PUBLIC COMMENT RELEASE

PUBLIC HEALTH ASSESSMENT

Y-12 Uranium Releases

OAK RIDGE RESERVATION (USDOE)

OAK RIDGE, ANDERSON COUNTY, TENNESSEE

EPA FACILITY ID: TN1890090003

Prepared by:

Federal Facilities Assessment Branch
Division of Health Assessment and Consultation
Agency for Toxic Substances and Disease Registry

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment-Public Comment Release was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6)), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate. This document represents the agency's best efforts, based on currently available information, to fulfill the statutory criteria set out in CERCLA section 104 (i)(6) within a limited time frame. To the extent possible, it presents an assessment of potential risks to human health. Actions authorized by CERCLA section 104 (i)(11), or otherwise authorized by CERCLA, may be undertaken to prevent or mitigate human exposure or risks to human health. In addition, ATSDR will utilize this document to determine if follow-up health actions are appropriate at this time.

This document has previously been provided to EPA and the affected state in an initial release, as required by CERCLA section 104 (i)(6)(H) for their information and review. Where necessary, it has been revised in response to comments or additional relevant information provided by them to ATSDR. This revised document has now been released for a 30-day public comment period. Subsequent to the public comment period, ATSDR will address all public comments and revise or append the document as appropriate. The public health assessment will then be reissued. This will conclude the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

Please address comments regarding this report to:

Agency for Toxic Substances and Disease Registry
Division of Health Assessment and Consultation
Attn: Chief, Program Evaluation, Records, and Information Services Branch, E-60
1600 Clifton Road, N.E., Atlanta, Georgia 30333

You May Contact ATSDR TOLL FREE at
1-888-42ATSDR or
Visit our Home Page at: http://www.atsdr.cdc.gov

FOREWORD

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

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

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

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

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

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

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

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

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

Letters should be addressed as follows:

Attention: Chief, Program Evaluation, Records, and Information Services Branch, Agency for Toxic Substances and Disease Registry, 1600 Clifton Road (E-60), Atlanta, GA 30333.

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ACRONYMS

ACAP	Atomic City Auto Parts
ALS	amyotrophic lateral sclerosis
AOEC	Association of Occupational and Environmental Clinics
ATSDR	Agency for Toxic Substances and Disease Registry
BW	body weight
CDC	Centers for Disease Control and Prevention
Cs 137	cesium 137
CEDE	committed effective dose equivalent
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
Co 60	cobalt 60
COPD	chronic obstructive pulmonary disease
CR	concentration ratio
DHHS	U.S. Department of Health and Human Services
DOE	U.S. Department of Energy
EFPC	East Fork Poplar Creek
EMEG	environmental media evaluation guide
EPA	U.S. Environmental Protection Agency
FACA	Federal Advisory Committee Act
FAMU	Florida Agricultural and Mechanical University
fCi/m^3	femtocuries per cubic meter
GAO	General Accounting Office
g/kg/day	grams per kilogram per day
µg/kg	micrograms per kilogram
$\mu g/m^3$	micrograms per cubic meter
ICRP	International Commission on Radiological Protection
IR	ingestion rate
kg	kilogram
LET	Linear Energy Transfer
LNT	linear nonthreshold
LOAEL	lowest-observed-adverse-effect level
m^3/day	cubic meters per day
MCL	maximum contaminant level
mrem	millirem
mrem/year	millirem per year
mg/day	milligrams per day
mg/kg	milligrams per kilogram
mg/kg/day	milligrams per kilogram per day
mg/m^3	milligrams per cubic meter
MRL	minimal risk level
MS	multiple sclerosis
NAACP	National Association for the Advancement of Colored People
NCEH	National Center for Environmental Health
NCRP	National Council on Radiation Protection and Measurements
NIOSH	National Institute for Occupational Safety and Health

NOAEL	no-observed-adverse-effect level
NPL	National Priorities List
ORHASP	Oak Ridge Health Agreement Steering Panel
ORR	Oak Ridge Reservation
ORRHES	Oak Ridge Reservation Health Effects Subcommittee
PCB	polychlorinated biphenyl
pCi/g	picocuries per gram
PHAWG	Public Health Assessment Work Group
ppb	parts per billion
ppm	parts per million
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation and Feasibility Study
ROD	Record of Decision
SDWA	Safe Drinking Water Act
SMR	standardized mortality ratio
Sr 90	strontium 90
Sv	sievert
TDEC	Tennessee Department of Environment and Conservation
TDOH	Tennessee Department of Health
TSCA	Toxic Substances Control Act
U	uranium
µg/L	micrograms per liter
USGS	U.S. Geological Survey
χ	chi

I. SUMMARY

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 nuclear 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) broadened widely to include a variety of nuclear research and production projects vital to national security.

In 1989, the ORR was added to the U.S. Environmental Protection Agency's National Priorities List because over the years the ORR operations have generated a variety of radioactive and nonradioactive wastes which are present in old waste sites and have been released into the environment. The U.S. Department of Energy is conducting clean-up activities at the ORR under a Federal Facility Agreement with the U.S. Environmental Protection Agency and the Tennessee Department of Environment and Conservation. These agencies are working together to investigate and take remedial action on hazardous waste from past and present activities at the site.

For the last 10 years, the Agency for Toxic Substances and Disease Registry (ATSDR) has responded to requests and addressed 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 to communities surrounding the ORR. 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 experienced exposures in the past, ATSDR's activities focused on current public health issues related to Superfund clean-up activities at the site. Prior to this public health assessment, ATSDR addressed current public health issues related to two off-site areas affected by ORR operations—the East Fork Poplar Creek area and the Watts Bar Reservoir area.

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 that may have been responsible for adverse health effects— radionuclides from White Oak Creek, iodine, mercury, and polychlorinated biphenyls (PCBs). 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 upon the efforts of the TDOH, and 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. Based on this review, ATSDR scientists are conducting public health assessments on the release of iodine 131, mercury, PCBs, radionuclides from White Oak Creek, uranium, fluorides, and on 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 information, data, and findings from previous studies and investigations to assess the public health implications of past and current exposure. The public health assessment is the primary public health process ATSDR uses to

1. Identify populations off the site who may have been exposed to hazardous substances at levels of health concern.
2. Determine the public health implications of the exposure.
3. Address the health concerns of people in the community.
4. Recommend follow-up public health actions or studies to address the exposure.

ATSDR scientists will also conduct a screening analysis of all available environmental sampling data from 1990 to the present to determine whether additional contaminants of concern need to be addressed.

This public health assessment evaluates the releases of uranium from the Y-12 plant; assesses past and current uranium exposure to residents living near the ORR, including the residents of the Scarboro community (the reference community); and addresses the community health concerns and issues associated with the uranium releases from the Y-12 plant. The release and exposure to other contaminants of concern such as mercury, iodine 131, PCBs, uranium from the K-25 facility, and fluorides are not addressed in this document. These contaminants and other topics will be evaluated by ATSDR in separate public health assessments.

The 825-acre Y-12 plant, now called the Y-12 National Security Complex, is located in Bear Creek Valley and is bordered by Chestnut Ridge and Pine Ridge. The Y-12 plant was used in the 1940s to electromagnetically enrich uranium. In 1952, the facility was converted to enrich lithium-6 using a column-exchange process and to fabricate components for thermonuclear weapons using high-precision machining and other specialized processes. In 1992, after the Cold War, Y-12's mission was curtailed, and the plant is currently used for weapons disassembly and weapon renovation operations. The National Nuclear Security Administration currently uses the Y-12 National Security Complex as the primary storage site for highly enriched uranium. While operational levels have increased since 1992, the total operations have not approached the levels experienced prior to the 1990s.

The Y-12 plant is located about 2 miles south of downtown Oak Ridge. However, the Y-12 plant is separated from the main residential areas of Oak Ridge by Pine Ridge, a ridge that rises to about 300 feet above the valley floor. In 1942, the city of Oak Ridge was established for the 13,000 persons who were expected to work at the ORR. The population peaked at 75,000 in 1945 and decreased to 30,229 in 1950. Since 1959, when the city of Oak Ridge became self-governing, the Oak Ridge population has been approximately 27,000. The Scarboro community is a residential area within the city of Oak Ridge, about a half mile from the Y-12 plant, and is separated from the Y-12 plant by Pine Ridge. Scarboro was established in 1950 to provide single-family homes, duplexes, apartments, and an elementary school to African American Oak Ridge residents. Scarboro remains predominantly African American and has a population of approximately 300 persons.

In this public health assessment, the Scarboro community is used as a reference location because it represents an established community surrounding ORR where residents resided during the years of uranium releases. In Phase II of the Oak Ridge Health Studies, the TDOH identified

Scarboro as a reference location using air dispersion modeling to estimate average ground-level air concentrations at locations surrounding the reservation. Based on the air dispersion modeling results, Scarboro was the off-site population likely to receive the highest exposures to past releases from the Y-12 plant. The Task 6 report stated that "while other potentially exposed communities were considered in the selection process, the reference locations [Scarboro] represent residents who lived closest to the ORR facilities and would have received the highest exposures from past uranium releases…Scarboro is the most suitable for screening both a maximally and typically exposed individual."

ATSDR evaluated past and current exposure to uranium released from the Y-12 plant and found that the levels of uranium were too low for exposure to be of health concern for both radiation and chemical health effects.

Past Exposure

ATSDR evaluated both radiation and chemical aspects of past uranium exposure. Neither the total radiation dose, nor the chemical ingestion and inhalation doses from exposure to uranium released from the Y-12 plant in the past would cause harmful health effects for the reference population, the residents of Scarboro.

To evaluate past exposure to uranium releases from the Y-12 plant, ATSDR primarily relied on data generated during Task 6 of the TDOH's Reports of the Oak Ridge Dose Reconstruction, *Uranium Releases from the Oak Ridge Reservation—a Review of the Quality of Historical Effluent Monitoring Data and a Screening Evaluation of Potential Off-Site Exposures* (referred to as the "Task 6 report"). The Scarboro community was selected as the reference population after air dispersion modeling indicated that its residents were expected to have received the highest exposures. Therefore, in this evaluation, conclusions regarding exposures to Scarboro residents are also applicable to other residents living near the Y-12 plant.

To evaluate cancer health effects from past radiation exposure, ATSDR adjusted the total uranium radiation doses reported in the Task 6 report to be equivalent to a 70-year exposure.[1] The total radiation dose received by the reference population, the Scarboro community, from all air, surface water, and soil exposure pathways (155 millirem [mrem] over 70 years) is well below (32 times less than) the ATSDR radiogenic cancer comparison value of 5,000 mrem over 70 years. This radiogenic cancer comparison value assumes that the entire radiation dose (a 70-year dose, in this case) from the intake of uranium is received in the first year following the intake. ATSDR believes this radiogenic comparison value to be protective of human health and, therefore, does not expect carcinogenic health effects to have occurred from exposure to uranium in the past.

