Meigs County is also within the study area. Figure 13 provides the current population distribution in the White Oak Creek Study area, and Figure 14 details current demographic information for areas within ½ mile, 1 mile, and 5 miles of the White Oak Creek study area. There are 13,362 people living within ½ mile, 20,573 people living within 1 mile, and 70,700 people living within 5 miles. For children aged 6 and younger, 983 live within ½ mile, 1,621 live within 1 mile, and 5,812 live within 5 miles.

II.E.1. Counties Within the White Oak Creek Study Area

Since 1940, the populations of Meigs County, Rhea County, and Roane County have all grown by over 50% (Bureau of the Census 1993, 2000). Table 4 presents the population over a 60-year time period for these counties and Figure 15 shows the population distribution over time.

Table 4. Populations of Meigs, Rhea, and Roane Counties From 1940 to 2000

County	*1940*	*1950*	*1960*	*1970*	*1980*	*1990*	*2000*
Meigs County	6,393	6,080	5,160	5,219	7,431	8,033	11,086
Rhea County	16,353	16,041	15,863	17,202	24,235	24,344	28,400
Roane County	27,795	31,665	39,133	38,881	48,425	47,227	51,910

Source: Bureau of the Census 1993, 2000

Figure 13. Population Distribution in the White Oak Creek Study Area

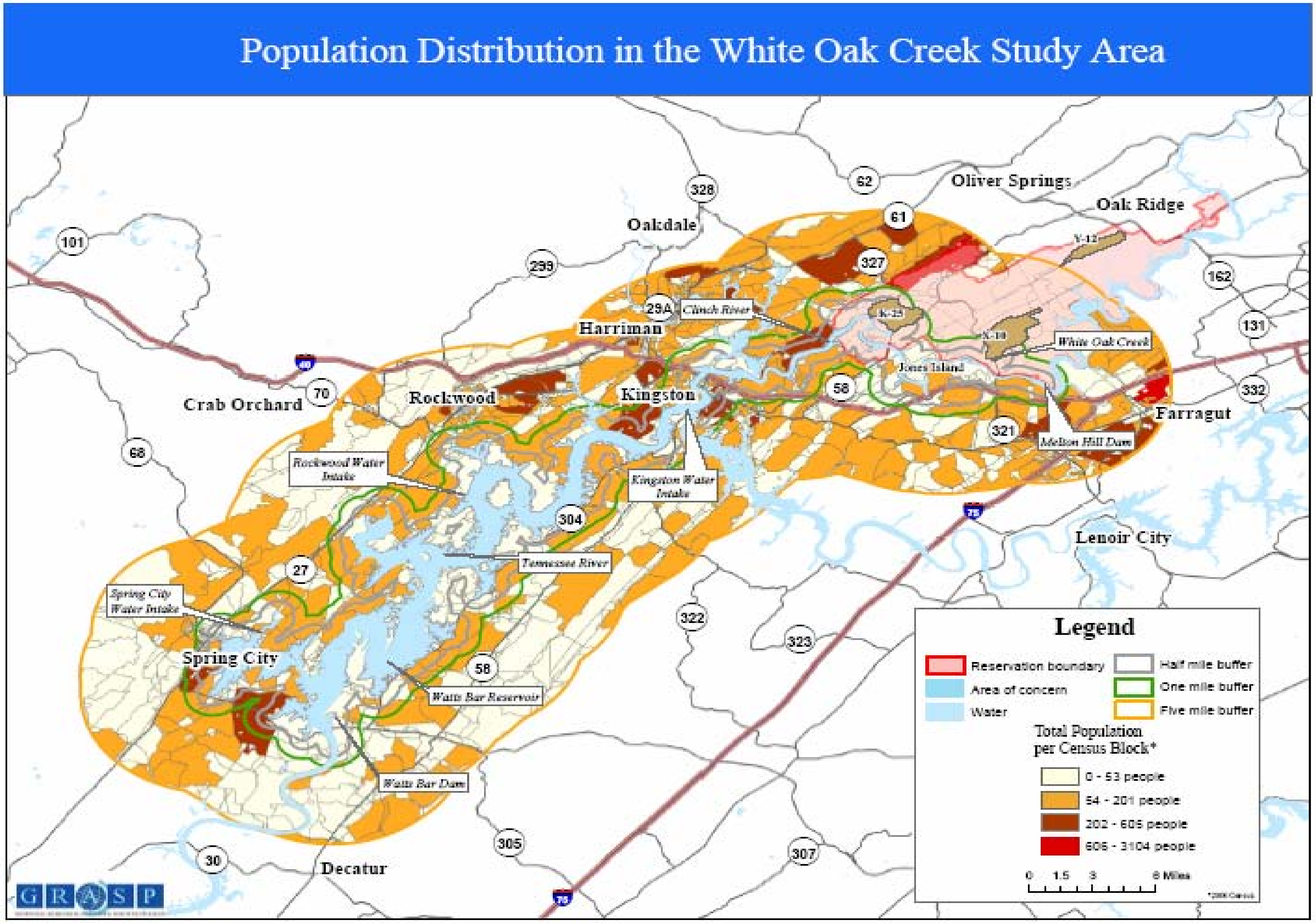
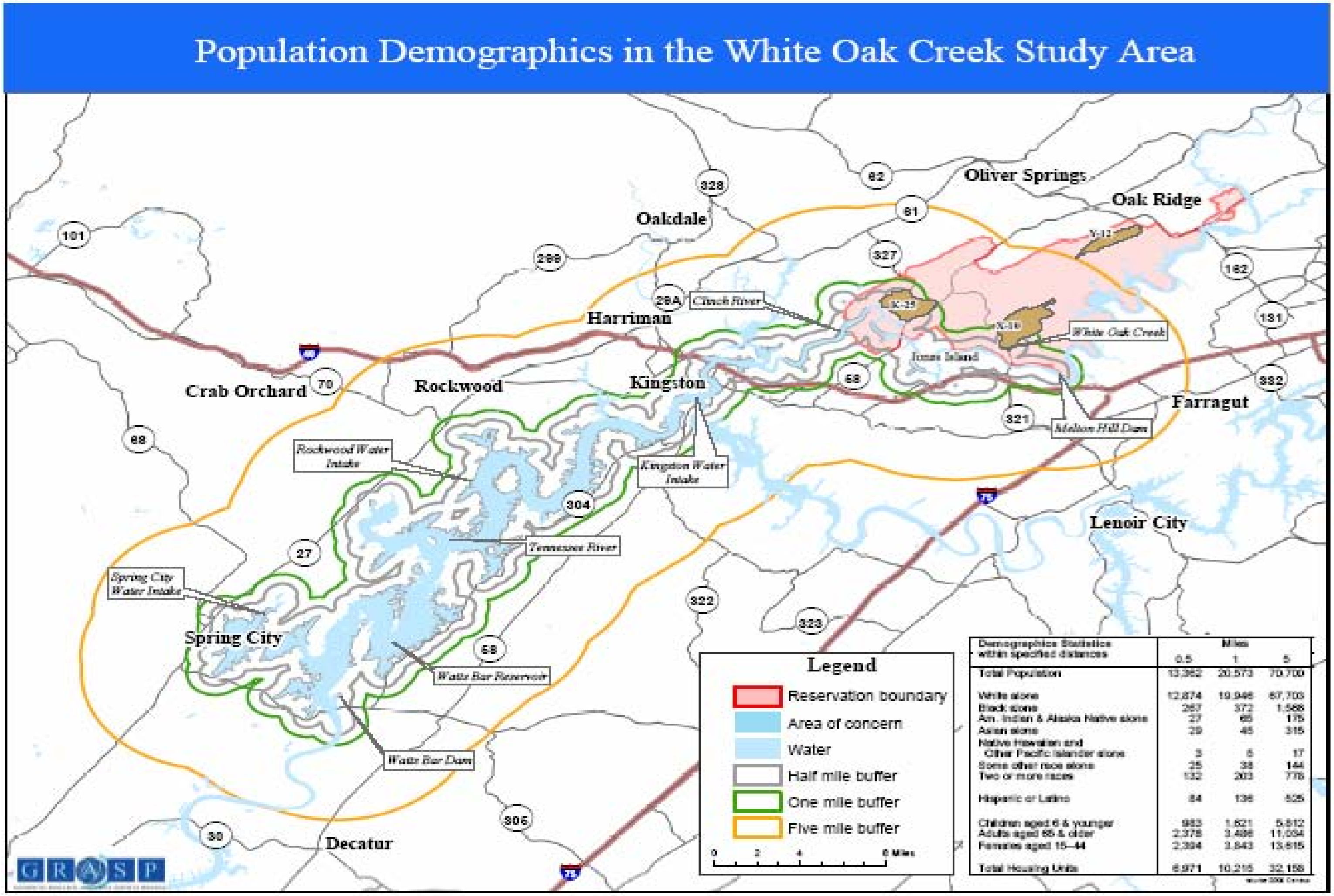
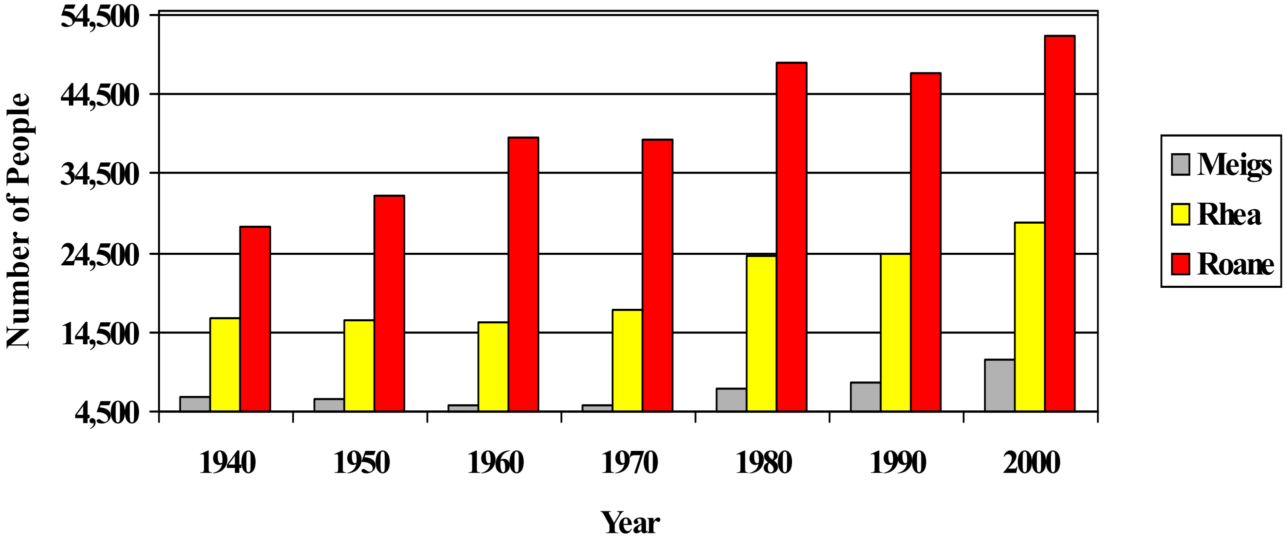


Figure 14. Population Demographics in the White Oak Creek Study Area



Demographics Statistics within specified distances	Miles 0.5	Miles 1	Miles 5
Total Population	13,362	20,573	70,700
White alone	12,874	19,946	67,703
Black alone	267	372	1,588
Am. Indian & Alaska Native alone	27	65	175
Asian alone	29	45	315
Native Hawaiian and Other Pacific Islander alone	3	6	17
Some other race alone	25	38	144
Two or more races	132	203	778
Hispanic or Latino	84	136	525
Children aged 6 & younger	983	1,621	5,812
Adults aged 65 & older	2,378	3,486	11,034
Females aged 15–44	2,394	3,843	13,615
Total Housing Units	6,971	10,216	32,158

Figure 15. Population Distribution of Meigs, Rhea, and Roane Counties From 1940 to 2000



Source: Bureau of the Census 1993, 2000

Meigs County

Although between 1940 and 1960, the population of Meigs County decreased, the population has more than doubled since that time, increasing from 5,160 to 11,086 (114.8%) (see Table 4 and Figure 15). The largest percentage increase in population occurred between 1970 and 1980, when the number of residents grew from 5,219 to 7,431 (42.4%). Since 1940, the population of Meigs County has grown by almost 75% (Bureau of the Census 1993, 2000). As of 2000, the majority of residents worked in the manufacturing industry. The Meigs County population is comprised of 10,826 Caucasians, 138 African-Americans, and 122 persons of other races. Also, the largest percentage of residents is between the ages of 35 and 44, and the median age is 36.7 (Bureau of the Census 2000).

Rhea County

The population of Rhea County declined between 1940 and 1960, but has continued to increase since the 1960s (see Table 4 and Figure 15). The largest increase (40.9%) occurred between 1970 and 1980, when the number of residents increased from 17,202 to 24,235. Over the past 60 years, the population of Rhea County has increased by nearly 75% (Bureau of the Census 1993, 2000). As of 2000, the majority of residents worked in the manufacturing industry. The Rhea

County population consists of 27,097 Caucasians, 580 African-Americans, and 723 persons of other races. In addition, the largest proportion of residents is between the ages of 35 and 44, with a median age of 37.2 (Bureau of the Census 2000).

Roane County

Over this 60-year period, the population of Roane County has grown by 86.8%, as shown in Table 4 (Bureau of the Census 1993, 2000). Slight declines in population occurred between 1960 and 1970, and between 1980 and 1990 (East Tennessee Development District 1995; Bureau of the Census 1993). Meanwhile, the county population increased during the remaining time periods to reach a population of 51,910 in 2000. Figure 15 shows the population distribution of the county over time (East Tennessee Development District 1995; Bureau of the Census 1993, 2000).

The majority of Roane County's 2000 population is Caucasian (49,440); the remaining portion of the population consists of African-American residents (1,409) and persons of other races (1,061) (Bureau of the Census 2000). Since the 1970s, the median age of Roane County residents has increased from 32.1 to 40.7, suggesting that the county has an aging population (East Tennessee Development District 1995; Bureau of the Census 2000). The X-10 site and the K-25 site are both located within Roane County (East Tennessee Development District 1995; Jacobs EM Team 1997a). Primarily because of these two facilities, between 1940 and 1990 manufacturing was the predominant occupation for Roane County residents (East Tennessee Development District 1995; Bureau of the Census 1993).

II.E.2. Cities Within the White Oak Creek Study Area

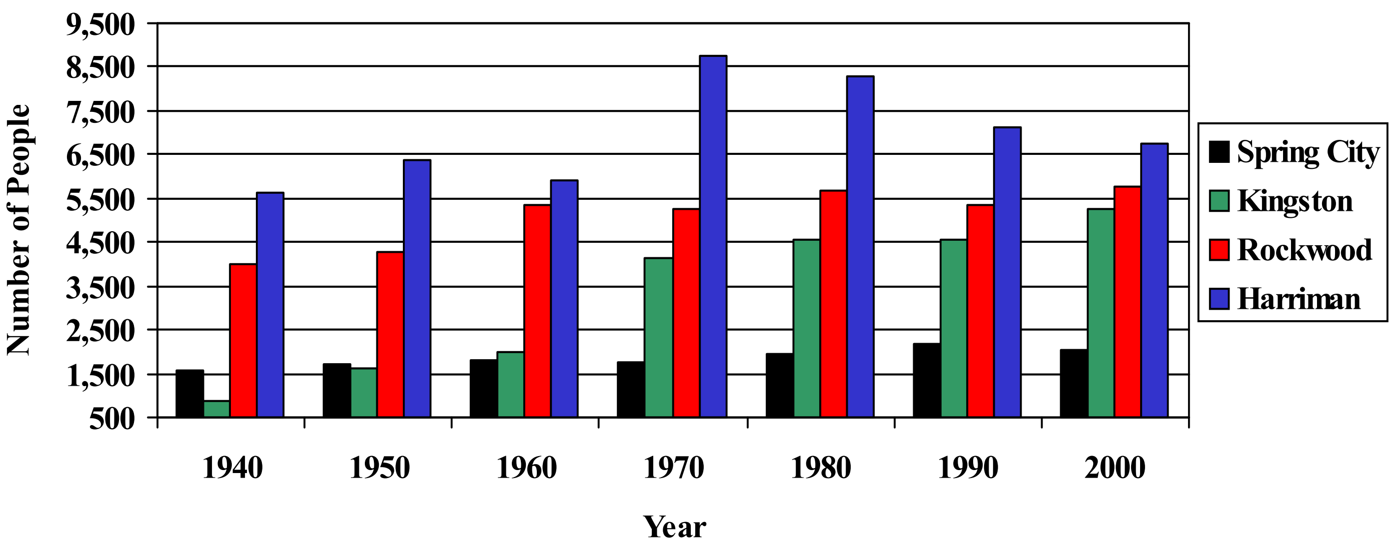
Three cities in the White Oak Creek study area—Kingston, Rockwood, and Harriman—are located in Roane County and Spring City is located in Rhea County. The population of these four cities between 1940 and 2000 (see Table 5), and the population distribution during that time period (see Figure 16) appear below.

Table 5. Populations of Spring City, Kingston, Rockwood, and Harriman From 1940 to 2000

City	*1940*	*1950*	*1960*	*1970*	*1980*	*1990*	*2000*
Spring City	1,569	1,725	1,800	1,756	1,951	2,199	2,025
Kingston	880	1,627	2,010	4,142	4,561	4,552	5,264
Rockwood	3,981	4,272	5,345	5,259	5,695	5,348	5,774
Harriman	5,620	6,389	5,931	8,734	8,303	7,119	6,744

Source: Bureau of the Census 1940, 1950, 1960, 1970, 1980, 1993, and 2000

Figure 16. Population Distribution of Spring City, Kingston, Rockwood, and Harriman From 1940 to 2000



Source: Bureau of the Census 1940, 1950, 1960, 1970, 1980, 1993, and 2000

Spring City

Spring City is approximately 49 miles southwest of the X-10 site (see Figure 11) (MapQuest 2003). Between 1940 and 2000, the population of Spring City continually fluctuated, as shown in Table 5. During this time period, the number of residents increased between 1940 and 1960 and between 1970 and 1990. The population declined from 1960 to 1970 and from 1990 to 2000. The largest percentage increase in population was seen between 1980 and 1990, followed by the largest decrease between 1990 and 2000 (Bureau of the Census 1940, 1950, 1960, 1970, 1980, 1993, 2000). As of 2000, the largest percentage (31.6%) of residents worked in the manufacturing industry. The population consists of 1,914 Caucasians, 91 African-Americans, and 20 persons of other races. The highest percentage of the population is between the ages of 35 and 44, and the city's median age is 44.0 (Bureau of the Census 2000).

Kingston

The city of Kingston, which is the seat of Roane County, is located at the confluence of the Clinch River and the Tennessee River (see Figure 11), and it is about 22 miles southwest of the X-10 site (MapQuest 2003). The population of Kingston (see Table 5) has grown steadily from 1940 to 2000, except for a 0.2% decrease between 1980 and 1990 (East Tennessee Development District 1995; Bureau of the Census 1993, 2000). In 1969, the city of Kingston had one manufacturing plant; by 1990, 6 of the 35 manufacturing plants in Roane County were in Kingston (East Tennessee Development District 1995). Since 1990, the greatest portion of residents has been employed in the professional services field (East Tennessee Development District 1995; Bureau of the Census 2000). In 2000, the population consisted of 4,935 Caucasians, 187 African-Americans, and 142 persons of other races. The majority of Kingston residents are between the ages of 45 and 54; the median age is 41.6 (Bureau of the Census 2000).

Rockwood

The city of Rockwood is about 33 miles southwest of the X-10 site (see Figure 11) (MapQuest 2003). The population of Rockwood has fluctuated from 1940 to 2000 (see Table 5). The city experienced steady growth between 1940 and 2000, except for slight declines that occurred between 1960 and 1970 and between 1980 and 1990 (East Tennessee Development District 1995; Bureau of the Census 1993, 2000). In 1969, 10 out of 29 manufacturing plants in Roane County were in Rockwood; by 1990, Rockwood had 13 out of the 35 manufacturing plants in the county (East Tennessee Development District 1995). The largest percentage of residents is employed in the manufacturing field. As of 2000, the Rockwood population consisted of 5,362 Caucasians, 314 African-Americans, and 98 persons of other races. The median age is 42.0, and the greatest portion of individuals is between the ages of 45 and 54 (Bureau of the Census 2000).

Harriman

The city of Harriman is about 24 miles west of the X-10 site (see Figure 11) (MapQuest 2003). As also seen in Table 5, the population of Harriman peaked between 1970 and 1980, and has continued to decline since that time (East Tennessee Development District 1995; Bureau of the Census 1993, 2000). In 1969, 18 of the 29 manufacturing plants in Roane County were located in the city of Harriman. By 1990, Roane County had 35 manufacturing plants, but the number within Harriman had fallen to 15 (East Tennessee Development District 1995). Still, as of 2000, manufacturing is the leading source of employment for Harriman residents. In 2000, the population consisted of 6,077 Caucasians, 501 African-Americans, and 166 persons of other races. The majority of residents are between the ages of 45 and 54, with the median age of 40.5 (Bureau of the Census 2000). As of 1990, Harriman had more minority residents than any other city in Roane County (East Tennessee Development District 1995).

II.F. Summary of Public Health Activities Pertaining to White Oak Creek Radionuclide Releases

This section describes the public health activities that pertain to radionuclide releases to White Oak Creek from the X-10 site. ATSDR, the TDOH, and other agencies have conducted additional public health activities at the ORR, which are described in Appendix C. Please see Figure 5 for a time line of public health activities related to radionuclide releases from X-10.

II.F.1. ATSDR

Since 1991, ATSDR has addressed the health concerns of community members, civic organizations, and other government agencies by working extensively to determine whether levels of environmental contamination at and near the ORR present a public health hazard. During this time, ATSDR has identified and evaluated several public health issues and has worked closely with many parties, including community members, civic organizations, physicians, and several federal, state, and local environmental and health agencies. While the TDOH conducted the Oak Ridge Health Studies to evaluate whether off-site populations have experienced exposures in the *past,* to prevent duplication of the state's efforts ATSDR's activities focused on *current* and *future* public health issues. The following paragraphs highlight major public health activities conducted by ATSDR that pertain to White Oak Creek radionuclide releases.

Health consultations, exposure investigations, and other scientific evaluations. ATSDR health scientists have addressed current public health issues related to the Watts Bar Reservoir area.

- *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 Lower Watts Bar Reservoir. DOE's plan called for leaving contaminated sediment in place with the use of institutional controls to prevent disruption of the contaminated sediment. (For example, people must apply for and obtain a permit from TVA, USACE, or TDEC before dredging any sediment in the Lower Watts Bar Reservoir. See Section III.B.3. for more details on the Watts Bar Interagency Agreement and the process to obtain a permit.) Local residents were worried about the contamination in the reservoir and they expressed their concerns about the adequacy of DOE's proposed remedial actions and controls. The residents requested that ATSDR assess the current and future health hazards associated with contaminants left in place in the Lower Watts Bar Reservoir sediment, and as a result, ATSDR conducted a health consultation on the area.

  To evaluate the chemical and radiological contaminants in the Lower Watts Bar Reservoir, ATSDR reviewed environmental sampling data from the 1980s and 1990s that had been assembled by DOE, TVA, and various consultants. In addition, ATSDR examined TVA's 1993 and 1994 Annual Radiological Environmental Reports for the Watts Bar nuclear plant. Initially, ATSDR screened the data to determine if any contaminants were present at levels that exceeded health-based comparison values. To determine if current chemical and radiological contaminant levels could potentially affect area residents, ATSDR used both worst-case exposure scenarios and realistic exposure scenarios to estimate the doses for any contaminants that were above the comparison values.

  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.

  ATSDR found that only polychlorinated biphenyls (PCBs) in the Lower Watts Bar Reservoir fish presented a public health concern. The agency found that frequent and long-term consumption of reservoir fish could moderately increase a person's chance of cancer, and that reservoir turtles could also contain PCBs at levels of public health concern (ATSDR et al. 2000).

  ATSDR also determined that present contaminant levels in the reservoir sediment and surface water were not of public health concern—the reservoir was safe for recreational activities, such as skiing, swimming, and boating, and the municipal water was safe to drink. Furthermore, ATSDR reviewed the DOE's remedial action plan and concluded the remedial actions were protective of public health. These remedial actions included continuing environmental monitoring; maintaining the fish consumption advisories; and implementing institutional controls to prevent resuspension, removal, disruption, or disposal of contaminated sediment (ATSDR et al. 2000). For more specific details on the findings of ATSDR's health consultation, see Section III.B.3. and Appendix D.

  Given its findings, ATSDR made the following recommendations:

1. To minimize exposure to PCBs, the Lower Watts Bar Reservoir fish advisory should remain in effect.

2. ATSDR should work with the state of Tennessee to implement a community health education program on the Lower Watts Bar fish advisory and on the health effects of PCB exposure.

3. The likelihood of health effects 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.

4. Surface and subsurface sediments should not be disturbed, removed, or disposed of without careful review by the interagency working group (this working group was previously discussed in Section II.C.3.).

5. Sampling of municipal drinking water at regular intervals should be continued. In addition, if a significant release of contaminants from the ORR is discharged into the tributaries of the Clinch River at any time, DOE should notify the municipal water systems and monitor surface water intakes.

- *Watts Bar Reservoir exposure investigation, March 1998*. Prior to this exposure investigation, studies on the Watts Bar Reservoir and on the Clinch River had reviewed several contaminants, but the only contaminant found to be of current public health concern was PCBs in reservoir fish. These past studies, which include DOE's remedial investigations on the Lower Watts Bar Reservoir (1994) and on the Clinch River/Poplar Creek (1996), as well as ATSDR's 1996 Health Consultation on the Lower Watts Bar Reservoir, based their findings on estimated PCB exposure doses and estimated increases of cancer likelihood after consuming large amounts of fish over extended time periods. Mainly, ATSDR conducted this exposure investigation because of the uncertainties associated with estimating exposure doses and with estimating increases in cancer likelihood from ingestion of reservoir fish and turtles. In addition, these past investigations did not confirm that people were actually being exposed or that they had elevated PCB or mercury levels. Also, a TDOH contractor suggested conducting an extensive, region-wide evaluation to assess the relevant exposures and health effects in counties surrounding the Watts Bar Reservoir (Thapa 1996). ATSDR believed, however, that before any agency conducted extensive investigations it should determine if mercury and PCBs were actually elevated in individuals who consumed large amounts of fish and turtles from the reservoir.

> Exposure investigations are one of the public health approaches that ATSDR used to develop a better characterization of past, present, or possible future human exposure to hazardous substances in the environment. These investigations only evaluate exposures and do not assess whether exposure levels resulted in adverse health effects.

The ATSDR exposure investigation evaluated exposures at one point in time (data and samples were collected September 15–28, 1997). Because, however, serum PCB levels are an indicator of chronic exposure (more than 1 year) and mercury blood levels are an indicator of intermediate exposure (from15 days to less than 1 year), the investigation results provide information on both past and present exposure. ATSDR focused its evaluation on individuals who consumed moderate to high amounts of fish and turtles from the Watts Bar Reservoir. Participants were recruited through fishing licenses, newspaper, radio, and television announcements, as well as through posters and flyers placed at various fishing-related locations (e.g., bait shops). ATSDR interviewed more than 550 volunteers; 116 of these individuals had consumed enough fish or turtles to be included in the investigation. A brief summary of this exposure investigation is provided in Appendix D.

The results of this investigation were disseminated to the public through a mailing and in a public forum. ATSDR concluded that the participants' serum PCB levels and blood mercury levels were consistent with those seen in the general population. The three major findings are listed below (ATSDR et al. 2000; ORHASP 1999):

1. The investigation participants' serum PCB levels and blood mercury levels were very similar to levels seen in the general population.
2. Of the 116 people tested, only 5 (4%) had serum PCB levels above 20 micrograms per liter (µg/L) or parts per billion (ppb), 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. One 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. Through this counseling, researchers were able to investigate other potential past exposure routes and to recommend behaviors that could reduce future exposure.
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.

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 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 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).

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, the National Center for Environmental Health (NCEH), the National Institute for Occupational Safety and Health (NIOSH), the Health Resources and Services Administration (HRSA), and DOE. These coordinated efforts led to the establishment of the Public Health Working Group in 1999, and then to the formation of the Oak Ridge Reservation Health Effects Subcommittee (ORRHES). In addition, ATSDR provided some assistance to TDOH in its study of past public health issues (ATSDR et al. 2000).

Oak Ridge Reservation Health Effects Subcommittee. The ORRHES was established in 1999 by ATSDR and the Centers for Disease Control and Prevention (CDC) under the authority of the Federal Advisory Committee Act (FACA), and 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 people who represented diverse interests, expertise, backgrounds, and communities, as well as liaison members from federal and state agencies. It was a forum for communication and collaboration between the citizens and the agencies that evaluate public health issues and 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, and everyone was invited to attend and present their ideas and opinions. The subcommittee performed the following functions:

- Served as a citizen advisory group to CDC and to ATSDR and made recommendations on matters related to public health activities and research at the ORR.
- Allowed citizens an opportunity to collaborate with agency staff members and to learn more about the public health assessment process and other public health activities.
- Helped to prioritize the public health issues and community concerns evaluated by ATSDR.

The ORRHES created various work groups that conducted in-depth exploration of specific issues and presented findings to the subcommittee for deliberation. Work group meetings were open to all who wished to attend and participate. Figure 17 shows the organizational structure of the

ORRHES, and Figure 18 is a chart that shows the process of providing input into public health assessments. For more information on the ORRHES, visit the ORRHES Web site at www.atsdr.cdc.gov/HAC/oakridge (ATSDR et al. 2000).

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

Where can one 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 the following three ways:

1. *Visit 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 1-888-42ATSDR (or 1-888-422-8737).

2. *Visit 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.

3. *Contact ATSDR directly.* Residents can contact representatives from ATSDR directly by dialing the agency's toll-free number, 1-888-42ATSDR (or 1-888-422-8737).

Figure 17. Organizational Structure for the Oak Ridge Reservation Health Effects Subcommittee

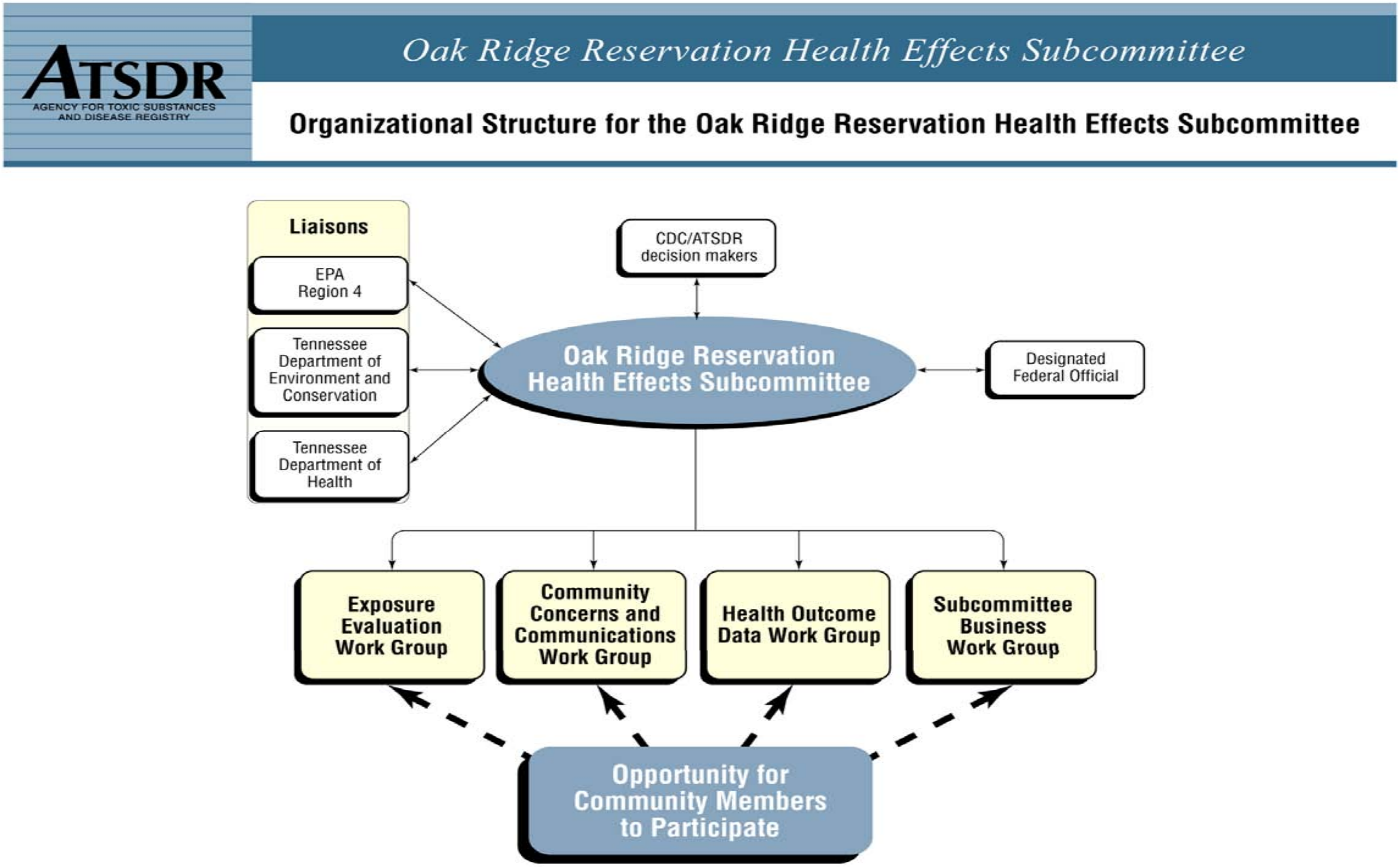
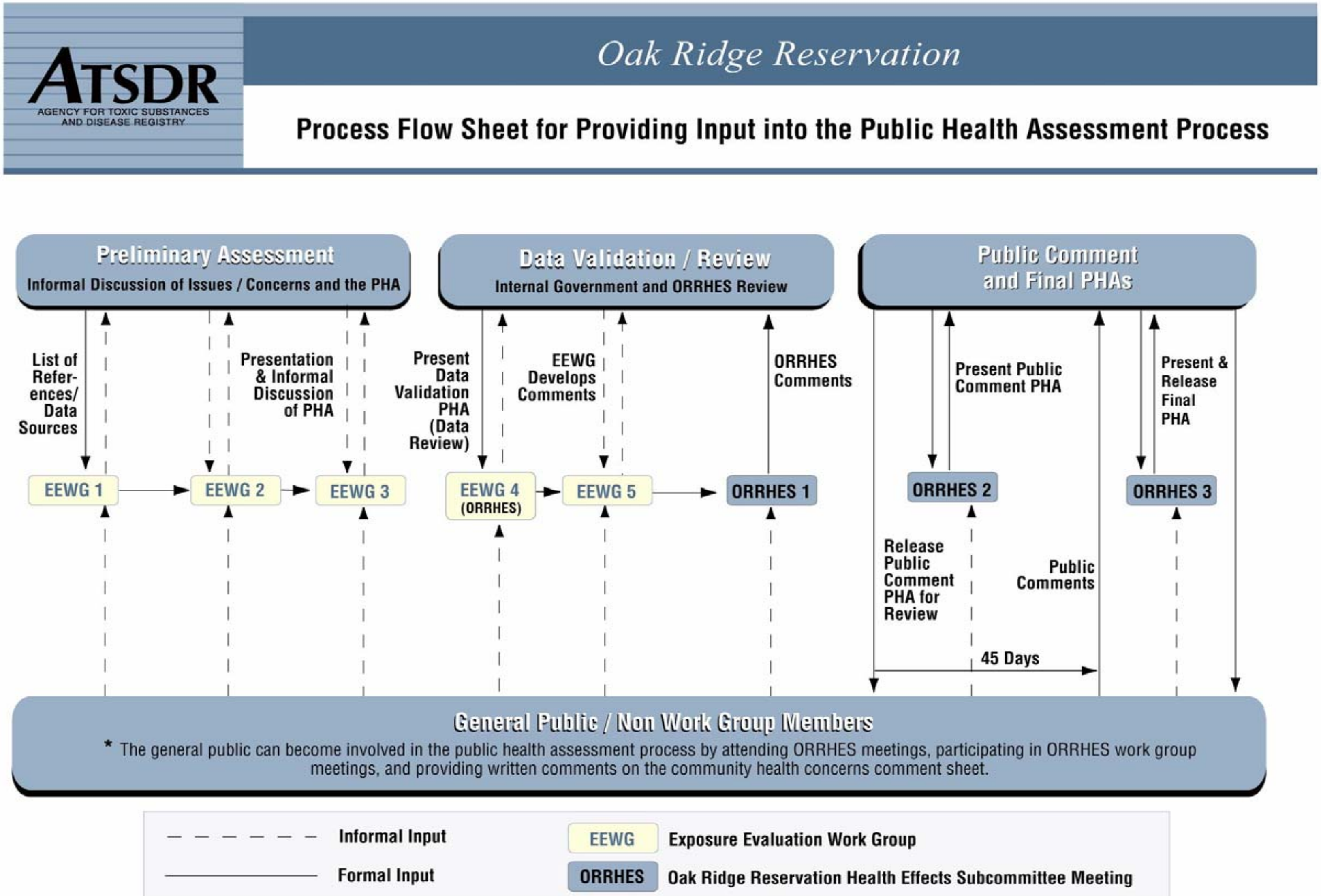


Figure 18. Process Flow Sheet for Providing Input Into the Public Health Assessment Process



II.F.2. TDOH

Oak Ridge Health Studies. In 1991, DOE and the state of Tennessee entered into the Tennessee Oversight Agreement, which allowed the TDOH to undertake a two-phase independent state research project to determine whether past environmental releases from ORR operations harmed people who lived nearby (ORHASP 1999). All of the technical reports produced for the TDOH Oak Ridge Health Studies are accessible in portable document format (PDF) at http://cedr.lbl.gov.

- *Phase I.* Phase I of the Oak Ridge Health Study is a Dose Reconstruction Feasibility Study. This feasibility study evaluated all past releases of hazardous substances and operations at the ORR. The objective of the study was to determine the quantity, quality, and potential usefulness of the available information and data on these past releases and subsequent exposure pathways. Phase I of the health studies began in May 1992 and was completed in September 1993 (ATSDR et al. 2000). A brief summary of the Phase I Feasibility Study is provided in Appendix D.

  During this process, the state reviewed thousands of documents and interviewed knowledgeable parties to assess the possibility of creating a dose reconstruction, and to examine historical releases from the ORR that posed the greatest threat to public health. The state reviewed documents related to four major facilities, X-10 (now ORNL), Y-12, K-25, and the former S-50, and for several off-site areas associated with ORR contamination (ChemRisk 1993a, 1999a). In the feasibility study, the state 1) evaluated historical activities at each facility on the ORR, 2) compiled an inventory of environmental sampling and research data for use in the dose reconstruction, 3) identified activities with the highest potential to release substantial quantities of contaminants to off-site populations, 4) determined the potential that the contaminants released could affect public health, 5) identified important environmental media and exposure pathways through which off-site populations could be exposed, 6) compiled a list of contaminants that needed further evaluation, 7) examined if a completed exposure pathway existed, and 8) assessed which pathways contributed significantly to the potential health risks for off-site populations. Through this extensive process, ChemRisk was able to identify the contaminants and pathways with the greatest likelihood for causing adverse health effects. *For information on other activities conducted during the feasibility study, please see ChemRisk's 1993 Oak Ridge Health Studies.*

  The findings of the Phase I Dose Reconstruction Feasibility Study indicated that a significant amount of information was available to reconstruct the past releases and potential off-site exposure doses for four hazardous substances that had the largest potential risk for adverse health effects. These four substances include 1) radioactive iodine releases associated with radioactive lanthanum processing at X-10 from 1944 through 1956; 2) mercury releases associated with lithium separation and enrichment operations at the Y-12 plant from 1955 through 1963; 3) PCBs in fish from East Fork Poplar Creek (EFPC), the Clinch River, and the Watts Bar Reservoir; and 4) radionuclides from White Oak Creek associated with various chemical separation activities at X-10 from 1943 through the 1960s (ATSDR et al. 2000).

- *Phase II (also referred to as the Oak Ridge Dose Reconstruction).* Phase II of the health studies conducted at Oak Ridge began in mid-1994 and was completed in early 1999. Phase II 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 also included additional detailed screening analyses for releases of uranium and several other toxic materials that had not been fully characterized in Phase I (a brief in Appendix D summarizes the *Screening-Level Evaluation of Additional Potential Materials of Concern, Task 7*). The significant findings for each of the substances evaluated, as well as the significant findings of the additional screening analyses in the Task 7 report, are presented in the following paragraphs.

  Radioactive iodine releases were associated with radioactive lanthanum processing at X-10 from 1944 through 1956. Results indicate that children who were born in the area in the early 1950s and who drank milk produced by cows or goats living in their yards had the highest theoretical increased risk of developing thyroid cancer. The results suggest that a female born in 1952 at Bradbury, Tennessee would have the highest risk of developing thyroid cancer from the radioactive iodine releases.

  The study evaluated mercury releases associated with lithium separation and enrichment operations at the Y-12 plant from 1955 through 1963. Results indicate that during the mid-1950s farm families living along East Fork Poplar Creek and children playing in the creek could have received annual average doses of mercury exceeding the EPA reference dose. The results also suggest that fetuses of pregnant women who ate significant quantities of fish from the Clinch River or Poplar Creek in the late 1950s and early 1960s are at the highest risk from methylmercury exposure.

  > 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 a significant increase in risk of adverse health effects.

  Additional studies were conducted on PCBs in fish from EFPC, the Clinch River, and the Watts Bar Reservoir. Preliminary results indicated that individuals who consumed a large amount of fish from these waters might have received doses that exceeded the EPA reference dose for PCBs.

  Radionuclides associated with various chemical separation activities at the X-10 site from 1943 through the 1960s were released into White Oak Creek. Initially, TDOH identified eight radionuclides as contaminants of concern: cesium 137, ruthenium 106, strontium 90, cobalt 60, cerium 144, zirconium 95, niobium 95, and iodine 131. Four of these radionuclides were deemed likely to carry significant health risks: cesium 137, cobalt 60, ruthenium 106, and strontium 90. The results indicate that the releases caused small increases in the radiation dose over background for individuals who consumed fish from the Clinch River near the mouth of White Oak Creek. The dose reconstruction scientists estimated that an adult male who annually consumed a maximum of 130 meals of fish caught near the mouth of White Oak Creek and who continued this diet for 50 years (worst-case scenario) had the highest theoretical increased risk of developing cancer. The risk from eating fish goes down proportionately for people who eat fewer fish and for people who eat fish caught farther downstream. A brief summary of the Task 4 report is provided in Appendix D.

Uranium was released from various large-scale uranium operations, primarily uranium processing and machining operations at the Y-12 plant and uranium enrichment operations at the K-25 and S-50 plants. 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. A brief summary of the Task 6 report is provided in Appendix D.

The *Screening-Level Evaluation of Additional Potential Materials of Concern* was conducted to determine if contaminants other than those identified in the *Oak Ridge Dose Reconstruction Feasibility Study* warranted further evaluation to assess their potential to cause health effects to 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. Based on the screening results, 5 materials used at the K-25 plant and 14 materials used 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 D.

The Oak Ridge Health Agreement Steering Panel (ORHASP)—a panel of experts and local citizens—was appointed to direct and oversee the Oak Ridge Health Studies and provide liaison with the community. Given the findings of the Oak Ridge Health Studies and what is generally known about the health risks posed by exposures to various toxic chemicals and radioactive substances, ORHASP concluded that, "past releases from the Oak Ridge Reservation were likely to have harmed some people." Two groups most likely to have been harmed were 1) local children who drank milk produced by a "backyard" cow or goat in the early 1950s and 2) fetuses of women who routinely ate fish from contaminated creeks and rivers downstream of the ORR in the 1950s and early 1960s. ORHASP noted, however, the Task 4 report determined that following exposure to fish contaminated with X-10 radionuclides via White Oak Creek, less than one excess cancer case was expected. Studies also indicate that elevated PCB concentrations drove the health risks associated with eating fish from the Clinch River and Watts Bar Reservoir. For additional information on the ORHASP findings, please see the final report of the ORHASP titled *Releases of Contaminants from Oak Ridge Facilities and Risks to Public Health* at http://www2.state.tn.us/health/CEDS/OakRidge/ORHASP.pdf.

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

Sampling of Public Drinking Water Systems in Tennessee. For 30 years, under the Safe Drinking Water Act of 1974 (summary available at http://www.epa.gov/safewater/index.html), 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. The public water supplies for Kingston, Spring City, Rockwood, and other supplies in Tennessee are monitored for substances that include 15 inorganic contaminants, 51 synthetic and volatile organic contaminants, and 4 radionuclides (USEPA 2004a). According to EPA's Safe Drinking Water Information System (SDWIS), the Kingston, Spring City, and Rockwood public water supply systems have not had any significant violations (USEPA 2004b). For EPA's monitoring schedules for each contaminant, go to http://www.epa.gov/safewater/pws/pdfs/qrg_smonitoringframework.pdf. On a quarterly basis, TDEC submits the individual water supply data to EPA's SDWIS (TDEC 2003c). 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.

> EPA's ERAMS program was established to provide radiological monitoring for public water supplies located close to US nuclear facilities.

In addition, in 1996 TDEC's DOE Oversight Division began participation in EPA's Environmental Radiation Ambient Monitoring System (ERAMS). 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 (TRM 568.4), DOE Water Treatment Plant at K-25 (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, TDEC collects finished drinking water samples from the Kingston Water Treatment Plant on a quarterly basis and then submits the samples to EPA for radiological analyses. The schedule and contaminants sampled at the Kingston Water Treatment Plant are available at http://www.state.tn.us/environment/doeo/pdf/EMP2006.pdf. Also see the TDEC–DOE Oversight Division's annual report to the public at http://www.state.tn.us/environment/doeo/active.shtml for a summary of radiological drinking water sampling results. TDEC has also conducted filter backwash sludge sampling at Spring City—radioactive contaminants from the reservation could potentially move downstream into community drinking water supplies. TDEC analyzed Spring City samples for gross alpha, gross beta, and gross gamma emissions (TDEC 2002, 2003a, 2003b). To ask specific questions related to your drinking water, contact TDEC's Environmental Assistance Center in Knoxville, Tennessee at 865-594-6035. To find additional information related to your water supply or other water supplies in the area, please call EPA's Safe Drinking Water Hotline at 800-426-4791 or visit EPA's Safe Drinking Water Web site at http://www.epa.gov/safewater.

Watts Bar Reservoir and Clinch River Turtle Sampling Survey, May 1997. TDEC conducted this survey to assess the body burdens of contaminants in snapping turtles in the Clinch River and in the Watts Bar Reservoir. Because of PCB contamination, fish advisories had been in effect for several years, and TDEC was concerned that people who consumed turtles from these water sources could also be exposed to PCBs. TDEC concluded that PCBs and additional contaminants accumulate in turtles from the Clinch River and the Watts Bar Reservoir. Data from the area fish advisories show that the PCB concentrations in turtle tissue were detected at levels of concern for human consumption. The majority of PCB contamination was detected in the fat tissue of the turtles, which is also seen in fish. Thus food preparation techniques, particularly tissue selection, can significantly influence the quantities of PCBs consumed with turtle meat (ATSDR et al. 2000). A brief summary of this survey is in Appendix D.

II.F.4. DOE

Watts Bar Interagency Agreement, February 1991. DOE, EPA, TVA, TDEC, and USACE comprise the Watts Bar Reservoir Interagency Working Group (WBRIWG), which works collaboratively through the Watts Bar Interagency Agreement—an agreement that established guidelines related to any dredging in Watts Bar Reservoir. Through this agreement, these agencies review permitting and all other activities that could possibly disturb the sediment of Watts Bar Reservoir, such as erecting a pier or building a dock (ATSDR 1996; Jacobs EM Team 1997b; USDOE 2003a). 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). According to the interagency agreement, DOE is required to take action if an institutional control is ineffective or if a sediment-disturbing activity could cause harm (USDOE 2003a).

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 EPA before conducting the normal permit review process to determine if there are any DOE contaminants in the sediments. The coordination follows a series of defined processes as outlined in the agreement.

The basic process of obtaining a permit, which is detailed in Section III.B.3, is the same for any organization or individual. If dredging is necessary in an area with contaminated sediments, DOE will assume the financial and waste management responsibility that is over and above the costs that would normally be incurred (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 1995a).

Oak Ridge Environmental Information System (OREIS), April 1999. Because an abundance of environmental data exists for the ORR, DOE created an electronic data management system to integrate all of the data into a single database. This database was developed to facilitate public and governmental access to environmental data related to ORR operations, while also maintaining data quality. DOE's objective was to ensure that the database had long-term retention of the environmental data and useful methods to access the information. OREIS contains data related to compliance, environmental restoration, and surveillance activities.

Information from all key surveillance activities and environmental monitoring efforts is entered into OREIS. These include but are not limited to studies of the Clinch River embayment and the Lower Watts Bar Reservoir, as well as annual site summary reports. As new studies are completed, the environmental data are entered as well (ATSDR et al. 2000).

Comprehensive Epidemiologic Data Resource (CEDR). CEDR is a public-use database that contains information pertinent to health-related studies performed at the Oak Ridge Reservation and at other DOE sites. DOE provides this easily accessible, public-use repository of data (without personal identifiers) collected during occupational and environmental health studies of workers at DOE facilities and nearby community residents. This large resource organizes the electronic files of data and documentation collected during these studies and makes them accessible on the Internet at http://cedr.lbl.gov. 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 (at http://cedr.lbl.gov/DR/ordr.html) that provides searchable text for about 1,800 original government documents (now declassified) used by the TDOH scientists for the Oak Ridge Dose Reconstruction. Also available through CEDR at http://cedr.lbl.gov are all of the technical and summary reports produced by this study. For the first time, this complex information is easily accessible in a concise, uncluttered, and easily comprehended manner. In addition, CEDR now provides images in slideshow format that give estimated concentrations, doses, and risk values for three contaminants (iodine, mercury, and uranium) in air at locations studied in TDOH's Dose Reconstruction.

III. Evaluation of Environmental Contamination and Potential Exposure Pathways

III.A. Introduction

In 2001, ATSDR scientists conducted a review and analysis of the Phase I and Phase II screening evaluation of TDOH's Oak Ridge Health Studies to identify contaminants that require further public health evaluation. In the Phase I and Phase II screening evaluation, TDOH conducted extensive reviews of available information and conducted qualitative and quantitative analyses of past (1944–1990) releases and off-site exposures to hazardous substances from the entire ORR. Having reviewed and analyzed Phase I and Phase II screening evaluations, ATSDR scientists determined that past releases of uranium, mercury, iodine 131, fluorides, radionuclides from White Oak Creek, and PCBs require further public health evaluation. The public health assessment is the primary public health process ATSDR is using to evaluate these contaminants further.

ATSDR scientists previously prepared a public health assessment on uranium releases from Y-12 and addressed current public health issues related to the East Fork Poplar Creek and the Lower Watts Bar Reservoir (LWBR). ATSDR is conducting public health assessments on the following releases: Y-12 mercury releases, X-10 iodine 131 releases, K-25 uranium and fluoride releases, and PCB releases from X-10, Y-12, and K-25. Public health assessments will also be conducted on other issues of concern, such as the Toxic Substances Control Act (TSCA) incinerator and off-site groundwater. In addition, ATSDR is screening current (1990 to 2003) environmental data to identify any other chemicals that will require further evaluation.

This public health assessment focuses on exposures to X-10 radionuclide releases to the Clinch River and the Lower Watts Bar Reservoir via White Oak Creek. More specifically, it evaluates 1) the data and findings of previous studies and investigations of X-10 radionuclide releases to the LWBR and the Clinch River via White Oak Creek; 2) assesses whether people who previously used the river, people who continue to use the river, or neighboring residents have been or could be exposed to radionuclides or radiation; and 3) determines the health implications of past, current, and future radiation exposure.

III.A.1. Exposure Evaluation Process

A release of a contaminant from a site does not always mean that the substance will have a negative impact on a member of the off-site community. For a substance to pose a potential health problem, exposure must first occur. Human exposure to a substance depends on whether a person comes in contact with the contaminant, for example by breathing, eating, drinking, or touching a substance containing it. If no one comes into contact with a contaminant, then no exposure occurs—and thus no health effects can occur. Even if the site is inaccessible to the public, contaminants can move through the environment to locations where people could come into contact with them. In the case of radiological contamination, exposure can occur without direct contact because of the emission of radiation, which is a form of energy.

> The five elements of an exposure pathway are (1) source of contamination, (2) environmental media, (3) point of exposure, (4) route of human exposure, and (5) receptor population. The source of contamination is where the chemical or radioactive material was released. The environmental media (e.g., groundwater, soil, surface water, air) transport the contaminants. The point of exposure is where people come in contact with the contaminated media. The route of exposure (e.g., ingestion, inhalation, dermal contact) is how the contaminant enters the body. The people actually exposed are the receptor population.

ATSDR evaluates site conditions to determine if people could have been or could be exposed to site-related contaminants. When evaluating exposure pathways, ATSDR identifies whether exposure to contaminated media (soil, water, air, waste, or biota) has occurred, is occurring, or will occur through ingestion, dermal (skin) contact, or inhalation. ATSDR also identifies an exposure pathway as *completed* or *potential,* or *eliminates the pathway from further evaluation*. Completed exposure pathways exist if all elements of a human exposure are present. (See "Exposure Pathway" in Appendix A for a description of the elements of a completed exposure pathway.) A potential pathway is one that ATSDR cannot rule out because one or more of the pathway elements cannot be definitely proved or disproved. A pathway is eliminated if one or more of the elements are definitely absent.

Identifying the Types of Radiation Exposure

There are two broad classes of radiation exposure: 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 an individual's internal or external exposure depends primarily on the type of radiation—that is, alpha and beta particles or gamma rays—to which a person was exposed. Most radionuclides associated with White Oak Creek releases are beta or gamma emitters. Through its scientific evaluation, ATSDR eliminated internal radiation exposure from alpha particles associated with X-10 releases as a concern (see the 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 that results in external radiation exposures. Most radionuclides from X-10 were beta or gamma emitters.

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. However, alpha particles were not associated with the majority of radionuclides released to White Oak Creek.

Source: ATSDR 1999b

Deriving Radiation Doses

ATSDR scientists calculate 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 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 that converts the radiation concentration to the radiation dose is applied. ATSDR scientists might use worst-case exposure factors as the basis for determining whether adverse health effects are *possible*. Because of this approach, the estimated radiation doses are usually much higher—that is, more conservative—than the levels to which the majority of people are exposed. Note that the concept of radiation dose is not as simple as related here; a number of other factors (for example, how radionuclides decay, the critical organ concept, particle size distribution, and the chemical form) might affect "dose" and therefore need to be factored into the dose derivation.

The radiation dose is the amount of energy from radiation that is actually absorbed by the body.

ATSDR uses the term "conservative" to refer to values that are protective of public health in essentially all situations. Values that are overestimated are considered to be conservative.

Internal radiation exposure from a radionuclide continues after the initial radioactive material has been taken into the body, even if no additional radionuclides are ingested or inhaled. That is, internal exposure of radiation from radioactive material commits the exposed person to receiving a radiation dose for a period of time that typically depends on the radionuclide's half-life and rate of elimination from the body. (See *III.A.2.a.* for a discussion on half-life.) This dose is called the *committed equivalent dose* for an organ-specific dose and the *committed effective dose* for a whole-body dose. Exposure to external radiation sources, however, stops when the source is removed or when a person moves away from the source. A dose associated with external radiation is called an *effective dose*. The doses are further defined as follows:

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 an individual will receive from an intake of radioactive material over a 50-year period following the intake for workers or adults and over a 70-year period following the intake for children.

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.

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.

The organ dose (equivalent, H_T) and the whole-body dose (effective, E) can be defined mathematically using the equations below. W and D are the weighting factor and dose, respectively. The subscripts R and T represent the type of radiation and the tissue of concern.

$$H_T = \sum_R W_R D_{R,T} \text{ (organ, equivalent dose)}$$

$$E = \sum_T W_T H_T \text{ (whole body, effective dose)}$$

The sum of the equivalent dose is theoretically equal to the effective dose (*E*). By rearranging the equations, one can solve for the equivalent dose from the whole-body (effective) dose:

$$H_T = \frac{E}{\sum_T W_T}$$

Weighting factors (W_T) are modifying factors selected for the type of radiation and its energy as it impacts matter to convert organ or tissue dose equivalents to committed effective dose equivalents for the whole body. They are used because the same radiation exposure to different parts of the body can have very different results. That is, if the entire body were irradiated, some parts of the body would react more dramatically than other parts. To take this effect into account, the ICRP developed weighting factors for a number of organs and tissues that most significantly contribute to the overall biological damage to the body (ICRP 1991).

The tissue weighting factors are based on both cancer fatality risk and the relative effect of an exposure to a single organ or tissue.[6] The grouping of tissues is complex, and substantial rounding of the values takes place. When summed for the entire body, the values of W_T are normalized to give a total of one. Table 6 gives the currently adopted tissue weighting factors.

Table 6. Tissue Weighting Factors

Tissue	w_T	$\sum w_T$
Bone marrow (red), colon, lung, and stomach	0.12	0.48
Bladder, breast, esophagus, liver, and thyroid	0.05	0.25
Bone surface and skin	0.01	0.02
Gonads	0.20	0.20
Remainder tissues–adrenals, brain, intestinal tract, kidneys, muscle, pancreas, spleen, thymus, and uterus	0.05	0.05
Total		**1.0**

[6] For 2005, the ICRP is proposing a new system, which still involves weighting factors, that uses cancer incidence and considers lethality rate, years of life lost, and weighted contribution from the nonfatal cancers and hereditary disorders.

Assessing Health Effects

In its public health assessments, ATSDR uses radiation doses *instead of risk* to evaluate potential human exposures and health effects. ATSDR defines **dose** as "The amount of a substance to which a person may be exposed, usually on a daily basis." Dose is often explained as the "amount of substances(s) per body weight per day" and is the basis for determining levels of exposure that might cause adverse health effects. The Society for Risk Analysis defines **risk** as

> "The potential for realization of unwanted, adverse consequences to human life, health, property, or the environment; estimation of risk is usually based on the expected value of the conditional probability of the event occurring times the consequence of the event given that it has occurred" (SRA 2004).

EPA-conducted risk assessments are useful in determining safe regulatory limits and in prioritizing sites for cleanup. These risk assessments provide estimates of theoretical risk from possible current or future exposures and consider all contaminated media—regardless of whether exposures are occurring or are likely to occur. That said, however, these quantitative risk estimates are not intended to predict the incidence of disease or to measure the actual health effects in people resulting from site-related hazardous substances. By design, these risk estimates are conservative predictions that generally overestimate risk. Risk assessments do not provide a perspective on what the risk estimates mean in the context of the site community, nor do they measure the actual health effects that hazardous substances have on people. Please see Appendix F for more information on risk.

ATSDR recognizes that every radiation dose, action, or activity may carry an associated risk. 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 for particular communities. A public health assessment provides conclusions about the actual existence and level of the health threat (if any) posed by a site, as well as recommendations to stop or reduce exposures. Because of uncertainties regarding exposure conditions and adverse effects related to environmental levels of exposure, definitive answers on whether health effects actually will or will not occur are not possible. A public health assessment can, however, provide a framework that puts site-specific exposures and the potential for harm in perspective. Thus, ATSDR recognizes that uncertainties exist with doses, but it addresses these uncertainties by using health-protective safety factors.

Exposure does not always result in harmful health effects. The type and severity of health effects a person can experience depend on the dose, which is based on age at exposure, the exposure rate (how much), the frequency or duration of exposure (how long), the route or pathway of exposure (breathing, eating, drinking, or skin contact), and the multiplicity of exposure (combination of contaminants). Once a person is exposed, characteristics such as age, gender, nutritional status, genetics, lifestyle, and health status influence how that person absorbs, distributes, metabolizes, and excretes the contaminant. The likelihood that adverse health outcomes will actually occur depends on site-specific conditions, individual lifestyle, and genetic factors that affect the route, magnitude, and duration of actual exposure—an environmental concentration alone will not cause an adverse health outcome.

ATSDR uses comparison values to identify hazardous substances that are not considered a health hazard at a site and hazardous substances that require an additional follow-up evaluation.

As a first step in evaluating radiation exposures, ATSDR health assessors screened the radiation doses against comparison values. ATSDR develops comparison values from available scientific literature concerning exposure, dose, and health effects. Comparison values represent radiation doses that are lower than levels at which no effects were observed in studies on experimental animals or in human epidemiologic studies. They are not thresholds for harmful health effects; instead, they reflect an estimated dose that is not expected to cause harmful health effects. Estimated doses below these comparison values are not considered a health hazard, so doses at or below the relevant comparison value can reasonably be considered safe. Doses above the comparison values, meanwhile, will not necessarily produce adverse health effects. This screening process enables ATSDR to safely eliminate contaminants that are not of health concern and to evaluate potentially harmful contaminants further.

If the estimated radiation doses at a site are above comparison values, ATSDR proceeds with a more in-depth health effects evaluation to determine if the doses are sufficient enough to trigger public health action to limit, eliminate, or further study any potential harmful exposures. ATSDR scientists conduct a health effects evaluation by carefully examining site-specific exposure conditions about actual or likely exposures; conducting a critical review of radiologic, medical, and epidemiologic information in the scientific literature to ascertain the levels of significant human exposure; and comparing an estimate of the radiation doses that 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 toxicologic, radiologic, epidemiologic, medical, and health outcome data to help determine whether exposure to contaminant levels might result in harmful effects. The goal of the health effects evaluation is to decide whether harmful effects might be observed in the exposed population by weighing the scientific evidence and keeping site-specific doses in perspective. See Figure 19 for ATSDR's health-based determination of radiological doses.

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/toc.html or by contacting ATSDR at 1-888-42-ATSDR. An interactive program that provides an overview of the 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.A.2. Radiation-Related Terms

Half-Life

The half-life of a radionuclide is the time that it takes for the activity of radioactive material (or radioactivity) to decrease by one-half. This is known as the physical half-life. Radionuclides that are taken into the body will also be eliminated by biological processes, such as excretion. The measure of time it takes to eliminate half of a material taken into the body by biological processes is called the biological half-life. The measure of the combined influences of these physical and biological half-lives is called the effective half-life. For example, as shown in Table 7, the physical half-life of strontium 90 is about 10,439 days and the biological half-life is about 18,000 days for bone. Therefore, the effective half-life of strontium 90 deposited in the bone is 6,400 days. That is, half the radioactivity of strontium 90 taken into the body will be gone after 6,400 days, another half of the remaining radioactivity will be depleted after an additional 6,400 days, and this process will continue as the radioactivity is depleted from the body. The effective half-life is always less than or equal to either its physical or biological half-life.

Figure 19. **ATSDR Health-Based Determination of Radiological Doses**

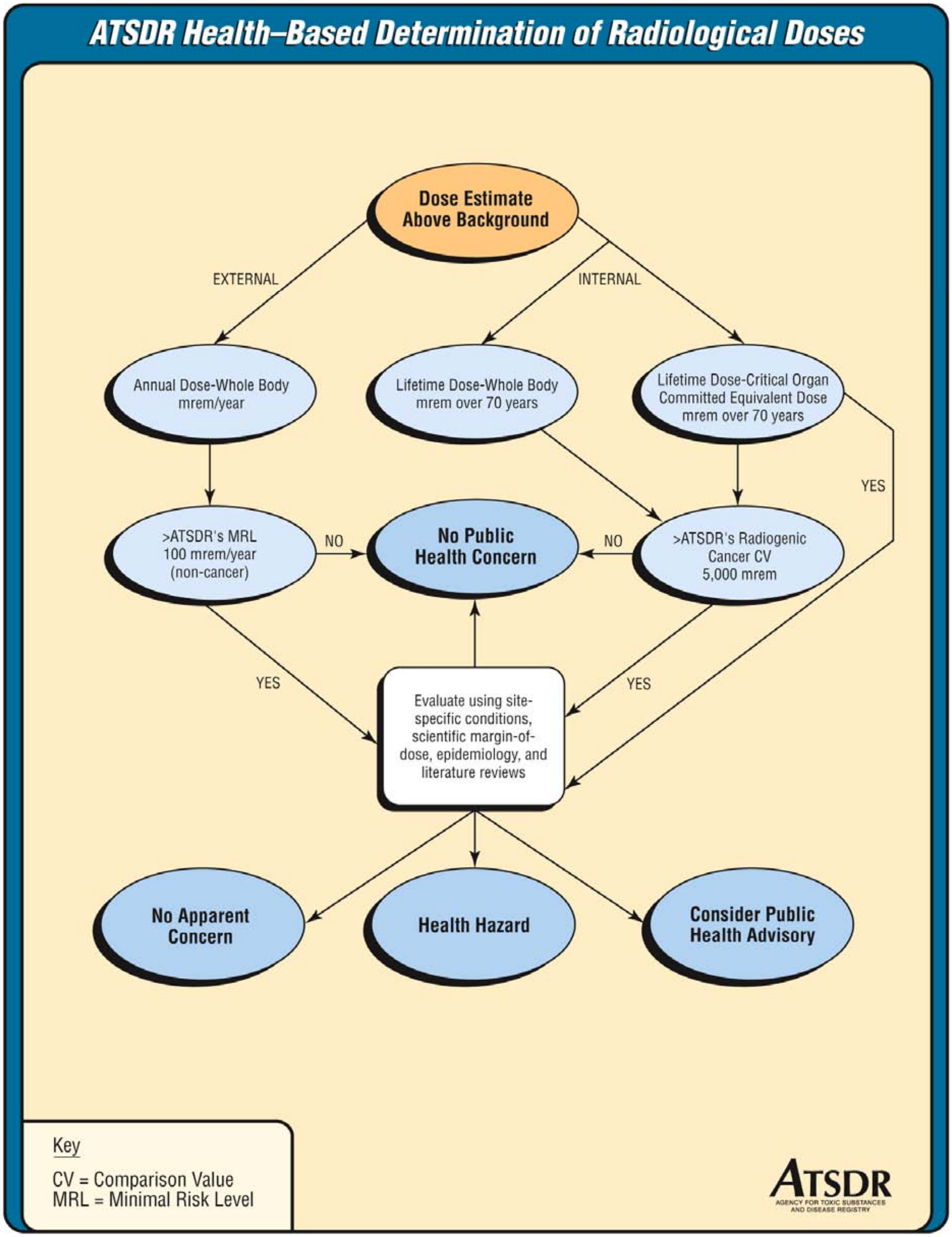


Table 7. Half-Lives (in days) of Selected Radionuclides in the WOC PHA

Radionuclide	*Physical Half-Life*	*Biological Half-Life*	*Effective Half-Life**
Tritium	4,490	12 (whole body)	12 (whole body)
Cesium 137	11,023	70 (whole body)	70 (whole body)
Strontium 90	10,439	18,000 (bone)	6,400 (bone)
Cobalt 60	1,935	9.5 (whole body)	9.5 (whole body)
Yttrium 90	2.7	14,000 (bone)	2.7

* Effective half-life is the time required for the radioactivity of a radionuclide to be diminished 50 percent through the combined action of radioactive physical decay and biological elimination.

Radiological Measurements

This PHA uses two systems for radiological measurements and doses: the Conventional System and the Systeme International. The key in Table 8 describes these units and lists their abbreviations.

Table 8. Units for Radiological Measurements

System	*Unit*	*Parameter/Description*
Conventional System	picocurie, pCi	The curie (Ci) is the basic unit of radioactivity. The pCi is 1,000,000,000,000 (one trillion) times smaller than one Ci.
	millirem, mrem	Dose is given in units "roentgen equivalent man" or rem. One mrem is 1,000 times smaller than one rem. This is the unit for both the equivalent dose and the effective dose.
Systeme International	becquerel, Bq	The basic unit of activity is the becquerel (Bq). The number of curies must be multiplied by 3.7×10^{10} to obtain an equivalent number of Bq.
	millisievert, mSv	The sievert (Sv) is the unit of equivalent dose and the effective dose. One mSv is 1,000 times smaller than one Sv. The number of millisieverts (mSv) must be multiplied by 100 to convert to millirem.

III.B. Exposure Evaluation of the Clinch River and Lower Watts Bar Reservoir

ATSDR evaluated past (Clinch River) and current exposures (Clinch River and LWBR) to radioactive contamination (based on environmental samples) that was released from X-10 via White Oak Creek. ATSDR evaluated future exposures to the Clinch River and the LWBR based on the current estimated exposure doses and the institutional and engineering controls that are in place for both of these watersheds. The highest exposure doses were estimated for people who frequently ate fish (1 to 2.5 fish meals a week) caught from the Clinch River near the mouth of White Oak Creek from 1944 to 1953. Doses were much lower for people who ate fewer fish or fished further downstream and for the other past and current exposure pathways evaluated in this public health assessment.

This section presents an overview of past, current, and future exposures to radioactive contaminants released to the Clinch River, and current and future exposure to radioactive contaminants released to the LWBR. An evaluation of potential public health hazards from likely exposures to White Oak Creek releases is presented in Section IV. Public Health Implications. ATSDR used the time periods and information presented below in its evaluation. Please note that because some studies are conducted simultaneously, the past and current time periods overlap slightly. The doses obtained from these studies are, however, based on different data. Therefore, even though the time periods overlap, the estimated *past* doses do not overlap with the estimated doses for *current* and *future* exposures.

- Past exposure: "Past" refers to the period from 1944 to 1991. For its evaluation of past exposures, ATSDR reviewed the Task 4 report and documents associated with the report. The Task 4 report is titled *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*. The complete project can be accessed through TDOH's Web site at http://www2.state.tn.us/health/CEDS/OakRidge/ORidge.html and a brief summary of the Task 4 report is provided in Appendix D.

- Current exposure: "Current" refers to the period 1988–2003. In evaluating current exposures and doses related to releases from White Oak Creek, ATSDR relied on data collected from 1988 to 1994 (as presented in its 1996 health consultation titled *Health Consultation for USDOE Oak Ridge Reservation: Lower Watts Bar Reservoir Operable Unit, Oak Ridge, Anderson County, Tennessee*) and on data collected from 1989–2003 from the Oak Ridge Environmental Information System (OREIS) (USDOE 1989–2003). A brief summary of the 1996 ATSDR health consultation on Lower Watts Bar Reservoir is provided in Appendix D.

- Future exposure: "Future" refers to exposures that occur after the present time period. ATSDR based its evaluation of future exposures on current doses and exposures related to releases from White Oak Creek, data on current contaminant levels in the LWBR and the Clinch River, consideration of the possibility that remedial activities could release radionuclides to White Oak Creek, engineering controls to prevent off-site contaminant releases, and institutional controls that are in place to monitor contaminants in the LWBR and the Clinch River. These institutional controls consist of the following: 1) prevention of sediment-disturbing activities in the Clinch River and LWBR; 2) DOE's annual monitoring of Clinch River and LWBR surface water, sediment, and biota; 3) DOE's monitoring of White Oak Creek releases; 4) TDEC's monitoring of public drinking water supplies in Tennessee under the Safe Drinking Water Act for EPA-regulated contaminants; and 5) TDEC–DOE Oversight Division's quarterly radiological monitoring of five public water supplies on the ORR and in its vicinity under the EPA's Environmental Radiation Ambient Monitoring System (ERAMS) program. Further, data show that because of remedial actions and preventive measures at X-10, physical movement of sediments from the area, and radiological decay, the radionuclide releases from White Oak Creek have decreased over time. Similarly, the concentrations of radionuclides in the water and along the shoreline have also decreased.

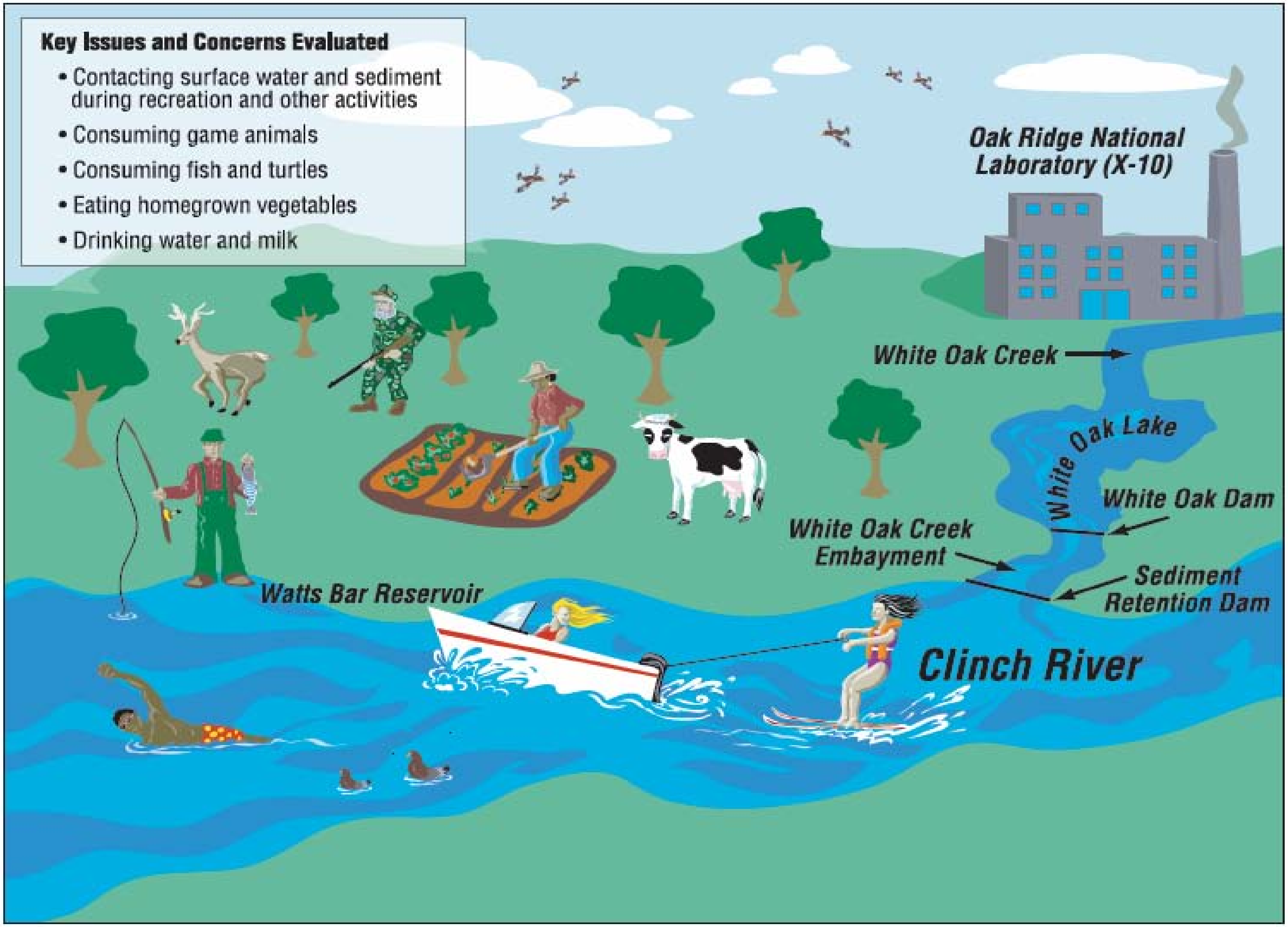
III.B.1. Possible Exposure Situations in the Clinch River and the Lower Watts Bar Reservoir Areas

People could come in contact with contaminants along the Clinch River and the Lower Watts Bar Reservoir via several different pathways. ATSDR analyzed radioactive contaminant data for surface water, sediment, and biota (aquatic and terrestrial) to determine whether the levels detected in these media might pose a past or current public health hazard. This evaluation looked at the level of contamination present, the extent to which individuals contact the contamination, and estimated doses to individuals coming in contact with the media under different exposure scenarios. ATSDR identified several exposure situations for the Clinch River and LWBR areas that required further evaluation. This PHA evaluates the following situations for exposures at the Clinch River, LWBR, or at both locations:

- Ingestion of drinking water
- External exposure from contact with water and sediment during recreational activities
- External contact with dredged sediment used as topsoil in home gardens
- Ingestion of locally produced milk and meats
- Ingestion of fish or local game animals
- Incidental ingestion of surface water during recreational activities

Exposure situations associated with radioactive contaminants released from White Oak Creek are evaluated in detail in the following discussion and depicted in Figure 20.

Figure 20. Possible Exposure Situations Along the Clinch River



To acquaint the reader with terminology and methods used in this PHA, 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 detailed remedial activities related to the study area; Appendix C summarizes other public health activities at the ORR; Appendix D contains summaries of ATSDR, TDEC, and TDOH studies or investigations; Appendix E provides a table of Task 4 conservative screening indices (i.e., the calculated probabilities of developing cancer) for radionuclides in the Clinch River; Appendix F includes a discussion on risk; Appendix G presents responses to public comments; and Appendix H provides responses to peer reviewer comments.

III.B.2. Past Exposure (1944–1991)

TDOH's Task 4 Study

Wastes from historical X-10 operations were released to White Oak Creek, which travels south along the eastern border of the X-10 site, flows into White Oak Lake, over White Oak Dam, and into the White Oak Creek Embayment before meeting the Clinch River at Clinch River Mile (CRM) 20.8 (see Figure 3 and Figure 4). Radionuclides were released when creek flow eroded the contaminated bottom sediment of White Oak Lake and carried them into the Clinch River. Some of the upstream river sediment containing radionuclides was scoured and the transport of the suspended contaminated sediment contributed to the buildup of radionuclides in sediment further downstream. Prior to the impoundment of Melton Hill Dam in 1963, the particulate in the water column was usually deposited near CRM 14 (close to the mouth of Grassy Creek). This is an area where the river is wider and is influenced by the Watts Bar Reservoir. After 1963, however, the pattern of particulate deposition in sediment changed because of the controlled releases from Melton Hill Dam (Blaylock 2004).

In 1996–1999, TDOH's Task 4 team prepared the *Reports of the Oak Ridge Dose Reconstruction, 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* (referred to as the "Task 4 report") to assess whether individuals visiting or living along the Clinch River area might have come in contact with harmful levels of radioactive materials in the past. Wastes generated at X-10 from 1944 to 1991 (the time frame covered in the

Task 4 report) included radionuclides in various chemical forms (solids and liquids). Specifically, the purpose of the Task 4 effort was to:

- Estimate the historical releases of radioactive materials from the X-10 processes to White Oak Creek.
- Review and evaluate the possible exposure pathways for the public who lived downstream from White Oak Creek along the Clinch River and the Tennessee River.
- From these potential exposure pathways, calculate both the radiation doses and risks associated with these exposures. Because historical records were not maintained to today's standards, the Task 4 team performed independent reviews of environmental monitoring reports and existing data on releases and also used mathematical models to estimate the radiation doses and the associated risks (ChemRisk 1999a).

Task 4 Screening Assessment

As an initial evaluation in 1996, the Task 4 team identified 24 radionuclides—americium 241, barium 140, cerium 144, cobalt 60, cesium137, europium 154, hydrogen 3, iodine 131, lanthanum 140, niobium 95, neodymium 147, phosphorus 32, promethium 147, praseodynium 143, plutonium 239/240, ruthenium 106, samarium 151, strontium 89, strontium 90, thorium 232, uranium 235, uranium 238, yttrium 91, and zirconium 95—that were released to the Clinch River via White Oak Creek from 1944 to 1991 (ChemRisk 1999a). The Task 4 team determined that a screening analysis would help focus its efforts on the most important radionuclides and on the ways that people could have been exposed to White Oak Creek radionuclide releases via the Clinch River. The Task 4 team used a risk-based screening process to calculate conservative human health risk estimates for reference individuals and target organs, assuming that exposure occurred between 1944 and 1991 (a period of up to 48 years, except where noted).[7] These risk estimates represented exposed individuals' increased likelihood of developing cancer—known as

Task 4 Phases

Initial Assessment
Radionuclides released to White Oak Creek
24
⇓
Screening Analysis
Radionuclides identified for further evaluation
8
⇓
Supplemental Analysis
Radionuclides identified as the important contributors to dose and health hazards
4

[7] For the purposes of the Task 4 study, a reference individual is a hypothetical or real unidentified person who resides in the area or who consumes contaminated foodstuffs from the area.

"excess lifetime cancer risk estimates." Because of the conservative assumptions used in calculating the estimates, the risk level would likely overestimate the public health hazard for exposed off-site populations. For comparison, the Task 4 team used an upper bound of 1 in 100,000 (1×10^{-5}) as the decision point, or minimal level of concern. This value was one-tenth of the ORHASP-recommended value of 1 in 10,000 (1×10^{-4}); thus, the value used by the Task 4 team was *more conservative* than the ORHASP-recommended value.

> The same value can be presented in different ways:
>
> 0.0001
> 1.0E-04
> 1×10^{-4}
> 1/10,000
> one in ten thousand

Through this screening process, the Task 4 team eliminated 16 out of 24 radionuclides released to the Clinch River from White Oak Creek because the estimated screening indices were below the minimal level of concern (1×10^{-5}). The eight radionuclides for which additional analysis would be necessary were cobalt 60 (Co 60), strontium 90 (Sr 90), niobium 95 (Nb 95), ruthenium 106 (Ru 106), zirconium 95 (Zr 95), iodine 131 (I 131), cesium 137 (Cs 137), and cerium 144 (Ce 144) (ChemRisk 1999a). Because the screening risk estimates for the swimming and irrigation pathways were below the minimal screening level for all 24 radionuclides, the team was able to eliminate these two exposure pathways (and therefore, consumption of locally grown crops) from further analysis. The team was also able to eliminate external exposure to dredged sediment, which only occurred in the Jones Island study area; the likelihood was low that individuals other than workers would have been exposed. The exposure pathways that required further evaluation were ingestion of fish, surface water, and meat and milk from cattle that grazed near the river, and external radiation from walking on shoreline sediment. Following this screening, the TDOH conducted a supplemental screening that included developing annual release amounts for the eight radionuclides and conducting a more comprehensive analysis of various exposure pathways.

Using its supplemental screening, the Task 4 team determined that four radionuclides (Cs 137, Co 60, Ru 106, and Sr 90) were more likely than the other four (Nb 95, Zr 95, Ce 144, and I 131) to cause adverse health effects to exposed off-site populations (ChemRisk 1999a). For more information on the screening process, see the brief summarizing the Task 4 report in Appendix D. For additional details and calculations used in the screening and supplemental screening processes in the Task 4 report, see Appendices 3A, 3B, and 4A of the document online at http://www2.state.tn.us/health/CEDS/OakRidge/WOak2.pdf.

Estimated Quantities of Radionuclides Released into White Oak Creek

Because accurate environmental monitoring and sampling data were not available, the Task 4 team performed an in-depth evaluation to estimate the amount of radionuclides that flowed from X-10, over White Oak Dam, and to the Clinch River. Through this evaluation, the team derived annual estimates for the eight radionuclides of interest: Co 60, Sr 90, Nb 95, Ru 106, Zr 95, I 131, Cs 137, and Ce 144. In total, about 200,000 curies of radioactive material were released from White Oak Creek into the Clinch River between 1944 and 1991 (ChemRisk 1999a). Using this information, the team then performed mathematical modeling to estimate the annual average concentrations of the eight radionuclides in water and sediment at specified locations downstream of White Oak Creek. To calculate doses for Cs 137, Sr 90, Ru 106, and Co 60, the Task 4 team used—when available—actual measurements from the Clinch River water it collected 1960–1990 at CRM 14.5 (K-25 Grassy Creek) and at 4.5 (Kingston Steam Plant). For the remaining radionuclides and for time periods when data were unavailable, the Task 4 team used modeling to estimate the historical radionuclide concentrations in Clinch River water. Limited available monitoring data were used to calibrate the results of the team's modeling efforts. For more information on the Task 4 team's modeling efforts, please refer to Section 6 of the Task 4 report, which is available at http://www2.state.tn.us/health/CEDS/OakRidge/WOak1.pdf.

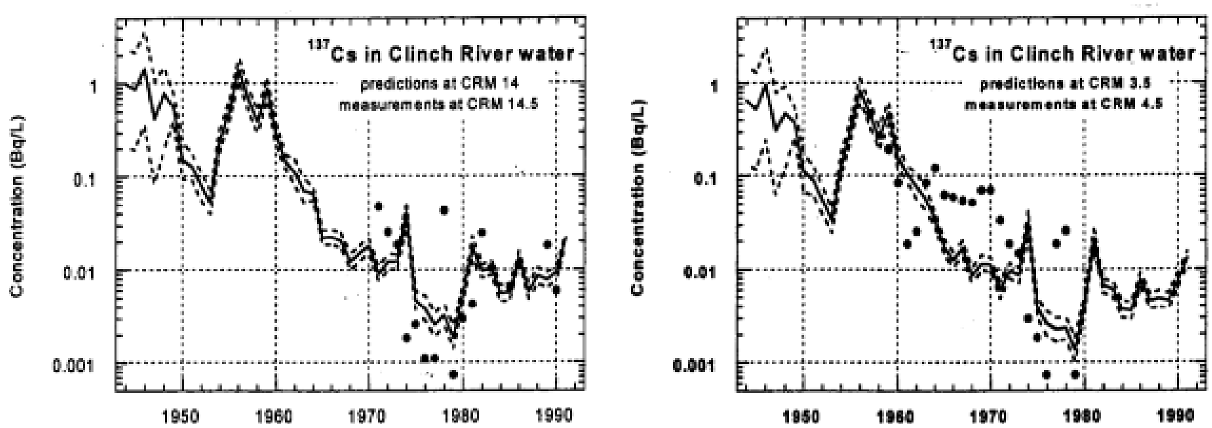
Releases of radionuclides to White Oak Creek from 1955 to 1959 were believed to account for the highest concentrations of Cs 137 that reached the Clinch River.

Concentrations of radionuclides in the Clinch River have decreased over time.

Of the radionuclides released to White Oak Creek, the greatest health hazards were believed to be associated with Cs 137. Cs 137 releases along White Oak Creek were highest from 1955 to 1959. The high Cs 137 releases during those years resulted when the creek flow eroded the contaminated bottom sediment of White Oak Lake after the lake was drained in 1955. This was particularly true during the heavy rains in the winter and early spring of 1956. Currently, the elevated levels of Cs 137 are limited to the subsurface sediment buried in the deep channels of the LWBR.

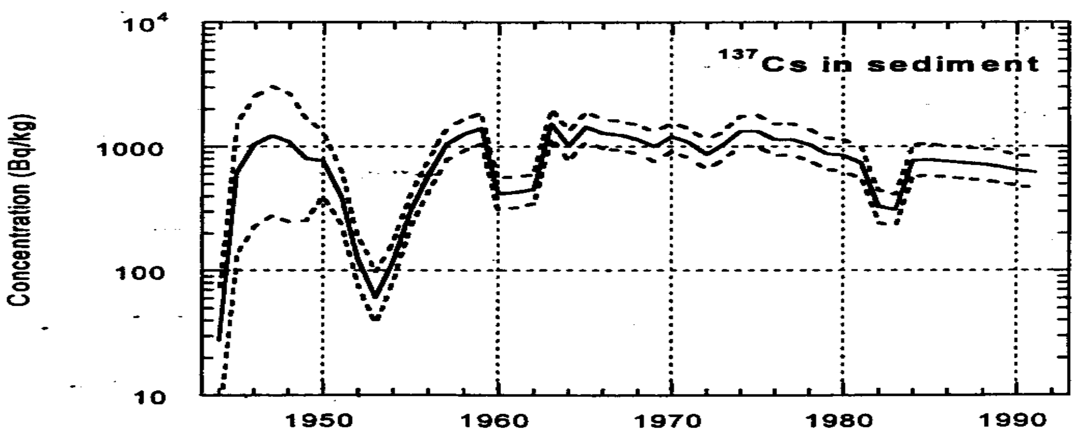
Because of remedial actions and preventive measures at X-10, physical movement of sediments from the area, and radiological decay, the radionuclide releases from White Oak Creek have decreased over time and the concentrations of radionuclides in the water and along the shoreline have decreased as well. For example, Cs 137 in the Clinch River water near CRM 14 and CRM 3 has decreased by about a factor of 100 (see Figure 21). Because Clinch River sediments are not as actively exchanged as the river water itself (i.e., the sediments do not mix as much as the surface water), the Cs 137 in sediment at CRM 14 has decreased as a function of its half-life (see Figure 22) (ChemRisk 1999a).

Figure 21. Comparison of Predicted Annual Average Concentrations of Cs 137 in Water



Comparison of predicted annual average concentrations of Cs 137 in water with measured annual average concentrations. Comparisons are shown for predictions at CRM 14 with measurements at CRM 14.5 (left) and for predictions at CRM 3.5 with measurements at CRM 4.5 (right). Solid lines indicate the central values of the predictions; dashed lines indicate predicted 95% confidence bounds based only on uncertainty in release estimates. Dark circles indicate measured values.
Source: ChemRisk 1999a

Figure 22. Annual Average Cs 137 Concentrations in Shoreline Sediment



Example of predicted annual average concentrations of Cs 137 in shoreline sediment for CRM 14. The solid line indicates the central values of the predictions; dashed lines indicate predicted 95% confidence bounds based only on the uncertainty in the release estimates.

Source: ChemRisk 1999a

Task 4 Exposure Pathways Evaluation

The greatest exposures to White Oak Creek releases occurred between 1944 and 1963.

For the eight radionuclides (Cs 137, Co 60, Ru 106, Sr 90, Nb 95, Zr 95, Ce 144, and I 131) requiring additional analysis, the Task 4 team conducted an in-depth exposure pathway evaluation of ingestion of fish, surface water, and meat and milk from cattle that grazed near the river, and external radiation from walking on shoreline sediment. Table 9 presents the past exposure pathways, the reference populations, and the radionuclides studied in the pathway exposure evaluation. Individuals were exposed over the entire 48-year study period, except for certain years pertaining to drinking water, external exposures, and meat and milk ingestion (excluded years are noted below in the table). For the fish consumption pathway, the Task 4 team considered three categories of fish consumers to account for differences in the amount of fish that individuals consume (Category I: 1 to 2.5 fish meals/week, Category II: 0.25 to 1.3 fish meals/week, and Category III: 0.04 to 0.33 fish meals/week)[8] (ChemRisk 1999a).

Table 9. Past Exposure Pathways Evaluated in the Task 4 Report

Exposure Pathway	*Reference Individuals*	*Radionuclide*
Fish ingestion	Adults eating fish from the Clinch River that were caught near Jones Island, K-25/Grassy Creek, Kingston Steam Plant, and the city of Kingston	Cs 137, Ru 106, Sr 90, Co 60
Drinking water ingestion*	Adult visitors to K-25 and the Kingston Steam Plant Adults and children in the city of Kingston	Cs 137, Ru 106, Sr 90, I 131
Meat ingestion*	Adults eating meat from cattle that had access to the Clinch River	Cs 137, Ru 106, Sr 90, Co 60
Milk ingestion*	Adults and children drinking milk from cows that had access to the Clinch River	Cs 137, Ru 106, Co 60, I 131
External exposure*	Adults walking along the shoreline on Jones Island, K-25/Grassy Creek, Kingston Steam Plant, and the city of Kingston	Cs 137, Ru 106, Sr 90, Co 60, Ce 144, Zr 95, Nb 95

* Drinking water exposures occurred from 1944 to 1991, except at the city of Kingston (1955–1991) and the Kingston Steam Plant (1954–1989). External exposures occurred from 1944 to 1991, except at Jones Island (1963–1991). Meat and milk ingestion exposures occurred from 1944 to 1991, except at Jones Island (1963–1991).

[8] A meal was defined as 0.1 to 0.3 kilograms (roughly 3.5 to 10.5 ounces) per meal for males and 0.08 to 0.25 kilograms (roughly 2.8 to 8.8 ounces) per meal for females.

The Task 4 study covered a broad area along the Clinch River, from the mouth of White Oak Creek to the confluence of the Clinch and Tennessee Rivers. Because exposure situations might vary with the differences in topography and land uses at various sections of the river, the Task 4 team divided the area of study into four segments. Table 10 gives the CRM range, location, and exposure situations evaluated for each segment.

Table 10. Locations and Exposure Scenarios Considered in the Task 4 Study

Clinch River Mile*	***Location***	***Exposure Scenarios***	
		Pathway†	***Years of Exposure***
21 to 17	Jones Island	• Ingestion of fish • Ingestion of meat and milk • External exposures to shoreline sediment	1944 to 1991 1963 to 1991 1963 to 1991
17 to 5	K-25/Grassy Creek	• Ingestion of fish • Ingestion of drinking water • Ingestion of meat and milk • External exposures to shoreline sediment	1944 to 1991 1944 to 1991 1944 to 1991 1944 to 1991
5 to 2	Kingston Steam Plant	• Ingestion of fish • Ingestion of drinking water • Ingestion of meat and milk • External exposures to shoreline sediment	1944 to 1991 1954 to 1989 1944 to 1991 1944 to 1991
2 to 0	City of Kingston	• Ingestion of fish • Ingestion of drinking water • Ingestion of meat and milk • External exposures to shoreline sediment	1944 to 1991 1955 to 1991 1944 to 1991 1944 to 1991

* The river mile is the distance from the mouth of the river. That is, Clinch River Mile 0 is where the Clinch River empties into the Tennessee River. White Oak Creek enters the Clinch River at Clinch River Mile 20.8.

† The Task 4 report originally included ingesting produce, swimming, irrigating, and contacting dredged sediment (varying by segment) as pathways in its screening analysis. Given the results of its initial screening, however, the Task 4 team eliminated these pathways from further evaluation.

The Grassy Creek area includes portions of the Clinch River from Clinch River Mile (CRM) 17 to CRM 14. The mouth of Grassy Creek empties into the river at CRM 14.5; a tenth of a mile below that (CRM 14.4) is the potable water intake for the K-25 Gaseous Diffusion Plant. Associated with the intake was a combined filtration plant (using sand as the filter) and water storage facility that supplied potable water to the K-25 facility. Any radiological contaminants in the water intake for K-25 originated from the releases from White Oak Creek, approximately 7 miles upstream from the K-25 intake area. ATSDR learned about issues related to the K-25 intake from members of the public at meetings held by the Exposure Evaluation Work Group

(EEWG), formerly known as the Public Health Assessment Work Group (PHAWG), as well as from the community concerns database maintained by ATSDR and discussions with DOE. ATSDR also learned from a community member that the K-25 intake was used at the J.A. Jones Construction Camp, which is locally referred to as the Happy Valley Settlement. The Happy Valley Settlement was first occupied in 1943 and 1944, primarily by construction workers, some family members, and a few concessionaires. At its peak in 1945, Happy Valley had more than 8,700 residents, including an estimated 5,600 workers and 3,100 dependents (Keith and Baker 1946; Prince 2003). Most people began leaving the settlement between the spring and fall of 1945, as construction of gaseous diffusion facilities was completed or permanent housing became available. Even so, anecdotal reports by an Oak Ridge community member suggest that the settlement might have been occupied as late as 1948. Because of possible exposure to contaminants in drinking water at Happy Valley, ATSDR conducted a separate evaluation for the Happy Valley community for the years the community was in existence.

Task 4 and ATSDR Estimated Radiation Doses

Radionuclides along the Clinch River could have contributed to an individual's internal or external dose of radiation. *Internal exposures* were due to internally-deposited radionuclides from ingestion of radionuclides in fish, meat, milk, and surface water. The main source of *external exposure* to the Clinch River was through exposure to shoreline sediment along the river.

The Task 4 team derived radiation doses for each pathway of interest to estimate the amount of radiation that a potentially exposed individual might have received.[9] In deriving the doses, the team used the International Commission on Radiological Protection's (ICRP) critical organ concept of dose limitation. ICRP's method limits dose (and long-term effects) to the critical organ—the organ most sensitive to or receiving the highest radiation dose following an intake of radioactive material. Using this approach, the cumulative dose to an organ from internally-deposited radionuclides is estimated separately from the dose attributed to external exposure (see text box).

The Task 4 team calculated the 95% confidence intervals for the cumulative organ dose equivalents. The 95% confidence interval is defined as the range of values, centered on the

[9] The Task 4 team's estimated organ doses, estimated cancer risk coefficients, and associated uncertainties and sensitivities of variables are reported in chapters 13 and 14 of the Task 4 study (ChemRisk 1999a).

estimated mean, within which there is a 95% probability that the true mean will actually fall.[10] The distributions from which the upper and lower confidence limits for each variable are obtained are based on the individual sets of measured data. For internal doses from ingestion, the Task 4 team considered exposure to Cs 137, Sr 90, Co 60, and Ru 106 and estimated dose factors for 22 organs for an adult; the team assessed exposure to I 131 and estimated thyroid doses for a child. The Task 4 team used different methods for estimating dose factors depending on the amount and quality of information available for each radionuclide (ChemRisk 1999a). For external exposures, the team evaluated the following seven radionuclides: Cs 137, Co 60, Ru 106, Zr 95, Nb 95, Sr 90, and Ce 144. The Task 4 team assumed that people were exposed for the entire study period of 48 years (1944 to 1991), except (as noted in Table 10) for a 29-year exposure duration associated with external exposure and ingestion of meat and milk at Jones Island, a 36-year exposure duration for drinking water at the Kingston Steam Plant, and a 37-year exposure duration for drinking water at the city of Kingston.

Using the 50th percentile value of the uncertainty distribution, ATSDR summarized the Task 4 organ doses for the bone, lower large intestine, red bone marrow, breast, and skin locations. The 50th percentile (central) values represent the medians of organ doses. ATSDR selected these organs because the contaminants of concern—particularly Sr 90 and Cs 137—tend to concentrate in these organs. ATSDR uses the central values because they provide the most realistic doses for potential past exposures to radionuclides in the Clinch River. Central estimates are used because they describe the risk or dose for a typical, realistic individual. When considering central estimates, half of the potential doses will fall above, and half will fall below the estimate. Therefore, an individual's actual dose would most likely be closer to the central value than to the high or low end of the dose estimate range. Further, ATSDR's external reviewers, who evaluated documents associated with the Oak Ridge Dose Reconstruction, recommended emphasizing the central estimate rather than the upper and lower bounds of the dose distribution.

ATSDR focused its evaluation on two potential exposure locations—Jones Island and the city of Kingston (see Table 11). ATSDR narrowed its evaluation to these two locations because Jones

[10] The confidence intervals are based on the assumption that the variable is normally or log-normally distributed in the population under consideration. Lognormal distributions are often used to describe the distribution of a variable that cannot become negative.

Table 11. Summary of Estimated Organ-Specific Doses and Whole-Body Doses for Each Past Radiation Exposure Pathway and the Estimated Lifetime Organ-Specific Doses and Lifetime Whole-Body Doses From All Past Radiation Exposure Pathways

Exposure Pathway	*Location*‡	*Organ-Specific Radiation Dose (mrem over 48 years)* «					*Whole-Body Dose*†«	
		Bone	*Lower Large Intestine*	*Red Bone Marrow*	*Breast*	*Skin*	*Annual (mrem per year)*	*Lifetime (mrem over 70 years)*
Fish ingestion	Jones Island	810	570	600	240§	310	3.4	238.6
	Kingston	96	64	65	30§	35	0.4	27
Drinking water ingestion	K-25/ Grassy Creek	110	81	46	2.1	2.4	0.3	24
	Kingston	3.5	6.2	1.7	0.12	0.14	<0.01	1.4
Meat ingestion	K-25/ Grassy Creek	1.4	2.1	0.81	0.31	0.31	<0.01	0.6
Milk ingestion	K-25/ Grassy Creek	0.84	0.13	0.42	0.046	0.048	<0.01	0.1
External radiation (walking on sediment) ¶	Jones Island	12	7.1	7.7	9.0	10	0.1	3.6
	Kingston	50	29	32	37	47	0.2	14.8
Estimated Committed Equivalent Doses (over 70 years) **		Less than 1,600 mrem	Less than 1,200 mrem	Less than 1,200 mrem	Less than 500 mrem	Less than 700 mrem	4††	278‡‡

* Data were derived from ChemRisk 1999a—Tables 13.3, 13.4, 13.5, and 13A.8. The organ-specific radiation doses are the 50th percentile (central estimate) as reported by the Task 4 authors for individuals exposed during the entire study period (48 years), except for specific years that were not included for certain areas (see Table 10).

« To compare the doses in the Task 4 report to the doses in this table, 1,000 mrem is equal to 1 centisievert (cSv). For example, 810 mrem (organ-specific radiation dose to the bone for fish ingestion at Jones Island) divided by 1,000 would equal 0.81 cSv—the same value presented in Table 13.3 of the Task 4 report.

† ATSDR approximated the annual (1-year) whole-body dose for each pathway by applying weighting factors (presented in Table 6) to Task 4's estimated 50th percentile organ-specific doses, adjusting for a 1-year exposure, and summing the adjusted organ doses across each pathway. ATSDR approximated the lifetime (70-year) whole-body dose for each pathway by adjusting the doses for a 70-year exposure and summing the adjusted doses for each pathway.

‡ The location represents the locations along the Clinch River of maximum exposure for each exposure pathway.

§ Doses are for females only; doses were too low to be significant in males.

¶ The doses are based on exposure to shoreline sediments.

** As a conservative measure, ATSDR estimated the committed equivalent doses for individuals who could have been exposed via all of the pathways and at all of the locations described above. To approximate a committed equivalent dose to an organ over 70 years, ATSDR summed the organ-specific radiation doses from the Task 4 report—based on up to 48 years of exposure—divided by 48, multiplied by 70 years, and rounded up.

†† ATSDR derived the total annual whole-body dose over a lifetime by summing the annual whole-body doses for each pathway.

‡‡ ATSDR derived the committed effective dose to the whole body by summing the equivalent doses for each organ using ICRP methodology.

Island is the closest land mass to the mouth of White Oak Creek and the city of Kingston is the closest large city downstream of the creek before the confluence of the Clinch River and Tennessee River. (For certain pathways, doses at K-25/Grassy Creek are presented as the location of maximum exposure.)

Weighting factors (explained on page 68) are used to convert an organ dose equivalent to a committed effective dose for the whole body that is lower than the organ dose. The committed effective dose is obtained by multiplying the organ dose by the weighting factor. For example, a 5 mrem dose to the thyroid would be multiplied by the weighting factor 0.05 to yield 0.25 mrem whole-body dose. For its evaluation, ATSDR applied weighting factors to the Task 4 organ doses and summed the adjusted organ doses across pathways to derive the annual and whole-body doses for each pathway. Then, ATSDR summed the annual and whole-body dose for each pathway to derive the total annual dose to the whole body and the *committed effective dose* to the whole body over 70 years. ATSDR also summed the organ doses to derive a *committed equivalent dose* to an organ over a 70-year (lifetime) exposure. When deriving the committed equivalent dose to an organ, ATSDR adjusted the Task 4 organ doses from a 48-year exposure (except in cases noted in Table 10) to a 70-year exposure so that ATSDR could compare these doses to health guidelines for radiation exposures to the public.

Table 11 presents the organ-specific and whole-body doses for all pathways of interest. As shown in Table 11, the maximum annual whole-body dose from all exposure pathways of interest is 4 mrem. This dose is about 2% of the 360 mrem that the average U.S. citizen receives each year from *background radiation* (i.e., levels typically found in the environment and in sources from human activities and products). About 300 mrem of background radiation is the amount of radiation to which a member of the general population is exposed from natural sources. These sources include terrestrial radiation from naturally occurring radionuclides in the soil, cosmic radiation originating from space, and naturally occurring radionuclides deposited in the human body. The remaining 60 mrem of background radiation results from sources related to human activities and products, such as medical and dental x-rays (Nuclear Energy Institute 2003). Of the 22 organs evaluated, the Task 4 authors predicted that the bone surface received the highest dose of radiation from any of the exposure pathways. The higher doses to the bone reflect the additional contribution from Sr 90.

After its review of Task 4 organ-specific doses and ATSDR-derived lifetime and whole-body doses, ATSDR determined that exposures to radionuclides by way of fish ingestion, water ingestion, and external radiation were more likely than the other pathways to result in higher radiation exposures in off-site populations. For comparison, doses from ingesting meat and milk were more than 1,000 times less than doses from eating fish (see Table 12). These calculated doses have been screened against the comparison values found in Table 22 of Section IV. Public Health Implications.

Table 12. Ratio of Adult Organ-Specific Radiation Doses Relative to Ingestion of Fish Caught Near Jones Island

Pathway†	***Location‡***	***Ratio of Radiation Dose****				
		Bone	***Lower Large Intestine***	***Red Bone Marrow***	***Breast***	***Skin***
Fish ingestion	Jones Island	1.0	1.0	1.0	1.0§	1.0
	Kingston	0.12	0.11	0.11	0.13	0.11
Drinking water ingestion	K-25/ Grassy Creek	0.14	0.14	0.08	0.01	0.01
	Kingston	<0.01	0.01	<0.01	<0.01	<0.01
Meat ingestion	K-25/ Grassy Creek	<0.01	<0.01	<0.01	<0.01	<0.01
Milk ingestion	K-25/ Grassy Creek	<0.01	<0.01	<0.01	<0.01	<0.01
External radiation (walking on sediment)¶	Jones Island	0.01	0.01	0.01	0.04	0.03
	Kingston	0.06	0.05	0.05	0.15	0.15

* The fish consumption dose used to calculate the ratio was the 50th percentile dose received by the maximally exposed individuals who consumed fish caught near Jones Island over the 48-year exposure.
† The pathway presented represents the maximally exposed category.
‡ When doses for two areas are given for the same pathway, ATSDR compared the highest dose to fish doses.
§ Doses are for females only; doses were too low to be significant in males.
¶ The doses are based on exposures from walking along the shoreline.

ATSDR discusses the fish ingestion, water ingestion, and external radiation exposure pathways below.

Fish Ingestion

The highest radiation dose associated with radionuclide releases to the Clinch River was from **frequent consumption of fish** (1 to 2.5 meals per week) caught near the mouth of White Oak Creek. The doses were much lower for other pathways and for individuals who ate fewer fish or caught fish further downstream.

The highest radiation doses were associated with eating fish taken from the Clinch River near Jones Island between 1944 and 1991. Doses were much lower for all other pathways (see Table 11 and Table 12). The Task 4 report's estimated organ doses

- to the bone,
- to the lower large intestine,
- to the red bone marrow,
- to the breast, and
- to the skin

from eating fish were at least 6 times greater than the radiation doses to these same organs from eating meat, drinking water and milk, and external radiation (Table 12). Likewise, ATSDR's derived annual whole-body and committed equivalent doses from eating fish were at least 10 times more than any of the other exposure pathways (Table 11).

The highest organ doses of radiation from fish consumption were estimated for the bone surface (810 mrem for males and 600 mrem for females, central values), and the lowest organ doses were estimated for the skin (310 mrem for males and 230 mrem for females, central values). Despite these differences, the organ doses varied by a factor of only 2 to 3 for males and 3 to 4 for females. This similarity between doses reflects the contribution of Cs 137 to organ doses. Cs 137 distributes rather uniformly throughout the body of the person eating the fish, and therefore, there was little difference among the various organ doses. It should be noted that because different organs are believed to have different sensitivities to radiation-induced cancer, the organ with the highest dose is not necessarily the organ with the highest probability of developing cancer.[11]

The dose for fish consumption depended on how often people ate fish and the area of the Clinch River where the fish were taken. The highest doses were received by individuals who consumed 1 to 2.5 fish meals per week and caught their fish near Jones Island, close to the mouth of White Oak Creek. The estimated annual whole-body dose of 3.4 mrem from eating frequent meals of fish caught near Jones Island was less than 1% of the average annual background dose of 360 mrem for a U.S. citizen. Doses were much lower for individuals who ate fewer fish or caught their fish further downstream from White Oak Creek and Jones Island. For example, organ-specific and whole-body doses for people who ate fish caught near Kingston were 8 times lower than doses from eating fish caught near Jones Island (see Table 12). People who ate fish caught near Kingston received an estimated annual whole-body dose of 0.4 mrem, which is 900 times less than the average annual background dose of 360 mrem for a U.S. citizen.

Drinking Water Ingestion

In Table 11, ATSDR summarizes radiation doses for drinking water at K-25/Grassy Creek (CRM 17 to 5) and the city of Kingston (CRM 0), located downstream from the mouth of White Oak Creek. These doses are from the Task 4 team's evaluation of drinking filtered, treated Clinch River water. Water from the Clinch River can travel up the Tennessee River when the Clinch River's flow is greater than the Tennessee River's flow. As a result of this backflow, the city of Kingston could receive Clinch River water (ChemRisk 1999a). The Task 4 team estimated 1) the amount of radiological contamination resulting from Clinch River backflow possibly entering the Kingston water intake and 2) the effect of water treatment on the drinking water (ORHASP 1999). The estimated organ-specific and whole-body radiation doses received from drinking water from the Clinch River were much lower than the radiation doses received from eating Clinch River fish. For example, the doses to the bone, lower large intestine, red bone marrow, breast, and skin from drinking Clinch River water were at least 7 times lower than the doses to those same organs from eating Clinch River fish. The highest annual whole-body dose from

[11] Because the risk level associated with iodine was below the screening level and none of the other radionuclides are associated with effects on the thyroid, the Task 4 team did not further evaluate the effects on this organ (ChemRisk 1999a).

drinking water of 0.3 mrem was estimated for K-25/Grassy Creek. This annual whole-body dose is more than 1,000 times less than the background dose of 360 mrem that the average U.S. citizen receives each year. Lower doses were associated with drinking water further downstream at the city of Kingston. Organ-specific doses from drinking city of Kingston water were at least 13 times less than the doses estimated for K-25/Grassy Creek drinking water.

In addition to the Task 4 team's analysis of exposure to X-10 contaminants via the K-25 water intake, ATSDR conducted a separate analysis of exposure of residents living in the Happy Valley settlement. In its evaluation, ATSDR derived whole-body doses for hypothetical residents of Happy Valley who drank water from the K-25 intake. Most information about Happy Valley indicates that workers and their families occupied the settlement between late 1943 and 1946. Anecdotal reports suggest, however, that some workers stayed on through 1948. Given the uncertainty about the actual time frame in which Happy Valley was occupied—and the duration of possible exposure—ATSDR overestimated the likely exposure period by conservatively assuming that Happy Valley residents could have been exposed over a 7-year period, from 1944 to 1950. Conservative assumptions such as this create a protective estimate of exposure, which allows ATSDR to evaluate the likelihood, if any, that the K-25 drinking water containing radionuclides could cause harm to Happy Valley residents.

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 Task 4 report. ATSDR's highest annual radiological dose estimate at the K-25 water intake was about 14 mrem/year. ATSDR predicted that Happy Valley residents who lived at the settlement from 1944 to 1950 would have received a dose of 98 mrem over the 7-year period. The whole-body dose for drinking water at Happy Valley (from the K-25 intake) was about 2.5 times less than the doses estimated for fish consumption.

External Radiation (Walking on Sediment)

Radionuclides that had accumulated in the sediment deposited along the Clinch River were found in the top layer (averaging about 6 to 7 centimeters [cm], but varying between 2 and 15 cm) of sediment. The Task 4 team derived organ doses for people who might have incurred external exposure to radionuclides while walking on Clinch River shoreline sediment from 1944 to 1991 (except at Jones Island where years of exposure evaluated were 1963 to 1991; see Table 10). When estimating doses from external exposure, the team used dose-rate factors (dose per unit intake) as reported by the ICRP and modified these factors to consider the thickness of the contaminated sediment layer and the width of the Clinch River shoreline. The Task 4 team obtained the external doses by combining the concentrations of radionuclides in sediment with the dose-rate factors and the exposure parameters.

ATSDR focused its evaluation on those exposures occurring near Jones Island and the city of Kingston. Overall, the Task 4 organ doses from walking on sediments were at least 6 times lower than doses received from eating Clinch River fish caught at or near Jones Island. Individuals walking on sediment in the Kingston area were predicted to receive slightly higher doses than individuals at Jones Island. Upstream sediment containing radionuclides was likely dislodged by the water flow and contributed to the buildup of sediment farther downstream. Even so, the maximum annual whole-body dose from external radiation by walking on Kingston sediments (0.2 mrem) is over 1,000 times less than the radiation dose of 360 mrem that the average U.S. citizen receives from background radiation each year (see Table 11).

ATSDR's Review of the Task 4 Dose Reconstruction Report

As part of its involvement at the ORR, ATSDR convened a panel of technical experts to evaluate the study design, the scientific approaches, the methodologies, and the conclusions of the Task 4 report. ATSDR had the report reviewed to determine if it would provide a foundation for follow-up public health actions or studies, particularly ATSDR's congressionally mandated public health assessment of the ORR. The reviewers agreed that the overall design and scientific approach were appropriate. One reviewer commented that the methods and analysis plan "break new and important ground in the use of uncertainty analysis in environmental assessment." The reviewers also commented that the results were generally quite valid and consistent with earlier studies, and were applicable to public health decision-making as long as careful attention was given to the assumptions behind the estimates. Some issues with the team's report raised some concern among the reviewers; in their opinion, however, the report was well written and advanced the science of dose reconstruction.

III.B.3. Current and Future Exposure (Years After 1987)

Lower Watts Bar Reservoir (1988–Present and Future)

Background

The LWBR extends from the convergence of the Clinch River and the Tennessee River (about 22 river miles downstream of White Oak Dam) to the Watts Bar Dam (see Figures 4 and 11). Community members use the reservoir for recreational activities, such as boating and swimming. The LWBR is also a popular recreational fishing spot for area anglers—an estimated 10,000 to 30,000 anglers fish at the Lower Watts Bar Reservoir each year (ORHASP 1999). In addition, Kingston, Rockwood, and Spring City obtain drinking water from surface water bodies flowing into the Watts Bar Reservoir. During rare circumstances, reverse flow conditions could result in ORR contaminants backflowing into these water intakes. Kingston maintains a water intake on Watts Bar Lake, which is upstream from the Clinch River confluence on the Tennessee River at Tennessee River Mile (TRM) 568.4 (Hutson and Morris 1992; G Mize, Tennessee Department of Environment and Conservation, Drinking water program, personal communication re: Kingston public water supply, 2004). Although the intake is slightly upstream, water flow direction in this area is impacted by the Tellico and Fort Loudon Dams and releases through the Watts Bar Dam. Thus, during a rare occurrence where backflow conditions affect these dams, this intake could potentially receive ORR contaminants. Spring City obtains its water from an intake on the Piney River branch of Watts Bar Lake (Hutson and Morris 1992). The city of Rockwood receives its water supply from an intake on the King Creek branch of Watts Bar Lake (Hutson and Morris 1992; TDEC 2001, 2006b). Therefore, ORR contaminants could potentially affect these three intakes, but only during the rare occurrence of reverse flow conditions.

In March 1995, DOE released a proposed plan that called for leaving the contaminated deep sediment in place at the reservoir; deep sediment is generally considered inaccessible to the public, and the LWBR sediment—if left undisturbed—is not expected to pose a concern for public exposure (USDOE 1995a). Because the reservoir was used so widely, some community members expressed concern to ATSDR about possible exposure to contaminants in the water and sediment. The community questioned whether DOE’s proposed actions were sufficient to protect people who use the reservoir from exposure to these contaminants. Subsequently, these residents asked ATSDR to evaluate the potential health risks from exposure to the LWBR contamination and provide an independent opinion on whether DOE's selected remedial actions were adequate to protect public health. ATSDR prepared a health consultation in 1996 to respond to community concerns about potential hazards associated with contaminants in the water and deep sediments of the LWBR (ATSDR 1996). See Section II.F.1. in this document and the brief in Appendix D for more details on ATSDR's health consultation.

Since February 1991, the Watts Bar Interagency Agreement has set guidelines related to any dredging in Watts Bar Reservoir and for reviewing potential sediment-disturbing activities in the Clinch River below Melton Hill Dam, including Poplar Creek (Jacobs EM Team 1997b). Under this agreement, the Watts Bar Reservoir Interagency Working Group (WBRIWG) reviews permitting and other activities, either public or private, that could possibly disturb sediment, such as erecting a pier or building a dock (ATSDR 1996; Jacobs EM Team 1997b; USDOE 2003a). The WBRIWG consists of DOE, EPA, USACE, TDEC, and TVA because of their permit authority or their knowledge of the sediment contamination and how that contamination could impact the public if disturbed (Jacobs EM Team 1997b).

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 EPA before conducting the normal permit review process to determine if there were any DOE contaminants in the sediments. The coordination follows a series of defined processes as outlined in the agreement.

The basic process of obtaining a permit is the same for any organization or individual:

1. An application is completed and submitted to TVA/USACE/TDEC (depending on scope of activity);
2. if the proposed activity would occur within the Watts Bar Reservoir and its tributaries, the application is forwarded to the WBRIWG for review;
3. the WBRIWG reviews available data for the location involved or DOE collects any necessary existing data on sediment contamination;
4. if the location is considered to be uncontaminated or clean enough to pose no significant health risks, then the application is forwarded back to TVA/USACE/TDEC for their standard review process; and

5. if the location is considered to be contaminated and sediments may pose a health risk, DOE works with the applicant to determine how best to conduct the requested activity (assuming TVA/USACE/TDEC permit the action based on their own statutory program of review). The interagency agreement covers any potential sediment-disturbing activity (other than locations predetermined to be free of DOE-related contaminants) (Jacobs EM Team 1997b).

If dredging is necessary in an area with contaminated sediments, DOE will assume the financial and waste management responsibility that is over and above the costs that would normally be incurred. Dredging and subsequent disposal of sediments will take place in accordance with best management practices and in compliance with all state and federal laws regarding downstream impacts and disposal of hazardous or radioactive materials (Jacobs EM Team 1997b).

Environmental Monitoring Data for the Lower Watts Bar Reservoir

To address the community concerns, ATSDR evaluated environmental monitoring data for surface and deep channel sediment, surface water, and local biota collected from the LWBR by DOE and TVA during the 1980s and 1990s (Olsen et al. 1992; USDOE 1994b).[12] In addition to these data, ATSDR evaluated the institutional controls in place to monitor contaminants in the LWBR. These controls, which include measures to keep sediment in place and ongoing water monitoring, have helped to minimize the potential for human exposure to contaminants in sediment and water. Data on radionuclides that were transported downstream from the ORR by the LWBR in sediment, surface water, and fish are discussed below.

Sediment

Radionuclides (Table 13) were detected in the *surface* and deep *subsurface* layers of sediment in the LWBR. The surface samples were collected from shallow areas of the reservoir and the subsurface samples were collected from the deep river channels—beneath several meters of water and 40 to 80 centimeters of sediment. Samples collected from the surface layer contained Cs 137, Sr 89/90, and Co 60. Other radionuclides were also detected, but at much lower frequencies and concentrations. The highest concentration of Cs 137 in surface sediment was below 15 pCi/g, the screening value adopted by the Interagency Working Group. This value is

[12] Additional sources used by ATSDR's evaluation of the Lower Watts Bar Reservoir included a 1992 Clinch River Scoping Report and the data summary for the 1994 near-sediment characterization task for the Clinch River environmental restoration program.

Table 13. Maximum Radionuclide Concentrations in Lower Watts Bar Reservoir Sediment

Radionuclide	*Activity (pCi/g)*	
	Surface Sediment	*Subsurface Sediment*
Americium 241	0.168	0.30
Beryllium 7	0.417	Not reported
Cesium 137	10.31	58.35
Cobalt 60	0.34	1.21
Curium 242	0.021	Not reported
Curium 243/244	0.040	0.04
Curium 245/246	Not reported	0.06
Curium 248	Not reported	0.06
Europium 152	0.241	Not reported
Europium 154	0.072	Not reported
Potassium 40	30.36	Not reported
Plutonium 238	0.230	0.23
Plutonium 239/240	0.072	0.45
Plutonium 241	20.00	Not reported
Plutonium 242	0.07	Not reported
Strontium 89	2.30	Not reported
Strontium 90	0.90	3.30
Uranium 234	0.096	3.08
Uranium 235	0.08	0.37
Uranium 238	0.07	2.45

also below the soil screening value for Cs 137 used by ATSDR as adopted from NCRP's Report 129 (NCRP 1999).

Historical documents suggest that 2 to 5 times more strontium than cesium was released to the Clinch River between 1982 and 1992; however, higher concentrations of Cs 137 were detected in the top layers of sediment (Martin Marietta Energy Systems, Inc. 1993). Both cesium and strontium tend to bind to sediment; although, cesium binds more strongly to sediment, while strontium is released from sediment more readily under certain conditions. Cs 137, Co 60, and Sr 90 are the most common radionuclides detected in the *subsurface* sediment. The depth of the peak concentrations appears to vary with the location in the reservoir, the rate of sediment accumulation, and the type of sediment. In general, radionuclide concentrations were higher in the subsurface sediment than in the surface sediment (see Figure 23), and increased with depth within the subsurface sediment. The highest concentration of Cs 137 (58.35 pCi/g) was found in the deep river channel subsurface sediment at a depth of 15 to 33 inches (Olsen et al. 1992).

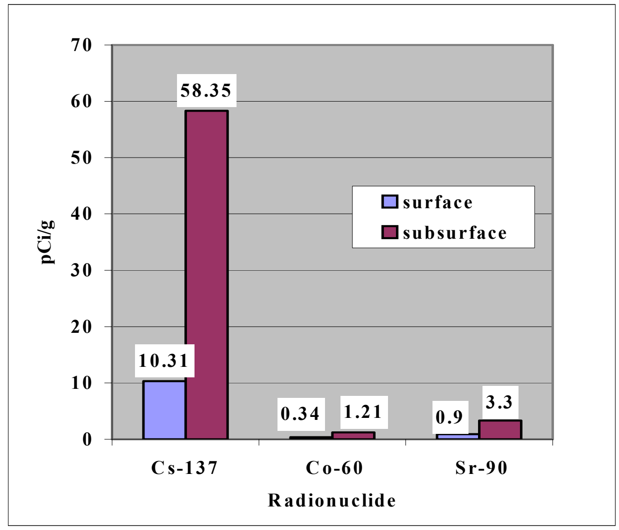


Figure 23. Radionuclide Concentrations in Surface Sediment vs. Subsurface Sediment

The vertical distribution of Cs 137 was strongly correlated to mercury (Hg) concentrations, with both exhibiting large subsurface maximum concentrations that coincided with their peak discharge histories. Sr 90 and Co 60 also existed in the subsurface sediment, but they were generally found at concentrations lower than Cs 137. Peak concentrations of Sr 90 and Co 60 do not strongly relate to peak concentrations of Cs 137 and they do not show a similar dramatic change in concentration with depth of sediment. Uranium concentrations were slightly higher than background concentrations for the region.

Surface Water

Some of the radionuclides released to White Oak Creek were suspended in the water. These radionuclides would be expected to decrease in concentration as they mixed with the surface water of the Clinch River before reaching the LWBR. To evaluate surface water sampling data for the reservoir, ATSDR reviewed TVA's 1991 sediment sampling report (TVA 1991) near major water intakes along the Tennessee River system reservoirs of the Watts Bar, Melton Hill, and Norris Dams; the *Phase 1 Data Summary Report for the Clinch River Remedial Investigation: Health Risk and Ecological Risk Screening Assessment* (Cook et al. 1992); and the *ORR 1992 Environmental Report* (Martin Marietta Energy Systems, Inc. 1993). Samples were collected from 29 locations at the reservoir and were analyzed for 11 radionuclides. ATSDR also reviewed water samples collected by TVA from the water intakes for the cities of Kingston, Spring City, and Rockwood (TVA 1991). Water sampling data consisted of both grab and composite samples. Composite samples were collected weekly, mixed in one container, and analyzed quarterly. Table 14 summarizes the surface water monitoring data for the Lower Watts Bar Reservoir.

Table 14. Maximum Radionuclide Concentrations in Lower Watts Bar Reservoir Surface Water

Radionuclide	*Maximum Concentration (pCi/L)*
Cesium 137	0.51
Cobalt 60	0.54
Hydrogen 3	853
Plutonium 238	0.0081
Plutonium 239	0.0049
Strontium 90	0.7
Uranium—total	0.13

Of the seven radionuclides detected, hydrogen 3 (H 3, also known as tritium) reached the highest concentration (853 pCi/L) in the collected surface water samples. According to the Task 4 report, over 90% of the total radioactivity released from White Oak Creek was in the form of H 3. Concentrations of the other radionuclides were less than 1 pCi/L. 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) of 20,000 pCi/L of H 3, an amount that would produce a radiation dose of 4 mrem/year if ingested at 2 liters of water per day for a year.

The MCL is the level of a contaminant that EPA allows in drinking water.

Drinking Water

The cities of Kingston, Spring City, and Rockwood have public drinking water supplies that draw water from the Tennessee River system. EPA's Safe Drinking Water Act (SDWA) requires all public water suppliers in Tennessee to monitor their water to ensure that it meets safe drinking water standards, or MCLs. The public water supplies for Kingston, Spring City, and Rockwood are monitored for substances that include 15 inorganic contaminants, 51 synthetic and volatile organic contaminants, and 4 radionuclides (USEPA 2004a). According to EPA's Safe Drinking Water Information System (SDWIS), the Kingston, Spring City, and Rockwood public water systems meet safe drinking water standards (USEPA 2004b). In 1996, TDEC's DOE Oversight Division started to participate in EPA's Environmental Radiation Ambient Monitoring System. Under this program, TDEC collects water samples from the Tennessee River system around Kingston and Spring City and analyzes them for radiological content. After its review of the public water supply monitoring and ERAMS results, ATSDR concludes that this water is safe for consumption and for other potable uses.

Fish

LWBR sediment and water quality have been affected by radioactive contaminants released from White Oak Creek to the Clinch River and the LWBR. Some of the radiological materials have long half-lives, and thus might remain in the environment for many years after being released. Even though radionuclide levels in surface water or surface sediment of the reservoir might be relatively low, certain contaminants can persist and accumulate in fish tissue. Fish are exposed to contaminants when they eat smaller fish or consume sediment that contains contaminants. Because of this process, larger and older fish can build up high levels of contaminants (TVA 1994).[13]

Limited data describing radionuclide concentrations in fish from the LWBR were available for ATSDR's review in 1995. The available data came from three sites along or downstream of the LWBR: Mid Watts Bar Reservoir (Tennessee River Mile 557.0), the LWBR north of the Watts Bar Dam (Tennessee River Mile 530.5), and the Upper Chickamaugua Reservoir (Tennessee River Mile 518.0 and below Watts Bar Dam). A combined total of 42 fish specimens were collected, coming from three different species—channel catfish, bluegill sunfish, and largemouth bass. All of the fish fillet samples were analyzed for Cs 137 and Co 60. Channel catfish samples with bones were also analyzed for Sr 90, since strontium is a bone-seeking radionuclide. As shown in Table 15, the radionuclides Cs 137, Co 60, and Sr 90 were detected at 0.16 pCi/g, 0.24 pCi/g, and 1.0 pCi/g, respectively.

Table 15. Maximum Radionuclide Concentrations in Lower Watts Bar Reservoir Area Fish

Radionuclide	***Maximum Concentration (pCi/g)***
Cesium 137	0.16
Cobalt 60	0.24
Strontium 90 (with bone)	1.00

[13] Available (though limited) sampling data of other biota (for example, turtles) were considered. No contaminants of concern were identified in these other biota samples collected at or near the Lower Watts Bar Reservoir.

Lower Watts Bar Reservoir Exposure Pathways and Estimated Radiation Doses

In its evaluation of exposures at the LWBR, ATSDR derived whole-body (committed effective) doses for hypothetical people who came in contact with radionuclides while walking on surface and dredged subsurface sediment, swimming or showering in surface water, drinking reservoir water, or consuming fish. When deriving the doses, ATSDR used *worst-case* exposure scenarios that relied on literature-based conservative (i.e., protective) assumptions for fish ingestion. The worst-case scenarios assumed that the most sensitive population (i.e., young children) was exposed to the highest concentration of radionuclides in sediment, surface water, or fish by the most likely exposure routes—inhalation, ingestion, dermal contact, and external radiation. Using these assumptions when estimating the hypothetical exposure doses likely overestimates the actual magnitude of exposure. These conservative assumptions create a protective estimate of exposure, which allows ATSDR to evaluate the likelihood, if any, that environmental media containing radionuclides could cause harm. ATSDR's estimated doses are summarized in Table 16 and in the discussion that follows.

Table 16. Estimated Whole-Body Doses for Current Lower Watts Bar Reservoir Exposure Pathways

Exposure Pathway		*Individual*	*Whole-Body Dose**	
			Annual (mrem per year)	*Estimated Committed Effective Dose (mrem over 70 years)*
Fish ingestion		Adult and child	6.0	420
Water ingestion		Child	0.25	17.5
External radiation	Contact with surface sediment	Child	15	1,050
	Contact with dredged channel sediment†		20	1,400
	Swimming or showering		0.05	3.5

* ATSDR's conservative assumptions used to estimate radiation doses likely created overestimates of the magnitude of the true exposure.

† ATSDR's evaluation of exposure to dredged sediment along LWBR also considered inhalation of, ingestion of, and dermal contact with contaminated dredged sediment.

Fish Ingestion

To determine if the consumption of contaminated fish could be detrimental to human health, ATSDR estimated doses for individuals who eat fish from the LWBR. Because uncertainty exists regarding how often people consume fish from the river and how large a portion might be eaten, ATSDR used worst-case scenarios that assumed an adult and child eat two 8-ounce meals of LWBR fish each week. ATSDR also assumed that the fish consumed contained the highest probable level of each of the primary radionuclides. For example, when evaluating the likelihood of health effects from strontium, ATSDR assumed that the fish fillet meal could include some bone because strontium is a bone-seeking radionuclide. For both an adult and a child, the dose estimated for the primary radionuclides were 6 mrem per year, or less than 420 mrem over 70 years for the committed effective dose. The annual whole-body dose of 6 mrem is more than 60 times less than the background dose of 360 mrem that the average U.S. citizen receives each year.

Water Ingestion

ATSDR examined the possibility that harmful health effects could result from exposure to the radionuclides detected in LWBR surface water. Local residents might be exposed to contaminants in unfiltered surface water through incidental ingestion of water when they use the reservoir for recreational activities, such as swimming. Residents of Kingston, Spring City, or Rockwood supplied with municipal water from the reservoir could potentially contact contaminants when they drink treated water from their taps or use it for other household purposes. That said, however, it is only possible for ORR contaminants to reach these intakes during the rare circumstances of reverse flow conditions resulting in contaminant backflow. Even so, potential exposures to harmful levels of radionuclides in the home from municipal water use are not expected—monitoring data indicate that the drinking water has met safe drinking water standards for radionuclides.

ATSDR evaluated exposure to surface water contaminants for a 10-year-old child who lives near the LWBR. ATSDR focused its evaluation on the child to consider the potential likelihood that this sensitive population might be exposed to surface water contaminants. ATSDR used conservative assumptions to examine how a child could be exposed to contaminants and how much contaminated water that child might ingest each day. In its evaluation, ATSDR assumed that the child drank unfiltered water. ATSDR's estimated dose to a child from drinking unfiltered water obtained from the LWBR is 0.25 mrem per year, or less than 17.5 mrem over 70 years for the committed effective dose. The annual whole-body dose of 0.25 mrem is about 1,440 times less than the background dose of 360 mrem that the average U.S. citizen receives each year.

External Radiation: Contact With Shoreline Sediment or Dredged Sediment

Relatively low levels of radioactive contaminants have been detected in the *surface* sediment of the LWBR (see Figure 23). People could be exposed to external radiation released from radionuclides in shallow areas of the reservoir or along the shore while swimming, fishing, or boating. The highest concentrations of radioactive contaminants are in subsurface sediment located in the deep river channels and are shielded by several meters of surface water and 15 inches or more of sediment on the river bottom—thus these areas with the highest concentrations are generally inaccessible to the public. In the unlikely event that these subsurface sediments might in the future be dredged from the river channel, ATSDR examined the potential exposure for a hypothetical individual who might come in contact with contaminants when walking on or handling sediment that was dredged from the deep river channel and deposited on the shoreline. ATSDR's committed effective doses to the whole body for individuals hypothetically exposed to external radiation from surface sediment or subsurface sediment were less than 1,050 mrem over 70 years and 1,400 mrem over 70 years, respectively.[14] These committed effective doses were based on annual doses of 15 mrem and 20 mrem for external radiation from surface sediment and subsurface sediment, respectively. These annual whole-body doses are more than 18 times less than the background dose of 360 mrem that the average U.S. citizen receives each year.

External Radiation: Swimming or Showering

Local residents might be exposed to contaminants in surface water through physical contact with water when they use the reservoir for recreational activities, such as swimming and boating. Residents of Kingston, Spring City, and Rockwood who are supplied with municipal water from the reservoir could also contact contaminants when showering or bathing. As previously noted, potential exposures to harmful levels of radionuclides in the home from municipal water use are not expected—monitoring data indicate that the drinking water has met safe drinking water standards for radionuclides.

[14] ATSDR determined that dredging might pose greater harm to human health from resuspension of sediment, which would subsequently increase the waterborne concentration of radionuclides in the Lower Watts Bar Reservoir and increase any potential exposure for employees involved in the dredging.

ATSDR used conservative, worst-case (i.e., protective) assumptions to examine how a 10-year-old child could be exposed to contaminants and how much contaminated water that child might contact each day. In its evaluation, ATSDR assumed that the child showered, or that the child swam in the reservoir, for up to 8 hours a day. In all likelihood, a child would spend far less time in either situation. Still, these assumptions enable ATSDR to calculate a conservative estimate of exposure that it uses to confidently evaluate the likelihood, if any, that contaminants in surface water could cause harm. Potential exposure was also evaluated for a person under similar circumstances who might live near the Watts Bar Lake for a lifetime (70 years). The dose to the whole body from external radiation via bathing or swimming is 0.05 mrem per year, or less than 3.5 mrem over 70 years for the committed effective dose. The annual whole-body dose is more than 7,200 times less than the background dose of 360 mrem that the average U.S. citizen receives each year.

ATSDR combined the annual doses for the surface water exposure pathways (i.e., 0.25 mrem from incidental ingestion and 0.05 mrem from contact via swimming or showering) to obtain the total dose from waterborne radioactive contaminants, which was below 1 mrem over 70 years—less than 1% of the typical background radiation dose that a U.S. citizen receives each year.

Clinch River (1989–Present and Future)

Environmental Data

To evaluate the current exposures and doses related to releases from White Oak Creek, ATSDR obtained data in electronic format from the Oak Ridge Environmental Information System (OREIS), detailed in Section II.F.4 of this document. The data received and analyzed by ATSDR covered the time period 1989–2003. Samples included surface waters collected from the LWBR and sediments from the associated shorelines. ATSDR also evaluated biota data that included fish, geese, and turtle samples. ATSDR analyzed samples for rivers in the watershed that included the Clinch River below Melton Hill Dam and the Tennessee River below the mouth of the Clinch River. For comparison, ATSDR reviewed data collected from background locations (Emory River, streams that feed into the Clinch River, the Clinch River above the Melton Hill Dam, and the Tennessee River upstream of the Clinch River). As stated previously, when contaminant concentrations in White Oak Creek surface water enter the Clinch River, those contaminant concentrations will become diluted. Further dilution will occur when the Clinch River meets the Tennessee River.

For the initial data sorting, ATSDR included the radionuclides associated with the Task 4 report, as well as the radionuclides reported in the OREIS data. The purpose of the data sorting was to collate data by the following parameters: river location, species (for biota), radionuclide, or a combination of one or more of these parameters. As a result of this sorting, ATSDR performed its evaluation on the radionuclides presented in Table 17.

Table 17. Summary of Radionuclides Evaluated for the Clinch River Area

Radionuclide	*Half-Life**	*Mode(s) of Decay†*	*Critical organ (ingestion) ‡*	*Decay Product§*
Cesium 137	30.2 years	Beta/gamma	Lower large intestine	Barium 137
Cobalt 60	5.3 years	Beta/gamma	Lower large intestine	Nickel 60
Strontium 90	28.6 years	Beta	Bone surface	Yttrium 90
Yttrium 90	64 hours	Beta/gamma	Lower large intestine	Zirconium 90
Americium 241	432 years	Alpha	Bone surface	Neptunium 237
Hydrogen 3	12.2 years	Beta	Whole body	Helium 3

* The half-life is the amount of time required for 50% of the initial amount present to physically decay.
† The mode of decay is the principal method whereby the isotope decays or releases energy. In those instances where a gamma mode is listed, this indicates that the decay product releases a gamma ray (photon) as a method of nuclear rearrangement.
‡ The critical organ, as defined by the International Commission on Radiological Protection, is the organ receiving the highest radiation dose following an intake of radioactive material.
§ The decay product is the first isotope produced during the decay of the parent radioisotope.

Exposure Pathways and Estimated Radiation Doses

ATSDR sorted the environmental monitoring data by pathway: ingestion of biota (fish, geese, and turtle), ingestion of water, and external radiation via walking on shoreline sediment or contacting water while swimming (see Table 18). Exposure scenarios were evaluated by using specific values from the EPA Exposure Factors Handbook, other federal guidance manuals, and/or interviews performed during ATSDR's 1998 exposure investigation that evaluated serum PCB and blood mercury levels in consumers of fish and turtles from the Watts Bar Reservoir. See Section II.F.1. in this public health assessment for additional details and Appendix D for a brief summary of the exposure investigation. In the discussion that follows, ATSDR evaluates these exposure situations and derives estimated radiation doses.

Table 18. Current Exposure Pathways Evaluated for the Clinch River Area

Exposure Pathway		*Individual*	*Description of Exposure Situation*
Biota ingestion	Fish	Adult, teenager, and child	Eating one 8-ounce fish meal each week for an adult and one 4-ounce fish meal each week for a child (ATSDR assumed lifetime exposure—until 70 years of age—for a 10-year-old child, a 15-year-old teenager, and a 20-year-old adult)
	Geese and turtle	Adult, teenager, and child	Eating about 1 pound of goose liver, 22 pounds of goose muscle, and 3.5 ounces of turtle each year (ATSDR assumed lifetime exposure—until 70 years of age—for a 10-year-old child, a 15-year-old teenager, and a 20-year-old adult)
Water ingestion (incidental ingestion of surface water)		Adult	Incidental ingestion while swimming: ingesting 0.1 liters per hour for 1 hour per day for 150 days per year
External radiation	Walking on sediment	Adult	Contact during recreational activities: 5 hours each day for 150 days per year
	Swimming	Adult	Contact while swimming: 1 hour per day for 150 days per year

ATSDR reviewed biota (fish, geese, and turtle), surface water, and sediment data for the presence of radionuclides. The samples were collected from the Clinch River below the Melton Hill Dam and from the Tennessee River below its confluence with the Clinch River. For comparison, ATSDR reviewed data collected from background locations (Emory River, streams that feed into the Clinch River, the Clinch River above the Melton Hill Dam, and the Tennessee River upstream of the Clinch River).

For the dose assessment, ATSDR looked at the critical organ and the radiation dose delivered to the whole body. For the time period of the dose assessment (1989 to the present), ATSDR set the age of an adult at 20 years and estimated the dose received until that person was 70 years of age; that is, ATSDR assumed exposure for a 50-year period. For a teenager and child, ATSDR also estimated the dose to age 70, but modified the years of exposure as appropriate for a 15-year-old (55 years) and a 10-year-old (60 years).

Biota Ingestion

ATSDR reviewed biota data for the presence of radionuclides. The biota samples included various species of fish, turtles, and geese that were collected from the Clinch River below the

Melton Hill Dam and from the Tennessee River below its confluence with the Clinch River. For comparison, ATSDR reviewed data for background locations.

Fish

In deriving radiation doses from the consumption of fish, ATSDR considered only fillet portions and muscle. ATSDR assumed that a child eating fish from the river consumes 113.4 grams (4 ounces) per week and that an adult consumes 227 grams (8 ounces) per week. Table 19 presents the estimated radiation doses by fish species consumed and the river where the samples were collected for an adult, teenager, and child (until age 70 years).

ATSDR's analysis of fish consumption indicates that the doses to the critical organ and to the whole body are very similar for the 10-year-old, the 15-year-old, and the 20-year-old. Some of the highest doses were associated with eating catfish or largemouth bass caught from the Clinch River below Melton Hill Dam. Even so, to age 70 the highest estimated whole-body dose, or committed effective dose, was 89.3 mrem. The highest committed equivalent dose of 114 mrem to the bone surface was estimated for a 15-year-old, based on a 55-year exposure. Because Sr 90 is a bone seeker and because much bone growth occurs during the teenage years, a 15-year-old could conceivably have a higher dose than either a 20-year-old adult or a 10-year-old child (see Table 19).

At one time, the Clinch River had many species of mussels and dredging for mussels took place in the lower Clinch River on a large scale. But the mussel population declined rapidly after the 1936 impoundment of Norris Dam and the 1963 impoundment of Melton Hill Dam. Many unconfirmed reports suggest that people consumed mussels from the Clinch River (usually on a very limited basis); however, there are no records of mussels being consumed on a regular basis and the Clinch River mussels were generally considered to be a poor source of food. Therefore, the likelihood is low that people consumed mussels from the Clinch River (Blaylock 2004).

Table 19. Estimated Radiation Doses From Current Ingestion of Fish

Location	*Fish Species*	*Organ†*	*Radiation Dose to Age 70 (mrem)**		
			Adult (50 years of intake)	*15-Year-Old (55 years of intake)*	*10-Year-Old (60 years of intake)*
Tennessee River below the confluence with the Clinch River	Channel catfish	Lower large intestine	2.13	2.65	4.07
		Whole body	0.99	0.818	1.01
	Largemouth bass	Lower large intestine	1.20	1.38	1.89
		Whole body	0.71	0.48	0.506
	Striped bass	Lower large intestine	0.74	0.769	0.839
		Whole body	0.56	0.31	0.26
Clinch River below Melton Hill Dam	Catfish	Lower large intestine	98.4	52.2	60.3
		Whole body	89.3	68.5	58.8
	Channel catfish	Lower large intestine	55.5	29.2	33.2
		Whole body	41.0	23.2	20.1
	Largemouth bass	Lower large intestine	109	57.2	63.8
		Whole body	82.1	45.8	39.2
	Striped bass	Lower large intestine	1.64	1.03	1.59
		Whole body	0.75	0.62	0.78
	Sunfish‡	Bone surface	46.5	114	71.7
		Whole body	3.15	4.94	4.08

* The doses are expressed in mrem calculated from age of intake to 70 years. For example, the intake for an adult occurs at age 20 and continues for 50 years.
† Doses are presented for the organ receiving the highest radiation dose and for the whole-body dose (the dose delivered to the entire body).
‡ The doses for sunfish are based on dry weight samples; all other doses are based on wet weight samples.

Turtles and Geese

Canadian geese were introduced into the X-10 area about 20 years ago. Turtles also inhabit the Clinch River environment. Contaminated geese and turtles have been identified in the radioactive ponds at X-10. Geese are grazers that only feed at the ponds in late winter and early spring. For several years, the ORR had a program to control access of waterfowl to radioactive waste ponds, mainly at X-10. These ponds were monitored, and geese that continued to use the ponds were collected. A few geese collected from 3504 waste disposal ponds at X-10 were found to have high concentrations of radionuclides, primarily Cs 137 in their tissues; however, the quantity of geese found with high radionuclide concentrations was extremely small. Further, the possibility of obtaining more than one goose or one turtle with high radioactive concentrations is "highly unlikely" (Blaylock 2004).

For hunters consuming geese, ATSDR assumed that not all portions of the animal would be consumed. Therefore, only the goose liver and the goose muscle were chosen for this analysis. ATSDR selected a consumption value of 500 grams of liver per year (about 1 pound) and 10 kilograms (approximately 22 pounds) of goose muscle per year. For turtle ingestion, only the muscle was analyzed at a consumption value of 100 grams (about 3.5 ounces) per year. For the critical organs, ATSDR used bone surface (Sr 90) and lower large intestine (Cs 137 and Co 60).

Estimated doses for the consumption of geese and turtles are shown in Table 20. As noted in the table, the estimated dose from ingestion of goose muscle and liver was greater than the estimated dose from ingestion of turtle, with most of the dose going to the bone surface. The highest committed effective dose to the whole body was 14 mrem to a 10-year-old child, based on a 60-year exposure for goose consumption. The highest committed equivalent dose was associated with eating geese—230 mrem over a 55-year exposure to the bone surface.

Table 20. Estimated Radiation Doses From Current Ingestion of Geese and Turtles

Food	***Organ†***	***Radiation Dose to Age 70 (mrem)****		
		Adult (50 years of intake)	***15-Year-Old (55 years of intake)***	***10-Year-Old (60 years of intake)***
Geese (muscle and liver)	Bone surface	154	230	190
	Lower large intestine	1.3	1.8	0.083
	Whole body	7.6	9.5	14
Turtle	Lower large intestine	0.029	0.03	0.033
	Whole body	0.022	0.025	0.021

* For radionuclides with similar critical organs, the doses from each radionuclide were added together. In the case of data reported as strontium 89/90, the doses were calculated as if the reported values were entirely strontium 90. Furthermore, the dose includes the presence of yttrium 90, which is the decay product of strontium 90.

† Doses are presented for the organ receiving the highest radiation dose and the whole-body dose (the dose delivered to the entire body).

<u>Water Ingestion</u>

A person swimming in the river might be exposed to radiation from incidental ingestion of radionuclides in the surface water. To evaluate potential hazards from contact with radionuclides, ATSDR estimated radiation doses for persons swimming in the river. In deriving these doses, ATSDR used exposure values published by the EPA in its *Federal Guidance Report 13*; these values are conservative and typically overestimate true exposure (USEPA 1999b). ATSDR assumed that a swimmer might incidentally ingest unfiltered surface water at a rate of 0.1 liters per hour (Stenge and Chamberlain 1995). For swimming frequency, ATSDR assumed an exposure of 1 hour per day for 150 days per year (as noted in the EPA Exposure Factors Handbook). Table 21 provides the results of this evaluation.

Table 21. Estimated Radiation Doses From Current Shoreline Recreational Activities for the Clinch River

Exposure Pathway		Location	Radiation Dose (mrem)*		
			Bone Surface	Skin	Whole Body
Water ingestion (incidental ingestion of surface water)		Background†	0.41	0.01	0.04
		Clinch River	2.8	0.006‡	0.13
		Lower Watts Bar Reservoir	0.072	<0.0001§	0.003
External radiation	Walking on shoreline sediment	Background†	1.57	0.18	0.14
		Clinch River	13	1.6	9.4
		Lower Watts Bar Reservoir	0.16	0.026	0.11
	Swimming	Background†	5.83	0.62	1.15
		Clinch River	1.2	3.9	0.82
		Lower Watts Bar Reservoir	0.048	0.1	0.033

* Doses are presented for the organ receiving the highest radiation dose and the whole-body dose (the dose delivered to the entire body). For organs receiving the highest dose, ATSDR estimated the committed equivalent dose over 70 years. For doses to the whole body, ATSDR estimated the committed effective dose to age 70. For the radionuclides with similar critical organs, the doses from each isotope were added together. In the case of data reported as strontium 89/90, the doses were calculated as if the reported values were entirely strontium 90.

† Background locations include areas above Melton Hill Dam, above the confluence of the Tennessee River and the Clinch River, Emory River, and streams that feed into the Clinch River. The background dose represents the average radiation dose at these background locations.

‡ The critical organ for incidental ingestion of Clinch River water is the lower large intestinal wall.

§ The dose is too low to be significant.

The analyses indicated that the committed effective dose received by the whole body in the study area of 0.13 mrem is about 3 times higher than the dose for background locations (0.4 mrem). The critical organ for exposure from incidental ingestion of surface water depended on the radionuclide that was ingested. As would be expected, however, the doses to the bone surface of up to 2.8 mrem were higher (by about two orders of magnitude) than those for skin (up to 0.006 mrem).

External Radiation: Contact With Sediment and Surface Water

To evaluate potential hazards from contact with radionuclides in sediment and surface water, ATSDR estimated radiation doses for persons who might walk along the shoreline and swim in the river. In deriving these doses, ATSDR used exposure values published by the EPA in its *Federal Guidance Report 13*; these values are conservative and typically overestimate true exposure (USEPA 1999b). ATSDR presumed that the average recreational users of the Clinch River would be 20-year-old adults and that they would be exposed to a 2-square-meter area of shoreline for 5 hours per day and for 150 days per year. For swimming frequency, ATSDR assumed an exposure of 1 hour per day for 150 days per year (as noted in the EPA Exposure Factors Handbook). Table 21 provides the results of this evaluation.

The analyses included the doses received by the entire body, as well as the estimated radiation doses to the organs that are receiving the highest radiation doses. (The exposures from the shoreline, both from walking and swimming, basically impacted the skin.) The highest estimated dose to the whole body within the study area of 9.4 mrem is associated with walking on sediment along the Clinch River below Melton Hill Dam. Walking on sediment at this location was also associated with the highest committed equivalent dose of 13 mrem to the bone surface.

The data indicate that the dose from walking along the sediment is higher in the study area along the Clinch River (below Melton Hill Dam) and Lower Watts Bar Reservoir than at the background locations. For example, the resulting committed effective dose to the whole body from walking on the sediment in the study area is over 60 times higher than for background locations. Similarly, the radiation dose to the bone is about eight times higher in the study area than in background locations. As one would expect from the amount of skin exposure, swimming in the Clinch River resulted in the highest doses to the skin out of all pathways evaluated. The estimated dose for swimming at background locations (based on average for all background locations) was, however, actually higher than in the study area.

IV. Public Health Implications

IV.A. Introduction

When evaluating the public health impact associated with exposures to hazardous substances, CERCLA, as amended by SARA §104 [i][6][f], requires that ATSDR consider such factors as

- the nature and extent of contamination,
- the existence of potential pathways of human exposure (including ground or surface water contamination, air emissions, and food chain contamination),
- the size and potential susceptibility of the community within the likely pathways of exposure,
- the comparison of expected human exposure levels to the short-term and long-term health effects associated with identified hazardous substances and any available recommended exposure or tolerance limits for such hazardous substances, and
- the comparison of existing morbidity and mortality data on diseases that could be associated with the observed levels of exposure.

To evaluate health effects from radiation doses received by individuals exposed to radionuclides released into the Clinch River from White Oak Creek, ATSDR used a "weight-of-dose approach." The weight-of-dose approach involves conducting a critical review of available radiological, medical, and epidemiologic information to ascertain levels of significant human exposure, and then comparing the estimated radiation doses that individuals might have encountered at the Clinch River and LWBR to situations that have been associated with disease and injury. This approach is used to determine whether or not harmful health effects might be possible and observable, and to determine if the doses require a public health action to limit, eliminate, or further study any potential harmful exposures.

The exposure pathways analysis in Section III of this public health assessment indicates that radioactive materials were released from X-10 via White Oak Creek. These radioactive contaminants have migrated off site to the Clinch River and the Lower Watts Bar Reservoir (LWBR), where people have or could come in contact with these contaminants. In this section, ATSDR assesses the health implications of past, current, and future exposures to radioactive contaminants released from White Oak Creek for people who used or lived—or currently use or live—near the Clinch River and LWBR. In assessing exposure, ATSDR evaluated radiation doses presented in the Task 4 report or derived radiation doses using available environmental data. When calculating doses, ATSDR made conservative assumptions about the frequency, duration, and magnitude of radiation exposures. These conservative estimates allow ATSDR to evaluate the likelihood, if any, that exposure to radionuclides is associated with adverse health effects. Because cancer is the most recognized adverse health outcome resulting from radiation exposure (though studies are beginning to show cardiovascular effects in atomic bomb survivors), ATSDR will discuss this disease in the public health implications section.

The public health implications of past exposures at the Clinch River and current exposures associated with the Clinch River and the LWBR are presented in Table 22 and Table 23, respectively, and in the discussion that follows.

Table 22. Past Radiation Doses for the Area Along the Clinch River (1944–1991)

Organ	*Dose Type*[*]	*Estimated Dose*[†]	*Comparison Value*	*Is the Estimated Dose Above or Below the Comparison Value?*	*Conclusion*
Whole body	Annual	4 mrem	100 mrem/year ATSDR MRL, ICRP, NCRP, and NRC[‡]	Below (25 times less)	The radiation doses received by people in the past are not likely to cause adverse health effects. Past releases of radioactive material from White Oak Creek are not a public health hazard for people who used or lived near the Clinch River and LWBR.
	Committed effective dose or lifetime	278 mrem	5,000 mrem[§]	Below (18 times less)	
Bone surface	Committed equivalent dose or lifetime	Less than 1,600 mrem	390,000–620,000 mrem[¶]	Below (243 times less)	
Lower large intestine	Committed equivalent dose or lifetime	Less than 1,200 mrem	5,000 mrem[§]	Below (4 times less)	
Red bone marrow	Committed equivalent dose or lifetime	Less than 1,200 mrem	390,000–620,000 mrem[¶]	Below (325 times less)	
Breast	Committed equivalent dose or lifetime	Less than 500 mrem	10,000 mrem**	Below (20 times less)	
Skin	Committed equivalent dose or lifetime	Less than 700 mrem	9,000 mrem[††]	Below (12 times less)	

[*] Annual dose considers a 1-year exposure. Committed effective doses and committed equivalent doses consider a 70-year exposure duration.
[†] The estimated doses were taken from Table 11. Please see the discussion related to Table 11 for an explanation on the derivations of the past radiation doses.
[‡] ATSDR's MRL for ionizing radiation is based on noncancer health effects only; it is not based on a consideration of cancer effects. A MRL is an estimate of daily human exposure to a substance that is likely, during a specified duration of exposure, to be without noncarcinogenic health effects (ATSDR 1999b). For more information on MRLs, please refer to http://www.atsdr.cdc.gov/mrls.html. The ICRP, NCRP, and NRC recommended value of 100 mrem/year for the public considers both noncancer and cancer health effects (Health Physics Society 2003; ICRP 1991; Nuclear Energy Institute 2003).
[§] Based on studies of atomic bomb survivors (National Research Council 1988).
[¶] A review of human radium dial workers suggests that a threshold for bone cancers induced by radium should be between 390,000 and 620,000 mrem (Rowland 1994).
[**] Based on studies of atomic bomb survivors (Schull 1995).
[††] Based on studies of patients irradiated for the treatment of ringworm (National Research Council 1990).

Table 23. Current Radiation Doses for the Lower Watts Bar Reservoir and Clinch River

Area and Time Frame	*Organ*	*Dose Type*[*]	*Estimated Dose*[†]	*Comparison Value*	*Is the Estimated Dose Above or Below the Comparison Value?*	*Conclusion*
Lower Watts Bar Reservoir *(1988–2003)*	Whole body	Annual	Less than 30 mrem/year	100 mrem/year ATSDR MRL, ICRP, NCRP, and NRC[‡]	Below (3 times less)	The current radiation doses received by people are not likely to cause adverse health effects. Current releases of radioactive material from White Oak Creek are not a public health hazard for people who currently use or live near the Clinch River and LWBR. [‡‡]
		Committed effective dose or lifetime	Less than 1,900 mrem	5,000 mrem[§]	Below (2.5 times less)	
Clinch River *(1989–2003)*	Whole body	Annual	Less than 3.4 mrem/year	100 mrem/year[‡]	Below (29 times less)	
		Committed effective dose or lifetime	Less than 236 mrem	5,000 mrem[§]	Below (21 times less)	
	Bone	Committed equivalent dose or lifetime	Less than 218 mrem	390,000–620,000 mrem[¶]	Below (1,788 times less)	
	Lower large intestine	Committed equivalent dose or lifetime	Less than 270 mrem	5,000 mrem[§]	Below (18 times less)	
	Skin	Committed equivalent dose or lifetime	Less than 6 mrem	9,000 mrem[††]	Below (1,500 times less)	

[*] Annual dose considers a 1-year exposure. Committed effective doses and committed equivalent doses consider a 70-year exposure duration for the LWBR and an exposure to age 70 for the Clinch River.

[†] The annual and committed doses are based on all exposure pathways combined. To derive the committed effective dose and the committed equivalent dose, the dose for a pathway was adjusted for a 70-year exposure for the LWBR and to age 70 for the Clinch River.

[‡] ATSDR's MRL for ionizing radiation is based on noncancer health effects only; it is not based on a consideration of cancer effects. A MRL is an estimate of daily human exposure to a substance that, during a specified duration of exposure, is likely to be without noncarcinogenic health effects (ATSDR 1999b). For more information on MRLs, please refer to http://www.atsdr.cdc.gov/mrls.html. The ICRP, NCRP, and NRC recommended value of 100 mrem/year for the public considers both noncancer and cancer health effects (Health Physics Society 2003; ICRP 1991; Nuclear Energy Institute 2003).

[§] Based on studies of atomic bomb survivors (National Research Council 1988).

[¶] A review of human radium dial workers suggests that a threshold for radium-induced bone cancers is between 390,000 and 620,000 mrem (Rowland 1994).

[††] Based on studies of patients irradiated for the treatment of ringworm (National Research Council 1990).

[‡‡] ATSDR assessed the estimated current doses in its evaluation of future exposures. See the discussion of future exposures in Section IV.C.

IV.B. Past Radiation Exposure (1944–1991)

ATSDR determined that levels of radioactive contaminants from X-10 that entered the Clinch River via White Oak Creek are not a public health hazard for individuals who, in the past, used or lived near the Clinch River. Past exposure to these radioactive contaminants is not expected to cause adverse health effects.

For *past exposures,* which for the purposes of this PHA occurred between 1944 and 1991, ATSDR evaluated the health implications of the radiation dose estimates presented in Task 4 of the TDOH's *Reports of the Oak Ridge Dose Reconstruction, 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* (referred to as the "Task 4 report"). As discussed in Section III, ATSDR evaluated the 50th percentile of the uncertainty distribution for doses reported by the Task 4 team. The doses considered past exposures (over a maximum 48-year exposure period) to radionuclides (Cs 137, Ru 106, Sr 90, Co 60, I 131, Ce 144, Zr 95, and Nb 95) via consumption of fish, meat, milk, and water, and external radiation from walking on shoreline sediment (see Table 11) (see Appendix E). ATSDR focused its evaluation on three locations: Jones Island (CRM 20.5), the K-25/Grassy Creek area (CRM 14), and the confluence of the Clinch River with the Tennessee River (CRM 0) near the city of Kingston. ATSDR then used the organ-specific doses derived by the Task 4 team to estimate both the whole-body dose (annual and committed effective dose over 70 years) and total lifetime organ doses for the bone, lower large intestine, red bone marrow, skin, and female breast.

Table 22 presents ATSDR's estimated whole-body dose (annual dose and committed effective dose over 70 years) and the committed equivalent dose to organs (bone, lower large intestine, red bone marrow, breast, and skin) for *past exposures* along the Clinch River. An individual exposed to the primary radionuclides in Clinch River water, fish, shoreline sediment, meat, and milk was expected to receive a committed effective dose to the whole body of less than 300 mrem over 70 years and an annual whole-body dose from combining the organ doses of 4 mrem/year. This whole-body dose is well below (18 times less than) ATSDR's radiogenic comparison value of 5,000 mrem over 70 years and the annual whole-body dose is well below (25 times less than) ATSDR's radiogenic minimal risk level (MRL) of 100 mrem/year, which is also the maximum dose constraint for members of the public 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). ATSDR also evaluated potential exposures to radionuclides in drinking water (from the K-25 intake) for residents who lived in the Happy Valley settlement camp between 1944 and 1950. ATSDR's estimates suggest that residents of the camp would have received an annual dose of 14 mrem to the whole body, which is at least 7 times less than the ATSDR radiogenic MRL of 100 mrem/year and the ICRP, NRC, and NCRP recommended maximum dose for the public of 100 mrem/year. ATSDR's evaluation of radiological, epidemiological, and medical literature shows that the estimated whole-body radiation doses were well below levels likely to cause observable or detectable health effects.

ATSDR derived the *radiogenic comparison value* of 5,000 mrem over 70 years after reviewing the peer-reviewed literature and other documents developed to review the health effects of ionizing radiation. Doses below this value are not expected to result in observable health effects. ATSDR's *MRL for ionizing radiation* of 100 mrem/year is based on noncancer health effects only; it is not based on a consideration of cancer effects. MRLs are estimates of daily human exposures to substances unlikely to result in noncancer effects over a specified duration (ATSDR 1999b). The ICRP, NRC, and NCRP maximum dose constraint for the public of 100 mrem/year considers both noncancer and cancer health effects (Health Physics Society 2003; ICRP 1991; Nuclear Energy Institute 2003).

The doses from past exposure to radionuclides in and along the Clinch River varied by the critical organ. ATSDR's further evaluation of the organ doses is in the discussion that follows.

- The bone received the highest estimated total committed equivalent dose over a lifetime (70 years) of exposure to the primary radionuclides along the Clinch River. ATSDR's estimates, however, suggest that the dose to the bone was less than 1,600 mrem over 70 years—at least 243 times lower than the doses of 390,000 to 620,000 mrem shown to cause bone cancers in radium dial workers. Eating many fish meals from the Jones Island area resulted in the highest estimated organ dose to the bone (810 mrem) (see Table 11). Doses to the bone were much lower for people who ate fewer fish or fished further downstream and for all other pathways. Strontium most likely contributed to the higher levels in the bone because it seeks out and accumulates in bone.

  Radiation effects on individual organs have not been studied extensively. Most of the available studies on the effects of radiation involve exposures associated with luminous dial painting, the atomic bombing of Japan, medical treatments, and uranium mining. ATSDR's comparison value for the dose to the bone comes from studies that evaluated exposures of radium dial painters to levels of radium known to cause adverse health effects following acute intakes of radium. Workers in these studies were exposed to larger doses and for longer periods of time than exposures associated with White Oak Creek releases. Bone cancers induced by radium exposure were evident in dial workers at doses ranging between 390,000 and 620,000 mrem (Rowland 1994). More recent studies have included workers at nuclear plants and other nuclear industries. For example, studies of nuclear workers at the Mayak facility in Russia suggest that chronic radiation exposure resulting in "chronic radiation syndrome" is associated with cumulative exposures to radiation above 100,000 mrem (USDOE, Office of International Health Programs 2001).[15] In 1999, the Airlie Conference concluded that 10,000 mrem was the lowest dose at which a statistically significant radiation risk has been shown, and that the effects of low-level radiation below 100 mrem/year above background are currently indistinguishable from those of everyday natural health hazards (Mossman et al. 2000).[16] The doses received by individuals in these studies are in substantial excess of the estimated doses from past exposures to White Oak Creek radionuclide releases.

- The committed equivalent dose to the *lower large intestine* was less than 1,200 mrem over 70 years. Exposure from eating fish, from drinking water, and from walking along the shoreline (external exposures) resulted in the highest doses to the lower large intestine. This estimated dose, however, is 4 times lower than ATSDR's radiogenic comparison value of 5,000 mrem over 70 years.

- The committed equivalent dose to the *red bone marrow* was less than 1,200 mrem over 70 years. Exposure from eating fish, drinking Clinch River water, and walking along the shoreline (external exposures) resulted in the highest doses to the red bone marrow. The highest committed equivalent dose, however, is more than 325 times lower than the lowest doses between 390,000 and 620,000 mrem, which is where bone cancers were first observed in radium dial workers with measured amounts of radium in their bodies (Rowland 1994). ATSDR's estimated committed equivalent dose to the red bone marrow for past exposure is also below the levels that epidemiological studies can detect, and below 25,000 mrem, which is the level generally related to blood disorders associated with acute exposures. Doses on the order of 25,000 mrem are believed to affect the formation of blood cells and may induce leukemia. Studies in the atomic bomb survivors indicated that leukemia was observed with acute doses as low as 50,000 millirads (assumed 50,000 mrem), with most of the leukemia occurring within the first 20 years following the bombings (Radiation Effects Research Foundation 2003).

- The committed equivalent dose to the *breast in females* was less than 500 mrem over a 70-year lifetime. Exposure to radionuclides from eating fish and walking on shoreline sediment contributed the highest doses to the breast. For comparison, the committed equivalent dose is 20 times less than doses shown to cause effects in atomic bomb survivors (Schull 1995).

- The committed equivalent dose to the *skin* over a 70-year lifetime of exposure to external radiation was less than 700 mrem. Organ doses to the skin from eating fish and walking along the shoreline exceeded dose estimates for all other pathways. Even so, the committed

[15] Please see http://www.utah.edu/radiobiology/mayak/index.html#toc for additional information.
[16] Please see http://www.inea.org.br/bridradia.htm for more details.

equivalent dose is 12 times below the value of 9,000 mrem, which is based on the Biological Effects of Ionizing Radiation (BEIR) V report of patients irradiated for the treatment of ringworm (National Research Council 1990).

Organ doses for people who ate fish from the Clinch River exceeded dose estimates for all other exposure pathways (drinking water, meat ingestion, milk ingestion, and external radiation) by at least a factor of 6 (see Table 12). Primarily, the organ dose depended on how often people ate fish and the area of the Clinch River where the fish were collected. The highest cumulative organ doses (1944–1991) were for individuals who consumed fish frequently (1 to 2.5 fish meals per week) and caught their fish near Jones Island, close to the mouth of White Oak Creek. For individuals who frequently ate fish caught near Jones Island and received maximum exposure to radionuclides released from White Oak Creek (see Table 11), ATSDR determined that the estimated doses to each organ were well below ATSDR's comparison values and levels associated with the development of disease or cancer.

Organ doses for people walking along the shore and ingesting milk, water, and meat were much lower than the doses received by people consuming fish (see Tables 11 and 12). For an individual with no exposures other than to shoreline contaminants, the bone and skin were the organs that received the greatest dose. The estimated doses to the bone and skin from walking along the shoreline are well below ATSDR's comparison values and levels associated with the development of disease or cancer. Also, individuals exposed to radionuclides in the past from walking along the shoreline or ingesting milk, water, meat, or fish (further downstream from Jones Island) were not expected to develop adverse health effects or cancer.

Lifetime inhabitants of Grassy Creek (CRM 14) who ingested meat, milk, and water received the highest radiation dose to the bone. ATSDR used the tissue weighting factors to convert each organ dose to the corresponding whole-body dose, and summed the values to achieve a whole-body dose less than 20 mrem. ATSDR does not expect these exposures to have resulted in any observable adverse health effects.

All the estimated doses for past exposure to radionuclides in the Clinch River released from White Oak Creek are lower than ATSDR's comparison values and doses reported in radiological and epidemiological studies on the effects of radiation exposure. Therefore, ATSDR does not expect carcinogenic health effects to have occurred from past exposure to radionuclides in the Clinch River.

IV.C. Current and Future Radiation Exposure (1988–Present and Future)

ATSDR determined that current and future exposure to radioactive materials is not a public health hazard for individuals who use or live near the Clinch River and the Lower Watts Bar Reservoir. Radiation doses for individuals who might contact even the highest current concentrations of radionuclides in Lower Watts Bar Reservoir or Clinch River fish, turtles, geese, surface water, and sediment are too low to be a health hazard now or in the future.

IV.C.1. Current Exposure

For *current exposures* (1988–present), ATSDR estimated radiation doses for conservative hypothetical scenarios that considered likely pathways of exposure for people who use the LWBR and the Clinch River. ATSDR evaluated current users' exposures to LWBR sediment, surface water, and fish (see Tables 13, 14, 15 for the maximum detected concentrations). ATSDR also evaluated current users' exposures to Clinch River biota (fish, turtles, and geese), external radiation (walking on sediment and swimming), and incidental ingestion of surface water (see Table 17 for the radionuclides evaluated and Table 18 for the exposure pathways evaluated). ATSDR's evaluation shows that current exposures to even the highest detected concentrations of radionuclides in the Clinch River or LWBR biota, sediment, and surface water are not likely to cause health effects for current users of these waterways. In addition, ATSDR analyzed drinking water samples collected around the cities of Kingston, Spring City, and Rockwood from 1990 to the present. ATSDR evaluated these samples for radiological content, and determined that all water samples were below the U.S. Environmental Protection Agency's maximum contaminant levels (MCLs), and therefore, ATSDR considers this water safe for consumption and other potable uses now and in the future.

Lower Watts Bar Reservoir (1988–present)

ATSDR's estimated committed effective dose to the whole body for all pathways combined is less than 1,900 mrem over 70 years—2.5 times below ATSDR's radiogenic CV of 5,000 mrem over 70 years. The estimated annual whole-body dose is less than 30 mrem, and below ATSDR's screening comparison value and ICRP's, NCRP's, and NRC's recommended values for the public of 100 mrem/year. Therefore, the estimated exposures for the LWBR are not expected to result in adverse health effects.

Clinch River (1989–present)

ATSDR's estimated committed effective dose to the whole body for all pathways along the Clinch River combined is less than 240 mrem to 70 years of age—more than 20 times below ATSDR's radiogenic CV of 5,000 mrem over 70 years. The estimated annual whole-body dose is less than 3.4 mrem, and nearly 30 times below the dose of 100 mrem per year recommended for the public by ATSDR, ICRP, NCRP, and NRC. Therefore, the estimated exposures for the Clinch River are not expected to result in adverse health effects.

The current radiation doses from exposure to radionuclides along the Clinch River varied by organ as summarized below.

- ATSDR estimated that the *bone* receives the highest total committed equivalent dose over a lifetime (i.e., to age 70) of exposure to the primary radionuclides detected along the Clinch River. The highest committed equivalent doses to the bone were estimated for a 15-year-old adolescent based on a 55-year exposure from ingestion of goose muscle or liver (230 mrem) and fish (114 mrem), which resulted in a committed equivalent dose of 344 mrem over 55 years. ATSDR's estimates indicate that the teenager would receive the highest dose because of the age-weighted dose coefficients associated with accelerated bone growth in this age group. The committed equivalent dose to the bone from all pathways combined was based on exposures for adults occurring over a 50-year period. Estimates suggest that the committed equivalent dose to the bone for adults from all pathways is less than 218 mrem to 70 years of age. This is at least 1,788 times lower than the doses of 390,000 to 620,000 mrem associated with bone cancers in radium dial workers. Much lower doses were associated with ingestion of Clinch River water (2.8 mrem) and external exposures from walking on sediment (13 mrem) and swimming (1.2 mrem) in the study area. Note that the bone dose for swimming at background locations (expressed as the average of all background locations under study) of 5.83 mrem exceeds the dose incurred from swimming in the Clinch River study area.

- On the basis of exposures estimated for a 20-year-old adult over 50 years, the committed equivalent dose to the *lower large intestine* from all pathways combined is less than 270 mrem. This estimated dose is about 18 times lower than ATSDR's radiogenic comparison value of 5,000 mrem over 70 years, which is based on studies of atomic bomb survivors, radiation workers, and radiation workers' children. Exposure to radionuclides from adults eating fish contributed to the highest committed equivalent dose—109 mrem—to the lower large intestine.

- The committed equivalent dose to the *skin* over a 50-year exposure for adults is less than 6 mrem, which is 1,500 times below the value of 9,000 mrem that is based on a review of the

BEIR V report of patients irradiated for ringworm treatment (National Research Council 1990). As one would expect from the amount of skin exposure, swimming in the Clinch River resulted in the highest dose to the skin (3.9 mrem) out of all pathways evaluated.

Estimated doses for current exposure to radionuclides in the LWBR and Clinch River released from White Oak Creek in the present are lower than ATSDR's screening comparison values and doses reported in radiological and epidemiological studies on the effects of radiation exposure. ATSDR does not expect these current exposures to result in any adverse health effects.

IV.C.2. Future Exposure

For *future exposures* (exposures occurring after the "current" time period), ATSDR evaluated current doses and exposures related to releases from White Oak Creek, data on current contaminant levels in the LWBR and the Clinch River, consideration of the possibility that radionuclides could be released to White Oak Creek during remedial activities, engineering controls to prevent off-site releases, and institutional controls that are in place to monitor contaminants in the LWBR and the Clinch River. These institutional controls consist of

- prevention of sediment-disturbing activities in the Clinch River and LWBR,
- the Department of Energy's (DOE) annual monitoring of Clinch River and LWBR surface water, sediment, and biota,
- DOE's monitoring of White Oak Creek releases,
- the Tennessee Department of Environment and Conservation's (TDEC) monitoring of public drinking water supplies in Tennessee under the Safe Drinking Water Act for EPA-regulated contaminants, and
- TDEC DOE Oversight Division's quarterly radiological monitoring of five public water supplies on the ORR and in its vicinity under the EPA's Environmental Radiation Ambient Monitoring System program.

Lower Watts Bar Reservoir and Clinch River

Because the current radionuclide levels in the Clinch River and LWBR are not expected to result in adverse health effects, because on-site engineering controls are in place to prevent off-site contaminant releases, and because institutional controls reduce and monitor contaminants released from White Oak Creek, ATSDR concludes that future contaminant levels in the Clinch River and LWBR will not increase as a result of White Oak Creek releases. This conclusion is also based on DOE continuing its expected comprehensive system of monitoring (e.g., of remedial activities and contaminant levels in media), maintenance, and institutional and engineering controls. Further, because of remedial actions and preventive measures at X-10, and because of physical movement of sediments from that area and radiological decay, the radionuclide releases from White Oak Creek have decreased over time. The concentrations of radionuclides in the water and along the shoreline have decreased as well. Though a slight potential remains that radionuclides could be released to White Oak Creek due to remedial activities taking place at the ORR, these releases are expected to be minimal, and as noted previously, would be monitored by DOE. Therefore, as current exposures are not expected to result in adverse health effects, ATSDR does not expect adverse health effects to result from future concentrations of radionuclides in the Clinch River or Lower Watts Bar Reservoir fish, geese, turtles, sediment, or surface water.

V. Health Outcome Data Evaluation

Health outcome data are measures of disease occurrence in a population. Common sources of health outcome data are existing databases (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. 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. They are exploratory as they could provide additional information about human health effects and they are useful to help identify the need for public health intervention activities (for example, community health education). That said, however, 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 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 to contaminants. In this public health assessment on X-10 radionuclide releases to the Clinch River and the Lower Watts Bar Reservoir from White Oak Creek, ATSDR scientists determined that people using the Clinch River and the Lower Watts Bar Reservoir for food, water, and recreation were exposed to radionuclides released via White Oak Creek from the 1940s to 2003.

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 scientists receive input from epidemiologists, toxicologists, environmental scientists, and community involvement specialists. These scientists consider the following criteria, based only on site-specific exposure considerations, to determine whether a health outcome data evaluation should be included in the public health assessment.

1. Is there at least one current (or past) potential or completed exposure pathway at the site?
2. Can the time period of exposure be determined?
3. Can the population that was or is being exposed be quantified?

4. Are the estimated exposure doses(s) and the duration(s) of exposure sufficient for a plausible, reasonable expectation of health effects?
5. Are health outcome data available at a geographic level or with enough specificity to be correlated to the exposed population?
6. 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?

Using the findings of the exposure evaluation in this public health assessment, ATSDR sufficiently documented completed exposure pathways to radionuclides via the surface water, sediment, and biota pathways from the mid-1940s to 2003 for people using the Clinch River and the Lower Watts Bar Reservoir. In this public health assessment, the documented evidence of off-site exposure to radionuclides indicates that estimates of past and current radiation doses are below doses associated with health effects (see Section IV. Public Health Implications).

The estimated radiation doses for people using the Clinch River and the Lower Watts Bar Reservoir for food, water, and recreation are less than the 1) average U.S. background radiation dose, 2) ATSDR's screening values for ionizing radiation, 3) the NCRP's, ICRP's, and NRC's recommended limits of exposure to the public, and 4) organ-specific doses shown to cause adverse health effects. Therefore, residents using the river and reservoir have not been exposed to harmful levels of radionuclides from White Oak Creek, and they are not currently being exposed to harmful levels of radionuclides released to White Oak Creek from the X-10 site. Because the estimated radiation doses are not expected to cause health effects, 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 on the basis of exposure is complete.

Responding to Community Concerns

Responding to community health concerns is an essential part of ATSDR's overall mission and commitment to public health. Concerns of all community members are important and must be addressed during the public health assessment process. 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 that are related to issues associated with radionuclides released from White Oak Creek.

Area residents have also voiced concerns about cancer. Citizens living in the communities surrounding the ORR expressed many concerns to the ORRHES about a perceived increase in cancer in areas surrounding the ORR. A 1993 TDOH survey of eight counties surrounding the ORR indicated that cancer was mentioned as a health problem more than twice as much as any other health problem. The survey also showed that 83% of the surveyed population 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 conduct an assessment of health outcome data (cancer incidence) in the eight counties surrounding the ORR. Therefore, ATSDR conducted an assessment of cancer incidence using data already collected by the Tennessee Cancer Registry. This assessment 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 provide citizens living in the Oak Ridge Reservation area with information regarding cancer rates in their county compared to the state of Tennessee. The 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.

"Cancer incidence" refers to newly diagnosed cases of cancer that are reported to the Tennessee Cancer Registry.

The results of the assessment of cancer incidence, released in 2006, indicated both higher and lower rates of certain cancers in some of the counties examined when compared to cancer incidence rates for the state of Tennessee. 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. ATSDR's ORR Assessment of Cancer Incidence 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, please see the Compendium of Public Health Activities at http://www.atsdr.cdc.gov/HAC/oakridge/phact/c_toc.html.

VI. Community Health Concerns

ATSDR actively gathers comments and other information from those who live or work near the ORR. ATSDR is particularly interested in hearing from area residents, civic leaders, health professionals, and community groups. ATSDR will be addressing these community site-related health concerns in the ORR public health assessments that are related to those 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 community health concerns related to the site. The database allows ATSDR to record, track, and respond appropriately to all community concerns, and also 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. These concerns were organized in a consistent and uniform format and imported into the database.

The community health concerns addressed in this public health assessment are those concerns in the ATSDR Community Health Concerns Database that are related to issues associated with radionuclide releases from White Oak Creek. The following table contains the actual comments and ATSDR's responses. These concerns and responses are sorted by category (e.g., X-10 facility processes and exposure pathway concerns, concerns about radionuclides associated with X-10's releases to White Oak Creek, concerns about contaminants released from the Oak Ridge Reservation, and general concerns related to the Oak Ridge Reservation).

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

	Actual Comment	*ATSDR's Response*
X-10 Processes and Exposure Pathways Evaluated		
1	My first thoughts are what are the routes of entry, what are we looking at from the waterway, from the airway, from the soil. Because if you are talking about the water and fisherman and residents you're talking downstream. But if you're talking wind, I don't know where that ends. I would like to hear what are you're thoughts are on what routes are we looking at. That would expand it even further if you look at sports men and the hunting migration.	This public health assessment evaluates the releases of radionuclides from the X-10 facility (now known as the Oak Ridge National Laboratory [ORNL]) into the water in White Oak Creek, and also assesses past, current, and future off-site exposures to these radionuclides in the water for residents living within the White Oak Creek study area (the area along the Clinch River and the Lower Watts Bar Reservoir from the Melton Hill Dam to the Watts Bar Dam [see Figure 11]). This public health assessment evaluates the following key issues and concerns: surface water and sediment (surface and deep channel), and surface water, milk, game animals, fish, turtles, and homegrown vegetables. Please see Section. III.B. Exposure Evaluation of the Clinch River and Lower Watts Bar Reservoir and Figure 20. Possible Exposure Situations Along the Clinch River for more details.
2	How did they/are we looking at the X-10's major processes that may still be delivering an effect? There were cesium releases from the dam in 1985. And a flood in 1964 along with regular releases.	The Tennessee Department of Health's 1999 *Reports of the Oak Ridge Dose Reconstruction, 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* (referred to as the "Task 4 report") focused on historical X-10 radionuclide releases to White Oak Creek dating back to 1944. ATSDR has evaluated the historical data, as well as data that were collected since the dose reconstruction (for example, data from the state of Tennessee, EPA, and DOE). As a result, this public health assessment evaluates the past and current, as well as future, off-site exposures related to radionuclides from X-10. In this public health assessment, ATSDR considers the potential effects from the releases of cesium that occurred in 1956 when severe rains caused a flood that eroded the bottom sediment of White Oak Lake (Blaylock et al. 1993; ChemRisk 1999a). In addition, the Task 4 report estimated the amount of radionuclides that were released to White Oak Dam, and ATSDR considers these releases in its public health assessment (ChemRisk 1999a). See Appendix D for a brief on the Task 4 report. Copies of the Task 4 report are available at the DOE Information Center located at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee (telephone number: 865-241-4780) or through DOE's public-use database at http://cedr.lbl.gov/DR/dror.html.

<table>
<tr><th></th><th>Actual Comment</th><th>ATSDR's Response</th></tr>
<tr><td>3</td><td>The problems of the buried waste include little documentation on low-level waste, and that the X-10 records on high-level waste were destroyed in 1984. Some were reconstructed, but in general that is not an accurate inventory. That makes more important the good records of the outflows off the reservation.</td><td>In general, the records on X-10's earlier operations are not complete. However, a rather accurate account of X-10's major waste generating programs has been created from reviewing available records and by interviewing employees who worked at X-10 throughout most of its operational history. Six activities were determined to be responsible for basically all of X-10's waste production and on-site waste disposal. The six activities were the following (USEPA 1996):

• Fuel reprocessing
• Isotope production
• Waste management
• Radioisotope applications
• Reactor developments
• Multi-program laboratory operations

The liquid and solid waste streams that were generated by these activities at X-10 can be described as non-hazardous, chemically hazardous, radioactive, or mixed (for example, consisting of both hazardous chemicals and radioactive substances). Even though X-10 generates various types of waste streams, the majority of its hazardous waste is mixed or radioactive. In addition to X-10's on-site waste production, a large amount of solid, low-level radioactive wastes that were produced at other sites are brought to the X-10 site for disposal. Several remedial activities have been conducted at the X-10 site (USEPA 1996). See Section II.C. Remedial and Regulatory History for more details.