To evaluate noncancer health effects from the total past uranium radiation dose (committed effective dose equivalent (CEDE) of 155 mrem over 70 years) received by the Scarboro community, ATSDR divided the CEDE of 155 mrem, which is based on 70 years of exposure, by 70 years to approximate a value of 2.2 mrem as the radiation dose for the first year. This approximate dose of 2.2 mrem is well below (45 times less than) the ATSDR minimum risk level (MRL) of 100 mrem/year for chronic ionizing radiation exposure. ATSDR believes the chronic ionizing radiation MRL of 100 mrem/year is below levels that might cause adverse health effects in people most sensitive to such effects and, therefore, does not expect noncancer health effects to have occurred from radiation doses received from past Y-12 uranium releases.

To evaluate potential chemical health effects from past uranium exposure, ATSDR estimated exposure through the air pathway and compared the yearly air concentrations in the Scarboro community to ATSDR's inhalation MRL for uranium. Yearly estimated average air concentrations of uranium in Scarboro ranged from 2.1×10^{-8} to 6.0×10^{-5} milligrams per cubic meter (mg/m^3). These air concentrations are less than 1% of the inhalation MRL for chemical effects (8×10^{-3} mg/m^3).

> The same value can be presented in different ways:
> 0.001
> 1.0E-03
> 1.0×10^{-3}
> 1/1,000
> one in a thousand

ATSDR also estimated exposure to uranium through the soil and surface water pathways and

[1] The values from the Task 6 report were multiplied by 1.35 (70 years/52 years) for comparison with ATSDR's comparison values.

compared the resulting doses to levels associated with known health effects. Yearly estimated doses from exposure to uranium via all soil ingestion and surface water exposure pathways ranged from 2.7×10^{-5} to 1.3×10^{-2} milligrams per kilogram per day (mg/kg/day). All doses are less than the dose (5×10^{-2} mg/kg/day) at which health effects (renal toxicity) have been observed in rabbits, the mammalian species most sensitive to uranium kidney toxicity. Therefore, ATSDR does not expect that residents were exposed in the past to levels of uranium that would cause harmful chemical effects.

Additionally, it should be noted that several levels of conservatism were built into this evaluation of past exposures. The values that ATSDR relied on to evaluate past exposures (those from the Task 6 report) came from a screening evaluation that routinely and appropriately used conservative and overly protective assumptions and approaches, which led to an overestimation of concentrations and doses. Even using these conservative overestimations of concentrations and doses, persons in the reference community (Scarboro) and other communities near the Y-12 plant were exposed to levels of uranium that are below health concern.

Current Exposure

ATSDR evaluated both radiation and chemical aspects of current uranium exposure. Based on our review of data collected in and around the Scarboro community, and as compared to background and distant areas, ATSDR has determined that the presence of uranium is not a public health concern.

To assess current exposure to uranium releases from the Y-12 plant, ATSDR evaluated air data from monitoring stations, surface water sampling from East Fork Poplar Creek and Scarboro, recent soil sampling from the Scarboro community, samples of garden crops from Scarboro, and garden crop samples from outlying areas. ATSDR evaluated the following pathways: (1) ingestion of soil, (2) ingestion of foods, (3) ingestion of water from nearby creeks, (4) inhalation of air, and (5) external exposure from uranium in soils.

To evaluate cancer effects of current radiation exposure to uranium, the radiation dose received by the reference population, the Scarboro community, from exposure to uranium through ingestion of soil and vegetables and inhalation of air (0.216 mrem) is well below (23,000 times less than) the radiogenic cancer comparison value of 5,000 mrem over 70 years. ATSDR derived this CEDE from the intake of uranium, with the assumption that the entire dose (a 70-year dose, in this case) is received in the first year following the intake. ATSDR believes this value to be protective of human health and, therefore, does not expect harmful radiation effects to occur from the exposure to uranium that is occurring currently.

ATSDR also evaluated noncancer health effect from the total current uranium radiation dose (CEDE of 0.216 mrem over 70 years) received by the Scarboro community, ATSDR divided the CEDE of 0.216 mrem, which is based on 70 years of exposure, by 70 years to approximate a value of 0.003 mrem as the radiation dose for the first year. This approximate dose of 0.003 mrem is well below (33,000 times lower than) the ATSDR minimum risk level (MRL) of 100 mrem/year for chronic ionizing radiation exposure. ATSDR believes the chronic ionizing radiation received by communities near the Y-12 plant from uranium exposure is below levels that might cause adverse health effects in people most sensitive to such effects and therefore does not expect noncancer health effects to occur from current radiation doses.

In addition, ATSDR compared the soil radioactivity concentrations in the reference location (Scarboro) with typical concentrations found in nature and from background samples collected from uncontaminated areas around the reservation. This evaluation showed that the soil radioactivity concentrations in Scarboro were indistinguishable from natural and background concentrations.

To evaluate potential chemical health effects, ATSDR estimated exposure through the air pathway and compared the yearly air concentrations in the Scarboro community to ATSDR's inhalation MRL. Average uranium air concentrations from monitoring stations near the ORR (ranging from 3.7×10^{-11} to 1.4×10^{-10} mg/m^3), including station 46 in Scarboro (5.4×10^{-11}), are several orders of magnitude below (over a million times less than) the intermediate-duration MRL of 87×10^{-3} mg/m^3 for insoluble forms of uranium. ATSDR also estimated exposure to uranium through the soil and surface water pathways and compared the resulting doses to ATSDR's screening values: the environmental media evaluation guide (EMEG) and the oral MRL. The concentrations of uranium found in the surface water from off-site areas of East Fork Poplar Creek (0.197 and 12.8 micrograms per liter (μg/L) are below ATSDR's EMEG of 20 μg/L. Additionally, the estimated doses from ingestion of uranium in soil (ranging from 2.07×10^{-6} to 1.4×10^{-5} mg/kg/day) and food (3.0×10^{-5} and 3.9×10^{-5} mg/kg/day in the Scarboro community) were well below the oral MRL of 2×10^{-3} mg/kg/day. The maximum uranium dose from ingestion of Scarboro soil is approximately 140 times less that the oral MRL for uranium, and the uranium dose from ingestion of vegetables grown in the private garden in Scarboro is 50 times less than the oral MRL for uranium. Therefore, ATSDR does not expect that residents are currently being exposed to levels of uranium that would cause harmful chemical effects.

II. BACKGROUND

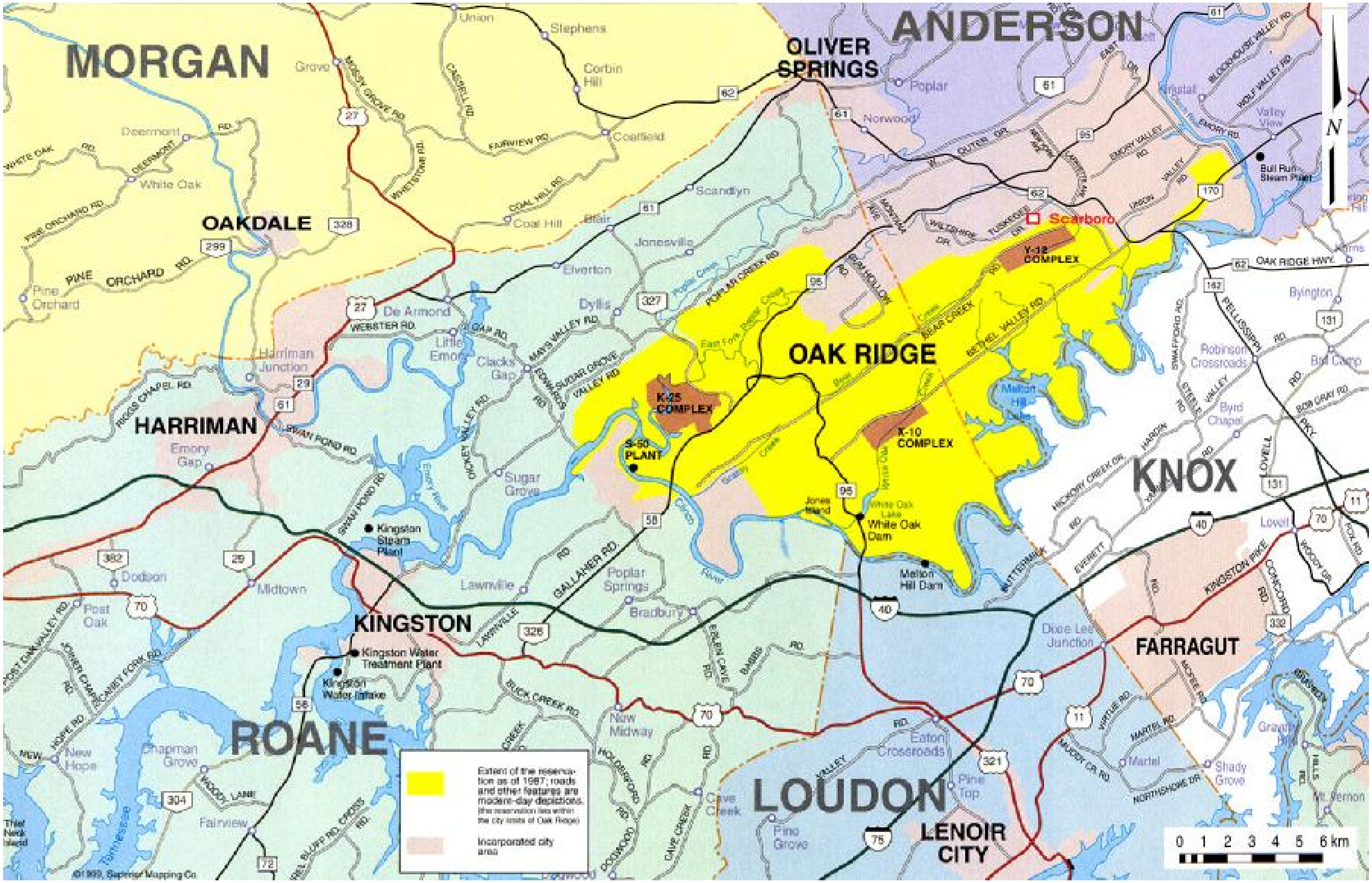
II.A. Site Description

In 1942, the federal government established the 58,000-acre Oak Ridge Reservation (ORR), located in Anderson and Roane counties in Tennessee, as part of the Manhattan Project to research, develop, and produce special nuclear materials for nuclear weapons (ChemRisk 1993a; TDOH 2000). Four facilities were built—the Y-12 plant, the K-25 site, and the S-50 site were created to enrich uranium (U), and the X-10 site was created to demonstrate processes for producing and separating plutonium (TDOH 2000).[2] The Clinch River forms the southern and western boundaries of the reservation and most of the property is within the Oak Ridge city limits (EUWG 1998). Please see Figure 1 for the location of the ORR.