In addition, the Tennessee Department of Health evaluated radioactive waste disposal at X-10 dating back to 1944 in its Task 4 report titled 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. See Appendix D for a brief on the 1999 Task 4 report. Copies of the Task 4 report are available at the DOE Information Center located at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee (telephone number: 865-241-4780) or through DOE's public-use database at http://cedr.lbl.gov/DR/dror.html.</td></tr>
</table>

	Actual Comment	ATSDR's Response
4	A subcommittee member asked whether, since vegetables and fish are the dominant pathways, people who live downstream are at higher risk.	In 1996, ATSDR conducted a health consultation to evaluate the health implications of current exposure to chemical and radiological contaminants in the Lower Watts Bar Reservoir (LWBR) surface water, sediment, and fish. ATSDR concluded that only PCBs in reservoir fish were of potential public health concern. The current levels of other contaminants in surface water, sediment, and fish were not a public health hazard. See Appendix D for a brief on the *1996 Health Consultation on the Lower Watts Bar Reservoir*. ATSDR evaluated radioactive contaminant data for the Clinch River and the LWBR surface water, sediment, and fish, as well as Clinch River vegetables, turtles, and local game animals. The agency's purpose was to determine whether the levels of radionuclides might pose a past, current, or future public health hazard. The evaluation included the following exposure scenarios (depending on the waterway and time period): • Incidental ingestion of water during recreational activities • Use of river or reservoir water as drinking water • Contact with water while recreating, while irrigating, or while showering • Contact with surface sediment • Contact with dredged sediment used as topsoil in home gardens • Consumption of locally grown milk, meat, or produce • Consumption of fish, turtles, or local game animals ATSDR concluded that people who used or who lived near the Clinch River could have contacted these radionuclides in the past by eating fish and meat, by drinking milk and water, and by walking along shoreline sediment. In the past, the highest cumulative organ doses were for people who frequently ate fish (i.e., 1 to 2.5 fish meals per week) caught near Jones Island, close to the mouth of White Oak Creek. For persons who frequently ate fish caught near Jones Island and who received maximum exposure to radionuclides released from White Oak Creek, ATSDR determined that the estimated doses to each organ were well below ATSDR's comparison values and below levels associated with the development of disease or cancer. In addition, past exposure to radionuclides from drinking milk and water, walking along the shoreline, or eating meat and fish further downstream from Jones Island is not a health hazard and is not expected to result in adverse health effects or cancer. Therefore, ATSDR concluded that past exposures to radionuclides in sediment, surface water, and food in the Clinch River pose *no apparent public health hazard*. ATSDR concluded that current and future exposures to radionuclides from drinking surface water, contacting surface water and shoreline sediment via recreation, and consuming fish and game is not a health hazard because current exposure to radionuclides in the Clinch River and LWBR would result in radiation doses below levels expected to cause adverse health effects. Thus, current exposure to radionuclides released to the Clinch River and the LWBR via White Oak Creek poses *no apparent public health hazard*.

	Actual Comment	*ATSDR's Response*
4	*continued*	ATSDR is still evaluating past exposure to mercury and PCBs in the Clinch River and Lower Watts Bar Reservoir, and will address the health implications of past exposure to these contaminants in future public health assessments.
5	My question is about safe gardening. How could you consider safe gardening in a contaminated soil?	The general answer is that it depends on what the soil is contaminated with and how much is contaminated. This public health assessment evaluates exposures to radioactive contaminants released to the Clinch River and the Lower Watts Bar Reservoir via White Oak Creek. In the dose reconstruction of radionuclides released historically, the Task 4 report determined that the radionuclide levels in irrigation water (for homegrown vegetables) were below screening levels and therefore were not considered a hazard to people who ate locally grown vegetables. Given its assessment of both past and current data, ATSDR does not believe that radionuclides in soil within the White Oak Creek study area present a health hazard for people who consume vegetables from their gardens. ATSDR will address this question further when it considers other contaminants in future public health assessments. As a general rule, ATSDR recommends that everyone wash and peel all homegrown fruits, vegetables, and root crops before consumption. For more information on ATSDR's analysis of homegrown vegetables, see Section III.B. Exposure Evaluation of the Clinch River and Lower Watts Bar Reservoir for more details.
6	Was any analysis done of the game living on the reservation?	The annual DOE monitoring reports include analysis of some of the game that live on the reservation. Also, some of the ecological studies conducted under EPA's Superfund clean up work will include data on game. These DOE monitoring reports are available from the DOE Information Center located at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee. You can obtain documents from the Information Center at http://www.oakridge.doe.gov/info_cntr/index.html or by calling 865-241-4780. This public health assessment evaluates the past consumption of fish and the current (1988–2003) consumption of fish, geese, and turtles that might have lived on the reservation property. Please see Section III.B. Exposure Evaluation of the Clinch River and the Lower Watts Bar Reservoir for more information.

	Actual Comment	ATSDR's Response
7	People, actually, some of you might kind of take this lightly, but a lot of people in Oak Ridge feel this same way, a lot of people in Oak Ridge don't drink Oak Ridge water. They buy water. They don't drink Oak Ridge water.	Oak Ridge is supplied with public water from a water treatment plant that draws surface water from Melton Hill Lake. The intake at the lake is located approximately 1 mile upstream of the ORR. Until May 2000, DOE owned and operated the water treatment plant at its Y-12 facility and sold drinking water to the city of Oak Ridge for distribution to residents and businesses. The city of Oak Ridge now owns and operates the water distribution system (City of Oak Ridge 2002). Under the Safe Drinking Water Act, EPA sets health-based standards for hundreds of substances in drinking water and specifies treatments for providing safe drinking water (USEPA 1999a). The public water supply for Oak Ridge is continually monitored for these regulated substances. The Tennessee Department of Environment and Conservation (TDEC) receives a copy of the monitoring report to ensure that people are receiving clean drinking water. More information about the quality of the Oak Ridge public water supply system can be found at: http://www.cortn.org/PW-html/CCR2004.pdf (City of Oak Ridge 2002.) To ask specific questions related to your drinking water, please call TDEC's Environmental Assistance Center in Knoxville, Tennessee at 865-594-6035. To find additional information related to your water supply or other water supplies in the area, please call EPA's Safe Drinking Water Hotline at 800-426-4791 or visit EPA's Safe Drinking Water Web site at http://www.epa.gov/safewater. You can also look up monitoring results for the Oak Ridge or other public water supplies by visiting EPA's Safe Drinking Water Information System at http://www.epa.gov/enviro/html/sdwis/sdwis_query.html.

	Actual Comment	ATSDR's Response
8	Do agencies do some of their own sampling even when it has already been done before? The Ten Mile area gets water from a company in Spring City and this company has another company of choice test it. The State has never tested it independently and did not follow-up on water testing. Could ATSDR take a sample?	If ATSDR believed that the water at Spring City was a public health issue, then it would recommend that sampling be conducted. However, based on this PHA's findings and ongoing monitoring programs, additional sampling is not necessary. Under the Safe Drinking Water Act, EPA sets health-based standards for hundreds of substances in drinking water and specifies treatments for providing safe drinking water (USEPA 1999a). The public water supplies for Kingston, Spring City, and Rockwood—systems in the White Oak Creek public health assessment study area that draw their water from the Tennessee River system—are continually monitored for these regulated substances. According to EPA's Safe Drinking Water Information System (SDWIS), the Kingston, Spring City, and Rockwood public water supply systems have not had any significant violations (USEPA 2004b). To look up information for these water supplies or other supplies in the area, go to EPA's SDWIS Web site at http://www.epa.gov/enviro/html/sdwis/sdwis_query.html. In 1996, the Tennessee Department of Environment and Conservation's (TDEC) DOE Oversight Division began participating in EPA's Environmental Radiation Ambient Monitoring System (ERAMS). Under this program, TDEC has conducted filter backwash sludge sampling at Spring City because contaminants from the ORR could potentially move downstream into community drinking water supplies. Also since 1996, EPA has analyzed samples from five public water suppliers located on and near the ORR through its ERAMS drinking water program. On a quarterly basis, TDEC takes finished drinking water samples from these locations and EPA analyzes the samples for radionuclides. The public water suppliers are as follows: Kingston Water Treatment Plant (TRM 568.4), DOE Water Treatment Plant at K-25 (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). In addition, the Tennessee Valley Authority (TVA) conducts sampling of radionuclides in fish tissues, and also analyzes the PCBs, pesticides, and metals in sediments from the river mile at Spring City.
9	When you're thinking of Bradbury (TN), that's basically going west of Exit 10. So the impact is basically southwest of the fact—to me it looks that people along the interstate, that area, would have been most susceptible to iodine than Bradbury. But Bradbury would be the most susceptible to some of the stuff dumped in White Oak Creek.	This public health assessment evaluates the X-10 releases of radionuclides into the water in White Oak Creek, which flows into the Clinch River and the Lower Watts Bar Reservoir. This assessment evaluates past, current, and future exposure to radionuclide releases for people who use or live along the Clinch River and the Lower Watts Bar Reservoir (the area along the Clinch River from the Melton Hill Dam to the Watts Bar Dam [see the study area in Figure 11]). Bradbury and I-40 areas are in the study area. This document does not address the X-10 releases of iodine 131 into the air. ATSDR will evaluate the release of iodine 131 into the air in a future public health assessment.
10	Two community members noted that there was a barrier at White Oak Creek, but that people still fished there. The community members continued that the barrier was simply a cable that went across with a sign that said not to enter the area. They said that people would lift this up, go under the cable, and fish at the creek.	White Oak Creek is located on the Oak Ridge Reservation. Because White Oak Creek is on the ORR, access to the creek is restricted and controlled by DOE (ChemRisk 1999a). DOE has a cable barrier that runs across White Oak Creek to prevent trespassers from entering the creek for fishing and other prohibited activities. Also, DOE has posted warning signs at the creek so that people will not enter the area (EEWG [former PHAWG] meeting minutes, May 5, 2003). Therefore, people who fish or enter White Oak Creek for other purposes are trespassing on DOE property.

	Actual Comment	ATSDR's Response
11	She wondered if there are any substances in the drinking water.	Kingston maintains public water supplies in the vicinity of the Oak Ridge Reservation (see Figure 13). The Kingston water supply has two water intakes, but only one of the intakes—located upstream on the Tennessee River in Watts Bar Lake at Tennessee River Mile (TRM) 568.4—would potentially be impacted by ORR contaminants (Hutson and Morris 1992; G. Mize, Tennessee Department of Environment and Conservation, Drinking Water Program, personal communication re: Kingston public water supply, 2004). Spring City obtains its water from an intake on the Piney River branch of Watts Bar Lake (Hutson and Morris 1992). The city of Rockwood receives its water from an intake on the King Creek branch of Watts Bar Lake, located at TRM 552.5 (TDEC 2001, 2006b; TVA 1991). Under the Safe Drinking Water Act, the EPA has set health-based standards for substances in drinking water and specified treatments for providing safe drinking water since 1974 (USEPA 1999a). 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. The public water supplies for Kingston, Spring City, Rockwood, and other supplies in Tennessee are monitored for substances that include 15 inorganic contaminants, 51 synthetic and volatile organic contaminants, and 4 radionuclides (USEPA 2004a). EPA's monitoring schedules for each contaminant is available at 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 2003c). According to EPA's SDWIS, the Kingston, Spring City, and Rockwood public water supply systems have not had any significant violations (USEPA 2004b). To look up information related to these and other public water supplies, go to EPA's Local Drinking Water Information Web Site at http://www.epa.gov/safewater/dwinfo.htm. In addition, in 1996 TDEC's DOE Oversight Division started to participate in EPA's Environmental Radiation Ambient Monitoring System (ERAMS). As part of the Oak Ridge ERAMS program, TDEC collects samples from five facilities on the ORR and in its vicinity. Under the Oak Ridge ERAMS, TDEC collects finished drinking water samples from the Kingston Water Treatment Plant on a quarterly basis and then submits the samples to EPA for radiological analyses. The schedule and contaminants sampled at the Kingston Water Treatment Plant are presented in Section II.F.3. Also see the TDEC–DOE Oversight Division's annual report to the public at http://www.state.tn.us/environment/doeo/active.shtml for a summary of radiological drinking water sampling results. TDEC has also conducted filter backwash sludge sampling at Spring City because radioactive contaminants from the ORR could potentially move downstream into community drinking water supplies. TDEC analyzed Spring City samples for gross alpha, gross beta, and gross gamma emissions (TDEC 2002, 2003a, 2003b). To ask specific questions related to your drinking water, please call TDEC's Environmental Assistance Center in Knoxville, Tennessee at 865-594-6035 or call EPA's Safe Drinking Water Hotline at 800-426-4791. More details are also available at EPA's Safe Drinking Water Web site at http://www.epa.gov/safewater/.

	Actual Comment	ATSDR's Response
Radionuclides Associated with X-10's Releases to White Oak Creek		
12	A subcommittee member asked about known health effects of niobium, sheet metal form.	Niobium has been used on the Oak Ridge Reservation at both the X-10 and Y-12 plants. In *Phase I of the Oak Ridge Health Studies (Dose Reconstruction Feasibility Study)*, the Tennessee Department of Health investigated niobium from the Oak Ridge Reservation and determined that it was not a high priority contaminant. In, however, the *Reports of the Oak Ridge Dose Reconstruction, 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* (referred to as the "Task 4 report"), TDOH reevaluated niobium 95 releases into White Oak Creek and the radiation dose from niobium 95 was included in the evaluation of external exposure from shoreline sediments. In addition, the state reevaluated niobium from Y-12 in the *Task 7 Report—Screening-level Evaluation of Additional Potential Materials of Concern*. Through its assessment, the state determined that quantities of niobium from Y-12 were not large enough to present health risks to off-site populations (ATSDR et al. 2000; ChemRisk 1999b). Data on the toxicological effects of niobium are very limited, and EPA has not established regulatory limits for chronic exposure to niobium (ChemRisk 1999b). Most people rarely encounter niobium compounds. Unless known otherwise, all niobium compounds should be regarded as highly toxic in the laboratory. The metal dust causes eye and skin irritation, and is likely to represent a fire hazard. See Appendix D for briefs on the 1993 Phase I *Dose Reconstruction Feasibility Study*, the 1999 Task 4 report, and the 1999 Task 7 report. Copies of these three reports are available at the DOE Information Center located at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee (telephone number: 865-241-4780) or through DOE's public-use database at http://cedr.lbl.gov/DR/dror.html.
13	Does cesium stay in the muscle?	Cesium can enter the body through ingestion, inhalation, or injury to the skin. Once cesium enters the body, it is dispersed throughout the body's soft tissues. Slightly larger concentrations of cesium are found in muscle compared with amounts of cesium found in bone and fat. Compared with some of the other radionuclides, cesium remains in the body for a fairly short period of time (USEPA 2003a). Cesium does not stay in the muscle or other tissues. Cesium has a physical half-life of about 30 years and a biological half-life of 70 days. Therefore, the cesium is removed from the body through urine in about 70 days (EEWG [former PHAWG] meeting minutes from December 10, 2001; USEPA 2003a).

	Actual Comment	ATSDR's Response
14	A community member thought that over 2,000 curies (Ci) were released in one year (1956) over White Oak Dam, but this was a short half-life. He thought that it was two weeks for ruthenium 106. The community member thought that ruthenium went to rhodium, which had the largest beta of any radionuclide.	Ruthenium (Ru) 106 is a fission product with a radioactive half-life of approximately 368 days. Ru 106 decays, releasing a beta particle with energy of 0.039 million electron volts (MeV). This means that Ru 106 is a very weak emitter; however, its decay product rhodium (Rh) 106 is a very strong beta particle emitter. Rh 106 has a radioactive half-life of about 30 seconds and the maximum beta particle energy emission is 3.5 MeV. Rh 106 also emits several gamma rays of varying energy. When Ru 106 is taken into the body, the dose methodology and the dose coefficients used take into account the production of rhodium by the radioactive decay of the ruthenium. However, the dose delivered by the rhodium is not considered because its half-life of 30 seconds is too short to have an impact. In fact, neither the ICRP nor the EPA publish dose coefficients for Rh 106.
15	Back in the 1950s and 1960s when they were doing a lot of testing, strontium was a big worry. I'd never heard of I 131. Everyone was concerned then about health effects from strontium. Now all this talk about I 131. All of this was from same fallout (I 131 and strontium). Strontium pathway is basically the same as iodine.	The Task 4 report evaluated the estimated amount of radioactivity that was released from X-10 into White Oak Creek. During its evaluation, the state determined that specific radionuclides required further investigation; strontium 90 and iodine 131 were both included in this group. In this PHA, ATSDR evaluated past and current exposure to strontium contamination released from White Oak Creek, and determined that the levels of strontium in the water, sediment, vegetables, fish, and game were too low to be of public health concern (ChemRisk 1999a). See Section III. Evaluation of Environmental Contamination and Potential Exposure Pathways in this PHA for ATSDR's analysis of past and present exposures to strontium. ATSDR will address historical exposures to iodine 131 released into the air from X-10 in a future PHA. Inhalation, drinking water, and food consumption are the pathways for both iodine and strontium. However, the primary health effects differ between these two radionuclides. Strontium 90 affects bone marrow and bone surfaces; its 29-year radioactive half-life and 30-year biological half-life make strontium one of the more hazardous contaminants associated with radioactive fallout. The primary health concerns for strontium include bone tumors and tumors in the blood cell forming organs. Whereas iodine 131 is deposited into the thyroid, and consequently, the primary health concern for iodine 131 is thyroid tumors. Traditionally, the primary exposure pathway to iodine 131 has been drinking milk from cows that consumed contaminated crops. Consumption of fruits and vegetables, and also inhalation, are other exposure pathways for iodine 131 (INEEL 2001a, 2001b). ATSDR will provide additional information on iodine from X-10 in a future PHA on iodine 131.

	Actual Comment	*ATSDR's Response*
Evaluation of Contaminants Released from the Oak Ridge Reservation		
16	The board (ORRHES) should familiarize itself with the off-site contamination that has gone on down river and downstream. There are 6 initial contaminants of concern (which include iodine 131, mercury, uranium, radionuclides in White Oak Creek, polychlorinated biphenyls, fluorine/fluoride), although there may be others. Why weren't the Oak Ridge signature contaminants of nickel, strontium, cesium, and chromium, which are in residents' bodies, included in the Phase I evaluation, and why was it not peer reviewed?	At the March 2001, June 2001, December 2001, and February 2002 Oak Ridge Reservation Health Effects Subcommittee (ORRHES) meetings, and at the Exposure Evaluation Work Group (formerly known as the Public Health Assessment Work Group [PHAWG]) meetings in 2001 and 2002, ATSDR presented and discussed in detail its screening process for evaluating past exposures (1944–1990) and determining contaminants of concern that warrant further evaluation. This comprehensive screening analysis included an evaluation of releases of hazardous substances (chemical and radiological) into the air, creeks, streams, and rivers from the Oak Ridge Reservation and the potential of off-site exposure to contaminants downstream. These detailed presentations also included discussions of ATSDR's review and analysis of the Tennessee Department of Health's • 1993 Phase I of the Oak Ridge Health Study—Dose Reconstruction Feasibility Study, and • 1999 Reports of the Oak Ridge Dose Reconstruction, The Report of Project Task 7—Screening-Level Evaluation of Additional Potential Materials of Concern. These studies evaluated past chemical and radionuclide releases from the Oak Ridge Reservation and the potential of their releases to impact the health of people living near the reservation. Using ATSDR's screening process for evaluating past exposures, ATSDR scientists are conducting public health assessments on the release of and exposure to uranium, iodine 131, mercury, PCBs, radionuclides from White Oak Creek, fluorides, and other topics, such as the TSCA incinerator and off-site groundwater. ATSDR will evaluate past and current off-site exposures to these contaminants. In addition, the EEWG conducted an evaluation of ATSDR's screening process for past exposures. The EEWG's evaluation consisted of a detailed review and understanding of ATSDR's screening presentations to the subcommittee, ATSDR's independent technical reviewers' comments, the subcommittee's review and assessment of technical documents (as needed), and related public concerns or issues (as needed). After completing its evaluation, the EEWG recommended at the February 2002 ORRHES meeting that the ORRHES endorse ATSDR's screening process for determining contaminants of concern for past exposures (1944–1990 data). This endorsement begins with using the state of Tennessee's screening process and associated findings that identified ORR off-site releases warranting further evaluation. The ORRHES approved the EEWG's recommendation to endorse ATSDR's screening evaluation of past exposures. The February 2002 ORRHES meeting minutes are available on the ATSDR Web site at http://www.atsdr.cdc.gov/HAC/oakridge/meet/orr/m8_27.html.

	Actual Comment	ATSDR's Response
16	*Continued*	Cesium and strontium were first evaluated by the state of Tennessee in its 1993 *Phase I of the Oak Ridge Health Study Dose Reconstruction Feasibility Study* and then reevaluated in the 1999 *Reports of the Oak Ridge Dose Reconstruction, 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* (referred to as the "Task 4 report"). ATSDR evaluated past, current, and future exposure to cesium and strontium in this public health assessment. Nickel and chromium were evaluated in the 1993 *Phase I of the Oak Ridge Health Study—Dose Reconstruction Feasibility Study* and reevaluated in the 1999 *Reports of the Oak Ridge Dose Reconstruction, The Report of Project Task 7—Screening-Level Evaluation of Additional Potential Materials of Concern* (ATSDR et al. 2000; ChemRisk 1999b). The Tennessee Department of Health had the 1993 *Phase I of the Oak Ridge Health Study—Dose Reconstruction Feasibility Study* reviewed by SENES Oak Ridge in 1995. This report titled A *Review of the Preliminary Screening Analysis Carried Out During the Oak Ridge Dose Reconstruction Feasibility Study* was evaluated by ATSDR and the EEWG (former PHAWG). See Appendix D for briefs on the 1993 Phase I feasibility study, 1999 Task 4 report, and the 1999 Task 7 report. 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: 865-241-4780) or through DOE's public-use database at http://cedr.lbl.gov/DR/dror.html.

<table>
<tr><th></th><th>Actual Comment</th><th>ATSDR's Response</th></tr>
<tr><td>17</td><td>I had some questions about your study of the hundred and sixteen people in the southern Watts Bar area. I don't know if I am being premature in my questions to you, but did you all come to the conclusion that there was no danger from eating the fish for anything other than PCBs, when that was the only thing you tested for?

If your testing was accurate and your conclusions were accurate, why hasn't something changed so far as all of those fish advisories?

I don't think the community would mind if you had an advisory on don't eat the turtles.</td><td>ATSDR conducted a health consultation in 1996 to evaluate the public health implications of current exposure to chemical and radiological contaminants in the Lower Watts Bar Reservoir surface water, sediment, and fish and the effectiveness of the Department of Energy's (DOE) proposed remedial action plan for protecting public health. ATSDR found that only PCBs in the reservoir fish were of potential public health concern. The current levels of other contaminants in the surface water, sediment, and fish are not a public health hazard.

After reviewing current levels of contaminants in the water, in sediment, and in local fish populations, ATSDR concluded that:
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. Drinking 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, was safe to drink.
DOE's selected remedial action was protective of public health.
ATSDR recommended that the Lower Watts Bar Reservoir fish advisory remain in effect to minimize exposure to PCBs.

ATSDR followed up the 1996 health consultation by conducting the Watts Bar Reservoir Exposure Investigation in March 1998. This study was done to measure actual PCB and mercury levels in people who have eaten large amounts of Watts Bar Reservoir fish or turtles. ATSDR tested for PCBs because previous investigations estimated that people who eat certain fish or turtles might have higher than average levels of PCBs in their bodies and suggested that the levels of PCBs in fish were a public health concern. ATSDR tested the blood samples for mercury because mercury was a historic contaminant of concern. Recent studies, however, have not detected mercury at levels of health concern in surface water, sediments, or fish from the Watts Bar Reservoir.</td></tr>
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	Actual Comment	ATSDR's Response
17	*Continued*	The ATSDR exposure investigation revealed that the 116 study participants who consumed moderate to large amounts of fish and turtles had PCB levels similar to those of the general population. The PCB and mercury levels were less than ATSDR health officials expected for people who consume moderate to large amounts of certain fish or turtles from the Watts Bar Reservoir. Five people (4% of the 116 participants) had elevated serum levels of PCBs (above 20 micrograms per liter), one person had PCB levels above those in the general population, and one person had elevated blood mercury levels (above 10 micrograms per liter). ATSDR health officials believed that health effects were not likely based on the PCB and mercury levels seen in the exposure investigation participants. ATSDR recommended that health education activities be targeted to local health care providers, pregnant and nursing mothers, and any other potentially vulnerable populations to minimize exposure to PCBs. ATSDR developed an instructive brochure on the Tennessee Department of Environment and Conservation (TDEC) fish consumption advisories for the Watts Bar Reservoir. The brochure was the result of the collaborative effort of local citizens, organizations, and state officials. See Appendix D for a brief of the exposure investigation and Section II.F.1. for ATSDR's public health activities related to White Oak Creek radionuclide releases (ATSDR et al. 2000; ORHASP 1999).
18	Since the contamination from fish ingestion will not necessarily be measurable in the bloodstream at high levels at all times, a challenge test is needed to detect it. This was not used by ATSDR and is not normally used in a standard physician's office visit test. The ATSDR study results are countered by other studies, and communities in the southeast whose problems were addressed by ATSDR were not helped.	There are reliable and accurate medical tests that measure the level of mercury in the body by analyzing blood, breast milk, hair, or urine samples. These are not routine clinical tests, but they could be requested from a doctor. Most of these tests do not determine the form of mercury to which an individual is exposed. These clinical tests can show if mercury exposure has occurred, provide an idea as to the extent of exposure, and can be used to assess if harmful health effects are likely to occur, but they cannot tell exactly how much exposure has occurred (ATSDR 1999a). For more information on mercury, review ATSDR's toxicological profile on mercury at http://www.atsdr.cdc.gov/toxprofiles/phs46.html. PCBs are pervasive environmental contaminants that are found in body tissue and fluids of the general population. There are also medical tests that measure the level of PCBs in the body by analyzing blood, body fat, and breast milk. Serum or plasma lipid PCB concentrations are an indicator of PCB body burden. These are not routine clinical tests, but they could be requested from a doctor. These tests can indicate if a person was exposed to PCBs, but they cannot determine the exact amount of exposure, type of PCBs, or if adverse health effects will occur. Though, these tests can indicate whether you have been exposed to PCBs to a greater extent than the general public. Blood tests are the best method for detecting recent exposure to large amounts of PCBs. Thus, a physician with a background in environmental and occupational health should carefully interpret the test results (ATSDR 2000). For more information on PCBs, visit ATSDR's Web site for the PCB toxicological profile at http://www.atsdr.cdc.gov/toxprofiles/phs17.html.

	Actual Comment	ATSDR's Response
18	*Continued*	Previous investigations identified PCBs in reservoir fish as a possible contaminant of public health concern. TDEC and DOE had detected PCBs at levels up to about 8 ppm in certain species of reservoir fish during past studies. In an investigation on turtles in the Watts Bar Reservoir and the Clinch River, TDEC detected the highest PCB concentrations in the fat tissue (ranged from 0.274 to 516 ppm) of snapping turtles. The PCB concentrations detected in the muscle tissue of turtles ranged from 0.032 to 3.38 ppm. In 1994 and 1996 remedial investigations, based on estimated PCB exposure doses and estimated excess cancer risks for people consuming large amounts of fish over an extended time period, DOE determined that the fish ingestion pathway had the greatest potential to cause adverse health effects in the Lower Watts Bar Reservoir and the Clinch River/Poplar Creek, respectively. ATSDR also conducted a 1996 health consultation on the Lower Watts Bar Reservoir that reached similar conclusions as found in the remedial investigation. None of these studies, however, considered actual blood levels in fish and turtle consumers nor confirmed if people were actually exposed to PCBs or had elevated PCB levels. Because of these reasons and since so many uncertainties are involved in estimating exposure doses and excess cancer risk from ingesting reservoir fish and turtles, ATSDR conducted an exposure investigation to actually measure the serum PCB levels in fish and turtle consumers. In fact, ATSDR knows of no other studies in the Oak Ridge area that measured actual blood levels in community members to evaluate exposures from fish and turtle consumption. For this investigation, ATSDR targeted people who consumed moderate to large amounts of reservoir fish and turtles. Based on the actual measurements of serum PCB levels in participants, only 1 out of 116 had a serum PCB level higher than levels observed in the general population. Therefore, based on actual levels—not theoretical estimates as used in previous studies—of people who consumed moderate to high amounts of fish and turtles from the reservoir, PCB levels were comparable to the general population. See Appendix D for a brief on the *1998 Watts Bar Reservoir Exposure Investigation* and a brief on the *Turtle Sampling in Watts Bar Reservoir and Clinch River.*
19	Concerning studies of PCBs and blood samples in people who eat fish, I wonder how valid the information would be. Do PCBs stay in the blood, for example, and were they are a lot higher, one would presume, right after eating a meal than a week later? Were those factors taken into account in the study?	The *1998 Watts Bar Reservoir Exposure Investigation* was a cross-sectional study because it evaluated PCB and mercury exposures at a specific point in time. Blood tests are the best method for detecting exposure to PCBs. Serum or plasma lipid PCB concentrations are indicators of PCB body burden and can indicate whether you have been exposed to PCBs to a greater extent than the general public. In this type of study (a cross-sectional study), PCB and mercury blood levels indicate both chronic and acute (short-term) exposures, depending on recent fish consumption. PCB blood levels are likely to be higher right after eating a fish meal containing PCBs. This factor was taken into account in the exposure investigation. The investigation is discussed in more detail in Section II.F.1. of this document. In addition, ATSDR will address issues solely related to PCBs in a separate public health assessment that will be released in the near future. See Appendix D for a brief on the *1998 Watts Bar Reservoir Exposure Investigation*.

	Actual Comment	ATSDR's Response
20	A community member said there are a couple of other dimensions that will complicate matters but she hopes they will be considered. One is the time frame. The workers and residents who lived nearby in the 50s and 60s had different exposures than now and will have different symptoms now. Also, geographically, the flow of water, the underground aquifer, that sort of thing. The two dimensions are geography and time will complicate this and shouldn't be overlooked. There may be people who lived in different locations and the well water was of different composition.	In this public health assessment, ATSDR evaluates radionuclides released into the surface water in White Oak Creek, and assesses past, current, and future impact from exposures to these radionuclide releases in the water for residents living off the Oak Ridge Reservation within the White Oak Creek study area (the area along the Clinch River and the Lower Watts Bar Reservoir from the Melton Hill Dam to the Watts Bar Dam [see Figure 11]). This PHA evaluates the following key issues and concerns: contacting surface water and sediment (both surface and deep channel) and consuming surface water, milk, game animals, fish, turtles, and homegrown vegetables. In addition to this PHA, ATSDR scientists are conducting public health assessments on the releases of iodine 131, mercury, PCBs, uranium, fluorides, and other topics including off-site groundwater. The geography and characteristics of the aquifer are considered in the groundwater public health assessment available at http://www.atsdr.cdc.gov/HAC/PHA/region_4.html#groundwater. In conducting PHAs, 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.
21	Will exposure investigations be done as they were for PCBs at Watts Bar?	ATSDR is not planning additional exposure investigations at this time. Instead, ATSDR is conducting public health assessments on the releases of iodine 131, mercury, PCBs, uranium, fluorides, and other topics. In conducting these 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. 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.
General Concerns Related to the Oak Ridge Reservation		
22	What is the probability of a clinic for residents closely associated and who live close by incinerators and the Clinch River and East Fork Poplar Creek?	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 (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,

	Actual Comment	ATSDR's Response
22	*Continued*	• 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. 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 were 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 was 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 was 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.
23	Will you screen the effects of the environmental pollutants from the Kingston and Bull Run power plants whose interaction with the ORR concerns many people?	ATSDR is not evaluating all sources of contaminants in the area and is not adding exposures from these other sources. Congress created ATSDR to implement the health related sections of the 1980 Superfund law. ATSDR's congressional mandate is to conduct a public health assessment at EPA's National Priorities List for Uncontrolled Hazardous Waste Sites (NPL). The DOE Oak Ridge Reservation (ORR) is on the NPL. ATSDR's focus is on ORR releases of contaminants to off-site locations. ATSDR is not going to conduct an evaluation of releases of contaminants from other industries in the area. However, environmental samples (air, water, sediment, and soil) collected in and around the ORR may contain contaminants released from other industries in the area (for example, arsenic, mercury, and uranium released from the two large Tennessee Valley Authority [TVA] power plants). ATSDR will evaluate the levels of contaminants in these samples regardless of the source of the contaminants. If ATSDR identifies contaminants in off-site locations during its assessment that are of public health concern, then ATSDR will address exposures to these contaminants in the PHA.

	Actual Comment	*ATSDR's Response*
24	This second paper in Radiation Research (after the Mangano paper) was a study of the mortality of 106,020 workers employed between 1943 and 1985 at the federal nuclear plants in Oak Ridge (who also live in communities around ORR). This second paper DID NOT find an increase in leukemia deaths relative to U.S. white males. A smaller group of 28,347 white males employed at X-10 or Y-12 who were at risk for exposure to external penetrating radiation was examined to determine if there was a relationship between rates of death from selected causes and level of radiation dose. There was no evidence for an association between leukemia deaths and external radiation. Leukemia death rates for X-10 workers were higher than U.S. rates and other similar Oak Ridge workers.	ATSDR is conducting public health assessments to evaluate whether the releases of contaminants from the Oak Ridge Reservation could be harmful to people who live in communities near the reservation. This assessment focuses on exposures to contaminants that occurred off the reservation. ATSDR does not evaluate health issues related to workplace exposures. ATSDR did, however, conduct an assessment of cancer incidence that evaluated cancers in the eight counties surrounding the reservation. For the review, ATSDR used cancer incidence data from the state of Tennessee's cancer registry. The assessment of cancer incidence report is available at http://www.atsdr.cdc.gov/HAC/oakridge/phact/cancer_oakridge/index.html. Information specific to workers can be found on the Internet at http://cedr.lbl.gov. This site provides information about epidemiologic studies of U.S. Department of Energy workers, including studies of workers at the Y-12, X-10, and K-25 sites.

VII. Child Health Considerations

ATSDR recognizes that infants and children can be more sensitive to environmental exposure than adults in communities faced with contamination of their water, soil, air, or food. This sensitivity is a result of the following factors: 1) children are more likely to be exposed to certain media (for example, soil or surface water) because they play and eat outdoors; 2) children are shorter than adults, which means that they can breathe dust, soil, and vapors close to the ground; and 3) children are smaller; therefore, childhood exposure results in higher doses of chemical exposure per body weight. Children can sustain permanent damage if these factors lead to toxic exposure during critical growth stages. ATSDR is committed to evaluating the special interests of children at sites such as the ORR.

Children playing in and living along the Clinch River and Watts Bar Reservoir could have been exposed to radiation when they used these waterways for food, water, or recreation. In addition, *in utero* and infant exposures could have resulted from exposure of pregnant or lactating women (or both) to radiation in and near the Clinch River and Watts Bar Reservoir. Radionuclide levels in water, sediment, and biota are, however, below levels shown to cause adverse health effects in these populations. For past exposures, the Task 4 team concluded that its estimated radiological doses and excess lifetime cancer risks were “incremental increases above those resulting from exposure to natural and other anthropogenic sources of radiation.” Still, they were “not large enough for a commensurate increase in health effects in the population to be detectable, even by the most thorough of epidemiological investigations.” The Task 4 team noted that “in most cases, the estimated organ-specific doses are clearly below the limits of epidemiological detection (1 to 30 cSv [1,000 to 30,000 mrem]) for radiation-induced health outcomes that have been observed following irradiation of large cohorts of individuals exposed either in utero (Doll and Wakeford 1997), as children, or as adults (NRC [National Research Council] 1990; Thompson et al. 1994; Pierce et al. 1996) (ChemRisk 1999a).”

Further, dose and risk factors for most radionuclides in the Task 4 analysis do not differ greatly between children and adults (ChemRisk 1999a). Exposure to iodine 131 has been shown to increase the likelihood of thyroid disorders in children—that is, exposed children could have an increased likelihood of developing a disease (e.g., thyroid cancer) in their lifetimes

(Vykhovanets et al. 1997; Astakhova et al. 1998; Heidenreich et al. 1999; Hahn et al. 2001). Nevertheless, based on the Task 4 analysis, the levels of iodine 131 in the surface water of the Clinch River and in the locally produced milk are too low to cause such health effects in children living near the Clinch River.

Therefore, even past radiation exposures—when doses were the highest—were not expected to cause harmful health effects *in utero*, in infants, and in children. Accordingly, because estimated doses for exposures to the Clinch River and Lower Watts Bar Reservoir have decreased over time, exposures to radiation *in utero*, in infants, and in children are not expected to cause adverse health effects in the present or in the future.

VIII. Conclusions

Having thoroughly evaluated past public health activities and available current environmental information, ATSDR has reached the following conclusions.

ATSDR concludes that exposures to X-10 radionuclides released from White Oak Creek to the Clinch River and to the Lower Watts Bar Reservoir are not a health hazard. Past and current exposures are below levels associated with adverse health effects and regulatory limits. Adults or children who have used, or might continue to use, the waterways for recreation, food, or drinking water are not expected to have adverse health impacts due to exposure. ATSDR has categorized those situations as posing *no apparent public health hazard* from exposure to radionuclides related to X-10. This classification means that people could be or were exposed, but that their level of exposure would not likely result in any adverse health effects. (Definitions of ATSDR's public health categories are included in the glossary in Appendix A.)

> ATSDR uses the ***no apparent public health hazard*** category in situations in which human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects.

Past Exposure

ATSDR concludes that past exposures to White Oak Creek radionuclide releases from walking on the shoreline, drinking milk and water, or eating meat and fish from the Clinch River are not a health hazard and are not expected to result in adverse health effects or cancer.

- Using the results of the Task 4 report, ATSDR re-evaluated *past* exposures (1944–1991) to radionuclides released from White Oak Creek into the Clinch River. People who used or lived near the Clinch River could have come in contact with X-10 radionuclides by eating fish and meat, drinking milk and water, and walking on shoreline sediment. Using organ doses from the Task 4 report, ATSDR estimated whole-body doses (annual dose and committed effective dose over 70 years). An individual exposed to the primary radionuclides in Clinch River fish, shoreline sediment, meat, milk, and drinking water was expected to receive a committed effective dose to the whole body of less than 300 mrem over 70 years. This dose is about 18 times less than ATSDR's radiogenic comparison value of 5,000 mrem over 70 years. Doses below the radiogenic comparison value are not expected to result in observable health effects.

- ATSDR's estimated annual whole-body dose from combining the organ doses was 4 mrem/year and well below (25 times less than) ATSDR's MRL of 100 mrem/year and the

ICRP, NRC, and NCRP maximum dose recommendation of 100 mrem/year for members of the public. ATSDR's MRL for ionizing radiation is based on noncancer health effects only; it is not based on a consideration of cancer effects. MRLs are estimates of daily human exposures to substances that are unlikely to result in noncancer effects over a specified duration. The maximum dose constraint for members of the public of 100 mrem/year recommended by the ICRP, NRC, and NCRP considers both noncancer and cancer health effects.

- The estimated committed equivalent doses to all the organs from eating fish caught near Jones Island exceeded dose estimates for all other exposure pathways (walking along the shore and ingesting water, milk, and meat) by at least a factor of six. The estimated committed equivalent doses to the organs from past exposures to radionuclides in and along the Clinch River varied by critical organ (bone, lower large intestine, red bone marrow, breast, and skin).

- The highest committed equivalent dose to the organs was 810 mrem to the bone for people who ate fish often (1 to 2.5 fish meals per week) and caught their fish near Jones Island. Doses to the bone were much lower for people who consumed fewer fish and who caught their fish further downstream. The estimated total committed equivalent dose to the bone over a lifetime (70 years) from all exposure pathways was less than 1,600 mrem over 70 years. This estimated total lifetime bone dose is well below (243 times less than) the doses of 390,000 to 620,000 mrem shown to cause bone cancers in radium dial workers.

- ATSDR analyzed radiation doses from drinking water at K-25/Grassy Creek (CRM 17 to 5) and the city of Kingston (CRM 2 to 0), located downstream from the mouth of White Oak Creek. The doses to the bone, lower large intestine, red bone marrow, breast, and skin from drinking Clinch River water were at least 7 times lower than the doses to those same organs from eating Clinch River fish. The highest annual whole-body dose from drinking water of 0.3 mrem was estimated for K-25/Grassy Creek. This annual whole-body dose is more than 1,000 times less than the background dose of 360 mrem that the average U.S. citizen receives each year. Lower doses were associated with drinking water further downstream at the city of Kingston. Organ-specific doses from drinking city of Kingston water were at least 13 times less than the doses estimated for K-25/Grassy Creek drinking water.

- After reviewing information provided by a community member about the former Happy Valley settlement, ATSDR conducted a separate analysis of possible exposures to radionuclides for Happy Valley residents who relied on the K-25 water intake for their drinking water. ATSDR's estimated annual whole-body dose of 14 mrem from drinking water for a former Happy Valley resident is at least 7 times lower than ATSDR's MRL of 100 mrem/year and the ICRP, NRC, and NCRP maximum dose recommendation of 100 mrem/year for members of the public.

- The estimated total committed equivalent dose to the lower large intestine from all pathways was less than 1,200 mrem over 70 years. This estimated dose is 4 times less than ATSDR's radiogenic comparison value of 5,000 mrem over 70 years, which is based on studies of atomic bomb survivors, radiation workers, and radiation workers' children.

- The estimated total committed equivalent dose to the red bone marrow over a lifetime (70 years) from all exposure pathways was less than 1,200 mrem over 70 years. This estimated total lifetime bone dose is well below (i.e., 325 times less than) the doses of 390,000 to 620,000 mrem associated with bone cancers in radium dial workers.

- The estimated total committed equivalent dose to the breast in females over a lifetime (70 years) from all exposure pathways was less than 500 mrem over 70 years, which is well below (20 times less than) the 10,000 mrem dose shown to cause effects in atomic blast survivors.

- The estimated total committed equivalent dose to the skin over a lifetime (70 years) from all exposure pathways was less than 700 mrem over 70 years, which is well below (12 times less than) the 9,000 mrem dose shown to cause effects in patients irradiated for the treatment of ringworm.

- All the estimated organ doses and whole-body doses from past exposure to radionuclides in the Clinch River are lower than ATSDR's comparison values and doses reported in radiological and epidemiological studies on the effects of radiation exposure. Therefore, considering the many conservative assumptions used in calculating the dose estimates, ATSDR believes that the actual likelihood of developing disease for people who were exposed to radionuclides in the Clinch River is small, if it exists at all.

Current Exposure

ATSDR concludes that current exposures to White Oak Creek radionuclide releases to the Clinch River and LWBR are not a health hazard and are not expected to result in adverse health effects or cancer. This conclusion is based on ATSDR's evaluation of current exposure to radionuclides by consumption of surface water, by dermal contact with surface water and sediment, and by consumption of fish from the Clinch River and the Lower Watts Bar Reservoir, as well as by consumption of turtles and geese from the Clinch River.

Lower Watts Bar Reservoir

- Using available environmental data collected from 1988 to 1994, ATSDR evaluated current exposures to radionuclides via ingestion of fish, ingestion of surface water, and external exposure from dermal contact with surface water and shoreline and dredged channel sediment of the Lower Watts Bar Reservoir. Even assuming maximum concentrations of radionuclides and using conservative exposure scenarios, current exposure to radionuclides in the Lower Watts Bar Reservoir would result in radiation doses below levels expected to cause adverse health effects. ATSDR's estimated committed effective dose to the whole body for all pathways combined is less than 1,900 mrem over 70 years—2.5 times below ATSDR's radiogenic CV of 5,000 mrem over 70 years. The estimated annual whole-body dose is less than 30 mrem, and below ATSDR's screening comparison value of 100 mrem/year. Therefore, the estimated exposures for the LWBR are not expected to result in adverse health effects based on an evaluation of radiological, epidemiological, and medical literature.

Clinch River

- Using available environmental data collected from 1989 to 2003, ATSDR evaluated current exposures to radionuclides via ingestion of biota (i.e., fish, geese, and turtles), incidental ingestion of surface water, and external exposure from dermal contact with surface water and shoreline sediment of the Clinch River. ATSDR's estimated committed effective dose to the whole body for all pathways along the Clinch River combined is less than 240 mrem to 70 years of age—more than 20 times below ATSDR's radiogenic CV of 5,000 mrem over 70 years. The estimated annual whole-body dose is less than 3.4 mrem, nearly 30 times below ATSDR's screening comparison value of 100 mrem/year. Therefore, the estimated exposures for the Clinch River are not expected to result in adverse health effects.

- Doses to organs varied by exposure pathway. ATSDR's estimates show that the *bone* would receive the highest total committed equivalent dose over a lifetime (to 70 years of age) of exposure to the radionuclides detected along the Clinch River. The highest doses to the bone were from ingestion of geese muscle or liver (230 mrem) and fish (114 mrem) by a 15-year-old based on a 55-year exposure, resulting in a committed equivalent dose of 344 mrem over 55 years. The committed equivalent dose to the bone from all pathways combined was based on exposures for adults, considering exposure to 70 years of age. The estimated dose to the bone is less than 218 mrem to 70 years of age—at least 1,788 times lower than the doses of 390,000 to 620,000 mrem associated with bone cancers in radium dial workers.

- The committed equivalent dose to the lower large intestine from all pathways combined, based on a 20-year-old adult exposed to age 70, was less than 270 mrem. This estimated dose is about 18 times lower than ATSDR's radiogenic comparison value of 5,000 mrem over 70 years.

- The committed equivalent dose to the skin over a 50-year exposure for adults is less than 6 mrem—1,500 times less than the value of 9,000 mrem. This is based on a review of the Biological Effects of Ionizing Radiation (BEIR) V report of patients irradiated for the treatment of ringworm.

- ATSDR analyzed drinking water samples collected around the cities of Kingston, Spring City, and Rockwood from 1990 to the present. ATSDR evaluated these samples for radiological content, and determined that all water samples were below EPA's maximum contaminant level (MCL). Therefore, ATSDR considers this water safe for consumption and other potable uses.

Future Exposure

Lower Watts Bar Reservoir and Clinch River

- ATSDR concludes that future exposures to White Oak Creek radionuclides released to the Clinch River and LWBR are not a health hazard and are not expected to result in adverse health effects or cancer. This is based on ATSDR's evaluation of current doses and exposures related to releases from White Oak Creek, data on current contaminant levels in the LWBR and the Clinch River, and consideration of the possibility that radionuclides could be released to White Oak Creek during remedial activities. ATSDR also factored in engineering controls to prevent off-site contaminant releases and institutional controls in place to monitor contaminants in the LWBR and the Clinch River, as well as the assumption that DOE will continue its expected appropriate and comprehensive system of monitoring, maintenance, and institutional and engineering controls. These institutional controls consist of

- prevention of sediment-disturbing activities in the Clinch River and LWBR,
- DOE's annual monitoring of Clinch River and LWBR surface water, sediment, and biota,
- DOE's monitoring of White Oak Creek releases,
- TDEC's monitoring of public drinking water supplies in Tennessee under the Safe Drinking Water Act for EPA-regulated contaminants, and
- TDEC DOE Oversight Division's quarterly radiological monitoring of five public water supplies on the ORR and in its vicinity under the EPA's Environmental Radiation Ambient Monitoring System program.

IX. Recommendations

Having evaluated the past, current, and future public health activities and the available environmental information, ATSDR offers the following:

1. Tennessee Department of Environment and Conservation (TDEC) should continue to monitor 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 should continue its 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.
2. Contaminants are not uniformly distributed in the sediment of the Lower Watts Bar Reservoir (LWBR) and their concentrations vary by sediment composition, location, and depth. Therefore, the contaminated sediment of the LWBR should not be removed, dredged, or otherwise disturbed without careful review by the Watts Bar Interagency Working Group in accordance with the permitting process outlined in the Watts Bar Interagency Agreement. Given the current knowledge of contamination, ATSDR believes that the measures undertaken by the working group, if followed, are protective of public health.
3. DOE should continue to annually monitor the Clinch River and the LWBR for ORR-related radiological contaminants in surface water, biota, and sediment, and also continue its regular monitoring of White Oak Creek radionuclide releases.

X. Public Health Action Plan

The Public Health Action Plan (PHAP) for White Oak Creek describes actions to be taken by ATSDR and other government agencies at and in the vicinity of the site after the completion of this public health assessment. The purpose of this PHAP 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 White Oak Creek releases to the Clinch River and the Lower Watts Bar Reservoir becomes available, then that information could change a conclusion or the conclusions of this public health assessment; if that occurs, then human exposure pathways should be re-evaluated and these conclusions and recommendations should be amended, as necessary, to protect public health.

- ORR staff will notify ATSDR if environmental monitoring data indicate that statistically significant contaminant levels in the Clinch River or the Lower Watts Bar Reservoir are increasing. Upon such notification, ATSDR will determine appropriate public health actions.
- ATSDR will develop and implement additional environmental health education materials as necessary to help community members understand the findings and implications of this public health assessment.
- ATSDR supports DOE's remedial actions for the Lower Watts Bar Reservoir (LWBR) as being protective of public health. These actions include leaving the contaminated sediment in place with ongoing environmental monitoring and applying institutional controls to prevent disruption of contaminated sediment. Under the Watts Bar Interagency Agreement (established by DOE, EPA, TVA, TDEC, and USACE), the agencies will continue to work together to review permitting and any other activities that could possibly disturb LWBR contaminated sediment.

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Appendix A. ATSDR Glossary of Environmental Health 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 (EPA), 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, 1-888-42-ATSDR (1-888-422-8737).

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

Activity
The number of radioactive nuclear transformations occurring in a material per unit time. The term for *activity* per unit mass is specific activity.

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].

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

Ambient
Surrounding (for example, *ambient* air).

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

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.

Background radiation
The amount of radiation to which a member of the general population is exposed from natural sources, such as terrestrial radiation from naturally occurring radionuclides in the soil, cosmic radiation originating from outer space, and naturally occurring radionuclides deposited in the human body, as well as the amount of radiation from human activities and products, such as medical x-rays.

Becquerel (Bq)
The Systeme International basic unit of radioactivity. The number of curies must be multiplied by 3.7×10^{10} to obtain an equivalent number of Bq.

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.

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

Cancer risk
A theoretical risk of 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-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.

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 (more than 1 year) [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].

Committed Effective Dose Equivalent (CEDE)
The sum of the products of the weighting factors applicable to each of the body organs or tissues that are irradiated and the committed dose equivalent to the organs or tissues. The *committed effective dose equivalent* is used in radiation safety because it implicitly includes the relative carcinogenic sensitivity of the various tissues. The unit of dose for the CEDE is the rem (or, in SI units, the sievert—1 sievert equals 100 rem).

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.

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

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.

Curie (Ci)
A unit of radioactivity. One *curie* equals that quantity of radioactive material in which there are 3.7×10^{10} nuclear transformations per second. The activity of 1 gram of radium is approximately 1 Ci; the activity of 1.46 million grams of natural uranium is approximately 1 Ci.

Decay product/daughter product/progeny
A new nuclide formed as a result of radioactive decay: from the radioactive transformation of a radionuclide, either directly or as the result of successive transformations in a radioactive series. A *decay product* can be either radioactive or stable.

Depleted uranium (DU)
Uranium having a percentage of U 235 smaller than the 0.7% found in natural uranium. It is obtained as a byproduct of U 235 enrichment.

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

DOE
The 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 milligrams (a measure of quantity) 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 gets 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).

EMEG
Environmental Media Evaluation Guide, a media-specific comparison value that is used to select contaminants of concern. Levels below the EMEG are not expected to cause adverse noncarcinogenic health effects.

Enriched uranium
Uranium in which the abundance of the U 235 isotope is increased above normal.

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.

EPA
The United States Environmental Protection Agency.

Epidemiologic 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.

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.

Equilibrium, radioactive
In a radioactive series, the state that prevails when the ratios between the activities of two or more successive members of the series remain constant.

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

Food chain
An arrangement of organisms within an ecological community according to the order of predation in which each uses the next usually lower member as a food source.

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

Gray (Gy)
The Systeme International unit for the energy absorbed from ionizing radiation, equal to one joule per kilogram.

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 other atoms (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 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. They are therefore more limited than public health assessments, which review 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 estimate the possible association between the occurrence and exposure to hazardous substances.

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.

Indeterminate public health hazard
The category used in ATSDR's public health assessment documents when a professional judgment about the level of health hazard cannot be made because information critical to such a decision is lacking.

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].

Ionizing radiation
Any radiation capable of knocking electrons out of atoms and producing ions. Examples: alpha, beta, gamma and x rays, and neutrons.

Isotopes
Nuclides having the same number of protons in their nuclei, and hence the same atomic number, but differing in the number of neutrons, and therefore in the mass number. Identical chemical properties exist in *isotopes* of a particular element. The term should not be used as a synonym for "nuclide," because "isotopes" refers specifically to different nuclei of the same element.

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.

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

mg/kg
Milligrams per kilogram.

mg/m^3
Milligrams 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 likely to be without 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].

Mortality
Death. Usually the cause (a specific disease, condition, or 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.

No apparent public health hazard
A category used in ATSDR's public health assessments for sites where human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but is not expected to cause any harmful health effects.

Noncancerous effects
Health effects or health endpoints other than cancer, such as cardiovascular disease or genetic effects, that result from exposure to a particular hazardous substance. ATSDR derives health guidelines for noncancerous effects, called minimal risk levels (MRLs), and compares exposure doses to these MRLs. Doses below MRLs are unlikely to cause noncancerous health effects; those above MRLs are evaluated further.

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.

No public health hazard
A category used in ATSDR's public health assessment documents for sites where people have never and will never come into contact with harmful amounts of site-related substances.

NPL
[See National Priorities List for Uncontrolled Hazardous Waste Sites.]

Parent
A radionuclide which, upon disintegration, yields a new nuclide, either directly or as a later member of a radioactive series.

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 in which 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).

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].

Prevention
Actions that reduce exposure or other risks, keep people from getting sick, or keep disease from getting worse.

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 plan
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 by 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 hazard
A category used in ATSDR's public health assessments for sites that pose a public health hazard because of long-term exposures (greater than 1 year) to sufficiently high levels of hazardous substances or radionuclides that could result in harmful health effects.

Public health hazard categories
Statements about whether people could be harmed by conditions present at the site in the past, present, or future. One or more hazard categories might be appropriate for each site. The five *public health hazard categories* are no public health hazard, no apparent public health hazard, indeterminate public health hazard, public health hazard, and urgent public health hazard.

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. It explains how people might be exposed to a specific substance and describes the known health effects of that substance.

Public meeting
A public forum with community members for communication about a site.

Quality factor (radiation weighting factor)
The linear-energy-transfer-dependent factor by which absorbed doses are multiplied to obtain (for radiation protection purposes) a quantity that expresses - on a common scale for all ionizing radiation - the approximate biological effectiveness of the absorbed dose.

Rad
The unit of absorbed dose equal to 100 ergs per gram, or 0.01 joules per kilogram (0.01 gray) in any medium [see dose].

Radiation
The emission and propagation of energy through space or through a material medium in the form of waves (e.g., the emission and propagation of electromagnetic waves, or of sound and elastic waves). The term "radiation" (or "radiant energy"), when unqualified, usually refers to electromagnetic *radiation.* Such *radiation* commonly is classified according to frequency, as microwaves, infrared, visible (light), ultraviolet, and x and gamma rays and, by extension, corpuscular emission, such as alpha and beta *radiation,* neutrons, or rays of mixed or unknown type, such as cosmic *radiation.*

Radioactive decay
Transformation of the nucleus of an unstable nuclide by spontaneous emission of charged particles and/or photons.

Radioactive material
Material containing radioactive atoms.

Radioactivity
Spontaneous nuclear transformations that result in the formation of new elements. These transformations are accomplished by emission of alpha or beta particles from the nucleus or by the capture of an orbital electron. Each of these reactions may or may not be accompanied by a gamma photon.

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.

RBC
Risk-based Concentration, a contaminant concentration that is not expected to cause adverse health effects over long-term exposure.

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.

Rem
A unit of dose equivalent that is used in the regulatory, administrative, and engineering design aspects of radiation safety practice. The dose equivalent in *rem* is numerically equal to the absorbed dose in rad multiplied by the quality factor (1 *rem* is equal to 0.01 sievert).

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.

RfD
[See reference dose.]

Risk
The probability that something will cause injury or harm.

Route of exposure
The way people come into contact with a hazardous substance. Three *routes of exposure* are breathing [inhalation], eating or drinking [ingestion], and contact with the skin [dermal contact].

Safety factor
[See uncertainty factor.]

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.

Screening index
A calculated probability of developing cancer.

Sievert (Sv)
The SI unit of any of the quantities expressed as dose equivalent. The dose equivalent in sieverts is equal to the absorbed dose, in gray, multiplied by the quality factor (1 sievert equals 100 rem).

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, gender, or behaviors (for example, cigarette smoking). Children, pregnant women, and older people are often considered *special populations.*

Specific activity
Radioactivity per unit mass of material containing a radionuclide, expressed, for example, as Ci/gram or Bq/gram.

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.

Surface water
Water on the surface of the earth, such as in lakes, rivers, streams, ponds, and springs [compare with groundwater].

Surveillance
[See epidemiologic 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.

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.

Uncertainty factor
A mathematical adjustment for reasons of safety when knowledge is incomplete—for example, a factor 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].

Units, radiological

Units	*Equivalents*
Becquerel* (Bq)	1 disintegration per second = 2.7×10^{-11} Ci
Curie (Ci)	3.7×10^{10} disintegrations per second = 3.7×10^{10} Bq
Gray* (Gy)	1 J/kg = 100 rad
Rad (rad)	100 erg/g = 0.01 Gy
Rem (rem)	0.01 sievert
Sievert* (Sv)	100 rem

*International Units, designated (Systeme International [SI])

Urgent public health hazard
A category used in ATSDR's public health assessments for sites where short-term exposures (less than 1 year) to hazardous substances or conditions could result in harmful health effects that require rapid intervention.

Watershed
A watershed is a region of land that is crisscrossed by smaller waterways that drain into a larger body of water.

Other Glossaries and Dictionaries

Environmental Protection Agency http://www.epa.gov/OCEPAterms/
National Center for Environmental Health (CDC) http://www.cdc.gov/nceh
National Library of Medicine http://www.nlm.nih.gov/medlineplus/mplusdictionary.html

Appendix B. Detailed Remedial Activities Related to the Study Area

Bethel Valley Watershed

The major operations at X-10 take place within the Bethel Valley Watershed. The main plant, key research facilities, primary administrative offices, as well as various forms of waste sites, are situated in Bethel Valley. Over the past 60 years, X-10 releases have contaminated the Bethel Valley Watershed. Mobile contaminants primarily leave the Bethel Valley Watershed via White Oak Creek. These contaminants travel from the Bethel Valley Watershed to the Melton Valley Watershed, where further contaminants enter White Oak Creek. Then, the contaminants that have been discharged to White Oak Creek are released over White Oak Dam and into the Clinch River (USDOE 2001b). The main remedial activities conducted in Bethel Valley are listed below. Please see Figure 10 in Section II.C.1. for a map of Bethel Valley that includes these areas.

- *Corehole 8 Plume*. The Corehole 8 Plume, which was identified at X-10 in 1991, is a plume of groundwater contaminated with Sr 90 (SAIC 2002; USEPA 2002a). In 1994, a remedial action assessment revealed that contaminated groundwater was leaching into X-10's storm drain system and was being released into First Creek. First Creek is a stream that feeds into White Oak Creek and ultimately flows into the Clinch River. Additional evaluation indicated that the contaminated groundwater was seeping into the storm drain system via three catch basins on the western portion of X-10 (SAIC 2002). In November 1994, an action memorandum was approved; by March 1995, a groundwater collection and transmission system at the Corehole 8 Plume prevented groundwater infiltration (SAIC 2002; USEPA 2002a). Through this system, groundwater is treated by X-10's Process Waste Treatment Plant (PWTP) and then released through a National Pollutant Discharge Elimination System (NPDES) outfall. In August 1995, DOE prepared a removal action report that required monthly monitoring of the storm drain outfall close to the joining of First Creek and the Northwest Tributary.

  See Figures 3 and 10 for the location of First Creek and the Northwest Tributary. In addition, based on suggestions from the 1997 remediation effectiveness report (RER), monthly composite samples are taken at this area, as well as at the Corehole 8 sump (SAIC 2002).

  Surface water monitoring in October 1997 revealed elevated levels of Sr 90 and uranium 233 (U 233) in First Creek. In December 1997, further investigation indicated that this contamination was entering the area through two unlined storm drain manholes. As a result, in March 1998, DOE established another interceptor trench that linked to one of the plume's collection sumps. An addendum to the original action memorandum was approved in September 1999. This addendum, which was intended to increase the effectiveness of the initial remedial action, endorsed more groundwater extraction and treatment activities at the

Corehole 8 Plume (SAIC 2002). Composite samples are collected monthly at the First Creek Weir, located above First Creek's confluence with the Northwest Tributary, and at the Corehole 8 sump (SAIC 2004). From spring 1995 through fiscal year 2004, the groundwater collection and transmission system reduced fluxes of Sr 90 within First Creek by more than 80% (SAIC 2005).

- *Gunite and Associated Tanks (GAAT)*. The GAAT are eight underground gunite tanks that were installed at the X-10 site in 1943 and were the primary holding tanks for LLLW at X-10 (SAIC 2002; USDOE 2001c). These inactive tanks are located in two tank farms—the North Tank Farm and the South Tank Farm—that are located in the middle of X-10's central plant area. The North Tank Farm consists of Tanks W-3 and W-4, and the South Tank Farm consists of Tanks W-5 through W-10 (USDOE 2001c). The majority of mixed waste was removed from the GAAT in the 1980s. However, following these removal actions, waste still remained in the tanks (SAIC 2002; USDOE 2001c).

  In September 1997, an Interim Record of Decision (IROD) was signed (SAIC 2002; USDOE 2001c). DOE identified the GAAT cleanup as a priority because of the amount of radiation associated with the tanks, the decaying composition of the tanks, and the considerable risk to X-10 workers and to the environment if a tank leaked or collapsed (USDOE 2001c). The interim action transferred approximately 87,000 gallons of transuranic mixed waste sludge from the GAAT to the Melton Valley Storage Tanks (MVST). The transferred waste was to be treated in the MVST and then shipped to DOE's Waste Isolation Pilot Plant in New Mexico for disposal. This interim action, which removed more than 78,000 curies of waste from the tanks (95% of the contamination), was completed in September 2000. The empty tanks were left in place and grouted (i.e., sealing off the flow of contaminants by pumping cement grout or chemicals into drill holes) in 2001; the remedial action report was approved in October 2001 (SAIC 2002, 2005; USDOE 2001c).

- *Inactive LLLW tanks*. The inactive LLLW tanks are situated in Bethel Valley, within the central plant area of X-10. In April 1999, an Engineering Evaluation/Cost Analysis (EE/CA) suggested removal of these steel tanks, but that a time-critical action was not necessary. In an action memorandum in May 1999, this EE/CA recommendation was approved. The action memorandum focused on 11 tanks holding sludge and residue that presented a risk to public health. The removal operations included the following:

  - extracting the liquid and solid waste from the tanks;
  - moving waste that was not within the waste acceptance criteria (WAC) to suitable treatment facilities;
  - moving liquid waste that was within the WAC to the X-10 LLLW system and moving solid waste to the X-10 solid waste storage facility;
  - isolating vents, piping, and support connections;
  - filling tanks with grout for stabilization;
  - extracting tanks if appropriate storage and removal facilities were available; and
  - using soil to cover unmoved tanks and to fill excavated areas (SAIC 2002).

  In September 1999, an addendum to this action memorandum added 13 tanks to the original removal action (for a total of 24 tanks), but required the same remedial activities as those specified for the initial 11 tanks. The two-phase removal action was finished in September

2001. Once the tanks were emptied, they were filled with grout and stabilized (SAIC 2002, 2005). In October 2001, a removal action report was approved for the first phase of the removal action. As of fiscal year 2005, the action report for the second removal phase was still awaiting final approval. No monitoring activities are required for the stabilized tanks (SAIC 2005).

- *Surface Impoundments Operable Unit*. This OU consists of four impoundments—Impoundments A, B, C, and D—located in the south–central part of the X-10 site (SAIC 2002, USDOE 2005). The impoundments were used to hold liquid low-level radioactive wastes, byproducts of material processing and various experiments at X-10. Impoundments A and B were unlined; Impoundments C and D were lined with clay. Consequently, Impoundments A and B contained a total of 4,560 cubic yards of radioactive-contaminated sediments, whereas Impoundments C and D contained a total of only 40 cubic yards of low-level, radioactive-contaminated sediments (SAIC 2002). A Record of Decision signed in September 1997 outlined the necessary remedial actions for the surface impoundments. A two-phase remedial alternative took place at this OU, with the initial remedial action phase conducted from August to September 1998. During this time, more sediment samples were collected at Impoundments C and D, and sediment, soil, and water were removed from the impoundments (C and D) and placed into Impoundment B. Following the removal, fresh soil was placed into the excavated areas (SAIC 2002). In April 1999, the remedial action report was approved for the initial remedial phase of Impoundments C and D (SAIC 2002, 2005).

  During the next phase, sediment from Impoundment A was moved to Impoundment B, and the excavated area was filled with new soil (SAIC 2002). The sediment in Impoundment B, which contained sediment from all four impoundments, was pumped to an on-site treatment facility, mixed with cement, and placed into a proper shipping container for disposal. In November and December 2002, about 10% of the solidified waste was transported off site for disposal. In spring and summer 2003, the remaining solidified waste was transported to the on-site Environmental Management Waste Management Facility (EMWMF) for disposal. After the sediments were removed, rock and flowable fill were placed into Impoundment B. In May 2004, the remedial action report for Impoundments A and B was approved. No monitoring or institutional controls are required (SAIC 2005).

- *Record of Decision (ROD)*. In May 2002, a ROD was signed to address several interim remedial actions in Bethel Valley. For environmental restoration purposes, Bethel Valley was divided into the following four areas: Central Bethel Valley, East Bethel Valley, West Bethel Valley, and Raccoon Creek. Various remedial activities, such as removal, containment, monitoring, treatment, stabilization, and land use controls, will be implemented under this ROD to address contaminated media, inactive units, and accessible contamination sources. The following will be addressed: underground LLLW tanks, contaminated buildings, decontaminating and decommissioning (D&D) buildings, accessible underground and LLLW transfer pipelines, buried waste, contaminated surface and subsurface soil that is accessible, and contaminated groundwater, sediment, and surface water (SAIC 2004).

  As of fiscal year 2004, three projects had begun under the Bethel Valley ROD: the Bethel Valley Groundwater Engineering Study; the T-1, T-2, and HFIR tank remediation; and the Hot Storage Garden remediation. In fiscal year 2004, the majority of fieldwork projects necessary for the Bethel Valley Groundwater Engineering Study were completed. The projects included installing 235 soil push probes and 199 soil gas sample receptors, and conducting groundwater, storm sewer, surface water, outfall, and process waste system sampling. In fiscal year 2005, an estimated 15 groundwater wells and 48 additional soil push probes will be installed (SAIC 2005).

The HFIR tank at the X-10 site holds radioactive resin and sludge containing transuranic elements, while two inactive underground storage tanks—T-1 and T-2—hold a mixture of transuranic ion-exchange sludge and resin. Grout will stabilize and keep the HFIR tank waste in place. The T-1 and T-2 tank wastes were mixed, and the remaining slurry moved to the X-10 site's LLLW system. Ultimately, the transferred slurry will be solidified at the TRU Waste Processing Facility before off-site disposal at the DOE Waste Isolation Pilot Plant in New Mexico. In January 2004, a remedial design report/remedial action work plan was approved. All three tanks will be filled with grout and subsequently closed. The schedule for completion is fiscal year 2005 (SAIC 2005).

The Hot Storage Garden, also known as Building 3597, lies in the central plant area of the X-10 site. Radioactive material was historically stored in the building. As a result, traces of radioactive material remain in the facility's old storage wells. Activities at 5 of the 14 wells have been completed. Remedial activities are expected to continue in fiscal year 2005. Due, however, to residual contamination at the facility, the remaining wells will be sealed until initiation of final cleanup efforts, scheduled for 2009 (SAIC 2005).

Melton Valley Watershed

X-10 disposed of its radioactive wastes (liquid and solid) in Melton Valley, and also operated its experimental facilities within this watershed (USDOE 2002a, 2002b). Discharges from Melton Valley's waste areas have produced secondary contamination sources that include sediment, groundwater, and soil contamination. Furthermore, contaminants that are discharged from Melton Valley travel off the reservation through surface water and flow into the Clinch River (SAIC 2002). As a result, the waste sites in the Melton Valley Watershed "…are the primary contributors to off-site spread of contaminants" from the ORR (USDOE 2002b).

The main remedial activities conducted in Melton Valley are detailed below (SAIC 2002; USDOE 2001d; USEPA 2002a). Please see Figure 12 in Section II.C.2. for a map of Melton Valley that includes these areas. Also, please refer to Figure B-1 for the details concerning the completed, current, and future remediation activities in Melton Valley and see Figure B-2 for the Melton Valley projected closure schedule for the current and future activities (USDOE 2003b). The current schedule was accelerated by 9 years to have all closure activities completed by September 2006 (SAIC 2005; USDOE 2003b).

- *Cesium Plots Research Facility*. This facility is located next to and within 50 yards of the Clinch River (SAIC 2002; USEPA 2002a). Eight "experimental" plots were created at X-10's Waste Area Grouping (WAG) 13 to study the fallout from nuclear weapons. Four of these plots were filled with Cs 137. In July 1992, an interim remedial investigation was conducted. This study found that the gamma radiation levels released from the plots were elevated, and that the plots presented a possible threat to public health and to the environment. In October 1992, the IROD was approved (SAIC 2002). Remedial actions were conducted and finished in July 1994 (SAIC 2002; USEPA 2002a). The main aspects of the interim action were

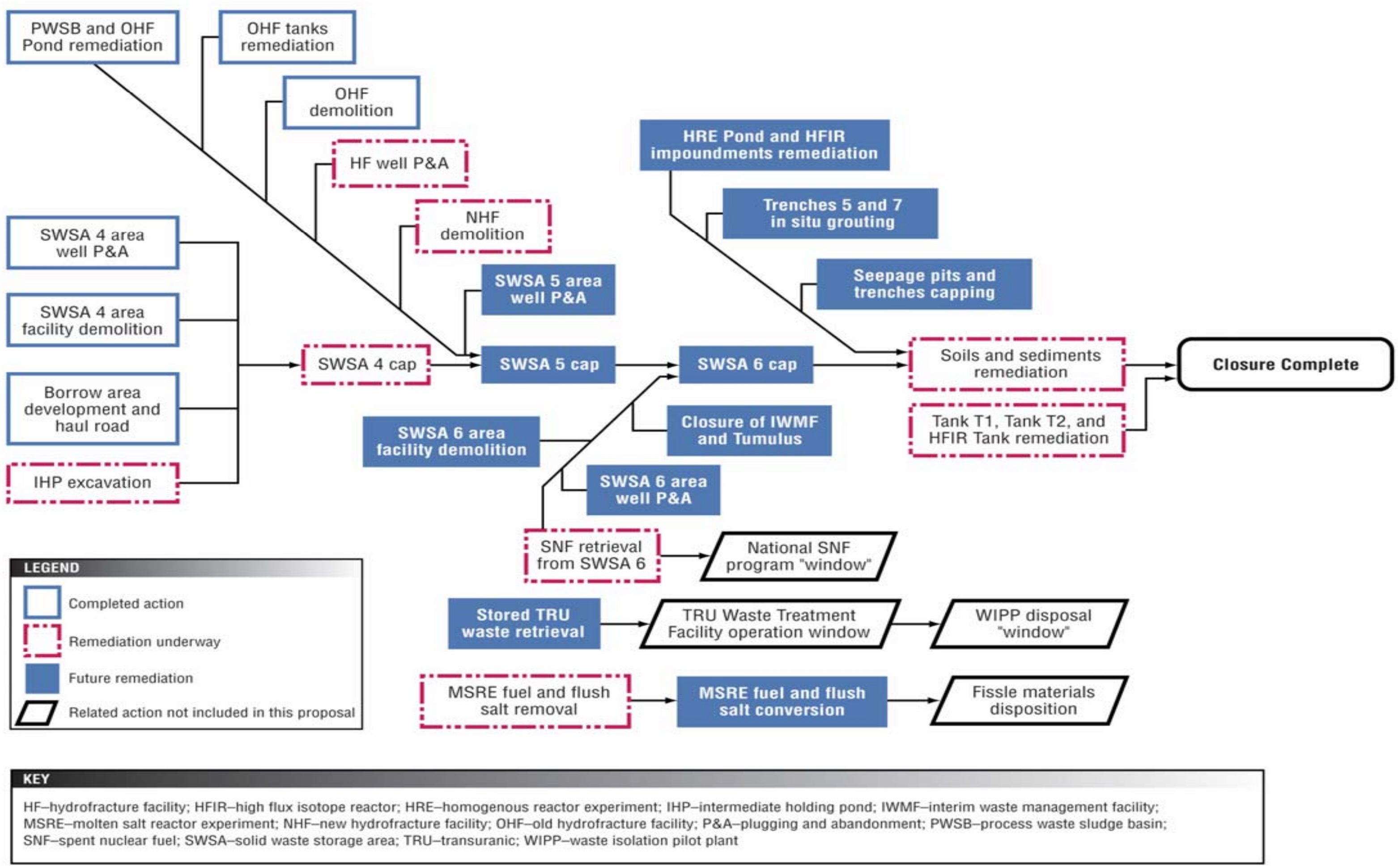
  - excavating soil until contamination was reduced to permissible levels;
  - placing extracted soil into boxes made to store low-level radioactive waste;
  - moving the soil to the low-level waste silos at WAG 6; and
  - placing a porous liner, clean fill material, and a clean top layer of soil over each excavated plot.

  Since the interim action, a fence with many locked gates has enclosed WAG 13. Several signs are posted to notify people that there is on-site soil contamination and restricted access to the site. In addition, the site undergoes surveillance and maintenance inspections on a quarterly basis (e.g., inspecting gates and fences to ensure they are secure) (SAIC 2002, 2005).

- *White Oak Creek Embayment (WOCE)*. From the X-10 site, White Oak Creek flows into White Oak Lake, over White Oak Dam, and into the WOCE before joining the Clinch River at Clinch River Mile (CRM) 20.8 (ChemRisk 1993b, 1999a; TDOH 2000; USDOE 2002a). Thus, the WOCE represents a hydrologic connection between the White Oak Dam and the Clinch River (USDOE 1996c). In 1991, a time-critical removal action was conducted at the WOCE. This action was performed because site-related data suggested that the embayment represented an "uncontrolled" source of sediment-binding substances, including Cs 137 and other contaminants (SAIC 2002).

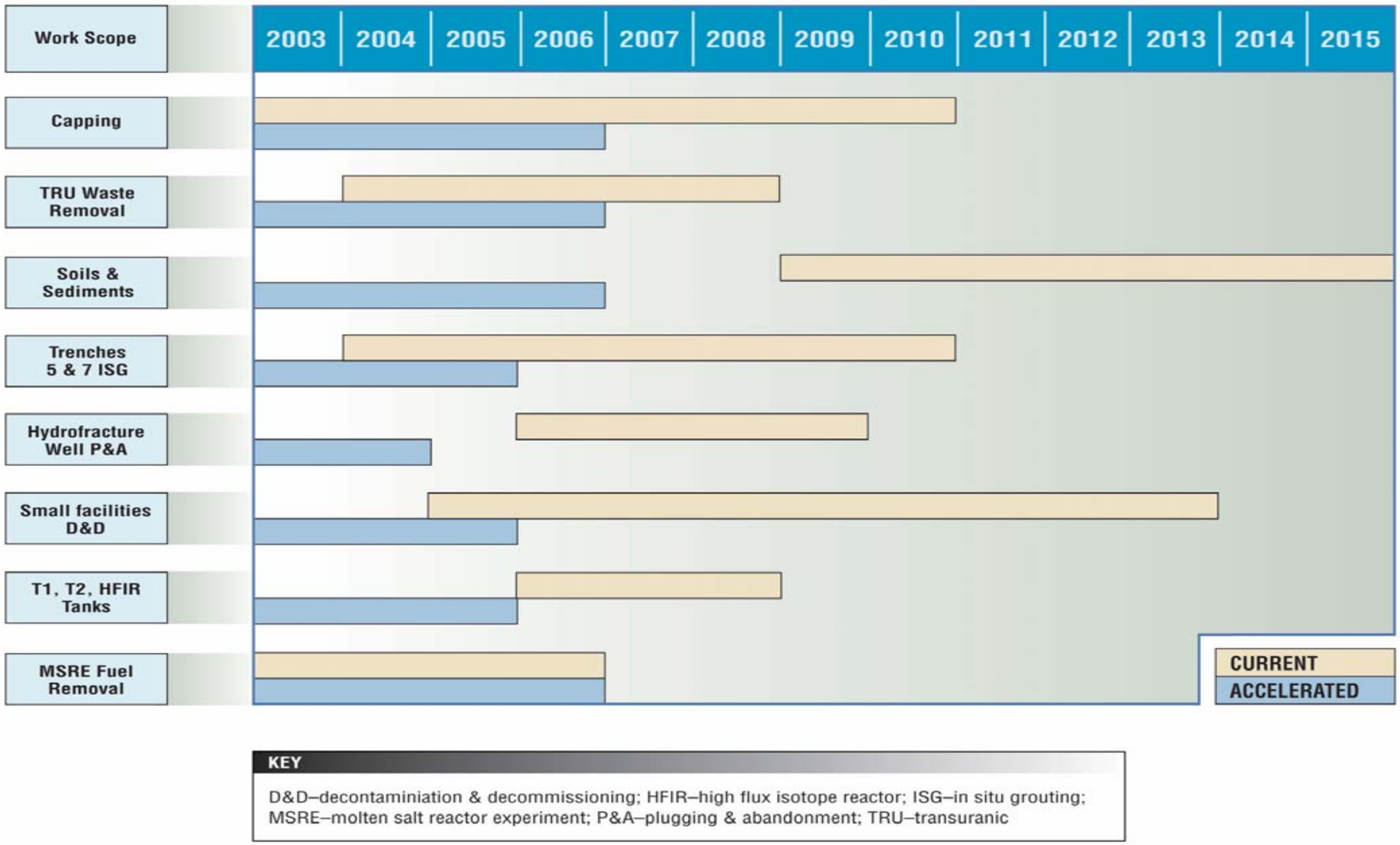
  Between June 1991 and April 1992, a removal action was conducted at the site. This action consisted of building a sediment retention structure (SRS) at the mouth of White Oak Creek to retain the sediments in the lower embayment and reduce the off-site movement of sediments to the Watts Bar Reservoir and to the Clinch River (SAIC 2002; USEPA 2002a). In 2001, the RER suggested the discontinuation of regular water level monitoring in the WOCE and in the Clinch River. This suggestion, which was implemented in fiscal year 2002, was based on about 10 years of information showing that the SRS could sustain sediment water coverage and prevent scouring of the WOCE (SAIC 2002, 2005). Though regular water level monitoring has ceased, monthly inspections of the SRS (e.g., checking warning signs, assessing if excessive debris has built up, and visually inspecting for indications of the dam shifting) continue to take place (SAIC 2005).

Figure B-1. Completed, Current, and Future Remedial Activities in Melton Valley



Source: Adapted from USDOE 2003b

Figure B-2. Melton Valley Closure Schedule



Source: USDOE 2003b
Note: The current Melton Valley closure schedule was accelerated by 9 years to have all closure activities completed by fiscal year 2006.

- *WAG 4*. The WAG 4 seeps area is located at the X-10 site (USDOE 2001e). Data collected at the ORR suggest that releases from WAG 4 have contributed to approximately 25% of the overall Sr 90 that is discharged over White Oak Dam (SAIC 2002). As a result, an action memorandum was prepared in February 1996, and DOE conducted an investigation to identify the X-10 sources that discharged Sr 90 (SAIC 2002; USDOE 2001e). The main contamination source of WAG 4 was found to be SWSA 4, which consists of 23 acres that were used between 1951 and 1974 for industrial and radioactive waste burial (SAIC 2002).

  DOE's investigation revealed that two seeps produced about 70% of the overall Sr 90 that was discharged from WAG 4 (SAIC 2002; USDOE 2001e). Because contaminants from these waste trenches migrated into White Oak Creek, grouting techniques were used to reduce the releases of Sr 90 from these trenches; these activities were completed in October 1996. The removal action report, completed in January 1997, identified five monitoring locations at WAG 4 (SAIC 2002; USEPA 2002a). For 5 years, monthly sampling was conducted at these monitoring stations, and as of 2001, the Sr 90 releases had been reduced by about 33% (SAIC 2002). Monitoring was, however, discontinued; it was superseded by a capping project conducted at SWSA 4 under the Melton Valley ROD (SAIC 2005).

- *WAG 5—Seeps C and D*. In 1994, DOE conducted an assessment and remedial activities at WAG 5 Seeps C and D. The assessment found that Sr 90 was discharged from the X-10 site, and that Seeps C and D were major sources of off-site releases. Seeps C and D are located in the southern portion of WAG 5, which consists of a burial site used for radioactive waste disposal between 1951 and 1959 (SAIC 2002; USDOE 2001f). Since Sr 90 constitutes a significant threat to off-site populations, one of DOE's main goals was to minimize these discharges from WAG 5 into the White Oak Creek system (SAIC 2002; USDOE 2001f; USEPA 2002a). The objective of these remedial activities was to reduce the quantity of Sr 90 in collected groundwater by at least 90% (SAIC 2002; USDOE 2001f).

  - *Seep C*. DOE's investigation in 1994 showed that Seep C was a major source of Sr 90 releases to White Oak Creek (SAIC 2002). Of the strontium detected at White Oak Dam between 1993 and 1994, 20% to 30% was released from Seep C. In March 1994, an action memorandum was approved, and by November 1994, a so-called French drain had been installed at Seep C. The French drain collects the groundwater and directs it to a unit for treatment; this treatment unit consists of drums filled with minerals that filter the Sr 90. Once the groundwater is treated, it is released into Melton Branch. Thus, the primary goal of these remediation activities is to lower the amount of Sr 90 released to Melton Branch and hence to off-site locations (SAIC 2002; USDOE 2001f).

    According to samples taken in 2000 and 2001, the treatment unit has prevented over 99% of the Sr 90 at Seep C from entering Melton Branch (SAIC 2002). The amount of Sr 90 is greater downstream from Seep C than upstream, which suggests that a portion of the Sr 90 from WAG 5 bypasses the treatment unit (SAIC 2002; USDOE 2001f). In 2002, bimonthly sampling and weekly inspections of the treatment unit at Seep C continued to occur (SAIC 2002). Environmental monitoring of the unit was, however, discontinued in September 2003, and the unit was shut down in fiscal year 2004 (SAIC 2004, 2005).

During its operation, the treatment unit at Seep C probably prevented as much as 3 curies of Sr 90 from being released into the Clinch River system (SAIC 2005).

- *Seep D*. DOE's investigation in 1994 revealed that Seep D was also a major source of Sr 90 to the White Oak Creek watershed (SAIC 2002). Of the Sr 90 detected at White Oak Dam between 1993 and 1994, approximately 7% was released from Seep D. In July 1994 an action memorandum was approved, and by November 1994 a groundwater treatment unit was installed and functioning at Seep D. The treatment unit collects groundwater from the bed of Melton Branch and pumps it through a group of mineral-filled columns that filter out Sr 90. Once the groundwater has been treated, it is restored to Melton Branch. Thus, the primary goal of these remediation activities is to decrease the quantity of Sr 90 that is discharged to Melton Branch, and therefore to off-site areas via White Oak Dam (SAIC 2002; USDOE 2001f).

  Data collected in 2000 and 2001 showed that this treatment unit has prevented over 99% of the Sr 90 at Seep D from entering Melton Branch (SAIC 2002). However, the amount of Sr 90 is greater downstream at Seep D than upstream. This suggests that small quantities of Sr 90 going into Melton Branch did not originate from the Seep D pumping location (SAIC 2002; USDOE 2001f). Daily inspections are conducted at Seep D and monthly sampling is performed on the treatment unit, as well as upstream and downstream of Melton Branch (SAIC 2002). In addition, as of fiscal year 2004, stream samples were being collected to identify the entry point of Sr 90 into the stream (SAIC 2004). After the first quarter of 2005, the collection system at Seep D will no longer operate. Remedial activities are not expected to include capping of the Seep D area. Nevertheless, the source of releases captured at the Seep D area will be isolated, and the releases will be piped and treated at a new water treatment plant (SAIC 2005).

- *Old Hydrofracture Facility (OHF) Tanks*. The OHF is located at the Oak Ridge National Laboratory within Melton Valley (SAIC 2002; USDOE 2002c). In 1963, this facility was built for low-level radioactive waste disposal (USDOE 2002c). From 1963 to 1980, the radioactive waste was combined with grout and then injected 1,000 feet below ground by hydraulically fracturing a shale layer and pumping the grouted waste into a thin layer that extended over many acres. The grout would then harden and become a part of the shale formation (SAIC 2002; USDOE 2002c). Five LLLW underground storage tanks were left at the OHF that contained an approximate total of 52,600 gallons (30,000 curies) of radioactive waste and other byproduct waste (e.g., sludge) (SAIC 2002; USDOE 2002c; USEPA 2002a). Because of concerns about the proximity of the tanks to White Oak Creek, the potential threat to environmental receptors, and the possibility of tank leakage, a September 1996 action memorandum authorized the movement and treatment of the tank waste. From June to July 1998, more than 98% of the waste was moved through a pipeline to the MVST, where additional treatment will occur (SAIC 2002; USDOE 2002c).

  In May 1999, another OHF-related action memorandum focused on tank stabilization and on the surface impoundment sediments associated with the OHF. The tank stabilization activities identified in the memorandum included removing the piping system, placing submersible pumps into the tanks, using mixer spool pieces, and grouting the tanks. For the surface impoundment, the remedial activities consisted of applying grout for sediment stabilization, placing grout into standpipes, removing excess water, treating any excess water at the PWTP, and using filler material to replenish the impoundment (SAIC 2002). Upon completion of these remedial activities, a May 2001 removal action report was released (SAIC 2002; USEPA 2002a). Under the Melton Valley ROD, the OHF site will be covered by the SWSA 5 cap (SAIC 2005).

- *Record of Decision*. In September 2000, a ROD was signed to address several remedial actions in Melton Valley. These actions focus on

  - remediating contaminated structures,
  - significant waste threats,
  - contaminated media, and
  - other main sources of contamination (SAIC 2002, 2005).

  In 2004, the ROD was amended to change the proposed treatment remedy at trenches 5 and 7 from *in situ* vitrification (ISV) to *in situ* grouting (ISG).[17]

  The Melton Valley ROD remedial activities and their status as of fiscal year 2005 are presented below (ORNL et al. 2004, 2005; SAIC 2002, 2004, 2005; USDOE 2004a, 2004b). Please see Figure 8 for the locations of these areas at X-10 and Figure B-2 for the completion schedule for these activities in Melton Valley.

  - Placing multi-layered caps over SWSA 4, SWSA 5 North (the upper four trenches, also referred to as the SWSA 5 North four-trench area), SWSA 5 South, SWSA 6, and sections of the seepage pits and trenches area (Pits 1, 2, 3, and 4; Trench 6). As of fiscal year 2005, cap construction activities were finished at SWSA 4; Pits 1, 2, 3, and 4; Trench 6; and SWSA 5 North four-trench area. In addition, construction had started on the SWSA 5 South cap and tree clearing and cap construction had begun at SWSA 6.
  - Using hydrologic isolation to prevent contaminant migration from the burial grounds (SWSAs 4, 5, and 6) and sections of the seepage pits and trenches area (Pits 1, 2, 3, and 4; Trench 6). When needed, trenches will be used to divert upgradient surface water and stormflow and to intercept downgradient contaminated groundwater. Activities to isolate hydraulically SWSA 4 and Pit 1 began in 2003 and were completed in fiscal year 2005. In 2004, construction of downgradient groundwater interception trenches was finished at SWSA 5 South and at Pits 2, 3, and 4. Remaining hydrologic isolation activities are scheduled for completion in 2006.

[17] *In situ* vitrification (ISV) is a process that applies electrical power to contaminated soil to produce the heat needed to melt and blend the soil and waste into an immobile form (USDOE 1995b). DOE determined, however, that ISV could be problematic because of standing water in the trenches and higher than anticipated expenses related to the process. Thus, in May 2004, DOE issued a proposed plan to amend the Record of Decision by replacing ISV with *in situ* grouting (ISG). ISG involves a low-pressure grouting method to inject Portland cement-based grout throughout the trenches. In addition, a solution grout would be used to treat soil adjacent to the trench walls to close potential seepage pathways (ORSSAB 2004). In September 2004, the proposed requirement for the Record of Decision and the remedial action work plan for ISG of the trenches were approved (ORNL 2005).

- Discarding contaminated soils from 22 trenches in SWSA 5 North, also referred to as the 22-Trench Area. Fieldwork began in fiscal year 2004 and is scheduled for completion in fiscal year 2006.
- Removing contaminated soils and backfill from the homogeneous reactor experiment (HRE) pond. Excavation activities began at the end of fiscal year 2004 and were ongoing as of fiscal year 2005.
- Removing contaminated sediment from the high flux isotope reactor (HFIR) ponds. Excavation activities started in summer 2004 and were mostly completed as of fiscal year 2005.
- Grouting the HRE fuel wells. As of fiscal year 2005, fieldwork was at or near completion.
- Stabilizing, isolating, and removing inactive waste pipelines (as needed). As of fiscal year 2005, planning and construction startup had commenced.
- Using ISG for seepage trench 5 (an estimated 300-foot-long trench containing about 138,000 curies of waste) and trench 7 (an estimated 200-foot-long trench containing about 122,000 curies of waste). As of fiscal year 2005, the trenches had been excavated to depths of 15 to 16 feet and an estimated 10-foot-thick crushed limestone layer was put into the trenches to facilitate percolation. Backfill soil was used to cover the remaining excavated area of the trenches. ISG is scheduled for fiscal year 2005.
- Removing the Intermediate Holding Pond and additional floodplain soil that was contaminated (exposure levels above 2,500 microroentgen per hour [µR/hr]). The remedial action was conducted from June to October 2002. Approximately 24,300 tons of contaminated soil were excavated from the pond and disposed of at the ORR's EMWMF. As of fiscal year 2005, remedial activities to restore the IHP to a wetland area were ongoing.
- Isolating and removing contaminated soils at leak and spill locations, as well as additional locations, if the soils exceeded remedial limits. In fiscal year 2003, planning was initiated for seven additional excavation sites and final planning for the remainder of contaminated soils was in progress. In fiscal year 2004, a remedial design report/remedial action work plan was submitted for the seven additional excavation sites. Once these soils have been removed, they will be disposed of at the ORR's EMWMF or at another approved facility.
- Plugging and abandonment (P&A) of unnecessary wells. From May 2001 through August 2003, a total of 110 of 111 hydrofracture wells were plugged and abandoned. The P&A of one remaining hydrofracture well—the HF-4 injection well at the New Hydrofracture Facility (NHF)—will be completed by the end of fiscal year 2005. P&A of all shallow nonhydrofracture wells (estimated total of 800 wells) was completed as of fiscal year 2005.
- Decontaminating and decommissioning (D&D) buildings. Several D&D activities occurred from fiscal year 2002 to 2004, including D&D activities at the OHF and many small facilities in Melton Valley. D&D activities at the NHF are scheduled for completion in fiscal year 2005. Upcoming D&D activities include various facilities,

such as ancillary buildings for the HRE, LLLW pumping stations, and miscellaneous buildings.

- Conducting groundwater, ecological, and surface water monitoring. A watershed monitoring plan for groundwater and surface water was completed in fiscal year 2002, and implementation of the plan commenced in fiscal year 2003. A first draft of the Melton Valley Ecological Study was submitted in fiscal year 2003 and a second draft in fiscal year 2004.
- Implementing land use controls as appropriate.

Appendix C. Summary of Other Public Health Activities

Summary of ATSDR Activities

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 if exposure to metals was related to these patients' various illnesses. ATSDR determined that the case data did not provide sufficient evidence to support an association between these diseases and low levels of metals. The TDOH, which also evaluated the information, reached the same conclusion as did ATSDR. In September 1992, ATSDR provided a copy of its review to Dr. Reid (ATSDR et al. 2000).

Clinical laboratory analysis. In June 1992, William Reid, M.D., an Oak Ridge physician, notified the ORHASP and the TDOH that he believed that about 60 of his patients had been exposed to numerous heavy metals through their occupations or through the environment. Dr. Reid believed that these exposures had caused a number of adverse health outcomes, which included immunosuppression, increased cancer incidence, neurologic diseases, bone marrow damage, chronic fatigue syndrome, autoimmune disease, and abnormal blood clots. Howard Frumkin, M.D., Dr.PH., from the Emory University School of Public Health, requested facilitated 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). Nevertheless, in an April 26, 1995, letter to the Commissioner of the Tennessee Department of Health, Dr. Frumkin suggested 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."