The Y-12 plant is located in the eastern end of Bear Creek Valley; it is bordered on the south by Chestnut Ridge and on the north by Bear Creek Road and Pine Ridge (ChemRisk 1999). The main Y-12 production area is about 0.6 miles wide and 3.2 miles long; the area contains roughly 240 principal buildings, of which about 18 were directly involved with processing and/or storage of uranium compounds (Patton 1963, UCC-ND 1983 as cited in ChemRisk 1999). The 825-acre Y-12 plant is located within the corporate limits of the city of Oak Ridge, about 2 miles south of downtown (ChemRisk 1999). It is located less than a half-mile from the Scarboro community. However, Pine Ridge, which rises to about 300 feet above the valley floor, separates the Y-12 plant from the main residential areas of Oak Ridge (TDOH 2000).

[2] Because this health assessment focuses on exposure to uranium released from the Y-12 plant, the other main facilities on ORR are not discussed in detail

Figure 1. Location of Oak Ridge Reservation



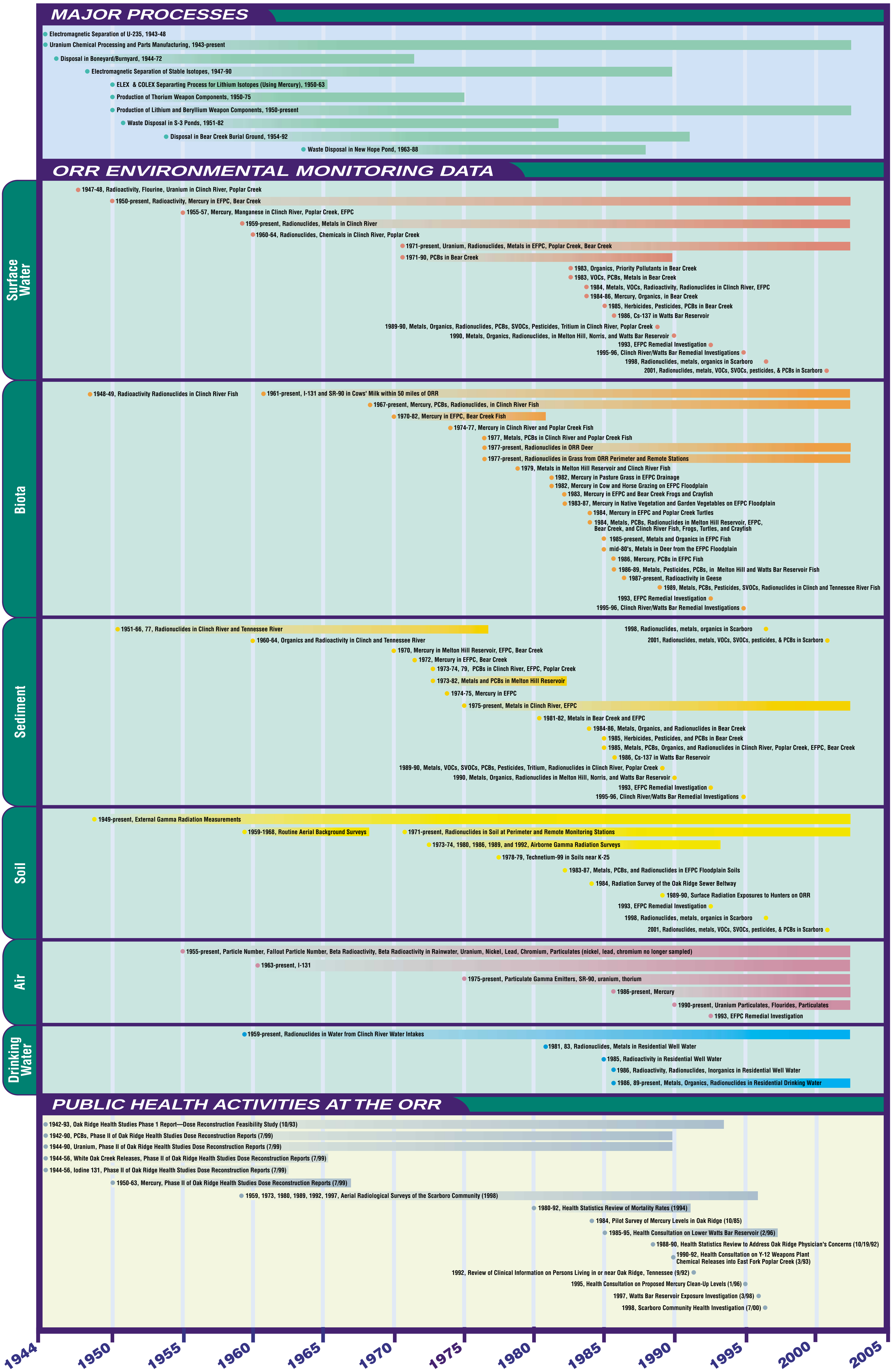
II.B. Operational History

Since the early 1940s, large quantities of uranium were processed on the ORR to enrich it into uranium 235 for production of nuclear weapon components and for use in various research and development projects (ChemRisk 1993a as cited in ChemRisk 1996).

From 1944 to 1947, the Y-12 plant was used to electromagnetically enrich uranium, but in 1952 the facilities were converted to fabricate nuclear weapon components (ChemRisk 1999). During the Cold War, a column-exchange process (Colex) that used large quantities of mercury as an extraction solvent to enrich lithium in lithium 6 was built and operated (TDOH 2000). At the end of the Cold War, the Y-12 missions were curtailed. In 1992 the major focus of the Y-12 plant was the remanufacture of nuclear weapon components and the dismantlement and storage of strategic nuclear materials from retired nuclear weapons systems. In October 2000, oversight of the Y-12 plant was changed from the U.S. Department of Energy (DOE) Oak Ridge Operations to the DOE National Nuclear Security Administration. The National Nuclear Security Administration currently uses the Y-12 National Security Complex as the primary storage site for highly enriched uranium. While operational levels have increased since 1992, the total operations have not approached the levels experienced prior to the 1990s. See Figure 2 for a time line of the major processes at the Y-12 plant.

Task 6 of the reports of the Oak Ridge Dose Reconstruction (ChemRisk 1999) describes in greater detail the operational history of the Y-12 plant. The key processes and activities associated with uranium include: (1) feed preparation for enrichment operations (1943–1947), (2) electromagnetic enrichment (1943–1947), (3) uranium recovery and recycle operations (1944–1951), (4) uranium salvage operations (1947–1951), (5) uranium preparation and recycling for weapons component operations (1949–1995), (6) uranium forming and machining for weapon component operations (1949–1995 [continuing to the present]), and (7) weapons component assembly operations (1952–1995 [continuing to the present]) (ChemRisk 1999). Please see Section 1.4 and Appendix A of Task 6 of the Reports of the Oak Ridge Dose Reconstruction, *Uranium Releases from the Oak Ridge Reservation—a Review of the Quality of Historical Effluent Monitoring Data and a Screening Evaluation of Potential Off-Site Exposures* for additional details (ChemRisk 1999) (referred to as the “Task 6 report”).

Figure 2. Y-12 Plant Time Line



II.C. Remedial and Regulatory History

Because ORR operations have generated a variety of radioactive and nonradioactive wastes, it was added to the National Priorities List (NPL) in 1989 (EPA 2002c). DOE is conducting clean-up activities at the ORR under a Federal Facility Agreement, which is an Interagency Agreement with the U.S. Environmental Protection Agency (EPA) and the Tennessee Department of Environment and Conservation (TDEC). This agreement allows for input from the public. These parties are working together to investigate and take remedial action on hazardous waste from past and present activities at the site. DOE is integrating required measures from the Resource Conservation and Recovery Act (RCRA) with response actions under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). See Figure 2 for a time line of surface water, biota, sediment, soil, air, and drinking water environmental monitoring data related to activities at the Y-12 plant.

> The Federal Facility Agreement, which was implemented on January 1, 1992, is a legally binding agreement to establish timetables, procedures, and documentation for remediation actions at ORR. The Federal Facility Agreement is available online at http://www.bechteljacobs.com/facts/or/ffa.pdf.

Contaminants, such as uranium and mercury, are present in old waste sites, which occupy 5% to 10% of the ORR. The abundant rainfall (annual average of 55 inches) and high water tables (for example, 0 to 20 feet below the surface) on the reservation contribute to leaching of these contaminants, resulting in contaminated soil, surface water, sediments, and groundwater (EUWG 1998).

Since 1986 (when initial clean-up activities commenced), DOE has initiated approximately 50 response actions under the Federal Facility Agreement that address contamination and disposal issues on the reservation. In order to consolidate investigation and remediation of environmental contamination, the contaminated areas were divided into five large tracts of land, generally associated with the major hydrologic watersheds (EUWG 1998). The following remedial actions pertain to the Y-12 plant specifically:

- *Upper East Fork Poplar Creek (EFPC)* is located entirely on the site. It originates from a spring beneath the Y-12 plant and is initially confined to a manmade channel and flows through the Y-12 plant along Bear Creek Valley. A Record of Decision (ROD) was negotiated between EPA, TDEC, and DOE that selected a number of different source control remedies to control the influx of mercury from the Y-12 plant into Upper EFPC. The major actions are the hydraulic isolation of contaminated soils in the West End Mercury Area, the treatment of the discharge of groundwater into Upper EFPC at Outfall 51, and the removal of contaminated sediments from Upper EFPC and Lake Reality. The goal is to restore surface water in Upper EFPC to human health recreational risk-based values at Station 17, which is where Upper EFPC flows into Lower EFPC (DOE 2002; EPA 2002a).

- *Lower East Fork Poplar Creek (EFPC)* flows north from the Y-12 plant off site into the city of Oak Ridge through a gap in Pine Ridge. Lower EFPC flows through residential and business sections of Oak Ridge to join Poplar Creek, which flows to the Clinch River. Lower EFPC was contaminated by releases of mercury and other contaminants, starting in the early 1950s. The remedial investigation/feasibility study (RI/FS) for Lower EFPC was completed in 1994. The ROD was approved in September 1995, and remediation field activities began in June 1996 (ATSDR et al. 2000). The Remedial Investigation and Proposed Plan ultimately led to the decision to excavate floodplain soils having mercury levels higher than 400 parts per million (ppm), sampling to ensure that all mercury above this level had been removed, and periodic monitoring (DOE 2001). The Agency for Toxic Substances and Disease Registry (ATSDR) evaluated the public health impacts of the 400 ppm clean-up level and concluded that it was protective of public health (ATSDR 1996).

- *Bear Creek Valley* is located on the reservation. A remedial decision for part of Bear Creek Valley was recently signed. Contaminated soil that is leaching uranium to groundwater and surface water is expected to be removed from the Boneyard/Burnyard and disposed of in an on-site CERCLA waste disposal facility and a capped aboveground disposal area. In addition, shallow groundwater near the S-3 ponds and the burial grounds will be treated through *in situ* reactive trenches (C.J. Enterprises 2001).

Further detailed information on remedial and regulatory information at the ORR can be found in *Oak Ridge Health Studies Phase 1 Report: Volume II – Part A – Dose Reconstruction Feasibility Study, Tasks 1 & 2, A Summary of Historical Activities on the Oak Ridge Reservation with Emphasis on Information Concerning Off-Site Emission of Hazardous Material* (ChemRisk 1993a); *Public Involvement Plan for CERCLA Activities at the U.S. Department of Energy, Oak Ridge Reservation* (C.J. Enterprises 2001); and *Oak Ridge Reservation Annual Site Reports*.

II.D. Land Use and Natural Resources

The ORR currently has about 35,000 acres with the three major DOE installations: the East Tennessee Technology Park (formerly the K-25 site), Oak Ridge National Laboratory (formerly the X-10 site), and the Y-12 National Security Complex (formerly the Y-12 plant) occupying about 30% of the reservation. The remaining 70% was established as a National Environmental Research Park in 1980, to provide protected land for environmental science research and education and to demonstrate that energy technology development can coexist with a quality environment. Large portions of the reservation, much of which had formerly been cleared for farmland, have grown into full forests over the past several decades. Some of this land includes areas known as “deep forest” that contain ecologically significant flora and fauna; portions of ORR are considered to be biologically rich (SAIC 2002).

The ORR also included an area set aside for residential, commercial, and support services. The city of Oak Ridge was created in 1942 to provide housing to the employees of ORR and was originally controlled by the military (Friday and Turner 2001). The self-governing portion of the city of Oak Ridge comprises about 14,000 acres and contains housing, schools, parks, shops, offices, and industrial areas. The urban population of Oak Ridge continued to grow over several decades, and some residential properties are located adjacent to the ORR boundary line. Outside the urban areas, much of the region (about 40%) is still a pattern of farms and small communities, as it was historically (ChemRisk 1993c).

Public access is restricted at the Y-12 plant, which is located entirely within the ORR “229 Boundary.” Y-12 is “an active production and special nuclear materials management facility [and so] additional security and access limitations apply" (DOE 2002). Out of 1,170 acres in the Upper EFPC area, 800 acres are currently used for industrial purposes. This area includes maintenance facilities, office space, training facilities, change houses, facilities that were formerly used by the Oak Ridge National Laboratory Biology Division, waste management facilities, construction contractor support areas, and a high-security portion that supports core National Nuclear Security Administration missions (DOE 2002).

A number of maps of this area indicate a wide range of land types, including "types of urban or built up land, agricultural land, rangeland, forestland, water, and wetlands," and uses that consist of "residential, commercial, public and semi-public, industrial, transportation, communication and utility, and extractive (e.g., mining)" (ChemRisk 1993c).

Agriculture (beef and dairy cattle) and forestry had been the two predominant land uses in the area around ORR; however, both of these uses are currently declining. For many years, milk was produced, bottled, and distributed locally. Corn, tobacco, wheat, and soybeans were the major crops grown in the area. Small game and waterfowl are hunted in the area continuously, and deer are hunted during certain periods (ChemRisk 1993c).

EFPC originates from within the Y-12 plant boundary, flows through the city of Oak Ridge for about 12 miles, and ultimately converges with Poplar Creek near the K-25 facility (DOE 1989). A number of small tributaries flow into the creek and support some small aquatic life. EFPC is classified by the state of Tennessee as appropriate for fishing, recreation, irrigation, livestock watering, and wildlife use (ATSDR 1993a). While people do not use the streams on the reservation, public access exists downstream from the reservation. The area that Lower EFPC flows through has many uses, which can be grouped into five categories: residential, commercial, agricultural, other, and DOE-owned (DOE 1995a). The creek appears to be too shallow for swimming, although some areas, particularly those near the confluence with Poplar Creek, are suitable for wading and fishing. TDEC issued a fishing advisory for EFPC that warns the public to avoid eating fish from the creek and to avoid contact with the water (ATSDR 1993a).

Groundwater is contaminated throughout much of the on-site Upper EFPC area. However, no one is currently using the groundwater in the area where a contaminated groundwater plume extends past the ORR boundary (i.e., in Union Valley to the east of ORR) (DOE 2002). The shallow groundwater along some off-site areas of the Lower EFPC floodplain contains metals at levels of public health concern; however, this off-site shallow groundwater is not used for drinking or other domestic purposes.

II.E. Demographics

Oak Ridge

The city of Oak Ridge, Tennessee, was established in Anderson County in 1942, for the 13,000 persons who were expected to work at the ORR (Friday and Turner 2001). By July 1944, the population of Oak Ridge had increased to 50,000. The population peaked at 75,000 in 1945 and decreased to 30,229 by 1950 (see Table 1) (Oak Ridge Comprehensive Plan 1988). In 1959, about 14,000 acres within the city of Oak Ridge became self-governing (ChemRisk 1993c). Almost since its establishment, the city of Oak Ridge has been the largest population center in the area (ChemRisk 1993c).

Table 1. Population of Oak Ridge from 1942 to 2000

	1942	1944	1945	1950	1960	1970	1980	1990	2000
Oak Ridge	13,000	50,000	75,000	30,229	27,169	28,319	27,662	27,310	27,387

Sources: ChemRisk 1993c; Oak Ridge Comprehensive Plan 1988; U.S. Census Bureau 2000

From 1940 to 1960, the city of Oak Ridge had a higher proportion of working age people and fewer seniors than the rest of Tennessee (ChemRisk 1993c). However, since 1960, the population of residents over age 35 and over age 55 has increased, while the population of children under age 16 has declined (Oak Ridge Comprehensive Plan 1988). The education level of Oak Ridge citizens is dramatically higher than in surrounding areas; Oak Ridge boasts one of the highest per capita ratios of Doctors of Philosophy (PhDs) of any city in the United States (Oak Ridge Comprehensive Plan 1988).

Scarboro

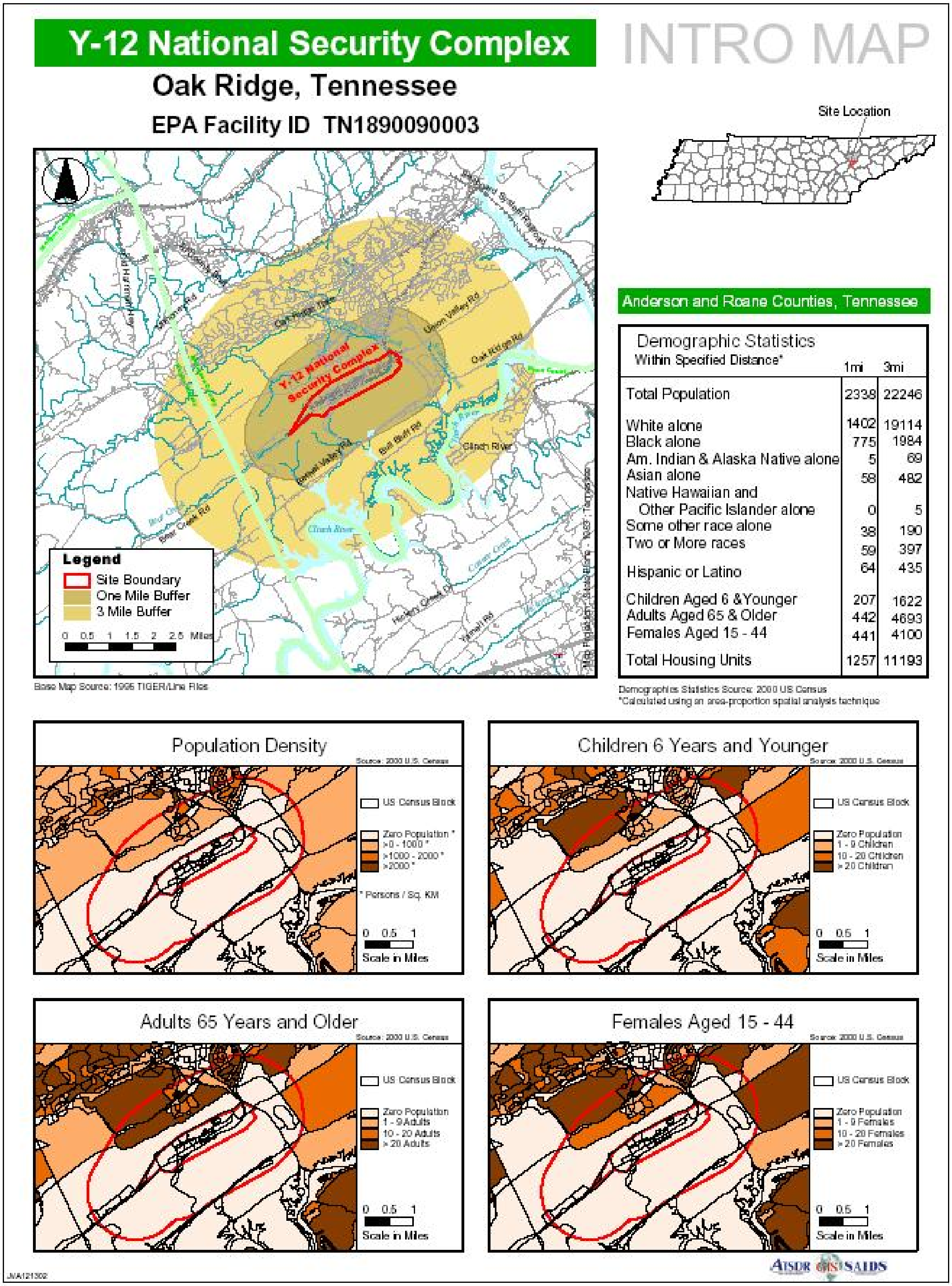
The Scarboro community is located within the city of Oak Ridge, about a half mile from the Y-12 plant and is separated from the Y-12 plant by Pine Ridge. Prior to 1950, the area was known as the Gamble Valley Trailer Camp, and the population was predominantly white. In 1950, Scarboro was established to provide single-family homes, duplexes, apartments, and an elementary school to African American Oak Ridge residents (Friday and Turner 2001). To this day, Scarboro remains predominantly African American (94%) (Joint Center Summary Number 4).