Health education. Another essential part of the public health assessment process is designing and implementing activities that promote health and providing 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 impacts 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 patients' 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 in 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 in 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 EEWG (formerly known as 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 titled *Cancer Mortality Near Oak Ridge, Tennessee* (International Journal of Health Services, Volume 24:3, 1994, page 521). Based on the EEWG critique, the ORRHES made the following conclusions and recommendations to ATSDR.

    1. The Mangano paper is not an adequate, science-based explanation of any alleged anomalies in cancer mortality rates of the off-site public.
    2. 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 general public.
    3. 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 efforts led to the establishment of the Public Health Working Group in 1999, which then led to the establishment 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 individuals regarding the creation of a public health forum. After careful consideration of the input gathered from community members, ATSDR and CDC determined that the most appropriate way to meet the needs of the community would be to establish the ORRHES.

Exposure investigations, health consultations, and other scientific evaluations. In addition to the Watts Bar Reservoir, ATSDR health scientists have addressed current public health issues and community health concerns related to other areas affected by ORR operations.

Following are summaries of other ATSDR public health activities involving EFPC:

- *Health consultation on Y-12 Weapons Plant chemical releases into East Fork Poplar Creek, April 1993*. As a result of community concerns, ATSDR conducted this health consultation to examine the potential health effects that could result from exposure to contaminants discharged into EFPC from the Y-12 plant (past and present). The Phase IA data assessed for this consultation suggest that the sediment, surface water, soil, fish, groundwater, and air in EFPC are contaminated with various chemicals. However, the only levels of public health concern are PCBs and mercury detected in fish, and mercury detected in soil and sediment. Based on these data, ATSDR made the following conclusions.

    1. Sediments and soil in specific areas along the EFPC floodplain are contaminated with mercury levels that present a public health concern.

2. Fish in EFPC have mercury and PCB levels that present a moderately increased risk of adverse health effects for people who consume fish regularly over extended time periods.
3. Shallow groundwater along the EFPC floodplain has metals that are at levels of public health concern; however, the shallow groundwater along EFPC is not utilized for drinking water or for other domestic purposes.
4. Other contaminants, including radionuclides found in soil, sediment, surface water, and fish, were not detected at levels of public health concern (ATSDR et al. 2000).

- *ATSDR science panel meeting on the bioavailability of mercury in soil, August 1995*. Based on 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., EPA), private consultants, and other individuals 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 regards 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 cleanup levels, January 1996*. Following a request from community members and the city of Oak Ridge, ATSDR prepared a health consultation to assess DOE's cleanup 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 would protect public health and would not present a health risk to adults or to children (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 ATSDR conduct an assessment of cancer incidence to evaluate cancer rates in these communities. For the assessment, 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: Anderson, Blount, Knox, Loudon, Meigs, Morgan, Rhea, and Roane Counties. To analyze the data and identify any increases in cancer incidence, ATSDR compared the number of observed cases in each of the eight counties to the expected number of cases in the state of Tennessee. The findings indicated that when compared to the cancer incidence rates in the state, in some of the counties both higher and lower rates of certain cancers appeared. But no consistent pattern of cancer occurrence was identified, and the reasons for the increases and decreases of cancer occurrence remain unknown. For more information, the assessment of cancer incidence (released for public comment in 2006) is available from http://www.atsdr.cdc.gov/HAC/oakridge/phact/cancer_oakridge/index.html.

Summary of U.S. Department of Health and Human Services Activities

U.S. Department of Health and Human Services' evaluation of data in an article from The Tennessean*, September 29, 1998.* In a November 2, 1998 letter, the Honorable William H. Frist, M.D., 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 article in *The Tennessean* describes 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 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, Donna E. Shalala, Secretary of DHHS, responded to Senator Frist's request. DHHS evaluated the article in *The Tennessean* and responded to Senator Frist's five specific issues. DHHS concluded the following:

1. The data in the article from *The Tennessean* 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, it is neither acceptable to tabulate data collected in an unstandardized manner, nor to assess illnesses and symptoms based on limited diagnostic information. Thus, it is not possible to determine if data in this report represent a new or unusual occurrence of symptoms in this population.
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. However, clinical data from the Fernald Medical Monitoring Program and the Scarboro, Tennessee, survey focus 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 is essential in order 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 findings 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 since historic exposures 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. However, where possible, 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 making environmental management decisions. CDC evaluated the methodology for this mercury level, and advised the TDOH to conduct a pilot survey to determine if 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. Further, 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. 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 that included immunosuppression, increased cancer incidence, neurologic diseases, bone marrow damage, chronic fatigue syndrome, autoimmune disease, and abnormal blood 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 to the state rates for Tennessee. The health statistics review determined that some of the counties' rates were low and some were high when compared to the state's rates; however, 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 that there were several community members who 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, TDOH determined that it was impossible to calculate reliable incidence rates for these diseases. 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.

- There were no significant differences in ALS mortality in any of the counties in comparison with the rest of the state.
- For Anderson County, the rate of age-adjusted deaths from chronic obstructive pulmonary disease (COPD) was significantly higher than rates in the rest of the state, but the rates for total deaths, deaths from stroke, deaths from congenital anomalies, and deaths from heart disease were significantly lower for 1980–1988. There were no significant differences in the rates of deaths due to cancer, for all sites, in comparison to rates for the rest of the state.

Rates of deaths from uterine and ovarian cancer were significantly higher than the rates in the rest of the state. The rate of death 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 1980–1988. 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. There was no significant difference in the total cancer death rate in comparison to the rest of the state.

- There were no significant exceedances for any cause of mortality studied in Knox, Loudon, Rhea, and Union Counties in comparison to the rest of the state.

- Rates of total deaths were significantly higher in Campbell, Claiborne, and Morgan Counties in comparison to the rest of the state.

- Cancer mortality was significantly higher in Campbell County in comparison to 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 to 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, attitudes, 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).

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. The surveyors attempted to elicit responses from the entire community, but achieved an 82% 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 Bureau of the Census. In addition, the assessment identified Scarboro's strengths and weaknesses, and illustrated the relative unimportance of environmental and health issues among residents in comparison to other community concerns. The assessment showed that environmental and health issues were not a priority among Scarboro residents, as the community was more concerned about crime, 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), along 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, conducted the analytical element of this study. These results were compared with findings from an October 1993 report by DOE, titled *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. However, about 10% of the soil samples indicated an enrichment of uranium 235. Alpha-chlordane, gamma-chlordane, heptachlor, and heptachlor epoxide exceeded the detection limits in one sample. 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 experienced high rates of respiratory illness, and that there were 16 children who repeatedly had "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 illnesses 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 of age. Both of these components (survey and exam) were essentially designed to measure the rates of common respiratory illnesses among Scarboro children, compare these rates to national rates for pediatric respiratory illnesses, and determine if 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 if the rates of specific diseases were higher in Scarboro when compared to the rest of the United States, and to determine if exposure to different factors increased the Scarboro residents' risk for 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 to 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, which was compared to 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).

After review of information obtained in the health investigation survey, 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 if the children with respiratory illnesses were receiving necessary medical care, and to confirm if 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. Out 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 see if any children required immediate intervention, but 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 to the parents of the children and their doctors by letter or telephone. 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 advised 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 during the examination. 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 not 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. Since some of the parents had more than one child who participated in the examination, the questions for the eight parents were applied to 14 children. Despite many attempts on different days, the parents of nine children could not be contacted by telephone (Johnson et al. 2000).

Out of the 14 children whose parents had been contacted, seven of the children had been to a doctor since the examinations. For the most part, the health of the children was about the same. However, since the examinations, one child had been in the hospital because of asthma and another child's asthma medication had been strengthened due to worsening asthma. 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, 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). 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 2003b).

  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 that there is not an elevation of chemical, metal, or radionuclides 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 2003b).

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 assessment according to the level of contaminants, and 3) determine if 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 the following: 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) re-filling the excavated areas with soil, and 5) providing a new vegetative cover over the excavated areas (ATSDR et al. 2000).

Appendix D. Summary Briefs

ORRHES Brief

Oak Ridge Reservation Health Effects Subcommittee

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

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. This 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), was 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 offsite 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 Barium-140 Cerium-144 Cesium-137 Cobalt-60 Iodine-129, -131, -133 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	Arsenic Beryllium Chromium (trivalent and hexavalent) Lead Mercury Nickel	Carbon tetrachloride Methylene chloride Polychlorinated biphenyls Tetrachloroethylene 1,1,1-Trichloroethane Trichloroethylene

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

ORRHES Brief

Oak Ridge Reservation Health Effects Subcommittee

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Reports of the Oak Ridge Dose Reconstruction, *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 (referred to as the Task 4)*

Site: Oak Ridge Reservation

Conducted by: ChemRisk/ORHASP for the Tennessee Department of Health

Time period: 1999

Location: Oak Ridge, Tennessee

Purpose

The purposes of Task 4 of the Oak Ridge Dose Reconstruction were (1) to estimate the historical radiological releases from the X-10 facility to the Clinch River, (2) to evaluate the potential pathways by which members of the public could have been exposed to radioactive effluents in the Clinch River between 1944 and 1991, and (3) to calculate radiation doses and risks to reference individuals who were potentially exposed to radioactivity released to the Clinch River from the X-10 facility. Direct measurement of the amounts of radionuclides taken up by the organs of specific individuals since 1944 was no longer feasible because most of these radionuclides do not stay in the human body for long periods of time. Therefore, a dose reconstruction was necessary to determine the magnitude and extent of past exposure and to interpret the health consequences of these exposures. This dose reconstruction relies upon independent evaluation of the amounts of radionuclides released, reported environmental measurements, and mathematical models to estimate the magnitude and extent of past exposures, doses, and health risks.

Background

Construction of the Oak Ridge National Laboratory (ORNL, which is also known as the "Clinton Laboratory" or "X-10 facility") began on February 10, 1943. The laboratory was built as a pilot plant for demonstrating the production and separation of plutonium. In 1944, the first radioactive effluents from the X-10 site entered White Oak Creek and flowed into White Oak Lake. White Oak Lake served as a settling basin for contaminants released to White Oak Creek. Radionuclides remaining in the water column were released from the X-10 site with the flow of water over White Oak Dam into the White Oak Creek Embayment, and then entered the Clinch River. The radionuclides in the surface water and sediments that traveled through the Clinch River eventually flowed into the Lower Watts Bar Reservoir.

During the early years of X-10 operations, the graphite reactor and the "hot pilot plant" (a chemical separation plant) were the major sources of radioactive wastes. Wastes from the "hot pilot plant" were placed into open waste pits; in 1959, high levels of ruthenium 106 (Ru 106) began seeping from the pits into White Oak Lake. Amounts of Ru 106 as high as 2,000 curries (7.4×10^{13} Bequerel [Bq])per year were released from White Oak Dam between 1959 and 1963. From 1944 to 1991, approximately 200,000 curies of radioactivity were released over White Oak Dam to the Clinch River; of this amount, 91% was tritium and the rest was mixed fission and activation products.

Evidence suggests that a secondary source of radionuclides released to the Clinch River was the scouring of contaminated sediment from White Oak Creek Embayment. After White Oak Lake was drained in 1955, heavy rainfall scoured the bottom sediment of White Oak Lake, resulting in the deposition of particle reactive radionuclides (primarily Cs 137) in White Oak Creek Embayment. The peaking discharges from Melton Hill Dam, which was completed in 1963, resulted in the backflow of water up White Oak Creek Embayment and the scouring of radionuclide-containing sediments into the Clinch River. A coffer cell dam was constructed at the mouth of White Oak Creek in the early 1990s to prevent the backflow of water up White Oak Creek Embayment, and scouring of embayment sediment ceased at that time.

Methods

The dose reconstruction relies on estimates and reported measurements of radionuclides released from White Oak Dam from 1944–1991. A detailed investigation was performed for (1) the methods used for measurements of radioactive releases from White Oak Dam, (2) the methods used for estimation of flow rates at White Oak Dam, and (3) the uncertainties associated with these measurements. Estimates that measured the amount of radionuclides historically released from White Oak Dam were based on laboratory documents, available log books, and interviews with personnel who were either responsible for or involved in the sampling and monitoring of radioactive releases at White Oak Dam. Direct measurements of the radionuclides released from White Oak Dam were available, except for the years 1944 to 1949. For these years, estimates were based on the fraction that each radionuclide contributed to a measurement or estimate of gross beta activity.

The Task 4 team conducted a screening analysis to select the radionuclides released to White Oak Creek and potential exposure pathways of most importance. Based on its screening, the Task 4 team concluded that 16 out of 24 radionuclides released to White Oak Creek did not need further evaluation because the estimated screening indices were below the minimal level of concern. Detailed source terms (annual release amounts) were developed for the following eight radionuclides deemed more likely to carry significant risks: Co 60, Sr 90, Nb 95, Zr 95, Ru 106, I 131, Cs 137, and Ce 144. The uncertainty of the amount released each year varied over time because of various changes in sampling and analytical methods as well as changes in waste disposal or treatment events.

Measured concentrations of radionuclides in water were available for many years for several locations downstream from the confluence of White Oak Creek and the Clinch River (Clinch River Mile [CRM] 20.8). These measurements were not entirely consistent as to location or method of measurement and did not include all of the radionuclides of concern. Therefore, a modeling effort was conducted to estimate the historical annual average concentrations of radionuclides in water at specific locations downstream of White Oak Creek.

Estimated shoreline concentrations of radionuclides in sediment were obtained to track the sediment inventory in various reaches of the Clinch River. Monitoring data collected in the 1990s were used to calibrate the shoreline sediment estimates.

Study Subjects

References individuals, or hypothetically exposed individuals, in this study were identified with respect to the pathways involved and the specific characteristics of the each of the five pathways. For the fish consumption pathway, reference individuals were defined in terms of fish consumption rate as Category I (1 to 2.5 meals per week), Category II (0.25 to 1.3 meals per week), or Category III (0.04 to 0.33 meals per week).

The evaluation also considered potential exposures for hypothetical individuals within five reference areas along the Clinch River.

These locations are CRM 21 to CRM 17 (Jones Island), CRM 17 to CRM 14 (Grassy Creek), CRM 14 to CRM 5 (K-25), CRM 5 to CRM 2 (Kingston Steam Plant), and CRM 2 to CRM 0 (city of Kingston).

Exposures

The following potential exposure pathways were evaluated: consumption of drinking water from the Clinch River, consumption of milk and beef, ingestion of fish caught from the Clinch River, and exposure to sediments along the shore of the Clinch River. Other pathways, such as swimming in the Clinch River, exposure to irrigation water from the Clinch River, and eating produce, were eliminated through the screening process because their estimated screening indices was below the level of minimal concern.

Outcome measure

Health outcomes were not studied.

Results

Ingestion of Fish: The estimated organ doses to individuals consuming fish exceeded the dose estimates for all other pathways. The organ doses depended on how often they ate fish and the area of the Clinch River where the fish were taken. The highest doses were for the maximum exposure scenario (Category I fish consumers) in which an individual ate 1 to 2.5 fish meals a week of fish caught at CRM 20.5 (just below the confluence of White Oak Creek and the Clinch River). Central values of the cumulative doses for 1944 to 1991 for specific organs ranged from 0.31 (skin) to 0.81 centisievert (cSv)(bone) for males and from 0.23 (skin) to 0.60 cSv (bone) for females. Estimated organ doses were lower for individuals who ate fewer fish (Category II and III fish consumers) or fished further downstream.

For Category I fish consumers near Jones Island (CRM 20.5), the 95% subjective confidence interval of the total excess lifetime risk of cancer incidence for all radionuclides and organs was 3.6×10^{-5} to 3.5×10^{-3} (central value, 2.8×10^{-4}) for males and 2.9×10^{-5} to 2.8×10^{-3} (central value, 2.3×10^{-4}) for females.

Other Exposure Pathways: Organ-specific doses from external exposure were about a factor of 1.1 to 3.5 lower than the doses to a Category I fish consumer at CRM 14, with the largest doses to skin, bone, and thyroid. For most organs, doses from drinking water at CRM 14 and CRM 3.5 were lower than the doses from external exposure at the same location. Estimated doses from ingestion of meat and milk were lower than those for ingestion of drinking water by 1 to 3 orders of magnitude. The highest doses were to the large intestine, bone, red bone marrow, and (for the ingestion of milk) the thyroid.

For the combined pathways at CRM 20.5, the upper bounds on the total excess lifetime risk were 3.6×10^{-3} for male consumers of fish in Category I.

Estimates of Thyroid Dose to a Child from the Drinking Water and Milk Ingestion Pathways: The 95% subjective confidence intervals for the estimated dose to a child 0 to 14 years of age drinking home-produced milk at CRM 14 or CRM 3.5 from 1946-1960 were 0.00058 to 0.054 cSv (0.0062 central value) and 0.00055 to 0.042 cSv (0.0044 central value), respectively.

The highest excess lifetime risk of thyroid cancer occurred for a female child ingesting milk obtained from an area near CRM 14 between 1946 and 1960 (95% confidence interval, 1.1×10^{-7} to 2.5×10^{-5}; central value, 1.8×10^{-6}).

Conclusions

The radiological doses and excess lifetime cancer risks estimated in this report were incremental increases above those resulting from exposure to background sources of radiation in the East Tennessee region. Nevertheless, for the exposure pathways considered in this task, the doses and risks were not large enough for a commensurate increase in health effects in the population to be detectable, even by the most thorough of epidemiological investigations. In most cases, the estimated organ doses were clearly below the limits of epidemiological detection (1 to 30 cSv) for radiation-induced health outcomes that were observed following irradiation of large cohorts of individuals exposed either *in utero,* as children, or as adults. Even in the case of Category I fish consumers, the upper confidence limits on the highest estimated organ-specific doses were below 10 cSv, and the central values were below 1 cSv. The lower confidence limits on these doses were well below limits considered for epidemiological detection in studies of cohorts of other exposed populations.

Even though this present dose reconstruction study identified increased individual risks up to 1×10^{-3} resulting from these exposures, it is unlikely that any observed trends in the incidence of disease in populations that used the Clinch River and Lower Watts Bar Reservoir after 1944 could be conclusively attributed to exposure to radionuclides released from the X-10 site.

ORRHES Brief

Oak Ridge Reservation Health Effects Subcommittee

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

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 comprised 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 Use classified	Air Surface Water	Inventory quantities and specific applications remain classified.
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 Use of copper powder is classified	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) <u>Evaluated qualitatively</u> (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) <u>Evaluated using Threshold Quantity Approach</u> (not enough material was present): • Niobium (noncancer) • TMAB • Zirconium (noncancer) <u>Evaluated qualitatively</u> (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)	

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.

ORRHES Brief
Oak Ridge Reservation Health Effects Subcommittee

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

Exposure Investigation, Serum PCB and Blood Mercury Levels in Consumers of Fish and Turtles from the Watts Bar Reservoir, March 5, 1998

Site: Oak Ridge Reservation
Conducted by: ATSDR
Time period: 1997
Study area: Watts Bar Reservoir

Purpose

The purpose of this exposure investigation was to determine whether people consuming moderate to large amounts of fish and turtles from the Watts Bar Reservoir were being exposed to elevated levels of polychlorinated biphenyls (PCBs) or mercury.

Background

Previous investigations of the Watts Bar Reservoir and Clinch River evaluated many contaminants, but identified only PCBs in reservoir fish as a possible contaminant of current health concern. The U.S. Department of Energy (DOE) and the Tennessee Department of Environment and Conservation (TDEC) detected PCBs at levels up to approximately 8 parts per million (ppm) in certain species of fish from the reservoir. PCBs were detected in turtles at levels up to 3.3 ppm in muscle tissue and up to 516 ppm in adipose tissue. Mercury is a historical contaminant of concern for the reservoir due to the large quantities released from the Oak Ridge Reservation. However, recent studies have not detected mercury at levels of health concern in surface water, sediments, or fish and turtles from the Watts Bar Reservoir.

The 1994 DOE remedial investigation for the Lower Watts Bar Reservoir and the 1996 DOE remedial investigation for Clinch River/Poplar Creek concluded that the fish ingestion pathway had the greatest potential for adverse human health effects. The Agency for Toxic Substance and Disease Registry's (ATSDR's) 1996 health consultation of the Lower Watts Bar Reservoir reached a similar conclusion. These investigations based their conclusions on estimated PCB exposure doses and estimated excess cancer risk for people consuming large amounts of fish over an extended period of time. Fish ingestion rates, however, provide large uncertainty to these risk estimates. In addition, these estimated exposure doses and cancer risks do not consider consumption of reservoir turtles because of the uncertainties regarding turtle consumption.

ATSDR conducted this investigation primarily because of the uncertainties involved in estimating exposure doses and excess cancer risk from ingestion of reservoir fish and turtles. Also, previous investigations did not confirm that people are actually being exposed or that they have elevated levels of PCBs or mercury. In addition, a contractor for the Tennessee Department of Health (TDOH) recommended that an extensive region-wide evaluation be conducted of relevant exposures and health effects in counties surrounding the Watts Bar Reservoir. Prior to the initiation of such evaluations, ATSDR believed that it was important to determine whether mercury and PCBs were actually elevated in individuals who consumed large amounts of fish and turtles from the reservoir. Mercury was included in this exposure investigation because it was a historical contaminant of concern released from the Oak Ridge Reservation.

Study Design and Methods

This exposure investigation was cross-sectional in design as it evaluated exposures of the fish and turtle consumers at the same point in time. However, because serum PCB and mercury blood levels are indicators of chronic exposure, the results of this investigation provide information on both past and current exposure for each study participant.

Exposure investigations are one of the approaches that ATSDR uses to develop better characterization of past, present, or possible future human exposure to hazardous substances in the environment. These investigations only evaluate exposures and do not assess whether exposure levels resulted in adverse health effects. Furthermore, this investigation was not designed as a research study (for example, participants were not randomly selected for inclusion in the study and there was no comparison group), and the results of this investigation are only applicable to the participants in the study and cannot be extended to the general population.

Specific objectives of this investigation included measuring levels of serum PCBs and blood mercury in people consuming moderate to large amounts of fish or turtles, identifying appropriate health education activities and follow-up health actions, and providing new information to help evaluate the need for future region-wide assessments.

Study Group

The target population was persons who consumed moderate to high amounts of fish and turtles from the Watts Bar Reservoir. ATSDR recruited participants through a variety of means, including newspaper, radio, and television announcements, as well as posters and flyers placed in bait shops and marinas. ATSDR representatives also made an extensive, proactive attempt to reach potential participants by telephoning several hundred individuals who had purchased fishing licenses in the area.

ATSDR interviewed more than 550 volunteers. Of these, 116 had eaten enough fish to be included in the investigation. To be included in the investigation, volunteers had to report eating one or more of the following during the past year: 1 or more turtle meals; 6 or more meals of catfish and striped bass; 9 or more meals of white, hybrid, or smallmouth bass; or 18 or more meals of largemouth bass, sauger, or carp.

Exposures

Human exposures to PCBs and mercury from fish and turtle ingestion were evaluated.

Outcome Measure

Outcome measures included serum PCB and total blood mercury levels. ATSDR also collected demographic and exposure information from each participant (for example, length of residency near the reservoir; species eaten, where caught, and how prepared).

Results

The 116 participants resided in eight Tennessee counties and several other states. The mean age was 52.5 years and 58.6% of the participants were male and 41.4% were female. A high school education was completed by 65%. Eighty percent consumed Watts Bar Reservoir fish for 6 or more years, while 65.5% ate reservoir fish for more than 11 years. Twenty percent ate reservoir turtles in the last year. The average daily consumption rate for fish or turtles was 66.5 grams per day.

Serum PCB levels above 20 parts per billion (ppb) were considered elevated, and only five individuals had elevated serum PCB levels. Of the five participants with elevated PCB levels, four had levels between 20 and 30 ppb. One participant had a serum PCB level of 103.8 ppb, which is higher than levels found in the general population. None of the participants with elevated PCB levels had any known occupational or environmental exposures that might have contributed to the higher levels.

Only one participant had an elevated blood mercury level—higher than 10 ppb. The remaining participants had mercury levels up to 10 ppb, which is comparable to levels found in the general population.

Conclusions

Serum PCB levels and blood mercury levels in participants were similar to levels found in the general population.

Based on the screening questionnaire, most of the people who volunteered for the study (over 550) ate little or no fish or turtles from the Watts Bar Reservoir. Those who did eat fish or turtles from the reservoir indicated that they would continue to do so even though they were aware of the fish advisory.

ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

ORRHES Brief

Oak Ridge Reservation Health Effects Subcommittee

Report on Turtle Sampling in Watts Bar Reservoir and Clinch River, May 1997

Site: Oak Ridge Reservation

Conducted by: Tennessee Department of Environment and Conservation

Time period: 1996

Study area: Watts Bar Reservoir and Clinch River

Purpose

The purpose of this study was to investigate levels of contaminants—especially polychlorinated biphenyls (PCBs)—in snapping turtles in the Watts Bar Reservoir and Clinch River/Poplar Creek water systems. The results of this study were used to assess exposure levels of people who might use the turtles for food.

Background

For more than 50 years, the U.S. Department of Energy's (DOE) Oak Ridge Reservation released radionuclides, metals, and other hazardous substances into the Clinch River and its tributaries. Subsequent studies conducted by DOE and the Tennessee Valley Authority (TVA) documented elevated levels of PCBs in certain species of fish in the Watts Bar Reservoir and Clinch River. As a result, the Tennessee Department of Environment and Conservation (TDEC) issued several consumption advisories on fish. Although noncommercial fishermen are known to harvest turtles, as well as fish, from the Watts Bar Reservoir, TDEC did not issue any consumption advisories on turtles. Since little information was available on contaminant levels in turtles and previous studies from other states indicated that snapping turtles have a tendency to accumulate PCBs (for example, in their fat tissue), the Agency for Toxic Substances and Disease Registry's (ATSDR) health consultation on the Lower Watts Bar Reservoir recommended sampling of turtles for PCBs.

Study Design and Methods

To evaluate levels of contaminants in turtles, TDEC collected 25 snapping turtles from 10 sampling stations in the Watts Bar Reservoir and Clinch River between April and June 1996. As recommended by the U.S. Environmental Protection Agency (EPA), the turtles were euthanized by freezing. Fat tissue and muscle tissue were analyzed separately, as were eggs when present. The samples were processed according to EPA guidelines.

Muscle tissue, fat tissue, and eggs were analyzed for PCBs using EPA methods. TDEC also conducted a PCB-congener[1] -specific analysis on the muscle tissue of two large turtles.To compare contaminant levels in turtles to contaminant levels previously detected in fish, TDEC analyzed turtle muscle tissue for metals and pesticides. Mercury analysis was performed on 13 turtles according to EPA method 245.6, and the remaining metals were analyzed using EPA method 200.1.

Specific pesticides and organic compounds analyzed for included chlordane, DDE, DDT, endrin, hexachlorobenzene, lindane, methoxychlor, and nonachlor. Specific metals analyzed for included arsenic, cadmium, chromium, copper, lead, and mercury.

[1] PCBs are mixtures of up to 209 individual chlorinated compounds referred to as congeners. For more information, see ATSDR's toxicological profile for PCBs at *http://www.atsdr.cdc.gov/toxprofiles/tp17.html.*

Study Group

Levels of contaminants were measured in turtles only. Human exposure levels were not investigated.

Exposures

No human exposure was assessed in this study.

Outcome Measure

Health outcomes were not evaluated.

Results

PCB concentrations were highest in the fat tissue of snapping turtles. Levels in fat tissue, muscle tissue, and eggs ranged from 0.274 parts per million (ppm) to 516 ppm, 0.032 ppm to 3.38 ppm, and 0.354 ppm to 3.56 ppm, respectively. Mean values for fat and muscle tissue were 64.8 ppm and 0.5 ppm, respectively.

Ten PCB congeners considered of highest concern by EPA were identified in the two turtles analyzed for congeners. The distribution of congeners in the two turtles was similar, but the concentrations varied considerably. The turtle with the higher concentrations of PCB congeners was caught from Poplar Creek.

Mercury and copper were the only metals detected in muscle tissue. Mercury concentrations were below the U.S. Food and Drug Administration (FDA) guidance level of 1.0 ppm, and ranged from 0.1 ppm to 0.35 ppm. Copper concentrations ranged from 0.2 ppm to 2.6 ppm.

Of the pesticides studied, *cis*-nonachlor, *trans*-nonachlor, and endrin were detected. They were detected at low levels: 0.001 ppm to 0.036 ppm for *cis*-nonachlor, 0.003 ppm to 0.045 ppm for *trans*-nonachlor, and 0.043 ppm to 0.93 ppm for endrin.

Conclusions

Turtle consumption practices should be further investigated before conducting quantitative assessments to evaluate risks to human health. In particular, it is important to determine which parts of the turtle are most commonly consumed (for example, fat or muscle tissue), as well as the frequency of consumption.

While it appears that PCBs concentrate at higher levels in turtles than in fish, caution is advised in comparing fish results to turtles. Unlike the turtle studies, previous fish studies did not analyze muscle tissue and fat tissue separately.

When assessing potential human health risks related to PCBs, it is important to consider the uncertainty in the toxicity values for PCBs. Because there are no toxicity values for individual PCB congeners, uncertainty in the toxicity of PCB mixtures remains.

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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 off-site 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.

Appendix E. Task 4 Conservative Screening Indices for Radionuclides in the Clinch River

Table E-1. Conservative Screening Indices for Radionuclides in the Clinch River

Isotope	*Exposure Pathway*								
	Drinking Water	*Fish Ingestion*	*External: Shoreline*	*Swimming*	*External: Dredged Sediment*	*Ingestion of Beef*	*Ingestion of Milk*	*Ingestion of Vegetables*	*Irrigation*
Cs 137	9.2 E-06	**4.0 E-04**	**8.0 E-03**	7.6 E-07	**1.6 E-03**	**5.9 E-03**	**5.7 E-03**	**5.6 E-04**	3.2 E-08
Ru 106	**7.7 E-05**	**1.7 E-05**	**1.1 E-03**	5.2 E-06	**4.5 E-05**	**1.6 E-04**	4.4 E-07	**5.8 E-05**	1.2 E-08
Sr 90	**2.5 E-05**	**3.3 E-05**	**7.1 E-05**	1.5 E-06	9.8 E-06	**1.7 E-02**	**2.5 E-02**	**6.4 E-03**	5.1 E-07
Co 60	2.8 E-06	**1.9 E-05**	**6.0 E-03**	1.7 E-07	**8.5 E-04**	**1.1 E-03**	**7.6 E-04**	**7.5 E-05**	6.2 E-09
Ce 144	4.2 E-06	2.7 E-06	**2.1 E-05**	2.6 E-07	7.2 E-08	1.1 E-08	7.4 E-08	3.2 E-07	2.2 E-09
Zr 95	8.1 E-07	5.3 E-06	**1.8 E-04**	4.3 E-07	5.1 E-09	8.8 E-11	2.7 E-10	2.1 E-12	3.1 E-12
Nb 95	4.2 E-07	2.7 E-06	**5.1 E-05**	2.0 E-07	3.1 E-09	1.4 E-11	9.1 E-11	1.4 E-11	3.7 E-12
I 131	**4.1 E-05**	6.7 E-06	7.2 E-08	4.1 E-06	3.2 E-12	6.0 E-07	**3.8 E-05**	1.1 E-11	9.3 E-10
U 235	1.5 E-07	3.2 E-08	5.0 E-06	9.4 E-09	7.8 E-07	2.8 E-07	2.7 E-07	4.6 E-07	1.8 E-10
U 238	1.3 E-07	2.9 E-08	8.4 E-07	8.0 E-09	1.4 E-07	2.5 E-07	2.4 E-07	4.2 E-07	1.6 E-10
Pu 239/240	9.8 E-07	6.4 E-07	1.4 E-07	5.9 E-08	1.5 E-09	3.8 E-07	2.8 E-08	3.1 E-06	2.4 E-10
Th 232	1.0 E-07	2.2 E-07	9.2 E-08	6.1 E-09	2.7 E-09	2.0 E-08	4.8 E-09	1.6 E-07	1.2 E-11
Am 241	1.0 E-07	6.7 E-08	3.8 E-06	6.2 E-09	2.0 E-07	1.7 E-08	1.6 E-08	2.8 E-07	2.5 E-11
Eu 154	4.9 E-06	5.3 E-06	3.6 E-08	1.1 E-06	5.1 E-09	1.3 E-06	1.7 E-07	1.0 E-06	4.4 E-10
La 140	4.9 E-06	2.7 E-06	1.0 E-06	1.8 E-06	2.0 E-09	1.1 E-07	1.6 E-08	7.2 E-12	3.9 E-13
Pm 147	7.4 E-07	4.8 E-07	2.6 E-08	4.4 E-08	1.1 E-11	1.7 E-08	2.8 E-09	6.0 E-10	3.6 3-11
Sm 151	2.3 E07	1.5 E-06	1.3 E-07	1.4 E-08	3.8 E-10	90 E-07	1.2 E-07	7.5 E-07	2.7 E-11
Sr 89	1.5 E-08	1.9 E-08	1.2 E-11	8.8 E-10	1.1 E-13	1.4 E-09	2.4 E-09	3.4 E-11	0.0 E+00
Ba 140	8.6 E-07	9.4 E-08	5.6 E-07	2.8 E-07	0.0 E+00	1.9 E-09	2.3 E-08	0.0 E+00	5.4 E-12
P 32	7.8 E-08	3.8 E-06	2.3 E-12	4.7 E-09	6.9 E16	4.2 E-08	3.3 E-13	3.3 E-13	1.6 E-13
Y 91	7.0 E-06	4.6 E-06	3.5 E-07	4.2 3-07	.3 E-11	7.6 E-08	2.3 E-08	1.1 E-10	2.9 E-11
Pr 143	3.5 E-06	2.3 E-06	9.6 E-09	2.1 E-07	1.5 E-12	7.6 E-08	1.1 E-08	8.3 E-12	0.0 E+00
Nd 147	3.1 E-06	2.0 E-06	1.6 E-06	2.7 E-07	3.6 E-10	6.8 E-08	1.0 E-08	6.0 E-12	0.0 E+00

Bold values represent radionuclides for each pathway that were carried into the next iteration of analysis in Task 4.
Screening indices are calculated probabilities of developing cancer.

Appendix F. Discussion of Risk

During the public health assessment process, ATSDR uses *radiation doses rather than risk*

- to evaluate potential human exposures and health effects associated with site-specific exposure factors, and
- to develop public health conclusions.

Public health assessments differ from the U.S. Environmental Protection Agency's (EPA) risk assessments, which evaluate hypothetical risk to determine safe regulatory limits and prioritize sites for cleanup. Typically, ATSDR does not incorporate risk numbers in public health assessments. Nevertheless, in response to public requests to describe the methodology used in this public health assessment to convert doses to risk numbers, ATSDR includes this supplemental risk appendix. By applying the methods described in this appendix, community members can estimate for themselves the theoretical risk from exposure to X-10 radionuclides released to the Clinch River and the Lower Watts Bar Reservoir via White Oak Creek.

Differences between Dose and Risk

Dose, as defined by ATSDR, is the "amount of a substance to which a person may be exposed, usually on a daily basis." For chemicals, dose is often referred to as the "amount of substances(s) per body weight per day" and is the basis for determining levels of exposure that might cause adverse health effects. In the case of radiation, dose is the amount of energy deposited in a specific body mass.

The Society for Risk Analysis defines **risk** as the "potential for realization of unwanted, adverse consequences to human life, health, property, or the environment; estimation of risk is usually based on the expected value of the conditional probability of the event occurring times the consequence of the event given that it has occurred."[18] The EPA defines risk as "a measure of the probability that damage to life, health, property, and/or the environment will occur as a result of a given hazard."[19]

18 [SRA] Society for Risk Analysis. 2004. Glossary of risk analysis terms. Available from: http://sra.org/resources_glossary.php. Last accessed 25 January 2006.
19 [USEPA] US Environmental Protection Agency 2006. Terms of environment: glossary, abbreviations and acronyms. Available from: http://www.epa.gov/OCEPAterms/rterms.html. Last accessed 14 April 2006.

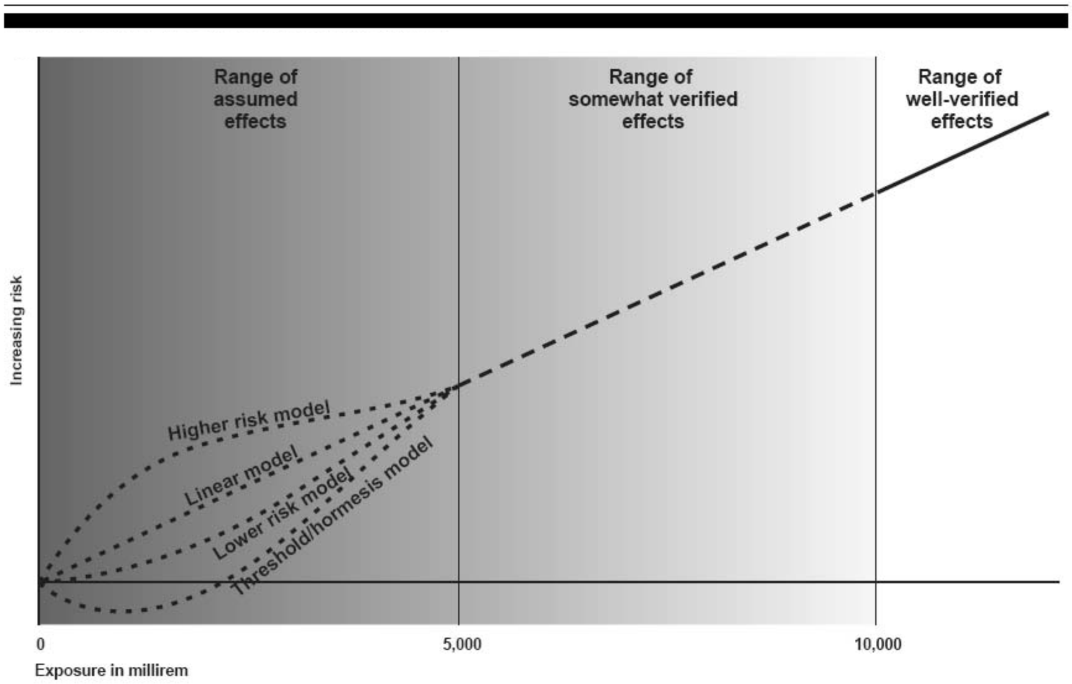
How Does a Risk Assessment Differ from a Public Health Assessment?

Again, EPA defines a risk assessment as a "qualitative and quantitative evaluation of the risk posed to human health and/or the environment by the actual or potential presence and/or use of specific pollutants." Risk assessments—useful in determining safe regulatory limits and prioritizing sites for cleanup—provide estimates of theoretical risk from possible current or future exposures and consider all contaminated media, regardless of whether exposures are occurring or are likely to occur. Quantitative risk estimates developed using the EPA risk assessment methodology include multiple safety factors and are not intended to predict the incidence of disease or measure the actual health effects in people resulting from hazardous substances at a site. By design, EPA risk estimates are conservative predictions that generally overestimate risk. Risk assessments do not provide a perspective on what the risk estimates mean in the context of the site community and do not measure the actual health effects hazardous substances have on people.

The mathematical formula used to calculate risk estimates assumes a linear (i.e., straight line) response to exposure, even though an actual effect may not be detected in an exposed population. The inability to detect an effect could result from the absence of an effect at lower levels of exposure or because the current epidemiological tools are not sufficient to demonstrate the existence of a very small excess of health effects, such as cancer incidence. The conservative approach to risk assessment, which likely overestimates the true potential impact of exposure, is appropriate for exposure prevention and prioritizing site cleanup. Please see Figure F-1 for examples of different models of low-level radiation effects, including the linear model used by governmental and nongovernmental entities to estimate radiation risks.

ATSDR recognizes that every radiation dose, action, or activity may carry an associated risk. 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 for particular communities. A public health assessment provides conclusions about the level of the health threat (if any) posed by a site, as well as recommendations to stop or reduce exposures. Because of uncertainties regarding exposure conditions and because of adverse effects related to environmental levels of exposure, definitive answers are not possible on whether health effects

Figure F-1. Examples of Different Models of Low-Level Radiation Effects[20]



actually will or will not occur. It is possible, however, for a public health assessment to provide a framework that puts site-specific exposures and the potential for harm in perspective.

ATSDR uses the public health assessment process to answer site-specific questions for people potentially exposed to hazardous substances:

- Have health effects been associated with my level of exposure?
- If so, which health effects have been seen at this level of exposure by physicians, epidemiologists, or toxicologists?
- What can I do to lessen the effects of exposure?

When answering community members' questions about impacts from past, current, and future exposures, extreme overestimations of possible effects can cause unnecessary fear and worry. Therefore, instead of using mathematical formulas to estimate *theoretical harm* caused by potential exposures, ATSDR provides the public with answers about health effects associated

20 [GAO] US General Accounting Office. 2000. Radiation standards. Scientific basis inconclusive, and EPA and NRC disagreement continues. Report to the Honorable Pete Domenici, US Senate. Washington, DC: US General Accounting Office. Report GAO/RCED-00-152; June. Available from: http://www.gao.gov/new.items/rc00152.pdf. Last accessed 25 April 2006.

with exposures based on *real observations* by physicians, epidemiologists, or toxicologists. Using this information, ATSDR will make necessary recommendations to prevent and to mitigate exposures potentially occurring at levels that have been shown to cause adverse health effects. If, however, exposures were at levels below those associated with adverse health effects, further actions would not be recommend.

For more information on the intentional differences between public health assessments and risk assessments, please see ATSDR's *Public Health Assessment Guidance Manual* (http://www.atsdr.cdc.gov/HAC/PHAManual/toc.html), EPA's *Risk Assessment Guidance for Superfund – Human Health Evaluation Manual* (http://cfpub1.epa.gov/superapps/index.cfm/fuseaction/pubs.results/results.cfm), and *A Citizen's Guide to Risk Assessments and Public Health Assessments at Contaminated Sites* (written jointly by ATSDR and EPA Region IV; see http://www.atsdr.cdc.gov/publications/CitizensGuidetoRiskAssessments.html).

Radiation Risks

Radiation risks are derived from many exposure studies that have undergone review by governmental and nongovernmental international groups, including

- the EPA,
- the U.S. Nuclear Regulatory Commission (NRC),
- the U.S. Department of Energy (DOE),
- various universities,
- the National Council on Radiation Protection and Measurements (NRCP),
- the International Commission on Radiological Protection (ICRP), and
- the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR).

These reviews assist scientists, legislators, regulators, and others in estimating the risks of cancer and deaths associated with radiological exposures and radiological doses.

In its 1991 Publication 60,[21] the ICRP discussed risk in terms of radiation detriment and derived probabilities of developing fatal cancers in various organs as measured by the effective dose. The commission also evaluated organ detriment by deriving tissue weighting factors. The ICRP defines a tissue weighting factor as "The factor by which the equivalent dose in a tissue or organ is weighted to represent the relative contribution of that tissue or organ to the total detriment resulting from uniform irradiation of the body." Thus weighting factors convert an organ dose equivalent to a committed effective dose for the whole body. (See Section III.A.1. in the PHA for more information on tissue weighting factors, organ dose equivalents, and effective doses). These weighting factors are applied to ensure the detriment produced is "broadly the same degree" regardless of the tissue or organ irradiated. As mentioned throughout this White Oak Creek public health assessment, the ICRP has a recommended annual radiation ***dose limit*** for the public of 100 millirem (mrem)/year. ICRP continues to state, however, that "The Commission does not yet recommend an annual [radiation] ***risk limit*** for individuals."

In 1993, the NCRP published risk estimates designed for radiation protection. The NCRP developed these estimates based on a review of studies from UNSCEAR and the National Academy of Sciences' Committee on Biological Effects of Ionizing Atomic Radiation (BEIR). These studies, which included investigations on radiation effects on the thyroid and the fetus, reported the risks associated with exposure to low doses of ionizing radiation. Given its review, the NCRP estimated the following risks for members of the public exposed to ionizing radiation: a lifetime cancer mortality risk of 0.05 per sievert (Sv) (5%); a hereditary risk of 0.01 per Sv (1%), and a risk of severe mental retardation for fetuses exposed at 8–15 weeks gestational age of 0.04 per Sv (0.4%).[22]

In 1994, the EPA published its methodology for estimating cancer risks from low-level radiation exposures. These estimates, derived from similar data used by the NCRP in Report 115, incorporated 1980 vital statistics to develop organ-specific risks for a stationary US population.[23] In Federal Guidance Report 13, released in 1999, the EPA presented refined risk estimates for low-level radiation exposures to be used for various purposes, such as assessing individual sites

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

22 [NCRP] National Council on Radiation Protection and Measurements. 1993. Risk estimates for radiation protection. NCRP Report 115. Bethesda, MD: National Council on Radiation Protection and Measurements.

23 [USEPA] US Environmental Protection Agency. 1994. Estimating radiogenic cancer risks. EPA 402-R-93-076; June. Available from: http://www.epa.gov/radiation/docs/rad_risk.pdf. Last accessed 15 March 2006.

and conducting general analysis for rule making. These estimates include risks from numerous radionuclides, routes of exposure, and ages of exposure.[24]

In 2005, the EPA released draft guidelines for carcinogenic risk assessments that discussed guidance for developing and using risk assessments.[25] The EPA stated "where alternative approaches have significant biological support, and no scientific consensus favors a single approach, an assessment may present results using alternative approaches. A nonlinear approach can be used to develop a reference dose or a reference concentration." Thus, the EPA indicates that multiple approaches using linear and nonlinear methods are appropriate if more than one mode of action exists. Also, in an EPA Risk Assessment Task Force report titled *An Examination of EPA Risk Assessment Principles and Practices,* the agency stated that the "risk estimates are designed to ensure that risks are not underestimated, which means that a risk estimate is the upper bound on the estimated risk." Further, the EPA explicitly stated that the true cancer potency "could be as low as zero."[26]

In a proposed risk assessment bulletin released in 2006, the US Office of Management and Budget (OMB) issued new technical guidance to improve risk assessments prepared by the federal government.[27] The bulletin emphasizes the importance of high-technical-quality risk assessments that present scientific issues in an objective manner. According to the OMB, risk assessments need to describe the basis of every critical assumption and specify how the assumptions affect the risk assessment's main findings. An assessment should also discuss the empirical data that both supports and conflicts with the assumptions. The OMB proposed bulletin stated that these discussions should include "the range of scientific opinions regarding the likelihood of plausible alternate assumptions" and "whenever possible, a quantitative evaluation

24 [USEPA] US Environmental Protection Agency. 1999. Cancer risk coefficients for environmental exposure to radionuclides. Federal Guidance Report 13. EPA 402-R-99-001. Washington, DC: US Environmental Protection Agency; September. Available from: http://www.epa.gov/radiation/docs/federal/402-r-99-001.pdf. Last accessed 15 March 2006.

25 [USEPA] US Environmental Protection Agency. 2005. Guidelines for carcinogen risk assessment. EPA/630/P-03/001B. Washington, DC: US Environmental Protection Agency; March. Available from: http://www.epa.gov/IRIS/cancer032505.pdf. Last accessed 25 April 2006.

26 [USEPA] US Environmental Protection Agency. 2004. An examination of EPA risk assessment principles and practices. EPA/100/B-04/001. Washington, DC: US Environmental Protection Agency; March. Available from: http://www.epa.gov/osa/pdfs/ratf-final.pdf. Last accessed 20 April 2006.

27 [OMB] US Office of Management and Budget. 2006. Proposed risk assessment bulletin. Available from: http://www.whitehouse.gov/omb/inforeg/proposed_risk_assessment_bulletin_010906.pdf. Last accessed 20 April 2006.

of reasonable alternative assumptions should be provided. If an assessment combines multiple assumptions, the basis and rationale for combining the assumptions should be clearly explained."

To summarize, many governmental and nongovernmental agencies use a linear approach for estimating radiation risks. This linear approach, called the linear nonthreshold (LNT) model, assumes an inherent risk irrespective of the dose. Although this risk has not been seen to date, various agencies use this approach to set regulatory limits, to develop recommended exposure limits for the public, and to evaluate public health hazards (e.g., ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years incorporates the LNT model).

Risk Limits

Table F-1 summarizes the organ-specific risk estimates developed by the ICRP (1991) and the EPA (1994 and 1999). The table expresses the results in units of equivalent (organ) dose, and the totals are expressed in terms of effective (whole-body) dose. For the purposes of this discussion, the dose units of Sv and gray (Gy) are interchangeable. The dose unit of rem is equal to 0.01 Sv or 0.01 Gy.

EPA guidance states that carcinogens should be limited to a risk range of 1 in 10,000 to 1 in 1,000,000 (1×10^{-4} to 1×10^{-6}), presumably above background exposure. EPA applies this range in its baseline risk assessments to rank sites relatively (primarily) for cleanup; EPA does not, however, determine the likelihood that health effects might occur. The following risk numbers are calculated when the ICRP risk coefficients presented in Table F-1 (converted to 0.0005 per rem) are multiplied by the background radiation dose of 360 mrem/year (including radon) and ATSDR's radiation screening value of 100 mrem/year (for radiation exposure in excess of background):

- Annual risk to average background radiation (360 mrem): $0.36 \times 0.0005 = 0.00018$
- Annual risk to the ATSDR screening value (100 mrem): $0.10 \times 0.0005 = 0.00005$

Exposure to average background radiation (1.8 in 10,000), which cannot be avoided and to which everyone is exposed, exceeds the EPA risk range. The ATSDR screening value of 100 mrem is, however, equivalent to a risk of 5 in 100,000, which falls near the center of EPA's prescribed risk range.

Table F-1. Summary of Organ-Specific Risk Estimates

Organ	*ICRP[*] (rem)*	*EPA[†] (rad)*	*EPA FGR 13[‡] (rad)*
Bladder	3E-05	2.49E-05	2.38E-05
Bone marrow	5E-05	4.96E-05	5.57E-05
Bone surface	5E-06	9.00E-07	9.50E-07
Breast	2E-05	4.62E-05	5.06E-05
Colon	8.5E-05	9.82E-05	1.04E-04
Liver	1.5E-05	1.50E-05	1.50E-05
Lung	8.5E-05	7.16E-05	9.88E-05
Esophagus	3E-05	9.00E-06	1.17E-05
Ovary	1E-05	1.66E-05	1.49E-05
Skin	2E-06	1.00E-06	1.00E-06
Stomach	1.1E-04	4.44E-05	4.07E-05
Thyroid	8E-06	3.20E-06	3.24E-06
Remainder	5E-05	1.29E-04	1.54E-01
Total (whole body) risk	5E-4 per rem per year	5.09E-04 per rad per year	5.75E-04 per rad per year
0.1 rem/y (100 mrem/y)	5.00E-05 per year	5.09E-05	5.75E-05

Calculation of Risk for the Oak Ridge Public Health Assessments

As previously discussed at public meetings, ATSDR does not perform risk assessments, nor does it report its findings in terms of risk. Calculating the risks from the doses reported by ATSDR in this PHA, however, only involves one additional step. To calculate the risk, multiply the doses reported by ATSDR by the appropriate organ risk factor from Table F-1, being sure to use consistent units throughout the calculations.

Using the following equation, here are some examples of how to calculate the risk from an estimated radiation dose.

$$\text{Risk} = \text{Annual Dose} \times \text{Risk Coefficient} \times \text{Years of Exposure}$$

Examples of Calculating Risks From Estimated Radiation Doses

Whole-body dose

Annual Dose (in rem):	100 mrem per year (0.1 rem)
Risk Coefficient:	0.0005 per rem per year
Years of Exposure:	5 years

Risk = 0.1 × 0.0005 × 5 = 0.00025 (2.5 per 10,000)

This result of 2.5 per 10,000 can then be compared to the estimated risk an individual would receive from typical exposures to background radiation during the same time period:

Risk = 0.36 × 0.0005 × 5 = 0.0009 (9 per 10,000)

Dose to the bone marrow

Annual Dose (in rem):	100 mrem per year (0.1 rem)
Risk Coefficient:	0.00005 per rem per year
Years of Exposure:	5 years

Risk = 0.1 × 0.00005 × 5 = 0.000025 (2.5 per 100,000)

Dose to the thyroid

Annual Dose (in rem):	10,000 mrem per year (10 rem)
Risk Coefficient:	0.000008 per rem per year
Years of Exposure:	5 years

Risk = 10 × 0.000008 × 5 = 0.0004 (4 per 10,000)

Appendix G. Responses to Public Comments on White Oak Creek Radionuclide Releases Public Health Assessment

The Agency for Toxic Substances and Disease Registry (ATSDR) received the following comments from the public and local organizations during the public comment period (May 6, 2005 to June 23, 2005) for the White Oak Creek Radionuclide Releases at the Oak Ridge Reservation (ORR) Public Health Assessment (PHA) (April 2005). Public comments received on the initial release version of the document (dated December 2003) are indicated herein; all remaining comments respond to the April 2005 version of the document. For comments that questioned the validity of statements made in the PHA, ATSDR verified or corrected the statements.

	Comment	ATSDR's Response
General Comments		
1	ATSDR, an agency of the federal government, has a clear conflict of interest when it prepares health assessments on sites where the federal government itself is the primarily responsible party. This conflict is never clearer than today, when the federal government gives itself a high five for being such a good, clean citizen in Oak Ridge. Either ATSDR's methodology is suspect, or their knowledge base is suspect, or their honesty is suspect. In either case, the public is ill served by false assurances. The finding of the ATSDR that releases from the Oak Ridge National Laboratories over the past 60 years have posed no public health threat is unconscionable, unsupported by the scientific community, and flat-out false. The declaration that Oak Ridge has never posed a health risk cannot be supported by science or by common sense. ATSDR's finding is either the result of half-hearted work or simple duplicity.	In 1980, Congress established the ATSDR to carry out the health-related responsibilities under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) commonly known as the Superfund Law. CERCLA charges the EPA to find and to clean up the most dangerous hazardous waste sites in the United States, and CERCLA charges ATSDR to determine the extent of human exposure to hazardous substances at those sites. In 1984, ATSDR's public health authority was extended to Solid Waste Disposal Act (SWDA) sites. The Superfund Amendments and Reauthorization Act of 1986 further extended ATSDR's authority to federal facilities. ATSDR has the following legislation authorities that pertain to its activities at DOE sites: ▪ Section 120 of CERCLA (42 USC 9620): concerns the application of CERCLA to federal facilities ▪ Section 104(i) of CERCLA: concerns ATSDR's authorities and responsibilities ▪ Section 107 of CERCLA: concerns liability ▪ Section 3019 of SWDA (42 USC 6939a): concerns exposure information and health assessments As the lead public health agency responsible for implementing the health-related provisions of Superfund, ATSDR is charged with assessing health hazards at specific hazardous waste sites, helping to prevent or reduce exposure and the illnesses that result, and increasing knowledge and understanding of the health effects that may result from exposure to hazardous substances. As the potentially responsible party (PRP), DOE is required to fund cleanup and public health investigations, such as the ATSDR PHAs, for the Oak Ridge Reservation. ATSDR as an advisory, non-regulatory public health agency conducts independent public health assessments and provides recommended actions to protect public health. It makes health calls following an independent evaluation of data and exposure situations; it does not make any decisions based on who is funding its work.

	Comment	ATSDR's Response
		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 disease related to toxic substances. The ATSDR public health assessment process serves as a mechanism to help ATSDR scientists sort through the many hazards at waste sites and determine when, where, and for whom public health actions should be taken. Through this process, ATSDR finds out whether people living near or at a hazardous waste site are exposed to toxic substances, whether that exposure is harmful, and what must be done to stop or reduce an exposure. ATSDR scientists use the detailed guidance in the updated ATSDR *Public Health Assessment Guidance Manual* to identify hazards and to recommend needed public health actions. 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/toc.html or by contacting ATSDR at 1-888-42-ATSDR. An interactive program that provides an overview of the 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. This public health assessment evaluates the releases of radionuclides to the Clinch River and the Lower Watts Bar Reservoir from the ORR via White Oak Creek; assesses past, current, and future exposure to radionuclide releases for people who use or live along the Clinch River; and addresses the community health concerns and issues associated with the radionuclide releases from White Oak Creek. ATSDR evaluated data and exposure situations to determine the public health implications of past, current, and future off-site exposures. ATSDR concluded that past, current, and future exposures to radionuclides released from White Oak Creek to the Clinch River and Lower Watts Bar Reservoir are not a public health hazard. Though people might have or might yet come in contact with X-10 radionuclides 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. That said, however, please note that ATSDR never states nor implies in this PHA that, "…releases from the Oak Ridge National Laboratories over the past 60 years have posed no public health threat…" This PHA only evaluates off-site exposures to X-10 radionuclides released to White Oak Creek that entered the Clinch River and Lower Watts Bar Reservoir. The PHA does not evaluate any on-site exposures (these are handled by other agencies) or exposures to other contaminants released from this facility. In addition to this PHA, ATSDR

	Comment	ATSDR's Response
		is also conducting public health assessments on X-10 iodine 131 releases, Y-12 mercury releases, K-25 uranium and fluoride releases, PCB releases from X-10, Y-12, and K-25, and other topics such as the Toxic Substances Control Act (TSCA) incinerator and off-site groundwater. For copies of these other assessments, please contact ATSDR's Information Center toll-free at 1-888-422-8737.
2	It never ceases to amaze me how our government officials like to pronounce threats as totally harmless. Over the years it has been contaminated geese and frogs, air and water, yet the threat is always stated to be so innocuous that the animals or fish could be eaten, yet millions of dollars are being spent to clean it up and dispose of it. Is it me or is there a real large logic gap here? What is wrong with this picture? If White Oak Creek Drainage Basin poses absolutely no threat, as the Agency for Toxic Substances and Disease Registry states, why are so many millions being spent to clean up and remediate the area by the Department of Energy? How can we find credibility amid the illogic of such duplicity? Either there is a real threat here, even though it may be fairly minor — a few deaths per 100,000 — or a lot of money is being poured into the waste heap. This certainly seems to be the case with money for the agency efforts that are obviously purely palliatives without a shred of credibility. It is time for real mortality-morbidity data to be placed on the table — no more empty pronouncements of complete safety. Only an idiot sees the world in such black-and-white contrast.	It is true that DOE has spent and continues to spend billions of dollars on environmental remediation at the Oak Ridge Reservation. As a result of past activities at the ORR, parts of the on-site facilities and lands have been contaminated with PCBs, radioactive elements, asbestos, mercury, and other industrial wastes. In November 1989, EPA listed the ORR on the final National Priorities List (NPL). DOE is performing remediation activities at the reservation under a Federal Facility Agreement (FFA), which is an interagency agreement between the DOE, EPA, and TDEC. EPA and TDEC, and the public help DOE select the details for remedial actions at the ORR. These stakeholders work collaboratively to ensure the remediation activities are adequate, and to ensure that hazardous waste related to previous and current ORR activities is completely studied and appropriate remedial action is taken. Environmental management is the largest program at Oak Ridge. Information on the program is available at http://www.oakridge.doe.gov/External/Default.aspx?tabid=42. Though DOE is remediating these wastes, it is extremely important to understand that the federal funding used to remediate these lands and facilities are only for contamination within the reservation—none of the funding is intended for clean up of off-site areas; the on-site areas currently undergoing remediation are not accessible to residents. Though costly, DOE is spending this money to prevent contamination from traveling off site, or at a minimum, to detect it in a timely manner before it affects off-site areas. ATSDR's PHAs are evaluations of exposures to off-site populations. This PHA evaluates the releases of radionuclides to the Clinch River and the Lower Watts Bar Reservoir from the X-10 site via White Oak Creek; assesses past, current, and future exposure to radionuclide releases for people who use or live along the Clinch River from the Melton Hill Dam to the Watts Bar Dam; and addresses the community health concerns and issues associated with the radionuclide releases from White Oak Creek. It is not an evaluation of people who were exposed while working on-site at the reservation. Other agencies handle that responsibility. ATSDR concluded that past, current, and future exposures to radionuclides released from White Oak Creek to the Clinch River and the Lower Watts Bar Reservoir are not a public health hazard. 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 X-10 radionuclides that entered the Clinch River or Lower Watts Bar

	Comment	ATSDR's Response
		Reservoir via White Oak Creek. ATSDR's evaluation of data and exposure situations for users of these waterways indicates, however, 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.
3	There is a need for an independent external peer review of this ATSDR PHA (from scientists who have not been selected by the ATSDR) to address issues of technical and public credibility. These reviewers should have independence from DOE and its contractors. They should also be free from local organizational and economic conflicts of interest. He expressed concern that the data validation process and internal ATSDR review did not catch what he considered to be discrepancies. In his opinion, this report contained major technical errors that had implications in terms of how ATSDR conducts business. In the past, CDC/NCEH relied on a standing committee of the NRC/NAS for peer reviews of CDC contractor dose reconstructions and risk evaluations. Such peer reviews by the NRC/NAS were conducted at Hanford, Fernald, INEL, and Savannah River. I recommend that consideration be given to the reactivation of this committee of the NRC/NAS for scientific peer review of the technical content of the ATSDR PHAs at Oak Ridge. In addition, such a peer review should address whether or not these PHAs have been responsive to community concerns.	The White Oak Creek Radionuclide Releases PHA underwent an internal ATSDR review, a data validation review by other government agencies (i.e., the Department of Energy and the Tennessee Department of Environment and Conservation), and an external review. Through its external peer review process, ATSDR's Office of Science had three scientific experts review this public health assessment (see Appendix H for the peer reviewer comments and ATSDR's responses). The agency's peer review process provides an objective and thorough evaluation of this PHA by experts in the fields this assessment covers—specifically, health physics. Individuals within the agency who have the proper background (e.g., toxicology and health physics) also reviewed the document during the agency's internal review process. During the external review process, scientists not employed by ATSDR or the CDC independently reviewed this document and provided us with their unbiased, scientific opinions. All peer reviewers approved of the assessment and found no major flaws that would invalidate ATSDR's conclusions and recommendations. In the words of one peer reviewer: "You [ATSDR] have done a good job under very difficult circumstances with a lot of unwanted publicity and carping. The science under the report is very good and the report is well written in a very good manner that is suitable for both an informed and interested public and the scientific community." Further, an external peer reviewer commented, "The study further addresses local concerns raised by the residents of the area even when it is doubtful that there is any validity to the concern raised."
4	Clearly define what is meant by a "public health hazard." Clearly distinguish between the ability to observe health effects and the potential existence of health effects that cannot be detected at low doses. The inability to detect effects does not mean zero risk of radiation exposure, as is implied at several points in the current draft.	Public health hazard is now defined in the summary of the final PHA on page 2 as "a source of potential harm to human health as a result of past, current, or future exposures." ATSDR recognizes that every radiation dose, action, or activity may have an associated risk. Given our evaluation in this public health assessment, ATSDR concludes that exposures to X-10 radionuclides released from White Oak Creek to the Clinch River and to the Lower Watts Bar Reservoir are not a health hazard. Past and current exposures are below levels associated with adverse health effects and regulatory limits. Adults or children who have used, or who might continue to use, the waterways for recreation, food, or drinking water are not expected to have adverse health effects due to exposure. ATSDR has categorized those situations as posing *no apparent public health hazard* from exposure to radionuclides related to X-10. This classification means that people could be or were

	Comment	ATSDR's Response
		exposed, but that the level of exposure would not likely result in any adverse health effects. Contrary to this commenter's statement, the document does not imply that the inability to detect effects means no risk of exposure. This is clearly evident by the use of the *no apparent public health hazard* conclusion category in this public health assessment. ATSDR uses this category in situations in which human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects. Therefore, it is evident that ATSDR is not saying there is no risk of radiation exposure. On the contrary, we are saying that radiation exposure is possible, but that this exposure is not expected to result in observable health effects. EPA-conducted risk assessments are useful in determining safe regulatory limits and in prioritizing sites for cleanup. These risk assessments provide estimates of theoretical risk from possible current or future exposures and consider all contaminated media regardless of whether exposures are occurring or are likely to occur. These quantitative risk estimates are not intended, however, to predict the incidence of disease or to measure the actual health effects in people caused by hazardous substances at a site. By design, these risk estimates are conservative predictions that generally overestimate risk. Risk assessments do not provide a perspective on what the risk estimates mean in the context of the site community and do not measure the actual health effects that hazardous substances have on people. 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 for particular communities. ATSDR scientists conduct a health effects evaluation by carefully examining site-specific exposure conditions about actual or likely exposures; conducting a critical review of available toxicological, medical, and epidemiologic information to ascertain the substance-specific toxicity characteristics (i.e., levels of significant human exposure), and comparing an estimate of the amount of chemical 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 effects. The goal of the health effects evaluation is to decide whether harmful effects might be possible in the exposed population by weighing the scientific evidence and by keeping site-specific doses in perspective. The output is a qualitative description of whether site exposure doses are of sufficient nature and magnitude to trigger a public health action to limit or eliminate, or to study further any potentially harmful exposures. The

	Comment	ATSDR's Response
		PHA 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. For detailed information on risk, please see Appendix F in the final PHA.
5	There are a lot of concerned individuals downwind and downstream of the Department of Energy Oak Ridge Reservation (DOE ORR). (*Comment received on the initial release PHA dated December 2003.)*	Thank you for your comment. Section VI. Community Health Concerns of the final PHA contains the public health concerns received from area residents, community groups, and other interested parties related to issues associated with radionuclide releases from White Oak Creek, as well as ATSDR's responses to these concerns. These concerns and responses are sorted by category (X-10 facility processes and exposure pathway concerns, concerns about radionuclides associated with X-10's releases to White Oak Creek, concerns about contaminants released from the Oak Ridge Reservation, and general concerns related to the Oak Ridge Reservation) and presented in tabular form in Section VI of the final PHA. Also, ATSDR developed a *Community Health Concerns Database* to compile and track community health concerns related to the ORR. 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, telephone calls, newspapers, comments made at public meetings (e.g., ORRHES and work group meetings), and surveys conducted by other agencies and organizations. Further, within this section of the final PHA ATSDR provides responses to the comments received on the public comment version of the White Oak Creek Radionuclide Releases PHA. During the PHA's external peer review process, a peer reviewer made the following comment regarding this issue: "The study further addresses local concerns raised by the residents of the area even when it is doubtful that there is any validity to the concern raised." Thus, as this reviewer points out, ATSDR is addressing all of the community concerns related to releases from X-10 to White Oak Creek.
6	According to the Final Report of the Oak Ridge Health Agreement Steering Panel titled: Releases of Contaminants from Oak Ridge Facilities and Risks to Public Health, December, 1999, ATSDR has not even scratched the surface of the bewildering array of public health concerns of the many communities downwind and downstream of DOE ORR. (*Comment received on the initial release PHA dated December 2003.)*	After reviewing the ORHASP report, it is unclear what concerns have not been addressed. ATSDR has reviewed this report and has an entire section (Section VI. Community Health Concerns) of the final PHA devoted to listing and addressing community concerns received about X-10 radionuclide releases to the Clinch River and the Lower Watts Bar Reservoir via White Oak Creek. In fact, from 1991 to 2000 ATSDR completed the following public health activities to address specific ***current*** off-site public health concerns and issues not addressed by the Tennessee Department of Health's Oak Ridge Health Studies. These studies only evaluated whether off-site populations experienced ***past*** exposures to radiological and

	Comment	ATSDR's Response
		chemical releases from the ORR. *Review of Clinical Information on Persons Living in or near Oak Ridge, Tennessee* dated September 10, 1992. *Health Consultation on Y-12 Weapon Plant Chemical Releases into East Fork Poplar Creek* dated April 5, 1993. DOE implemented many of ATSDR's recommendations before finalizing the Remedial Investigation and Feasibility Study on Lower East Fork Poplar Creek and the 1995 Record of Decision for the Lower East Fork Poplar Creek. *Clinical Laboratory Support* in 1994. ATSDR and the National Center for Environmental Health (NCEH) facilitated clinical laboratory support by the NCEH Environmental Health Laboratory for patients referred to the Emory University School of Public Health by an Oak Ridge physician. *ATSDR Science Panel on the Bioavailability of Inorganic Mercury* in August 1995. Four papers were published by science panel members in *Risk Analysis*.17 (5), 527-569 (1996). *Health Consultation on DOE's Proposed Mercury Clean-up Level for the East Fork Poplar Creek Floodplain Soil* dated January 1996. DOE cited the conclusions of this health consultation in the 1995 Record of Decision for the Lower East Fork Poplar Creek. *Health Consultation on Lower Watts Bar Reservoir* dated February 1996. DOE cited this health consultation in the 1995 Record of Decision for the Lower Watts Bar Reservoir. The state of Tennessee followed up on the recommendation to analyze for PCBs in turtles. *Physician Health Education Program on Cyanide* in August 1996. The physician education program supplied health care providers with information on health impacts of possible cyanide intoxication. *Community and Physician Education on PCBs in Fish* in September 1996. ATSDR developed a community and physician education program on PCBs in Watts Bar Reservoir fish to follow up on recommendations contained in the ATSDR health consultation. *Watts Bar Reservoir Fish Advisory Pointers* brochure dated 1997. ATSDR worked with the state of Tennessee and local community groups to develop the brochure as a follow up on recommendations contained in the ATSDR health consultation. *Exposure Investigation on Serum PCB and Blood Mercury Levels in Consumers of Fish and Turtles from Watts Bar Reservoir* dated March 1998. This exposure investigation is a follow-up activity to the ATSDR Health Consultation on Lower Watts Bar Reservoir dated February 1996 and to respond specifically to an informal recommendation from the Oak Ridge Health Agreement Steering Panel, as well as respond to general community interest. This study

	Comment	ATSDR's Response
		was done to measure actual PCB and mercury levels in people who have eaten large amounts of Watts Bar Reservoir fish or turtles. ATSDR tested for PCBs because previous investigations estimated that people who eat certain fish or turtles might have higher than average levels of PCBs in their bodies and suggested that the levels of PCBs in fish were a public health concern. ATSDR tested the blood samples for mercury because mercury was a historic contaminant of concern. Recent studies, however, have not detected mercury at levels of health concern in surface water, sediments, or fish from the Watts Bar Reservoir. *Compendium of Public Health Activities at the U.S. Department of Energy Oak Ridge Reservation* (updated version) dated November 2000. ATSDR initiated and coordinated the development of the compendium to outline the past and present strategies used to address and evaluate public health issues related to chemical and radioactive substances released from the Oak Ridge Reservation. Copies of ATSDR documents are available on ATSDR's Oak Ridge Reservation Public Health Web site at http://www.atsdr.cdc.gov/HAC/oakridge/index.html. In addition, detailed summaries of the public health activities prior to 2000 are available in the *Compendium of Public Health Activities at the U.S. Department of Energy* dated November 2000 on the ATSDR's Oak Ridge Reservation Public Health Web site at http://www.atsdr.cdc.gov/HAC/oakridge/phact/c_toc.html. In 2001, ATSDR scientists conducted a review and analysis of the Phase I and Phase II screening evaluations of the Tennessee Department of Health's Oak Ridge Health Studies to identify contaminants that required further public health evaluation. ATSDR staff presented this review and analysis of the Phase I and Phase II screening evaluations to the Oak Ridge Reservation Health Effects Subcommittee (ORRHES). Given ATSDR's review and the comments received from the ORRHES, ATSDR scientists decided to use the ATSDR public health assessment process to conduct chemical-specific and issue-specific public health assessments and to address issues and community health concerns related to the following: ▪ Past and current exposure to uranium released from the Y-12 Weapons Plant, ▪ Exposure to contaminants released from the Toxic Substances Control Act (TSCA) incinerator, ▪ Past and current exposure to radionuclides released from White Oak Creek, ▪ Exposure to contaminated off-site groundwater, ▪ Past exposure to radioactive iodine (I 131) released from X-10, ▪ Past and current exposure to mercury released from the Y-12 Weapons Plant, ▪ Past and current exposure to uranium and fluoride released from K-25, ▪ Past and current exposure to PCBs released from X-10, Y-12, and K-25

	Comment	ATSDR's Response
		▪ Current (1990-2003) and future exposure to other chemicals near the reservation, and ▪ Overall summary on the screening process and exposures to a mixture of chemicals and radionuclides. At the February 11, 2002 ORRHES meeting, the ORRHES approved a recommendation endorsing ATSDR's screening process to determine the list of contaminants for further evaluation using the ATSDR public health assessment process.
Evaluation of Additional Populations		
7	Pp. i. Line 34, and ii. Line 5. Given the emphasis placed on consideration of children, it would be appropriate to add pregnant and lactating women to the list of high risk groups. This will cover the fetus and the breast-fed infant. It's also a nice thing to do for women of childbearing age given the potential adverse impact of radiation exposure on their reproductive experience.	The section referenced by the commenter is ATSDR's standard forward used in all public health assessments. This particular group is not being added to our standard forward because it is particular to this evaluation and not necessarily appropriate for all public health assessments. But a discussion of this group has been added to Section VII. Child Health Considerations in the final PHA.
8	Page 105, Line 29. Stakeholders believe that ATSDR is not taking into consideration subsistence fishers who will consume much more than the standard "reference man" that ATSDR is utilizing. Stakeholders believe that ATSDR is 'blowing off' the more significant hazard that these fish present to growing children and pregnant women by ingestion of fish. Of special concern is ingestion of fish contaminated with Sr-90 and Cs-137. These three exposure considerations were, in fact, the most important 'risk drivers' of exposure to the consumption of radioactively contaminated fish downstream from another DOE facility, the Savannah River Site, near Aiken, SC. (*Comment received on the initial release PHA dated December 2003.)*	To evaluate past, current, and future exposures to radionuclides in Clinch River and Lower Watts Bar Reservoir fish, average fish consumers were evaluated (detailed below). In its Exposure Factors Handbook (available at http://www.epa.gov/ncea/pdfs/efh/front.pdf) that outlines factors commonly used in exposure assessments EPA recommends using an assumed average intake rate for fish consumption for the general population of 20.1 grams/day (140.7 grams/week) of total fish. Of this fish intake rate, however, only 6.0 grams/day (42 grams/week) is considered as an average intake rate for the general population consuming freshwater and estuarine fish. All of the exposure assumptions used by ATSDR for past, current, and future exposures to radionuclides in Clinch River and Lower Watts Bar Reservoir fish were at least five times **more than** this average intake for the general population eating freshwater and estuarine fish. As detailed below, even when evaluating fish consumption by using assumed intake rates significantly above these recommended assumptions, ATSDR's estimated doses for past, current, and future exposures were below health-based comparison values. In the Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report), past exposures to radionuclides in Clinch River fish were evaluated for high fish consumers. Reportedly, a maximum fish consumer in the east south central region of the country would eat about 2.4 fish meals per week (based on a 200 gram per meal fish portion) (Rupp et al. 1980. Age dependent values of dietary intake for assessing human exposures to environmental pollutants. Health Physics 39: 151-163. Cited in the Task 4 report). The Task 4 report evaluated high fish consumers, who were referred to as "Category I fish consumers" and were described as individuals who frequently

	Comment	ATSDR's Response
		(between 1 and 2.5 fish meals per week) ate fish. To evaluate past exposure to radionuclides in the Clinch River, ATSDR summarized the Task 4 organ doses from the Task 4 report for the bone, lower large intestine, red bone marrow, breast, and skin locations using the 50th percentile value of the uncertainty distribution. The 50th percentile (central) values represent the medians of organ doses. The highest radiation doses were associated with eating fish taken from the Clinch River near Jones Island between 1944 and 1991. Doses were much lower for all other pathways (see Table 11 and Table 12 in the final PHA). The Task 4 report's estimated organ doses to the bone, lower large intestine, red bone marrow, breast, and skin from eating fish were at least six times greater than the radiation doses to these organs from ingesting meat and milk, drinking water, and external radiation (see Table 12 in the final PHA). Likewise, ATSDR's derived annual whole-body and committed equivalent doses from eating fish were at least 10 times more than any of the other exposure pathways (see Table 11 in the final PHA). As mentioned and shown in Table 11, radiation doses from eating fish were highest near Jones Island—these annual whole-body and lifetime (70-year) doses were more than eight times greater than for people consuming fish from the Clinch River further downstream near Kingston. The annual whole-body dose was less than 3.4 mrem/year for an individual ingesting fish near Jones Island more than 29 times less than the 100 mrem/year recommended dose limit for the public 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). The whole-body lifetime dose for an individual ingesting fish caught near Jones Island was 238.6 mrem over 70 years more than 20 times less than ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years. To evaluate current and future exposure to radionuclides in Lower Watts Bar Reservoir fish, this public health assessment used data from ATSDR's Health Consultation on the Lower Watts Bar Reservoir. The health consultation used worst-case scenarios to evaluate radiological exposure to fish, assuming adults and children consumed two 8-ounce fish meals per week (454 grams/week), which is 10 times the intake rate (42 grams/week) recommended by EPA for freshwater fish. Even using these conservative exposure assumptions, the estimated dose was 6 mrem per year or less than 420 mrem over 70 years for the committed effective dose. The annual whole-body dose of 6 mrem per year is more than 16 times less than the dose of 100 mrem/year recommended for the public by the NCRP, ICRP, and NRC. The committed effective dose of 420 mrem over 70 years is more than 11 times less than ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years. To evaluate current and future exposure to radionuclides in Clinch River fish, ATSDR

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		assumed a child ate 4 ounces of fish per week (113.4 grams/week) and an adult ate 8 ounces of fish per week (227 grams/week). This fish intake rate is based on a survey of high to moderate fish consumers during the ATSDR *Exposure Investigation on Serum PCB and Blood Mercury Levels in Consumers of Fish and Turtles from Watts Bar Reservoir* dated March 1998. Based on this intake rate, the highest estimated whole-body dose of 89.3 mrem—calculated for a 20-year-old adult exposed over 50 years (to age 70)—is 55 times less than ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years. Further, the PHA evaluates childhood exposures within Section III. Evaluation of Environmental Contamination and Potential Exposure Pathways and in Section VII. Child Health Considerations of the final PHA. In addition, a discussion of pregnant women has been added to Section VII of the final document.
9	Page 124, Line 1. ATSDR has omitted the risk to unborn children sustained by their mothers consuming fish contaminated with radioactive cesium, strontium, and other radionuclides. This is especially important because there has never been a Tennessee fish advisory in place in any of these downstream communities to warn the public of the imminent and substantial hazard posed by consuming 'hot fish' downstream of DOE ORR. The only warning is the PCBs – radioactive contamination is never even mentioned once on any of the stream signage or in any of Tennessee's official fish advisories. (*Comment received on the initial release PHA dated December 2003.)*	A discussion of exposure *in utero* has been added to Section VII. Child Health Considerations in the final PHA. In the Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report), the Task 4 team concluded that its estimated radiological doses and excess lifetime cancer risks were "incremental increases above those resulting from exposure to natural and other anthropogenic sources of radiation," but were "not large enough for a commensurate increase in health effects in the population to be detectable, even by the most thorough of epidemiological investigations." The Task 4 team noted that "in most cases, the estimated organ-specific doses are clearly below the limits of epidemiological detection (1 to 30 cSv [centisievert]) for radiation-induced health outcomes that have been observed following irradiation of large cohorts of individuals exposed either in utero (Doll and Wakeford 1997), as children, or as adults (NRC 1990; Thompson et al. 1994; Pierce et al. 1996)" (ChemRisk 1999a). Thus, because past radiation exposures—when doses were the highest—were not expected to cause harmful health effects *in utero*, in infants, and in children, adverse health effects would also not be expected to occur as a result of current and future radiation exposures to the Clinch River and Lower Watts Bar Reservoir. White Oak Creek radionuclide releases and contaminant concentrations have continued to decrease over time. Regarding the fish advisories, the Tennessee Department of Environment and Conservation's (TDEC) Division of Water Control is responsible for issuing and posting fish advisories. Evaluating fish tissue problems in the state of Tennessee involves a multi-agency effort, comprised of DOE, EPA, TDEC, the Tennessee Wildlife Resources Agency (TWRA), and the Tennessee Valley Authority (TVA). An abundance of data are available on contaminants in fish in these systems, including data collected by TVA, DOE, TWRA, and TDEC. These agencies use Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) criteria to analyze fish tissue in these waterways, which applies EPA

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		risk assessment to evaluating potential exposures to contaminants in fish. DOE, TDEC, and EPA have responsibilities under CERCLA, but the state has ultimate responsibility for the advisories. The state fish advisories are available at http://www.state.tn.us/twra/fish/contaminants.html. It is important to understand that although radionuclides and other contaminants might be present in fish in the Clinch River and the Lower Watts Bar Reservoir, **only PCBs** have been found at levels in particular species of fish that could potentially cause adverse health effects. This is why radionuclides are not part of the advisories for these waterways—they have not been detected at harmful levels in these water systems. These agencies are basing their advisories on numerous data collected over several years by different entities, all of which show that radionuclides are not present in fish in the Lower Watts Bar Reservoir and the Clinch River at levels that could cause adverse health effects. ATSDR's evaluation in this public health assessment concurs with the findings of the state, EPA, and these other entities. In addition, ATSDR is preparing a public health assessment that will evaluate PCB releases from the three main ORR facilities: X-10, Y-12, and K-25. When available, copies of ATSDR's public health assessment on PCBs can be obtained by contacting ATSDR's Information Center toll-free at 1-888-422-8737.
Evaluation of Past Exposures		
10	Page 4, lines 18–20: ATSDR should provide the rationale for the conclusion that "Because of conservative parameters used by the Task 4 team, the calculated risk and true exposure would not be underestimated for people who actually lived in the community." As currently presented, this is an opinion that is not supported either by the analysis of the Task 4 report in Sect. III.B or by the summary in Appendix D. It is an important conclusion that deserves to be fully documented.	The comment is noted. To align the text more with the statements in the Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report), this text was changed to the following in the final PHA: "The Task 4 team used conservative screening parameters with the intention of calculating estimates of risk that are not likely to underestimate the actual risk to any exposed individual. Meaning, for each radionuclide and exposure pathway evaluated, the Task 4 team expected these calculated estimates to overestimate the risk for most or all real individuals."
11	There are several problems with the analysis, the first of which is that ATSDR ignored doses to organs/tissues other than bone surface, lower large intestine, red bone marrow, the female breast, and skin in calculating the effective dose (their whole-body dose). ATSDR's approach to dose estimation was seriously flawed because it ignored dose contributions to organs and tissues other than those currently listed in Table 11. Thus, until those flaws are corrected, the above comments, which were based on the erroneous (incomplete) sets of doses, are superfluous.	The effective dose is the sum of the dose received by all organs of the body. The equivalent dose is the dose received by specific organs. This approach varied in the public health assessment depending on the specific radionuclides being evaluated. See Section III. Evaluation of Environmental Contamination and Potential Exposure Pathways in the final PHA for more specific information on this evaluation. ATSDR uses the critical organ concept. The critical organ, as defined by the International Commission on Radiological Protection (ICRP), is the organ receiving the highest radiation dose following an intake of radioactive material. Basically, the critical organ is the organ or organ system most susceptible to radiation damage resulting from the specific exposure conditions being evaluated. This concept also takes into account the dose received by

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		various parts of the body under these exposure conditions. For its public health evaluation of past exposures (those referenced by the commenter), ATSDR considered the contaminants of concern for X-10 radionuclide releases to White Oak Creek and chose the organ systems based on this critical organ concept. For the dose assessment, ATSDR looked at the following critical organs: bone, lower large intestine, red bone marrow, breast, and skin. For example, cesium 137 is a whole-body issue. It is distributed fairly uniformly throughout the body, with the intestines receiving the highest radiation dose. Strontium 90, however, is considered a bone-seeking radionuclide because while about 70-80% of the amount of ingested strontium 90 passes through the body, nearly all of the remaining 20–30% of strontium 90 is absorbed and deposited in the bone.
	They simply divide this value by 48 (number of years of exposure) to estimate an annual average dose to the whole body. Their approach yielded an annual average dose to the whole body of ~4 mrem/year (which is based primarily on the doses to a Category I fish eater who consumed fish caught near Jones Island). They then compare this value with the "100-mrem per year dose recommended for the public" by ATSDR, the ICRP, the NRC, and the NCRP, and reach the obvious conclusion that this annual dose is small in comparison to the recommended dose (limit).	The method described by the commenter is used as a first approximation of the annual dose. This method is generally used by many agencies, including the U.S. Environmental Protection Agency (EPA), the U.S. Department of Energy (DOE), and the U.S. Nuclear Regulatory Commission (NRC) in determining the accumulated dose in the first year following an intake. This issue was discussed at several Exposure Evaluation Work Group meetings (EEWG, formerly known as the Public Health Assessment Work Group [PHAWG]) and at the Oak Ridge Reservation Health Effects Subcommittee (ORRHES) meetings where the screening process was discussed. The reason for dividing the total dose by 48 years (for certain exposure scenarios, ATSDR divided the total dose by a different number of years; see Table 10 in the final PHA for these specific scenarios) was to establish a first approximation of the dose, as this would allow for comparison to the 100 mrem/year dose limit recommended for the public by the ICRP, the National Council on Radiation Protection and Measurements (NCRP), the NRC, and ATSDR. ATSDR approximated the annual whole-body dose for each pathway by applying weighting factors to the Task 4's estimated 50th percentile organ-specific doses, adjusting for a 1-year exposure, and summing the adjusted organ doses across each pathway. The first approximation value of 4.0-mrem/year for past exposures is 25 times less than the 100 mrem/year dose limit recommended for the public. Because this approximated value is so much lower than the dose limit recommended for the public during the screening-level evaluation, no further actions were necessary. Had the approximation shown an annual dose close to 100 mrem/year, ATSDR would have re-assessed the evaluation and conducted further investigation.
	However, doses for an essentially complete suite of organs/tissues were provided in Appendix 13A in the Task 4 report. When a complete accounting of organ/tissue doses is made using 50th percentile estimates in conjunction with the tissue weighting factors given in Table 6 of the PHA, the average annual dose to male and female Category I fish eaters over the 1944–1991 exposure period increases to 9.4 mrem/year and 6.4	Yes, this is correct. Even when using different calculations and including all organs and tissues evaluated in the Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report) to estimate doses for the worst-case exposure scenario (i.e., a Category I fish consumer near Jones Island), the annual doses would still be more than 10 times less than 100 mrem/year—the radiation dose limit recommended for the public by the NCRP, NRC, and ICRP. Thus, even when different

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	mrem/year, respectively, or, on average, about twice what ATSDR calculated.	calculations are applied, the commenter still calculated an estimated dose significantly below the 100 mrem/year recommended dose limit.
12	Page 5, paragraph 3: The authors focus exclusively on 50th percentile estimates of "whole-body doses" and derived annual average dose, while their analysis of the Task 4 report in Sect. III.B covers critical, but incomplete, information on a suite of doses to individual organs/tissues. Furthermore, the summation of 50th percentiles as point estimates will underestimate the median value for the total dose and risk. The ATSDR PHA uses statistically inappropriate procedures for dose summation of annual doses. The original Task 4 report produced 95% credibility intervals for all dose and risk estimates. The central value of these intervals was the median, 50th percentile of the underlying probability distribution or obtained from a quantitative uncertainty analysis. Using median values as point values to sum each annual dose to produce a lifetime cumulative dose will underestimate the median value of the cumulative dose. When estimating risk for individuals exposed to radiation, the full credibility interval of dose is more scientifically appropriate than the central value. The arithmetic mean of that distribution is more appropriate than the median value for estimating the average dose and risk to a group of exposed individuals. The mean value of risk is the summarization of the full weight of evidence that cancer could be induced due to exposure. There is the potential for substantial underestimation of annual doses and cumulative lifetime effective whole body doses to maximally exposed persons. This issue is exacerbated by ignoring 95% credibility intervals on the dose estimates reported in the original Task 4 report and by failure to sum across all of the organs irradiated through ingestion of Cs-137. For most organs, the dose is the result of ingestion of Cs-137. Thus, the whole-body dose and the organ-specific doses are nearly identical. There is some additional dose to the bone and red bone marrow contributed by ingestion of Sr-90 and to the gastrointestinal tract from ingestion of Ru-106. It is the range of doses (represented by the 95% credibility intervals provided in the Task 4 report) that should have been used in the ATSDR analysis. A value based solely on a 50th percentile estimate is an	Contrary to this commenter's opinion, using the full estimated interval of the dose is not more scientifically appropriate than the 50th percentile estimate when evaluating health effects from exposure. Instead, use of the full interval of the dose or the central estimates depends on the realistic, site-specific exposure conditions about the actual or likely exposures evaluated. Further, use of the upper-bound value artificially increases the risk: the calculated uncertainty in many cases is at least an order of magnitude or greater than the 50th percentile value. In this public health assessment ATSDR uses the central values because they provide the most realistic doses for potential exposures to radionuclides in the Clinch River and the Lower Watts Bar Reservoir. Central estimates describe the risk or dose for a typical, realistic individual. The goal of the health effects evaluation is to decide whether harmful health effects might be possible in the exposed population by weighing the scientific evidence and by keeping the site-specific doses in perspective. When considering central estimates, half of the potential doses will fall above and half will fall below the estimate. Therefore, an individual's actual dose would be most likely closer to the central value than near the high or low end of the dose estimate range. In fact, ATSDR's external reviewers who evaluated documents associated with the Oak Ridge Dose Reconstruction recommended emphasizing the central estimate rather than the upper and lower bounds of the dose distribution. For its evaluation of past exposures to X-10 radionuclide releases via White Oak Creek, ATSDR used a dose methodology and considered the 50th percentile estimates provided in the Task 4 report (available at http://www2.state.tn.us/health/CEDS/OakRidge/WOak1.pdf). The Task 4 team, on the other hand, used a risk model and the upper 95th percentile dose and risk levels. Nonetheless, even using different approaches, ATSDR came to the same basic conclusions as described below. According to page 15-2 of the Task 4 report, "The highest exposures, doses, and estimated lifetime risks of excess cancer incidence were from the ingestion of contaminated fish. The most highly contaminated fish would have been harvested in the vicinity of CRM [Clinch River Mile] 20.5, near Jones Island." Further, according to page 13-18 of the Task 4 report, "For the Jones Island area (CRM 20.5), the large total risk from ingestion of fish for the Category I consumer is considered by the study team to be a conservative estimate, because the likelihood is small that someone consumed that mush fish from only the Jones Island area." On page 15-4 of the Task 4 report, the authors' state: that "The radiological doses and excess lifetime cancer risks estimated in this report are incremental increases above those resulting from exposure to natural and other anthropogenic sources of

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	insufficient estimator of true dose and subsequent risks. When the average annual effective doses are derived using the 95th percentile estimates of doses over the 48-year exposure period, the values for both male and female Category I fish consumers fall in the 75–80 mrem/year range (or ~4 rem/40 mSv over 48 years). Although the average annual doses for female fish consumers based on the 50th percentile dose estimates are lower than those for males, the ratios of the 95th to the 50th percentile significantly higher for females (cf. values in Table 13.A.1 and 13.A.4 in the Appendices to the Task 4 report). These 95th percentile dose estimates are fairly close to the annual 100-mrem dose (limit) used as a Minimum Risk Level "Comparison Value" by the ATSDR.	radiation. Nevertheless, for the exposure pathways considered in this task, the doses and risks are not large enough for a commensurate increase in health effects in the population to be detectable, even by the most thorough of epidemiological investigations. In most cases, the estimated organ-specific doses are clearly below the limits of epidemiological detection (1 to 30 cSv [centisievert]) for radiation-induced health outcomes that have been observed following irradiation of large cohorts of individuals exposed either in utero, as children, or as adults." "Even in the case of Category I consumers of fish, the upper confidence limits on the estimated organ-specific doses are below 10 cSv, and the central values are below 1 cSv. The lower confidence limits on these doses are well below levels that have been considered as limits of epidemiological detection in studies of cohorts of other exposed populations. The large uncertainty, combined with the small number of individuals comprising Category I consumers, diminishes the statistical power available to detect a dose response through epidemiological investigation. Therefore, it is unlikely that any observed trends in the incidence of disease in populations that utilized the Clinch River and Lower Watts Bar Reservoir after 1944 could be conclusively attributed to exposure to radionuclides released from the X-10 site, even though this present dose reconstruction study has potentially identified increased individual risks resulting from these exposures." Also, the Task 4 report was reviewed by the Oak Ridge Health Agreement Steering Panel (ORHASP)—a panel of experts and local citizens appointed to direct and oversee the Oak Ridge Health Studies. On page 12 of the ORHASP's final report titled *Releases of Contaminants from Oak Ridge Facilities and Risks to Public Health* (available at http://www2.state.tn.us/health/CEDS/OakRidge/ORHASP.pdf), the panel determined, "Although the White Oak Creek releases caused increases in radiation dose, the calculated exposures were small, and less than one excess cancer is expected." In addition, on page 38 of the ORHASP report regarding the number of health effects that would be expected from exposure to X-10 radionuclide releases via White Oak Creek, the panel estimates "less than one excess cancer case from 50 years of contaminated fish consumption" would result. On page 147 of the final public health assessment, "ATSDR concludes that exposures to X-10 radionuclides released from White Oak Creek to the Clinch River and to the Lower Watts Bar Reservoir are not a health hazard. Past and current exposures are below levels associated with adverse health effects and regulatory limits. Adults or children who have used, or might continue to use, the waterways for recreation, food, or drinking water are not expected to have adverse health impacts due to exposure. ATSDR has categorized those situations as posing *no apparent public health hazard* from exposure to radionuclides related to X-10. This classification means that people could be or were exposed, but that their level of exposure would not likely result in adverse health effects."