In the fall of 1999, the Joint Center for Political and Economic Studies conducted a survey of the broader Scarboro community (Friday and Turner 2001). The staff identified 380 residences, of which 326 were occupied, and about 266 persons responded to the survey (82%). The report generated from the survey is one of the few sources of detailed information available on the Scarboro community (Friday and Turner 2001). Some of the demographic information resulting from this survey is presented in the following paragraphs. For additional details, please see the *Scarboro Community Assessment Report* (Friday and Turner 2001).

The Scarboro community is aging—the average respondent is almost 53 years old and only 36% of participating households reported having at least one member between the ages of 18 and 34 years old. About half of the households reported having one senior citizen or more, while only 23% of the surveyed households reported having children. Additionally, 39% of respondents were retired. As of 1999, the average length of residence in Scarboro was 29 years. However, many (82%) of the young adult residents (18–30 years old) moved to Scarboro after 1994.

Figure 3 provides the current demographics for a 1-mile and 3-mile radius of the Y-12 plant.

Figure 3. Demographics within 1 and 3 miles of the Y-12 Plant



II.F. Summary of Public Health Activities Pertaining to Y-12 Uranium Releases

This section describes the public health activities that pertain to Y-12 uranium releases. Several additional public health activities that have been conducted at the ORR by ATSDR, the Tennessee Department of Health (TDOH), and other agencies are described in Appendix B. See Figure 2 for a time line of public health activities related to the Y-12 plant.

II.F.1. ATSDR

For the last 10 years, ATSDR has addressed 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 local, state, and federal 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*, ATSDR's activities focused on *current* public health issues to prevent duplication of the state's efforts. The following paragraphs highlight major public health activities conducted by ATSDR that pertain to Y-12 uranium releases.

Exposure Investigations, Health Consultations, and Other Scientific Evaluations. ATSDR health scientists have addressed current public health issues related to two areas affected by ORR operations—the EFPC area and the Watts Bar Reservoir area.

- *Health Consultation on Y-12 Weapons Plant Chemical Releases Into East Fork Poplar Creek, April 1993*. This health consultation provided DOE with advice on current public health issues related to past and present chemical releases into the creek from the Y-12 weapons plant. DOE implemented many of ATSDR's recommendations before finalizing its remedial investigation and feasibility study on EFPC. The EFPC Phase IA data evaluated for this health consultation indicate that the creek's soil, sediment, groundwater, surface water, air, and fish are contaminated with various chemicals. ATSDR made the following public health conclusions.

1. Soil and sediments in certain locations along the EFPC floodplain are contaminated with levels of mercury that pose a public health concern.

2. Fish in the creek contain levels of mercury and polychlorinated biphenyls (PCBs) that pose a moderately increased risk of adverse health effects to people who eat fish frequently over long periods of time.

3. Shallow groundwater in a few areas along the EFPC floodplain contains metals at levels of public health concern; however, this shallow groundwater is not used for drinking or other domestic purposes.

Other contaminants, including radionuclides found in soil, sediment, surface water, and fish, were not detected at levels of public health concern.

- *Health Consultation on the Lower Watts Bar Reservoir, February 1996*. ATSDR concluded that PCBs detected in fish from lower Watts Bar Reservoir pose a public health concern. Frequent and long-term ingestion of fish from the reservoir poses a moderately increased risk of cancer and may increase the possibility of developmental effects in infants whose mothers consume fish regularly during gestation and while nursing. ATSDR also found that current levels of contaminants in the reservoir surface water and sediment were not a public health concern, and that the reservoir was safe for swimming, skiing, boating, and other recreational purposes. Additionally, water from the municipal water systems was safe to drink. ATSDR also reported that DOE's selected remedial actions would protect public health. These actions include maintaining the fish consumption advisories; continuing environmental monitoring; implementing institutional controls to prevent disturbance, resuspension, removal, or disposal of contaminated sediment; and providing community and health professional education about the PCB contamination.

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 efforts with TDOH, TDEC, the National Center for Environmental Health (NCEH), the National Institute for Occupational Safety and Health (NIOSH), and DOE. This effort led to the establishment of the Public Health Working Group in 1999, which led to the establishment 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 has also obtained and interpreted studies prepared by academic institutions, consulting firms, community groups, and other parties.

- *Oak Ridge Reservation Health Effects Subcommittee.* ORRHES was created to provide a forum for communication and collaboration between citizens and the agencies that are evaluating public health issues and conducting public health activities at the ORR. The ORRHES was established in 1999 by ATSDR and Centers for Disease Control and Prevention (CDC) under the authority of the Federal Advisory Committee Act (FACA) 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 consists of individuals who represent diverse interests, expertise, backgrounds, and communities, as well as liaison members from state and federal agencies. To help ensure citizen participation, meetings of the Subcommittee's work groups are open to the public and anyone may attend and present ideas and opinions. The Subcommittee performs the following functions:

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

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

- Helps to prioritize the public health issues and community concerns to be evaluated by ATSDR.

Figure 4 shows the organizational structure of the ORRHES, and Figure 5 provides a chart that graphically demonstrates the process of providing input into the public health assessment process. For more information on the ORRHES, visit the ORRHES Web site at http://www.atsdr.cdc.gov/HAC/oakridge/index.html.

- *ORRHES Work Groups*. The ORRHES may create various work groups to conduct in-depth exploration of specific issues and present findings to the Subcommittee for deliberation. Work group meetings are open to all who wish to attend and participate. The following ORRHES work groups were established:

  - Agenda Work Group
  - Communications and Outreach Work Group
  - Health Education Needs Assessment Work Group
  - Public Health Assessment Work Group
  - Guidelines and Procedures Work Group

- *ATSDR Field Office*. In 2001, ATSDR opened a field office in Oak Ridge. The office was opened to promote collaboration between ATSDR and communities surrounding the ORR by providing community members with opportunities to become involved in ATSDR's public health activities at the ORR. The ATSDR field office is located at 1975 Tulane Avenue, Oak Ridge, Tennessee. ATSDR field office staff can be contacted by calling 865-220-0295.

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 B, 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 for the ORR, along with publications from other agencies, can be viewed in records repositories at the Oak Ridge Public Library, the DOE Information Center in Oak Ridge, and the TDOH. For directions to these repositories, please contact the ATSDR Oak Ridge field office at 865-220-0295.

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 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/c_toc.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 4. Organizational Structure for the Oak Ridge Reservation Health Effects Subcommittee

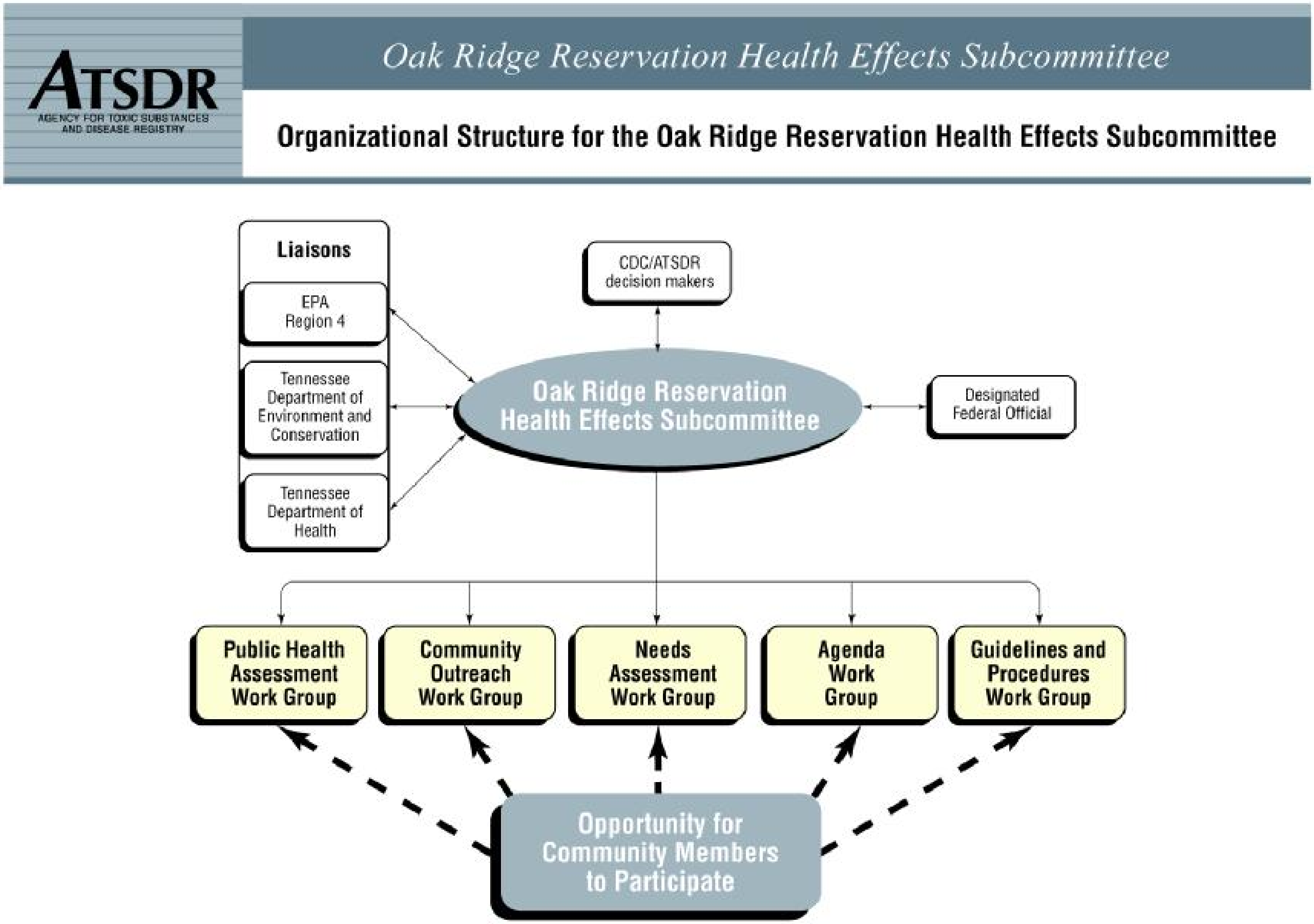
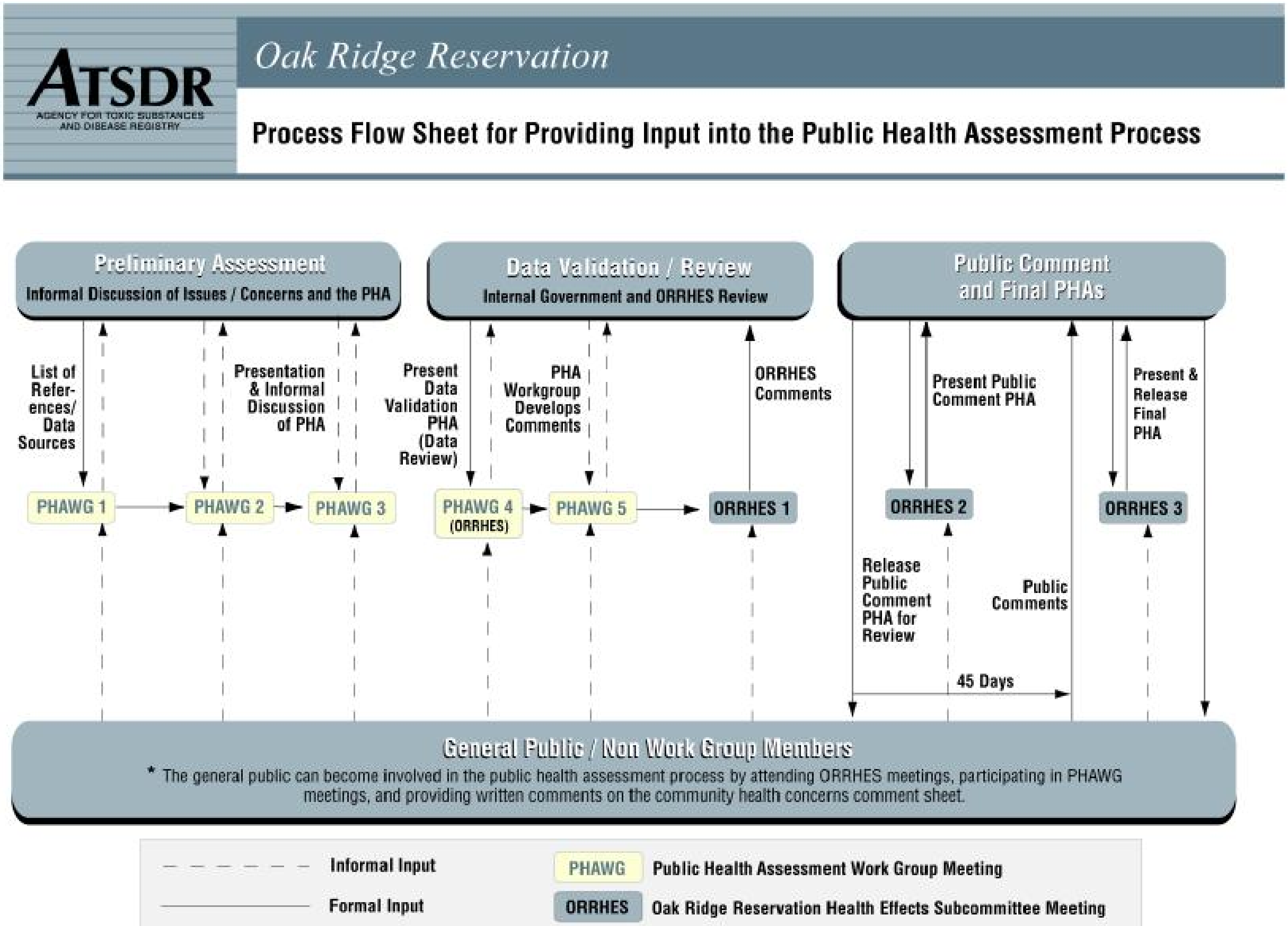