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		Thus, even though ATSDR used a dose methodology and considered the 50th percentile estimates, while the Task 4 team used a risk model and the upper 95th percentile dose and risk levels, ATSDR came to the same basic conclusion. ORHASP found that less than one excess cancer case would be expected to occur as a result of exposure to X-10 radionuclide releases via White Oak Creek; ATSDR concluded that this exposure was not expected to cause adverse health effects.
	The premise that best estimate (mean or median) values are inadequate for communicating with the general public is another statement based on facts not in evidence. The public has little appetite for statistics that they don't think they need. What they do want is straight answers, not maybes. Median values give the public what they want and expect.	Thank you for your comment. As described above, we agree that using the 50th percentile estimates provide a much more realistic framework for evaluating exposures to the public.
13	The annual variation in risks from consumption of 1 lb of fish caught near Grassy Creek (CRM 14) from 1944–1991, given in Table 13.11 of the Task 4 report, can be used as a surrogate for the variation over time in doses resulting from consumption of fish caught near Jones Island. Doses (risks) estimated in this manner for the period 1944–1948 were three times greater than the average [which was estimated from the sum of risks for each year in the period given in the table (2.4×10^{-6}), divided by 48 years]. Thus, the upper credibility limits of doses to all Category I fish consumers of fish caught near Jones Island during 1944–1948 would be about 230 mrem/year, and thus well above the dose (limit) used for comparative purposes by the ATSDR. The upper credibility limits of the dose estimates calculated in this way fall to less than 100 mrem/year (averaging ~40 mrem/year) during the period from 1950–1953. They increase again during 1954–1959 to average levels that are nearly identical to those incurred during 1944–1949. Not surprisingly, the peak releases of Cs-137, which is the primary contributor to the dose from fish consumption and to the doses from several other pathways (see Tables 13.8 and 13.9 in the Task 4 report), took place during the years 1944–1949 and 1954–1959 (see Table 2 and Fig. 21 in the ATSDR PHA). Based on the information presented in the SENES Oak Ridge, Inc., Task 4 Report, in Table 13.11 (Annual risk / lb of fish at CRM 14), Fig. 13.3 (Comparison of risks at different CRM), Table 12.11 (Risk coefficients), and Page 13-4 (fish consumption rates for different categories of people), I can state that the upper bound of doses from fish consumption at CRM 20.5 (Jones Island) and CRM 14.0 exceeded 100 mrem/yr in some years (e.g., 1946, 1956) for people in fish consumption Categories I (about 20	Because the use of the upper bound value artificially increases the risk as the calculated uncertainty in many cases is at least an order of magnitude or greater than the 50th percentile value, ATSDR used the 50th percentile (central) value from the Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report). The values calculated by ATSDR are in line and agree with the Task 4 values, even though the methods of analyses were different (see the response to comment 12 for more information on how these different methods were used to develop the same basic conclusions). ATSDR uses the central values in this public health assessment because they provide the most realistic doses for potential exposures to radionuclides in the Clinch River and the Lower Watts Bar Reservoir. Central estimates are used because they describe the risk or dose for a typical person. When considering central estimates, half of the potential doses will fall above and half will fall below the estimate. Therefore, a person's actual dose would most likely be closer to the central value than near the high or low end of the range of dose estimates. In fact, ATSDR's external reviewers who evaluated documents associated with the Oak Ridge Dose Reconstruction recommended emphasizing the central estimate rather than the upper and lower bounds of the dose distribution. As noted above, the commenter is using the maximum annual dose calculated from the upper 95th percent confidence level in the Task 4 Report. This unrealistic, upper-bound value artificially increases the doses. Although this method may be appropriate for regulatory matters, ATSDR uses the central values (50th percent or mean value). The agency believes this is a more realistic expression of the potential for exposure and resulting dose. The scenarios associated with using the upper-bound (95% confidence level) to estimate the maximum annual dose would require over many years almost daily intakes of the maximum concentrations found in water and fish associated with a specific location around Jones Island.

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	kg/yr) and II (10 kg/yr). Doses from drinking water or from external exposure to contaminated sediments are not included in these tables. Using a nominal radiogenic lifetime risk of cancer incidence of 8% per Sv, and dividing into the reported upper bound risk levels (which are the result mostly of uncertainty associated with exposure to Cs-137) indicates that individual cumulative whole body doses could have been larger than the ATSDR whole body radiogenic cancer CV of 5000 mrem. Given that the peak exposures occurred within two five-year periods between 1944 and 1959, it can be shown that the maximum annual doses could have exceeded 100 mrem/y during these years. By contrast, the annual dose reported in the ATSDR PHA is 4 mrem. ATSDR does not acknowledge that there are large uncertainties in these estimates, and that, because of large variations in releases from White Oak Creek over time, annual doses to individuals exposed in the 1940s and 1950s, when releases were at their highest levels, would have been significantly higher than values based on an average dose over 48 years. In his opinion, inappropriate averages were being used to present a positive view of the results. When the increased levels of annual releases and exposure (i.e., consumption of fish caught during the 1940s and 1950s when releases were much higher than the average) are factored into the analysis, effective doses exceed the 100-mrem per year dose limit at the upper limit of the 95% credibility interval of the annual dose received via all pathways of exposure.	The nominal cancer risk factor used by many regulatory agencies, including the U.S. Environmental Protection Agency (EPA), the U.S. Nuclear Regulatory Commission (NRC), and the U.S. Department of Energy (DOE), is 5%—not 8% as indicated by the commenter. The 8% includes cancer, hereditary effects, and other non-specific risks. The method described by the commenter is used as a first approximation of the annual dose. The EPA, NRC, and DOE generally use this method in determining the accumulated dose in the first year following an intake. This issue was discussed at several Exposure Evaluation Work Group meetings (EEWG, formerly known as the Public Health Assessment Work Group [PHAWG]) and at the Oak Ridge Reservation Health Effects Subcommittee (ORRHES) meetings where the screening process was discussed. The reason for dividing the total dose by 48 years (for certain exposure scenarios, ATSDR divided the total dose by a different number of years; see Table 10 in the final PHA for these specific scenarios) was to establish a first approximation of the dose. This would allow for comparison to the 100 mrem/year dose limit recommended for the public by the International Commission on Radiological Protection (ICRP), the National Council on Radiation Protection and Measurements (NCRP), the NRC, and ATSDR's minimal risk level (MRL). Furthermore, as specified in ICRP Publication 60, "The limit should be expressed as an effective dose of 1mSv [millisievert] [100 millirem] in a year. However, in special circumstances a higher value of effective dose could be allowed in a single year, provided that the average over 5 years does not exceed 1 mSv per year." ATSDR approximated the annual whole-body dose for each pathway by applying weighting factors to the Task 4's estimated 50th percentile organ-specific doses, adjusting for a 1-year exposure, and summing the adjusted organ doses across each pathway. The first approximation value of 4.0 mrem/year for past exposures is 25 times less than the 100 mrem/year dose limit recommended for the public by the ICRP, NCRP, and NRC. Because this approximated value was so much lower than the dose limit recommended for the public during the screening-level evaluation, no further actions were necessary. Had the approximation shown an annual dose close to 100 mrem/year, ATSDR would have re-assessed the evaluation and conducted further investigation.
14	P. 57. Line 23 et seq. The quoted conclusion from the ORHASP report about past releases and harm need to be reconciled with the conclusions of this report.	The comment is noted. The following text was added to clarify that these risks were not associated with radionuclides from X-10, but with elevated mercury and PCB concentrations: "ORHASP noted, however, the Task 4 report determined that following exposure to fish contaminated with X-10 radionuclides via White Oak Creek, less than one excess cancer case was expected. Studies also indicate that elevated PCB concentrations drove the health risks associated with eating fish from the Clinch River and Watts Bar

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		Reservoir."
15	Page 84, Table 9. Summary of Estimated Organ-Specific (Equivalent) Radiation Doses For Past Exposure Pathways. One more overly complex and undecipherable table. Stakeholders are wondering if this is intentional on ATSDR's part. Is ATSDR attempting to bury critical information in technical jargon and a cobbling of critical exposure information? If this is not, in fact intentional on ATSDR's part, it certainly is obscuring to the stakeholders. Most stakeholders hold little hope that ATSDR can improve its public health practice without a sea change in both its cooperate attitude and its senior management. *(Comment received on the initial release PHA dated December 2003.)*	This table was changed in subsequent revisions and is presented in the final PHA as Table 11. Summary of Estimated Organ-Specific Doses and Whole-Body Doses for Each Past Radiation Exposure Pathway and the Estimated Lifetime Organ-Specific Doses and Lifetime Whole-Body Doses From All Past Radiation Exposure Pathways. This table provides the whole-body and organ-specific doses for all of the pathways of interest in the Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report). ATSDR is unclear on what information could be buried in this table and on what "technical jargon" is used. Without more information or specific details on what is undecipherable, ATSDR is not sure what changes could be made. But please note that the table has been completely modified since December 2003. It now consists of numbers (doses) only and provides footnotes to explain how the doses were calculated and where the information was obtained from (various tables in the Task 4 report). ATSDR believes that the table provides necessary information on these doses and how they were calculated. For more information, please refer to the Task 4 report available online at http://www2.state.tn.us/health/CEDS/OakRidge/WOak1.pdf and see Appendix D for a brief on the 1999 Task 4 report. Copies of the Task 4 report are also available at the DOE Information Center located at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee (telephone number: 1-865-241-4780).
16	P. 84. Table 11. A preliminary check of the organ doses, weighting factors, products, and sums (effective doses), between the Task 4 report and this report indicates that the numbers given in this report have been abbreviated with respect to those given in the Task 4 report. Therefore, it is not obvious that the numbers supposedly leading to the stated effective doses given in this report are numerically consistent, by themselves, with their stated relationship. Consequently, this will have to be demonstrated by a table of doses, weighting factors, products, and sums that, by calculation, actually agree with the results given on p.84. Otherwise, the stated results given in this report will have greatly diminished credibility.	The only difference between the tables is that Table 11 in the final PHA presents the doses in millirem, whereas the Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report) uses centisieverts. For example, in Table 13.3 on page 13-6 of the Task 4 report, the Category I bone dose for male fish consumers is 0.81 centisieverts, which is 0.81 rem or 810 millirem—the value presented in Table 11 of the final PHA. Instead of creating another table, a footnote has been added to Table 11: "To compare the doses in the Task 4 report to the doses in this table, 1,000 mrem is equal to 1 centisievert (cSv). For example, 810 mrem (organ-specific radiation dose to the bone for fish ingestion at Jones Island) divided by 1,000 would equal 0.81 cSv—the same value presented in Table 13.3 of the Task 4 report."
17	Page 84, table 11: The values given in Columns 2–6 in the last row of the table bear little or no relationship to the information upon which they were reportedly based. For example, if we apply ATSDR's formula to estimate a 70-year organ/tissue dose for bone (surface), we get a value of 1181 mrem from ingestion of fish caught near Jones Island alone. If we include	As a conservative measure, ATSDR recalculated the estimated committed equivalent doses presented in Table 11 to account for individuals who could have been exposed via all of the pathways and at all of the locations presented in the table. To approximate a committed equivalent dose to an organ over 70 years, ATSDR summed the organ-specific radiation doses from the Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge

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	the lowest estimates of doses to bone from the other exposure pathways, we obtain an additional dose of ~24 mrem. The sum of these two doses exceeds 1200 mrem. If we perform the same exercise for the data in Columns 3 and 4, the totals are <900 mrem. The values in Columns 5 and 6 in the last row of the table would make sense if they were reversed.	Dose Reconstruction (Task 4 report) based on up to 48 years of exposure (for certain exposure scenarios, the dose was based on a different number of years; see Table 10 in the final PHA for these specific scenarios)—divided by 48, multiplied by 70 years, and rounded up.
18	Page 85, lines 8–9 (also Page 5, line 9), 11: The statement needs to be revised to say "at least 6 times greater ... from drinking water ingestion, eating meat and milk, and via external radiation." The doses to both the breast and the skin from external radiation at Kingston were about 6.5 times those from eating fish (Table 12), and drinking water ingestion was omitted from the original listing of pathways. The table reference in line 11 should have been to Table 11, and not to Table 10.	Once the worst-case drinking water ingestion dose at K-25/Grassy Creek is incorporated into this statement, it would be "6 times greater." The change was made in the final PHA. Also, we believe the commenter meant to say "about 6.5 times *less than* those from eating fish." Thank you for the comment. The change was made in the final PHA.
19	Page 87, paragraph 3: Where are the data for the dose calculations to Happy Valley residents presented? Based on what is said, it is clear that the 50th percentile estimates of annual doses from fish consumption would have been about 35 mrem/year. By analogy with the comments on the material in paragraph 3 on page 5, 95th percentile estimates of the effective doses would have exceeded the 100 mrem/year criterion and the 95th percentile estimates of the organ/tissue doses would undoubtedly have exceeded the 5000 mrem total dose criterion as well (see results for the Grassy Creek Area, Clinch River Mile 14, in Table 13.A).	As a note of clarification, the commenter is making statements regarding "fish consumption" related to ATSDR's evaluation of Happy Valley residents in the PHA. To clarify, this part of Section III in the PHA refers to **drinking water ingestion** for Happy Valley residents, not fish consumption. Consequently, the commenter's statements do not apply to the referenced section of the document. Regarding this drinking water evaluation, the Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report) conducted an analysis of exposure to X-10 contaminants via the K-25 water intake, but not a separate analysis for residents living in the Happy Valley settlement such as ATSDR conducted in this public health assessment (described on pages 90–91 of the final PHA). ATSDR used the 50th percentile of the modeled radioactivity concentrations in the Grassy Creek area of the Clinch River from the Task 4 report. Given ATSDR's derived annual whole-body doses for these residents, the highest annual radiological dose to a hypothetical Happy Valley resident (residing there from 1944 to 1950) from drinking water from the K-25 water intake was 14 mrem or 98 mrem over the 7-year period. This annual dose is at least seven times less than the 100 mrem/year dose recommended for the public by the International Commission on Radiological Protection (ICRP), the National Council on Radiation Protection and Measurements (NCRP), and the U.S. Nuclear Regulatory Commission (NRC). See Sections III.B.2. and IV.B. in the final PHA for more details.
20	Page 111, table 22: This table presents the summed doses from Table 11, which are erroneous as discussed above, in Column 3; the ATSDR criteria used to assess whether the doses represent a health hazard in Column 4;	As a conservative measure, ATSDR recalculated the estimated committed equivalent doses presented in Table 11 to account for individuals who could have been exposed via all of the pathways and at all of the locations presented in the table. To approximate a committed

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	the results of the comparison (Column 5); and the conclusion that these (1) are not likely to cause adverse health effects and (2) that releases from White Oak Creek were not a public health hazard. Because the doses are in error, for reasons given above, all of the comparisons and the conclusions need to be revised. In addition, the implication that these releases could not have caused <u>any</u> adverse health effects in at least some exposed individuals is improper, and should be purged from the document, along with other such statements, for reasons discussed earlier.	equivalent dose to an organ over 70 years, ATSDR summed the organ-specific radiation doses from the Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report)—based on up to 48 years of exposure (except where noted in Table 10 of the final PHA)—divided by 48, multiplied by 70 years, and rounded up. These changes have been reflected in Table 22. Still, even with considering potential exposures via all of the pathways and at all of the locations presented in Table 11, all estimated doses are below levels shown to cause adverse health effects. Based on our evaluation in this public health assessment, ATSDR concludes that exposures to X-10 radionuclides released from White Oak Creek to the Clinch River and to the Lower Watts Bar Reservoir are not a health hazard. Past and current exposures are below levels associated with adverse health effects and regulatory limits. Adults or children who have used, or might continue to use, the waterways for recreation, food, or drinking water are not expected to have adverse health impacts due to exposure. ATSDR has categorized those situations as posing *no apparent public health hazard* from exposure to radionuclides related to X-10. This classification means that people could be or were exposed, but that their level of exposure would not likely result in any adverse health effects. This commenter is incorrect in implying that the document states "these releases could not have caused <u>any</u> adverse health effects." This is clearly evident by the use of the *no apparent public health hazard* conclusion category in this public health assessment. ATSDR uses this category in situations in which human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure **is not expected** to cause any harmful health effects. Therefore, ATSDR is not saying that these releases could not have caused any health effects. On the contrary, we are saying that radiation exposure is possible, but that this exposure is not expected to result in adverse health effects.
21	The ATSDR PHA states that dose estimates in the original Task 4 report of the Oak Ridge Dose Reconstruction were conservative (i.e., likely to overstate true doses to real persons). This conclusion is not true. The Task 4 report was specifically designed to produce realistic dose and risk results for reference individuals, fully accounting for the presence of multiple sources of uncertainty. The uncertainty about central values of dose is substantial, approaching a factor of 10 or more about the 50th percentile value. It has published the conclusion that our past work produced "conservative" estimates of dose without justification. Our estimates of doses to	In the Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report), the authors state that they used measured concentrations when available. But if these data were not available, estimations were made via the use of modeled parameters. These estimations were subjective probability distributions as discussed in Chapter 4 of the task report. Given the nature of the subjective analyses, ATSDR believes these to be appropriately conservative in nature and application. As discussed in NCRP Commentary 14 entitled A Guide for Uncertainty Analysis in Dose and Risk Assessments Related To Environmental Contamination, a quantitative uncertainty analysis, "usually requires that the state of knowledge about the uncertain components of the mathematical model be described by probability distributions." If this knowledge is

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	representative individuals as the result of past operations at ORNL were made without the intent to bias the conclusions in a manner that would overestimate the true exposure. This is precisely why we embraced the application of quantitative methods of uncertainty analysis. The summary document indicated that the Task 4 Report was inherently conservative. In his opinion, he said, this means that there is an inherent bias towards overstating the truth of unknown exposure or risk, which according to him, was not true and was the reason quantitative uncertainty analysis was used in the approach.	unavailable, then professional judgment is used to evaluate the site-specific parameters. NCRP Commentary 14 also states that if the results of an assessment indicate that doses are below regulatory limits, then a quantitative uncertainty analysis may not be necessary. The Task 4 report used conservative parameters to estimate a 95% confidence interval for risks and doses from past exposures to X-10 radionuclides released to White Oak Creek. ATSDR calculated doses using the findings of the Task 4 report, and obtained estimated doses that were well below very conservative, regulatory limits. In developing their conclusions, the Task 4 authors used a worst-case scenario considering the upper confidence limits for the highest fish consumers ingesting fish caught near Jones Island (the study area with the highest detected radionuclide concentrations). Even using this worst-case scenario, the Task 4 authors concluded that "the upper confidence limits on the estimated organ-specific doses are below 10 cSv [centisievert]…," which lies in the range that the authors describe as "clearly below the limits of epidemiological detection (1 to 30 cSv) for radiation-induced health outcomes that have been observed following irradiation of large cohorts of individuals…" Therefore, even considering this worst-case scenario, the Task 4 authors found that "…for the exposure pathways considered in this task, the doses and risks are not large enough for a commensurate increase in health effects in the population to be detectable, even by the most thorough of epidemiological investigations." NCRP Commentary 14 also states that, following an uncertainty analysis, if the 95th percentile exceeds a standard or regulatory limit and the 50th percentile is less than the standard or regulatory limit, then additional evaluations may be recommended (page 23). ATSDR performed this additional evaluation and concluded that the more reasonable result was that the doses received from the intake of potentially contaminated foods (the pathway yielding the highest doses) were below regulatory limits and levels of a public health hazard. Even if doses from all other pathways evaluated were combined with the ingestion pathway, the doses were still sufficiently low and below levels where tolerable and observable adverse health effects would be expected.
22	The belief that the contents of the Task 4 report have not been considered is not accurate, certainly with respect to the Exposure Evaluation Work Group (EEWG). I presented the chain of logic used to develop best estimate (median) values of dose and risk in the Task 4 report to the then Public Health Work Group (PHAWG) on July 19, 2004. This information was supplementary to the attention given to the Task 4 report by the authors of the White Oak Creek PHA. The work of the EEWG is a team effort. Individuals do not seek credit for their comments on the draft PHAs.	Thank you for your comment.

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23	There are major technical inaccuracies, misinterpretations, and omissions in the dose and risk information obtained from the original Oak Ridge Dose Reconstruction (Task 4) reports. The most serious of these issues involve the lack of consideration of information on uncertainty in dose and risk, the failure to report individual risk estimates, the failure to report the 95% credibility intervals on dose and risk, and lifetime averaging of doses over the entire period of release, obscuring the relatively high annual doses for the early years of release (1944-1949, 1954-1959) to give the impression that annual doses were acceptably small.	ATSDR did not omit, misrepresent, or have technical inaccuracies in the information used from the Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report) for the evaluation in this public health assessment. The dose information obtained from the Task 4 report was accurate and data relevant to this evaluation were not omitted. ATSDR evaluated the need for an uncertainty analysis as outlined in NCRP Commentary 14 titled *A Guide for Uncertainty Analysis in Dose and Risk Assessments Related to Environmental Contamination.* In essence, the use of conservative and biased screening calculations indicated the possible resulting dose would be clearly below a regulatory limit. "Conservative screening calculations are designed to provide a risk estimate that is highly unlikely to underestimate the true dose or risk. Therefore, a more detailed analysis will likely demonstrate that the true risk is even less." The document states that screening can be considered among the first steps in conducting an uncertainty analysis as this roughly defines the upper and lower bounds of a distribution of exposed populations or individuals. If these screening calculations are to be used successfully, a decision point has to be determined to establish the boundary at which no further analyses are necessary. According to NCRP Commentary 14, "For example, for dose reconstruction, the National Academy of Sciences has suggested that an individual lifetime dose of 0.07 Sv [sievert] be used as a decision criterion for establishing the need for more detailed investigation (NAS/NRC 1995 [National Research Council. 1995. Radiation dose reconstruction for epidemiologic uses. Committee on an assessment of CDC radiation studies. Board on Radiation Effects Research, Commission on Life Sciences. Washington, DC: National Academy of Sciences.])." A value of 0.07 Sv is equivalent to 7 rem or 7,000 mrem—a value that is 40% higher than ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years. Thus, ATSDR's screening value is more conservative than the criteria suggested by the National Academy of Sciences as reported by the NCRP. Regarding risk estimates, please see Appendix F in the final PHA and the response to comment 44 within this appendix. ATSDR uses the central values—not the upper-bound value of the dose estimates—because these provide the most realistic doses for potential exposures to radionuclides in the Clinch River and the Lower Watts Bar Reservoir. Central estimates are used because they describe the risk or dose for a typical, realistic individual. When considering central estimates, half of the potential doses will fall above and half will fall below the estimate. Therefore, an individual's actual dose would most likely be closer to the central value than near the high or low end of the range of dose estimates. In fact, ATSDR's external reviewers who evaluated documents associated with the Oak Ridge Dose Reconstruction

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		recommended emphasizing the central estimate rather than the upper and lower bounds of the dose distribution. The method described by the commenter is used as a first approximation of the annual dose. This method is generally used by many agencies, including the U.S. Environmental Protection Agency (EPA), the U.S. Department of Energy (DOE), and the U.S. Nuclear Regulatory Commission (NRC) in determining the accumulated dose in the first year following an intake. This issue was discussed at several Exposure Evaluation Work Group meetings (EEWG, formerly known as the Public Health Assessment Work Group [PHAWG]) and at the Oak Ridge Reservation Health Effects Subcommittee (ORRHES) meetings where the screening process was discussed. The reason for dividing the total dose by 48 years (for certain exposure scenarios, ATSDR divided the total dose by a different number of years; see Table 10 in the final PHA for these specific scenarios) was to establish a first approximation of the dose, as this would allow for comparison to the 100 mrem/year dose limit recommended for the public by the International Commission on Radiological Protection (ICRP), the National Council on Radiation Protection and Measurements (NCRP), the NRC, and ATSDR. ATSDR approximated the annual whole-body dose for each pathway by applying weighting factors to the Task 4's estimated 50th percentile organ-specific doses, adjusting for a 1-year exposure, and summing the adjusted organ doses across each pathway. The first approximation value of 4.0 mrem/year for past exposures is 25 times less than the 100 mrem/year dose limit recommended for the public. Because this approximated value is so much lower than the dose limit recommended for the public during the screening-level evaluation, no further actions were necessary. Had the approximation shown an annual dose close to 100 mrem/year, ATSDR would have reassessed the evaluation and conducted further investigation.
Evaluation of Current and Future Exposures		
24	Page 6, Line 17: ATSDR has determined that exposure to the current levels of radionuclides in the surface water, sediment, fish, and game are not expected to cause any harmful health effects in the present and future. Therefore, ATSDR concluded that current and future off-site exposure to radionuclides in the Clinch River and the LWBR via White Oak Creek is not a public health hazard. The statement seems to assume conditions on the ORR will remain static in the future. This does not seem likely, given the longevity (e.g., millions of years) and dynamics associated with many of the contaminants that will be left in place, as well as the complexity of the site as whole. To a large degree, assurance that the health of the public and environment will be	Thank you for your comment. Text in Section I. Summary of the final PHA was changed to the following: "ATSDR's review of environmental data collected in and around the Clinch River and LWBR areas shows that the following practices ▪ annual environmental monitoring, ▪ institutional controls intended to prevent disruption of sediment, ▪ on-site engineering controls to prevent off-site contaminant releases, and ▪ DOE continuing its expected appropriate and comprehensive system of monitoring (e.g., of remedial activities and contaminant levels in media), maintenance, and institutional and engineering controls, have limited exposure to the current levels of radionuclides in surface water, sediment, fish, and game to the point that radionuclides are not expected to cause any current or future

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	protected in the future appears to rely on the demonstrated success of current remedial activities and DOE's commitment to providing perpetual support of a comprehensive system of monitoring, maintenance, and institutional controls. To support that contention that there will be no detectable public health effects from exposures to future WOC radionuclide releases, wording should be added that current remediations and engineering controls at existing operable units in the White Oak Creek watershed must be maintained for the foreseeable future. The future safety of the public is dependent upon a continuing long term stewardship program which will ensure the integrity of the engineering controls that are being installed upstream in Melton Valley and elsewhere. P. 7. Line 4. Concerning future exposures, has ATSDR evaluated the effects of current environmental restoration activities at ORNL?	harmful health effects. Given this evaluation, ATSDR concludes that current and future off-site exposure to radionuclides in the Clinch River and the LWBR via White Oak Creek is not a public health hazard." Similar text was also added to Section IV. Public Health Implications and Section VIII. Conclusions of the final PHA regarding future exposures.
25	P. 34. The conclusions of the baseline risk assessment (Jacobs EM Team 1997b) appear to imply that consuming any fish taken from Poplar Creek, or bass from the Clinch River below Melton Hill Dam, pose a health risk. CRM 20.5 at Jones Island is only about three miles below Melton Hill Dam. How are the Jacobs conclusions to be reconciled with the final conclusions of this report?	Your comment is noted. The text has been clarified to explain that primary risks in DOE's risk assessment were not associated with radionuclides in fish: "The assessment also determined that because of PCB and mercury contamination, the consumption of any type of fish in Poplar Creek posed a health risk. Similarly, consumption of bass from the Clinch River below Melton Hill Dam posed a health risk due to PCB contamination. Still, no primary risks were associated with exposure to radionuclides in fish from the Clinch River or from Poplar Creek."
26	The document should explain why some past waste-disposal sites, which are not current public health concerns, are now subject to remediation. Though expensive, this ensures that long-term safety is maintained and that catastrophic or chronic releases are prevented, or at minimum, detected in a timely manner. It may also be necessary to meet environmental contamination standards which are often more stringent than human health criteria. The rationale of spending money now on currently satisfactory waste disposal scenarios in order to maintain their long-term safety should be explained. How can a responsible party recommend putting off necessary maintenance until after the disaster has occurred? *An ounce of prevention is worth a pound of cure.*	The following text was added to the introductory portion of Section II.C. Remedial and Regulatory History: "Although not current public health concerns, some of these former waste disposal sites are nonetheless subject to remediation. DOE is remediating these sites to ensure long-term safety is and to prevent off-site releases. More information on DOE's environmental management program can be obtained at http://www.oakridge.doe.gov/External/Default.aspx?tabid=42."

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ATSDR's Health Guidelines for Radiation Effects		
27	Similar concerns appear when we look at individual organ or tissue doses, where, in some cases, the upper credibility limit of the cumulative doses exceed the ATSDR's radiogenic cancer "Comparison Value" of 5000 mrem over 70 years. For example, the upper credibility limits of cumulative doses to bone surfaces for individuals of either sex who were Category I consumers of fish caught near Jones Island exceeded 7000 mrem over 48 years. The upper credibility limit of cumulative dose to the lower large intestine for males who were Category I consumers of fish caught near Jones Island was 5200 mrem over 48 years. Upper credibility limits of cumulative doses to red bone marrow for individuals of either sex who were Category I consumers of fish caught near Jones Island were 4800 mrem over 48 years, and the upper credibility limit of the cumulative dose to the lower large intestine for females who were Category I consumers of fish caught near Jones Island was 4500 mrem over 48 years. Addition of doses received via other pathways could increase each of these doses by another 10–20%, and adjusting for a 70-year exposure results in an increase of 46% (see Table 11 on page 84). Thus, the upper credibility limits for the cumulative doses for all of the organs or tissues cited above would exceed the ATSDR's 5000-mrem criterion when extended over 70 years.	ATSDR uses the central values—not the upper-bound value of the dose estimates. These provide the most realistic doses for potential exposures to radionuclides in the Clinch River and the Lower Watts Bar Reservoir. Because the use of the upper-bound value artificially increases the risk as the calculated uncertainty in many cases is at least an order of magnitude or greater than the 50^{th} percentile value, ATSDR used the 50^{th} percentile (central) value from the Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report). The values calculated by ATSDR are in line and agree with the Task 4 values, even though the methods of analyses were different (see the response to comment 12 for more information on how these different methods were used to develop the same basic conclusions). Central estimates describe the risk or dose for a typical, realistic individual. When considering central estimates, half of the potential doses will fall above and half will fall below the estimate. Therefore, an individual's actual dose would most likely be closer to the central value than near the high or low end of the range of dose estimates. In fact, ATSDR's external reviewers who evaluated documents associated with the Oak Ridge Dose Reconstruction recommended emphasizing the central estimate rather than the upper and lower bounds of the dose distribution. When using the central estimates, all estimated doses in this public health assessment were below levels shown to cause observable and tolerable effects. In fact, ATSDR's calculated whole-body dose for past exposures via all pathways was 278 millirem over 70 years—more than 17 times less than ATSDR's radiogenic cancer comparison value of 5,000 millirem over 70 years.
	For whole body exposures, the excess risk of cancer incidence associated with the 5000 mrem CV *exceeds several chances in one thousand*. Consideration of the uncertainty in radiogenic cancer risk, as obtained using the NIH update of the 1985 Radioepidemiological Tables (Land et al., 2003) combined with information on the baseline incidence of cancer from the NCI SEER registry (1973-2002), would show that a cumulative whole body dose of 5000 mrem could approach or *exceed an excess lifetime risk of cancer incidence of one chance in 100* depending on the individual's gender and age during the years of highest exposure. At the dose levels equal to ATSDR's radiogenic cancer CVs, the relative risk of radiogenic cancer could be sufficiently high to warrant compensation and medical care for those who were exposed before the age of twenty and have been diagnosed with cancer a few decades later. [This statement applies only if the same relative risks used for compensating sick DOE workers for Cold War era exposures to radiation	The risk range cited is the typical risk range used by the U.S. Environmental Protection Agency (EPA) in its evaluations of contaminants in the environment. Many of these evaluations may not necessarily be based on health, but could be based entirely on risk assessments. The ATSDR Cancer Policy Framework, adopted in 1993, addresses many factors to be evaluated in analyzing environmental exposures. ATSDR recognizes that, at present, no single generally applicable procedure for exposure assessment is available, and therefore exposures to carcinogens are best assessed on a case-by-case basis with an emphasis on prevention of exposure. "A risk assessment does not measure the actual health effects that hazardous chemicals at a site have on people. Risk assessments are conducted without determination of actual exposure." A PHA "reviews site-related environmental data and general information about toxic chemicals. Then it compares an estimate of the amount of chemical exposure (i.e., dose) to which people might frequently encounter in situations that have been associated with disease and injury. However, unlike a risk assessment, a PHA factors in information from the adjacent community about actual or likely exposures and information from the community about their health concerns."

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	were to be extended to the general public. The National Research Council/National Academies of Sciences (2005) has recently recommended that Congress consider such an extension.] For example, the relative risk would be in the compensable range for a person exposed at age 10 and diagnosed with acute lymphocytic leukemia at age 20, when the whole body dose is 5,000 mrem. In his opinion, implying that there is no public health concern below 5,000 mrem over 70 years is wrong. ATSDR staff health physicists appear to be relying on the advice of others within the Health Physics community who erroneously claim that there is no evidence for increased cancer risk below an effective whole body dose of 10 rem and who urge that risk not be quantified at effective whole body doses below 5 rem in one year or 10 rem lifetime. The possible extent of dose underestimation is large enough that, under some circumstances, both the ATSDR MRL of 100 mrem for exposure in a single year and cancer Comparison Values for the whole body and the lower large intestine (5000 mrem) could have been exceeded.	Therefore, it is not appropriate to base the decision of public health on risk assessment cleanup criteria. See the response to comment 44 for additional information distinguishing a risk assessment from a health assessment. In this public health assessment, ATSDR compares annual doses to the 100 mrem/year dose limit of the International Commission on Radiological Protection (ICRP), the National Council on Radiation Protection and Measurements (NCRP), and the U.S. Nuclear Regulatory Commission (NRC), as well as ATSDR's minimal risk level (MRL). ATSDR compares lifetime doses to the agency's radiogenic cancer comparison value of 5,000 mrem over 70 years, which is based on peer-reviewed literature and other documents developed to review the health effects of ionizing radiation. These values, used as screening tools during the public health assessment process, are levels below which adverse health effects are not expected to occur. If the screening indicates that past or current doses exceed our comparison values, then we would conduct further in-depth health evaluation. ATSDR incorporated safety margins when developing its screening values for radiation exposures. The approach ATSDR uses to derive MRLs, such as those in the Toxicological Profile for Ionizing Radiation, was developed in collaboration with the EPA. The screening value includes the use of a no observed adverse effect level (NOAEL) or a lowest observed adverse effect level (LOAEL) as well as three or more situation-specific uncertainty factors. When multiplied, these factors give a total uncertainty factor generally ranging from 1 to 1,000, based on the studies used. Furthermore, the ATSDR legislative authority, as discussed many times, limits ATSDR to evaluate exposures based on observable and tolerable adverse health effects. If adverse health effects are not observed in an epidemiological study, then the doses used in the study should be considered tolerable. ATSDR's radiogenic comparison value of 5,000 millirem over 70 years incorporates the linear no-threshold (LNT) model for evaluating public health hazards associated with exposure to radiation. It assumes a total lifetime dose (70 years of exposure) above background that is considered safe in terms of cancer induction. In addition to the LNT model, ATSDR also incorporates a margin-of-dose (MOD) approach into this comparison value. During an evaluation, if ATSDR determines that further investigation is needed, scientific literature associated with radiological doses and dose estimates—particularly those related to adverse health effects—is reviewed. Then, ATSDR compares the dose estimates from scientific literature to site-specific dose estimates. Thus, ATSDR uses the LNT model to determine when a more detailed site-specific evaluation is necessary, and uses the MOD approach to develop realistic information for communities regarding what is known and unknown about radiation levels at a particular site.

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		An independent expert panel convened to review site-specific approaches that ATSDR used to evaluate past, current, and future radiation risks to communities surrounding the Oak Ridge Reservation. The panel concluded that this combination of approaches (LNT and MOD) is appropriate for ATSDR to determine radiation levels at which health effects actually occur. The panel found that ATSDR's use of the MRL of 100 millirem and radiogenic cancer comparison value of 5,000 millirem were appropriate screening values. If extrapolated over 70 years assuming constant exposure, the radiogenic cancer comparison value dose estimate would be about 71 millirem per year—a level the panel determined to be protective of public health in terms of cancer and noncancer risks. The panel also concluded that ATSDR's approach considers evidence for both individual organs and whole-body doses (effective doses), noting that a whole-body dose could not be developed without accounting for doses to single organs. Further, the panel determined that ATSDR's method of distinguishing dose levels from risk levels was acceptable because ATSDR incorporated risk and LNT explicitly and implicitly when calculating doses. In the words of one peer reviewer regarding ATSDR's radiogenic cancer comparison value, "The general consensus is that the linear non-threshold hypothesis is scientifically reasonable for the purpose of radiation protection. The recent NCRP comprehensive review and UNSCEAR [United Nations Scientific Committee on the Effects of Atomic Radiation] evaluations do not find any alternative model to be better, including one with a threshold. While epidemiology is not capable of detecting risks in the low dose domain, under say 10,000–20,000 millirem, there are cellular experiments and theoretical reasoning that support a linear response."
	The assertion that there is still significant public health concern for adverse health effects below a lifetime whole body dose of 5000 mrem needs its basis stated explicitly. A report entitled, "Bridging Radiation Policy and Science", from an international conference held in December 1999, (see the citation for Mossman et al. 2000, listed at the top of p.155 of the draft White Oak Creek PHA) states that the lowest dose at which a statistically significant radiation risk has been shown is about 10,000 mrem. The lowest dose from whole body irradiation at which a statistically significant relative risk has been established is less than 10 mGy (less than one rad). This does not mean, however, that health effects from doses below 10 mGy are not to be observed or expected to occur. See recent publications and presentations by Dr. David Brenner from Cornell University. He and Mossman debated each other last summer on this very topic. Mossman lost resoundly.	Thank your for your comment. An extended abstract for the referenced debate and follow-up lecture between Drs. David Brenner and Kenneth Mossman titled *Do Radiation Doses Below 1 cGy Increase Cancer Risks?* is available at http://dceg.cancer.gov/pdfs/travis1636952005.pdf. ATSDR contacted Dr. Mossman who, contrary to this commenter's opinion, stated that the claim that he lost "resoundly" was not shared by everyone attending the American Statistical Association Conference on Radiation and Health meeting (June 2004), including representatives from EPA. As Dr. Mossman stated to ATSDR, "I don't argue that the risk is zero; my view is that the risk is too small to measure reliably." According to the abstract, Dr. Mossman finds that "Direct measurement of risks at very small radiation doses is difficult because of limitations of epidemiological studies to detect risk. Accordingly, risks are estimated by extrapolating from direct observations made at high doses to the low-dose region using predictive theories such as the linear, no-threshold theory. However, estimates are highly uncertain because the required dose extrapolation is

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		very large." "Estimating low-dose risks using very large dose extrapolations strains the credibility of risk assessment. Accordingly, numbers of cancer deaths due to low levels of radiation exposure must be considered speculative; risk estimates at low doses have great uncertainties because they are derived theoretically." "The possibility that there may be no health risks from radiation doses comparable to natural background radiation levels cannot be ruled out; at low doses and dose rates, the lower limit of the range of statistical uncertainty includes zero." Therefore, Dr. Mossman's position on this matter is not in line with the commenter's implication that "health effects from doses below 10mGy are not to be observed or expected to occur." Given the abstract and Dr. Mossman's statement to ATSDR above, his position is that "if risks exist below 1 cGy, they are too small to measure reliably." Also, please refer to the summary of the debate, which states that "the lowest radiation dose associated with statistically significant increased risk remains controversial. Epidemiological studies are not powerful enough to detect risks at doses approximating 1 cGy in the general population because the necessary large populations are not available…although unequivocal evidence of risk is unavailable at very low doses, this does not mean that increased risks do or do not exist. That said, however, if a risk below 1 cGy is present, it is very small for any given individual—the controversial issue being the risk to a large population potentially exposed to these small risks." Furthermore, another radiation expert conveyed to ATSDR that much difficulty is involved in understanding the concept of extrapolated risk "such as 5 extra cancer deaths over a lifetime per 100 million persons exposed to 1 µSv (0.1 mrem)." For example, this expert stated, "It would take more than the world's population of 5 billion persons to be exposed to one gamma ray for even a single excess cancer death to occur. The probability of the event is of the order of one in a million billion, i.e., less than one in a trillion. This probability might be placed in context with the fact that each hour over 200 million gamma rays pass through our bodies as the result of exposure from naturally occurring radiation in the soil, building materials, food commodities, and from cosmic rays." Therefore, ATSDR—as well as other experts in the field of radiation epidemiology and radiation health—believe that it is inappropriate, misleading, and not good science to apply a tiny dose far below the level for which health effects have been observed to a large population and compute or assign predicted numbers of excess cancers that "could" occur over decades.

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28	Page 8, lines 20–21: The implication that a dose of 390,000 to 620,000 mrem is associated with measurable bone cancer in radium dial workers is incorrect. The analysis by Thomas (1995) (see discussion in Annex G of the UNSCEAR 2000 report) indicated that this dose range represented a *threshold* for tumor induction, i.e., at or below which no tumors were observed. He further proposed a rounded value of 10 Gy (1,000,000 mrem) as a "practical threshold" below which there should be little cause for concern. [Although the ATSDR cites the report by Rowland (1994) as the source of its information, the follow-up analysis by Thomas postdates that of Rowland, and was cited by UNSCEAR.] The ATSDR's use of epidemiologically derived "Comparison Values" is reportedly not consistent with its practice in other PHAs. One such "value," a dose range of 390,000 to 620,000 mrem cited for red bone marrow, is not technically justifiable. Most concerning to me is the cancer comparison value that ATSDR has given for bone and red bone marrow of 390,000 to 600,000 mrem (3.9 to 6.0 Gy). This cancer comparison dose value is inconsistent with the scientific literature of epidemiological studies of human populations (workers including members of the public) exposed to ionizing radiation. For radiogenic leukemia, the ATSDR cancer comparison value of 390,000 mrem to 600,000 mrem to the red bone marrow (equivalent to organ doses of 390 rem to 600 rem) is neither protective of public health nor is it commensurate with a value below which the risk of cancer can be considered to be negligible. The cancer CV for radiogenic leukemias of 390,000 to 620,000 mrem to the bone marrow is far above the lower limits of statistical significance of an observed relative risk in human cohorts. A more thorough review of the literature would show that statistically significant relative risks of leukemia have been reported in public and worker cohorts exposed to radiation at doses ranging from below 1,000 mrem to 40,000 mrem, which is a factor of about 10 to 400 below that given by ATSDR as a cancer CV for the red bone marrow. In his opinion, it was misleading the public by promulgating these numbers and implying that there is no public health concern below them. In his opinion, these numbers were not scientifically defensible or commensurate with standard practice in radiation health assessment.	As discussed in the public health assessment, ATSDR's use of the cancer comparison value for bone surface and red bone marrow is based on reviews of radium dial painters. The values used are derived from analyses of radium dial painter remains (autopsy), tissue analysis, direct measurements of absorbed dose, and observations. The doses we cite are typically considered a threshold dose for the appearance of bone sarcomas associated with alpha particles. Therefore, we believe their use is appropriate. ATSDR has also consulted with the former director of the United States Uranium and Transuranium Registry who agreed with the agency's use of these numbers. Our selection of the dose was derived from several sources that evaluated the radiation dose to humans involved in the radium dial painting during the early part of the 20th century. One advantage of these studies was the ability to measure the amount of radium in the bone—the major organ where the radium was stored. Moreover, one could determine the radiation dose to the skeleton and a correlation of the dose to clinically observed skeletal damage. At the time the radium studies ended in 1993, about 1,000 of the estimated 2,400 dial painters were still alive. The radium dial studies have shown that following the ingestion of less than 100 microcuries of radium, the probability of developing a bone sarcoma is very low. The reports also state, "no symptoms from internal radium have been recognized at levels lower than those associated with radium-induced malignancy." Even at intakes of about 1,000 times greater than background, there does not appear to be any or little evidence of damage to the skeleton. Based on Federal Guidance Report 13, the ingestion of 100 microcuries of Ra-226 imparts a dose to the red bone marrow of 1,500 rem for a 15-year-old and 320 rem for an adult. The dose to the bone surface is 35,000 rem and 4,610 rem for a 15-year-old and an adult, respectively. This is in line with the ATSDR comparison value used in this public health assessment. The Biological Effects of Ionizing Radiation (BEIR) V study evaluated various studies of x-rays or gamma radiation to the bone. In one study the BEIR V committee stated that no bone sarcomas were found when the dose to bone was less than 30 Gray (Gy, or 3,000 rads) over a 3-week period. Nonetheless, other studies were either inconclusive or showed large uncertainties. Thus, the BEIR V committee stated that studies of alpha emitters such as radium intake studies should be used to evaluate the induction of radiation-induced bone cancer. From a risk perspective, BEIR V stated that the risk of bone sarcoma per person was on the order of 1.4×10^{-6} per rad with the peak occurrence at 8 years following exposure.

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	A critic of the document has noted that "ATSDR uses a 'cancer comparison value' of 390,000 mrem for the irradiation of the red bone marrow. This rather high dose level is based on the limits of epidemiological detection in the cohort of radium dial painters. The implication is that doses at or below 390 rem to the red bone marrow are of no concern for public health. Such a conclusion is … not consistent with mainstream science, nor is it consistent with how ATSDR evaluates minimum risk levels for other known human carcinogens." Please address this criticism and explain why this dose level was used.	We agree that studies are available showing damage at doses lower than these. We are, however, applying our screening value as a *long-term* screen. Many of the studies you may be referring to involve *acute* or short-term exposures. There is much disagreement in the scientific community as to the methods used to adjust long-term exposures to short-term exposures. Also, as a reminder, the studies mentioned by the commenter are retrospective, whole-body exposures based on cohort or case-controlled studies with poor dosimetry. By contrast, the radium dial studies are based on analyses of radium dial painter remains (autopsy), tissue analysis, direct measurements of absorbed dose, and observations, and these studies are not affected by weighting factors (rad versus rem). There are subtle differences between ATSDR's process of evaluating chemicals and radiation, such as dose to individual organs, age-specific dose coefficients, and other metabolic differences as discussed in several International Commission on Radiological Protection (ICRP) publications. It is of interest to note that in its 1989 Report 96 (titled: *Comparative Carcinogenicity of Ionizing Radiation and Chemicals*), the National Council on Radiation Protection and Measurements (NCRP) stated that less than 30 chemicals were known to be cancer inducing in man and of those, in most it was not possible to define a dose-incidence relationship except generally. Also, there is much more uncertainty in chemical metabolism, additive or synergistic effects between or among chemicals, potency, and dosimetry than in radiation evaluations. The NCRP stated that risk assessment for chemicals is "generally more uncertain than risk assessments for radiation." Because of these statements by the NCRP, ATSDR does not, in the true sense of the comment, evaluate radiation in the similar manner as the agency evaluates chemicals.
	Page 115: The ATSDR report states: "Doses on the order of 25,000 mrem are believed to affect the formation of blood cells and may induce leukemia." ATSDR also states on page 115 that leukemia in A-bomb survivors was observed for doses as low as 50,000 mrem. However, they use a dose limit for bone of 390,000 to 620,000 mrem as obtained from the radium dial workers. The difference between the lowest doses producing a statistically significant relative risk from the A-bomb Survivors and those from the radium dial workers is only due to the difference in exposure rate (acute vs. chronic exposure). The radium dial painters were adults at the time of exposure, and the study included a smaller number of people than the A-bomb survivors. Thus, we do not believe that the CVs derived from the radium dial workers are realistic, or representative for the population exposed downstream of White Oak Creek.	It is true there is a major difference in the values cited in the case of acute versus chronic exposure. What is not clearly evident is that the critical organs for each exposure scenario are different: bone marrow (acute) and bone surface (chronic). The atomic bomb survivor studies only a few years following the exposure identified leukemia as the major cancer observed. Also, the atomic bomb survivor cancer rates have been used to estimate both acute and chronic cancer risks associated with radiation exposure. Use of the comparison value for bone cancer is appropriate as the values used for bone surface and red bone marrow doses are based on autopsy and actual bone uptake, measurements, and observations.
	P. 111. The comparison values listed on p. 111 for bone surface and red bone marrow look quite high. All the comparison values listed on p. 111,	As mentioned, the values used for bone surface and red bone marrow doses are based on autopsy and actual bone uptake, measurements, and observations. Therefore, we believe

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	except the one for a whole body dose, are apparently single organ doses. These can and should be checked for reasonableness and consistency by using the weighting factors listed on p .66 to calculate the corresponding effective whole body doses, which should all be less than 5000 mrem. The comparison values for bone surface and red bone marrow fail this test. Therefore, these values need more scrutiny.	their use is appropriate. In the public health assessment, the use of weighting factors as described by the International Commission on Radiological Protection (ICRP) is to ensure equal detriment to all organs of exposure; that is, when evaluating future exposures, weighting factors are a type of risk analysis and probability exercise. The dose coefficients, tissue weighting factors, and radiation weighting factors are based on statistical estimates of the energy absorbed, risks of cancer or other deleterious effects, and the relative harm or damage caused by a specific type of radiation—alpha, beta, or gamma. These units are combined to give an estimate of the dose coefficient. When insufficient information is given, these values are used to project or predict a radiation dose. In the case of the dose comparison value used by ATSDR for the dose to the bone, however, we relied on human data as discussed in the next paragraph.
	ATSDR has changed from its past proclamation that a cancer CV is legitimate at 5,000 mrem over 70 years to using a CV of 390,000–620,000 mrem for red bone marrow based on apparent limits of epidemiologic detection in radium dial painters. In his opinion, it is well known that the radium dial painters consisted of a statistically low power cohort, and a statistically significant dose response is unlikely with low power epidemiologic studies. The ATSDR has produced lifetime cumulative doses, defined as cancer Comparison Values (CVs) that are inappropriate for the evaluation of the health risk to individuals who may have been exposed to past, present, and future releases of radioactive substances from White Oak Creek. These cancer CVs for radiation exposure, which range from 5,000 mrem to 620,000 mrem, are associated with high relative and absolute risks of excess cancer incidence. With the exception of the CV used for the red bone marrow, they are approximately equal to the lowest published dose at which a *statistically significant* relative risk has been reported from epidemiological investigations in human cohorts. They are not, however, dose levels below which "no health effects have been observed or expected to occur."	For the evaluation of bone sarcoma, ATSDR used data derived from human observation of the radium dial painters via autopsy, bone analyses, and other direct observation studies. The doses we cite are typically considered a threshold dose for the appearance of bone sarcomas associated with alpha particles. Furthermore, the commenter's statement that "ATSDR has changed from its past proclamation that a cancer CV is legitimate at 5,000 mrem over 70 years to using a CV of 390,000–620,000 mrem for red bone marrow" is incorrect and indicates a misunderstanding of ATSDR's radiogenic cancer comparison value. Our radiogenic cancer comparison value of 5,000 millirem over 70 years is used for comparing estimated whole-body, lifetime committed effective doses, whereas the CV of 390,000–620,000 millirem in this public health assessment compares estimated committed equivalent doses over a lifetime for both bone and red bone marrow. As noted, the radium dial painters are actual measured doses as seen in the expression of their doses (rads). ATSDR has also consulted with the former director of the United States Uranium and Transuranium Registry who agreed with ATSDR's use of these numbers.
	He referred to Table 2 [of the summary document], reading that the implication was that the dose for red bone marrow is "less than 1,100 mrem." If reviewing the dose estimates, the confidence intervals would overlap and exceed 5,000 mrem. He expressed his belief that only the 50th percentile of the uncertainty analysis is being used and the remaining probability distribution is being ignored. In his opinion, this was censoring	ATSDR uses the central values—not the upper-bound value of the dose estimates—because these provide the most realistic doses for potential exposures to radionuclides in the Clinch River and the Lower Watts Bar Reservoir. The use of the upper-bound value artificially increases the risk as the calculated uncertainty in many cases is at least an order of magnitude or greater than the 50th percentile value. Thus ATSDR used the 50th percentile (central) value from the Task 4 of the Tennessee Department of Health's Reports of the

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	important information and was not representative of the less than value. It implies that a radiation dose to the red bone marrow of "less than 1,100 mrem" is of no concern for public health, yet the uncertainty analysis produced by our dose reconstruction indicates the potential for red bone marrow doses to have been much higher than this value.	Oak Ridge Dose Reconstruction (Task 4 report). The values calculated by ATSDR are in line and agree with the Task 4 values, even though the methods of analyses were different (see the response to comment 12 for more information on how these different methods were used to develop the same basic conclusions). Central estimates are used because they describe the risk or dose for a typical, realistic individual. When considering central estimates, half of the potential doses will fall above and half will fall below the estimate. Therefore, an individual's actual dose would most likely be closer to the central value than near the high or low end of the range of dose estimates. In fact, ATSDR's external reviewers who evaluated documents associated with the Oak Ridge Dose Reconstruction recommended emphasizing the central estimate rather than the upper and lower bounds of the dose distribution. When using the central estimates, all estimated doses in this public health assessment were below levels shown to cause observable and tolerable effects.
	Although the epidemiological study of radium dial painters which was used to generate the Comparison Value for red bone marrow did not indicate an excess of leukemias attributable to radiation exposure, it is inapplicable to the exposures that resulted from the past releases from White Oak Creek and the contamination of the Clinch River and Lower Watts Bar Reservoir. Exposures resulted largely from whole body exposure to Cs-137 gamma radiation, with an additional contribution from Sr-90 beta particles. The statistical power to detect leukemias in the radium dial painters was relatively low, and there are serious unanswered technical questions about the relative biological effectiveness of exposures from radium because of non-uniform irradiation of the bone marrow and a potential protective effect of irradiated marrow (Spiers and Vaughan 1989; Stebbings 1998).	We agree that the bone marrow alpha particle dose should not be used to estimate leukemia, and we did not use this as a comparison value. For annual whole-body doses, we used the annual screening dose limit of 100 millirem per year recommended for the public by the International Commission on Radiological Protection (ICRP), the National Council on Radiation Protection and Measurements (NCRP), and the U.S. Nuclear Regulatory Commission (NRC), as well as ATSDR's minimal risk level (MRL). ATSDR compared lifetime doses to the agency's radiogenic cancer comparison value of 5,000 mrem over 70 years, which is based on peer-reviewed literature and other documents developed to review the health effects of ionizing radiation. These values, used as screening tools during the public health assessment process, are levels below which adverse health effects are not expected to occur. Because the screening indicated that past or current doses did not exceed our comparison values, further in-depth health evaluation was determined unnecessary.
	Studies of the Japanese atomic bomb survivors and a variety of other groups who were exposed to external irradiation or to a mixture of external and internal radiation (e.g., the Techa River population) have shown that there are significant excess relative risks of leukemia at doses of 1 Sv (100,000 mrem) or less (Little et al. 1999; UNSCEAR 2000). The leukemia risks (either incidence or mortality) in the A-bomb survivors were significantly elevated at all doses $\geq$400 mSv (400,000 mrem, UNSCEAR 2000). Estimated risks for leukemia induction based on the international study of combined cohorts of radiation workers do not suggest that current estimates of leukemia risks at low levels of exposure based on the A-bomb survivor data are appreciably in error (Cardis et al. 2001). Another set of	As noted, the radium dial painter values are actual measured doses as seen in the expression of their doses (rads). The values cited in this comment are not absorbed doses, but are calculated estimated doses expressed as effective doses since the unit Sievert is given. If these were measured doses the units would have been Grays. ATSDR has also consulted with the former director of the United States Uranium and Transuranium Registry who agreed with the agency's use of these numbers.

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	information on leukemia risks at low doses is that resulting from exposures to children and young adults in Utah who were aged 0–19 years when exposed to fallout from the Nevada Test Site (Stevens et al.1990; UNSCEAR 1994). Significant excess risks (defined on the basis of 95% confidence levels) were observed in the groups who received 6.0–30 mGy (600 to 30,000 mrem) to the bone marrow.	
29	In my comments submitted on the ATSDR PHA on Radionuclides Released from White Oak Creek to Clinch River, I have remarked that the cancer Comparison Values for radiation that have been produced by ATSDR for PHAs at Oak Ridge are inconsistent with ATSDR practices for other known human carcinogens provided. These are presented in the ATSDR PHA Guidance Manual and ATSDR Cancer Policy Framework that clearly document the policy of ATSDR regarding other carcinogens. The opinion that there is no need for communication of risk to the public at levels below the ATSDR cancer comparison values is certainly a topic that should be subjected to community debate. However, the conclusion that radiogenic cancer risk is inherently negligible at doses below the ATSDR cancer comparison values is inconsistent with mainstream science in radiation protection, radiation epidemiology, and radiation biology, and it is inconsistent with the manner in which ATSDR evaluates the risk to public health from exposures to other toxic substances. The issue regarding ATSDR's review of dose levels defining statistically significant relative risks for radiogenic cancers and the use of these dose levels as "cancer comparison values," is extremely important. This is coupled with the concern that ATSDR has adopted an administrative policy to not acknowledge nor discuss the range of risks of past exposures below these dose levels. These concerns are not new. They have been raised by many others in the past. Not only are the cancer comparison values (in the PHA) incorrect, but the dose levels are high. It's misleading to the public to imply that there is no concern for public health. In his opinion, the CVs being used were not only conceptually incorrect, but the numbers were above dose levels where there has been statistically significant confirmation of radiogenic cancer in populations. He expressed	In Section III. H. of ATSDR's Cancer Policy Framework, the agency recognizes that, at present, no single generally applicable procedure for exposure assessment is available. Therefore exposures to carcinogens must be assessed on a case-by-case or context-specific basis. While the need for, and reliance on, models and default assumptions is acknowledged, ATSDR strongly encourages the use of applicable empirical data (including ranges) in exposure assessment. Also, in Section IV. A, subsections 1 and 2, the position of ATSDR is interpreted as being related to chemical carcinogens and is not related to radiological contamination. Following the ATSDR Cancer Framework Policy, ATSDR does not perform risk assessments. The agency, however, does recognize the importance of the U.S. Environmental Protection Agency's (EPA) risk assessment and risk analysis to determine whether levels of chemicals at hazardous waste sites pose an unacceptable risk as defined by regulatory standards and requirements and to help regulatory officials make decisions in support of cleanup strategies that will ensure overall protection of human health and the environment. ATSDR acknowledges that conservative safety margins are built into EPA risk assessments and that these assessments do not measure the actual health effects that hazardous chemicals at a site have on people. For additional information, please see the response to comment 44 regarding the intentional differences between a public health assessment and a risk assessment and review the framework policy that can be found at http://www.atsdr.cdc.gov/cancer.html. In this public health assessment ATSDR compares annual whole-body doses to the 100 mrem/year dose limit of the International Commission on Radiological Protection (ICRP), the National Council on Radiation Protection and Measurements (NCRP), and the U.S. Nuclear Regulatory Commission (NRC), as well as ATSDR's minimal risk level (MRL). ATSDR compares lifetime whole-body doses to the agency's radiogenic cancer comparison value of 5,000 mrem over 70 years, which is based on peer-reviewed literature and other documents developed to review the health effects of ionizing radiation. These values, used as screening tools during the public health assessment process, are levels below which adverse health effects are not expected to occur. If the screening indicates that past or current doses exceed our comparison values, then we would conduct further in-depth health evaluation.

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	his belief that statistical limits of epidemiologic detection should not be used as limits of concern. In his opinion, this violated the standard practice of radiation health assessment and environmental risk assessment, and inaccurately implied that there was no concern at levels below these cancer CVs. In his opinion, these CVs were in violation of any scientific knowledge of interaction of radiation and the ability of radiation to cause cancer in human and animal populations. He expressed his belief that this work was misleading, technically deficient, and inappropriate. I believe the values proposed as "cancer comparison values" are not consistent with proper evaluation of radiogenic cancer risk in exposed populations. I know of no other known human carcinogen for which ATSDR has chosen a dose level approximately equal to a lowest observed adverse health effect level (or lower limit of epidemiological detection) as a surrogate for a limit of public health concern. The use of the lowest observable adverse effects level as an equivalent for a safe or negligible level of exposure is in fact inconsistent with ATSDR policy and practices used for all potentially toxic substances including those attributable to non-cancer health endpoints and those that cause cancer. For other toxic substances, ATSDR applies a considerable margin of safety to the lowest observed adverse effects level before designating an exposure or dose level as being commensurate with a minimal public health risk. For radiation, however, ATSDR designates dose levels that are considered to be at or just below the limits of statistical significance in epidemiological studies as "cancer comparison values," and implies that there is no concern for public health at doses below these levels. I do not object to the reporting of radiation dose levels that are equivalent to epidemiological limits of statistical detection in specific exposed cohorts. This is appropriate information to convey to the general public, as long as the attendant risk of exposure to doses below these levels are also communicated. It's a totally different matter, however, to assert that such dose levels are equivalent to safe or negligible risk levels, and to ignore or censor information about the potential for risk at lower dose levels. For instance, in my recent reading of the ATSDR PHA for radiation released from X-10 to the Clinch River, I have discovered that ATSDR has issued "cancer comparison values" of 5000 mrem to the whole body and	When ATSDR developed its screening values for radiation exposures, safety margins were incorporated. The approach ATSDR uses to derive MRLs, such as those in the Toxicological Profile for Ionizing Radiation, was developed with the EPA. The screening value includes the use of a no observed adverse effect level (NOAEL) or a lowest observed adverse effect level (LOAEL) as well as three or more situation-specific uncertainty factors. When multiplied, these factors give a total uncertainty factor generally ranging from 1 to 1,000, based on the studies used. Furthermore, the ATSDR legislative authority, as discussed many times, limits ATSDR to evaluation of exposures based on observable and tolerable adverse health effects. If adverse health effects are not observed in an epidemiological study, then the doses used in the study should be considered tolerable. ATSDR's radiogenic comparison value of 5,000 millirem over 70 years incorporates the linear no-threshold (LNT) model for evaluating public health hazards associated with exposure to radiation. It assumes a total lifetime dose (70 years of exposure) above background that is considered safe in terms of cancer induction. In addition to the LNT model, ATSDR also incorporates a margin-of-dose (MOD) approach into this comparison value. During an evaluation, if ATSDR determines that further investigation is needed, scientific literature associated with radiological doses and dose estimates, particularly those related to adverse health effects, is reviewed. ATSDR then compares the dose estimates from scientific literature to site-specific dose estimates. Thus, ATSDR uses the LNT model to determine when a more detailed site-specific evaluation is necessary, and uses the MOD approach to develop realistic information for communities regarding what is known and unknown about radiation levels at a particular site. An independent expert panel convened to review ATSDR's site-specific approaches used to evaluate past, current, and future radiation risks to communities surrounding the Oak Ridge Reservation concluded that this combination of approaches (LNT and MOD) is appropriate for ATSDR to use to determine radiation levels at which health effects actually occur. The panel found that ATSDR's use of the MRL of 100 millirem and radiogenic cancer comparison value of 5,000 millirem were appropriate screening values. If extrapolated over 70 years assuming constant exposure, the radiogenic cancer comparison value dose estimate would be about 71 millirem per year—a level the panel determined to be protective of public health in terms of cancer and noncancer risks. The panel also concluded that ATSDR's approach considers evidence for both individual organs and whole-body doses (effective doses), noting that a whole-body dose could not be developed without accounting for doses to single organs. Further, the panel determined that ATSDR's method of distinguishing dose levels from risk levels was acceptable because ATSDR incorporated risk and LNT explicitly and implicitly when calculating doses. In the words of one peer reviewer regarding ATSDR's radiogenic cancer comparison value,

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	lower large intestine, 9,000 mrem for the skin, 10,000 mrem for the breast, and 390,000 to 620,000 mrem to the bone surface and red bone marrow. These values are not appropriate for use as safe or negligible risk levels for exposures in human populations to ionizing radiation. This is most certainly the case for radiogenic leukemia, which is manifested through irradiation of the red bone marrow. The fact that such high dose cancer comparison values have been officially released for public communication by ATSDR is a matter that I find most troubling, both personally and professionally. When I evaluate the relative risk associated with this dose comparison value, I find the risk of radiogenic cancer to be extremely high. Yet, ATSDR is implying that doses at or below this level are inconsequential.	"The general consensus is that the linear non-threshold hypothesis is scientifically reasonable for the purpose of radiation protection. The recent NCRP comprehensive review and UNSCEAR [United Nations Scientific Committee on the Effects of Atomic Radiation] evaluations do not find any alternative model to be better, including one with a threshold. While epidemiology is not capable of detecting risks in the low dose domain, under say 10,000–20,000 millirem, there are cellular experiments and theoretical reasoning that support a linear response." Also, in this public health assessment ATSDR uses different comparison values depending on the organs and tissues being evaluated. While the cancer comparison value of 5,000 mrem over 70 years is used to compare effective whole-body doses over a lifetime and the 100 mrem/year is used to compare annual whole-body doses, these organ comparison values (discussed in detail below) were used to screen committed equivalent doses to organs over a lifetime. A comparison value of 390,000–620,000 millirem was used to compare estimated committed equivalent doses over a lifetime for bone surface and red bone marrow. ATSDR's use of the cancer comparison value for bone surface and red bone marrow, as discussed in the public health assessment, is based on reviews of radium dial painters. The values used are based on analyses of radium dial painter remains (autopsy), tissue analysis, and direct measurements of absorbed dose, and observations. The doses we cite are typically considered a threshold dose for the appearance of bone sarcomas associated with alpha particles. Therefore, we believe their use is appropriate. ATSDR has also consulted with the former director of the United States Uranium and Transuranium Registry who agreed with the agency's use of these numbers. Our selection of the dose was derived from several sources that evaluated the radiation dose to humans involved in the radium dial painting during the early part of the 20th century. One advantage of these studies was the ability to measure the amount of radium in the bone—the major organ where the radium was stored. Moreover, one could determine the radiation dose to the skeleton and a correlation of the dose to clinically observed damage to the skeleton. At the time the radium studies ended in 1993, about 1,000 of the estimated 2,400 dial painters were still alive. The radium dial studies have shown that following the ingestion of less than 100 microcuries of radium, the probability of developing a bone sarcoma is very low. The reports also state that "no symptoms from internal radium have been recognized at levels lower than those associated with radium-induced malignancy." Even at intakes of about 1,000 times greater than background, there appears to be little or no evidence of damage to the skeleton. Based on Federal Guidance Report 13, the ingestion of 100 microcuries of Ra-

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		226 imparts a dose to the red bone marrow of 1,500 rem for a 15-year-old and 320 rem for an adult. The dose to the bone surface is 35,000 rem and 4,610 rem for a 15-year-old and an adult, respectively. This is in-line with the ATSDR cancer comparison value being used in this public health assessment. The Biological Effects of Ionizing Radiation (BEIR) V study evaluated various studies of x-rays or gamma radiation to the bone. In one study, the BEIR V committee stated that no bone sarcomas were found when the dose to bone was less than 30 Gy (3,000 rads) over a 3-week period. Nonetheless, other studies were either inconclusive or showed large uncertainties. Thus, BEIR V stated that studies of alpha emitters such as radium intake studies should be used to evaluate the induction of radiation-induced bone cancer. From a risk perspective, BEIR V stated that the risk of bone sarcoma per person was on the order of 1.4×10^{-6} per rad, with the peak occurrence at 8 years following exposure. For evaluating estimated committed, equivalent, lifetime doses to the breast, ATSDR used a comparison value of 10,000 mrem over a lifetime. This value (reported in Schull's 1995 *Effects of Atomic Radiation: A Half-Century of Studies from Hiroshima and Nagasaki*) is based on an investigation focusing on a sample of women from the Life Span Study—a Radiation Effects Research Foundation program investigating the long-term effects of atomic bomb radiation on cancer incidence and causes of death. On the basis of an investigation focusing on women in the Life Span Study, women who were irradiated before 20 years of age experienced the highest rates of radiation-related breast cancer when receiving a dose of at least 0.10 Gy (10 rad or 10,000 mrem) of radiation. To evaluate estimated committed equivalent lifetime doses to the skin, ATSDR used a comparison value of 9,000 mrem over a lifetime. This value is based on the BEIR V report (titled *Biological Effects of Ionizing Radiation*) that evaluated potentially the most extensive study of radiation-induced skin cancer. In 1990, the National Research Council reviewed and evaluated the findings presented in BEIR V on the relationship between skin cancer and radiation and presented its findings in a 1990 report titled *Health Effects of Exposure to Low Levels of Ionizing Radiation*. The study involved investigating 2,226 individuals who had received radiation to the scalp for the treatment of ringworm during childhood. On average, these persons were studied for over 25 years. Basal cell carcinomas of the skin appeared in 41 of the 2,226 exposed individuals. These carcinomas began to appear after about 20 years of exposure. Instead of concentrating in the most heavily irradiated areas of the scalp, most of the tumors tended to appear at the margins of the scalp and in nearby areas of skin that had not been covered by clothing or hair. An excess of skin cancers was identified on the neck and cheek even though doses to the cheeks were approximately only 12 rad (12 rem or 12,000 mrem) and

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		doses to the neck were only 9 rad (9 rem or 9,000 mrem). In the ICRP's Publication 59 (1991), the agency stated, "Although it has traditionally been thought that there was little if any risk of skin cancer below 10 Gy [1,000 rad or 1,000,000 mrem], there are now several sets of data indicating excess skin cancer following doses of a few grays [a few hundred rad], with one study suggesting risk below 1 Gy [100 rad or 100,000 mrem]. The evidence does not indicate that the risk per unit dose is greater at higher doses than at lower [doses]." Therefore, the value of 9,000 mrem used as a comparison value for committed equivalent lifetime doses to the skin is based on absorbed dose and direct observation of individuals who received radiation of the scalp. This is the lowest reported dose where adverse effects have been observed following irradiation of the skin and significantly below dose levels reported by the ICRP as having resulted in health effects. For evaluating estimated committed equivalent lifetime doses to the lower large intestine, ATSDR used the radiogenic cancer comparison value of 5,000 mrem over a lifetime in the PHA. ATSDR could not locate a reliable comparison value to estimate a dose to the lower large intestine so ATSDR used the whole-body CV of 5,000 millirem over 70 years. We believe this is appropriate for the following reason. In general, the faster a cell system divides, the more sensitive that system is to the effects of radiation. The intestinal tract cell lining divides rapidly; the blood cells, especially the red blood cells, divide fastest (estimated production of RBC is 2.5 million per second). Following an acute radiation exposure to humans resulting in a dose of about 100 rads, the gastrointestinal tract begins to show damage. The dose of 100 rads agrees with the single dose to mouse intestinal cells of 130 rads. In humans, however, the Centers for Disease Control and Prevention (CDC) reports that symptoms may not appear until a dose of 600 rads has been received. The full expression of damage may require up to 1000 rads. And the dose of 600 rads is about 120 times higher than the estimated ATSDR CV for the large intestine. Therefore we believe the use of 5,000 millirem over 70 years is justified.
30	The NAS/NRC has recently recommended the use of the NIH-Interactive Radioepidemiological Program (IREP) program for estimating the attributable risk (or assigned share) for individuals diagnosed with disease who were exposed in the past to radioactivity released from the testing of nuclear weapons who should be evaluated for medical screening and compensation. Until such time as the publication of BEIR VII is released to the public, I believe the NIH-IREP program is the most thorough quantitative evaluation of the uncertainty in radiogenic cancer risk currently	In 1985, a working group for the National Institutes of Health (NIH) initially created the radioepidemiological tables the commenter references. The tables, updated in 2003, are used by the Department of Veterans Affairs as a reference for estimating the probability of causation for **workers** with cancer who had been exposed to ionizing radiation. The Department of Labor uses a version of the Interactive Radioepidemiological Program (IREP), referred to as the National Institute for Occupational Safety and Health (NIOSH)-IREP, to address workers under the Energy Employees' Occupational Illness Compensation Program Act (EEOICPA). The NIOSH-IREP, most recently updated in 2006, was created to evaluate the probability of causation associated with radiation and risks specific to energy

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	available. In current radiation compensation programs administered by the Department of Veterans Affairs and the Dept. of Labor, the value of the Probability of Causation/Assigned Share (PC/AS) used for the adjudication of claims is the upper 99th percentile of the probability distribution of PC. If a DOE worker had cancer, it would be compensable at these dose levels. He knew this because his company developed the probability of causation and radio-epidemiological tables being used for adjudicating claims by the Department of Labor and the Department of Veteran Affairs. He expressed his belief that these were high doses, which were not commensurate with levels below which there should be no health concern. To clarify a statement that exposure rates in this document are at a level that would be compensable under the Energy Employees Occupational Illness Compensation Program Act (EEOICPA) without any other exposures, he answered that the cancer CVs would be compensable, and the upper bounds of exposure that exceeded the 5,000 mrem whole-body dose for some cancers and some age groups would be compensable. The current rules extend only to workers, not to the general public. He expressed his belief that this was particularly true considering the red bone marrow cancer CV (390,000–620,000 mrem), which in his opinion, was high and not appropriate to use.	employees for the purpose of adjudicating claims. Please note that these radioepidemiological tables are **only** used for litigation purposes and for the adjudication of claims for workers. This means that worker exposures are evaluated from a legal perspective—this is not a health-based assessment. As mentioned on several occasions, ATSDR's congressional mandate does not allow an evaluation of worker exposures. Therefore, this public health assessment evaluates **off-site exposures** to White Oak Creek radionuclide releases for downstream residents and others who use or live along the Clinch River and the Lower Watts Bar Reservoir only. It does not evaluate any exposures potentially occurring onsite at the reservation, including exposures to workers and other individuals who may contact contaminants while at the ORR. ATSDR does not prepare any public health assessments to evaluate on-site worker exposures. Other agencies are responsible for evaluating worker exposures that occur on site. 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 for particular communities. ATSDR health physicists conduct a health effects evaluation by carefully examining site-specific exposure conditions about actual or likely exposures; conducting a critical review of available radiological, medical, and epidemiologic information to ascertain the substance-specific toxicity characteristics (levels of significant human exposure); and comparing an estimate of the amount of radiological 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 effects. The goal of the health effects evaluation is to weigh the scientific evidence and keep site-specific doses in perspective when deciding whether harmful effects might be possible in the exposed population. The output is a qualitative description of whether doses are of sufficient nature and magnitude to trigger a public health action to limit, eliminate, or study further any potentially harmful exposures. The PHA presents conclusions about the actual existence and level of the health threat (if any) posed by a site.
	He expressed surprise that this had passed through the extensive review process, and questioned whether ORRHES might not have the necessary technical expertise to review these documents.	The White Oak Creek Radionuclide Releases PHA underwent several phases of review before its final release, including an internal ATSDR review, a data validation review by other agencies (i.e., DOE, EPA, and TDEC), an Oak Ridge Reservation Health Effects Subcommittee (ORRHES) review, an independent external peer review, and a public comment review. During the agency's internal review process, individuals within the agency who have the proper background (e.g., toxicology and health physics) carefully reviewed

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		the document for technical content and other aspects. After receiving comments from other agencies during the data validation review, ATSDR made changes to the document as appropriate. ORRHES members consisted of individuals with different expertise, backgrounds, interests, and geographic areas from communities surrounding the Oak Ridge Reservation. ORRHES included among its members technical experts in toxicology, health physics, medicine, geology, and other disciplines. ORRHES members carefully reviewed this PHA, discussed suggested editorial and technical changes among themselves, then submitted recommendations to ATSDR for changing the document. Through its external peer review process, ATSDR's Office of Science had three scientific experts review this public health assessment (see Appendix H for the peer reviewer comments and ATSDR's responses). The agency's peer review process allows an external and thorough evaluation of this PHA by experts in the field that this assessment covers: health physics. During the external review process, individuals not employed by ATSDR or the CDC independently reviewed this document and provided their unbiased, scientific opinions. Also, several times at public meetings, including work group and ORRHES meetings, ATSDR presented the data and information used in this public health assessment. In addition, during the public comment period, any member of the public can provide comments to ATSDR. These public comments, such as those presented within this appendix, are addressed for each public health assessment. ATSDR uses a multi-disciplinary approach for reviewing public health assessments; experts in toxicology, medicine, health physics, and other disciplines review our work. All peer reviewers approved of this assessment and found no major flaws that would invalidate ATSDR's conclusions and recommendations. In the words of one peer reviewer: "You [ATSDR] have done a good job under very difficult circumstances with a lot of unwanted publicity and carping. The science under the report is very good and the report is well written in a very good manner that is suitable for both an informed and interested public and the scientific community."
31	P. 111. The footnotes on pages 111, line 4-5 and 112, line 5-6 as well as the definition in the glossary on page A-7 are expressed as a double negative "unlikely and non-cancerous." Is there a more positive way to define MRL that will facilitate understanding? Perhaps, give an example in the glossary or context of the report that demonstrates what is meant by non-cancerous effects and how they are taken into consideration. Also, it may be helpful to refer the reader to the ATSDR web site to read the document on MRLs (http://www.atsdr.cdc.gov/mrls.html). [In that document it says "An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse	Thank you for your comment. The definitions were changed in the footnotes for Tables 22 and 23, and in the glossary in Appendix A. "Unlikely" was changed to "likely to be without" as suggested. The term "noncancerous" is a standard term used by ATSDR and other agencies, and was retained throughout the document. Also, "noncancerous effects" was added to the glossary in Appendix A of the final PHA with the following definition: "Health effects or health endpoints other than cancer, such as cardiovascular disease or genetic effects, that result from exposure to a particular hazardous substance. ATSDR derives health guidelines for noncancerous effects, called minimal risk levels (MRLs), and compares exposure doses to these MRLs. Doses below

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	non cancer health effects over a specified duration of exposure."] Is the MRL more conservative (protective) than CVs that take into consideration cancer effects alone? What really distinguishes the MRL from the CVs from other sources?	MRLs are unlikely to cause noncancerous health effects; those above MRLs are evaluated further." Also, the Web site link was added to the footnotes of Tables 22 and 23 for readers who would like to see more information on MRLs. MRLs for radiation are estimates of daily human exposure to an amount of radiation that is likely to be without appreciable risk of adverse noncancer health effects. MRLs are screening tools used by public health professionals to determine which exposure situations require further evaluation. The chronic MRL for ionizing radiation is 100 mrem/year. This is consistent with the dose limits recommended for the public by the International Commission on Radiological Protection (ICRP), the National Council on Radiation Protection and Measurements (NCRP), and the U.S. Nuclear Regulatory Commission (NRC). Although the MRL is for noncancerous health effects, when deriving the MRL no studies were identified that did not result in cancer as the specific end point. In this public health assessment, ATSDR compares annual doses to the 100 -mrem/year dose limit of the ICRP, NCRP, and NRC, as well as ATSDR's MRL. ATSDR compares lifetime doses to the agency's radiogenic cancer comparison value of 5,000 mrem over 70 years, which is based on peer-reviewed literature and other documents developed to review the health effects of ionizing radiation. These values, used as screening tools during the public health assessment process, are levels below which adverse health effects are not expected to occur. If the screening indicates that past or current doses exceed these values, then we would conduct further in-depth health evaluation. When ATSDR developed its screening values for radiation exposures, safety margins were incorporated. The approach ATSDR uses to derive MRLs, such as those in the Toxicological Profile for Ionizing Radiation, was developed with the U.S. Environmental Protection Agency (EPA). The screening value includes the use of a no observed adverse effect level (NOAEL) or a lowest observed adverse effect level (LOAEL) as well as three or more situation-specific uncertainty factors. When multiplied, these factors give a total uncertainty factor generally ranging from 1 to 1,000, based on the studies used. Furthermore, the ATSDR legislative authority, as discussed many times, limits ATSDR to evaluate exposures based on observable and tolerable adverse health effects. If adverse health effects are not observed in an epidemiological study, then the doses used in the study should be considered tolerable. ATSDR's radiogenic comparison value of 5,000 millirem over 70 years incorporates the linear no-threshold (LNT) model for evaluating public health hazards associated with exposure to radiation. It assumes a total lifetime dose (70 years of exposure) above background that is considered safe in terms of cancer induction. In addition to the LNT model, ATSDR also incorporates a margin-of-dose (MOD) approach into this comparison value. During an evaluation, if ATSDR determines that further investigation is needed,

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		scientific literature associated with radiological doses and dose estimates, particularly those related to adverse health effects, is reviewed. ATSDR then compares the dose estimates from scientific literature to site-specific dose estimates. Thus, ATSDR uses the LNT model to determine when a more detailed site-specific evaluation is necessary, and uses the MOD approach to develop realistic information for communities regarding what is known and unknown about radiation levels at a particular site. An independent expert panel convened to review ATSDR's site-specific approaches used to evaluate past, current, and future radiation risks to communities surrounding the Oak Ridge Reservation concluded that this combination of approaches (LNT and MOD) is appropriate for ATSDR to use to determine radiation levels at which health effects actually occur. The panel found that ATSDR's use of the MRL of 100 millirem and radiogenic cancer comparison value of 5,000 millirem were appropriate screening values. If extrapolated over 70 years assuming constant exposure, the radiogenic cancer comparison value dose estimate would be about 71 millirem per year—a level the panel determined to be protective of public health in terms of cancer and noncancer risks. The panel also concluded that ATSDR's approach considers evidence for both individual organs and whole-body doses (effective doses), noting that a whole-body dose could not be developed without accounting for doses to single organs. Further, the panel determined that ATSDR's method of distinguishing dose levels from risk levels was acceptable: when calculating doses, ATSDR explicitly and implicitly incorporated risk and LNT. There are subtle differences in ATSDR's process of evaluating chemicals and radiation, such as dose to individual organs, age-specific dose coefficients, and other metabolic differences as discussed in several ICRP publications. Interestingly, in its 1989 NCRP Report 96 (titled: *Comparative Carcinogenicity of Ionizing Radiation and Chemicals*), the NCRP stated that less than 30 chemicals were known to be cancer inducing in man and of those, in most it was not possible to define a dose-incidence relationship except generally. Also, there is much more uncertainty in chemical metabolism, the possibility of additive or synergistic effects between or among chemicals, potency, and dosimetry than there is in radiation evaluations. The NCRP stated that risk assessment for chemicals is "generally more uncertain than risk assessments for radiation." Because of these statements by the NCRP, ATSDR does not, in the true sense of the comment, evaluate radiation in a similar manner to which it evaluates chemicals. 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/toc.html or by contacting ATSDR at 1-888-42-ATSDR. An interactive program that provides an overview of the process ATSDR uses to evaluate whether people will be harmed by hazardous materials is available at

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		http://www.atsdr.cdc.gov/training/public-health-assessment-overview/html/index.html.
32	A rationale for the nature and level of the ATSDR dose criteria for public health purposes and especially how the resulting doses vary from the more conservative levels used by the Environmental Protection Agency and other environmental agencies to meet their regulatory responsibilities should be explained. The differences from the liberal National Institute for Occupational Safety and Health work place levels should also be explained. This addition should also attempt to make clear the various connotations of the terms, "zero" and "none" as applied to risk analysis and public exposures.	For this PHA, ATSDR added an appendix (Appendix F) to discuss risk terminology, radiation risk, and risk limits in detail. The appendix also explains the differences between ATSDR public health assessments and EPA risk assessments and shows the method for converting the doses in this PHA to risk numbers. Since ATSDR does not use risk to develop public health conclusions, such an appendix is not normally included in ATSDR's public health assessments. Please note that ATSDR does not base its public health conclusions on these risk numbers—they are presented in this PHA to provide detailed information on risk for the community. In addition, text was added to Section III. Evaluation of Environmental Contamination and Potential Exposure Pathways to explain the difference between dose and risk. Note further, however, that ATSDR does not discuss the National Institute for Occupational Safety and Health (NIOSH) work place levels. This public health assessment does not deal with worker exposures; it solely evaluates exposures for off-site communities.
33	The use of natural background radiation in some comparisons can also be misleading, because the risks from some components of background (e.g., radon) are not negligible. Indoor exposure to the decay products of radon are now known to be the second leading cause of lung cancer (Field 2001, 2003).	ATSDR agrees that radon should not be included in background unless directly comparing to radon levels. As the commenter points out, radon progeny contribute to lung dose and should not be mixed with whole-body dose. The natural range of background, not including radon, ranges from 80 mrem/year to 26,000 mrem/year (1). The nominal background dose from naturally occurring radiation in the contiguous United States is 100 mrem/year not including radon, but can range from 80 to about 1,000 mrem/year (2). No data suggest that radiation doses from background, excluding radon, have any deleterious effects. In fact, recent studies from the high background region in Ramsar, Iran, have shown protective effects up to doses of 10,000 mrem/year (3,4,5,6). The ATSDR MRL of 100 mrem/year is 0.38% of the range of natural background, not including radon. In addition, the Iowa Radon Study [Field RW, et al. (7)], referenced by the commenter, suffers from the following problems: 1. The total difference in lung cancer cases can be accounted for by natural variation among the cases (n=413). The natural variation in the number of cases is 20.3, while the 33% of cases exposed above 4 pCi/L and 28% of controls corresponds to 5% of 413 cases, or 20.6. 2. The study controls have an 11% higher rate of post-secondary education than the cases. Highest educational level has been strongly correlated to greater longevity and overall health. It does not appear that the odds ratios were corrected for educational level.

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		3. Due to the etiology of lung cancer, the mean life expectancy after diagnosis is around 5 years. Therefore, it is unreasonable to exclude cases that died during the 5-year study, but it may be reasonable to exclude only those cases for which the families disposed of the radon measuring devices before a radon measurement could be made. 4. If statistical significance can only be achieved by omitting cases that died during the study period, this might "imply" a protective effect from radon exposure. 5. A possible smoking and radon-exposure synergistic effect for developing lung cancer may not be accounted for in the analysis. Many of the uranium miner studies did not clearly identify the smoking status of those with lung cancer. The uranium miner studies appear only to show a relationship between radon exposure and cancer among the smokers and miners of unknown smoking status. 6. The cases had an ever-smoked rate of 86% versus a rate of 32% ever-smoked among the controls. The smoking correction is not defined, and the much higher rate of smoking among the cases is going to make the corrected odds ratio extremely sensitive to the smoking correction. 7. The intervals of cumulative radon exposure are made at strange, noninteger values and are not evenly spaced. No cases or controls were exposed to **zero** pCi/L of radon. There was a threshold of exposures. What was that value? 8. When confidence intervals are graphed for the odds ratios versus exposure categories, no clear dose response appears. A line requires at least two significant points to test for linearity, and the origin does not count. Overall, this study does not appear to demonstrate any statistically significant association or dose response between residential radon and lung cancer. (1) Ghiassi-nejad M, Mortazavi SM, Cameron JR, Niroomand-rad A, and Karam PA. 2002. Very high background radiation areas of Ramsar, Iran: preliminary biological studies. Health Phys 82(1):87–93; January. (2) Eisenbud M and Gesell T. 1997. Environmental radioactivity from natural, industrial, and military sources. Fourth edition. Pp. 198–200. San Diego, CA: Academic Press. (3) Masoomi JR, Mohammadi Sh, Amini M, and Ghiassi–Nejad M. 2006. High background radiation areas of Ramsar in Iran: evaluation of DNA damage by alkaline single cell gel electrophoresis (SCGE). J Environ Radioact 86(2):176–86.

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		(4) Ghiassi-Nejad M, Zakeri F, Assaei RG, and Kariminia A. 2004. Long–term immune and cytogenetic effects of high level natural radiation on Ramsar inhabitants in Iran. J Environ Radioact 74(1-3):107–16. (5) Ghiassi-Nejad M, Beitollahi MM, Asefi M, and Reza-Nejad F. 2003. Exposure to (226)Ra from consumption of vegetables in the high level natural radiation area of Ramsar-Iran. J Environ Radioact 66(3):215–25. (6) Saadat M. 2003. No change in sex ratio in Ramsar (north of Iran) with high background of radiation. Occup Environ Med 60(2):146–7; February. (7) Field RW, Steck DJ, Smith BJ et al. 2000. Residential radon gas exposure and lung cancer: The Iowa Radon Lung Cancer Study. Am J Epidemiol 151:1091–102.
34	The excess lifetime risk levels associated with ATSDR's cancer CVs for radiation are much higher than the risk levels ATSDR uses in its evaluation of other human carcinogens. For exposures to other human carcinogens, ATSDR usually considers risks in the range of one chance in ten thousand to one chance in one million to warrant more detailed investigation. For non-cancer producing toxic substances, ATSDR typically applies a series of safety factors to the lowest observed adverse effects level to derive an exposure level that can be considered to have a minimum risk. For exposure to radiation, the majority of scientific opinion is that there is no threshold dose below which the risk from exposure can be considered to be zero.	The risk range cited is the typical risk range the U.S. Environmental Protection Agency (EPA) uses in its evaluations of contaminants in the environment. Many of these evaluations may not necessarily be based on health, but entirely on risk assessments. The ATSDR Cancer Policy Framework, adopted in 1993, addresses many factors that must be evaluated in analyzing environmental exposures. ATSDR recognizes that, at present, no single generally applicable procedure for exposure assessment is available, and therefore exposures to carcinogens are best assessed on a case-by-case basis with an emphasis on prevention of exposure. The general consensus is that the linear nonthreshold hypothesis is scientifically reasonable for the purpose of *radiation protection.* The recent National Council on Radiation Protection and Measurement's (NCRP) comprehensive review (Report No. 136 titled *Evaluation of the Linear-Nonthreshold Dose-Response Model for Ionizing Radiation*) and the United Nations Scientific Committee on the Effects of Atomic Radiation's (UNSCEAR) evaluations did not find any alternative model to be better, including one with a threshold. The NCRP Report No. 136 also states that some adaptive responses may come into play at low doses, and these responses may result in the variations seen at low dose response levels. Further, the NCRP concluded "there is no conclusive evidence on which to reject the assumption of a linear-nonthreshold dose-response relationship for many of the risks attributable to low-level ionizing radiation although additional data are needed. However, while many, but not all, scientific data support this assumption, the probability of effects at low doses such as are received from natural background is so small that it may never be possible to prove or disprove the validity of the linear-nonthreshold assumption." Therefore, ATSDR does not deny the presence or absence of a linear response and the presence of risk at low levels. We evaluate public health implications based on the observations of adverse health impacts at low doses.

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35	The comparison of ATSDR dose estimates between past, present, and future exposures makes no sense. ATSDR states that the maximum cumulative dose from past releases was 278 mrem to the whole body, but that for present releases (1988 to the present time) the doses would be "less than 1,900 mrem for Lower Watts Bar Reservoir and 235 mrem for the Clinch River." This is absurd. There is no conceivable way that the doses from past releases are equal to or less than the doses from present releases. It appears as if two completely different methods of exposure analysis have been applied, one for past releases and another for present releases, with two completely different sets of assumptions. However, a comparison between the ATSDR estimates of present and future doses with those from the past indicate that widely different methods and assumptions have been used, giving the misleading impression that present and future exposures are of the same magnitude or larger than past exposures. This is clearly not the case.	ATSDR's evaluation of past exposures in this public health assessment is based on doses presented in Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report). The Task 4 report only evaluated the area along the Clinch River from the mouth of White Oak Creek to the confluence of the Clinch and Tennessee Rivers. The Task 4 team's analysis did not, however, include evaluating exposures to the Lower Watts Bar Reservoir. In evaluating current and future exposures for the Lower Watts Bar Reservoir in this public health assessment, ATSDR based its analysis on our 1996 health consultation, which calculated doses by incorporating conservative exposure assumptions using worst-case scenarios. Table 22 in the final PHA presents the committed effective dose to the whole-body of 278 mrem for past radiation exposure associated with the area along the Clinch River, based on data presented in the Task 4 report. Table 23 presents the committed effective dose to the whole-body of less than 236 mrem for current and future exposures to the Clinch River, based on ATSDR's individual evaluation, which is indeed lower than the whole-body dose for past exposure to the Clinch River of 278 mrem. The dose referred to in this comment of "less than 1,900 mrem" refers to the estimated whole-body dose for exposure to the Lower Watts Bar Reservoir, which was based on the findings of ATSDR's 1996 *Lower Watts Bar Reservoir Health Consultation.* Thus, because the Lower Watts Bar Reservoir was not evaluated by the Task 4 team in its evaluation of past exposures to X-10 releases to the Clinch River via White Oak Creek, this dose cannot be compared to the past exposure dose.
Miscellaneous Radiation Comments		
36	Pp. 68 and 70. If the effective rate of decrease of radiation in the body is the sum of the rates of decrease due to radioactive decay and biological elimination, then the reciprocal of the effective half-life should be the sum of the reciprocals of the physical and biological half-lives. The numbers for Sr-90 on p. 68, and in Table 7, don't quite satisfy this relationship, as well as the numbers for Sr-90 on p. 68 not quite agreeing with those in Table 7. The numbers on p. 68 need to agree with those in Table 7, and all the numbers need to satisfy their correct relationship.	Your comment is noted. ATSDR compared the reciprocal of the effective half-life for the radionuclides presented in Table 7 with the sum of the reciprocals of their physical and biological half-lives, and they match. The correct definition of effective half-life is the sum of the radioactive decay constant and the biological decay constant. The decay constant is defined as ln2/half-life, where ln is the natural log. The radioactive decay constant and the biological decay constant have to be in the same units, as they are in Table 7 and in the discussion on pages 71 and 73 of the final PHA.
37	P. 69. Table 7. Compare years rather than days for Strontium 90 to correspond with the discussion on page 68 in which years are used.	ATSDR presented the data in days because the original reference material expressed the biological half-lives in terms of days. Therefore, changes were made in the final PHA to present half-lives in terms of days throughout the discussion on pages 71 and 73 and in the text in Table 7.
38	Please adopt a consistent set of radiation units.	These changes have been made in the final PHA.

	Comment	ATSDR's Response
39	Present-day radiation dose limits by national regulatory authorities and national and international advisory committees on radiation protection have been misrepresented. The ATSDR PHA and its accompanying summary document state that the public dose limit of the ICRP, NCRP, and NRC of 100 mrem/y is equivalent to saying that 7000 mrem over a 70-year lifetime is an acceptable cumulative dose. This is not true. These dose limits apply to a single year of exposure from multiple sources of operations (releases). Furthermore, the public dose constraint for releases from a single source is 25 mrem/y. In addition, there is the overarching provision that actual doses to real persons be restricted to levels that are as low as is reasonably achievable. The NCRP negligible dose level is 1 mrem/y. Federal radiation protection standards and ICRP and NCRP recommendations for the limitation of public exposures to ionizing radiation have been improperly cited by ATSDR. These are maximum annual dose limits that apply to the total dose received from multiple sources of exposure. ATSDR misinterprets these annual limits as annual averages that apply over a 70 year lifetime for limitation of public exposures originating from a single operation or source.	No section of this PHA extrapolates the 100 mrem/year dose limit to 7,000 mrem over a 70-year lifetime. Instead, in this PHA ATSDR compares estimated annual doses to the 100 mrem/year dose limit of the International Commission on Radiological Protection (ICRP), the National Council on Radiation Protection and Measurements (NCRP), and the U.S. Nuclear Regulatory Commission (NRC), as well as ATSDR's minimal risk level (MRL). ATSDR compares estimated lifetime doses to the agency's radiogenic cancer comparison value of 5,000 mrem over 70 years, which is based on peer-reviewed literature and other documents developed to review the health effects of ionizing radiation. These values are used as screening tools during the public health assessment process. If the screening indicates that past or current doses exceed our comparison values, then we would conduct further in-depth health evaluation. Even though this was not explicitly stated in the document as implied by the commenter, ATSDR believes that the first approximation of the 100 mrem/year recommended dose limit equates into a 7,000 mrem dose over 70 years (100 mrem/year × 70 years). This lifetime dose is higher than ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years. As a matter of note, please recognize that as a first approximation, ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years is less than 100 mrem/year (5,000 mrem ÷ 70 years = 71 mrem/year). This value of 71 mrem/year is less than 100 mrem/year as recommended for the public by the ICRP, NCRP, and NRC. ATSDR publicly discussed this issue in at least four Exposure Evaluation Work Group (EEWG) meetings, formerly known as Public Health Assessment Work Group (PHAWG), and three Oak Ridge Reservation Health Effects Subcommittee (ORRHES) meetings. The Ionizing Radiation Toxicological Profile states: "the annual dose of 3.6 mSv [360 mrem] per year has not been associated with adverse health effects or increases in the incidences of any type of cancers in humans or other animals" (ATSDR 1999b). The past annual doses for the Clinch River, as well as the current radiation doses for the Lower Watts Bar Reservoir and the Clinch River, for all pathways combined were below ATSDR's comparison values and below the 100 mrem/year dose limit for the public as recommended by the ICRP, NCRP, and NRC.
40	Delete all wording indicating that exposure to radionuclides originating in White Oak Creek, the Clinch River, or the Lower Watts Bar Reservoir in the past, present, or future have not caused any "harmful health effects" (e.g., as on page 4), "are not expected to cause *any* harmful effects" (e.g., as on page 6), or	The complete wording as presented in the PHA for the sections referenced by the commenter are presented below: Page 4: "ATSDR's evaluation showed that the estimated external and internal radiation doses ***were not expected to cause harmful health effects***. Therefore, ATSDR concluded that past off-site exposure to those radionuclides traveling from X-10 to the Clinch River via

	Comment	ATSDR's Response
	"pose *no* threat to public health" (as on page 8) (emphasis added). On the basis of current knowledge, no dose of radiation, including that resulting from exposures to natural background (which includes radon, for which significant health effects have been documented, e.g., even in some residential exposure settings), can be assumed to be completely without risk. All national and international organizations responsible for setting radiation standards and estimating risks posed by radiation exposure recognize that, despite uncertainties in risks at low doses and dose rates, "no alternate dose-response relationship appears to be more plausible than the linear-non-threshold model on the basis of present scientific knowledge" (NCRP 2001). The current wording reflects adversely on the credibility of the ATSDR and the dose levels chosen to represent radiogenic cancer CVs for radiation. Regarding the findings that it was safe to use the shoreline and waterways for recreation, food, and drinking water, he said that's just not right.	White Oak Creek was not a public health hazard." Page 7: "ATSDR's review of environmental data collected in and around the Clinch River and LWBR areas shows that the following practices ▪ annual environmental monitoring, ▪ institutional controls intended to prevent disruption of sediment, ▪ on-site engineering controls to prevent off-site contaminant releases, and ▪ DOE continuing its expected appropriate and comprehensive system of monitoring (e.g., of remedial activities and contaminant levels in media), maintenance, and institutional and engineering controls, have limited exposure to the current levels of radionuclides in surface water, sediment, fish, and game to the point that radionuclides ***are not expected to cause any current or future harmful health effects***. Given this evaluation, ATSDR concludes that current and future off-site exposure to radionuclides in the Clinch River and the LWBR via White Oak Creek is not a public health hazard." Page 10: "ATSDR considers that current exposures to detected levels of radionuclides in sediment, surface water, fish, geese, and turtles of the Clinch River ***pose no threat to public health***." Having thoroughly evaluated past public health activities and available current environmental information, ATSDR concludes that exposures to X-10 radionuclides released from White Oak Creek to the Clinch River and to the Lower Watts Bar Reservoir are not a health hazard. Past and current exposures are below levels associated with adverse health effects and regulatory limits. Adults or children who have used, or might continue to use, the waterways for recreation, food, or drinking water are not expected to have adverse health effects due to exposure. ATSDR has categorized those situations as posing *no apparent public health hazard* from exposure to radionuclides related to X-10. This classification means that people could be or were exposed, but that their level of exposure would not likely result in any adverse health effects. For its evaluation of past exposures to X-10 radionuclide releases via White Oak Creek, ATSDR used a dose methodology and considered the 50th percentile estimates provided in Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report) (available at http://www2.state.tn.us/health/CEDS/OakRidge/WOak1.pdf). The Task 4 team, on the other hand, used a risk model and the upper 95th percentile dose and risk levels. Nonetheless, even using different approaches, we came to the same basic conclusions as described below.

	Comment	ATSDR's Response
		On page 15-4 of the Task 4 report, the authors' state: "The radiological doses and excess lifetime cancer risks estimated in this report are incremental increases above those resulting from exposure to natural and other anthropogenic sources of radiation. Nevertheless, for the exposure pathways considered in this task, the doses and risks are not large enough for a commensurate increase in health effects in the population to be detectable, even by the most thorough of epidemiological investigations. In most cases, the estimated organ-specific doses are clearly below the limits of epidemiological detection (1 to 30 cSv [centisievert]) for radiation-induced health outcomes that have been observed following irradiation of large cohorts of individuals exposed either in utero, as children, or as adults." "...it is unlikely that any observed trends in the incidence of disease in populations that utilized the Clinch River and Lower Watts Bar Reservoir after 1944 could be conclusively attributed to exposure to radionuclides released from the X-10 site, even though this present dose reconstruction study has potentially identified increased individual risks resulting from these exposures." Also, the Task 4 report was reviewed by the Oak Ridge Health Agreement Steering Panel (ORHASP)—a panel of experts and local citizens appointed to direct and oversee the Oak Ridge Health Studies. On page 12 of the ORHASP's final report titled *Releases of Contaminants from Oak Ridge Facilities and Risks to Public Health* (available at http://www2.state.tn.us/health/CEDS/OakRidge/ORHASP.pdf), the panel determined, "Although the White Oak Creek releases caused increases in radiation dose, the calculated exposures were small, and less than one excess cancer is expected." In addition, on page 38 of the ORHASP report regarding the number of health effects that would be expected from exposure to X-10 radionuclide releases via White Oak Creek, the panel estimates "less than one excess cancer case from 50 years of contaminated fish consumption" would result. On page 147 of the final public health assessment, "ATSDR concludes that exposures to X-10 radionuclides released from White Oak Creek to the Clinch River and to the Lower Watts Bar Reservoir are not a health hazard. Past and current exposures are below levels associated with adverse health effects and regulatory limits. Adults or children who have used, or might continue to use, the waterways for recreation, food, or drinking water are not expected to have adverse health impacts due to exposure. ATSDR has categorized those situations as posing *no apparent public health hazard* from exposure to radionuclides related to X-10. This classification means that people could be or were exposed, but that their level of exposure would not likely result in adverse health effects." Thus, even though ATSDR used a dose methodology and considered the 50^{th} percentile estimates, while the Task 4 team used a risk model and the upper 95^{th} percentile dose and risk levels, we came to the same basic conclusion. ORHASP found that less than one

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		excess cancer case would be expected to occur as a result of exposure to X-10 radionuclide releases via White Oak Creek; ATSDR concluded that this exposure was not expected to cause adverse health effects.
Quantitative Risk Assessment and Uncertainty/Sensitivity Analyses		
41	The failure of ATSDR to acknowledge the presence and magnitude of individual risk from radiation is inconsistent with ATSDR practice for other known human carcinogens. This long-standing concern has been raised before the ORRHES and the ATSDR by many members of the Oak Ridge community and others. ATSDR has remained persistently non-responsive in this matter. I believe that it would be appropriate for the range of risks associated with doses below the ATSDR cancer comparison values to be discussed and acknowledged. The ATSDR draft PHA concludes that there is no health hazard from exposure to past, present, or future releases, but does not discuss or disclose the levels of individual risks of radiogenic cancer incidence that are associated with these exposures. The impression that there is no concern at doses below the specified cancer Comparison Values (CVs) for radiation exposure is misleading. A distinction needs to be made between levels of exposure likely to produce statistically significant relative risks in an epidemiological study and levels of exposure that constitute significant relative and excess lifetime risks to individuals. Discussion of individual risks of cancer is notably lacking in the PHA, even though the quantification of excess risk, with uncertainty, was the main focus of the Oak Ridge Dose Reconstruction Task 4 Report. In the Oak Ridge Dose Reconstruction Task 4 Report, the upper limits of the 95% credibility interval of the excess lifetime risk range from 1.6 to 4 chances in ten thousand at Kingston, and from 5.4 chances in ten thousand to 3.8 chances in one thousand at Jones Island on the Clinch River (see Table 13.D.1 of Apostoaei et al, 1999). The lower credibility limits approach or exceed a risk of one in one hundred thousand at all locations.	ATSDR recognizes that every radiation dose, action, or activity may have an associated risk. The fact that we did not previously present details on individual risk for radiation in the public health assessment is not inconsistent with ATSDR practice, as suggested by the commenter, because to develop conclusions we use a dose methodology in our assessments. In the public health assessment process, techniques similar to those of the quantitative risk assessment methods (i.e., generating quantitative "risk estimates"), such as those used in the Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report), may be used primarily as a screening tool to rule out clearly the existence of public health hazards or as a way of understanding regulatory concerns. If, however, exposure at a site exceeds one or more media-specific comparison values (dose-based comparison values or quantitative risk estimates), the public health assessment process proceeds with a more in-depth health effects evaluation. ATSDR scientists conduct a health effects evaluation by carefully examining site-specific exposure conditions about actual or likely exposures; conducting a critical review of available toxicological, medical, and epidemiologic information to ascertain the substance-specific toxicity characteristics (levels of significant human exposure); and comparing an estimate of the amount of chemical 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 effects. The goal of the health effects evaluation is to decide whether harmful effects might be possible in the exposed population by weighing the scientific evidence and by keeping site-specific doses in perspective. The output is a qualitative description of whether site exposure doses are of sufficient nature and magnitude to trigger a public health action to limit, eliminate, or study further any potential harmful exposures. 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. The conclusions and recommendations are based on the professional knowledge and judgment of the health assessment team members. Because, however, of uncertainties regarding exposure conditions and because of adverse effects associated with

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		environmental levels of exposures, definitive answers on whether health effects actually will or will not occur are not possible. That said, providing a framework that puts site-specific exposures and the potential for harm in perspective is possible and is one of the primary goals of the public health assessment process. For this PHA, ATSDR added an appendix (Appendix F) to discuss risk terminology, radiation risk, and risk limits in detail. The appendix also explains the differences between ATSDR public health assessments and EPA risk assessments and shows the method for converting the doses in this PHA to risk numbers. Please note that although ATSDR does not base its public health conclusions on these risk numbers, they are presented in this PHA to provide for the community detailed information on risk.
42	The excess lifetime risk levels associated with ATSDR's cancer CVs for radiation are much higher than the risk levels ATSDR uses in its evaluation of other human carcinogens. For exposures to other human carcinogens, ATSDR usually considers risks in the range of one chance in ten thousand to one chance in one million to warrant more detailed investigation. For non-cancer producing toxic substances, ATSDR typically applies a series of safety factors to the lowest observed adverse effects level to derive an exposure level that can be considered to have a minimum risk. For exposure to radiation, the majority of scientific opinion is that there is no threshold dose below which the risk from exposure can be considered to be zero.	The risk range cited is the typical risk range used by the U.S. Environmental Protection Agency (EPA) in its evaluations of contaminants in the environment. Many of these evaluations may not necessarily be based on health, but entirely on risk assessments. The ATSDR Cancer Policy Framework, adopted in 1993, addresses many factors that must be evaluated in analyzing environmental exposures. ATSDR recognizes that at present no single generally applicable procedure for exposure assessment is available, and therefore exposures to carcinogens are best assessed on a case-by-case basis, with an emphasis on exposure prevention. There are subtle differences in ATSDR's process of evaluating chemicals and radiation such as dose to individual organs, age-specific dose coefficients, and other metabolic differences as discussed in several ICRP publications. In its 1989 Report 96 (titled: *Comparative Carcinogenicity of Ionizing Radiation and Chemicals*), the National Council on Radiation Protection and Measurements (NCRP) stated that less than 30 chemicals were known to be cancer-inducing in humans and of those, in most it was not possible to define a dose-incidence relationship except generally. Also, there is much more uncertainty in chemical metabolism, the possibility of additive or synergistic effects between or among chemicals, potency, and dosimetry than in radiation evaluations. The NCRP stated that risk assessment for chemicals is "generally more uncertain than risk assessments for radiation." Because of these statements by the NCRP, ATSDR does not, in the true sense of the comment, evaluate radiation in the similar manner as it evaluates chemicals. In this public health assessment, ATSDR compares annual doses to the 100 mrem/year dose limit of the International Commission on Radiological Protection (ICRP), the NCRP, and the U.S. Nuclear Regulatory Commission (NRC), as well as ATSDR's minimal risk level (MRL). ATSDR compares lifetime doses to the agency's radiogenic cancer comparison value of 5,000 mrem over 70 years, which is based on peer-reviewed literature and other documents developed to review the health effects of ionizing radiation. These values, used

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		as screening tools during the public health assessment process, are levels below which adverse health effects are not expected to occur. If the screening indicates that past or current doses exceed our comparison values, then we would conduct further in-depth health evaluation. ATSDR incorporated safety margins when it developed its screening values for radiation exposures. The approach ATSDR uses to derive MRLs, such as those in the Toxicological Profile for Ionizing Radiation, was developed with the EPA. The screening value includes the use of a no observed adverse effect level (NOAEL) or a lowest observed adverse effect level (LOAEL) as well as three or more situation-specific uncertainty factors; when multiplied, these factors give a total uncertainty factor generally ranging from 1 to 1,000 based on the studies used. Furthermore, the ATSDR legislative authority, as discussed many times, limits ATSDR to evaluate exposures based on observable and tolerable adverse health effects. If adverse health effects are not observed in an epidemiological study, then the doses used in the study should be considered tolerable. ATSDR's radiogenic comparison value of 5,000 millirem over 70 years incorporates the linear no-threshold (LNT) model for evaluating public health hazards associated with exposure to radiation. It assumes a total lifetime dose (70 years of exposure) above background that is considered safe in terms of cancer induction. In addition to the LNT model, ATSDR also incorporates a margin-of-dose (MOD) approach into this comparison value. During an evaluation, if ATSDR determines that further investigation is needed, scientific literature associated with radiological doses and dose estimates, particularly those related to adverse health effects, is reviewed. Then, ATSDR compares the dose estimates from scientific literature to site-specific dose estimates. Thus, ATSDR uses the LNT model to determine when a more detailed site-specific evaluation is necessary, and uses the MOD approach to develop realistic information for communities regarding what is known and unknown about radiation levels at a particular site. An independent expert panel convened to review ATSDR's site-specific approaches used to evaluate past, current, and future radiation risks to communities surrounding the Oak Ridge Reservation concluded that this combination of approaches (LNT and MOD) is appropriate for ATSDR to use to determine radiation levels at which health effects actually occur. The panel found that ATSDR's use of the MRL of 100 millirem and radiogenic cancer comparison value of 5,000 millirem were appropriate screening values. If extrapolated over 70 years assuming constant exposure, the radiogenic cancer comparison value dose estimate would be about 71 millirem per year—a level the panel determined to be protective of public health in terms of cancer and noncancer risks. The panel also concluded that ATSDR's approach considers evidence for both individual organs and whole-body doses (effective doses), noting that a whole-body dose could not be developed without accounting

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		for doses to single organs. Further, the panel determined that ATSDR's method of distinguishing dose levels from risk levels was acceptable because ATSDR incorporated risk and LNT explicitly and implicitly when calculating doses. In the words of one peer reviewer regarding ATSDR's radiogenic cancer comparison value, "The general consensus is that the linear non-threshold hypothesis is scientifically reasonable for the purpose of radiation protection. The recent NCRP comprehensive review and UNSCEAR [United Nations Scientific Committee on the Effects of Atomic Radiation] evaluations do not find any alternative model to be better, including one with a threshold. While epidemiology is not capable of detecting risks in the low dose domain, under say 10,000–20,000 millirem, there are cellular experiments and theoretical reasoning that support a linear response."
43	Needless to say, the ATSDR could have avoided considerable negative criticism among scientists knowledgeable in the estimation of radiogenic cancer risk if the Agency had produced a quantitative estimate of cancer risk, instead of relying on crude estimates of epidemiological limits of detection in human epidemiological studies and making a policy decision that epidemiological limits of detection for radiogenic cancers in human cohorts are appropriate as surrogates for a limit of public health concern.	The independent external peer reviewers were satisfied with the results expressed in dose in this public health assessment (see Appendix H for the peer reviewer comments and ATSDR's responses). This comment is interesting, considering that risk estimates are based on the "crude estimates of epidemiological limits of detection." ATSDR's policy decision was reviewed by an external independent peer review panel comprised of radiation scientists and epidemiologists (see the response to comment 42 for more information on the findings of the peer review panel). The agency also solicited comments from reviewers at the National Cancer Institute and the International Epidemiology Institute. The peer reviewers were satisfied with ATSDR's approach. In the words of one peer reviewer, a highly respected radiation epidemiologist, "The general consensus is that the linear non-threshold hypothesis is scientifically reasonable for the purpose of radiation protection. The recent NCRP [National Council on Radiation Protection and Measurements] comprehensive review and UNSCEAR [United Nations Scientific Committee on the Effects of Atomic Radiation] evaluations do not find any alternative model to be better, including one with a threshold. While epidemiology is not capable of detecting risks in the low dose domain, under say 10,000–20,000 mrem, there are cellular experiments and theoretical reasoning that support a linear response." In response to a dose versus risk issue, this expert also stated that "Radiation protection is based on limiting dose to the public and to workers. Thus international and national committees make recommendations and national policy and regulatory bodies make judgments as to the allowable doses for the population. Dose limits are roughly based on risk of adverse health effects, and in the case of exposure to ionizing radiation it is primarily the cancer risk at low doses that is of concern. Heritable effects (genetic effects in future generations) have not been demonstrated in humans and are now believed to be much

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		lower than originally suspected based on experimental studies." Further, the issue with applying a "quantitative" risk coefficient to any dose is that one can calculate any risk and this is "perceived" as a true value. As stated in the ATSDR Cancer Framework Policy, "This artificial appearance of precision can lead decision makers to rely heavily on numerical risk estimates. Although ATSDR recognizes the utility of numerical risk estimates in risk analysis, the Agency considers these estimates in the context of the variables and assumptions involved in their derivation and in the broader context of biomedical opinion, host factors, and actual exposure conditions." For additional information, please review the framework policy that can be found at http://www.atsdr.cdc.gov/cancer.html. For this PHA, ATSDR nonetheless added an appendix (Appendix F) to discuss risk terminology, radiation risk, and risk limits in detail. The appendix also explains the differences between ATSDR public health assessments and EPA risk assessments and shows the method for converting the doses in this PHA to risk numbers. Please note that ATSDR does not base its public health conclusions on these risk numbers; they are presented here to provide the community with detailed information on risk.
44	Page 6, Line 2: ATSDR needs to remain instep with the EPA in the methodology for performing risk assessments for DOE sites. It is EPA and CERCLA (Comprehensive Environmental Response Compensation and Liability Act) and not ATSDR that has the regulatory authority to stipulate the proper methodology to be used to perform radiological risk assessments. ATSDR needs to follow EPA's lead of using CERCLA slope factors for radionuclides, and not the 'millirem approach' in its estimation of risks from the ingestion of radioactively contaminated fish. In case ATSDR is uniformed about how to do this please refer to an EPA publication that documents the proper selection of risk assessment tools to be used in the evaluation of a radioactively contaminated stream. EPA 904-R-97-010. Title: Compendium of Issues surrounding the levels of contaminants contained in fish collected in tributaries leaving the Savannah River Site (SRS) and associated risk from exposure to those levels of contaminants. It was this risk assessment that documented a hazard with radioactive contamination of fish in the Savannah River (located between Georgia and South Carolina and downstream from another DOE facility, the Savannah River Site in Akin, SC. The characterization of these environmental	ATSDR and EPA have distinct purposes and goals that necessitate different types of assessments, as explained in ATSDR"s Public Health Assessment Guidance Manual (http://www.atsdr.cdc.gov/HAC/PHAManual/toc.html), EPA's *Risk Assessment Guidance for Superfund – Human Health Evaluation Manual*, and in *A Citizen's Guide to Risk Assessments and Public Health Assessments at Contaminated Sites* (written jointly by ATSDR and EPA Region IV; see http://www.atsdr.cdc.gov/publications/CitizensGuidetoRiskAssessments.html). An ATSDR health assessment is a mechanism to provide the community with information on the public health implications of a specific site, identifying populations for which further health actions or studies are needed. The health assessment might also make recommendations for actions necessary to protect public health. An EPA baseline risk assessment is used to support the selection of a remedial measure at a site. 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. A comprehensive guide to the Superfund risk assessment process is available from EPA on the Internet at: http://www.epa.gov/superfund/health/risk/index.htm. To understand why in the public health assessment process ATSDR scientists use doses (instead of the quantitative baseline risk assessments conducted by regulatory agencies,

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	releases of hazardous chemical (both radioactive and non-radioactive) from SRS directly resulted in a Fish Advisory being issued to advise the public of associated health risks. This joint effort of EPA, DOE, Georgia, and South Carolina added significant value to these agencies' joint efforts to protect the public health. ATSDR should use this laudatory state and federal collaboration as a case study in how to proceed in a constructive fashion in their work with stakeholders downwind and downstream of the DOE ORR. Page 93, Table 15. Estimated Whole Body Radiation Does For Current Lower Watts Bar Reservoir Exposure Pathways. Refer to the comment concerning need to use 'slope factors,' and not 'millirems' in performing CERCLA risk analyses for ingested radionuclides. Page 100, Table 20. Estimated Radiation Doses From Current Consumption of Fish. Refer to comment for Page 90, Table 13. This PHA is becoming increasingly complicated because of ATSDR's intransigence in not utilizing the standard methodology specified in EPA CERCLA RAGs for risk analyses of ingested radionuclides. ATSDR needs to better inform itself by consulting with available guidance on EPA's Superfund Web sites to obtain information on how to perform a risk analysis that can meet the muster of CERCLA. After all ATSDR is supposed to already know this and should not have to be informed of this from stakeholders. Better, ATSDR should immediately consult with its sister federal agency, specifically the EPA Southeastern Regional Office of EPA in Atlanta, GA as to how was it that the EPA was able to facilitate an interstate fish advisory for the Savannah River because of offsite radioactive releases from the Savannah River site (SRS), near Akin, SC. Also, consult the EPA's OLS (Online Library System) at the following website: www.epa.gove/natlibra/ols.htm and use the search terms Savannah River Fish. This search will give you the details of a risk assessment for radioactively contaminated fish. ATSDR should use a comparable approach, one consistent with current EPA CERCLA RAGs, to produce a more valid PSA for communities downstream from DOE ORR. Here is the OLS citation and call number for EPA 904/R-96/006 as it appears online: Main Title Potential human health effects of ingesting fish which are taken from locations near the Savannah River site (SRS). Publisher US Environmental Protection Agency, Region 4. Year Published	such as EPA) it is important to understand the intentional differences between ATSDR's health assessments and EPA's risk assessments. The public health assessment is different from a risk assessment in its purpose, its goals, the exposures evaluated, and the use of information. The table below outlines the primary differences between an ATSDR public health assessment and an EPA baseline risk assessment. **ATSDR Public Health Assessment vs. EPA Baseline Risk Assessment**

Agency	ATSDR	EPA
Type of Assessment	**Public Health Assessment**	**Baseline Risk Assessment**
Description	The public health assessment process is an evaluation of data and information (environmental data, health outcome data, and community concerns) pertaining to the release of hazardous substances into the environment. Its purpose is to assess the likelihood of health effects from exposure to hazardous substances and to identify appropriate public health actions to evaluate or prevent health effects. In addition, ATSDR uses the process to respond to site-specific community health concerns. It is qualitative, site-specific, and focuses on medical and public health perspectives.	The quantitative baseline risk assessment, the framework of the EPA human health evaluation, is a numerical analysis of environmental data used to characterize the probability (theoretical risk) of adverse effects as defined by regulatory standards and the requirement for the remedial investigation/ feasibility study (RI/FS) at Superfund sites. It is a quantitative, chemical-oriented characterization that uses statistical models to estimate risk from a regulatory perspective.
Purpose	To provide community members and environmental	To assist risk management decision-making in the

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1996. OCLC Number 36482354. Report Number EPA 904/R-96/006. Holdings LIBRARY CALL NUMBER EKAM. RA602.F5P6. Owner Libraries EKA – Region 4 Library/Atlanta, GA. Holding Modified LIBRARY Date Modified EKA 19970314. Place Published Atlanta, GA. Bib Levl m. OCL Time Stamp 19970304154240. Cataloging SOURCE OCLC/T. Language ENG. PUB Date Free Form May 1996. Collation var. paging chiefly table 28 cm. Notes "EPA 904/R-96/006" "May 1996."
Subject Added Net Health risk assessment-Savannah River Region (Ga. And S.C.); Fish as food-Contamination-Savannah River Region (Ga. And S.C.); Water quality – Savannah River Region (Ga. And S.C.). CORP Au Added Net United States. Environmental Protection Agency. Region IV ; United States. Department of Energy; United States. Environmental Protection Agency. Region IV; United States. Department of Energy. OCLC Rec Leader 00953nam 2200241Ka 45010.
Stakeholders know this volume is an easy to read guide on how to perform their own risk analysis of radioactively contaminated fish. This guide should prove useful in performing a comparable risk analysis of fish downstream from DOE ORR, from Clinch River Mile 1 (CRM1) to at least to the TVA Mocassin Bend embayment.
The radionuclide fish tissue is reality extractable from the OREIS database and can be easily analyzed according to the method in the EPA report.
This guide could also be used to map 'hot spot' fishing holds throughout the TVA dendritic system fro Oak Ridge, TN to Paducah, KY. The TVA has an online, interactive, map of the TVA tributaries for all seven states of the system, and the necrotic locations are easily identified. Also, TVA's three nuclear pants are pinpointed as well: Browns Ferry, Sequoia, and Watts Bar. The Web site for this very useful map of the area(s) potentially impact by these radioactively contaminated fish is available online at:
www.tva.gov/sites/sites ie2.htm.
Page 102, Table 21. Summary of Public Health Implications From ATSDR's Evaluation of Past and Current Exposure to Radionuclides Released to the Clinch River/Lower Watts Bar Reservoir. The 'millirem' approach that ATSDR is persisting to utilize here is not in sync with current EPA RAGs guidance for doing risk analyses. Redo all of these analyses using current EPA RAGs guidance. Potentially exposed stakeholders will
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<tr><td></td><td>and public health agencies with conclusions about the actual existence or level of the public health hazard posed by exposure to hazardous substances at a specific site and to identify populations for which further public health actions or studies are needed to evaluate or prevent health effects.</td><td>selection of remedial actions involving hazardous site cleanup strategies (the determination of permit levels for the discharge, storage, or transport of hazardous waste; the establishment of clean-up levels; the determination of allowable levels of contamination).</td></tr>
<tr><td>Goal</td><td>To determine whether harmful health effects are expected from contaminants in the environment and to make recommendations for actions needed to protect public health, which may include issuing health advisories.</td><td>To provide a framework for developing the risk information necessary to assist decision-making at remedial sites.</td></tr>
<tr><td>Objectives</td><td>•To determine the nature and extent of contamination
•To define potential human exposure pathways
•To identify populations who may be or may have been exposed
•To determine the health implications and public health hazards of site-related exposures, using environmental, toxicological, medical, and health outcome data</td><td>•To help determine whether additional remedial response action is necessary at a site
•To provide a basis for determining residual chemical levels that are adequately protective of health
•To provide a basis for comparing potential health impacts of various remedial alternatives
•To help support selection</td></tr>
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definitely be doing their own risk analyses of these exposures. These risk analyses will be using the now standard EPA approach cited above that uses, for example, pCi/gm of radionuclides in fish. These stakeholders will not be using the millirem' approach that ATSDR persists in using because it is too easy to discount each incremental cumulative radiation exposure one at a time as being inconsequential. ATSDR should be doing so too so that it can catch up with the stakeholders' own assessments.
In addition to the OREIS fish data, ASER also has robust fish data in its data volume which can be accessed at http://www.ornl.gov/sci/env_rpt/. To get to the data volume you need to scroll down to the index and the data bookmark is typically near the bottom for each year. All fish data are given in picocuries per gram. (1 pCi = 3.75E-02 Bequerels [Bq]). This is another good reason that ATSDR must move to using the standard EPA 'slope factor' approach, which measures exposure dose in pCi – not millirems (mrem). If ATSDR persists in using the dated mrem approach in performing its exposure assessment it will be out of sync with both standard EPA practice and those stakeholders doing their own 'alternative' risk analyses.
Also, the OREIS biota/fish data date all the way back to 1985. A plethora of fish data for stakeholders interested in detailed data – or in doing risk calculation and statistics on their own ATSDR should reasonably anticipate that there will be plenty of 'alternative' stakeholder-developed risk analyses of WOC releases. How will ATSDR contend with these foreseeable developments if it is not using the same methodology that stakeholders will be using?
Page 108, Line 17. ATSDR is utilizing methodology, which is not consistent to the legal requirements of CERCLA. ATSDR must use standard EPA Risk Assessment Guidelines (RAGs) for ingested radionuclides. These ingested radionuclides are to be treated the same as all other chemical carcinogens. These ingested radionuclides are not to be cranked into the dated approach of simply comparing 'millirems' of exposure to a hypothetical annual dose for an 'average' citizen.
ATSDR is ostensibly a 'client' federal agency for EPA, and EPA is one of its 'customer' federal agencies – also partnering with DOE and DOD. All three federal agencies contribute millions of dollars to fund ATSDR through interagency transfer of tax dollars. Why is ATSDR so
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<tr><td></td><td>•To address those public health implications by recommending relevant public health actions to prevent harmful exposures
•To identify and respond to community health concerns</td><td>of the "no-action" remedial alternative
•To identify remedial actions that pose an acceptable risk as defined by regulatory standards</td></tr>
<tr><td>Exposures and Pathways Evaluated</td><td>To evaluate site-specific exposure conditions about actual or likely past, current, and future exposures.</td><td>To evaluate possible current or future exposures and consider all contaminated media regardless of whether exposures are occurring or likely to occur.</td></tr>
<tr><td>Result</td><td> The public health assessment provides ATSDR's conclusion regarding the degree of public health hazard, if any, posed by a site or hazardous substances in the environment and recommends appropriate public health actions needed to limit, eliminate, or further study any potential harmful exposures. The report provides a qualitative description of whether exposures to hazardous substances are of sufficient nature and magnitude to be a public health hazard and trigger </td><td> The EPA baseline risk assessment provides a quantitative estimate of theoretical risk used to support the selection of a remedial measure at a site. These quantitative estimates of risk are based on default exposure and toxicity assumptions that represent a prudent conservative (protective) approach: that of prevention. These conservative assumptions ensure that remedial actions are amply safe and protective of health. The risk estimates are not </td></tr>
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<tr><th></th><th>Comment</th><th colspan="3">ATSDR's Response</th></tr>
<tr><td rowspan="2"></td><td rowspan="2"> unresponsive to using standard EPA Risk Assessment Guidelines (RAGs) for ingested radionuclides? The citizens of Oak Ridge and the citizens of all downwind and downstream potentially impacted communities will do their own research to come up with valid risk analyses if they have to, and ATSDR should realize that we are fully capable of protecting our own public health. (Comments received on the initial release PHA dated December 2003.) No mention is made of the EPA regulatory standards for public exposure to radiation, which includes the Safe Drinking Water Act of 4 mrem per year, or the fact that EPA generally regards cumulative individual risks to maximally exposed individuals on the order of one chance in ten thousand (approximately equal to about 100 mrem cumulative whole body dose over a 30 year exposure period) to merit consideration for remedial action. For carcinogenic chemicals, excess lifetime risks to maximally exposed individuals from between one chance in ten thousand and one chance in one million may be considered for remedial action at contaminated sites, but usually some form of action is taken when these risks exceed one chance in ten thousand. </td><td></td><td> public health actions. Because of uncertainties, a definitive answer on whether health effects actually will or will not occur is not possible. However, the report puts exposures and the potential for harm in perspective. </td><td>intended to predict the incidence of disease or measure the actual health effects in people as a result of a site.</td></tr>
<tr><td>Methods</td><td> The public health assessment process is iterative and dynamic. In the initial screening evaluation, similar techniques to those of the quantitative risk assessment methods may be used primarily as a screening tool to clearly rule out the existence of public health hazards. If, however, during this screening assessment the estimated dose exceeds one or more media-specific comparison values (dose-base comparison values or quantitative risk estimates), the public health assessment process proceeds with a more in-depth health effects evaluation. ATSDR scientists conduct a health effects evaluation by carefully examining site-specific exposure conditions and comparing an estimate </td><td> The quantitative theoretical risk estimates are based on statistical and biological models that include a number of protective assumptions about exposure and toxicity to ensure protection of the public. By design, they are conservative estimates that generally overestimate health risk. Therefore, people will not necessarily be affected even if they are exposed to materials at dose levels higher than those estimated by the risk assessment. For cancer effects, risks are expressed as probabilities. These probability risks are not intended to predict the incidence of disease or measure the actual health effects a site has on people. For noncancer effects, exposure levels are </td></tr>
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		<table><tr><td></td><td>of the amount of chemical exposure (i.e., dose) that 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 toxicologic, epidemiologic, radiologic, and medical information to help determine whether exposure to contaminant levels might result in harmful effects. The goal of the health effects evaluation is to decide whether or not harmful effects might be possible in the exposed population by weighing the scientific evidence and by keeping site-specific doses in perspective.</td><td>compared to pre-established levels deemed to be safe.</td></tr></table> **Public Health Assessment** The public health assessment process serves as a triage for evaluating the public health implications of exposure to environmental contamination and for identifying appropriate public health actions for particular communities. PHAs are used to identify off-site populations 1) who are exposed to hazardous substances; 2) to determine how and when they were exposed; 3) to determine whether these past, present, or future exposures are likely to lead to illness; and 4) to recommend follow-up public health actions to address the exposure and ensure the protection of public health. The public health assessment process, which may lead to a variety of public health actions, serves as a mechanism through which

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		the agency responds to site-specific community health concerns. In the public health assessment process, similar techniques to those of the quantitative risk assessment methods (i.e., generating quantitative "risk estimates") may be used primarily as a screening tool to clearly rule out the existence of public health hazards or as a way of understanding regulatory concerns. If, however, exposure at a site exceeds one or more media-specific comparison values (dose-based comparison values or quantitative risk estimates), the public health assessment process proceeds with a more in-depth health effects evaluation. ATSDR scientists conduct a health effects evaluation by carefully examining site-specific exposure conditions about actual or likely exposures; conducting a critical review of available toxicological, medical, and epidemiologic information to ascertain the substance-specific toxicity characteristics (levels of significant human exposure); and by comparing an estimate of the amount of chemical 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 effects. The goal of the health effects evaluation is to decide whether harmful effects might be possible in the exposed population by weighing the scientific evidence and by keeping site-specific doses in perspective. The output is a qualitative description of whether site exposure doses are of sufficient nature and magnitude to trigger a public health action to limit, eliminate, or further study any potential harmful exposures. The PHA 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. The conclusions and recommendations are based on the professional knowledge and judgment of the health assessment team members. Because, however, of uncertainties regarding exposure conditions and adverse effects associated with environmental levels of exposure, definitive answers on whether health effects actually will or will not occur are not possible. But providing a framework that puts site-specific exposures and the potential for harm in perspective is possible. In fact, it is one of the primary goals of the public health assessment process. **Baseline Risk Assessment** The quantitative baseline risk assessment (the framework of the EPA human health evaluation) is a numerical analysis used to determine whether levels of chemicals at hazardous waste sites pose an unacceptable risk as defined by regulatory standards and requirements. The risk assessment process is used by regulators as part of site remedial investigations to support risk management decisions and to define remedial actions

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		involving hazardous site cleanup strategies (the determination of permit levels for the discharge, storage, or transport of hazardous waste; the establishment of clean-up levels; and the determination of allowable levels of contamination) that ensure overall protection of human health and the environment. Remedial plans based on a quantitative risk assessment represent a prudent public health approach—that of prevention. The EPA risk assessment provides an estimate of theoretical risk from possible current or future exposures and considers all contaminated media regardless of whether exposures are occurring or are likely to occur. For cancer effects, risks are expressed as probabilities. For noncancer effects, exposure levels are compared to pre-established levels deemed to be safe. The quantitative risk estimates are not, however, intended, to predict the incidence of disease or measure the actual health effects in people resulting from hazardous substances at a site. The estimated predictions are based on statistical and biological models that include a number of protective assumptions about exposure and toxicity to ensure protection of the public. By design, they are conservative predictions that generally overestimate risk. For this reason, risk estimates are very useful in deciding the extent to which a site needs to be cleaned up (and to what levels) to protect public health adequately. Risk assessment involves estimating exposure doses based on conservative (protective) standard (or default) exposure and toxicity assumptions (which often overestimate health risk) to ensure that remedial actions are amply safe and protective of health. Therefore, people will not necessarily be affected even if they are exposed to materials at dose levels higher than those estimated by the risk assessment. EPA's quantitative risk assessments, which are used for regulatory purposes, do not provide perspective on what the risk estimates mean in the context of the site community and do not measure the actual health effects that hazardous substances have on people. **Conclusions** For its evaluation of past exposures to X-10 radionuclide releases via White Oak Creek, ATSDR used a dose methodology and considered the 50^{th} percentile estimates provided in Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (available at http://www2.state.tn.us/health/CEDS/OakRidge/WOak1.pdf). The Task 4 team, on the other hand, used a risk model and the upper 95^{th} percentile dose and risk levels. Nonetheless, even using different approaches, we came to the same basic conclusions as described below. According to page 15-4 of the Task 4 report, "The radiological doses and excess lifetime cancer risks estimated in this report are incremental increases above those resulting from exposure to natural and other anthropogenic sources of radiation. Nevertheless, for the exposure pathways considered in this task, the doses and risks are not large enough for a

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		commensurate increase in health effects in the population to be detectable, even by the most thorough of epidemiological investigations. In most cases, the estimated organ-specific doses are clearly below the limits of epidemiological detection (1 to 30 cSv [centisieverts]) for radiation-induced health outcomes that have been observed following irradiation of large cohorts of individuals exposed either in utero, as children, or as adults." "…it is unlikely that any observed trends in the incidence of disease in populations that utilized the Clinch River and Lower Watts Bar Reservoir after 1944 could be conclusively attributed to exposure to radionuclides released from the X-10 site, even though this present dose reconstruction study has potentially identified increased individual risks resulting from these exposures." Also, the Task 4 report was reviewed by the Oak Ridge Health Agreement Steering Panel (ORHASP)—a panel of experts and local citizens appointed to direct and oversee the Oak Ridge Health Studies. On page 12 of the ORHASP's final report titled *Releases of Contaminants from Oak Ridge Facilities and Risks to Public Health* (available at http://www2.state.tn.us/health/CEDS/OakRidge/ORHASP.pdf), the panel determined that "Although the White Oak Creek releases caused increases in radiation dose, the calculated exposures were small, and less than one excess cancer is expected." On page 147 of the final public health assessment, "ATSDR concludes that exposures to X-10 radionuclides released from White Oak Creek to the Clinch River and to the Lower Watts Bar Reservoir are not a health hazard. Past and current exposures are below levels associated with adverse health effects and regulatory limits. Adults or children who have used, or might continue to use, the waterways for recreation, food, or drinking water are not expected to have adverse health impacts due to exposure. ATSDR has categorized those situations as posing *no apparent public health hazard* from exposure to radionuclides related to X-10. This classification means that people could be or were exposed, but that their level of exposure would not likely result in adverse health effects." Thus, even though ATSDR used a dose methodology and considered the 50th percentile estimates, while the Task 4 team used a risk model and the upper 95th percentile dose and risk levels, we came to the same basic conclusion. ORHASP found that less than one excess cancer case would be expected to occur as a result of exposure to X-10 radionuclide releases via White Oak Creek; ATSDR concluded that this exposure posed *no apparent public health hazard*. That said, for this PHA ATSDR added an appendix (Appendix F) to discuss risk terminology, radiation risk, and risk limits in detail. The appendix also explains the differences between ATSDR public health assessments and EPA risk assessments and shows the method for converting the doses in this PHA to risk numbers. Please note that

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		ATSDR does not base its public health conclusions on these risk numbers; they are presented in this PHA only to provide detailed information on risk for the community.
45	Page 106, Line 5. This is ridiculous. ATSDR, an advisory federal agency, is supposed to work hand-in-glove with EPA, a regulatory federal agency, to protect the public health of stakeholders downwind, downstream, and down-aquifer form DOE ORR. Yet ATSDR persists in not using standard EPA risk assessment guidance in developing its WOC 'Public Health Assessment.'	Please see the response to comment 44 regarding ATSDR's policy on performing risk assessments. Also, for this PHA, ATSDR added an appendix (Appendix F) to discuss risk terminology, radiation risk, and risk limits in detail. The appendix also explains the differences between ATSDR public health assessments and EPA risk assessments and shows the method for converting the doses in this PHA to risk numbers. Please note that ATSDR does not base its public health conclusions on these risk numbers; they are presented in this PHA only to provide detailed information on risk for the community.
	ATSDR states flatly: "Currently, there are not federal regulations pertaining to the ingestion of radiological contaminated food." This is a very ignorant statement, which is not factual. ATSDR needs to use the following reference, which includes guidance of the risk analysis of radioactive contaminants for all possible routes of exposure, including fish: Main Title Risk Assessment Guidance for Superfund. Volume 1. Human Health Evaluation Manual (Part B, Development of Risk-Based Preliminary Remediation Goals [PRGs]). Corp Author Environmental Protection Agency, Washington, DC. Office of Emergency and Remedial Response. Publisher Dec 91 Year Published 1991 Report Number OSWER-9285.7-01B; Stock Number PB92-963333 Subjects Hazardous materials; Public health; Pollution Control; Toxicity; Exposure; Investigations; Objectives; Selection; Decision making; Superfund; Remedial response Holding. Chapter 4 of this volume, RISK-BASED PRGs FOR RADIOACTIVE CONTAMINANTS, is the one that ATSDR need to acquit itself with because this is the reference that EPA and other stakeholders in the community are using. ATSDR, and stakeholders as well, can access this reference online at the following website: www.epa.gov/superfund/programs/risk/ragsb/chapt4.pdf.	The referenced statement, "Currently, there are no federal regulations pertaining to the ingestion of radiological contaminated food," was removed during subsequent revisions and is not included in the final PHA. It is nonetheless important to note that this is not, as this comment states, a "very ignorant statement, which is not factual." Guidance documents refer to ingestion of radiologically contaminated food, but these are not the same as federal regulations. In contrast to federal regulations, guidance documents, while they may offer suggested guidelines, are not legally enforceable.
	ATSDR needs to desist from its fallacious assertions of 'No Risk' when it is not even using standard EPA risk analysis guidelines. Consequently, this entire WOC PHA is fatally flawed and should be immediately redrafted using the standard EPA guidance cited above. (*Comment received on the initial release PHA dated December 2003.)*	ATSDR is not sure what is referenced in the comment that "ATSDR needs to desist from its fallacious assertions of 'No Risk.'" As mentioned in the response to comment 44, ATSDR does not perform risk assessments; we conduct public health assessments. Further, neither previous versions of this PHA nor the final version mention "no risk." . As explained previously (see response to comment 27), ATSDR bases its conclusions on estimated doses compared to health guidelines (e.g., MRL) where observable health effects have been observed—not on theoretical risk for possible exposures whether they are occurring or are likely to occur. Therefore, ATSDR would not make a "no risk" conclusion. Instead, in this final PHA, ATSDR concludes that "Exposures to X-10 radionuclides released from White

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		Oak Creek to the Clinch River and to the Lower Watts Bar Reservoir are not a health hazard. Past and current exposures are below levels associated with adverse health effects and regulatory limits. Adults or children who have used, or might continue to use, the waterways for recreation, food, or dinking water are not expected to have adverse health impacts due to exposure. ATSDR has categorized those situations as posing *no apparent public health hazard* from exposure to radionuclides related to X-10."
46	Why doesn't ATSDR choose to give EPA, as its customer agency, a product here that EPA is demanding? Could it be that ATSDR is more interested in low-balling DOE's risk estimates by hacking out lower risk estimates by using the FDA 'millirem' vis-à-vis the PA PRGs? ATSDR should not go searching for some way out of 'discovering' that fishers downstream of WOC may be in harm's way. In fact, there may be serious potential human health effects from ingesting fish taken from many locations downstream of WOC. The citizens of Oak Ridge, Kingston, Spring City, and all other downstream communities from DOE ORR demand a better product from ATSDR, and one consistent with the legal requirements of CERCLA. (*Comment received on the initial release PHA dated December 2003.)*	Please refer to the response to comment 44 regarding the intentional differences between ATSDR's health assessments and EPA's risk assessments. In 1980, Congress established ATSDR, part of the U.S. Department of Health and Human Services, under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), also referred to as Superfund. This law was established so that funding would be available to identify and clean up hazardous waste sites throughout the country. While EPA and 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 site on EPA's National Priorities List. Also to clarify, this commenter refers to ATSDR using "DOE's risk estimates" in this public health assessment, which is not true. This public health assessment uses data and doses from Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report) and documents associated with the report to evaluate past exposures. For current exposures, ATSDR uses data collected from 1988 to 1994 as presented in ATSDR's 1996 *Lower Watts Bar Reservoir Health Consultation*, including environmental sampling data from the 1980s and 1990s that had been collected and assembled by DOE, TVA, and various consultants, as well as data from TVA's 1993 and 1994 annual radiological environmental reports for the Watts Bar Nuclear Plant. ATSDR also used data collected from 1989 to the present (2003) in the Oak Ridge Environmental Information System. For future exposures, ATSDR based its evaluation on current exposures and doses related to releases from White Oak Creek, data on current contaminant levels in the Clinch River and Lower Watts Bar Reservoir, institutional controls in place to monitor contaminants in these water bodies, and consideration of the possibility that remedial activities could release radionuclides to White Oak Creek. Thus, as required by law under CERCLA, ATSDR prepared a public health assessment to evaluate these various exposure scenarios. Using the data mentioned above, ATSDR calculated dose estimates for past, current, and future off-site exposures to X-10 radionuclide releases to the Clinch River and Lower Watts Bar Reservoir via White Oak Creek. Given ATSDR's independent evaluation, we determined that past, current, and future uses of these watersheds do not pose a health hazard for people who have used or

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		might continue to use these waterways for food, drinking water, or recreation.
47	Pages 120-121: ATSDR limits health outcome evaluation to disease occurrence in a population. ATSDR seems to ignore the fact that, even though the population around the Clinch River was not exposed to levels that would lead to a statistically significant increase in the number of disease cases, some individuals may have been subject to non-negligible risk. It is important that ATSDR quantify the risk of disease for different categories of individuals in addition to quantification of the risk in the population. Examples of such categories are: Anglers who fished close to White Oak Creek and who consumed relatively large amounts of the fish they caught. Children living in the area. Children are more radiosensitive than adults. This aspect has not been explicitly addressed in the SENES Oak Ridge, Inc., Task 4 Report. It would be useful for ATSDR to address this issue. Note that the exposures in the first two decades of releases (1944-1953 and 1954-1963) are significantly larger than exposures in the next two decades (1964-1973, 1974-1991), as described in the SENES Task 4 report.	Following the ATSDR Cancer Framework Policy, ATSDR does not perform risk assessments. The agency does however recognize the importance of EPA risk assessment and risk analysis to determine whether levels of chemicals at hazardous waste sites pose an unacceptable risk as defined by regulatory standards and requirements. Risk analysis also helps regulatory officials make decisions in support of cleanup strategies that will ensure overall protection of human health and the environment. ATSDR acknowledges that conservative safety margins are built into EPA risk assessments and that these assessments do not measure the actual health effects that hazardous chemicals at a site have on people. For additional information, please review the framework policy at http://www.atsdr.cdc.gov/cancer.html. Current ATSDR policy does not allow for the use of risk coefficients in determining public health impacts. The issue with applying a "quantitative" risk coefficient to any dose is that one can calculate any risk, and this is "perceived" as a true value. As stated in the ATSDR Cancer Framework Policy, "this artificial appearance of precision can lead decision makers to rely heavily on numerical risk estimates. Although ATSDR recognizes the utility of numerical risk estimates in risk analysis, the Agency considers these estimates in the context of the variables and assumptions involved in their derivation and in the broader context of biomedical opinion, host factors, and actual exposure conditions." The agency acknowledges that at present no single generally applicable procedure for exposure assessment is available, and therefore exposures to carcinogens must be assessed on a case-by-case or context-specific basis. For additional information, please review the framework policy at http://www.atsdr.cdc.gov/cancer.html. Nonetheless, for this PHA ATSDR added an appendix (Appendix F) to discuss risk terminology, radiation risk, and risk limits in detail. The appendix also explains the differences between ATSDR public health assessments and EPA risk assessments and shows the method for converting the doses in this PHA to risk numbers. Please note that ATSDR does not base its public health conclusions on these risk numbers; they are presented in this PHA only to provide for the community detailed risk information.
48	I was immediately concerned with the fact it appears that no uncertainty estimates are given on reconstructed doses and no information is given on the cancer risks of past exposure. Instead, the report makes simple comparisons against doses that ATSDR calls "cancer comparison values" that are given with the intent that they represent a dose level below which	ATSDR evaluated the need for an uncertainty analysis as outlined in NCRP Commentary 14 titled *A Guide for Uncertainty Analysis in Dose and Risk Assessments Related to Environmental Contamination.* In essence, the use of conservative and biased screening calculations indicated the possible resulting dose would be clearly below a regulatory limit. "Conservative screening calculations are designed to provide a risk estimate that is highly

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	there should be no public concern for past exposure to radiation. Our own past work in historic dose reconstruction at Oak Ridge has been misrepresented by ATSDR. It has failed to acknowledge the uncertainty in doses that we reconstructed for reference individuals and instead has chosen to focus only on median estimates. It has inappropriately averaged relatively high annual doses that occurred during the early years of operation over a lifetime of 70 years to give the impression that annual doses were merely small fractions of natural background. The implications of such uncertainties need to be forthrightly acknowledged by ATSDR, even if they consider the upper credibility limits to be conservative. Since ATSDR has not demonstrated that the parameters, and hence the dose distributions, derived in the Task 4 report were conservative, it is all the more critical that the PHA include this consideration.	unlikely to underestimate the true dose or risk. Therefore, a more detailed analysis will likely demonstrate that the true risk is even less." The document states that screening can be considered among the first steps in conducting an uncertainty analysis, as this roughly defines the upper and lower bounds of a distribution of exposed populations or individuals. If these screening calculations are to be used successfully, a decision point has to be determined to establish the boundary at which no further analyses are necessary. According to NCRP Commentary 14, "For example, for dose reconstruction, the National Academy of Sciences has suggested that an individual lifetime dose of 0.07 Sv be used as a decision criterion for establishing the need for more detailed investigation (NAS/NRC 1995 [National Research Council. 1995. Radiation dose reconstruction for epidemiologic uses. Committee on an assessment of CDC radiation studies. Board on Radiation Effects Research, Commission on Life Sciences. Washington, DC: National Academy of Sciences.])." A value of 0.07 Sv is equivalent to 7 rem or 7,000 mrem—a value that is 40% higher than ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years. Thus, ATSDR's screening value is more conservative than the criteria suggested by the National Academy of Sciences as reported by the NCRP. For information on the difference between EPA risk assessment and ATSDR performing public health assessments, please see the response to comment 44. Further, for this PHA, ATSDR added an appendix (Appendix F) to discuss risk terminology, radiation risk, and risk limits in detail. The appendix also explains the differences between ATSDR public health assessments and EPA risk assessments and shows the method for converting the doses in this PHA to risk numbers. It is important to note that ATSDR does not base its public health conclusions on these risk numbers; they are presented in this PHA to provide for the community detailed information on risk. Use of the upper bound value artificially increases the risk, as the calculated uncertainty in many cases is at least an order of magnitude or greater than the 50^{th} percentile value. ATSDR uses the central values in this public health assessment because they provide the most realistic doses for potential exposures to radionuclides in the Clinch River and Lower Watts Bar Reservoir. Central estimates are used because they describe the risk or dose for a typical, realistic individual. When considering central estimates, half of the potential doses will fall above and half will fall below the estimate. Therefore, an individual's actual dose would most likely be closer to the central value than near the high or low end of the range of dose estimates. In fact, ATSDR's external reviewers who evaluated documents associated with the Oak Ridge Dose Reconstruction recommended emphasizing the central estimate rather than the upper and lower bounds of the dose distribution. The method the commenter describes is a first approximation of the annual dose. This

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		method is generally used by many agencies, including the U.S. Environmental Protection Agency (EPA), the U.S. Department of Energy (DOE), and the U.S. Nuclear Regulatory Commission (NRC) in determining the accumulated dose in the first year following an intake. This issue was discussed at several Exposure Evaluation Work Group meetings (EEWG, formerly known as the Public Health Assessment Work Group [PHAWG]) and at the Oak Ridge Reservation Health Effects Subcommittee (ORRHES) meetings where the screening process was discussed. The reason for dividing the total dose by 48 years was to establish a first approximation of the dose, as this would allow for comparison to the 100 mrem/year dose limit recommended for the public by the ICRP, the National Council on Radiation Protection and Measurements (NCRP), the NRC, and ATSDR. ATSDR approximated the annual whole-body dose for each pathway by applying weighting factors to the Task 4's estimated 50th percentile organ-specific doses, adjusting for a 1-year exposure, and summing the adjusted organ doses across each pathway. The first approximation value of 4.0 mrem/year for past exposures is 25 times less than the 100 mrem/year dose limit recommended for the public. Because this approximated value is so much lower than the dose limit recommended for the public during the screening-level evaluation, no further actions were necessary. Had the approximation shown an annual dose close to 100 mrem/year, ATSDR would have re-assessed the evaluation and conducted further investigation. In the Task 4 report the authors state they used measured concentrations when available. If however, these data were not available, estimations were made via the use of modeled parameters. As discussed in Chapter 4 of the task report, these estimations were subjective probability distributions. Given the nature of the subjective analyses, ATSDR believes these to be conservative in nature and application. A quantitative uncertainty analysis, as discussed in NCRP Commentary 14, "usually requires that the state of knowledge about the uncertain components of the mathematical model be described by probability distributions." If this knowledge is unavailable, then professional judgment is used to evaluate the site-specific parameters. NCRP Commentary 14 also states that if the results of an assessment indicate that doses are below regulatory limits, then a quantitative uncertainty analysis may not be necessary. The Task 4 report used conservative parameters (similar to worst-case) to estimate risks and doses from past exposures to X-10 radionuclides released to White Oak Creek. ATSDR calculated doses using the findings of the Task 4 report and obtained estimated doses well below conservative, regulatory limits. NCRP Commentary 14 also states that following an uncertainty analysis, if the 95th percentile exceeds a standard or regulatory limit and the 50th percentile is less than the standard or regulatory limit, then additional evaluations may be recommended (page 23).

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		ATSDR performed this additional evaluation and concluded that the more reasonable result was that the doses received from the intake of potentially contaminated foods (i.e., the pathway yielding the highest doses) were below regulatory limits and below levels of a public health hazard. Even if doses from all other pathways evaluated were combined with the ingestion pathway, the doses were still sufficiently low and were below levels where tolerable and observable adverse health effects would be expected.
49	Reflecting on the Community Concerns and Communications Work Group (CCCWG) minutes for June 14, 2005, it is clear that further discussion on the subjects of criteria, the review of draft public health assessments, and the need for uncertainty analysis, is warranted and should be beneficial. In addition, the statement is made in NCRP Commentary 14 that the National Academy of Sciences (NAS) has suggested that an estimated individual lifetime (whole body) dose below which further investigation is not necessary is 7000 mrem.	ATSDR evaluated the need for an uncertainty analysis as outlined in the National Council on Radiation Protection and Measurements' (NCRP) Commentary 14 titled *A Guide for Uncertainty Analysis in Dose and Risk Assessments Related to Environmental Contamination.* In essence, the use of conservative and biased screening calculations indicated the possible resulting dose would clearly be less than a regulatory limit. "Conservative screening calculations are designed to provide a risk estimate that is highly unlikely to underestimate the true dose or risk. Therefore, a more detailed analysis will likely demonstrate that the true risk is even less." The PHA states that screening can be considered among the first steps in conducting an uncertainty analysis, as this roughly defines the upper and lower bounds of a distribution of exposed populations or individuals. If these screening calculations are to be used successfully, a decision point has to be determined to establish the boundary at which no further analyses are necessary. According to NCRP Commentary 14, "For example, for dose reconstruction, the National Academy of Sciences has suggested that an individual lifetime dose of 0.07 Sv be used as a decision criterion for establishing the need for more detailed investigation (NAS/NRC 1995 [National Research Council. 1995. Radiation dose reconstruction for epidemiologic uses. Committee on an assessment of CDC radiation studies. Board on Radiation Effects Research, Commission on Life Sciences. Washington, DC: National Academy of Sciences.])." A value of 0.07 Sv is equivalent to 7 rem or 7,000 mrem—a value that is 40% higher than ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years. Thus, ATSDR's screening value is more conservative than the criteria suggested by the National Academy of Sciences as reported by the NCRP.
	There is a difference between a dose so low that a statistically significant epidemiological relative risk is not expected, and a dose below which the risk to the general public can be considered to be negligible. The failure of an epidemiological study to determine statistically significant relative risks is not sufficient to conclude "no health hazard" at lower doses. It is well understood amongst professionals in radiation epidemiology and radiation risk assessment that epidemiology by itself can never prove the null. For epidemiological investigations, a recommendation based on the	ATSDR recognizes that every radiation dose, action, or activity may have an associated risk. Given our evaluation in this public health assessment, ATSDR concludes that exposures to X-10 radionuclides released from White Oak Creek to the Clinch River and to the Lower Watts Bar Reservoir are not a health hazard. Past and current exposures are below levels associated with adverse health effects and regulatory limits. Adults or children who have used, or might continue to use, the waterways for recreation, food, or drinking water are not expected to have adverse health impacts due to exposure. ATSDR has categorized those situations as posing *no apparent public health hazard* from exposure to

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	highest dose attained, must take into account age at time of exposure, gender, and number of individuals exposed, uncertainty in exposure, and the inter-individual differences in exposure, before determining whether or not an epidemiological study will or will not have sufficient statistical power to detect an effect. For the ATSDR PHA, the risk below the limits of epidemiological detection should be disclosed with uncertainty. Anything else is censorship of information.	radionuclides related to X-10. This classification means that people could be or were exposed, but that their level of exposure would not likely result in any adverse health effects. But this public health assessment does not imply that an inability to detect effects is the same as no risk of exposure. This is clearly evident by the use of the *no apparent public health hazard* conclusion category in this public health assessment. ATSDR uses this category in situations in which human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects. Radiation exposure is possible; still, such exposure is not expected to result in observable and tolerable health effects. EPA-conducted risk assessments are useful in determining safe regulatory limits and prioritizing sites for cleanup. Risk assessments provide estimates of theoretical risk from possible current or future exposures and consider all contaminated media, regardless of whether exposures are occurring or are likely to occur. These quantitative risk estimates are not intended, however, to predict the incidence of disease or to measure the actual health effects in people resulting from hazardous substances at a site. By design, these risk estimates are conservative predictions that generally overestimate risk. Risk assessments do not provide a perspective on what the risk estimates mean in the context of the site community and do not measure the actual health effects that hazardous substances have on people. 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 for particular communities. ATSDR scientists conduct a health effects evaluation 1) by carefully examining site-specific exposure conditions about actual or likely exposures; 2) by conducting a critical review of available toxicological, medical, and epidemiologic information to ascertain the substance-specific toxicity characteristics (levels of significant human exposure); and 3) by comparing an estimate of the amount of chemical 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 effects. The goal of the health effects evaluation is to decide whether harmful effects might be possible in the exposed population by weighing the scientific evidence and by keeping site-specific doses in perspective. The output is a qualitative description of whether site exposure doses are of sufficient nature and magnitude to trigger a public health action to limit, eliminate, or further study any potential harmful exposures. The PHA presents conclusions about the

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		actual existence and level of the health threat (if any) posed by a site. It also recommends ways to stop or reduce exposures. For detailed information on risk, please see Appendix F in the final PHA. In this public health assessment, ATSDR compares annual doses to the 100 mrem/year dose limit of the International Commission on Radiological Protection (ICRP), the NCRP, and the U.S. Nuclear Regulatory Commission (NRC), as well as ATSDR's minimal risk level (MRL). ATSDR compares lifetime doses to the agency's radiogenic cancer comparison value of 5,000 mrem over 70 years, which is based on peer-reviewed literature and other documents developed to review the health effects of ionizing radiation. These values, used as screening tools during the public health assessment process, are levels below which adverse health effects are not expected to occur. If the screening indicates that past or current doses exceed our comparison values, then we would conduct further in-depth health evaluation. When ATSDR developed its screening values for radiation exposures, safety margins were incorporated. The approach ATSDR uses to derive MRLs, such as those in the Toxicological Profile for Ionizing Radiation, was developed with the U.S. Environmental Protection Agency (EPA). The screening value includes the use of a no observed adverse effect level (NOAEL) or a lowest observed adverse effect level (LOAEL) as well as three or more situation-specific uncertainty factors. When multiplied, these factors give a total uncertainty factor generally ranging from 1 to 1,000, based on the studies used. Furthermore, as discussed many times, the ATSDR legislative authority limits ATSDR to the evaluation of exposures based on observable and tolerable adverse health effects. If adverse health effects are not observed in an epidemiological study, then the doses used in the study should be considered tolerable. ATSDR's radiogenic comparison value of 5,000 millirem over 70 years incorporates the linear no-threshold (LNT) model for evaluating public health hazards associated with exposure to radiation. It assumes a total lifetime dose (70 years of exposure) above background that is considered safe in terms of cancer induction. In addition to the LNT model, ATSDR also incorporates a margin-of-dose (MOD) approach into this comparison value. During an evaluation, if ATSDR determines that further investigation is needed, it reviews scientific literature associated with radiological doses and dose estimates, particularly those related to adverse health effects. ATSDR then compares the dose estimates from scientific literature to site-specific dose estimates. Thus, ATSDR uses the LNT model to determine when a more detailed site-specific evaluation is necessary, and uses the MOD approach to develop realistic information for communities regarding what is known and unknown about radiation levels at a particular site.

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		An independent expert panel convened to review ATSDR's site-specific approaches used to evaluate past, current, and future radiation risks to communities surrounding the Oak Ridge Reservation concluded that this combination of approaches (LNT and MOD) is appropriate for ATSDR to use to determine radiation levels at which health effects actually occur. The panel found that ATSDR's use of the MRL of 100 millirem and radiogenic cancer comparison value of 5,000 millirem were appropriate screening values. If extrapolated over 70 years assuming constant exposure, the radiogenic cancer comparison value dose estimate would be about 71 millirem per year—a level the panel determined to be protective of public health in terms of cancer and noncancer risks. The panel also concluded that ATSDR's approach considers evidence for both individual organs and whole-body doses (effective doses), noting that a whole-body dose could not be developed without accounting for doses to single organs. Further, the panel determined that ATSDR's method of distinguishing dose levels from risk levels was acceptable because ATSDR incorporated risk and LNT explicitly and implicitly when calculating doses. In the words of one peer reviewer regarding ATSDR's radiogenic cancer comparison value, "The general consensus is that the linear non-threshold hypothesis is scientifically reasonable for the purpose of radiation protection. The recent NCRP comprehensive review and UNSCEAR [United Nations Scientific Committee on the Effects of Atomic Radiation] evaluations do not find any alternative model to be better, including one with a threshold. While epidemiology is not capable of detecting risks in the low dose domain, under say 10,000–20,000 millirem, there are cellular experiments and theoretical reasoning that support a linear response."
Discussion of Multiple Radionuclide and Pathway Exposures		
50	Page 6, Line 7: Are these doses added together for each route of exposure to obtain a cumulative dose for a person that may be exposed by consumption of ALL available aquatic species, PLUS game animals, swimming and sediment contact? Or is the method used something like this: each exposure is "dropped out" of the analysis if he/she doesn't exceed the threshold for that specific route of exposure and environmental media. This is important, because radiation doses ARE CUMULATIVE and an exposed individual will, in actuality, retain the additional dose from each route of exposure, even though its incremental calculation is "dropped out" for each separate exposure. Then, the sum of all 'sub-dangerous' individual does that he or she would sustain would, actually, exceed the EPA acceptable risk threshold of $1x10^{-4}$ (one extra case of cancer per	Past exposure pathways (see Table 11) included fish ingestion, drinking water ingestion, meat ingestion, milk ingestion, and external radiation via walking on sediment. For current exposure pathways for the Lower Watts Bar Reservoir, as presented in Table 16, ATSDR evaluated fish ingestion, water ingestion, contact with surface and dredged channel sediment, and swimming in, or showering with, surface water. For current exposure pathways for the Clinch River area, shown in Table 18, ATSDR evaluated ingestion of biota (i.e., fish, geese, and turtles), incidental ingestion of surface water, walking on sediment, and swimming. As explained in the Evaluating Exposures section of the final PHA (Section III.B.2. and III.B.3.), ATSDR calculated estimated annual and lifetime whole-body radiation doses for the Lower Watts Bar Reservoir and the Clinch River by **combining the pathways** evaluated (also see Table 22 and Table 23 the Public Health Implications section, Section IV.A.). To explain further, for its evaluation of past exposures, ATSDR applied weighting factors

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	10,000 potentially exposed individuals). (*Comment received on the initial release PHA dated December 2003.)*	(see Table 6 and page 68 of the final PHA) to Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report) organ doses and summed the adjusted organ doses across pathways to derive the annual and whole-body doses for each pathway. ATSDR then summed the annual and whole-body dose for each pathway to derive the total annual dose to the whole body and the *committed effective dose* to the whole body over 70 years. ATSDR also summed the organ doses to derive a *committed equivalent dose* to an organ over a 70-year (lifetime) exposure. In its evaluation of current exposures for the Lower Watts Bar Reservoir, ATSDR derived whole-body (committed effective) doses for hypothetical people exposed to radionuclides through contacting surface and dredged sediment, swimming in or showering with surface water, ingesting surface water, or consuming fish. When deriving the doses, ATSDR used *worst-case* exposure scenarios, assuming that the most sensitive population—that is, young children—were exposed by the most likely exposure routes to the highest concentration of radionuclides in sediment, surface water, or fish: inhalation, dermal contact, and external radiation. In its evaluation of current exposures for the Clinch River, ATSDR examined incidental surface water ingestion, external radiation via walking on shoreline sediment or contacting water while swimming, and consumption of fish, geese, and turtles. For the dose assessment, ATSDR looked at the critical organ and the radiation dose delivered to the whole body. ATSDR concluded that past, current, and future exposures to radionuclides released from White Oak Creek to the Clinch River and Lower Watts Bar Reservoir are not a public health hazard for people who use these water bodies. Though people might have or might yet come in contact with X-10 radionuclides that entered the Clinch River or Lower Watts Bar Reservoir via White Oak Creek, ATSDR's evaluation of data for users of these waterways indicates that the levels of radionuclides in biota, sediment, and surface water are—and have been in the past—too low to cause observable health effects.
51	Page 84, Table 9. Summary of Estimated Organ-Specific (Equivalent) Radiation Doses For Past Exposure Pathways. ATSDR is supposed to use the standard 'slope factor' approach to ingested radionuclides (discussed previously in these comments), and not the 'millirem' approach. According to standard EPA Risk Assessment Guidelines (RAGs), ingested radionuclides are to be treated the same as all other chemical carcinogens and not to be cranked into the dated approach of simply comparing 'millirems of exposure to a hypothetical annual dose for an 'average' citizen. There is a good reason not to do this. The doses that citizens of	Please see the response to comment 44 regarding the policy on ATSDR performing health assessments—not risk assessments. For past, current, and future exposures to White Oak Creek radionuclide releases, ATSDR estimated maximum whole-body doses over a person's lifetime as well as annual whole-body doses for all radiation exposure pathways. Lifetime doses were compared to ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years, which includes a linear no-threshold factor. In addition, all of ATSDR's dose calculations use the dose coefficients published in EPA's Federal Guidance Report 13, which are actually based on the

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	Oak Ridge, downwind, downstream, and down-aquifer from DOE ORR are IN ADDITION TO THE AVERAGE CITIZEN'S EXPOSURE. To simply compare these exposed individuals to that for the 'average' exposed individual deceitfully lowballs all radiation exposures these stakeholders are sustaining. Also, all of these radiation doses are CUMULATIVE and in addition to the 'average' dose they are already sustaining. This kind of inconclusive risk analysis is at best deceitful, if not downright malevolent. (*Comment received on the initial release PHA dated December 2003.)*	International Commission of Radiation Protection (ICRP) reports released after ICRP 60 that incorporate linear no-threshold and the dose coefficients. Estimated annual whole-body doses were compared to the dose of 100 mrem per year recommended for the public by ATSDR, the ICRP, the National Council on Radiation Protection and Measurements (NCRP), and the U.S. Nuclear Regulatory Commission (NRC). This 100 mrem/year recommended dose is based on exposures from all sources of radiation (including future sources), except for medical and background sources considered to be the annual background dose received each year by average U.S. citizens. These recommendations also conservatively assume that there is no threshold dose below which there are no health effects (a linear no-threshold model). The estimated doses presented in the table being referenced by the commenter (Table 11 in the final PHA) are above doses that people normally receive. Thus, these estimated doses are in addition to the average background received by U.S. citizens. The annual and lifetime doses calculated in this public health assessment include doses from all exposures and pathways combined. For past exposures for the Clinch River, the maximum whole-body dose over a lifetime (estimated committed effective dose of 278 mrem over 70 years) from all evaluated exposure pathways is well below (18 times less than) ATSDR's radiogenic cancer comparison value. Doses below this value are not expected to result in observable health effects. Radiation lifetime doses to critical organs (e.g., bone, lower large intestine, red bone marrow, breast, and skin) are also less than ATSDR's comparison values. For current exposures for Lower Watts Bar Reservoir, ATSDR estimated committed effective doses (whole-body doses occurring over a lifetime, or 70 years) for exposures to radionuclides by contacting shoreline or dredged sediment, swimming in or showering with surface water, ingesting surface water, or eating fish. ATSDR's committed effective dose to the whole body for all pathways combined is less than 1,900 mrem over 70 years—2.5 times below ATSDR's radiogenic CV of 5,000 mrem over 70 years. The estimated annual whole-body dose is less than 30 mrem, which is below (3 times less than) the dose of 100 mrem per year recommended for the public by ATSDR, ICRP, NCRP, and NRC. For current exposures for the Clinch River, ATSDR's estimated committed effective dose to the whole body for all pathways combined is less than 240 mrem—more than 20 times below ATSDR's radiogenic CV of 5,000 mrem. The estimated annual whole-body dose is less than 3.4 mrem—about 30 times below ATSDR's screening CV and about 30 times below ICRP's, NCRP's, and NRC's recommended value for the public of 100 mrem/year. Therefore, ATSDR concludes that past, current, and future uses of these watersheds would not pose a health hazard for people exposed to White Oak Creek radionuclide releases. As

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		demonstrated throughout the PHA and as detailed in this response, estimated exposure doses are below levels at which adverse health effects have been observed, even when taking into account the background radiation dose already received annually by average U.S. citizens.
52	Radionuclides are not the only contaminants of concern in White Oak Creek, the Clinch River, or the Lower Watts Bar Reservoir. As noted in Sect. III. A, the ATSDR previously prepared a PHA on uranium releases from the Y-12 Plant and is planning to conduct one on PCB releases from ORNL, the Y-12 Plant, and the K-25 site. There is considerable evidence that risks for some radiogenic cancers (e.g., breast cancers) are additive with those associated with other factors (see, e.g., Annex I in the UNSCEAR 2000 report). Thus, an assessment that evaluates each type of contaminant in isolation, i.e., without considering their combined effects, may significantly underestimate the total risk. This concern should be acknowledged in the revised report.	After completing each individual public health assessment, ATSDR will be evaluating potential health effects from multiple chemical and radiological exposures.
Data and Modeling		
53	Page 2, Line 13: "radionuclides from White Oak Creek." High levels of these specific radionuclides have been earmarked in the OREIS (Oak Ridge Environmental Information System) database for decades. OREIS is not now readily available to the general public, but it is readily available to State of Tennessee scientists and public health officials. Many citizens also hold archives of these environmental releases from the time before DOE limited access to it. DOE's own sampling data, especially from its key fish sampling locations has been carefully archived for decades and these data confirm high levels of Cs-137 and Sr-90 and other radionuclides and fish tissue in many locations downstream of WOC. ATSDR should immediately get access to the OREIS database, confirm these findings, and release this information to the public. (*Comment received on the initial release PHA dated December 2003.)*	ATSDR has access to and has obtained data in electronic format from the Oak Ridge Environmental Information System (OREIS) (as mentioned throughout the final PHA; OREIS is detailed in Section II.F.4.). ATSDR used the OREIS data covering the time period from 1989 to 2003 to evaluate the current and future exposures and doses related to radionuclide releases from White Oak Creek. Samples included surface waters collected from the Lower Watts Bar Reservoir and sediments from the associated shorelines. ATSDR also evaluated biota data, including fish, geese, and turtle samples. ATSDR analyzed samples for rivers in the watershed that included the Clinch River below Melton Hill Dam and the Tennessee River below the mouth of the Clinch River. For comparison purposes, ATSDR reviewed data collected from background locations (Emory River, streams that feed into the Clinch River, the Clinch River above the Melton Hill Dam, and the Tennessee River upstream of the Clinch River). In addition, ATSDR evaluated data from the Tennessee Department of Environment and Conservation (TDEC) and the Tennessee Valley Authority (TVA), and used doses calculated in Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report) to evaluate past exposures. When initially sorting the data, ATSDR included the radionuclides associated with the Task 4 report, as well as the radionuclides reported in the OREIS data. The purpose of the data sorting was to collate data by the following parameters: river location, species (for biota), radionuclide, or a combination of one or more of these parameters. As a result of this sorting, ATSDR performed its evaluation on the radionuclides presented in Table 17 of the

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		final PHA. As shown in this table, OREIS data for cesium 137 and strontium 90, as well as cobalt 60, yttrium 90, americium 241, and hydrogen 3 were evaluated. ATSDR's estimated doses for current and future exposures to radionuclides from White Oak Creek based on these OREIS data were below levels shown to cause adverse health effects. Accordingly, ATSDR concluded that these current and future exposures are not a health hazard.
54	Page 4, Line 4: "ATSDR determined that the levels of radioactive contaminants that entered the Clinch River, and as well as those that reached the downstream Lower Watts Bar Reservoir, are too low to cause observable adverse health effects for most people who used or continue to use the river for food or recreation." This statement cannot be supported by publicly available information from both DOE itself (documented in the OREIS database, the technical information that supports the DOE ORR's own ASER (Annual Site Environmental Report), and scientific reports of fish tissue content available from the TVA (Tennessee Valley Authority). ATSDR's failure to adequately explore the publicly available data for decades of fish tissue analyses both on the Reservation and downstream is blatantly irresponsible. (*Comment received on the initial release PHA dated December 2003.)*	In the PHA, "ATSDR concluded that past, current, and future exposures to radionuclides released from White Oak Creek to the Clinch River/Lower Watts Bar Reservoir are not a public health hazard. 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 X-10 radionuclides that entered the Clinch River or Lower Watts Bar Reservoir via White Oak Creek. However, 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." As part of ATSDR's public health assessment process, we conducted a thorough search for available data to evaluate exposures to White Oak Creek radionuclide releases via biota, sediment, and surface water. For past exposure, ATSDR reviewed and evaluated Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report) and documents associated with this report. The Task 4 team performed extensive searches to obtain data for X-10 radionuclide releases to the Clinch River via White Oak Creek during the time period 1944 to 1991. The Task 4 team based its quantity estimates on log books, interviews with personnel associated with collecting samples and monitoring radioactive releases from White Oak Dam, and laboratory documents. For current and future exposures for the Lower Watts Bar Reservoir, ATSDR evaluated data collected from 1988 to 1994 as presented in ATSDR's 1996 *Lower Watts Bar Reservoir Health Consultation.* For the Lower Watts Bar Reservoir, this incorporated environmental monitoring data for surface and deep channel sediment, surface water, and local biota (including fish) collected from the Lower Watts Bar Reservoir by DOE and TVA during the 1980s and 1990s. For current and future exposures for the Clinch River, data were obtained from the Oak Ridge Environmental Information System (OREIS). OREIS contains data from all key surveillance activities and environmental monitoring efforts, including annual site summary reports and studies of the Clinch River and the Lower Watts Bar Reservoir. The data received and analyzed by ATSDR covered the time period from 1989 to 2003. Samples included surface waters collected from the Lower Watts Bar Reservoir and sediments from the associated shorelines. ATSDR also evaluated biota data that included fish, geese, and turtle samples. ATSDR analyzed samples for rivers in the watershed that

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		included the Clinch River below Melton Hill Dam and the Tennessee River below the mouth of the Clinch River. For comparison, ATSDR also reviewed data collected from OREIS for background locations (Emory River, streams that feed into the Clinch River, the Clinch River above the Melton Hill Dam, and the Tennessee River upstream of the Clinch River). In addition, ATSDR presented the data sources to be used to the former Public Health Assessment Work Group (PHAWG), later referred to as the Exposure Evaluation Work Group (EEWG), to determine whether any additional data sources were available. This information was also shared with the Oak Ridge Reservation Health Effects Subcommittee, as well as with state and federal agencies (i.e., the U.S. Department of Energy [DOE], the Tennessee Department of Environment and Conservation [TDEC], and the Tennessee Department of Health [TDOH]).
55	Page 39, Lines 1–2. Again, ATSDR's Watts Bar is fundamentally flawed because ATSDR did not account for DOE's own fish sampling data in OREIS. ATSDR cannot reconcile this BRA with these fish sampling data that exist for downstream communities from at least 1985. (*Comment received on the initial release PHA dated December 2003.)* Page 38, Line 10. Please see the TWRA website for (Tennessee Wildlife Resources Agency) fish advisories for Watts Bar and other locations downstream: http://www.state.tn.us/twra/fish/contaminants.html. If ATSDR had even visited this website it would quickly learn that the fish consuming citizens of Tennessee are not even informed about their fish being contaminated with Sr-90, Cs-137, and other radionuclides released from DOE ORR. This amounts to a deliberate and unconscionable attempt to cover-up the fact that the fish in the TVA system have been and continue to be radioactively contaminated. This denial of these stakeholders fundamental right-to-know borders on conspiracy to obstruct justice. (*Comment received on the initial release PHA dated December 2003.)* Many citizens downstream of the DOE ORR are particularly concerned that the State of Tennessee has yet to inform its citizens of the real risks that they are sustaining from consuming fish collected in tributaries leaving the DOE ORR. Although the State of Tennessee has posted a fish advisory for PCBs on its website, there is not one mention of these fish also being contaminated with radionuclides, especially high levels of Cesium 137 (Cs-137) and Strontium-90 (Sr-90). This inability for the State of Tennessee to inform its citizens that these fish are also radioactively contaminated is unconscionable. ATSDR should, and must, take	This referenced statement of the document—"The largest threat to public health from the Lower Watts Bar Reservoir is related to the consumption of PCB-contaminated fish."— does not refer to the U.S. Department of Energy's (DOE) baseline risk assessment as indicated by the commenter, but to the record of decision (ROD) for the Lower Watts Bar Reservoir (accessible online at http://www.epa.gov/superfund/sites/rods/fulltext/r0495249.pdf). This finding in the ROD is based on the conclusions of the baseline risk assessment, which determined that standards for environmental and human health would not be reached if people consumed moderate to high quantities of specific fish that contained increased levels of PCBs. The ROD is agreed to by the three members of the Federal Facility Agreement (FFA): DOE is the lead agency that issued the ROD, and the U.S. Environmental Protection Agency (EPA) and the Tennessee Department of Environment and Conservation (TDEC) are supportive agencies. In a 1996 health consultation, ATSDR conducted an independent analysis of the Lower Watts Bar Reservoir data to evaluate whether radiological and chemical contaminants in reservoir fish, surface water, and sediment posed a public health hazard. ATSDR concluded that PCB levels in fish were the only contaminants that posed a public health hazard. ATSDR determined that no public health hazards were associated with the three primary radioactive contaminants (cesium 137, cobalt 60, and strontium 90) in reservoir fish and that current levels of chemical and radiological contaminants in reservoir surface water and sediment did not pose a public health hazard. To evaluate current and future exposures for the Clinch River and the Lower Watts Bar Reservoir, ATSDR did obtain and evaluate biota, surface water, and sediment sampling data from OREIS from 1989 to 2003 in this final PHA. ATSDR determined that radionuclides in fish, sediment, and surface water do not pose a health hazard for people who used and continue to use the Clinch River and the Lower Watts Bar Reservoir. Therefore, even

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	immediate action to issue a public health advisory warning people of the danger. The State of Tennessee should, and must, immediately post this information (that it has known about for decades) on its fish advisory website, and immediately change all affected stream signage to reflect this warning. At each and every location where it has already posted its PCB warnings, it must also specify the risks from radionuclides, especially Cs-137 and Sr-90. These two radionuclides are particularly dangerous to growing children and pregnant women. (*Comment received on the initial release PHA dated December 2003.)*	though radionuclides might be present in the Clinch River and the Lower Watts Bar Reservoir, only PCBs in certain fish species have been found at levels that might cause adverse health effects. TDEC's Division of Water Control is responsible for issuing and posting fish advisories. Evaluating fish tissue problems in the state of Tennessee involves a multi-agency effort, comprised of DOE, EPA, TDEC, the Tennessee Wildlife Resources Agency (TWRA), and the Tennessee Valley Authority (TVA). An abundance of data are available on contaminants in fish in these systems, including data collected by TVA, DOE, TWRA, and TDEC. These agencies use Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) criteria to analyze fish tissue in these waterways, which applies EPA risk assessment to evaluating potential exposures to contaminants in fish. DOE, TDEC, and EPA have responsibilities under CERCLA, but the state has ultimate responsibility for the advisories. The state fish advisories are available at: http://www.state.tn.us/twra/fish/contaminants.html. It is important to understand that although there might be radionuclides and other contaminants present in fish in the Clinch River and the Lower Watts Bar Reservoir, **only PCBs** have been found at levels in particular species of fish that could potentially cause adverse health effects. This is why radionuclides are not part of the advisories for these waterways—they have not been detected at harmful levels in these water systems. These agencies are basing their advisories on numerous data collected over several years by different entities, all of which show that radionuclides are not present in fish in the Lower Watts Bar Reservoir and the Clinch River at levels that could cause adverse health effects. ATSDR's evaluation in this public health assessment concurs with the findings of the state, EPA, and these other entities. In addition, ATSDR is preparing a public health assessment that will evaluate PCB releases from the three main ORR facilities: X-10, Y-12, and K-25. When available, copies of ATSDR's public health assessment on PCBs can be obtained by contacting ATSDR's Information Center toll-free at 1-888-422-8737. As a public health agency, ATSDR could make recommendations for public health actions if our evaluation showed that radionuclides in the Lower Watts Bar Reservoir and the Clinch River posed a potential health hazard for people living along and using these waterways. For past exposures to X-10 radionuclide releases via the Clinch River, estimated annual and lifetime whole-body radiation doses for all pathways combined were 25 and 18 times less, respectively, than health-based comparison values. For current exposures to the Lower Watts Bar Reservoir, estimated annual and lifetime whole-body radiation doses for all pathways combined were 3 and 2.5 times less, respectively, than health-based comparison values. For current exposures to the Clinch River, estimated annual and lifetime whole-body radiation doses for all pathways combined were 30 and 20 times less than, respectively,

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		ATSDR's health-based comparison values. Therefore, based on an analysis and evaluation of data in our 1996 health consultation and in this public health assessment, we have concluded that exposure to X-10 radionuclides released from White Oak Creek to the Clinch River and the Lower Watts Bar Reservoir via biota, surface water, and sediment is not a public health hazard. Please see the final PHA for more details on ATSDR's evaluation.
56	Page 76, line 28: Mathematical modeling was used to estimate the annual average concentrations of the radionuclides in water and sediment downstream from White Oak Creek. We used actual measurements in water, when available, to calculate doses.	Thank you for your comment. The following text was added to the final PHA: "To calculate doses for Cs 137, Sr 90, Ru 106, and Co 60, the Task 4 team used—when available—actual measurements from the Clinch River water it collected 1960–1990 at CRM 14.5 (K-25 Grassy Creek) and at 4.5 (Kingston Steam Plant). For the remaining radionuclides and for time periods when data were unavailable, the Task 4 team used modeling to estimate the historical radionuclide concentrations in Clinch River water."
57	Page 90, Table 13. Maximum Radionuclide Concentrations in Lower Watts Bar Reservoir Area Fish. Page 99; Table 19. Estimated Radiation Doses From Current Consumption of Geese and Turtle. Page 100; and Table 20. Estimated Radiation Doses From Current Consumption of Fish. This information is not factual. DOE's own fish sampling data in its ACER data volumes are in excess of these levels. ATSDR and all interested stakeholders can easily access these data at: http://www.ornl.gov/sci/env_rpt/. To get the desired data volume the stakeholder needs to scroll down the index and the data bookmark is typically near the bottom for each year. These data volumes provide a wealth of additional data that most will be very interested in as well! ATSDR needs to do a better job on its homework in obtaining the same additional, publicly available data sets that interested downstream, downwind, and down-aquifer stakeholders are already using to do their own competing risk analyses. Page 102, Table 21. Summary of Public Health Implications From ATSDR's Evaluation of Past and Currently Exposure to Radionuclides Released to the Clinch River/Lower Watts Bar Reservoir. There are over 150 species of fish and other aquatic animals that dwell in the Clinch River, and many are used for food. Some of the available organisms from the Clinch River and TVA's reservoirs are not included in this PHA are crayfish and frogs. Nevertheless, DOE ORR has radiological sampling data in the OREIS database on all of these. There is no paucity of extensively archived and publicly available data	The former Table 13 being referenced by the commenter is now Table 15 in the final PHA. The information presented in this table is based on data collected from 1988 to 1994 as presented in ATSDR's 1996 *Lower Watts Bar Reservoir Health Consultation*, including environmental sampling data from the 1980s and 1990s that had been collected and assembled by the U.S. Department of Energy (DOE), the Tennessee Valley Authority (TVA), and various consultants. Also, ATSDR analyzed data from TVA's 1993 and 1994 annual radiological environmental reports for the Watts Bar Nuclear Plant. Thus, the data contained in this table are inclusive of data collected by DOE during the time periods of study. For the health consultation, ATSDR analyzed chemical and radiological data in surface water, sediment, and fish. ATSDR evaluated potential exposures by using worst-case scenarios assuming the most sensitive population was exposed to the maximum concentrations of each contaminant in each media. ATSDR concluded that exposure to radionuclides detected in Lower Watts Bar Reservoir fish, surface water, and sediment was not a public health hazard. Again, as noted previously, these conclusions were based on available data not only collected from DOE, but also from TVA and from various consultants. In the final PHA, the referenced former Tables 19 and 20 are now Table 19. Estimated Radiation Doses From Current Ingestion of Fish and Table 20. Estimated Radiation Doses From Current Ingestion of Geese and Turtles. The radiation doses presented in Table 19 and Table 20 are based on an evaluation of data collected from the Oak Ridge Environmental Information System (OREIS). When calculating the doses, ATSDR used the concentration of the radionuclides in the environment, and site-specific factors if they were available, such as the amount of fish consumed based on ATSDR's 1998 Watts Bar Reservoir exposure investigation. Default values were used when site-specific factors were

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	regarding the radionuclide content of an immense array of other aquatic organisms (or their consumers) that people in the TVA region consume as well. For example, there are extensive archives of radionuclide contents of the following: turtles, mussels, crayfish, raccoons, beaver, and many others. ATSDR must come to grips with the publicly available sampling data. Thereafter is must apply standard EPA risk assessment methodologies to these voluminous data. Instead of trying to find ways not to find and evaluate the immense volumes of publicly available data confirming the existence of threats to the public health, downwind and downstream of the DOE ORR, ATSDR must start now and evaluate the levels of these radionuclides in fish and other biota used as food by the many residents downstream. Since many of these radioactively contaminated fish definitely don't remain 'in residence' near WOC, but could range far and wide throughout the TVA system, this PHA is definitely over simplistic and is lulling stakeholders into a false sense of security when it deals with fish consumption. (*Comments received on the initial release PHA dated December 2003.)*	not available, such as for drinking water ingestion. These two tables present estimated whole-body doses, as well as doses for the critical organs—those organs receiving the highest radiation doses. OREIS consists of data from all key surveillance activities and environmental monitoring efforts associated with the Oak Ridge Reservation operations, including DOE's annual site environmental reports (ASERs). When initially sorting the data, ATSDR included the radionuclides associated with Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report), as well as the radionuclides reported in the OREIS data. The purpose of the data sorting was to collate data by the following parameters: river location, species (for biota), radionuclide, or a combination of one or more of these parameters. As a result of this sorting, ATSDR performed its evaluation on the radionuclides presented in Table 17 of the final PHA. As shown in this table, OREIS data were evaluated for cesium 137, strontium 90, cobalt 60, yttrium 90, americium 241, and hydrogen 3. ATSDR conducted a thorough search for available data to determine whether exposure to White Oak Creek radionuclide releases were and are a public health hazard for people who used and continue to use the Clinch River and the Lower Watts Bar Reservoir. For past exposure, ATSDR reviewed and evaluated the Task 4 report and documents associated with this report. The Task 4 team performed extensive searches to obtain data for X-10 radionuclide releases to the Clinch River via White Oak Creek during the time period 1944 to 1991. The Task 4 team focused its information collection activities on records at the X-10 Laboratory Records (containing "active" types of records, such as technical reports and memorandums regarding X-10 activities) and the X-10 Records Center (containing more "archived" types of records). The Task 4 team based its quantity estimates on various sources utilized during data collection activities, including log books, interviews with personnel associated with collecting samples and monitoring radioactive releases from White Oak Dam, and laboratory documents. For current and future exposures for the Lower Watts Bar Reservoir, ATSDR evaluated data collected from 1988 to 1994 as presented in ATSDR's 1996 *Lower Watts Bar Reservoir Health Consultation.* For the Lower Watts Bar Reservoir, this incorporated environmental monitoring data for surface and deep channel sediment, surface water, and local biota (including fish) collected from the Lower Watts Bar Reservoir by DOE and TVA during the 1980s and 1990s. For current and future exposures for the Clinch River, data were obtained from OREIS. The data received and analyzed by ATSDR covered the time period from 1989 to 2003. Samples included surface waters collected from the Lower Watts Bar Reservoir and sediments from the associated shorelines. ATSDR also evaluated biota data that included fish, geese, and turtle samples. ATSDR analyzed samples for rivers in the watershed that included the Clinch River below Melton Hill Dam and the Tennessee River

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		below the mouth of the Clinch River. For comparison, ATSDR also reviewed data collected from OREIS for background locations (Emory River, streams that feed into the Clinch River, the Clinch River above the Melton Hill Dam, and the Tennessee River upstream of the Clinch River). Contrary to this commenter's statements, the OREIS database does not contain radiological sampling data for the "over 150 species of fish and other aquatic animals that dwell in the Clinch River." Reportedly, the Clinch River Valley actually maintains over 350 different species of wildlife. Data contained in OREIS from 1989 to 2003, however, only include radiological sampling data for the areas of study and radionuclides of interest (see Table 17 in the final PHA) for the following species in the Clinch River known as food sources: fish (bass, catfish, and sunfish), geese, and turtles. ATSDR evaluated available sampling data for these particular species for the study areas and radionuclides of interest (see Table 17), as well as on the known exposure pathways to these wildlife. Data for the radionuclides and areas of interest were available for fish in the Clinch River and the Lower Watts Bar Reservoir for past and current exposures, as well as for geese and turtles in the Clinch River for current exposures. No radiological data are contained in OREIS for 1989 to 2003 for other wildlife species in these areas of study known as food sources, including crayfish or frogs (as specifically requested by the commenter). Particular to this commenter's list, data for turtles were available and evaluated in Section III.B.3. of the final PHA for current exposures to the Clinch River. Mussels are detailed in the PHA (see Section III.B.3) regarding the Clinch River, and how the likelihood is low that people consumed mussels from the Clinch River. Data for the remaining species on the commenter's list, as well as additional species, were not evaluated because the data are not available for the radionuclides of interest and the study area of interest, or people are not known to consume the particular species. ATSDR not only looked at fish remaining near White Oak Creek, ATSDR evaluated fish data for the entire White Oak Creek study area, consisting of the area along the Clinch River from the Melton Hill Dam to the Watts Bar Dam. Section III. Evaluation of Environmental Contamination and Potential Exposure Pathways in the final PHA details ATSDR's analysis of past, current, and future exposures to White Oak Creek radionuclide releases via consumption of fish and other biota. Section IV. Public Health Implications details the weight-of-evidence approach ATSDR used to compare estimated radiation doses to situations associated with disease and injury to determine whether harmful health effects could be possible and observable. Using our evaluation, ATSDR determined that the levels of radionuclides in biota, sediment, and surface water were too low to cause observable health effects. Accordingly, ATSDR concluded that past, current, and future exposures to radionuclides released from White Oak Creek to the Clinch River and the

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		Lower Watts Bar Reservoir are not a public health hazard for people who lived along or used these waterways in the past, present, and future. Regarding ATSDR applying EPA risk assessment methodologies, please refer to Appendix F in the final PHA and the response to comment 44 within this appendix.
Accuracy/Clarification of Statements		
58	Page 20, Table 2. Estimated Discharges (in curies) of Radionuclides from White Oak Creek. This table is busy and seems to hide information instead of revealing the nature and extent of radioactive discharges from White Oak Creek. Is this obfuscation by design on ATSDR's part? Page 13, Line 22. Thorium and plutonium releases are detailed in the OREIS database. These two extremely long-lived radionuclides should be cited in Table 2 and Table 3, but are conspicuously absent. Was ATSDR's omission of thorium and plutonium from these two tables purposeful? (*Comments received on the initial release PHA dated December 2003.)*	Table 2 in the final PHA was taken directly from the *Remedial Investigation/ Feasibility Study of the Clinch River/Poplar Creek Operable Unit* prepared by Jacobs Engineering Group Inc. in 1996. It is available at http://www.osti.gov/bridge/servlets/purl/226399-5omhIT/webviewable/226399.pdf. The table presents the estimated discharges (in curies) for only those radionuclides released from White Oak Creek to the Clinch River that required investigation. It contains the radionuclides, the year of release, and the estimated discharges in curies. We believe that this table provides useful information for the reader. Table 3 in the final PHA was taken directly from the Tennessee Department of Health's Oak Ridge Dose Reconstruction Summary Report available at http://www2.state.tn.us/health/CEDS/OakRidge/ProjSumm.pdf. This was based on the Task 4 report titled *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*. The Task 4 team identified 24 radionuclides during its screening assessment that had been released to the Clinch River via White Oak Creek from 1944 to 1991. Among this group of 24 radionuclides were thorium and plutonium. Using a risk-based screening process, however, 16 of the radionuclides were eliminated because the estimated screening indices were below the Task 4 team's minimal level of concern (1×10^{-5}). Both plutonium and thorium were removed from further evaluation because the releases of the contaminants to the Clinch River via White Oak Creek were below the team's minimal level of concern. Therefore, to be clear, these tables were created by entities other than ATSDR, but we did review their work prior to including it in this public health assessment. Also, please note that there are many radionuclides in OREIS other than thorium, plutonium, and those presented in these tables. Thorium and plutonium, as well as other radionuclides, are not presented in these tables because their releases to the Clinch River via White Oak Creek have not been found at levels of concern and at levels requiring further investigation. See Appendix D for a brief on the 1999 Task 4 report. Copies of the Task 4 report are available at the DOE Information Center located at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee (telephone number: 1-865-241-4780) or at http://www2.state.tn.us/health/CEDS/OakRidge/WOak1.pdf.