Figure 5. Process Flow Sheet for Providing Input into the Public Health Assessment



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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).

- *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.

  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 may have been responsible 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 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.

- *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 substances that had not been fully characterized in Phase I. The significant findings for each of the substances evaluated 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 an increased risk of developing thyroid cancer. The report stated that children living within a 25-mile radius of Oak Ridge were likely to have had an increased risk of more than 1 in 10,000 of developing thyroid cancer.

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

> 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 their lifetime without experiencing 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. Eight radionuclides (cesium 137, ruthenium 106, strontium 90, cobalt 60, cerium 144, zirconium 95, niobium 95, and iodine 131) deemed more likely to carry significant risks were studied. The results indicate that the releases caused small increases in the radiation dose of individuals who consumed fish from the Clinch River near the mouth of White Oak Creek. The dose reconstruction scientists estimated that a man who ate up to 130 meals of fish from the mouth of White Oak Creek every year for

50 years (worst-case scenario) would face an excess cancer risk ranging from 4 to 350 in 100,000. The risk from eating fish goes down proportionately for people who eat fewer fish and for people who eat fish caught farther downstream.

- 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 were slightly below the decision guide of one chance in 10,000, which indicated that more work may be needed to better characterize uranium releases and possible heath risk.

➢ *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. Based on 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 ORR were likely to have affected the health of 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 ORR in the 1950s and early 1960s. The Panel made eight recommendations in their project summary report:

1. Three specific initiatives directed to public health intervention should be undertaken:

    a) In partnership with a local college or university, a series of workshops should be periodically conducted for local physicians and other health professionals who need to be educated on ORR environmental and occupational health issues arising from the Oak Ridge Health Agreement Studies and other related health studies, as results become available.

b) In partnership with a local community college or community outreach program, a public information colloquium should be conducted to provide continuing dialogue and education on environmental and occupational health issues relevant to past, current, and future ORR operations.

c) A partnership working group of local, state, and federal public health officials, health care professionals and representatives of the greater Oak Ridge community should be established to evaluate the need for a formal clinical evaluation process. If such a process is determined to be feasible, the group should formulate recommendations for the development of (1) a goal for a formal community clinical evaluation process; (2) the types of and qualifications for health care professionals who would be involved in the clinical evaluations of concerned members of the community; and (3) protocol guidelines for individual clinical evaluations and referral for follow-up examinations. The group suggested that the results contained in this report and the other reports published as part of the Oak Ridge Health Agreement Studies serve as a basis for the development of such protocol guidelines.

2. Formal epidemiologic studies of populations exposed to iodine 131, mercury, PCBs, and radionuclides from White Oak Creek are unlikely to be successful and should not be performed at this time.

3. DOE, EPA, the state (and perhaps other agencies) should undertake a coordinated program to obtain needed information and satisfy stakeholder concerns. A soil sampling program is vital to gain information relevant to the historic contamination levels in residential areas closest to the ORR plants. Detailed sampling is recommended in all of the most closely situated neighborhoods and also in a few residential areas at greater distances. Any decision about additional dose reconstruction studies should be deferred until the results of the

recommended soil sampling program have been obtained and carefully interpreted.

4. DOE should undertake a program to measure the atmospheric dispersion of controlled tracer releases from representative stacks and vents at Y-12. The primary goal of these measurements would be to define the transport of a nondepositing tracer such as SF6 from the Y-12 plant to populated areas of Oak Ridge, including the Scarboro and Woodland communities, which are both relatively close to the plant.

5. More definitive information is needed to better understand the potential toxic effects of exposures to mixtures of contaminants—mercury and PCBs, for example—on the same organ systems. Studies relating to this topic should be undertaken by one or more appropriate government-sponsored public health research agencies.

6. DOE should take action to assure that copies of the important documents used in the health effects studies are properly indexed and retained at a secure location, irrespective of future shifts of contractor responsibility at the ORR facilities.

7. DOE should assure the long-term continuation of the ORR environmental monitoring program. The program should include routine measurements in critical media for those materials found to be most important in the health agreement studies, if the material in question could still be present in the local environment. Specifically, the ORR program should (a) continue to monitor the remaining environmental burden of mercury in EFPC within the Y-12 plant, in the lower EFPC floodplain, and in sediment in the downstream watercourses, tracking the resulting methyl mercury risk to consumers of fish taken from downstream fisheries; and (b) assure that the program continues to monitor uranium contamination originating from Y-12, with due consideration of isotopic form.

8. In the area of statewide health effects registries, (a) the state should continue efforts to improve the accuracy and completeness of the cancer incidence registry, and (b) the state should continue to seek funding for a statewide birth defects registry.

- *Feasibility of Epidemiologic Studies*. A study was conducted to explore the feasibility of initiating analytical (for example, case-control or cohort) epidemiological studies to address potential health concerns in the off-site populations surrounding the ORR. TDOH and the ORHASP contracted with a physician from Vanderbilt University's Department of Preventive Medicine to conduct the study. The study was released in July 1996. The study concluded that the feasibility and desirability of initiating future analytical epidemiologic studies would be significantly influenced by the findings of the dose reconstruction studies which will clarify the extent and magnitude of releases and possible human exposure from past releases of radioactive iodine, mercury, PCBs, uranium, and other radionuclides, including cesium 137.

- *Public Meetings*. Between January 1992 and December 1999, TDOH and ORHASP held open meetings in Oak Ridge (more than 40 meetings), Nashville (5 meetings), Harriman (2 meetings), and Knoxville (3 meetings). In addition, the ORHASP held two meetings in the Scarboro area to update the residents on Phase II of the Oak Ridge Health Studies. The first meeting was held at the Oak Valley Baptist Church in November 1995, and the second meeting was held at the Scarboro Community Center in September 1997.

II.F.3. Other Agencies

Scarboro Community Health Investigation. In November 1997, a Nashville newspaper published an article about illnesses among children living near the nuclear weapons facility at the ORR in eastern Tennessee. The article described a high rate of respiratory illness among residents of the nearby community of Scarboro; it told of 16 children who had repeated episodes of "severe ear, nose, throat, stomach, and respiratory illnesses." Among those respiratory illnesses were asthma, bronchitis, sinusitis, allergic rhinitis, and otitis media. The article implied that exposure to the

ORR caused these illnesses especially given the proximity of these children's residences to ORR facilities. In response to this article, the Commissioner of the TDOH asked the CDC to work with the department to investigate the situation in Scarboro. The Scarboro Community Health Investigation, which included a community health survey and a follow-up medical evaluation of children under 18 years of age, was coordinated by TDOH to investigate a reported excess of respiratory illness among children in the Scarboro community. This investigation, both the survey and the examination components, was mainly designed to measure the rates of common respiratory illnesses among children who reside in Scarboro, compare these rates with national rates, and to determine if there were any unusual characteristics of these illnesses. The investigation was not designed to find what caused the illnesses.