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59	He questioned the PHA's statement (on page 16, line 7) that the X-10 facility still produces isotopes.	According to the Tennessee Department of Environment and Conservation's (TDEC) 2004 Status Report to the Public (available at http://www.local-oversight.org/TDEC2004.pdf, see pages 14–15) and the U.S. Department of Energy (DOE), the High Flux Isotope Reactor (HFIR) and the Radiochemical Engineering and Development Center (REDC) are active facilities at the Oak Ridge National Laboratory (ORNL), formerly known as X-10, used for the production of medical and industrial isotopes. For more information, see the Web sites for the HFIR facility (http://web.ornl.gov/sci/rrd/pages/hfir.html), and the REDC (http://www.ornl.gov/sci/nuclear_science_technology/redc/).
60	P. 27. The statement about designs lacking, "adequate containment structures", taken from the Oak Ridge End Use Working Group (EUWG) report, reveals an inadequate understanding of hydrogeologic design on the part of the EUWG. How would they design a septic tank drain field? Any sort of impervious barrier would simply lead to flooding and stop the process. Furthermore, the comment about, "improper design", appears not to be a quote from, but rather an inaccurate and unjustified addition to, the wording of the EUWG report. This phrase should be deleted. The trenches functioned as natural electrostatic filters. They were not improperly designed.	In the final PHA the text has been changed to the following: "Radioactive waste material, such as Cs 137 and Sr 90, is 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."
61	Page 34 Line 18: The largest concentrations of radionuclides that have been detected are buried between 8 and 32 inches into the deep sediments; radionuclide contamination has not been detected in the shoreline sediment (Jacobs EM Team 1997b). Radionuclides have been reported in shoreline sediments of the Clinch. Consequently, the above statement appears to be incorrect.	Thank you for the clarification. This information was obtained from the Clinch River/Poplar Creek record of decision that states, "Those few DOE-related contaminants above background levels in the near-shore sediments are arsenic in McCoy Branch, and chromium and manganese in Poplar Creek." The correction will be made to reflect this updated information.
62	Page 34, Line 27. Has any treatment of these wastes actually occurred yet, or are they still residing in place at the MVSTs? In other words, specifically state here which, if any, fraction of these wastes have actually been removed and treated, and which fraction remains in situ. If in fact, the wastes still remain in place this passage is misleading to the reader and gives the public a false sense of 'security' that these stored wastes, in leaking concrete containers, are being 'remediated.' The citizens of Oak Ridge and all downstream and down-aquifer deserve a straight answer from ATSDR. (*Comment received on the initial release PHA dated*	The Melton Valley Storage Tanks (MVSTs) consist of eight underground storage tanks (USTs) each with an approximate 50,000-gallon capacity, located in Melton Valley. The MVSTs are used to store transuranic (TRU) waste from past processes and remedial activities, including the old hydrofracture facility (OHF) tanks referenced by the commenter (see Appendix B in the final PHA for more information on the OHF tanks). First of all, it is important to note that contrary to the commenter's statement, the OHF tanks were not leaking. In fact, the waste was moved to the MVSTs for safer storage of wastes remaining in the tanks before treatment took place and before any of the tanks could potentially leak. Because there were concerns about the proximity of the tanks to White Oak

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	December 2003.)	Creek, the potential threat to environmental receptors, and the **possibility** of tank leakage, an action memorandum was prepared in September 1996 to move and treat the tank waste. The memorandum outlined an aboveground, double-walled hose system to transfer the tank contents and waste to the MVSTs. Prior to the transfer, some treatment of the waste occurred so that the waste would meet the waste acceptance criteria for the MVSTs. From June to July 1998, more than 98% of the waste was moved through a pipeline to the MVSTs, where additional treatment will occur. Another action memorandum for the OHF, prepared in May 1999, focused on tank stabilization and on the surface impoundment sediments associated with the OHF. The tank stabilization activities included removing the piping system, placing submersible pumps into the tanks, using mixer spool pieces, and grouting the tanks. For the surface impoundment, the remedial activities consisted of applying grout for sediment stabilization, placing grout into standpipes, removing excess water, treating any excess water at the Process Water Treatment Plant (PWTP), and using filler material to replenish the impoundment. These remedial activities were completed, and in May 2001 a removal action report was released. Waste to be treated at the ORR's Transuranic Waste Processing Facility is still being stored or consolidated in the MVSTs. After the TRU waste is treated, it will be shipped off site for disposal at the Waste Isolation Pilot Plant in Carlsbad, New Mexico. Processing of the waste is underway and completion of off site disposal is expected to occur in 2008.
63	P. 57. Line 19. Do you really mean Cr (VI) at all three ORR sites when you state "ORR?"	Yes, this statement is correct as presented in the PHA. Hexavalent chromium was used in cooling towers at K-25, Y-12, and X-10. Please refer to Sections 5.4 (Hexavalent Chromium Releases from the Oak Ridge Reservation) and 7.0 (Conclusions) in Task 7 of the Reports of the Oak Ridge Dose Reconstruction titled *Screening-Level Evaluation of Additional Potential Materials of Concern*. The report is available online at http://www2.state.tn.us/health/CEDS/OakRidge/Screen.pdf.
64	P. 72 (and Appendix E). Shouldn't the term "screening index" be identified as being a calculated probability, or risk?	An explanation that a "screening index" is a calculated probability of developing cancer has been added to the summary, page 77, and to Appendix E. In addition, the term "screening index" was added to and defined in the glossary in Appendix A.
65	Page 92 line 6, Table 13. Maximum Radionuclide Concentrations in Lower Watts Bar Reservoir Sediment: Table 13 indicates that Strontium-89 was detected at 2.30 pCi/g in Lower Watts Bar Reservoir surface sediment. Strontium-89 is a short-lived fission product with a half-life of only 2.1 days; consequently, it seems unlikely the radionuclide would have originated from historical wastes. Since a recent nuclear reaction would be required to produce the isotope, is it reasonable to assume the contaminant	Your comment is noted. We agree that because Strontium 89 has a short half-life, this reported concentration of 2.30 picocuries per gram (pCi/g) in Table 13 could either be a misidentification or the radionuclide was released from the High Flux Isotope Reactor (HFIR) at the Oak Ridge National Laboratory.

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	originated at the High Flux Isotope Reactor or is the result due to laboratory error?	
66	The report should acknowledge that White Oak Creek and its discharges affect Roane County, not Anderson County. The title of the report is misleading in this case.	Thank you for the clarification. The X-10 site and White Oak Creek are located in Roane County, not Anderson County, and this change has been made to the title of the final PHA. It is important to note, however, that the study area for this public health assessment (see Figure 11 of the final PHA) consists of the area along the Clinch River from the Melton Hill Dam to the Watts Bar Dam. This not only includes Roane County, but also Meigs and Rhea Counties. ATSDR evaluated these areas in the final PHA because they are potentially impacted by X-10 radionuclide releases to White Oak Creek via the Clinch River and the Lower Watts Bar Reservoir. Please see Section II.E. Demographics in the final PHA for a description of the communities included within this study area.
67	It should be more clearly stated that this Public Health Assessment (PHA) is for off-site downstream residents exposed to radioactive elements and not for anyone working in the waste disposal areas. Other PHAs for this geographic scope should be cited, summarized, and referenced.	Your comment is noted. Under ATSDR's Evaluation of Exposure to Radionuclide Releases From X-10 in Section I. Summary of the final PHA, the following was added to the end of the first paragraph: "Please note that this document only evaluates **off-site exposures** to White Oak Creek radionuclide releases for downstream residents and others who use or who live along these waterways. It does not evaluate any exposures potentially occurring on site at the reservation, including exposures to workers and other individuals who may contact contaminants while at the ORR." Please note further that ATSDR does not prepare any public health assessments to evaluate on-site worker exposures. Other agencies are responsible for evaluating worker exposures that occur on site. ATSDR scientists have also conducted or are currently conducting public health assessments on: Y-12 uranium releases, off-site groundwater, Toxic Substances Control Act (TSCA) Incinerator releases, Y-12 mercury releases, X-10 iodine 131 releases, K-25 uranium and fluoride releases, PCB releases from X-10, Y-12, and K-25, and a current screening (1990 to 2003) of environmental data. For copies of these public health assessments, please contact ATSDR's Information Center toll-free at 1-888-422-8737.
Groundwater		
68	Page 11, Figure 3. Location of X-10 in Relation to Bethel Valley and Melton Valley. Display Bethel Valley and Melton Valley watersheds with depiction of existing groundwater plumes of contamination. Include the names of the underlying aquifers and their directional flow. Display the potential number of consumers that may be using these contaminated aquifers as a drinking water source.	In this public health assessment, ATSDR evaluated radioactive contaminant data for White Oak Creek releases that enter the Clinch River and travel downstream to the Lower Watts Bar Reservoir. To be clear, this public health assessment only evaluated X-10 radionuclides in White Oak Creek after the surface water was released off site. We recognize that oftentimes contaminants released into surface water may originate from contaminated groundwater, including on-site seeps and other sources of groundwater contamination. These potential exposures to off-site groundwater associated with the Oak Ridge

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	Page 17, Line 23. Add a statement that this means of disposal was entirely unprotective of the groundwater below these pits because of the very porous nature of the geology of this region. This region is nearly entirely very porous karst limestone. Contaminants released onto it leak through it like a sieve. The true extent of groundwater contamination from these unlined earthen pits is well know to ATSDR, EPA, TDH, TDEC, and DOE, but it has yet to be revealed by any of these 'public health' and/or 'regulatory' agencies. This passage will be useful in identifying the Primary Responsible Parties (PEPS) under CERCLA that will be responsible for paying for the cleanup of sediments if the Clinch River is ever dredged and cleaned up, just like has already been done with the Hudson River in New York. Page 18, Figure 7. Location of Solid Waste Storage Areas (SWSAs) at the X-10 Site. Show the contaminate plumes under these sites that are known to ATSDR, EPA, TDEC, TDH, and DOE. Show the directional flow of these contaminant plumes wit their directional flow and the aquifers that they have already reached as well as those others at risk. Show the potential numbers of people consuming water from these affected aquifers that these contaminant plumes drain into, both now and in the future. Page 19, Line 8. 'Hydrofacture technology' has most probably irrevocably contaminated deep groundwater beneath the facility where it occurred. Which aquifers have been contaminated by this technology at Oak Ridge National Laboratory (ORNL)? What is the latitude and longitude of all injection sites on the DOE ORR where these injections were made? This information will be necessary so that environmental advocacy groups, institutions of higher learning, and other stakeholders can utilize desktop Geographical Information Systems (GIS) to further analyze where these contaminants have migrated. These analyses will allow stakeholders to determine, on their own, the true extent of groundwater contamination from these unlined earthen pits. Is the true nature and extent of groundwater contamination from these unlined earthen pits known to ATSDR, EPA, TDH, TDEC, and DOE? Have federal and state public health and regulatory agencies withheld this information from stakeholders? Page 19, Line 11. The public also has a fundamental Right-to-Know right to this information concerning the nature and extent of this actual deep	Reservation, however, are addressed in another public health assessment titled *Evaluation of Potential Exposures to Contaminated Off-site Groundwater From the Oak Ridge Reservation (USDOE)*. This assessment addresses all of the issues presented by the commenter including plumes, contaminants flowing from groundwater, the underlying aquifers, and the other questions posed as well. Copies of this and other ATSDR documents are available from the ATSDR Information Center. You may call the center toll-free at 1-888-422-8737 or view the groundwater document online at http://www.atsdr.cdc.gov/HAC/PHA/region_4.html#groundwater. In addition, remedial actions are underway at the Oak Ridge Reservation and are proceeding according to the requirements of the Comprehensive Environmental, Response, Compensation, and Liability Act of 1980 (CERCLA). Completed and ongoing actions, including those associated with on-site groundwater contamination, are published annually in a remediation effectiveness report (RER). The RER is available at the DOE Information Center located at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee (telephone number: 1-865-241-4780).

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	groundwater contamination and the potential numbers of consumers of these waters. Page 22, Line 22. Include a diagram of the extent of this watershed within DOE ORR. Include a depiction of the affected aquifers from the contaminant plumes beneath these tracts of land. Include the prospective numbers of populations that have in the past or will most probably in the future use these potentially contaminated aquifers for drinking water. Page 22, Line 29. Provide a detailed map of these five watersheds. Annotate this detailed map with their respective receiving aquifer(s) and the numbers of people who are either current or future consumers of these waters. Page 25. Figure 9. Map of the Major Remedial Activities in Bethel Valley. Several three dimensional depictions of affected groundwater aquifers and contaminant plumes have been developed by DOE and should be added to this PHA as companion figures to Figure 9. If ATSDR has trouble locating these, either check with several stakeholders that know of their whereabouts. Alternatively, and probably faster, check with the EPA Southeastern Regional Office in Atlanta, TDH, or TDEC. All of the above agencies already have these maps of contaminant plumes beneath this portion of DOE ORR. To date, these 'public health' and 'regulatory' agencies have simply withheld this critical information from the other stakeholders. Are there still contaminated groundwater plumes left in place below these 'grouted' tanks? If so, what is the nature and extent of the contamination of groundwater at these location, especially the radionuclides involved? Which specific radionuclides have been identified in these plumes? Which aquifers do they drain to? How many current and future users of these aquifers have been identified? Page 26, Line 25. Are there still contaminated plumes left in place below these 'grouted' tanks? If so, what are the specific radionuclides in these respective plumes? Which aquifers do these plumes drain into? What are the numbers of people either current or future consumers of water from these aquifers? These are critical answers for ATSDR to formulate responses to because on Page 27, line 25 ATSDR cites a DOE document	

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	(US DOE 2002b) as follows: "As a result, the waste sites in the Melton Valley Watershed…" are the primary contributors to off-site spread of contaminants" from the ORR. The citizens of Oak Ridge and all of its downstream (and down-aquifer) consumers of these waters are not reassured by ATSDR's seemingly superficial treatment of these critical exposure issues. Page 35, Line 19. Since ATSDR cites the interception of "downgradient contaminated groundwater:" Which specific radionuclides are contaminating the groundwater? What is the approximate curie load of each respective radionuclide? Which aquifer(s) are receiving this "downgradient contaminated groundwater? What are the numbers of current and future users of this contaminated groundwater? (*Comment received on the initial release PHA dated December 2003.)*	
69	Appendix A. ATSDR Glossary of Environmental Health Terms, Page A-1, Line 38. Down-aquifer stakeholders note that 'aquifer' is absent from this glossary. This is unfortunate because this PHA discusses groundwater injection of radioactive wastes at WOC, which of course has contaminated WOC's underlying groundwater. Groundwater leads to an AQUIFER. Stakeholders, many quite distant from WOC, may be drawing water from a contaminated aquifer. It would be helpful if aquifer were to be included in this glossary. (*Comment received on the initial release PHA dated December 2003.)*	This term is defined in ATSDR's PHA titled *Evaluation of Potential Exposures to Contaminated Off-site Groundwater From the Oak Ridge Reservation (USDOE)* available online at http://www.atsdr.cdc.gov/HAC/PHA/region_4.html#groundwater. Copies of this and other ATSDR documents are also available from the ATSDR Information Center. You may call the center toll-free at 1-888-422-8737.
Concerns of Conflicts of Interest		
70	Page 125, Line 25. ATSDR is not fulfilling its public health mandate because of an obvious conflict of interest with its funding from DOE. This PHA should be immediately redrafted using the many years of fish sampling data in the OREIS database. This robust data set dates from 1985. Importantly, next time use EPA standard CERCLA guidance and its risk-based PRGs for radioactive contaminants. Page 127, Line 6. Simply put, stakeholders believe that ATSDR is betraying the public health trust of the citizens of East Tennessee. DOE accepts DOE funding to perform DOE's "health studies." ATSDR and DOE both know the true extent of which radioactive contaminants that downwind, downstream, and down-aquifer stakeholders are being	In 1980 Congress created ATSDR to implement the health-related sections of laws protecting the public from hazardous wastes. ATSDR is a public health agency within the U.S. Department of Health and Human Services (HHS), and the lead agency for implementing the health-related provisions of the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA), referred to as Superfund. Since the 1986 Superfund Amendments and Reauthorization Act (SARA), ATSDR has been required by law to conduct public health assessments at each site on the U.S. Environmental Protection Agency's (EPA) National Priorities List. The investigation and the clean up of these sites is the responsibility of EPA and the individual states. As a potentially responsible party (PRP), the U.S. Department of Energy (DOE) provides funding to HHS for its Worker and Public Health Activities Program. The goal of this

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	exposed to. The risk estimates of these known exposure are being handled in a schizophrenic fashion: low-balling the estimates for the public and other "unsanitized" and probably higher estimates for DOE's epidemiological archives. (*Comments received on the initial release PHA dated December 2003.)*	program is to improve understanding of the effects on workers and people living in communities surrounding DOE facilities from exposures to ionizing radiation and other hazardous materials used in DOE activities. Under a memorandum of understanding (MOU) between DOE and HHS, three agencies within HHS will independently perform public health activities—ATSDR, the National Institute for Occupational Safety and Health (NIOSH), and the National Center for Environmental Health (NCEH). NIOSH performs epidemiological studies of DOE workers and NCEH conducts community-based epidemiologic studies and historical dose reconstruction projects. ATSDR conducts studies to determine if environmental contaminants could have caused past, present, and future health effects for off-site communities near DOE Superfund sites. As the lead public health agency responsible for implementing the health-related provisions of Superfund, ATSDR is charged with assessing health hazards at specific hazardous waste sites, helping to prevent or reduce exposure and the illnesses that result, and increasing knowledge and understanding of the health effects that may result from exposure to hazardous substances. As the PRP, DOE is required to fund cleanup and public health investigations, such as the ATSDR PHAs, for the Oak Ridge Reservation. The DOE funding is outlined in the MOU between HHS and DOE (see http://www.eh.doe.gov/health/documents/mou.pdf). This MOU also addresses ATSDR's public health responsibilities around DOE sites including public health assessments, health studies, health surveillance, and exposure registries. Implementing this MOU requires significant interaction with communities living in proximity to DOE sites. This charter is in response to requests from community representatives surrounding DOE sites to provide consensus advice and recommendations on community concerns to CDC's and ATSDR's activities related to the sites. As a federal advisory agency, ATSDR conducts independent and objective public health evaluations. We make our decisions based on available data and current science—the source of our funding does not bias our evaluations, our assessment of data, or our scientific conclusions. In public health assessments for the ORR, ATSDR uses available data not only from DOE, but from other government agencies such as the Tennessee Valley Authority (TVA). ATSDR conducts its own evaluations of data and makes its own conclusions; it does not depend on previous conclusions and findings from DOE, other governmental agencies (federal, state, or local) or private entities. In addition, to ensure accuracy of this PHA's data and conclusions the White Oak Creek Radionuclide Releases document underwent several phases of review before its final release, including an internal ATSDR review, a data validation review by other agencies (i.e., DOE, EPA, and the Tennessee Department of Environment and Conservation

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		[TDEC]), an Oak Ridge Reservation Health Effects Subcommittee (ORRHES) review, an independent external peer review, and a public comment review. During the agency's internal review process, individuals within the agency who have the proper background (e.g., toxicology and health physics) carefully reviewed the document for technical content and other aspects. After reviewing comments received from other agencies during the data validation review, ATSDR made changes to the document as appropriate. ORRHES members consisted of individuals representing different expertise, backgrounds, geographic areas, and interests from the communities surrounding the Oak Ridge Reservation. ORRHES had technical experts in toxicology, health physics, medicine, geology, and other disciplines as well. ORRHES members carefully discussed all suggested editorial and technical changes and then submitted recommendations to ATSDR for changing the document. Through its external peer review process, ATSDR's Office of Science had three scientific experts review this public health assessment (see Appendix H for the peer reviewer comments and ATSDR's responses). The agency's peer review process allows an external, thorough evaluation of this PHA by experts in the field that this assessment covers—health physics. During the external review process, individuals (not employed by ATSDR or the CDC) independently reviewed this document and provided their unbiased, scientific opinions of it. ATSDR also presented the data and information used in this public health assessment several times at public meetings, including work group and ORRHES meetings. In addition, during the PHA public comment period, any member of the public can provide comments to ATSDR. The public comments are presented and responded to within this appendix. Regarding EPA CERCLA guidance, please see the response to comment 44 in this appendix describing the differences between risk assessments and public health assessments. HHS and DOE's Office of Health Studies collaboratively develop an Agenda for HHS Public Health Activities at DOE Sites, including the Oak Ridge Reservation. The most recent version of the agenda is available online at http://www.eh.doe.gov/health/documents/Agenda2003-08.pdf. The agenda includes HHS committees' proposals for health studies and public health activities for DOE sites. In addition, for some sites such as the Oak Ridge Reservation, the agenda includes feedback provided during open public meetings. The agenda identifies issues needing attention at each DOE site and outlines proposed future public health activities. A draft agenda is released for public comment and the input received is reflected in the final agenda. In 2001, ATSDR scientists conducted a review and analysis of the Phase I and Phase II screening evaluation of the Tennessee Department of Health's (TDOH) Oak Ridge Health Studies, available at http://www2.state.tn.us/health/CEDS/OakRidge/ORidge.html to identify

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		contaminants that require further public health evaluation. In the Phase I and Phase II screening evaluation, TDOH conducted extensive reviews of available information and conducted qualitative and quantitative analyses of past (1944–1990) releases and off-site exposures to hazardous substances from the entire Oak Ridge Reservation. Having reviewed and analyzed Phase I and Phase II screening evaluations, ATSDR scientists are conducting nine public health assessments on: Y-12 uranium releases, White Oak Creek radionuclide releases, off-site groundwater, Toxic Substances Control Act (TSCA) Incinerator releases, Y-12 mercury releases, X-10 iodine 131 releases, K-25 uranium and fluoride releases, PCB releases from X-10, Y-12, and K-25, and a current screening (1990 to 2003) of environmental data. For copies of these public health assessments, please contact ATSDR's Information Center toll-free at 1-888-422-8737.
71	With respect to ATSDR work at Oak Ridge, the local situation has become quite serious. There appears to be willful administrative intent to ignore both internal and outside comments and criticism. Members of the local ORR Health Effects Subcommittee have been allowed to influence discussions and voting procedures who have known organizational and economic conflicts of interest. Yet, few members of the ORRHES have the required expertise in dose reconstruction, risk evaluation, and quantitative uncertainty analysis in order to effectively oversee the technical work of ATSDR and properly interpret past work in dose reconstruction conducted at Oak Ridge. Those who have raised critical concerns and comments have been summarily dismissed.	In 1999, ATSDR established the Oak Ridge Reservation Health Effects Subcommittee (ORRHES) under the laws, rules, and guidelines of the Federal Advisory Committee Act (FACA) to provide ATSDR with advice and recommendations related to public health activities and research at the ORR. FACA requires all committee members to be "fairly balanced in terms of the points of view represented and the functions to be performed." As a result, the selected subcommittee members consisted of individuals representing different expertise, backgrounds, geographic areas, and interests. ORRHES had technical experts in toxicology, health physics, medicine, geology, and other disciplines as well. Regarding the statement concerning ORRHES members having known conflicts of interest, every ORRHES member was considered a special government employee. Under this role, each subcommittee member had to comply with the Standards of Ethical Conduct for Employees of the Executive Branch, Conflict of Interest Statues, the U.S. Department of Health and Human Services (HHS) Standards of Conduct, and regulations governing confidentiality and procurement integrity. Under these guidelines, ORRHES members had to be impartial in their roles and responsibilities while serving on the subcommittee. All ORRHES meetings followed the operation of FACA. ORRHES and work group meetings were open to the public, and ATSDR considered feedback and opinions from public members as well as from ORRHES members. The subcommittee voted to use Robert's Rules of Order, and operated its meetings in accordance with these guidelines. No individual ORRHES member was able to influence or change these established rules governing the subcommittee and its operations. Every change and recommendation in ORRHES was not accepted unless it was approved by a two-thirds majority vote within the subcommittee. Though ATSDR gave significant weight to the ORRHES's consensus recommendations when making its decisions, ATSDR retained independent decision-making authority for public health activities. Over the past 5 years, more than 25 ORRHES

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		and 135 work group meetings were held. During this time, ATSDR staff members gave numerous technical presentations on public health assessments and related issues to ORRHES and work groups and technical experts in various disciplines presented to ORRHES as well. For information on meeting agendas and meeting minutes, please visit the ORRHES Web site at http://www.atsdr.cdc.gov/HAC/oakridge/. In addition, all nine public health assessments undergo several phases of review, including internal ATSDR review, a data validation review by other agencies (i.e., DOE, EPA, and TDEC), an ORRHES review, an independent peer review, and a public comment review (see the response to comment 70 for more details). Thus, even though participants at ORRHES and work group meetings provided expertise in these areas mentioned by the commenter (i.e., dose reconstruction, risk evaluation, and quantitative uncertainty analysis), these are not the only individuals reviewing this document. It undergoes several rounds of review by experts in these fields of study and other areas of interest for this document (e.g., health physics). All comments received during the public comment period and review are responded to and included within this appendix in the final PHA. In addition, comments received by the peer reviewers and ATSDR's responses are included in Appendix H of the final PHA.
Additional Comments		
72	Page 5, line 4: ATSDR needs to amplify its very limited bibliography to, at a minimum, include the website for DOE's OREIS database and users guide. (*Comment received on the initial release PHA dated December 2003.)*	The Oak Ridge Environmental Information System (OREIS) has been added to the reference list. The references presented in Section XII of this PHA include the resources used to prepare this final PHA. Though the documents such as reports, the OREIS users guide, and other available information about the ORR are numerous, only resources used to prepare the report are presented in the reference list.
73	Page 7, Line 24. There was another facility near this location as well, the S-50 plant. We believe that it was a nuclear reactor used to make an atomic aircraft. The project was subsequently abandoned. This should be included here because it is on the map in Figure 1, and its contaminants possibly are still in place, especially Co-60, Sr-90, and Cs-137. (*Comment received on the initial release PHA dated December 2003.)*	ATSDR scientists conducted a review and analysis of the Phase I and Phase II screening evaluation of the Tennessee Department of Health's (TDOH) Oak Ridge Health Studies to identify contaminants that require further public health evaluation. In the Phase I and Phase II screening evaluation, TDOH conducted extensive reviews of available information and conducted qualitative and quantitative analyses of past (1944–1990) releases and off-site exposures to hazardous substances from the entire Oak Ridge Reservation. Using this review, ATSDR scientists are conducting nine public health assessments on ▪ Y-12 uranium releases, ▪ White Oak Creek radionuclide releases, ▪ off-site groundwater, ▪ Toxic Substances Control Act (TSCA) Incinerator releases, ▪ Y-12 mercury releases,

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		▪ X-10 iodine 131 releases, ▪ K-25 uranium and fluoride releases, ▪ PCB releases from X-10, Y-12, and K-25, and ▪ a current screening (1990 to 2003) of environmental data. For copies of these public health assessments, please contact ATSDR's Information Center toll-free at 1-888-422-8737. As noted, this includes a public health assessment on uranium and fluoride releases from the K-25 site, which comprises the former S-50 plant. For more information on the screening evaluation, please see the Phase I Dose Reconstruction Feasibility Study and Task 7 Screening Level Evaluation of Additional Potential Materials of Concern briefs in Appendix D of the final PHA. For additional information on how specific contaminants were identified as requiring further evaluation based on screening evaluations that evaluated past exposures, please see the TDOH's Oak Ridge Health Studies at http://www2.state.tn.us/health/CEDS/OakRidge/ORidge.html. The S-50 site contained approximately 37 acres and was located next to the K-25 Power House along the Clinch River. This site operated for less than 1 year; however, and is now part of the K-25 site. As all of the facility's buildings were destroyed and buried in 1946, no physical evidence of S-50 at the K-25 site remains. Construction of the former S-50 liquid thermal diffusion plant began on June 6, 1944, and it was fully operational by October 1944. The purpose of the plant was to assess the financial and scientific feasibility of separating uranium 235 (U 235) from uranium 238 (U 238) through liquid thermal diffusion. Because of constant equipment malfunctions and releases to the Clinch River and to the air, the plant was closed in September 1945. The only documented process at the S-50 site was liquid thermal diffusion enrichment between 1944 and 1945.
74	Page 12, Figure 4. Location of White Oak Creek (WOC) and the Relationship Between X-10, White Oak Lake, White Oak Dam, the Clinch River, and the Watts Bar Reservoir. In the legend, the direction of primary river flow is indicated. No information indicates the existence of the well-known 'back flow' of the river caused by hydraulic changes in the directional flow due to 'draw downs' in the TVA system, power generation events at Watts Bar, and other events. This is important because the water supply for towns like Kingston is, in fact, water intakes that do draw water from the Clinch River from water that occasionally FLOWS BACKWARDS. This means that even though Kingston's water intake appears to be upstream from the contaminated confluence of tributaries from K-25 Kingston's water intake is actually downstream during frequent river backflow events. This unfortunate set of circumstances means that the	Kingston maintains public water supplies in the vicinity of the Oak Ridge Reservation (see Figure 13). The Kingston water supply has two water intakes, but ORR contaminants would potentially affect only one of the intakes located upstream on the Tennessee River in Watts Bar Lake at Tennessee River Mile (TRM) 568.4. Spring City obtains its water from an intake on the Piney River branch of Watts Bar Lake. The city of Rockwood receives its water from an intake on the King Creek branch of Watts Bar Lake, located at TRM 553. These three intakes could potentially be affected, however, only during reverse flow conditions. Under the Safe Drinking Water Act, the U.S. Environmental Protection Agency (EPA) has set health-based standards for substances in drinking water and specified treatments for providing safe drinking water since 1974 (USEPA 1999). 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, the Tennessee Department of Environment and Conservation's (TDEC) Division of Water Supply regulates drinking

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	entire population of towns like Kingston are drawing water from the contaminated confluence of K-25's tributary to the Clinch. Local citizens are particularly aware of this [backwards flow] during periodic fish kills near Kingston. Anyone can watch the dead fish float from the K-25 confluence right up to Kingston's water intake for the city. Some citizens have documented these events with photographs, in case ATSDR did not realize that the people of Kingston are, in fact exposed via drinking water because of the backflow events described above. The citizens of communities like Kingston, Spring City, and many others do not believe that ATSDR had done its homework in contemplating the consequences of the backflow events of the Clinch in determining possible routes of exposure by drinking water. The citizens of communities along the Clinch again do not believe that ATSDR has done an adequate job of determining where the radioactive fish actually are because of Agency's simplistic assumption that fish contaminated by radioactive sediments at the confluence of tributaries draining from waste sites like WOC and K-25 simply stay put. Fish don't stay put. Fish swim around and do leave the area. Some species travel far downstream and upstream. Bottom feeders, which are most probably contaminated via consumption of sediment can be flushed out during reservoir drawdowns and/or power generation events. This means that radioactively contaminated fish are not 'contained' by Watts Bar, but most probably have already either migrated upstream or have been 'flushed downstream.' (*Comment received on the initial release PHA dated December 2003.)*	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. The public water supplies for Kingston, Spring City, Rockwood, and other supplies in Tennessee are monitored for substances that include 15 inorganic contaminants, 51 synthetic and volatile organic contaminants, and 4 radionuclides. See http://www.epa.gov/safewater/pws/pdfs/qrg_smonitoringframework.pdf for EPA's monitoring schedules for each contaminant. On a quarterly basis, TDEC submits the individual water supply data to EPA's Safe Drinking Water Information System (SDWIS). According to EPA's SDWIS, the Kingston, Spring City, and Rockwood public water supply systems have not had any significant violations. To access information related to these and other public water supplies, go to EPA's Local Drinking Water Information Web Site at http://www.epa.gov/safewater/dwinfo.htm. In addition, in 1996 TDEC's DOE Oversight Division began to participate in EPA's Environmental Radiation Ambient Monitoring System (ERAMS). As part of the Oak Ridge ERAMS program, TDEC collects samples from five facilities on the ORR and in its vicinity. Under the Oak Ridge ERAMS, TDEC collects finished drinking water samples from the Kingston Water Treatment Plant on a quarterly basis and then submits the samples to EPA for radiological analyses. The contaminants sampled at the Kingston Water Treatment Plant are presented in Section II.F.3. of the final PHA. TDEC has also conducted filter backwash sludge sampling at Spring City because radioactive contaminants from the ORR could potentially move downstream into community drinking water supplies. TDEC analyzed Spring City samples for gross alpha, gross beta, and gross gamma emissions. To inquire about your drinking water, please call TDEC's Environmental Assistance Center in Knoxville, Tennessee at 1-865-594-6035 or call EPA's Safe Drinking Water Hotline at 1-800-426-4791. More details are also available at EPA's Safe Drinking Water Web site at http://www.epa.gov/safewater/. For past exposure, Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report) (presented in Section III.B.2. Past Exposure of the final PHA) estimated the amount of radiological contamination resulting from Clinch River backflow that could have entered the Kingston water intake, as well as the effect of water treatment on the drinking water. Nonetheless, under drinking water ingestion in Section III.B.2. of the final PHA, the following was added to the discussion of how the Task 4 team evaluated drinking water for the city of Kingston: "Water from the Clinch River can travel up the Tennessee River when the Clinch River's flow is greater than the Tennessee River's flow. As a result of this backflow, the city of Kingston could receive Clinch River water. The Task 4 team estimated 1) the amount of radiological contamination resulting from Clinch River backflow possibly entering the Kingston water intake and 2) the effect of

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	Page 38, line 25: Kingston public water supply is located about one mile up the Tennessee River from the mouth of the Clinch, which is not in the study area; however, at times Clinch River Water can enter the intake on the Tennessee River.	water treatment on the drinking water." Although during backflow Clinch River water can enter these intakes, this water is treated before it is distributed to Kingston city drinking water consumers. Further, the past estimated whole-body lifetime (over 70 years) dose from ingestion of city of Kingston drinking water was 1.4 mrem, which is more than 3,500 times less than ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years. Because of strict regulatory guidelines and water treatment prior to distribution, potential current and future exposures to harmful levels of radionuclides in the home from municipal water use are expected to be limited—monitoring data indicate that drinking water has met safe drinking water standards for radionuclides. Regarding the "fish kills" mentioned by the commenter, it is important to note that there has never been enough (at least 2,000 rad) acute radioactive pollution in the Clinch River or White Oak Creek to kill fish. The highest radiation doses for past exposures to the Clinch River were associated with consuming fish collected from the Clinch River near Jones Island. For fish ingestion near Jones Island, ATSDR's derived annual whole-body dose was less than 3.4 mrem/year—nearly 30 times less than the 100 mrem/year dose limit recommended for the public 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). The lifetime whole-body dose from ingesting fish near Jones Island was 238.6 mrem over 70 years, which is more than 20 times less than ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years. Because even the worst-case scenario was not found to be a public health hazard, areas downstream of White Oak Creek—where X-10 radionuclide concentrations would be lower—would also not be expected to pose a hazard. Please note that the White Oak Creek study area, as shown in Figure 11 and discussed throughout the final PHA, consists of the area along the Clinch River and the Lower Watts Bar Reservoir from the Melton Hill Dam to the Watts Bar Dam. In the final PHA, please also see Figure 13 and Figure 14 for the location of the Kingston water intake included in this study area. Further, page 90 of the final PHA discusses how Clinch River water can enter the Kingston water intake.
75	Page 15, Line 12. What were the major components of these liquid wastes which were discharged into White Oak Creek (WOC)? According to the ORHASP Final Report, p. 40, releases of Cs-137, which contributed most to the risk, were highest in 1955 to 1959. WOC was drained in 1955 and the lake stayed low until 1960. This allowed the high creek flows	See Table 2 in the final PHA for the estimated discharges of radionuclides from White Oak Creek to the Clinch River as reported in the Clinch River/Poplar Creek remedial investigation/feasibility study (RI/FS) (http://www.osti.gov/bridge/servlets/purl/226399-5omhIT/webviewable/226399.pdf). The radionuclides expected to be of most concern are depicted in gray—cesium 137, ruthenium 106, strontium 90, and cobalt 60. Table 3 in the

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	accompanying heavy rains, especially in the winter and early spring of 1956, to scour the sediments in which radionuclides had accumulated. Releases during these years are believed to be responsible for the relative high concentrations of Cs-137 found in subsequent cores and samples from WOC below: the lake, the Clinch River, and lower Watts Bar. Additionally, because Cs-137 is in the same chemical periodic table family as Potassium (K), it, like K, Cs-137 in the environment is incorporated into the flesh of fish and other aquatic species. Were there also large releases of Sr-90 as well? ATSDR's Public Health Assessment (PHA) is apparently silent on this. Page 38 of the ORHASP Final Report indicates that the main radionuclides releases to WOC were: Cs-137, Ruthenium-106 (Ru-106), Co-60, and Sr-90. The releases of Sr-90 are particularly important to human health because, analogous to Cs-137 substituting for K, Sr-90 is likewise in the same chemical periodic table family as Calcium (Ca). Consequently, Sr-90 in the environmental will bioaccumulate into the bones of fish. Thereby, if fish are either stewed or made into patties the Sr-90 in the fish bone will end up in the bones of the people who consume them. (*Comment received on the initial release PHA dated December 2003.)*	final PHA presents a summary of the peak annual releases from White Oak Dam for the eight key radionuclides as reported in the Oak Ridge Dose Reconstruction Project Summary Report (available at http://www2.state.tn.us/health/CEDS/OakRidge/ProjSumm.pdf). In addition, see Section III.B.2. Past Exposure in the final PHA for a description of the screening evaluations conducted in the *Task 4 of the TDOH's Reports of the Oak Ridge Dose Reconstruction: 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* (referred to as the "Task 4 report"). A brief on the Task 4 report is also available in Appendix D of the final PHA and the report can be viewed at http://www2.state.tn.us/health/CEDS/OakRidge/WOak1.pdf. There were also large releases of strontium 90 in addition to cesium 137 releases. This is mentioned throughout the PHA (see Sections II.C., III.B.2., and III.B.3) and past, current, and future potential exposures to this radionuclide are evaluated in this document. According to the RI/FS for the Clinch River/Poplar Creek, since 1944 the X-10 radionuclides disposed of in the largest quantities—either via on-site burial or liquid waste discharge to pits and trenches—are cesium 137, strontium 90, and unidentified beta emitters. Please note, however, that these are releases that occurred **on site**. ATSDR only evaluated radionuclides released into White Oak Creek that traveled off site into the Clinch River and the Lower Watts Bar Reservoir. Strontium 90 is chemically similar to calcium and tends to deposit in bone and blood-forming tissue (bone marrow). Accordingly, strontium 90 is referred to as a "bone seeker." For evaluating past exposures, ATSDR summarized the Task 4 organ doses for the bone, lower large intestine, red bone marrow, breast, and skin. The contaminants of concern, particularly strontium 90 and cesium 137, tend to concentrate in these organs. For current exposures at the Lower Watts Bar Reservoir, ATSDR evaluated fish sampled for cesium 137, cobalt 60, and strontium 90 and estimated whole-body doses resulting from potential exposure to these contaminants via fish consumption. For strontium 90, ATSDR assumed that the meal could include some bone. For current exposures for the Clinch River, ATSDR evaluated cesium 137, cobalt 60, strontium 90, yttrium 90, americium 241, and hydrogen 3 based on the Oak Ridge Environmental Information System (OREIS) fish data. ATSDR evaluated the critical organ for each radionuclide and estimated the radiation dose delivered to the whole body. These evaluations show that the level of potential radiological exposure from radioactive contaminants in Clinch River and Lower Watts Bar Reservoir fish do not represent a past, current, or future public health hazard. This evaluation is discussed in detail in Section III.B. Exposure Evaluation of the Clinch River and Lower Watts Bar Reservoir in the final PHA.

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		For information on fish advisories, please refer to the response to comment 9 in this appendix.
76	Page 22, line 18: "The building of a coffer cell dam to prevent the backflow of water from the Clinch River into White Oak Creek Embayment:" Prior to 1963 there was little backflow into White Oak Creek embayment except during floods on the Clinch River. However, in 1963 Melton Hill Dam was impounded and became a peaking unit which means that water from the dam was released during the morning and evening hours for a short period of time to meet the increased electrical demands. However, the amount released was about equivalent to the daily flow of the Clinch River at White Oak Creek. This large volume released from Melton Hill Dam would cause a backflow up White Oak Creek Embayment and would result in the scouring of sediment from the embayment. The large amount of Cesium-137 released in 1956 after the draining of White Oak Dam that had been covered by sedimentation was gradually uncovered by the backflow of water from Melton Hill Dam that was being transported into the Clinch River. This change in flow of water below Melton Hill Dam also changed the distribution of radionuclides released into the Clinch River. Whereas previously a more or less constant flow of water passed the mouth of White Oak Creek, afterwards (except during peaking operations) there was virtually no flow past the mouth of White Oak Creek. The outflow from White Oak Creek would often flow upstream in the Clinch River.	Thank you for your suggestions. We have similar text on pages 14, 17, and 25 of the final PHA, and incorporated some of these suggested changes into that text.
77	Page 28, Line 5. Regarding these eight 'experimental' plots – was this an actual DOE experiment, or actually a cheap-and-dirty disposal practice, similar to the common practice of drying municipal sewage on land? (*Comment received on the initial release PHA dated December 2003.)*	The referenced section is no longer within the main text, but in Appendix B of the final PHA. As discussed in the record of decision for the waste area grouping (WAG) 13 cesium plots (available at http://www.epa.gov/superfund/sites/rods/fulltext/r0493137.pdf), these plots are the result of an actual U.S. Department of Energy (DOE) experiment at the Oak Ridge National Laboratory (ORNL) to simulate conditions of a nuclear fallout. These plots are located on site and access is restricted. In this public health assessment, ATSDR evaluates exposures occurring off site only. In 1968, each of four 33-by-33-foot treatment plots were contaminated with 2.2 curies of cesium 137 via fusing the cesium with silica sand particles at high temperatures; four "control" plots were not contaminated. Cesium 137 was selected because it is a long-lived component of weapons fallout. The main purpose of the experiment was to evaluate the

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		long-term, low-dose effect of radiation to the environment, specifically to vegetation. The plots occupy an approximate 6-acre area and are enclosed by a perimeter fence. Sheet metal, extending 18 inches below and 24 inches above ground surface, enclosed each plot. Before the experiment, ORNL researchers suspected that the fused cesium particles would not migrate horizontally in any direction or more than 6 to 12 inches vertically. Soil samples collected at the site in 1987 indicated, however, that cesium had migrated horizontally in a northwest plume of several feet and vertically to depths of 3 to 4 feet. To prevent potential threats to public health and the environment, remedial actions were conducted and finished in July 1994. The main aspects of the interim action were: ▪ excavating soil until contamination was reduced to permissible levels; ▪ placing extracted soil into boxes made to store low-level radioactive waste; ▪ moving the soil to the low-level waste silos at WAG 6; and ▪ placing a porous liner, clean fill material, and a clean top layer of soil into each excavated plot. Since completion of the interim action, a fence containing many locked gates has enclosed WAG 13. Several signs are posted to notify people of on-site soil contamination and of restricted access to the site. In addition, the site is inspected on a quarterly basis.
78	Page 28, Line 27. What is meant by "uncontrolled?" It should intend that the contaminated sediments from WOC moved offsite to the Clinch River, onto Watts Bar, and to other downstream locations. Most probably, these contaminated sediments, and the bottom fish and other aquatic organisms that feed on them, have undoubtedly been flushed far and wide through the TVA system. The extent of this spread either through electrical power generation events or drawdowns in the series of TVA reservoirs has likely spread these sediments and the aquatic organisms that feed on them to at least Mocassin Bend in Chattanooga, TN if not to the TVA confluence at Paducah, KY. For ATSDR to simply postulate that the dam at Watts Bar contains the problem and the dredging these radioactive sediments is not an option is baseless. The citizens of Oak Ridge, Kingston, Spring City, and all other downstream communities along the hundreds of miles of the TVA system from Clinch River Mile 1 to the confluence of the Tennessee and Ohio Rivers are not buying it. All of these stakeholders insist that ATSDR start sampling sediments from at least Oak Ridge to at least the embayment at Mocassin	Please note that the referenced section is no longer within the main text, but in Appendix B of the final PHA. "Uncontrolled" refers to how surface sediments containing cesium 137 and other sediment-bound contaminants in the White Oak Creek Embayment can erode and be transported downstream to the Clinch River system. Daily releases of water from Melton Hill Dam and flood flows in White Oak Creek caused water to surge into and out of the White Oak Creek Embayment, resulting in the erosion of cesium 137 and other contaminant-containing sediments. In the early 1990s, however, a sediment retention structure was built at the mouth of White Oak Creek to retain the sediments in the lower White Oak Creek Embayment and lessen the off-site movement of the sediments to the Clinch River and the Watts Bar Reservoir. According to various studies, most of the sediment-associated contaminants released from the Oak Ridge Reservation collected in the Lower Watts Bar Reservoir. Therefore, concentrations of sediment-associated contaminants released from the reservation are significantly lower in reservoirs located downstream of Watts Bar Dam. Past studies have found that detected levels of contaminants released from the ORR into the Tennessee River system—below the Watts Bar Dam—are far below levels found to be hazards for human health in the Watts Bar Reservoir baseline risk assessment. If ATSDR believed that the

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	Bend in Chattanooga. Otherwise, ATSDR doesn't really know which sediments are affected downstream, who is actually exposed now, and who is likely to be exposed in the future from radioactive contamination of fish and other aquatic organisms all along the TVA system. (*Comment received on the initial release PHA dated December 2003.)*	sediments and fish were a public health issue, then we would recommend that additional sampling be conducted. The findings in this PHA, past studies on the Tennessee River system, and ongoing monitoring programs, however, show that additional sampling is unnecessary. The record of decision (ROD) for the Lower Watts Bar Reservoir (available at http://www.epa.gov/superfund/sites/rods/fulltext/r0495249.pdf), issued by the U.S. Department of Energy (DOE) and supported by the U.S. Environmental Protection Agency (EPA) and the Tennessee Department of Environment and Conservation (TDEC), determined that buried sediments remaining in place pose no health risk because of the absence of any exposure pathway for humans. In 1996, ATSDR conducted a health consultation on the Lower Watts Bar Reservoir that concurred with the ROD. ATSDR reviewed these findings in this public health assessment and we continue to support this conclusion. Based on our findings in this PHA, we concur with DOE, EPA, and TDEC that leaving deep sediments in place poses no public health hazard. According to the record of decision and ATSDR's evaluations, the only threat to human health was associated with the consumption of certain fish species due to PCB contamination—no health hazards were found to be associated with ORR-related radionuclide releases in Watts Bar Reservoir sediment (if left undisturbed), surface water, or biota. Please note: as shown in Figure 11 and discussed throughout the final PHA, the White Oak Creek study area consists of the area along the Clinch River and the Lower Watts Bar Reservoir from the Melton Hill Dam to the Watts Bar Dam.
79	Page 28, Line 28. What are the radiological measurements of this area, both before and after 'remediation?' If these areas have actually been 'remediated' to acceptable levels of public exposure, why is the hazard warning signage still in place? (*Comment received on the initial release PHA dated December 2003.)*	Please note that the referenced section is no longer within the main text, but in Appendix B of the final PHA. This section of the document refers to the White Oak Creek Embayment located on site at the reservation where access is restricted; our public health assessment evaluates radionuclides that traveled off site. Sediment samples collected in summer 1990 from the lower portion of the White Oak Creek Embayment showed the presence of cesium 137 and cobalt 60 in near-surface sediment (upper 2 to 4 inches). Levels of cesium 137 were higher than expected—a finding based on sediment samples collected at the embayment in 1979 and 1984 that showed contamination only in deeper sediment (about 1 to 2 feet below surface). These results in 1990 caused concern: White Oak Creek Embayment sediments were uncontrolled at that time, meaning surface sediments could erode and travel downstream to the Clinch River. As explained in Appendix B of the final PHA, in the early 1990s a removal action was conducted at the embayment. This action consisted of building a sediment retention structure at the mouth of White Oak Creek in the early 1990s to prevent contaminants in

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		surface sediments from traveling from the White Oak Creek Embayment to the Clinch River system. Thus, this time-critical removal action resulted in retaining the sediments in the lower embayment and reducing off-site movement of the sediments to the Watts Bar Reservoir and the Clinch River. In 2001, after about 10 years of data collection and monitoring, a remediation effectiveness report suggested discontinuing regular water level monitoring at the embayment because data showed that the sediment retention structure prevented scouring of the embayment and sustained sediment water coverage. Completed and ongoing actions at the reservation, including those associated with the White Oak Creek Embayment, are published annually in a remediation effectiveness report (RER). The RER is available at the DOE Information Center located at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee (telephone number: 1-865-241-4780).
80	Page 35, Line 24. Regarding the "contaminated sediment from the high flux isotope reactor (HFIR) ponds." Which specific radionuclides are related to this process? Which are known to be in this 'contaminated sediment?' Are these contaminated sediments still in place or have they been removed? If they have been removed, where did they go? Are they still at DOE ORR? Have they been taken to an offsite location? If they are still in the bottom of the HIFR ponds are they continuing to leach into WOC? ATSDR needs to be more forthcoming about the nature, extent, and actual location of these contaminated sediments and whether or not they still pose an ongoing public health hazard. What is the actual state of affairs here? Are these contaminants still there leaking into the groundwater? Are the citizens of Oak Ridge and downstream communities still at risk from leachate from the HFIR ponds into WOC? Which is ostensibly ATSDR's main purpose in producing this PHA? (*Comment received on the initial release PHA dated December 2003.)*	Please note that the referenced section is no longer within the main text, but in Appendix B of the final PHA. In addition, it is important to understand that the high flux isotope reactor ponds (HFIR) are located on site at the reservation; this public health assessment evaluates radionuclides released to White Oak Creek that traveled off site into the Clinch River and the Lower Watts Bar Reservoir. Nonetheless, we would like to provide responses to your questions below. The HFIR at the Oak Ridge National Laboratory (ORNL) has operated since 1966 to produce radioisotopes for medical, academic, and industrial purposes, as well as perform other scientific functions (e.g., irradiation tests and experiments). The HFIR uses highly enriched uranium 235 as fuel for this light water-cooled reactor. Radioisotopes produced at the HFIR include einsteinium 253, iridium 192, platinum 195, berkelium 249, lutetium 177, cobalt 60, nickel 63, californium 252, holmium 166, tin 177, fermium 257, tungsten 188, rhenium 186, and others. From the 1960s until 1986 radioactive contaminants related to processes at the HFIR were placed into four ponds, also referred to as surface water impoundments or subbasins. These ponds, located south of the HFIR building, are inactive and lie along Melton Branch. According to the Melton Valley remedial investigation, no data are available on radionuclides in HFIR pond sediment. Sediment data show, however, the presence of cobalt 60 and cesium 137 in contaminated sediment along Melton Branch downstream of the HFIR facility. Soil data for the ponds show the presence of cesium 137, cobalt 60, strontium 90, and thorium 288. Primarily, cesium 137 and cobalt 60 are contaminants of concern for the area. But according to the ORNL's risk assessment information system (available at http://risk.lsd.ornl.gov/maps/x-10/x10_relsites.shtml), these disposal ponds have not released radionuclides.

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		Because of the short half-life of cobalt 60 (5.3 years), releases of this contaminant from the HFIR ponds has decreased to the point of no longer being detectable in surface water near the ponds. A surface water monitoring location on Melton Branch is just downstream of the HFIR drainage areas. In 1993 and 1994, these areas only contributed <1% of tritium and <0.2% of strontium 90 releases into White Oak Dam, but reportedly contributed 17.2% of cesium 137 to White Oak Dam based on remedial investigation data for waste area grouping (WAG) 5 (though data at this monitoring station usually show nondetects for cesium 137). Excavation activities began in summer 2004 to remove contaminated sediment at the four HFIR ponds—7905, 7906, 7907, and 7908. The HFIR ponds, built for storing wastewater from the HFIR and for providing further settling before treatment or discharge to surface waters, are clay-lined, earth-bermed, and open. The ponds are located in Melton Valley, a restricted area of the reservation remaining under DOE control. Remediation goals were established based on anticipated future use of the land. No residents have access to this land and future use is expected to remain industrial. The waste is being disposed of on site at the Oak Ridge Environmental Management Waste Management Facility (EMWMF) located in Bear Creek Valley near the Y-12 Plant. In addition, contaminated soils, liquids, and sludges associated with the ponds will be removed. According to the Melton Valley remedial investigation, no groundwater contaminants of concern associated with the HFIR ponds have been identified. For information on ATSDR's evaluation of off-site exposure to groundwater related to the ORR, please refer to the PHA titled *Evaluation of Potential Exposures to Contaminated Off-site Groundwater From the Oak Ridge Reservation (USDOE)* (available at http://www.atsdr.cdc.gov/HAC/PHA/region_4.html#groundwater). Copies of this and other ATSDR documents are available from the ATSDR Information Center. The center can be reached toll-free at 1-888-422-8737. Section III. Evaluation of Environmental Contamination and Potential Exposure Pathways in the final PHA details ATSDR's analysis of past, current, and future exposures to White Oak Creek radionuclide releases via fish and other biota. Section IV. Public Health Implications details the weight-of-evidence approach ATSDR used to compare estimated radiation doses to situations associated with disease and injury to determine whether harmful health effects could be possible and observable. Based on our evaluation, ATSDR concluded that past, current, and future exposures to radionuclides released from White Oak Creek to the Clinch River and the Lower Watts Bar Reservoir are not a public health hazard for people who lived along or used these waterways in the past, or who currently do so or will in the future. Thus, even if radionuclide releases did occur from the HFIR ponds to White Oak Creek, exposures to radionuclide releases from the creek via the Clinch River and the

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		Lower Watts Bar Reservoir would not be expected to cause adverse health effects.
81	Page 36, Line 9. Offsite Locations. Name the top twenty radioactive contaminants that have actually been released to the Clinch River and Watts Bar Reservoir from WOC. Give an estimate of the respective curie loads of each of these radionuclides. Cite the actual levels of these radionuclides in fish sampling data in the OREIS database. The DOE ASERs (Annual Site Environmental Reports) contain data volumes that are available to stakeholders. For example, these data volumes cite that Cs-137 concentrations in fish filets is 0.44 pCi/gm, which should be a significant risk driver for further investigations far downstream of DOE ORR. If the sediments contain Cs-137 and Sr-90 then the bottom feeding fish surely contain these radionuclides as well. This is amply demonstrated in both DOE's ASERs and its OREIS database. (*Comment received on the initial release PHA dated December 2003.)*	As presented in Section III.B.2. Past Exposure in the final PHA and discussed in the Oak Ridge Health Agreement Steering Panel (ORHASP) report titled *Releases of Contaminants from Oak Ridge Facilities and Risks to Public Health* (available at http://www2.state.tn.us/health/CEDS/OakRidge/ORHASP.pdf), an initial evaluation conducted by Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report) identified 24 radionuclides that were released to the Clinch River via White Oak Creek from 1944 to 1991: americium 241, barium 140, cerium 144, cobalt 60, cesium 137, europium 154, hydrogen 3, iodine 131, lanthanum 140, niobium 95, neodymium 147, phosphorus 32, promethium 147, praseodynium 143, plutonium 239/240, ruthenium 106, samarium 151, strontium 89, strontium 90, thorium 232, uranium 235, uranium 238, yttrium 91, and zirconium 95. The Task 4 team identified eight key radionuclides of potential concern based on its screening analysis: cobalt 60, strontium 90, niobium 95, ruthenium 106, zirconium 95, iodine 131, cesium 137, and cerium 144. Table 3 in the final PHA presents the peak annual releases in curies for these key radionuclides. In Section III.B.3. Current and Future Exposure of the final PHA, the maximum radionuclide concentrations are presented for Lower Watts Bar Reservoir sediment (Table 13), surface water (Table 14), and fish (Table 15). In addition, as mentioned in the final PHA, ATSDR obtained data in electronic format from the Oak Ridge Environmental Information System (OREIS) (detailed throughout the document and in Section II.F.4.). ATSDR used the OREIS data, covering the time period from 1989 to 2003, to evaluate the current and future exposures and doses related to releases from White Oak Creek. Samples included surface waters collected from the Lower Watts Bar Reservoir and sediments from the associated shorelines. ATSDR also evaluated biota data, including fish, geese, and turtle samples. ATSDR analyzed samples for rivers in the watershed that included the Clinch River below Melton Hill Dam and the Tennessee River below the mouth of the Clinch River. For comparison purposes, ATSDR reviewed data collected from background locations (Emory River, streams that feed into the Clinch River, the Clinch River above the Melton Hill Dam, and the Tennessee River upstream of the Clinch River). DOE's annual site environmental reports (ASERs) are included in OREIS. Please refer to Section II.F.4 of the final PHA and the response to comment 54 for a detailed discussion on OREIS.
82	Page 36, Line 9. Offsite Locations. The ATSDR BRA (Baseline Risk Assessment), which unfortunately established PCBs, instead of strontium-90 and cesium-90, is fatality and irrevocably flawed and must be redrafted. ATSDR's finding of 'No Public Health Risk' is irresponsible at best and	As a clarification, the commenter refers to a U.S. Department of Energy (DOE) baseline risk assessment in the remedial investigation/feasibility study for Clinch River/Poplar Creek available at http://www.osti.gov/bridge/servlets/purl/226399-5omhIT/webviewable/226399.pdf. This was not an assessment conducted by ATSDR. It is important to note that the findings of the baseline risk assessment were approved and

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	possibly fraudulent. This BRA is not supported by the high levels of Sr-90 and Cs-137 documented in DOE's own fish sampling data in DOE's own OREIS database. As long as these radioactive sediments remain in place they are and will continue to be mobilized in the environment and bioaccumulation in fish and other aquatic organisms — and on to those people consuming them. The risk of consuming PCBs in these fish, compared to the risks of ingesting radioactively contaminated fish is literally a 'red herring' foisted onto stakeholders in these downstream communities in order to quell their legitimate public health concerns. The citizens of Oak Ridge, Kingston, Spring City, and all other communities downstream absolutely reject out-of-hand ATSDR's patronizing, condescending finding of 'No Risk' from these contaminated sediments. Stakeholders demand that ATSDR immediately reorient itself to the reality of the existing DOE and TVA fish tissue data. ATSDR must attempt to redeem itself by reworking this fatally flawed BRA and try to earn the trust of these stakeholders now, which it certainly neither has nor deserves. (*Comment received on the initial release PHA dated December 2003.)*	agreed to by the U.S. Environmental Protection Agency (EPA), the Tennessee Department of Environment and Conservation (TDEC), and DOE. ATSDR's findings in this final public health assessment concur with the findings of the baseline risk assessment that radionuclides in fish, sediment, and surface water in the Clinch River do not present a health hazard. TDEC's Division of Water Control is responsible for issuing and posting fish advisories. Evaluating fish tissue problems in the state of Tennessee involves a multi-agency effort, comprised of DOE, EPA, TDEC, the Tennessee Wildlife Resources Agency (TWRA), and the Tennessee Valley Authority (TVA). An abundance of data are available on contaminants in fish in these systems, including data collected by TVA, DOE, TWRA, and TDEC. These agencies use Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) criteria to analyze fish tissue in these waterways, which applies EPA risk assessment to evaluating potential exposures to contaminants in fish. DOE, TDEC, and EPA have responsibilities under CERCLA, but the state has ultimate responsibility for the advisories. The state fish advisories are available at: http://www.state.tn.us/twra/fish/contaminants.html. Although radionuclides and other contaminants might be present in fish in the Clinch River and the Lower Watts Bar Reservoir, **only PCBs** have been found at levels in particular species of fish that could potentially cause adverse health effects. This is why radionuclides are not part of the advisories for these waterways—they have not been detected at harmful levels in these water systems. These agencies are basing their advisories on numerous data collected over several years by different entities, all of which show that radionuclides are not present in fish in the Lower Watts Bar Reservoir and the Clinch River at levels that could cause adverse health effects. ATSDR's evaluation in this public health assessment concurs with the findings of the state, the EPA, and these other entities. In addition, ATSDR is preparing a public health assessment that will evaluate PCB releases from the three main ORR facilities: X-10, Y-12, and K-25. When available, copies of ATSDR's public health assessment on PCBs can be obtained by contacting ATSDR's Information Center toll-free at 1-888-422-8737.
83	Page 39, Line 4-5. Any objective environmental scientist, with access to the OREIS database, can demonstrate many instances as to why this uninformed statement is wholly fallacious. (*Comment received on the initial release PHA dated December 2003.)*	As reported in the record of decision (ROD) for the Lower Watts Bar Reservoir, human health standards would not be met if deep channel sediments containing cesium 137 were dredged and placed in a residential area. The ROD concluded, however, that these sediments, if left in place and undisturbed, pose no human health threat: no exposure pathway exists to the contaminants in the deep sediment. ATSDR has reviewed and evaluated the Oak Ridge Environmental Information System (OREIS) data and reports indicating the presence of radionuclides in the deep channel sediments (beneath several

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		meters of water and 40 to 80 centimeters of sediment) of the Lower Watts Bar Reservoir. In addition, in 1996 ATSDR prepared a health consultation to review various potential exposures associated with the reservoir. We concluded that the current levels of radiological contaminants in sediment posed no public health hazard and recommended that reservoir sediment not be removed, disturbed, or disposed of without prior careful review of sediment sampling data for the specific area. Furthermore, as discussed in the final PHA in Section III.B.3. Current and Future Exposure, since February 1991 the Watts Bar Interagency Agreement has set guidelines related to any dredging in the Watts Bar Reservoir and for reviewing potential sediment-disturbing activities in the Clinch River below Melton Hill Dam. Under this agreement, the Watts Bar Reservoir Interagency Working Group (WBRIWG) reviews permitting and other activities, either public or private, that could possibly disturb sediment, such as erecting a pier or building a dock. The WBRIWG consists of the U.S. Department of Energy (DOE), the U.S. Environmental Protection Agency (EPA), the U.S. Army Corps of Engineers (USACE), the Tennessee Department of Environment and Conservation (TDEC), and the Tennessee Valley Authority (TVA) because of their permit authority or their knowledge of the sediment contamination and how that contamination if disturbed could affect the public. Therefore, based on the enormous amount of data available, ATSDR's own independent evaluation of the deep channel sediment at the reservoir, and controls in place to prevent the disturbance of deep channel sediment, ATSDR believes that this finding approved by DOE, EPA, and TDEC is supported by the available data indicating that because of the absence of an exposure pathway, people would not come in contact with cesium 137 buried in deep channel sediment.
84	Page 43, Figure 13. Map of the White Oak Creek Study Area. The study area does not extend far enough downstream. It should include at least all downstream communities that appear in the Spatial Query Tool of the DOE OREIS database. More appropriate would be to include other sampling sites that TVA has included in its analyses of radioactively contaminated fish. Yes, these data are available too, if stakeholders ask for them. Certainly, ATSDR should be interested too. More appropriately, the study area should extend to at least to the TVA embayment at Mocassin Bend in Chattanooga — if not the entire TVA dendritic system, which extends to Paducah, KY. (*Comment received on the initial release PHA dated December 2003.)*	The White Oak Creek study area (see Figure 11 in the final PHA) consists of the area along the Clinch River from the Melton Hill Dam to the Watts Bar Dam. Past studies have shown that most sediment-associated contaminant releases from the reservation have collected in the Lower Watts Bar Reservoir. Concentrations of ORR-related sediment-associated contaminants have been detected at much lower levels in reservoirs located downstream of the Watts Bar Dam, and accordingly, also at concentrations well below levels found to be of human health concern. ATSDR extended its evaluation in this public health assessment to the Watts Bar Dam because this is the downstream boundary of the reservation. No public health hazards associated with ORR releases have been identified downstream of Watts Bar Dam. This information is based on many past studies and a baseline risk assessment prepared for the Lower Watts Bar Reservoir. Please see the record of decision for the Lower Watts Bar Reservoir for more information at http://www.epa.gov/superfund/sites/rods/fulltext/r0495249.pdf. The record of decision was

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		issued by the U.S. Department of Energy (DOE), as well as approved by the U.S. Environmental Protection Agency (EPA) and the Tennessee Department of Environment and Conservation (TDEC). The baseline risk assessment 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. But there is no exposure pathway to this deep channel sediment. Thus, areas of the Lower Watts Bar Reservoir do not pose a health hazard for radionuclides. Areas further downstream—where contaminants associated with the ORR have been detected at much lower concentrations than at the Lower Watts Bar Reservoir and at levels not of public health concern would therefore not need to be included in this evaluation of White Oak Creek radionuclide releases to the Clinch River and the Lower Watts Bar Reservoir; they are not an ORR contaminant-related public health hazard.
85	Page 66, Line 3. Why is the DOE OREIS database no longer readily accessible to the public? ATSDR should take immediate steps to insist that DOE be more flexible in granting groups like institutions of higher learning, civic community organizations, churches, civil rights organizations, non-governmental environmental advocacy groups, and indeed any 'legitimate' stakeholder group access to this robust database. These user groups should be given group accounts to the OREIS database, along with the easy to read OREIS Users Guide. ATSDR should take immediate steps to facilitate stakeholders access to this crucial environmental data. Think of the millions of dollars of taxpayers money that went into archiving this data into OREIS. Downstream stakeholders have a fundamental Right-to-Know about the sampling data in OREIS which amply demonstrates that here should, in fact, be considerable concern about the risk manage of environmental releases from DOE ORR. There needs to be a 'sea change' at ATSDR in the project management of this PHA — it is superficial and simply attempts to lull downstream stakeholders into a woefully false sense of security. (*Comment received on the initial release PHA dated December 2003.)*	The U.S. Department of Energy (DOE) created the Oak Ridge Environmental Information System (ORIES)—an electronic data management system that integrates an abundance of environmental data into a single database. OREIS was developed to facilitate access to environmental data related to ORR operations while also maintaining data quality. DOE's objective was to ensure that the database had long-term retention of the environmental data and useful methods to access the information. OREIS contains data related to compliance, environmental restoration, and surveillance activities. Information from all key surveillance activities and environmental monitoring efforts is entered into OREIS. These include but are not limited to studies of the Clinch River embayment and the Lower Watts Bar, as well as annual site summary reports. Before September 11, 2001, OREIS was accessible to the public. Following these events, however, access of OREIS was restricted due to sensitive information contained within the database, such as geographic information system (GIS) data identifying locations of buildings on the Oak Ridge Reservation. Today, DOE and its contractors and subcontractors, the U.S. Environmental Protection Agency (EPA), the Tennessee Department of Environment and Conservation (TDEC), ATSDR, and other agencies have access to OREIS through officially obtained user ids and passwords. Members of the public can request a user id and password, but the applicant would have to be sponsored by a DOE or other government representative. The public can contact bjc-oreis@bechteljacobs.org to request a user account and password, but only those with proper sponsorship will be provided access. Further, OREIS could be accessible to the public again soon; DOE's subcontractors are in the process of working on the database so that it can be made publicly available in the near future.

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		ATSDR is not involved in the management of OREIS or in providing people with access to the database. We understand DOE's need to remove the database from public access due to the sensitivity of information within OREIS, but again, this was not our decision and we have no involvement in OREIS other than using the data contained within it.
86	Page 116, Actual Comment #11, third paragraph, Line 2. The list of potential contaminants of significant concern is inadequate and incomplete. The ORHASP Final Report, in fact, lists eighteen cardinal contaminants of concern as having been released off site by DOE ORR. (*Comment received on the initial release PHA dated December 2003.)*	As a clarification, the statement referenced by the commenter is not a list of potential contaminants of concern. Instead, it is a list of the contaminants for which ATSDR is preparing public health assessments. The rationale for the selection of these contaminants is detailed below. During Phase I and Phase II of the Oak Ridge Health Studies, the Tennessee Department of Health (TDOH) conducted extensive reviews and screening analyses of the available information and identified four hazardous substances related to past ORR operations that could have been responsible for adverse health effects: radioactive iodine, mercury, polychlorinated biphenyls (PCBs), and radionuclides from White Oak Creek. In addition to the dose reconstruction studies on these four substances, the TDOH conducted additional screening analyses for releases of uranium, radionuclides, and several other toxic substances. To expand on TDOH efforts—but not duplicate them—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. Using this review, in addition to this public health assessment on X-10 radionuclide releases to White Oak Creek, ATSDR scientists are conducting public health assessments on: Y-12 uranium releases, X-10 iodine 131 releases, Y-12 mercury releases, K-25 uranium and fluoride releases, PCB releases from X-10, Y-12, and K-25, and other topics such as the Toxic Substances Control Act (TSCA) incinerator and off-site groundwater. In conducting these public health assessments, ATSDR scientists are evaluating and analyzing the data and findings from previous studies and investigations to assess the public health implications of past, current, and future exposures. Contrary to the commenter's statement, the Oak Ridge Health Agreement Steering Panel (ORHASP) (see page 72 of its final report at http://www2.state.tn.us/health/CEDS/OakRidge/ORHASP.pdf) lists the primary Oak Ridge Reservation contaminants as iodine 131, mercury, PCBs, and White Oak Creek radionuclide releases—the same as those identified during the Oak Ridge Dose Reconstruction. The statement questioned by the commenter in ATSDR's public health assessment for which public health assessments are being conducted lists the same contaminants identified as priority contaminants by ORHASP. Further, ATSDR is conducting assessments on additional topics because of community concern, including the

	Comment	ATSDR's Response
		TSCA Incinerator, uranium and fluoride releases from K-25, and off-site groundwater.
87	Page 125, Line 6. This statement is not true. This PHA is fatally flawed and should be redone in its entirety. Next time try to have it prepared by competent, credentialed health professionals. This PHA in definitely lacking the caliber of talent that is elemental in such a serious task. Peoples' health and lives are at stake and ATSDR should not be so cavalier in assigning the preparation of this PHA to non-medical staff. We stakeholders, many of us already sick, demand that the next time ATSDR tries to float this PHA that it have at least one medical doctor in charge of its preparation and at least three other physicians sign off on it. ATSDR might think that our health and welfare can be easily discounted by such an inane, superficial, and incompetently prepared PHA. We stakeholders and the State of Tennessee know better and we are not going to stand for this level of tyrannical federal arrogance that ATSDR has demonstrated in its attempt to foist unto us this fatally flawed PHA. What health professional – meaning a physician or nurse, and not simply a non-medical staff member without any medical or nursing credential – would ever risk putting his or her signature on this – it would be indefensible in federal and state court. Note, by the way, that there is not, in fact any credentialed health professional that ever did sign off on this PHA. See comment regarding the PREPARERS OF REPORT. Of all the fleet of well credentialed physicians that ATSDR has on its payroll, not one, repeat, not one of them has committed his or her signature to this PHA. Stakeholders believe that this is because they well know that if a fatally flawed PHA looks like a duck, walks like a duck, and quacks like a duck – it might be a duck, or some other fowl. (*Comment received on the initial release PHA dated December 2003.)*	The referenced conclusion was altered slightly in the final public health assessment to the following: "ATSDR concludes that exposures to X-10 radionuclides released from White Oak Creek to the Clinch River and to the Lower Watts Bar Reservoir are not a health hazard. Past and current exposures are below levels associated with adverse health effects and regulatory limits. Adults or children who have used, or might continue to use, the waterways for recreation, food, or drinking water are not expected to have adverse health impacts due to exposure. ATSDR has categorized those situations as posing *no apparent public health hazard* from exposure to radionuclides related to X-10. This classification means that people could be or were exposed, but that their level of exposure would not likely result in any adverse health effects." Contrary to this commenter's opinion, this conclusion is factual based on ATSDR's thorough evaluation of data, exposure situations, and public health activities associated with radionuclides released from White Oak Creek to the Clinch River and the Lower Watts Bar Reservoir. Please note that the White Oak Creek Radionuclide Releases PHA underwent several phases of review before its final release, including an internal ATSDR review, a data validation review by other agencies (i.e., the U.S. Department of Energy [DOE], the U.S. Environmental Protection Agency [EPA], and the Tennessee Department of Environment and Conservation [TDEC]), an Oak Ridge Reservation Health Effects Subcommittee (ORRHES) review, an independent external peer review, and a public comment review. During the agency's internal review process, individuals within the agency who have the proper background (e.g., toxicology and health physics) carefully reviewed the document for technical content and other aspects. After reviewing comments from other agencies received during the data validation review, ATSDR made changes to the document as appropriate. ORRHES members consisted of individuals representing different expertise, backgrounds, geographic areas, and interests from the communities surrounding the Oak Ridge Reservation. ORRHES had technical experts in toxicology, health physics, medicine, geology, and other disciplines as well. ORRHES members carefully discussed all suggested editorial and technical changes and then submitted recommendations to ATSDR for changing the document. Through its external peer review process, ATSDR's Office of Science had three scientific experts review this public health assessment. The agency's peer review process allows an external, thorough evaluation of this PHA by experts in the field that this assessment covers—health physics. During the external review process, individuals (not employed by ATSDR or the CDC) independently reviewed this document and provided their unbiased, scientific opinions of it (see Appendix H for the peer reviewer comments and ATSDR's responses). ATSDR also presented the data and information used in this public health assessment several times at public meetings, including work group and

	Comment	ATSDR's Response
		ORRHES meetings. In addition, during the public comment period, any member of the public, including physicians, nurses, and other members of the community, can provide comments to ATSDR, which are included within this appendix. ATSDR uses a multi-disciplinary approach for reviewing public health assessments, including having experts in toxicology, medicine, health physics, and other disciplines review our work. All peer reviewers approved of the assessment and found no major flaws that would invalidate ATSDR's conclusions and recommendations. In the words of one peer reviewer: "You [ATSDR] have done a good job under very difficult circumstances with a lot of unwanted publicity and carping. The science under the report is very good and the report is well written in a very good manner that is suitable for both an informed and interested public and the scientific community."
88	Appendix C. A Conservative Approach in Radiation Dose Assessment, Issues Associated with Being Protective or Overestimating Radiation Doses, ATSDR can become more sensitive to the legitimate concerns of fish consuming stakeholders downstream of DOE ORR by commissioning a subsistence fisher study. (*Comment received on the initial release PHA dated December 2003.)*	This appendix was removed during subsequent revisions and is not included in the final PHA.
89	Appendix D. Implications of Exposure to the Eight Radionuclides Identified for Further Evaluation in the D*ose Reconstruction Report*, Page D-1, Line 1. See comment for Page 125, Line 25. Also, this list of only potential contaminants of significant concern is inadequate and incomplete. The ORHASP Final Report, in fact, lists eighteen cardinal contaminants of concern as having been released off site by DOE ORR. (*Comment received on the initial release PHA dated December 2003.)*	This appendix was removed during subsequent revisions and is not included in the final PHA. Please see Table 2 and Table 3 in the final PHA, as well as information on the screening process from Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report) described in Section III.B.2. Past Exposure.
90	Appendix D. Implications of Exposure to the Eight Radionuclides Identified for Further Evaluation in the *Dose Reconstruction Report,* Page D-16, Line 22. This is not true. If pregnant mothers are consuming Clinch River fish, or indeed any fish taken from many other downstream waters, this most probably has already occurred. (*Comment received on the initial release PHA dated December 2003.)*	This appendix was removed during subsequent revisions and is not included in the final PHA. Please see Section VII of the final PHA for a discussion of potential exposures to pregnant women, including ingestion of Clinch River fish.
91	Appendix D. The brief of the Watts Bar Reservoir (WBR) exposure investigation assumes that an average fish consumption rate of 66.5 g/day corresponds to a median of 33.1 meals per year. However, the calculated portion size for this assumed combination of numbers is 26 ounces per	To clarify the statements made by this commenter, the average daily consumption rate presented in the Watts Bar Exposure Investigation brief is for fish and turtles—not only fish. Only persons who consumed **moderate to large amounts** of fish and turtles from the Watts Bar Reservoir (generally more than 15 grams/day) were included in this investigation. The

	Comment	ATSDR's Response
	meal, which is unreasonably high. Therefore, the original data from the WBR exposure investigation needs to be re-examined to determine the proper relationship between the two given numbers.	average fish and turtle consumption rate (66.5 grams per day) presented in this brief is based on self-reported estimations of actual (not assumed) consumption frequency and meal size from 116 individuals who participated in the exposure investigation. Following a review of these comments, ATSDR evaluated the data further. A rate of 66.5 grams per day is slightly more than two 8-ounce fish meals per week, which would be expected among moderate to large fish and turtle consumers. The median value presented of 33.1 meals per year is, however, much lower than would be expected from this population. Therefore, the value of 33.1 meals per year was removed from the exposure investigation brief in the final PHA.
92	The nature of the Clinch River/WOC plume should be described as lying adjacent to the DOE property where it dissipates before reaching the K-25 water intake, a point of frequent sampling and overview by the State.	We agree and recognize that the concentration of contaminants released from White Oak Creek is diluted by the tremendous amount of water in the Clinch River.
93	It should be stressed that the dilution ratio at the Clinch River/White Oak Creek confluence is in excess of 1000 and that the Kingston water intake is located in the Tennessee River just above its confluence with the Clinch. The Tennessee River supplies an additional dilution factor for downstream water usage.	Thank you for your comment. Changes have been made in Section I. Summary and under the Clinch River in Section III.B.3. of the final PHA.
94	No medical professionals, meaning no medical doctor or nurse, have been included in the preparation of this PHA. Considering the significant number of omissions in delineating actual exposures for downstream stakeholders, we recommend that at least one qualified physician from ATSDR's large complement of medical staff on their payroll be in charge of the preparation of a complete redraft of this PHA. Further, stakeholders insist that this redrafted PHA be internally peer reviewed by at least three other of its qualified physicians. These physicians should attach their signatures and state license numbers to the PHA's front page. This should prevent further flagrant omissions by ATSDR evidenced in this one. Additionally, attaching medical doctor signatures to this PHA will facilitate appropriate rectification of any future 'omissions' through federal tort action. (*Comment received on the initial release PHA dated December 2003.)*	The White Oak Creek Radionuclide Releases PHA underwent an internal ATSDR review, a data validation review by other government agencies (i.e., the U.S. Department of Energy [DOE] and the Tennessee Department of Environment and Conservation [TDEC]), and an external review. Through its external peer review process, ATSDR's Office of Science had three scientific experts review this public health assessment. The agency's peer review process allows an external, thorough evaluation of this PHA by experts in the field that this assessment covers: health physics. Individuals within the agency who have the proper background (e.g., toxicology and health physics) reviewed the document during the agency's internal review process. ATSDR and CDC do have physicians on their staff; that said, however, individuals within the agency who have the proper background reviewed the document during the agency's internal review process. During the external review process, individuals (not employed by ATSDR or the CDC) independently reviewed this document and provided their unbiased, scientific opinions of it (see Appendix H for the peer reviewer comments and ATSDR's responses). During this external review period, any member of the public, including physicians, nurses, and other members of the community, can provide comments to ATSDR. ATSDR uses a multi-disciplinary approach for reviewing public health assessments, including having experts in toxicology, medicine, health physics, and other disciplines review our work.

	Comment	ATSDR's Response
		All peer reviewers approved of the assessment and none found any major flaws that would invalidate ATSDR's conclusions and recommendations. In the words of one peer reviewer: "You [ATSDR] have done a good job under very difficult circumstances with a lot of unwanted publicity and carping. The science under the report is very good and the report is well written in a very good manner that is suitable for both an informed and interested public and the scientific community."
Editorial Comments		
95	Page 2, Line 13: "radionuclides from White Oak Creek," The specific radionuclides should be identified here. Uranium is specified, as is Iodine-131; why not the others such as Cs-137, Sr-90, and Cobalt-60 (Co-60). For starters, identify the specific radionuclides being evaluated here. (*Comment received on the initial release PHA dated December 2003.)*	Uranium and iodine131 are discussed here, but not in the context of listing radionuclides that were released from White Oak Creek. Instead, this referenced part of the document is listing the PHAs ATSDR is preparing because these particular contaminants required further evaluation based on ATSDR's review, the screening analysis of the Tennessee Department of Health's (TDOH's) Phase I and II screening-level evaluation of past exposure (1944–1991), and community concerns. Thus, the text reads: "…ATSDR scientists are conducting public health assessments on X-10 iodine 131 releases, Y-12 mercury releases, K-25 uranium and fluoride releases, PCB releases from X-10, Y-12, and K-25, and other topics such as the Toxic Substances Control Act (TSCA) incinerator and off-site groundwater." This statement is not, however, listing the contaminants released from White Oak Creek. In fact, in this context, uranium refers to releases from the Y-12 plant and the K-25 site and iodine131 refers to releases from the X-10 site, but not into White Oak Creek. TDOH's Oak Ridge Health Studies, conducted over 9 years, investigated historical releases from the ORR facilities to see if these releases could have caused health problems for nearby residents. The project included dose reconstruction studies focusing on four areas: ▪ Iodine131 releases from X-10 ▪ Mercury releases from the Y-12 Plant ▪ PCB releases from ORR facilities ▪ X-10 radionuclide releases to the Clinch River via White Oak Creek All of the final reports from the Oak Ridge Health Studies are available online at http://www2.state.tn.us/health/CEDS/OakRidge/ORidge.html. In addition, you may contact ATSDR's Information Center toll-free at 1-888-422-8737 for copies of ATSDR public health assessments that evaluate contaminants released from these facilities.
96	P. 4. Line 23. Define "Screening Index."	The comment is noted. The text was changed in the final PHA by adding "or calculated probabilities of developing cancer" after the term screening indices.
97	Pp. 5-6. On pp. 5-6, the statement is made that radiation lifetime doses to critical organs (e.g. bone, lower large intestine, red bone marrow, breast,	This information is presented in various parts of the document to correspond to different portions of the evaluation conducted as part of the public health assessment process. The

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	and skin) are less than ATSDR's comparison values. Then, on pp. 65-66, 82, and in the footnotes to Table 11 on p. 84, it is explained that the individual annual organ doses are each multiplied by "weighting factors," the products summed, and the sums multiplied by 70 to get lifetime effective whole-body doses. However, mention is not made on pp. 82 or 84 that the "weighting factors" are listed in Table 6 on p. 66, nor is the reader directed to Table 22, on p. 111 where the calculated doses are finally compared to the "comparison values." This information is out of order and too strung out. It should be collected and presented in one place.	information referred to is detailed in the summary, in the introductory information describing the exposure evaluation process, in the description of Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report) and ATSDR estimated radiation doses, in the summary table for past radiation doses, and in the public health implications section. The information is intentionally presented in these various sections to help readers as they go through the different portions of the evaluation. Although these sections will not all be put into one place, changes were made as suggested to refer the reader to Table 6 in the notes for Table 11. In addition, the following sentence was added after Table 11 (page 88) regarding Table 22: "These calculated doses have been screened against the comparison values found in Table 22 of Section IV. Public Health Implications."
98	P. 6. Line 9. "…that are not considered to be a public health hazard."	The comment is noted. The text was changed in the final PHA.
99	P. 7. Line 12. "of chemical contaminants…."	The comment is noted. The text was changed in the final PHA.
100	P. 7. Line 17. "ATSDR estimated committed effective…."	The comment is noted. The text was changed in the final PHA.
101	P. 7. Line 18. "for adults and children…."	The comment is noted. The text was changed in the final PHA.
102	Page 7, Line 24. There is an incomplete sentence at the end of this page. Content of this passage doesn't flow with the discussion resuming at the top of page 10. (*Comment received on the initial release PHA dated December 2003.)*	This incomplete sentence was fixed in subsequent versions of the document and the two passages now flow together. The referenced passages are two separate paragraphs—not one continuous paragraph as it might have appeared since the last sentence was incomplete in this former version of the document. To clarify further, the paragraph on former page 7 provided a general overview and background of the main ORR facilities: X-10, Y-12, K-25, and S-50. The next paragraph on former page 10 narrows the focus to discussing only X-10 because this PHA evaluates those radionculides released from this facility that entered White Oak Creek.
103	P. 8. Line 11. Define "screening comparison value."	The following information was added into a text box in the final PHA to define this term: "Comparison values (CVs) are doses (health guidelines) or substance concentrations (environmental guidelines) set well below levels known or anticipated to result in adverse health effects. *Health guidelines* are derived based on data drawn from the epidemiologic and toxicologic literature with many uncertainty or safety factors applied to ensure that they are amply protective of human health. *Environmental guidelines* are derived from the health guidelines and represent concentrations of a substance (e.g., in water, soil, and air) to which humans may be exposed via a particular exposure route during a specified period of time without experiencing adverse health effects. During the public health assessment

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		process, ATSDR uses CVs as screening levels. Substances detected at concentrations or doses above CVs might be selected for further evaluation."
104	He suggested changing the word "reasonably" on line 25 of page 8 to better suit the public.	The comment is noted. The word "reasonably" was changed to "be expected to."
105	Page 8, Figure 1. Location of the DOE ORR. Make sure the fish sampling sites are identified as such. Add a legend note to explain that the 'CRMs' are sampling sites with extensive and continuous fish sampling data archived into the OREIS. Also mention that this data, now withheld from the public, is still available to group users, such as non-governmental organizations, institutions of higher learning, environmental advocacy groups, civil rights groups, church groups, et al. Mention that robust fish sampling data in OREIS dates from 1985. (*Comment received on the initial release PHA dated December 2003.)*	Please refer to the Oak Ridge Reservation Annual Site Environmental Reports (ASERs) for information on areas sampled during investigations. These reports are available online at http://www.ornl.gov/sci/env_rpt/ and the findings are also included in the Oak Ridge Environmental Information System (OREIS). Also, the Tennessee Department of Environment and Conservation (TDEC), DOE Oversight Division, has published its environmental monitoring plan online at http://www.state.tn.us/environment/doeo/pdf/EMP2005.pdf. This indicates the areas where fish sampling will be conducted.
106	Page 9, Figure 2. Original and Current ORR Boundaries. The 'Current' boundaries are not visualized on this map. It is impossible to visualize the information in the legend in black and white because it is probably in color: Land Transferred from DOE Ownership, Pending Transfer, and Leased Land. Add to this map all land that has been 'transferred' without substantive environmental cleanup. Also add a note to this map in the legend that DOE is still responsible for any 'misadventures' in its Land Use Controls (LUCs) in the event any future lease holders of transferred become sick, injured, or die consequent to properties on this site being transferred without actually fulfilling the legal requirements of CERCLA. For example, if any workplaces on these transferred sites remain contaminated and a leaseholder business decides to place a daycare center on site at that workplace, then DOE would still be liable for such misadventure, despite its 'property transfer.' In other words, there should be explicit mention on this map, which depicts property transfers and leased land that, in fact, DOE is still liable for subsequent injuries, illnesses, and/or deaths which might devolve from a 'land rush' to transfer property with marginal and/or environmental cleanup beforehand. (*Comment received on the initial release PHA dated December 2003.)*	The April 2005 public comment PHA and the final PHA present this map in color. The current lands comprising the DOE Oak Ridge Reservation, land transferred from DOE ownership, lands pending transfer, and leased lands are all identified by different colors on the map and outlined in the legend. Section 120 (h) of the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) requires documentation of the condition of federal lands upon sale or transfer, and it establishes the federal government as the responsible party for any remedial action found to be necessary after land transfer. Under a Covenant Deferral Request, DOE can transfer properties if it can show that the land is protective for the intended use. This enables DOE to transfer properties before CERCLA remedial activities are completed. Properties could only be transferred if they were considered safe for their intended future use. Moreover, ATSDR is evaluating wastes that traveled off site only—not wastes remaining on the reservation. Through various measures, including monitoring, remediation, institutional controls, engineering controls, and sampling, DOE continues to evaluate contaminant releases on the reservation and to mitigate contaminants from leaving the ORR. ATSDR considered these measures, including institutional and engineering controls, and evaluates and discusses them in the final PHA.

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107	Page 10, Line 1. There appears to be missing text at the top of this page because the content is out of place because it does not flow with the end of page 7, the immediate preceding passage. (*Comment received on the initial release PHA dated December 2003.)*	No incomplete sentence was found at the end of the page on this previous version of the document. The passages being referenced are actually two separate paragraphs—not one continuous paragraph as it might have appeared since the last sentence ended at the bottom of page 7 in this previous version. It is clear that these are two separate paragraphs in the final PHA. To clarify further, the paragraph on former page 7 provided a general overview and background of the main ORR facilities: X-10, Y-12, K-25, and S-50. The next paragraph on former page 10 narrows the focus to discussing only X-10, given that this PHA evaluates radionculides released from this facility that entered White Oak Creek. Thus, ATSDR believes that these passages do indeed flow in the order they are presented within the document, as the initial paragraph provides a general overview of the facilities and the following statements focus on the facility of interest for this PHA.
108	P. 12. Line 15. Clinch River Mile (CRM) is defined, but Fig. 3 presents the acronym "CRK," that is not defined in the text, the figure, nor in the list of acronyms. The conversion 1 km = 0.6214 mi. should also be given in the nomenclature, or in Fig.3. It should also be noted that CRK 33 is also CRM 20.5, which is the reference location on Jones Island.	Thank you for your comment. To be consistent throughout the document, the Clinch River Kilometers (CRKs) have been replaced with the equivalent distances in Clinch River Miles (CRMs).
109	Page 14: Figure 5. X-10 Facility Time Line: Missing depiction. (*Comment received on the initial release PHA dated December 2003.)*	This figure was inadvertently missing from the December 2003 version, but it is included in subsequent revisions of the document, including the final PHA.
110	Page 15, Line 27. Which contaminants ended up on the Clinch River? Name them and the approximate curie load of each of those contaminants which are radioactive. (*Comment received on the initial release PHA dated December 2003.)*	This PHA evaluates the releases of radionuclides—not all contaminants—to the Clinch River and the Lower Watts Bar Reservoir from the X-10 site via White Oak Creek. The estimated discharges (in curies) of radionuclides released to the Clinch River via White Oak Creek are presented in Table 2 of the final PHA.
111	P. 15. Line 20. "nuclear fission products"	The comment is noted. The text was changed in the final PHA.
112	Page 16, Figure 6. Location of the Gunite Tanks at the X-10 Site. Define 'WAG', 'gunite', and 'grout sheets' in the legend. Also mention, both here and in the text, that 'gunite' is actually just concrete and state the average life expectancy of concrete (approximately 84 years). This means that the integrity these aging 'gunite tanks' are most probably already compromised. Identify on this figure those gunite tanks that are known to be leaking by DOE, ATSDR, EPA, and TDEC collectively. (*Comment received on the initial release PHA dated December 2003.)*	The legend is a guide for terms used in the figure; WAG, gunite, and grout sheets are not presented in the figure. The following was added as a footnote to define "gunite": "Tanks were constructed of a water, concrete, and sand mixture called 'gunite,' which was sprayed over a wire mesh and steel reinforcing rod frame." Most of the mixed waste was removed from the gunite and associated tanks in the 1980s. In September 1997, an interim record of decision identified these tanks as a priority for clean up, partly because of the risk to the public, to workers, or, if a tank leaked or collapsed, to the environment. A total of 87,000 gallons of sludge and 250,000 gallons of liquid waste were treated and transferred off site. The action was completed in September

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		2000. The tanks were empty, left in place, and grouted in 2001. Information on the gunite tanks suggests that these remedial actions were conducted to **prevent** leaks, not because leaks had already taken place. Thus, ATSDR is unable to identify leaking tanks on the figure because evidence supports that the waste was removed before any leakages occurred. In addition, the life expectancy of concrete is irrelevant for this discussion because the tanks are empty. Please refer to Appendix B in the final PHA for more details on these remedial activities.
113	P. 17. Fig. 5 is impossible to read.	An 11 x 17 size of this time line was incorporated into the final PHA.
114	Page 17, Line 14. Name the 'top twenty' of these contaminants by 'curie load' and identify the 'top twenty' radionuclides contributed by these facilities. Provide two pie charts for this information. (*Comment received on the initial release PHA dated December 2003.)*	To be clear, this PHA **only** evaluates the releases of radionuclides to the Clinch River and the Lower Watts Bar Reservoir from the X-10 site via White Oak Creek. The estimated discharges (in curies) of radionuclides released to the Clinch River via White Oak Creek are presented in Table 2 of the final PHA. Also, a detailed discussion of the 24 radionuclides initially evaluated and the process of determining particular contaminants for additional screening are presented under Task 4 Screening Assessment in Section III.B.2. Past Exposure (1944-1991). You can also refer to the Oak Ridge Dose Reconstruction Task 4 report online at http://www2.state.tn.us/health/CEDS/OakRidge/WOak1.pdf for more information on estimated radionuclide releases.
115	Page 17, Line 23. After the word 'seven' add the words 'unlined and unprotective.' (*Comment received on the initial release PHA dated December 2003.)*	Thank you for your comment. The term "unlined" was added to the referenced sentence in the final PHA.
116	P. 18. Fig. 6 lacks a color legend, especially for the unlabeled blue areas.	Thank you for your comment. The blue shading was removed in the final PHA.
117	P. 19. Line 19. Specify how the waste managed to "travel over the dam."	The wording was changed to the following: "This dam was used as a basin for further settling of the solids that remained…But some waste products did not settle into the 3513 Pond or White Oak Lake; instead, some of the flow spilled over White Oak Dam into the White Oak Creek Embayment and then reached the Clinch River."
118	P. 20. Insert "tags" that identify areas of interest in Fig. 7.	Thank you for your comment. Labels were added to this figure in the final PHA to identify the locations of the Clinch River, X-10/ORNL, the X-10/ORNL disposal area, White Oak Lake, White Oak Creek, White Oak Dam, White Oak Creek Embayment, and the Sediment Retention Dam.
119	Page 20, Table 2. Estimated Discharges (in curies) of Radionuclides from White Oak Creek. Line 9: "The four radionuclides expected to be of most concern are highlighted in gray." Okay, we can't guess what these four	The gray highlighting is apparent in the April 2005 public comment version of the PHA as well as in the final PHA.

<table>
<tr><th></th><th>Comment</th><th>ATSDR's Response</th></tr>
<tr><td></td><td>most important ones are; there is no gray shading on this document. Please identify them specifically. Please prioritize them, along with the route of exposure of most concern.

(Comment received on the initial release PHA dated December 2003.)</td><td>In this public health assessment, ATSDR evaluated radioactive contaminant data for the Clinch River and the Lower Watts Bar Reservoir surface water, sediment, and fish, as well as vegetables, turtles, and local game animals for the Clinch River, to determine whether the levels of radionuclides might pose a past, current, or future public health hazard. Depending on the waterway and time period, the evaluation included the following exposure scenarios:

▪ Incidental ingestion of water during recreational activities,
▪ Ingestion of river or reservoir water for drinking water,
▪ Contact with water during recreational activities, irrigation, or showering,
▪ Contact with surface sediment,
▪ Contact with dredged sediment used as topsoil in home gardens,
▪ Consumption of locally grown milk, meat, or produce, and
▪ Consumption of fish, turtles, or local game animals.

Section III. Evaluation of Environmental Contamination and Potential Exposure Pathways presents a detailed evaluation of past, current, and future exposure to these radionuclides based on the various exposure scenarios presented above. Please refer to this section of the final PHA for more information.</td></tr>
<tr><td>120</td><td>Page 21, Line 18: Table 3. Summary of Peak Annual Releases for the Eight Key Radionuclides. There are more than twenty four radionuclides that have been released to WOC over the years. This fact is documented in the ORHASP (Oak Ridge Health Agreement Steering Panel) Final Report, although they are not cited individually. Citizens can access this complete report themselves at the following website, and ATSDR should include that website at this point in its text: http://www2.state.tn.us/health/CEDS/OakRidge/Oridge.html. All of these radionuclides should be identified here and the 'Eight Key Radionuclides' simply highlighted on the more inclusive list. What are the target organs of concern if citizens have been exposed to these twenty-four contaminants?

(Comment received on the initial release PHA dated December 2003.)</td><td>Page 12 of the Oak Ridge Health Agreement Steering Panel (ORHASP) final report states: "Of the more than two dozen radionuclides that have been released to White Oak Creek over the years, eight were identified as historically most important: cesium 137, iodine 131, strontium 90, cobalt 60, ruthenium 106, niobium 95, zirconium 95, and cerium 144." These are the same eight radionuclides presented in Table 3 of the final PHA that presents a summary of peak annual releases from White Oak Dam for the eight key radionuclides. Thus, the table presents a summary of those releases found to be of most concern; it does not present all of the radionuclides released because many of them were not released at levels determined to be of potential concern to the public and therefore do not require in-depth discussion or evaluation.

In addition, in Section III.B.2. Past Exposure of the final PHA, ATSDR details the Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report) screening assessment that involved a phased approach, including a discussion on the target organs, radionuclides of concern, and pathways requiring further evaluation. First, the Task 4 team identified 24 radionuclides released from the X-10 site into the Clinch River from 1944 to 1991 as potential contaminants of concern. These were not the only radionuclides released, but these were the only ones identified as potential contaminants of concern based on the Task 4 team's initial assessment. Through a risk-based screening process, the Task 4 team then calculated conservative human health risk</td></tr>
</table>

	Comment	ATSDR's Response
		estimates for reference individuals and target organs to further determine the radionuclides and exposure pathways of concern. Eight radionuclides required further evaluation; following a supplemental analysis, four radionuclides were found to be important contributors to dose and health hazards. Please see this section of the final PHA for more information and the Task 4 report at http://www2.state.tn.us/health/CEDS/OakRidge/WOak1.pdf. The ORHASP final report is discussed in detail in Section II.F.2. of the final PHA. The Web site link to the report was added to the paragraph on ORHASP: "For additional information on the ORHASP findings, please see the final report of the ORHASP titled *Releases of Contaminants from Oak Ridge Facilities and Risks to Public Health* at http://www2.state.tn.us/health/CEDS/OakRidge/ORHASP.pdf."
121	P. 22. Terminology describing "earthen pits" (aka LLW seepage pits) and "earth-covered trenches" (aka LLW seepage trenches) should be consistent between text and Fig. 8.	Thank you for your comment. The text was changed as suggested. In the final PHA, it now reads: "In 1960, the 'earthen pit' (also known as a low-level waste [LLW] seepage pit) was changed to an 'earth-covered trench' (also called a LLW seepage trench) to reduce inadvertent radiation exposure and rainwater buildup."
	The principle of operation of the liquid waste disposal trenches should be described. These trenches operated hydraulically in a manner similar to a septic tank drain field, but with the waste being retained closely downstream rather than upstream, in this case, by virtue of the electrostatically polar nature of the clay and shale particles surrounding the trenches. These particles attracted and held a large fraction of the radioisotopes seeping out of the trenches. The trenches were also originally known as "Intermediate Level" liquid waste disposal trenches.	Thank you for this suggestion. This text was added verbatim as a footnote to describe the operation of the waste disposal trenches.
	If possible, the percentage of the radioisotopes pumped into the trenches that were retained by the shale and clay should be estimated and stated.	Please note that the percentage of radioisotopes pumped into and retained in the trenches relates to contamination remaining on site at the reservation. In this public health assessment, ATSDR is only evaluating releases that traveled off site from the ORR.
122	P. 23. It would be instructive to identify the Intermediate Holding Pond and the Wastewater Treatment Process Plant in Fig. 8.	The Intermediate Holding Pond and the Process Waste Treatment Plant have been added to Figure 8 in the final PHA.
123	Page 23, Figure 8. Map of the Bethel Valley Watershed and the Melton Valley Watershed. This diagram does not delineate the boundaries of each respective watershed. Where are the other three watersheds cited in Page 22, Line 29? (*Comment received on the initial release PHA dated December 2003.)*	To facilitate the investigation and remediation of contamination related to the reservation, the contaminated areas on the ORR were separated into five large tracts of land that are typically associated with the major hydrologic watersheds. The contaminated areas associated with X-10 (the only releases evaluated in this PHA were from X-10) are, however, located in the Bethel Valley Watershed and the Melton Valley Watershed. Therefore, only these two watersheds are highlighted on Figure 9 in the final PHA and

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		described in detail in the document. For information on additional watersheds, please refer to the PHA titled *Evaluation of Potential Exposures to Contaminated Off-site Groundwater From the Oak Ridge Reservation (USDOE)* (available at http://www.atsdr.cdc.gov/HAC/PHA/region_4.html#groundwater) for ATSDR's evaluation of off-site groundwater. Copies of this and other ATSDR documents are available from the ATSDR Information Center. You may call the center toll-free at 1-888-422-8737.
124	Page 25. Figure 9. Map of the Major Remedial Activities in Bethel Valley. Where are Core Hole 8 Plume (cited in Page 24, Line 15) and First Creek (cited in Page 26, Line 2) on this map? Where are the MVSTs (Melton Valley Storage Tanks) on this map? Add a legend for all the acronyms for these remedial activities: HFIR, HPFR, TSF, CFRF, and others. Define "grouted." (*Comment received on the initial release PHA dated December 2003.)*	The Corehole 8 plume and First Creek are both identified in the final PHA on Figure 10. Map of the Major Remedial Activities in Bethel Valley. This map, as the title indicates, only presents where major remedial activities are taking place in Bethel Valley. These actions are described in further detail in Appendix B of the final PHA. The Melton Valley Storage Tanks are not depicted on this map because they are not considered part of the major remedial activities occurring in Bethel Valley for a few reasons. These eight approximate 50,000-gallon underground storage tanks (USTs), located in Melton Valley, are used to contain transuranic (TRU) waste from past processes and remedial activities. Thus, these tanks are not currently being remediated, but are being used to contain wastes resulting from on-site remediation activities at the X-10 site. As a clarification, the acronyms mentioned in this comment (HFIR, HPRR [not HPFR], TSF, and CFRF) are not on the map of major remedial activities in Bethel Valley because they are not remedial activities—they are various facilities on the ORR: consolidated fuel recycling facility (CFRF), high flux isotope reactor (HFIR), health physics research reactor (HPRR), and tower shielding facility (TSF). These acronyms, which are presented in the final PHA in Figure 9. Map of the Bethel Valley Watershed and the Melton Valley Watershed, have been defined in the map's legend. The section describing these remedial activities is now presented in Appendix B. The referenced sentence was changed to the following to define the term "grouted:" "The empty tanks were left in place and grouted (i.e., sealing off the flow of contaminants by pumping cement grout or chemicals into drill holes) in 2001; the remedial action report was approved in October 2001."
125	Page 28, Line 28. Which other contaminants? Specifically name them. (*Comment received on the initial release PHA dated December 2003.)*	The following reference was used for this information: ▪ Science Applications International Corporation. 2002. 2002 remediation effectiveness report for the US Department of Energy, Oak Ridge Reservation, Oak Ridge, Tennessee. Science Applications International Corporation. US Department of Energy: Office of Environmental Management; March. This document states that "The WOCE TC RmA [White Oak Creek Embayment Time-

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		Critical Removal Action] was initiated in 1991 after site characterization data indicated the embayment was an uncontrolled source of cesium 137 and **other sediment-bound contaminants** to the Clinch River system." No other contaminants are specifically mentioned regarding the "other sediment-bound contaminants." Thus, ATSDR is unable to provide the additional requested information.
126	Page 29, Figure 20. Map of the Major Remedial Activities in Melton Valley. A recurrent omission on most of ATSDR's figures. Please spell out all acronyms used in the figure in a legend: WAG, SEEP, OHF, and others. (*Comment received on the initial release PHA dated December 2003.)*	The acronyms are presented on the figure in the final PHA. Please note, however, that "seep" is not an acronym.
127	Page 30, Figure 11. Completed, Current, and Future Remedial Activities in Melton Valley. Please spell out all acronyms used in the figure in a legend: SWSA, MSRE, OHF, and others. (*Comment received on the initial release PHA dated December 2003.)*	Acronyms are included in this figure (Figure B-1) in the final PHA.
128	Page 35, Line 1. What is "grouting?" (*Comment received on the initial release PHA dated December 2003.)*	"Grouted" was defined previously in the final PHA as "sealing off the flow of contaminants by pumping cement grout or chemicals into drill holes."
129	P. 36. Line 33. "When the government…" (Delete the comma.)	The comment is noted. The text was changed in the final PHA.
130	Page 38, Lines 22-25. Unclear what is trying to be said here — rework this passage. (*Comment received on the initial release PHA dated December 2003.)*	The text was rewritten as the following: "The baseline risk assessment 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."
131	P. 39. Lines 22-26. These are parenthetical statements.	ATSDR contacted an editor regarding this comment. Though these are not truly "parenthetical statements" per say, the sentences are an aside from the preceding text. To address this comment, ATSDR separated these statements from the other text by placing the information in a text box.
132	P. 40. Line 9. In this and in subsequent text, please state clearly to which year these data apply and consistently provide a reference.	Historical census data for Meigs, Rhea, and Roane Counties were obtained from Bureau of the Census 1993: *1990 Census of Population and Housing, Population and Housing Unit Counts, United States*. This might seem out of place as this reference is dated 1993, but it provides county data for 1940, 1950, 1960, 1970, 1980, and 1990. See Table 30 (page 107) of the reference at http://www.census.gov/prod/cen1990/cph2/cph-2-1-1.pdf for more information.

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		Census data for Harriman, Kingston, Rockwood, and Spring City were obtained from census reports for the individual years (i.e., 1940, 1950, 1960, 1970, 1980, 1990, and 2000). The reference was consistently changed to Bureau of the Census.
133	P. 61. Lines 14–17. The statement about providing images in slideshow format in FY 2004 needs updating.	ATSDR contacted DOE to inquire about the status of the Comprehensive Epidemiologic Data Resource (CEDR). According to DOE, CEDR now provides images in slideshow format that give estimated concentrations, doses, and risk values for three contaminants (iodine, mercury, and uranium) in air at locations studied in the Tennessee Department of Health's (TDOH) Oak Ridge Dose Reconstruction. The text was changed to reflect this updated information in the final PHA.
134	P. 66. Line 10. Put Footnote 3 on this page. The footnote should also state whether or not the "new system" still involves "weighting factors."	The comment is noted. The footnote (now footnote 6) was moved to this page in the final PHA and changed to the following: "For 2005, the ICRP is proposing a new system, which still involves weighting factors, that uses cancer incidence and considers lethality rate, years of life lost, and weighted contribution from the nonfatal cancers and hereditary disorders."
135	P. 66. Line 11. Note that the term should be "W_T."	The comment is noted. The text was changed in the final PHA.
136	P. 68. Line 16. Replace the word *decay* with the words *be eliminated*. The sentence would read: "Radionuclides that are taken into the body will also be eliminated by biological processes such as excretion."	The comment is noted. The text was changed in the final PHA.
137	P. 68. Line 25. Delete the sentence containing the words *always less* to avoid confusion when the reader sees rounded values that are the same in Table 7 on page 69.	The comment is noted. The text was changed to: "The effective half-life is always less than *or equal to* either its physical or biological half-life."
138	P. 72. Line. 27. "provides a table of Task 4…."	The comment is noted. The text was changed in the final PHA.
139	P. 77. Lines 14–16. The sentence beginning on line 14 is hard to understand because of its grammar ("Though, because…") and because the phrase, "actively exchanged," is not explained.	The sentence was changed to the following in the final PHA: "Because Clinch River sediments are not as actively exchanged as the river water itself (i.e., the sediments do not mix as much as the surface water), the Cs 137 in sediment at CRM 14 has decreased as a function of its half-life."
140	Page 77, Table 6. Conservative Screening Indices for Radionuclides in the Clinch River. This table is useless for the reader. This information should be parceled out into nine separate tables, according to the nine Exposure Pathways displayed. Each of these separate tables should then be rank ordered according to the decreasing levels of risk for respective	This table was taken directly from Table 3.1 on page 3-10 of Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report); it was not modified by ATSDR. ATSDR believes that this table, which is in Appendix E of the final PHA, provides a useful summary of the conservative screening indices (or calculated probabilities of developing cancer) for radionuclides in the Clinch River as reported in the

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	radionuclides. Add a tenth table to summarize the preceding nine tables by teasing out only those bold values in the present Table 6 (i.e., only the first eight lines). Please avoid the use of the words 'Conservative Screening Indices.' Stakeholders may misconstrue this as inferring a relationship to the right wing of the Republican party. Instead substitute the words: 'Screening Levels Which are Protective of Public Health' — which should be done through out all your PSAs. Briefly explain to the reader the CERCLA risk range of discretion — 1×10^{-4} to 1×10^{-6}. Otherwise, how will stakeholders glean from this monstrosity of a table which of these scientific notation numbers are critically important to their public health? For instance, The reader has a fundamental right-to-know that the first line of this table is displaying information to the effect that the Cs-137 contamination of fish in the Clinch River is at a higher level than the CERCLA 'acceptable' risk range above. The EPA risk limits are also exceeded for separate exposure to all of the following: ▪ Sediments along the shoreline ▪ Dredged sediments ▪ Eating beef ▪ Drinking milk ▪ Eating vegetables How are stakeholders supposed to ferret this critical exposure information from this table? To the interested stakeholder, this regurgitation of undecipherable critical exposure information, with exposure levels hidden in the cryptographic hieroglyphics of scientific notation, is not helpful. Stop 'talking down' to stakeholders by providing overly complex tables of important exposure data, which cannot possibly be deciphered by most stakeholders downstream of DOE ORR. Is this purposeful on ATSDR's part — or is this just plain stupid? Interested readers and all downstream stakeholders deserve better. (*Comment received on the initial release PHA dated December 2003.)*	Task 4 report. See Appendix D for a brief on the 1999 Task 4 report. Copies of the Task 4 report are available at the DOE Information Center located at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee (telephone number: 1-865-241-4780) or at http://www2.state.tn.us/health/CEDS/OakRidge/WOak1.pdf. ATSDR finds that creating 10 tables to display the information that is already presented in this one table would complicate the information for the reader. The purpose of this table is to summarize the conservative screening indices from the Task 4 report and indicate those (in bold) that were carried into the next iteration of analysis by the Task 4 team. The Task 4 team's analysis and the radionuclides and pathways that were evaluated in detail are presented in Section III. Evaluation of Environmental Contamination and Potential Exposure Pathways in the final PHA. Anyone who would like additional information is prompted throughout the final PHA to the original source material, but again, the purpose here is to present the information in a concise and user-friendly format. The term "conservative screening indices" was used by the Task 4 team, and thus ATSDR uses the team's terminology when presenting this information and would not feel comfortable changing it. The term is, however, defined in the summary section of the final PHA as "calculated probabilities of developing cancer." Contrary to trying to hide or make information undecipherable, ATSDR is summarizing and providing this complex data in an easy-to-read, user-friendly format. In fact, a commenter at a work group meeting noted, "the document as a whole was easy to read." Please refer to Section III.B.2. Past Exposure (1944–1991), Task 4 Screening Assessment, in the final PHA. This section discusses that the Task 4 team used an upper bound of 1 in 100,000 (1×10^{-5}) as the decision point, or minimal level of concern, during its assessment. This value was one-tenth of the Oak Ridge Health Agreement Steering Panel (ORHASP)-recommended value of 1 in 10,000 (1×10^{-4}); thus, the value used by the Task 4 team was *more conservative* than the ORHASP-recommended value. The remaining text of this section of the PHA explains in user-friendly detail how certain pathways and radionuclides were evaluated and retained for further analysis. Please see this section of the document and refer to the Task 4 report for any additional information.
141	P. 81. Line 29. The definition of the 95% confidence interval needs improvement. The 95% confidence interval is the range of values, centered on the estimated mean, within which there is a 95% probability	The comment is noted. The text was changed in the final PHA based on this suggested wording.

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	that the true mean will actually fall. Note that "95th confidence level" is improper terminology.	
142	P. 82. Line 13. "ATSDR narrowed its evaluation…"	The comment is noted. The text was changed in the final PHA.
143	P. 82. Line 18. Explain "weighting factors," and give examples.	Weighting factors are explained and examples are provided on page 68 of the final PHA. A reference to this table and explanation is now provided in the suggested paragraph of the final PHA.
144	P. 86. Place footnote 8 on this page, not on the following page.	The footnote, now footnote 11, has been placed on the correct page in the final PHA.
145	P. 95. Line 23. Note that "becquerel" is not defined here nor in Appendix A.	Becquerel is defined in Table 8 of the final PHA. The term becquerel was added to Appendix A.
146	Page 102, Table 21. Summary of Public Health Implications From ATSDR's Evaluation of Past and Currently Exposure to Radionuclides Released to the Clinch River/Lower Watts Bar Reservoir. Separate this table into three tables, one for past exposure and one for current exposures. Keep the current exposure all on the same page. Create an additional table which drops all the text in the third column and simply displays columns one, two, and four. Row one of this table states that people sustain greater exposure if they take fish closer to the confluence of WOC and the Clinch. No mention of the range of travel of these 'hot fish' is provided and fish swim around. Fish don't simply stay put. Fish are occasionally 'flushed' out of Watts Bar Reservoir by reservoir drawdowns and power generation events. Certain species in the Clinch, like the Gizzard Shad, migrate from the Ohio River near Paducah, Kentucky, even to locations upstream of DOE ORR, and back downstream. The migratory patterns of the many species are not discussed at all. (*Comment received on the initial release PHA dated December 2003.)*	This table was completely modified during subsequent revisions of the document. In the final PHA, this is broken into two tables: Table 22. Past (1944 to 1991) Radiation Doses for the Area Along the Clinch River and Table 23. Current Radiation Doses for the Lower Watts Bar Reservoir and Clinch River. The third column no longer exists as it was; instead, there are six columns in Table 22 and seven columns in Table 23. The information is now presented in a much more simplified manner so the reader can easily see the estimated doses, comparison values, and whether these doses were above or below the comparison values.
147	Page 109. Except for the first two lines, the lines of text are unnumbered. For what would be Line 11, stakeholders are providing this additional collection of citizen's concerns, which ATSDR may not yet be aware. (*Comment received on the initial release PHA dated December 2003.)*	All of the line numbers were removed in the final PHA. ATSDR appreciates your comments, which are addressed here, as well as all of the concerns provided by residents and other interested parties. All of the concerns received by ATSDR regarding radionuclide releases to the Clinch River and the Lower Watts Bar Reservoir via White Oak Creek are addressed in this final PHA. Community concerns related to other topics are covered in corresponding PHAs.

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148	P. 111. Footnote 11. Shouldn't the word "data" be replaced with the word "survivors?" Also, the reference (Schull 1995) does not appear to be in the reference list.	Thank you for your comments. The table note was changed to the following in the final PHA: "Based on studies of atomic bomb survivors." In addition, the following was added to the reference list in the final PHA: Schull WJ. 1995. Effects of atomic radiation: a half century of studies from Hiroshima and Nagasaki. New York: John Wiley and Sons, Inc.
149	P. 144. Line 10. "Ringworm" is like the word "deer;" it has no plural form ("ringworms"). The word is used correctly in footnotes of page 111, line 12 and on page 112, line 11.	The comment is noted. The text was changed in the final PHA.
150	Appendix A. Undefined terms include "screening index" and "gray."	Thank you for your comment. Both of these terms are defined in Appendix A in the final PHA.
151	Appendix A. ATSDR Glossary of Environmental Health terms, Page A-2, Line 18. Fishers and other stakeholders note that 'bioaccumulation' and 'food chain' are conspicuous by their absence from this glossary. This is important because certain non-radioactive contaminants like mercury, and certain radioactive contaminants like Sr-90 and Cs-137, all three are amplified up the 'food chain' and their effects can be magnified far above what might be expected from their initial release concentrations. Again, it would be helpful if bioaccumulation were to be included in this glossary.	ATSDR provides this glossary to define certain terms that are used throughout the final PHA. "Food chain" was added to and defined in the glossary because the term is used in Section IV. Public Health Implications of the final PHA. Because, however, the term "bioaccumulation" is not used anywhere in the document, it was not added to the glossary.
152	Appendix A. ATSDR Glossary of Environmental Health Terms, Page A-5, Line 41. A definition for "environmental fate" needs to be included as well. Again, it would be helpful if environmental fate were to be included in this glossary. (*Comment received on the initial release PHA dated December 2003.)*	ATSDR provides a glossary in Appendix A of the final PHA to define terms used in the document. The term "environmental fate" was not added to the glossary because it is not used anywhere in the final PHA.
153	Appendix A. ATSDR Glossary of Environmental Health Terms, Page A-12, Line 37. Add a definition of what is meant by "reference man." "Reference man" is cited multiple times throughout this PHA, but not explained. For instance, see Appendix C, Page C-1, Line 26 and Page C-2, Line 24. (*Comment received on the initial release PHA dated December 2003.)*	This appendix, which previously used the term "reference man," was removed during subsequent revisions of the PHA. The term is not included in the final PHA, and therefore it was not added to the glossary in Appendix A.
154	Page B-6. The note that Trenches 5 and 7 are to be remediated by in-situ vitrification (ISV) is out of date. In May 2004, the method of remediation was changed from in-situ vitrification to in-situ grouting. (See the article in the *Knoxville News Sentinel* dated March 15, 2004, and a letter from Mr. David Mosby of the Oak Ridge Site Specific Advisory Board to Mr. Steve	Thank you for your comment. In May 2004, the U.S. Department of Energy (DOE) issued a proposed plan to substitute in situ vitrification with *in situ* grouting. This proposed requirement for the record of decision and the remedial action work plan for *in situ* grouting were approved in September 2004. The acronym has been changed in the figure noted by the commenter (Figure B-2) and the

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	McCracken, DOE-ORO, dated July 15, 2004).	term was changed on Figure B-1. In addition, the following text was added to footnote 17 (which describes in situ vitrification) in the final PHA: "*In situ* vitrification (ISV) is a process that applies electrical power to contaminated soil to produce the heat needed to melt and blend the soil and waste into an immobile form (USDOE 1995b). DOE determined, however, that ISV could be problematic because of standing water in the trenches and higher than anticipated expenses related to the process. Thus, in May 2004, DOE issued a proposed plan to amend the Record of Decision by replacing ISV with *in situ* grouting (ISG). ISG involves a low-pressure grouting method to inject Portland cement-based grout throughout the trenches. In addition, a solution grout would be used to treat soil adjacent to the trench walls to close potential seepage pathways (ORSSAB 2004). In September 2004, the proposed requirement for the Record of Decision and the remedial action work plan for ISG of the trenches were approved."
155	Pp. C-1, Line 16, and C-6, Line 21. Replace "blot clots" with "blood clots."	The comment is noted. The text was changed in the final PHA.
156	Please number the pages of Appendix D.	Page numbers have been added to all of the pages in Appendix D in the final PHA.
157	Appendix D. Implications of Exposure to the Eight Radionuclides Identified for Further Evaluation in the Dose Reconstruction Report, Page D-14, Line 19. State which types of cancer would probably be produced (e.g., soft tissue sarcomas). *(Comment received on the initial release PHA dated December 2003.)*	This appendix was removed during subsequent revisions and is not included in the final PHA.
158	Table E-1. What are the units of "Screening Index?"	The screening indices in this table are presented directly as reported in the Task 4 report titled *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*. See Appendix D for a brief on the 1999 Task 4 report. Copies of the Task 4 report are available at the DOE Information Center located at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee (telephone number: 1-865-241-4780) or at http://www2.state.tn.us/health/CEDS/OakRidge/WOak1.pdf. To estimate the screening index, or screening-level risk, the Task 4 team used different equations to represent the various possible exposure pathways. According to the Task 4 report: "These screening values represent conservative estimates of excess lifetime risk of cancer incidence from an exposure duration equal to the number of years of historical releases. The contaminants and pathways with a screening index above 10^{-5} have been analyzed in more detail …" Each equation considered different parameters with varying units. These equations are presented for all of the pathways (drinking water, fish ingestion, external exposure to the shoreline, swimming, external exposure to dredged sediment,

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		ingestion of beef, ingestion of milk, ingestion of vegetables, and irrigation) in Appendix 3A of the Task 4 report at http://www2.state.tn.us/health/CEDS/OakRidge/WOak2.pdf. Though most of the various parameters considered in these screening index equations had units, the screening index is a risk level calculated and compared to the decision point or the minimal level of concern—determined as 1×10^{-5} (also written as one in 100,000) by the Task 4 team. Any screening indices that exceeded the minimal level of concern were carried through the screening evaluation and further analyzed.

Appendix H. Responses to Peer Reviewer Comments on White Oak Creek Radionuclide Releases Public Health Assessment

The Agency for Toxic Substances and Disease Registry (ATSDR) received the following comments from independent peer reviewers for the White Oak Creek Radionuclide Releases at the Oak Ridge Reservation (ORR) Public Health Assessment (PHA) (April 2005). For comments that questioned the validity of statements made in the PHA, ATSDR verified or corrected the statements.

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Does the public health assessment adequately describe the nature and extent of contamination?		
1	It does quite a good job at this. The radionuclides were the appropriate ones to examine, as were the environmental media in which they were determined. The authors have chosen the appropriate locations to characterize the contamination, given the use of the region by the surrounding population.	Thank you for your comment.
2	Yes, it appears that the study carefully considers the local and disseminated levels of contamination of both radionuclide and chemical contaminants. The study further addresses local concerns raised by the residents of the area even when it is doubtful that there is any validity to the concern raised.	Thank you for your comment.
3	To the careful reader it is clear that ATSDR does not generate any contamination level information by direct measurement but rather relies on the information published by others for the ATSDR analysis. This feature of the report should be directly stated in the introductory aspect of the report as the conclusions reached in the report are based on the accuracy of this information.	ATSDR does explain the sources of information used to evaluate past, current, and future exposures in Section I. Summary and Section III. Evaluation of Environmental Contamination and Potential Exposure Pathways of the public health assessment. For past exposures, we state that ATSDR primarily relied on data generated during *Task 4 of the TDOH's Reports of the Oak Ridge Dose Reconstruction: 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 (referred to as the "Task 4 report")*. For current exposures to the Clinch River and Lower Watts Bar Reservoir, the summary section details how ATSDR uses data collected from 1988 to 1994 as presented in ATSDR's 1996 *Lower Watts Bar Reservoir Health Consultation*. It has been added to the summary section of the PHA that these data include environmental sampling data from the 1980s and 1990s collected and assembled by the U.S. Department of Energy (DOE), the Tennessee Valley Authority (TVA), and various consultants, as well as data from TVA's 1993 and 1994 annual radiological environmental reports for the Watts Bar Nuclear Plant. In addition, the PHA states that ATSDR used data collected from 1989 to the present (2003) in the Oak Ridge Environmental Information System (OREIS). The PHA explains that OREIS falls

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		under DOE ownership, and that OREIS contains data related to compliance, to environmental restoration, and to surveillance activities (including but not limited to studies of the Clinch River embayment and the Lower Watts Bar, as well as annual site summary reports). For future exposures, the PHA states that ATSDR based its evaluation on current exposures and doses related to releases from White Oak Creek, data on current contaminant levels in the Clinch River and Lower Watts Bar Reservoir, institutional controls in place to monitor contaminants in these water bodies, and consideration of the possibility that remedial activities could release radionuclides to White Oak Creek. Further, the data show that because of remedial actions and preventive measures at X-10, because of physical movement of sediments from the area, and because of radiological decay, the radionuclide releases from White Oak Creek have decreased over time, and the concentrations of radionuclides in the water and along the shoreline have decreased as well.
4	Yes! Most emphatically! So many different agencies and very interested and competent individuals have been involved in this process that it would be difficult if not impossible to not perform a complete assessment of the nature and extent of contamination.	Thank you for your comment.
Does the public health assessment adequately describe the existence of potential pathways of human exposure?		
5	Yes, these are the appropriate pathways given the nature of the contamination and the environmental media affected. However, I am not fully comfortable with the way in which selected exposure pathways were dropped from the analysis. The approach taken by the authors (in which the relative contribution from each exposure pathway is determined by a screening assessment, and the pathway is retained only if it is in some upper percentile of the contributions by all pathways) is often taken in risk assessment, and so is valid from that perspective. But the description in the text did not convince me that the SUM of the doses from the rejected pathways was significantly smaller than the SUM of the doses from the retained pathways. I suspect their assumption is valid, and the authors have the results to show that this is the case, and so they should make that point more forcefully. Otherwise, there can be a stream of public complaints that pathways X, Y and Z aren't reflected in the summary dose tables at the end. Page 76 is where the issue of dropping radionuclides, and then dropping pathways, becomes important. I am not suggesting any specific changes here, but the process used seems to me to run the danger of leaving most of the risk within the pool of dropped radionuclides and pathways. If you subdivide the total	The authors of the *Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report)* used a screening assessment to identify the most important radionuclides and pathways associated with past exposures to X-10 radionuclides released off site to the Clinch River via White Oak Creek. Because the Task 4 team evaluated each radionuclide individually by pathway for its screening analysis, the team compared conservative screening estimates to a minimal screening level of 1×10^{-5}—a factor of ten below the Oak Ridge Heath Agreement Steering Panel's (ORHASP) decision guide value of 1×10^{-4}. Because the screening risk estimates for the swimming and irrigation pathways were below the Task 4 report's minimal risk level for all 24 radionuclides, the Task 4 team was able to eliminate these two exposure pathways (and therefore, consumption of locally grown crops) from further analysis. It is important to note that no swimming is allowed in White Oak Creek and no irrigation water comes from the creek, which is located on site at the reservation where public access is restricted. The Task 4 team determined that swimming in the past primarily occurred in creeks emptying into the Clinch River—not in the river itself—and the

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	exposure enough, you eventually find that no one cell is contributing much. If I were a new reader, I might worry that the contribution of the dropped radionuclides and pathways may in the end be greater than that of the retained pathways. Similar to the comments made on an expansion of the summation of the organ dose hazards previously mentioned, the hazards for 16 radioisotopes are each individually discussed and found to be below the CV for the isotope and thus not subject to further study (page 75). A brief treatment of the fact that the sum of the effects of the 16 are also below any CV would be appropriate.	screening analysis did not identify this as a significant pathway. Also, the Task 4 team found that irrigation was not a relevant exposure pathway for additional analysis because the only documented incidence of river water use was to irrigate a small acreage of peaches. The irrigation scenario produced a screening value below 1×10^{-5}. Therefore, any potential exposure occurring via these pathways was determined to be so low that it would not yield doses or risks capable of producing adverse health effects. According to page 3-8 of the Task 4 report, "A value of 10^{-5} was used because each radionuclide was compared to the decision guide independently for each exposure pathway. Using the more conservative decision guide for the screening analysis results in high confidence that the radionuclides assigned low priority for a pathway do not in fact contribute significantly to the overall dose or risk for that pathway." Further, the Task 4 team stated: "If the maximally exposed target individual has a low screening index for a contaminant (i.e., the screening estimate of risk for that contaminant is below the decision guide), then the true but unknown risk to members of the general population is expected to be even lower." In other words, as presented on page 3-1 of the Task 4 report, "Detailed study for contaminants whose presence is clearly below a minimum level of concern is not warranted, as further investigation is expected to show that the risk to any actual individual would have been much less than that calculated during the conservative screening analysis (Thiessen et al. 1996)." In addition, ORHASP—a panel of experts and local citizens—provided technical guidance and community oversight of the Task 4 report. The state of Tennessee also had the Task 4 report externally peer-reviewed prior to its release, and ATSDR had the report evaluated by independent technical reviewers. ATSDR's reviewers agreed that the overall design and the scientific approach of the Task 4 report were appropriate, the results generally quite valid and consistent with earlier studies, and the findings applicable to public health decision-making. Furthermore, ATSDR reviewed the radionuclides and exposure pathways excluded in the Task 4 report and concurred that further evaluation was not necessary. Thus, ATSDR agrees with the findings of the Task 4 report and believes that even if these excluded pathways and radionuclides were summed with those that were retained, the estimated doses and risks would be minimal and still below levels expected to cause adverse health effects.
6	Yes, the potential pathways are carefully addressed and such minor ones as the geese feeding in the river habitat, migrating to another area, and subsequently being shot by a hunter and eaten are shown to be of negligible consequence.	Thank you for your comment.

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7	The treatment of the variation of the pathways importance with time such as the pumping of the corehole #8 plume and the benefit of radioactive decay is not directly treated. A resident of the area who is a casual reader might draw some solace from a conservative discussion of these ameliorating factors even though they are in the predicted doses for future exposures.	In this public health assessment, ATSDR evaluated radioactive contaminant data for White Oak Creek releases that enter the Clinch River and travel downstream to the Lower Watts Bar Reservoir. To be clear, this public health assessment only evaluated X-10 radionuclides in White Oak Creek after the surface water was released off site. We recognize that oftentimes contaminants released into surface water may originate from contaminated groundwater, including on-site seeps and other sources of groundwater contamination such as the corehole 8 plume. These potential exposures to off-site groundwater associated with the Oak Ridge Reservation were, however, addressed in another public health assessment entitled *Evaluation of Potential Exposures to Contaminated Off-site Groundwater From the Oak Ridge Reservation (USDOE).* This groundwater PHA addresses issues including plumes, contaminants flowing from groundwater, underlying aquifers, and other topics as well. Copies of this and other ATSDR documents are available from the ATSDR Information Center. You may call the center toll-free at 1-888-422-8737 or view the document online at http://www.atsdr.cdc.gov/HAC/PHA/region_4.html#groundwater. In Section III. Evaluation of Environmental Contamination and Potential Exposure Pathways of the PHA, ATSDR states that because of remedial actions and preventive measures at X-10, physical movement of sediments from the area, and *radiological decay*, the radionuclide releases from White Oak Creek have decreased over time and the concentrations of radionuclides in the water and along the shoreline have decreased as well. Similar text has also been added to the I. Summary and IV. Public Health Implications sections of the document, and the term *radioactive decay* has been added to the glossary in Appendix A of the final PHA.
8	The non-disturbance of the sediment is a critical factor in the calculations of future exposures to both chemical and radioactive materials. This is recognized by the agencies involved and stated in the report but it might be emphasized more strongly. It appears to be the most significant factor in the assumptions made on future exposures to the carcinogens.	ATSDR agrees that the nondisturbance of sediment is a critical factor in considering potential future exposures to radionuclides in the Lower Watts Bar Reservoir and the Clinch River. For this reason, nondisturbance of sediment is discussed throughout the document in Sections II.C. Remedial and Regulatory History, II.F. Summary of Public Health Activities Pertaining to White Oak Creek Radionuclide Releases, III.B.3. Current and Future Exposure, and VIII. Conclusions. These sections provide information on the institutional controls in place to prevent disruption of sediment, ATSDR's evaluation of DOE's remedial measures to keep contaminated deep channel sediment in place, and ATSDR's current and future evaluation of potential exposures to sediment in the Lower Watts Bar Reservoir and the Clinch River. Also, please refer to the brief in Appendix D of the final PHA on ATSDR's *Lower Watts Bar Reservoir Health Consultation*, which evaluated DOE's remedial decisions for the reservoir

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		including leaving contaminated deep channel sediment in place. In the health consultation, ATSDR concluded: "Current levels of chemical and radioactive contaminants in the reservoir sediment do not and will not pose a public health problem. For the sake of caution and to prevent unnecessary exposure to workers and the public, sediment should not be disturbed without thorough review of sediment sampling data in the specific area where sediment-disturbing activities will take place."
9	From the radiological viewpoint or my area of competence, it does a very good job of describing the existence of potential pathways of human exposure. I would call this one of the strong points of the report. I believe that it has also done a good job on chemicals but I am not competent to judge that.	Thank you for your comment.
Are all relevant environmental and toxicological data (i.e., hazard identification, exposure assessment) being appropriately used?		
10	Very few data make an appearance in the document. Most results appear to be from modeling. This is in part surprising for the exposure assessment, as there is a strong dataset for at least some of the geographic locations considered. There is an attempt to at least display some of the data in Figure 21, but no mention is made of the degree of fit between data and models, and whether this supports confidence in the models. I do think the authors could have done a better job of showing how well model results on contamination agree with available monitoring data, as there are quite a few datasets available.	For evaluating past exposures to X-10 radionuclides released off site to the Clinch River via White Oak Creek, ATSDR primarily relied on data generated during *Task 4 of the TDOH's Reports of the Oak Ridge Dose Reconstruction: 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 (referred to as the "Task 4 report")*. Because historical records were not maintained to today's standards, the Task 4 team performed independent reviews of environmental monitoring reports and existing data on releases and also used mathematical models to estimate the radiation doses and the associated risks. According to the Task 4 report, accurate environmental monitoring and sampling data **were not available** to evaluate thoroughly past exposures for X-10 radionuclides released to the Clinch River. Therefore, the Task 4 team performed an in-depth evaluation to estimate the amount of radionuclides that flowed from X-10, over White Oak Dam, and into the Clinch River. Through this evaluation the team derived annual estimates for the eight radionuclides of interest: Co 60, Sr 90, Nb 95, Ru 106, Zr 95, I 131, Cs 137, and Ce 144. Using this information, the team then performed mathematical modeling to estimate the annual average concentrations of the eight radionuclides in water and sediment at specified locations downstream of White Oak Creek. According to the Task 4 report and one of its authors, when available, the Task 4 team used actual measurements in Clinch River water collected at CRM 14.5 (K-25/Grassy Creek) and 4.5 (Kingston Steam Plant) from 1960–1990 to calculate doses for Cs 137, Sr 90, Ru 106, and Co 60. The Task 4 team used modeling to

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		estimate the historical radionuclide concentrations in Clinch River water for the remaining radionuclides and for time periods when data were unavailable. Limited available monitoring data were used to calibrate the results of the team's modeling efforts. Limited information on the Task 4 team's efforts to estimate annual average radionuclide concentrations in Clinch River water and shoreline sediments with the HEC-6-R model is presented in Section 6 of the Task 4 report (available at http://www2.state.tn.us/health/CEDS/OakRidge/WOak1.pdf). The HEC-6-R model, developed by the Hydrologic Engineering Center at the U.S. Army Corps of Engineers, can be used for: a) water surface and energy profile simulation, b) sediment scour and deposition modeling, c) sediment transport modeling, and d) river geometry simulation. For more information on the model, a fact sheet is available at http://www.epa.gov/ORD/NRMRL/pubs/600r05149/600r05149hec6.pdf and the model program files are available for free downloading at http://www.hec.usace.army.mil/software/legacysoftware/hec6/hec6-documentation.htm. Similar concerns were also mentioned by ATSDR's technical peer reviewers regarding the Task 4 report. One reviewer stated, "The report does not present any statistically sound comparisons for the measured and modeled concentrations." Another reviewer stated, "The report does not provide sufficient details to allow calculations and model estimates to be duplicated and verified. In my opinion, this is the primary weakness of the report." In response, one of the authors of the Task 4 report stated, "We agree, more documentation of the models and coefficients used for sediment and water transport are needed and presently missing from the Task 4 report. This section of the Task 4 report could be improved. The detailed documentation of the HEC-6-R sediment and water transport code resides with ChemRisk." The Task 4 report states that the modeled and measured values were comparable in many cases, but that the concentrations based on measurements generally reflected a higher degree of confidence (lower uncertainty) than the modeled concentrations. ATSDR understands and recognizes that insufficient details are provided on the modeling efforts used in the Task 4 report. Nonetheless, a panel of technical experts convened to evaluate the study design, the scientific approaches, the methodologies, and the conclusions of the Task 4 report commented that the results were generally quite valid, consistent with earlier studies, and applicable to public health decision-making as long as careful attention was given to the

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		assumptions behind the estimates. The reviewers agreed that the overall design and scientific approach were appropriate. Therefore, ATSDR believes that the findings of the Task 4 report are appropriate for evaluating past exposures to X-10 radionuclide releases to the Clinch River via White Oak Creek and for making public health decisions regarding these past exposures.
11	On page 95, bone samples appear to be included as part of the Sr90 concentrations in catfish. Why is this done? Sr90 accumulates in bone, but do people really eat the bones? This does not seem to have been assumed for other fish.	According to DOE officials and the *Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report)*, research and anecdotal information suggest that people living in the Oak Ridge area have consumed fish patties comprised of ground fish, consisting of fish bones and fish flesh. When preparing the health consultation in 1995, limited data describing radionuclide concentrations in fish from the Lower Watts Bar Reservoir were available for ATSDR's review. The available data came from three sites along or downstream of the reservoir: Mid Watts Bar Reservoir (Tennessee River Mile 557.0), the Lower Watts Bar Reservoir north of the Watts Bar Dam (Tennessee River Mile 530.5), and the Upper Chickamaugua Reservoir (Tennessee River Mile 518.0 and below Watts Bar Dam). A combined total of 42 fish specimens were collected, coming from three different species—channel catfish, bluegill sunfish, and largemouth bass. All of the fish fillet samples were analyzed for cesium 137 and cobalt 60. Channel catfish samples were also sampled and analyzed for strontium 90. Because strontium is a bone-seeking radionuclide, higher concentrations of strontium 90 appear in whole fish rather than in fish flesh alone (see Section 8 of the Task 4 report). Thus, ATSDR evaluated consumption of channel catfish with bones since these strontium 90 data were available. ATSDR used a worst-case scenario using the maximum concentration and assuming that adults and children consumed two 8-ounce fish meals a week and that the meal could include some bone. ATSDR concluded that the level of potential radiological exposure from these radioactive contaminants in reservoir fish posed no public health hazard.
12	On page 105, it is mentioned that some geese had high measured concentrations, but then it seems these higher concentrations were not used in calculations because the authors believe it is unlikely a hunter would catch one of them. This may be the opinion of Blaylock (2004), but I don't see why this opinion is valid. How "likely" is "unlikely"?	ATSDR included information from this source (Blaylock 2004) in the text of the PHA only to provide background information on goose consumption for the reader. These comments neither affected nor influenced how ATSDR selected the radionuclide concentrations for estimating exposure doses via goose consumption. To evaluate the current exposures and doses for goose ingestion, ATSDR used data from the Oak Ridge Environmental Information System (OREIS), detailed in Section II.F.4 of the final PHA. The data received and

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		analyzed for geese covered the time period from 1989 to the present (2003). To estimate the radiation doses from ingestion of geese, ATSDR used the average radionuclide concentrations from OREIS to obtain realistic doses to the bone surface, lower large intestine, and whole body (the estimated radiation doses are presented in Table 20 of the final PHA). The highest committed effective dose to the whole body from goose consumption was 14 mrem to a 10-year-old child based on a 60-year exposure—over 355 times less than ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years.
13	The reader is dependent on the author to present all of the existing toxicological environmental data for the area. It appears that this is the case as data from both state, federal regulatory, and laboratory sources are quoted and used in the report. The authors are to be complimented on presenting the information in a clear format that is both readable by the non-scientific resident of the area and the radiation protection community. The methods of radiological hazard estimation used in the report appear to follow the "best practice" calculational techniques in existence at this time.	Thank you for your comments.
14	The relative weighting of the radiological vs. chemical hazards has not been made and this is probably prudent as the risk levels associated with each are open to much interpretation.	This public health assessment evaluates off-site exposure to radionuclide releases from X-10 via the Clinch River and Lower Watts Bar Reservoir. Because no chemical exposures are evaluated in this public health assessment, weighing radiological versus chemical hazards is not applicable. The radioactive materials released from White Oak Creek are chemical in nature, and in most cases, heavy metals. The potential health effects resulting from their intake are driven by their radiological properties, however, not their chemical properties. Hypothetically, if an individual had an intake sufficient to result in heavy metal toxicity, the radiation levels would be sufficient to result in adverse health effects. Adverse effects from radiation could occur following exposure to levels well below those required to result in heavy metal poisoning; natural uranium, however, is the only radioactive material where this does not apply. Therefore, as a conservative (protective) measure, ATSDR sets its minimal risk level (MRL) values for radioactive elements (other than uranium) on their radiological properties, not on their chemical properties.
15	As I understand the situation, I believe that all relevant environmental and toxicological data have been appropriately used.	Thank you for your comment.

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Does the public health assessment accurately and clearly communicate the health threat posed by the site?		
16	Yes, it does a very good job of this, conditional on the analysis in the report. There is a good summary of the doses received, and a comparison of these against dose limits selected by the authors. Further, the dose limits selected are appropriate.	Thank you for your comments.
17	I do disagree with the claim by the authors throughout that staying below such limits precludes adverse health effects. They seem to be assuming a threshold model as is typical in non-cancer effects. Such a model has not been recommended by the ICRP or the NCRP, and so is inappropriate here. The wording needs to be changed to refer to a risk that is below unacceptable levels. This will pose a bit of a challenge because the dose limit proposed is on the order of 5,000 mrem over a lifetime. Using the ICRP risk coefficient, which is now close to 5 E-4 per rem, 5,000 mrem (or 5 rem) would produce a lifetime excess probability of cancer of 2.5 E-3. This is well above what is normally considered an acceptable lifetime risk for chemicals. It is inherent in the dose limits, and I don't expect ATSDR to change the regulations, but it does point to a potential public health controversy, and the authors might need to find some wording to convey this.	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 for particular communities. ATSDR health physicists conduct a health effects evaluation by carefully examining site-specific exposure conditions about actual or likely exposures; conducting a critical review of available radiological, medical, and epidemiologic information to ascertain the substance-specific toxicity characteristics (levels of significant human exposure); and comparing an estimate of radiological dose people might frequently encounter at a site to situations 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 effects. The goal of the health effects evaluation is to decide whether harmful effects might be possible in the exposed population by weighing the scientific evidence and by keeping site-specific doses in perspective. The output is a qualitative description of whether doses are of sufficient nature and magnitude to trigger a public health action to limit, eliminate, or study further any potential harmful exposures. 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. For detailed information on risk, please see Appendix F in the final PHA. This appendix, which is not normally included in ATSDR's public health assessments, was added to this PHA because of public requests for risk information. It is important to note that ATSDR does not base its public health conclusions on these risk numbers; they are included in this PHA to provide detailed information on risk for the community. Risk assessments conducted by the U.S. Environmental Protection Agency (EPA) are useful in determining safe regulatory limits and prioritizing sites for cleanup. These risk assessments provide estimates of theoretical risk from possible current or future exposures and consider all contaminated media regardless of whether exposures are occurring or are likely to occur. These quantitative risk estimates are not intended, however, to predict the incidence of disease or measure the actual health effects in people resulting from hazardous substances at a site. By

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		design, these risk estimates are conservative predictions that generally overestimate risk. Risk assessments do not provide a perspective on what the risk estimates mean in the context of the site community and do not measure the actual health effects that hazardous substances have on people. There are subtle differences in ATSDR's process of evaluating chemicals and radiation such as dose to individual organs, age-specific dose coefficients, and other metabolic differences as discussed in several publications from the International Commission on Radiological Protection (ICRP). It is of interest to note that the National Council on Radiation Protection and Measurements (NCRP) in 1989 released a report titled: *Comparative Carcinogenicity of Ionizing Radiation and Chemicals*, NCRP Report 96. In its conclusion, the NCRP stated that fewer than 30 chemicals were known to be cancer-inducing in humans and of those, in most it was not possible to define a dose-incidence relationship except generally. Also, there is much uncertainty in chemical metabolism, in the possibility of additive or synergistic effects between or among chemicals, in the potency of chemicals, and in the dosimetry of chemicals than there is in radiation evaluations. The NCRP stated that risk assessment for chemicals is "generally more uncertain than risk assessments for radiation." Because of these statements by the NCRP, ATSDR does not, in the true sense of the comment, evaluate radiation in the similar manner as the agency evaluates chemicals. ATSDR recognizes that every radiation dose, action, or activity may have an associated risk. In this public health assessment, ATSDR compares annual doses to the 100 mrem/year dose limit of the ICRP, NCRP, and U.S. Nuclear Regulatory Commission (NRC), as well as ATSDR's MRL. ATSDR compares lifetime doses to the agency's radiogenic cancer comparison value of 5,000 mrem over 70 years, which is based on peer-reviewed literature and other documents developed to review the health effects of ionizing radiation. These values, used as screening tools during the public health assessment process, are levels below which adverse health effects are not expected to occur. If the screening indicates that past or current doses exceed our comparison values, then we would conduct further in-depth health evaluation. When ATSDR developed its screening values for radiation exposures, safety margins were incorporated. The approach ATSDR uses to derive MRLs, such as those in the Toxicological Profile for Ionizing Radiation, was developed with the EPA. MRLs for radiation are estimates of daily human exposure to an amount of radiation that is likely to be without appreciable risk of adverse noncancer health effects. MRLs are screening tools used by public health professionals to

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		determine which exposure situations require further evaluation. The chronic MRL for ionizing radiation is 100 mrem/year, which is consistent with the dose limits recommended for the public by the ICRP, NCRP, and NRC. The ATSDR MRL for ionizing radiation is based on numerous evaluations of health effects from exposures to background and occupational levels of radiation. The Ionizing Radiation Toxicological Profile states: "The annual dose of 3.6 mSv [360 mrem] per year has not been associated with adverse health effects or increases in the incidences of any type of cancers in humans or other animals" (ATSDR 1999b). The MRL was derived by reducing the 360 mrem/year by a factor of three to account for human variability (and conservatively rounded down from 120 mrem/year to 100 mrem/year) to be protective of human health. Although the MRL is for noncancerous health effects, when deriving the MRL, no studies were identified that did not result in cancer as the specific end point. Furthermore, the ATSDR legislative authority, as discussed many times, limits ATSDR to evaluating exposures based on observable and tolerable adverse health effects. If adverse health effects are not observed in an epidemiological study, then the doses used in the study should be considered tolerable. Contrary to this reviewer's comment, ATSDR's radiogenic comparison value of 5,000 millirem over 70 years incorporates the linear no-threshold (LNT) model for evaluating public health hazards associated with exposure to radiation. It assumes a total lifetime dose (70 years of exposure) above background that is considered safe in terms of cancer induction. In addition to the LNT model, ATSDR also incorporates a margin-of-dose (MOD) approach into this comparison value. During an evaluation, if ATSDR determines that further investigation is needed, we review scientific literature associated with radiological doses and dose estimates particularly related to adverse health effects. ATSDR then compares the dose estimates from scientific literature to site-specific dose estimates. Thus, ATSDR uses the LNT model to determine when a more detailed site-specific evaluation is necessary and uses the MOD approach to develop realistic information for communities regarding what is known and unknown about radiation levels at a particular site. An independent expert panel convened to review ATSDR's site-specific approaches used to evaluate past, current, and future radiation risks to communities surrounding the Oak Ridge Reservation concluded that this combination of approaches (LNT and MOD) is appropriate for ATSDR to use to determine radiation levels at which health effects actually occur. The panel found that ATSDR's use of the MRL of 100 millirem per year and radiogenic cancer

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		comparison value of 5,000 millirem over 70 years were appropriate screening values. If extrapolated over 70 years assuming constant exposure, the radiogenic cancer comparison value dose estimate would be about 71 millirem per year—a level the panel determined to be very protective of public health in terms of cancer and noncancer risks. The panel also concluded that ATSDR's approach considers evidence for both individual organs and whole-body doses (effective doses), noting that a whole-body dose could not be developed without accounting for doses to single organs. Further, the panel determined that ATSDR's method of distinguishing dose levels from risk levels was acceptable; when calculating doses, ATSDR incorporated risk and LNT explicitly and implicitly. Given our evaluation in this public health assessment, ATSDR concludes that exposures to X-10 radionuclides released from White Oak Creek to the Clinch River and to the Lower Watts Bar Reservoir are not a health hazard. Past and current exposures are below levels associated with adverse health effects and regulatory limits. Adults or children who have used, or might continue to use, the waterways for recreation, food, or drinking water are not expected to have adverse health impacts due to exposure. ATSDR has categorized these exposure situations as posing *no apparent public health hazard*. ATSDR uses this category in situations in which human exposure to contaminated media might be occurring, might have occurred in the past, or might occur in the future, but where the exposure is not expected to cause any harmful health effects. Therefore, we are conveying to the public that radiation exposure is possible, but that this exposure is not expected to result in observable and tolerable health effects.
18	The report is well written and well referenced so the reader can go to the source document for any studies concerning the measurement of the levels of contamination reported.	Thank you for your comment.
19	With the exception of the committed effective whole body doses, the hazard level of each isotope/toxic compound is calculated separately and compared to the ATSDR CV. The casual reader might appreciate some expansion of the CEDE discussion which emphasizes that it is indeed the summation of the individual dose hazards which are listed below it in the tables.	Thank you for your comment. On page 67 of the final PHA the committed effective dose is defined as 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.

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20	Yes. This has been described in detail by comparison with known hazards and the doses causing these known hazards.	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?		
21	The authors have done a nice job of summarizing and justifying their conclusion.	Thank you for your comment.
22	Based on the information presented, the conclusions and recommendations appear to be fully warranted.	Thank you for your comment.
23	The continued need for public information/education could be stressed more.	Throughout our involvement in public health activities associated with the Oak Ridge Reservation, ATSDR has promoted and been involved in outreach efforts to educate the community on various topics. In its 1996 health consultation of the Lower Watts Bar Reservoir, ATSDR recommended working with the state of Tennessee to implement a community health education program on the Lower Watts Bar fish advisory and on the health effects of PCB exposure. As a follow-up to the recommendations in the *Lower Watts Bar Reservoir Health Consultation*, ATSDR created a program to educate the community and 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 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 the Tennessee Department of Environment and Conservation's (TDEC) fish consumption advisories for the Watts Bar Reservoir. The Tennessee Wildlife Resources Agency (TWRA) also has an information and education department (see http://www.state.tn.us/twra/infoed.html) that distributes information to the public. In addition, ATSDR has held many educational workshops and presentations in the community on topics such as iodine and radiation. ATSDR has also created numerous fact sheets for the community to convey the findings of our public health assessments and other studies. Further, particular to this public health assessment on White Oak Creek Radionuclide Releases, ATSDR is presenting the document and its findings to the public and to health officials, creating a video to communicate the findings of this public health assessment to the public, and distributing fact sheets to communicate the PHA's conclusions. In addition,

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		ATSDR has a Web site solely dedicated to public health activities associated with the Oak Ridge Reservation (available at http://www.atsdr.cdc.gov/HAC/oakridge/).
24	Information such as the results of the quarterly water testing should be publicized and historical results shown so the general population can see the trends in the measurements.	TDEC–DOE Oversight Division publishes its environmental monitoring results in an annual report to the public, including the results of radiological water monitoring. For example, the Annual Report to the Public for 2004 provides findings of radiological water testing dating from 1996 to 2004. These reports are available on line at http://www.state.tn.us/environment/doeo/active.shtml and this link has been added to the public health assessment where appropriate. Copies of the report are also available from the TDEC–DOE Oversight office at 865-481-0995 and the Local Oversight Committee (LOC) office at 865-483-1333. In addition, copies of the reports are available for review at the DOE Reading Room (PD-01816), Information Resource Center, and public libraries located in Kingston, Oak Ridge, Clinton, Knoxville, Meigs County, Loudon County, Dayton, and Wartburg, Tennessee.
25	This reviewer was not impressed with the PCB warning being placed on the Tennessee fishing license material. It appears to be an ineffective way to get the message across. Bolder and more pointed methods should be used to get this message across.	ATSDR developed a brochure on the Tennessee Department of Environment and Conservation (TDEC) fish consumption advisories for the Watts Bar Reservoir. The brochure was the result of the collaborative effort of local citizens, organizations, and state officials. See Appendix D for a brief of the exposure investigation and Section II.F.1. for ATSDR's public health activities related to White Oak Creek radionuclide releases. TDEC's Division of Water Control is responsible for issuing and posting fish advisories. Evaluating fish tissue problems in the state of Tennessee involves a multi-agency effort, comprised of DOE, EPA, TDEC, the Tennessee Wildlife Resources Agency (TWRA), and the Tennessee Valley Authority (TVA). The state fish advisories are available at http://www.state.tn.us/twra/fish/contaminants.html and the current fishing regulations are available at http://www.state.tn.us/twra/fish/fishmain.html. Though PCBs are not within the scope of this public health assessment that focuses solely on radionuclide releases to the Clinch River and Lower Watts Bar Reservoir, ATSDR is preparing a public health assessment that will evaluate PCB releases from the three main ORR facilities: X-10, Y-12, and K-25. When available, copies of ATSDR's public health assessment on PCBs can be obtained by contacting ATSDR's Information Center toll-free at 1-888-422-8737.
26	Yes. I believe they have arrived at a well thought out position supported by a lot of measurements and considerable epidemiological data.	Thank you for your comment.

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Are there any other comments about the public health assessment that you would like to make?		
27	Nowhere in the document does the assessment consider a subsistence fisher, which the EPA often considers. I am not suggesting one, but it may be a point of contention. I assume the upper bound consumption rate considered is to be an approximation to this susceptible subpopulation.	To evaluate past, current, and future exposures to radionuclides in Clinch River and Lower Watts Bar Reservoir fish, higher than average fish consumers were evaluated (detailed below). In its Exposure Factors Handbook (available at http://www.epa.gov/ncea/pdfs/efh/front.pdf) that outlines factors commonly used in exposure assessments, EPA recommends for fish consumption using an assumed average intake rate for the general population of 20.1 grams/day (140.7 grams/week) of total fish. Of this fish intake rate, however, only 6.0 grams/day (42 grams/week) is considered as an average intake rate for the general population consuming freshwater and estuarine fish. All of the exposure assumptions used by ATSDR for past, current, and future exposures to radionuclides in Clinch River and Lower Watts Bar Reservoir fish were at least five times **more than** this average intake for the general population eating freshwater and estuarine fish. As detailed below, even when evaluating fish consumption by using assumed intake rates significantly above these recommended assumptions, ATSDR's estimated doses for past, current, and future exposures were below health-based comparison values. In the *Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report)*, past exposures to radionuclides in Clinch River fish were evaluated for high fish consumers. Reportedly, a maximum fish consumer in the east south central region of the country would eat about 2.4 fish meals per week (based on a 200 gram per meal fish portion) (Rupp et al. 1980. Age dependent values of dietary intake for assessing human exposures to environmental pollutants. Health Physics 39:151-163. Cited in the Task 4 report). The Task 4 report evaluated high fish consumers, who were referred to as "Category I fish consumers" and were described as individuals who frequently ate fish (between 1 and 2.5 fish meals per week). ATSDR summarized the Task 4 organ doses for the bone, lower large intestine, red bone marrow, breast, and skin locations using the 50th percentile value of the 95% confidence interval. The 50th percentile (central) values represent the medians of organ doses. The highest radiation doses were associated with eating fish taken from the Clinch River near Jones Island between 1944 and 1991. Doses were much lower for all other pathways (see Table 11 and Table 12 in the final PHA). The Task 4 report's estimated organ doses to the bone, lower large intestine, red bone marrow, breast, and skin from eating fish were at least six times greater than the radiation doses to these organs from ingesting meat and milk, drinking water, and via external radiation (see Table 12 in the final PHA). Likewise, ATSDR's derived annual whole-body and committed equivalent doses

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		from eating fish were at least 10 times more than any of the other exposure pathways (see Table 11 in the final PHA). As mentioned and shown in Table 11, radiation doses from eating fish were highest near Jones Island—these annual whole-body and lifetime (70-year) doses were more than eight times greater than for people consuming fish from the Clinch River farther downstream near Kingston. The annual whole-body dose was 3.4 mrem/year for an individual ingesting fish near Jones Island—more than 29 times less than the 100 mrem/year recommended dose limit for the public by the NCRP, ICRP, and NRC. The whole-body lifetime dose for an individual ingesting fish caught near Jones Island was 238.6 mrem over 70 years, which is more than 20 times less than ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years. To evaluate current and future exposures to radionuclides in Lower Watts Bar Reservoir fish, this public health assessment used data from ATSDR's *Lower Watts Bar Reservoir Health Consultation*. The health consultation used worst-case scenarios to evaluate radiological exposure to fish, assuming adults and children consumed two 8-ounce fish meals per week (454 grams/week). Even using these conservative assumptions, the estimated dose was 6 mrem per year or less than 420 mrem over 70 years for the committed effective dose. The annual whole-body dose of 6 mrem per year is more than 16 times less than the dose of 100 mrem/year recommended for the public by the NCRP, ICRP, and NRC. The committed effective dose of 420 mrem over 70 years is more than 11 times less than ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years. To evaluate current and future exposures to radionuclides in Clinch River fish, ATSDR assumed a child ate 4 ounces of fish per week (113.4 grams/week) and an adult ate 8 ounces of fish per week (227 grams/week). The highest estimated whole-body dose of 89.3 mrem was calculated for an adult based on a 50-year intake to age 70—less than 55 times below ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years.
28	Around page 45, there is information provided on populations. However, this information is never used, or even relevant, given the later focus on exposure scenarios and individual risk. It is not clear why the information is provided.	The White Oak Creek study area evaluated in this public health assessment consists of the area along the Clinch River from the Melton Hill Dam to the Watts Bar Dam. All ATSDR public health assessments regularly include demographic information. Such information helps to identify and define the size, characteristics, locations (distance and direction), and possible susceptibility of known populations related to the site and study area. Demographic data provide information on potentially exposed populations and can provide important information for determining site-specific exposure pathways. The information presented in this section is for the largest communities located within the study area (Harriman,

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		Kingston, Rockwood, and Spring City) that could potentially be exposed to radiological contamination in the Clinch River and Lower Watts Bar Reservoir. For more information on ATSDR's public health assessments, please see our *Public Health Assessment Guidance Manual* online at http://www.atsdr.cdc.gov/HAC/PHAManual/toc.html.
29	On page 64, line 22, the statement is made that the doses are higher than the levels to which people are really exposed. I think you should say "the levels to which the majority of people are exposed." The point of using an upper-bound, conservative, procedure is that it captures a plausible upper bound, not that it creates a fictitious dose. If the latter is implied, that will cause controversy.	Thank you for your comment. The change was incorporated into the final public health assessment.
30	On page 66, the description of weighting factors is poor. It needs to be re-written. I am not convinced the authors understand this concept, given the description they provide.	Thank you for your comment. On page 68 of the final PHA, ATSDR not only defines weighting factors but presents a user-friendly table detailing the currently adopted weighting factors by tissue. The term *weighting factors* (W_T) is defined as modifying factors selected for the type of radiation and its energy as it impacts matter to convert organ or tissue dose equivalents to committed effective dose equivalents for the whole body. They are used because the same radiation exposure to different parts of the body can have very different results. That is, if the entire body were irradiated, some parts of the body would react more dramatically than other parts. To take this effect into account, the ICRP developed weighting factors for a number of organs and tissues that most significantly contribute to the overall biological damage to the body. The tissue weighting factors are based on both cancer fatality risk and the relative effect of an exposure to a single organ or tissue. The grouping of tissues is complex, and substantial rounding of the values takes place. When summed for the entire body, the values of W_T are normalized to give a total of one.
31	The figure on page 74 caused me to wonder whether exposures to aerosolized radionuclides hitting a skier might be important. I doubt they are, but the figure does raise the issue.	Thank you for your comment. This possible exposure was implicitly evaluated in the intake of Lower Watts Bar Reservoir and Clinch River surface water by recreational users.
32	Page 81 seems to raise an issue of variability and uncertainty analysis, but I cannot follow how these analyses were done. Distributions are mentioned, and said to be related to "individual sets of measured data," but no detail is provided on this. The EPA has a good Exposure Factors Handbook, and perhaps this is what the authors mean by data? But I could not determine the distributions used. And I am uncomfortable in assessing whether the authors have properly disentangled uncertainty and intersubject variability. This becomes particularly troubling to me	The uncertainty analysis was performed by the Tennessee Department of Health's (TDOH) contractors, not by ATSDR. For ATSDR's analysis, we used the EPA's Exposure Factors Handbook to select values reflective of lifestyle patterns for people living in the area of study—the southeastern United States. The wording "50^{th} percentile of the 95% confidence interval" has been clarified in the text and represented as the "50^{th} percentile of the uncertainty distribution" as

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	on page 82, lines 8-10, where the authors speak of the 50th percentile of the 95% confidence interval. That is strange wording. Is this 95% interval variability or uncertainty. And a confidence interval does not have a 50th percentile, the underlying distribution from which the confidence interval is constructed has this 50th percentile. The authors need to better describe how variability and uncertainty are being reflected, and how these relate to specific confidence intervals mentioned.	reported in the Task 4 report.
33	I see no description of the pharmacokinetic and dosimetric models used. Are they the ICRP ones? Are they buried inside ChemRisk? EPA has created RadRisk for radionuclides. Why was that system not used?	Please see Section 11. Internal Dosimetry of the *Task 4 of the TDOH's Reports of the Oak Ridge Dose Reconstruction: 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 (referred to as the "Task 4 report")*. As noted in this section, to calculate doses to people ingesting contaminated drinking water or food, the Task 4 team used the internal dosimetry methodology of the International Commission on Radiological Protection (ICRP) that is based on the ICRP models for bioaccumulation and transfer of radionuclides in the body. This methodology was used to estimate ingestion dose factors and their uncertainty for adults ingesting cesium 137, strontium 90, cobalt 60, and ruthenium 106; for iodine 131, estimates were made for a child up to age 15. Please refer to Section 11 in the Task 4 report for specific details on the internal dosimetry methodology used by the Task 4 team.
34	On page 87 and elsewhere, ingestion doses for water are mentioned. Is treatment of the water assumed? Many water treatment systems will remove radionuclides such as Cs and Sr to some extent.	For past exposures, the Task 4 team evaluated the ingestion of filtered, treated Clinch River water as drinking water. For current exposures to Lower Watts Bar Reservoir surface water, ATSDR evaluated potential exposures to unfiltered surface water via recreational activities and exposure to treated water via municipal waters from household taps. For current exposures to Clinch River surface water, ATSDR evaluated potential exposures to unfiltered surface water via recreational activities. This information has been clarified in the text in the final public health assessment.
35	On page 88, there must be some mention of the exposure duration assumed for external exposures on the shore.	Table 10 in the final public health assessment provides the years of exposure considered for each exposure scenario. As shown in the table, the time period varied by location for external exposures to shoreline sediment. For Jones Island, the years of exposure evaluated were 1963 to 1991. The years of exposure evaluated for external exposures to shoreline sediment at K-25/Grassy Creek, the Kingston Steam Plant, and the City of Kingston were 1944 to 1991. The years of exposure, along with a reference to Table 10, have been added to this section of the final public health assessment.

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36	On page 88, the authors mention (on line 27) an uncertainty analysis. But I can find no details on that, and whether it was a nested variability-uncertainty analysis (which would be appropriate and state-of-the-art).	This refers to a comment made by a technical peer reviewer who was part of a panel of experts ATSDR convened to evaluate the Task 4 report. More details on this uncertainty analysis are not provided in the public health assessment itself, but additional information can be found by accessing the Task 4 report online at http://www2.state.tn.us/health/CEDS/OakRidge/WOak1.pdf.
37	On page 94, tritium is called a "very weak emitter" of radiation. This is not a relevant characterization, since the betas it emits have sufficient range and energy to strike and break DNA bonds. In fact, the RBE of tritium is above 1.	Thank you for your comment. The text was removed from the referenced sentence, which now reads as the following: "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) of 20,000 pCi/L of H 3, an amount that would produce a radiation dose of 4 mrem/year if ingested at 2 liters of water per day for a year."
38	Some ingestion rates are used throughout, but no mention is made of the percentile of the intersubject variability distribution represented by these assumed rates of ingestion. Are these upper percentiles (to be protective)?	To evaluate past, current, and future exposures to radionuclides in Clinch River and Lower Watts Bar Reservoir fish, higher than average fish consumers were evaluated (detailed below). In its Exposure Factors Handbook (available at http://www.epa.gov/ncea/pdfs/efh/front.pdf) that outlines factors commonly used in exposure assessments, EPA recommends for fish consumption using an assumed average intake rate for the general population of 20.1 grams/day (140.7 grams/week) of total fish. Of this fish intake rate, however, only 6.0 grams/day (42 grams/week) is considered as an average intake rate for the general population consuming freshwater and estuarine fish. All of the exposure assumptions used by ATSDR for past, current, and future exposures to radionuclides in Clinch River and Lower Watts Bar Reservoir fish were at least five times **more than** this average intake for the general population eating freshwater and estuarine fish. As detailed below, even when evaluating fish consumption by using assumed intake rates significantly above these recommended assumptions, ATSDR's estimated doses for past, present, and future exposures were below health-based comparison values. In the *Task 4 of the Tennessee Department of Health's Reports of the Oak Ridge Dose Reconstruction (Task 4 report)*, past exposures to radionuclides in Clinch River fish were evaluated for high fish consumers. Reportedly, a maximum fish consumer in the east south central region of the country would eat about 2.4 fish meals per week (based on a 200 gram per meal fish portion) (Rupp et al. 1980. Age dependent values of dietary intake for assessing human exposures to environmental pollutants. Health Physics 39:151-163. Cited in the Task 4 report). The Task 4 report evaluated high fish consumers, who were referred to as "Category I fish consumers" and were described as individuals who frequently ate fish (between 1 and 2.5 fish meals per week). See Table 7.3 in the Task 4 report

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		for more information on the parameters used for fish ingestion rates. Also, the Task 4 report used different ingestion rates to evaluate the water and milk/meat ingestion pathways. See Table 7.2 and Table 7.4 in the Task 4 report for the rates used to evaluate the water and milk/meat ingestion pathways, respectively. ATSDR summarized the Task 4 organ doses for the bone, lower large intestine, red bone marrow, breast, and skin locations using the 50th percentile value of the uncertainty distribution. The 50th percentile (central) values represent the medians of organ doses. To evaluate current and future exposures to radionuclides in Lower Watts Bar Reservoir fish, this public health assessment used data from ATSDR's *Lower Watts Bar Reservoir Health Consultation*. The health consultation used worst-case scenarios to evaluate radiological exposure to fish, assuming adults and children consumed two 8-ounce fish meals per week (454 grams/week). To evaluate exposures via water ingestion at the Lower Watts Bar Reservoir, ATSDR used data from the health consultation that conservatively assumed a worst-case scenario using the maximum concentrations for each radionuclide. ATSDR evaluated exposure to children aged about 10-years-old and assumed they drank and showered with unfiltered reservoir water and swam in the reservoir daily. To evaluate current and future exposures to radionuclides in Clinch River fish, ATSDR assumed a child ate 4 ounces of fish per week (113.4 grams/week) and an adult ate 8 ounces of fish per week (227 grams/week). For evaluating potential exposures for the Clinch River via water ingestion, ATSDR used exposure values from the EPA's *Federal Guidance Report 13*. These values assumed that a swimmer might incidentally ingest surface water at a rate of 0.1 liters per hour while swimming. ATSDR used a swimming frequency of 1 hour per day for 150 days per year as noted in the EPA's *Exposure Factors Handbook*. These values are conservative, and therefore typically overestimate true exposure. Also, to evaluate potential exposures related to current and future goose and turtle consumption, ATSDR used consumption values based on the findings of ATSDR's *Watts Bar Exposure Investigation* of 500 grams of goose liver per year (about 1 pound) and 10 kilograms (about 22 pounds) of goose muscle per year. For turtle consumption, ATSDR estimated doses based on ingesting 100 grams (about 3.5 ounces) of turtle each year. ATSDR conservatively assumed hunters might consume as much as 10 kilograms (about 22 pounds) of goose muscle per year. This amount averages to about one 6 to 8 ounce serving per week or 27 grams/day. Based on fish consumers surveyed during the exposure investigation, the high, average, and low

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		consumption groups consumed about 108, 66.5, and 1.9 grams of fish per day, respectively. Assuming that similar consumption ratios apply to goose consumption, ATSDR calculated that the amount and ratios for a 70-kilogram adult goose consumer would be 27, 17, and 0.5 grams/day, respectively, for high, average, and low consumption groups. If, as assumed for the fish, 10-kilogram children eat one-third the portion sizes that adults eat, their consumption levels would be in the ratios of 9, 5.6, and 0.16 grams/day of goose muscle for high, moderate, and low consumers, respectively. From the exposure investigation, ATSDR learned that average consumers eat about 100 grams of turtle meat a year (0.27 grams/day). High consumers eat turtle meals twice as often as moderate consumers (0.55 g/day), and low consumers eat one-sixth the amount that moderate consumers do (0.05 g/day).
39	On page 107, Table 21, it seems odd to me that the bone and skin ratios for Clinch River (external) divided by background are around 10, and then the ratio for whole body is 60. Bone is representative of the deep dose and skin of the shallow dose, so usually these bracket the ratio for the whole body. But in this case, the whole body ratio is a factor of 6 higher than for either the shallow or deep doses. It may be correct, but it does seem odd to me. The authors should check this.	The variation of ratios is a result of the time weighted averages, the time spent on the shoreline and in the water, and the ingestion and uptake coefficients—each calculated for a specific radionuclide.
40	As a non-regulatory agency, ATSDR keeps a low profile in the public press. Those that are impacted by the Superfund clean up efforts learn of the agency, but the typical citizen has no idea ATSDR exists. Strongly recommend that the introduction be enhanced to give a brief overview to what ATSDR is and how it relates to DHS, CDC, NIOSH, and other similar agencies. I mentioned the CDC and NIOSH only because both make the popular press on a frequent basis and are known to the public.	Additional text describing ATSDR's relationship to the U.S. Department of Health and Human Services (HHS), the Centers for Disease Control and Prevention (CDC), and the National Center for Environmental Health (NCEH) has been added to Section I. Summary on page 1 of the final PHA. Also, Internet links for ATSDR (http://www.atsdr.cdc.gov/) and CDC (http://www.cdc.gov/) have been added as resources for more information about these and affiliated agencies.
41	Reference page 71: One time scope is the period 1988 to present but given the time to publish such a report, present might be defined. Then the past exposure period is 1944 to 1991. The reader gets the impression that the doses for the 3-year period overlap are being double counted. If this overlap is accounted for in any manner, this reader missed it.	The time periods for ATSDR's evaluation of past exposures (1944–1991) and current and future exposures (1988–present and future for Lower Watts Bar Reservoir; 1989–present and future for Clinch River) overlap slightly due to some studies being conducted simultaneously. The doses obtained from these studies are, however, based on different data. Therefore, the estimated past doses do not overlap with the estimated doses for current and future even though the time periods overlap. Text has been added to the final PHA to explain the overlapping time periods. Further, ATSDR's evaluation of future exposures includes exposures occurring after the present time period (2003) evaluated in the PHA.
42	It would be prudent to add statistical uncertainty information to the tabulated	Because of uncertainties regarding exposure conditions and adverse effects

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	dose/hazard data. One result is within a factor of 3 of a CV. What range is this expected to be within: 2.5 or 3.5? Such information would be beneficial to the non-scientific reader.	related to environmental levels of exposure, definitive answers on whether health effects actually will or will not occur are not possible. That said, it is possible for a public health assessment to provide a framework that puts site-specific exposures and the potential for harm in perspective. ATSDR recognizes that uncertainties exist with its dose-based assessments, but using health protective safety factors addresses these uncertainties. ATSDR evaluated the need for an uncertainty analysis as outlined in NCRP Commentary 14 entitled *A Guide for Uncertainty Analysis in Dose and Risk Assessments Related to Environmental Contamination.* In essence, the use of conservative and biased screening calculations indicated the possible resulting dose would be clearly below a regulatory limit. "Conservative screening calculations are designed to provide a risk estimate that is highly unlikely to underestimate the true dose or risk. Therefore, a more detailed analysis will likely demonstrate that the true risk is even less." The document states that screening can be considered among the first steps in conducting an uncertainty analysis as this roughly defines the upper and lower bounds of a distribution of exposed populations or individuals. To use these screening calculations successfully, a decision point has to be determined to establish the boundary at which no further analyses are necessary. According to NCRP Commentary 14, "For example, for dose reconstruction, the National Academy of Sciences has suggested that an individual lifetime dose of 0.07 Sv be used as a decision criterion for establishing the need for more detailed investigation (NAS/NRC 1995)." A value of 0.07 Sv is equivalent to 7 rem or 7,000 mrem—a value that is 40% higher than ATSDR's radiogenic cancer comparison value of 5,000 mrem over 70 years. Thus, ATSDR's screening value is more conservative than the criteria suggested by the National Academy of Sciences as reported by the NCRP. Furthermore, the calculations of other comparison values used by ATSDR in this public health assessment incorporate health-protective safety factors to account for uncertainty, such as human variability and sensitivity of populations.
43	Page 114, line 11: I would replace the word "derived" with "arrived at" or similar wording as the NRC limit was accepted rather than derived.	For clarification, the line being referenced by the peer reviewer does not refer to a U.S. Nuclear Regulatory Commission (NRC) limit. Instead, this line refers to ATSDR's radiogenic comparison value of 5,000 millirem over 70 years that was derived after a review of peer-reviewed literature and other documents developed to review the health effects of ionizing radiation.

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44	Page 123: Of the 2,500 community health concerns logged, what is the basis for the listing of the sample on pages 124–140?	As detailed in the introductory text of Section VI. Community Health Concerns, the community health concerns addressed in this public health assessment are those concerns in ATSDR's Community Health Concerns Database related to issues associated with radionuclide releases from White Oak Creek. These include X-10 facility processes and exposure pathway concerns, concerns about radionuclides associated with X-10's releases to White Oak Creek, concerns about contaminants released from the Oak Ridge Reservation, and general concerns related to the Oak Ridge Reservation.
45	Appendix B, page B-6: The bar graph is clear and informative only if the sentence on line 4, page B-4 is noted. As the initial schedule is no longer being used, recommend that the initial schedule be eliminated and the revised schedule only be shown.	The following sentence was added as a note to the bottom of Figure B-2: "The current Melton Valley closure schedule was accelerated by 9 years to have all closure activities completed by fiscal year 2006." The figure presents both the initial and revised schedule in order to show which closure activities in Melton Valley have been accelerated from the current schedule.
46	I would not change the public health assessment which has been made. This is a group effort from a lot of very competent and interested professionals who have a lot riding on the outcome and who I believe have done a very good job under difficult circumstances.	Thank you for your comment.
47	This document presents ATSDR in a pretty favorable manner. You have done a good job under very difficult circumstances with a lot of unwanted publicity and carping. The science under the report is very good and the report is written in a very good manner that is suitable for both an informed and interested public and the scientific community.	Thank you for your comment.