In 1998, a study protocol was developed and a community health survey was administered to the members of each household in the community. The purpose of the survey was to determine whether the rates of certain diseases were higher in Scarboro than elsewhere in the United States and to determine whether exposure to various factors increased residents' risk for health problems. In addition, information regarding occupations, occupational exposures, and general health concerns was collected for adults. The participation/response rate of the health investigation survey was 83% (220/264 households) and included 119 questionnaires about children living in these households and 358 questionnaires about adults. In September 1998, CDC released the preliminary results of the survey. The asthma rate was 13% among children in Scarboro, compared to national estimates of 7% among all children aged 0–18 years and 9% among African American children aged 0–18 years. The Scarboro rate was, however, within the range of rates from 6% to 16% reported in similar studies throughout the United States. The wheezing rate among children in Scarboro was 35%, compared to international estimates that range from 1.6% to 36.8%. With the exception of unvented gas stoves, no statistically significant association was found between exposure to common environmental triggers of asthma (that is, pests, environmental tobacco smoke, and the presence of dogs or cats in the home) or potential occupational exposures (such as living with an adult who works at the ORR or living with an adult who works with dust and fumes and brings exposed clothes home for laundering), and asthma or wheezing illness.

Based on the information obtained in the health investigation survey, 36 children, including those identified in the media report, were invited to receive a physical examination. These examinations were conducted in November and December 1998 to confirm the results of the community survey, to determine whether children with respiratory illnesses were getting the medical care they needed, and to determine whether the children reported in the newspaper to have respiratory medical problems really had these problems. Children who were invited to participate met one or more conditions: (1) severe asthma, defined as more than 3 episodes of wheezing or visiting an emergency room because of these symptoms; (2) severe undiagnosed respiratory illness, defined as more than 3 episodes of wheezing and visiting an emergency room because of these symptoms; (3) respiratory illness and no regular source of medical care; or (4) identified as having respiratory illness in newspaper reports. Of the 36 children invited, 23 participated in the physical examination. Some of the eligible 36 children had moved out of Scarboro; others either were not available or decided not to participate.

During the physical examination, nurses asked children who participated and their parents a series of questions about the health of the child; volunteer pediatricians reviewed the results of the nurse interview and examined the children. In addition to direct physical examinations, children also underwent a blood test and a special breathing test. If the examining doctor thought the child needed an x-ray to complete the assessment, this was done. All examinations, tests, and transportation to and from Knoxville were provided free of charge.

Immediately after the examinations, the results were reviewed and none of the children had findings that needed immediate intervention. A number of laboratory tests were found to be either above or below the normal range, such as blood calcium level, blood hemoglobin level, or breathing test abnormality. Following the initial review of results, laboratory results were communicated by letter or telephone to the parents of the children and their doctors. If the parents did not want the results sent to a doctor, the results were given to the parents by telephone. The parents of children with any health concern identified as a result of the examination were sent a personal letter from Paul Erwin, M.D., of the East Tennessee Regional Office of the TDOH, informing them of the need for follow-up with their medical provider. If they did not have a medical provider, they were to contact Brenda Vowell, RNC, Public Health

Nurse, East Tennessee Regional Office of the TDOH, for help in finding a provider and possible TennCare or Children's Special Service.

In January 1999, a team of physicians representing CDC, TDOH, the Oak Ridge medical community, and the Morehouse School of Medicine, thoroughly reviewed the findings of the physical examinations and the community survey. Of the 23 children who were examined, 22 had evidence of some form of respiratory illness (reported during the nurse interview or discovered during the doctor's examination). Overall, the children appeared healthy and no problems that needed urgent management were identified. Several children had mild respiratory illnesses at the time of the examination; only one child had findings of an abnormality of the lungs at the time of the examination. None of the children had wheezing. The examinations did not indicate any unusual pattern of illness among children in Scarboro. The illnesses that were detected were not more severe than would be expected and were typical of those that might be found in any community. The findings of examinations essentially confirmed the results of the community health survey. The results of the review were presented on January 7, 1999, at a community meeting in Scarboro. The final report was released in July 2000.

Three months after the letters went to the parents and physicians about the findings, attempts were made to telephone the parents of children who participated. Eight parents were successfully contacted. Because some of the parents had more than one child who was examined, questions addressed the health of 14 children. Parents of nine children could not be contacted despite attempts on several days to contact them by telephone.

Of the 14 children whose parents had been contacted, 7 had seen a doctor since the examinations. In most cases, the health of the child was the about the same, although one child had been hospitalized because of asthma, and another child's asthma medication had been increased to treat worsening asthma. Several children had nasal allergies, and several parents mentioned difficulties in obtaining medicines because of cost and lack of coverage by TennCare for the particular medicines. Health department nurses subsequently have assisted these parents in getting the needed medicines.

Scarboro Community Environmental Study. In 1998, soil, sediment, and surface water were sampled in the Scarboro community to address community concerns about environmental monitoring in the Scarboro neighborhood. The analytical component of the study was conducted by the Environmental Sciences Institute at Florida Agricultural and Mechanical University (FAMU) and 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, and by DOE subcontractors in the Neutron Activation Analysis Group at the Oak Ridge National Laboratory. Organic compounds were only detected in one of the samples tested. This same sample also contained lead and zinc at concentrations twice as high as that found in the Background Soil Characterization Project (DOE 1993). Mercury was found within the range given in the Background Soil Characterization Project, and about 10% of the soil samples showed evidence of enrichment in uranium 235. The final Scarboro Community Environmental Study was released in September 22, 1998, during a Scarboro community meeting (FAMU 1998).

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). A draft report was released in September 2002 (EPA 2002b). EPA concluded that the results support the sampling performed by FAMU in 1998, and that the residents of Scarboro are not currently being exposed to harmful levels of substances from the Y-12 plant.

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, the 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. On the basis of ATSDR's review and analysis of 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 evaluations. The public health assessment is the primary public health process ATSDR is using to further evaluate these contaminants. The public health assessment process will

1. Identify populations off the site who may have been exposed to hazardous substances at levels of health concern.
2. Determine the public health implications of the exposure.
3. Address the health concerns of people in the community.
4. Recommend follow-up public health actions or studies to address the exposure.

ATSDR scientists are conducting public health assessments on the following releases: Y-12 releases of uranium, Y-12 releases of mercury, X-10 release of iodine 131, X-10 release of radionuclides from White Oak Creek, K-25 releases of uranium and fluoride, and PCBs released from all three facilities. 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. ATSDR is also screening current (1990 to 2003) environmental data to determine whether additional chemicals will require further evaluation.

This public health assessment on the Y-12 uranium releases evaluates and analyzes the information, data, and findings of previous studies and investigations of releases of uranium from the Y-12 plant and assesses the health implications of past and current uranium exposures to residents living near the ORR, specifically the residents of the reference community (that is, Scarboro).

III.A.1. Exposure Evaluation

What is meant by exposure?

ATSDR's public health assessments are driven by exposure or contact. Contaminants (chemicals or radioactive materials) released into the environment have the potential to cause harmful health effects. Nevertheless, a release does not always result in exposure. People can only be exposed to a chemical contaminant if they come into contact with that contaminant. If no one comes into contact with a contaminant, then no exposure occurs, and thus no health effects could occur. Often the general public does not have access to the source area of contamination or areas where contaminants are moving through the environment. This lack of access to these areas becomes important in determining whether people could come into contact with the contaminants.

> An exposure pathway has five elements: (1) a source of contamination, (2) an environmental media, (3) a point of exposure, (4) a route of human exposure, and (5) a receptor population. The source is the place where the chemical or radioactive material was released. The environmental media (such as, groundwater, soil, surface water, or air) transport the contaminants. The point of exposure is the place where persons come into contact with the contaminated media. The route of exposure (for example, ingestion, inhalation, or dermal contact) is the way the contaminant enters the body. The people actually exposed are the receptor population.

However, 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 route of a contaminant's movement is the pathway. ATSDR identifies and evaluates exposure pathways by considering how people might come into contact with a contaminant. An exposure pathway could involve air, surface water, groundwater, soil, dust, or even plants and animals. Exposure can occur by breathing, eating, drinking, or by skin contact with a substance containing the chemical contaminant. Exposure to radiation can occur by being near the radioactive material.

How does ATSDR determine which exposure situations to evaluate?

ATSDR scientists evaluate site-specific conditions to determine whether people are being exposed to site-related contaminants. When evaluating exposure pathways, ATSDR identifies whether exposure to contaminated media (soil, water, air, waste, or biota) is occurring through ingestion, dermal (skin) contact, or inhalation.

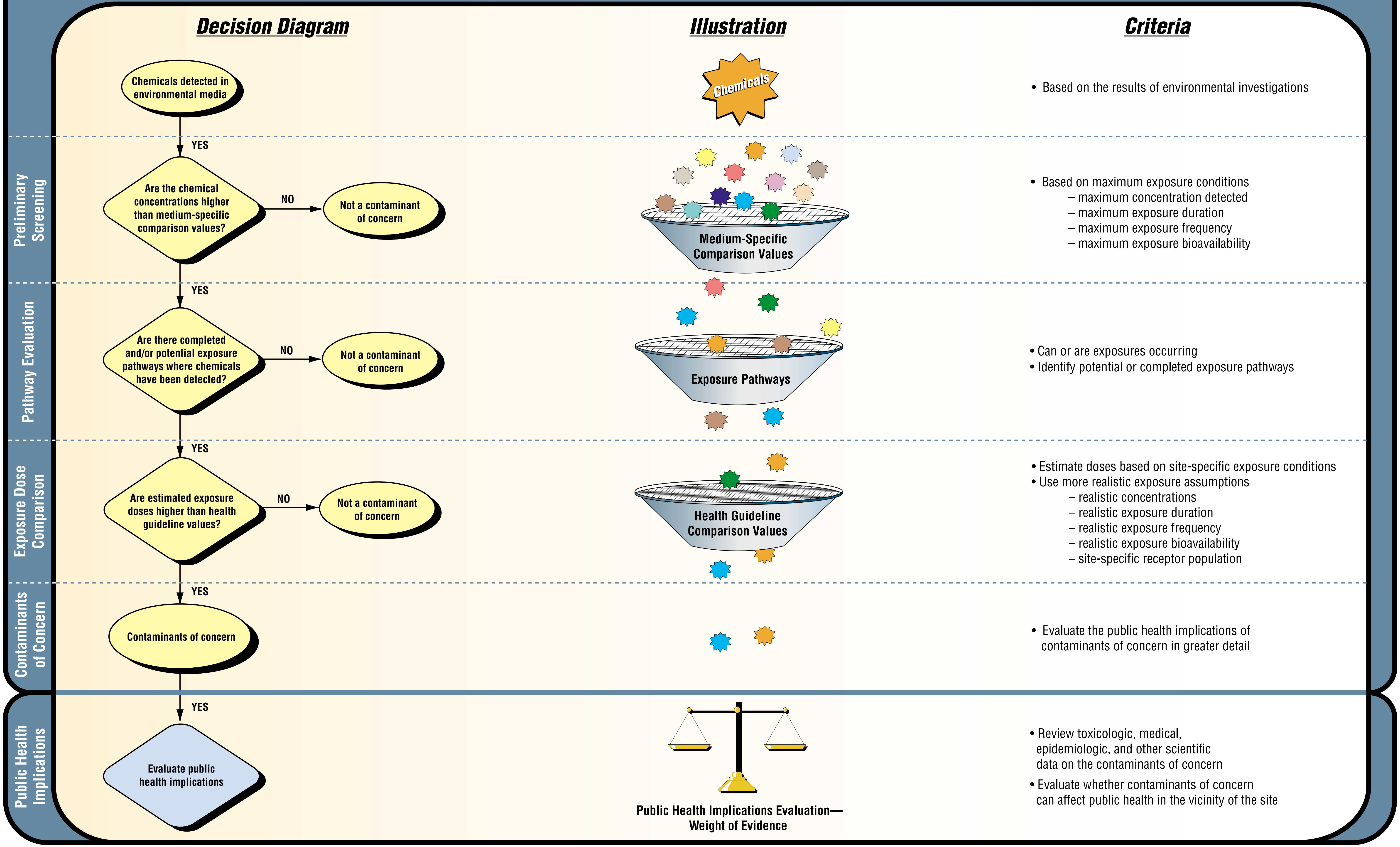
If exposure is possible, ATSDR scientists then consider whether environmental contamination is present at levels that might affect public health. ATSDR evaluates environmental contamination using available environmental sampling data and, in some cases, modeling studies. ATSDR selects contaminants for further evaluation by comparing environmental contaminant concentrations against **health-based comparison values**. Comparison values are developed by ATSDR from available scientific literature concerning exposure and health effects. Comparison values are derived for each of the media and reflect an estimated contaminant concentration that is not expected to cause harmful health effects for a given contaminant, assuming a standard daily contact rate (for example, the amount of water or soil consumed or the amount of air breathed) and representative body weight.

> A comparison value is used by ATSDR to screen chemicals that require additional evaluation.

Comparison values are not thresholds for harmful health effects. ATSDR comparison values represent contaminant concentrations that are many times lower than levels at which no effects were observed in studies on experimental animals or in human epidemiologic studies. If contaminant concentrations are above comparison values, ATSDR further analyzes exposure variables (such as site-specific exposure, duration, and frequency) for health effects, including the toxicology of the contaminant, other epidemiology studies, and the weight of evidence. Figure 6 illustrates ATSDR's chemical screening process.

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/HAGM/ or by contacting ATSDR at 1-888-42-ATSDR.

Figure 6. ATSDR Chemical Screening Process



If someone is exposed, will they get sick?

Exposure does not always result in harmful health effects. The type and severity of health effects that occur in an individual as the result of contact with a contaminant depend on the exposure concentration (how much), the frequency (how often) and 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 exposure occurs, characteristics such as age, sex, nutritional status, genetics, lifestyle, and health status of the exposed individual influence how that individual absorbs, distributes, metabolizes, and excretes the contaminant. Taken together, these factors and characteristics determine the health effects that can occur as a result of exposure to a contaminant in the environment.

III.A.2. Evaluating Exposure

To evaluate exposures to the reference population, Scarboro, ATSDR evaluated available past and current data to determine whether uranium concentrations were above natural background levels and/or ATSDR's comparison values. In the case of radiation doses, ATSDR calculated the doses based on site-specific data obtained from various environmental investigations and exposure factor sources. ATSDR also reviewed relevant toxicologic and epidemiologic data to obtain information about the toxicity of uranium (discussed in Appendix C). Both the chemical and radioactive properties of uranium can be harmful, and therefore they are evaluated separately.

It is important to remember that exposure to a certain contaminant does not always result in harmful health effects. The type and severity of health effects expected to occur depend on the exposure concentration, the toxicity of the contaminant, the frequency and duration of exposure, and the multiplicity of exposures.

Comparing Environmental Data to ATSDR's Comparison Values

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.

Comparison values are derived using conservative exposure assumptions and health-based doses. Comparison values reflect concentrations that are much lower than those that have been observed to cause adverse health effects. Thus, comparison values are protective of public health in essentially all exposure situations. As a result, **concentrations detected at or below ATSDR's comparison values are not considered to warrant health concern**. While concentrations at or below the relevant comparison value can reasonably be considered safe, it does not automatically follow that any environmental concentration exceeding a comparison value would be expected to produce adverse health effects. **It cannot be emphasized strongly enough that comparison values are not thresholds of toxicity.** 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.

When evaluating chemical effects of uranium exposure, ATSDR scientists used comparison values that are specific to each environmental media. The comparison values used are shown in Table 2.

Table 2. Comparison Values for Uranium

Media	Comparison Value	Source
Air	0.3 μg/m^3	Chronic EMEG for highly soluble uranium salts
Surface water	20 μg/L	Intermediate child EMEG for highly soluble uranium salts
Soil	100 mg/kg	Intermediate child EMEG for highly soluble uranium salts
Fish	4.1 mg/kg	RBC for soluble uranium salts

μg/m^3: microgram per cubic meter
μg/L: microgram per liter
mg/kg: milligram per kilogram

ATSDR's environmental media evaluation guides (EMEGs) are nonenforceable, health-based comparison values developed for screening environmental contamination for further evaluation. EPA's risk-based concentration (RBC) is a health-based comparison value developed to screen sites not yet on the NPL, respond rapidly to citizens' inquiries, and spot-check formal baseline risk assessments.

Comparing Estimated Doses to ATSDR's Minimal Risk Level and Other Comparison Values

Deriving exposure doses

> A toxicologic dose is the amount of chemical a person is exposed to over time. The radiation dose is the amount of energy from radiation that is actually absorbed by the body.

Exposure doses are expressed in milligrams per kilogram per day (mg/kg/day). When estimating exposure doses, health assessors evaluate chemical concentrations to which people could have been exposed, together with the length of time and the frequency of exposure. Collectively, these factors influence an individual's physiological response to chemical exposure and potential outcomes. Where possible, ATSDR used site-specific information regarding the frequency and duration of exposures. When site-specific information was not available, ATSDR employed several conservative exposure assumptions to estimate exposures.

The following equation was used to estimate uranium chemical doses via ingestion from the surface water and soil pathways: Dose = Intake / Body Weight, where intake is defined as the concentration times the intake rate (Conc × IR); an adult male was assumed to weigh 78 kilograms (kg), an adult female was assumed to weigh 71 kg, a 12-year-old child was assumed to weigh 45 kg, and a 6-year-old child was assumed to weigh 23 kg. The adult body weights are representative of the average African American man and woman age 18–74 (National Center for Health Statistics 1987 as cited in EPA 1997). The child body weights are representative of an average 12-year-old and 6-year-old child (all races, both genders) (National Center for Health Statistics 1987 as cited in EPA 1997).

Minimal Risk Level

When evaluating chemical effects, ATSDR also derived toxicologic doses that residents living near the site may have received and compared these estimated site-specific doses against

ATSDR's minimal risk levels (MRLs). MRLs are based on noncancer health effects only and are not based on a consideration of cancer effects. MRLs are derived when reliable and sufficient data exist to identify the target organs of effect or the most sensitive health effects for a specific duration for a given route of exposure. Proposed MRLs undergo a rigorous review process: Health Effects/MRL workgroup reviews within ATSDR's Division of Toxicology; expert panel of external peer reviews; and agency-wide MRL workgroup reviews, with participation from other federal agencies, including EPA; and are then submitted for public comment.

An MRL is an estimate of the daily human exposure to a hazardous substance that is likely to be without appreciable risk of adverse *noncancer* health effects over a specified duration of exposure. These substance-specific estimates, which are intended to serve as screening levels, are used by ATSDR health assessors to identify contaminants and potential health effects that are not expected to cause adverse health effects. It is important to note that MRLs are not intended to define clean-up or action levels. MRLs are intended only to serve as a screening tool to help public health professionals decide where to look more closely.

MRLs are derived for hazardous substances using the no-observed-adverse-effect level (NOAEL)/uncertainty factor approach. They are below levels that might cause adverse health effects in the people most sensitive to such effects. Most MRLs contain a degree of uncertainty because of the lack of precise toxicologic information on the people who might be most sensitive (for example, infants, the elderly, or persons who are nutritionally or immunologically compromised) to the effects of hazardous substances. Consistent with the public health principle of prevention, ATSDR uses a conservative (that is, protective) approach to address this uncertainty.

MRLs are generally based on the most sensitive end point considered to be of relevance to humans. Serious health effects (such as birth defects or irreparable damage to the liver or kidneys) are not used as a basis for establishing MRLs. Exposure to levels above the MRL does not mean that adverse health effects will occur. Estimated doses that are less than these values are not considered to be of health concern. To maximize human health protection, MRLs have built-in uncertainty or safety factors, making these values considerably lower than levels at which health effects have been observed. The result is that even if a dose is higher than the MRL, it does not necessarily follow that harmful health effects will occur.

Table 3 shows the MRLs developed for uranium. Figure 7 shows ATSDR's process of determining radiological doses. More detailed information is available in two ATSDR publications, the Toxicological Profile for Uranium (ATSDR 1999a) and the Toxicological Profile for Ionizing Radiation (ATSDR 1999b). Additional information about the toxicologic implications of uranium exposure is provided in Appendix C.

Other Comparison Values

When evaluating the carcinogenic effects of radiation from uranium exposure, ATSDR scientists use the dose of 5,000 millirem (mrem) over 70 years as the radiogenic cancer comparison value. This value is a committed effective dose equivalent (CEDE) calculated from the intake of uranium, with the assumption that the entire dose (a 70-year dose, in this case)[3] is received in the first year following the intake. ATSDR believes the radiogenic cancer comparison value of 5,000 mrem over 70 years is protective of human health. ATSDR derived this value after reviewing the peer-reviewed literature and other documents developed to review the health effects of ionizing radiation (see Appendix D for more information about ATSDR's derivation of the radiogenic cancer comparison value of 5,000 mrem over 70 years).

> The committed effective dose equivalent (CEDE) is the radiation dose accumulated over a 70-year exposure and assuming the entire 70-year dose is received in the first year following intake of a radioactive substance. By definition, the CEDE is 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 CEDE is used in radiation safety because it implicitly includes the relative carcinogenic sensitivity of the various tissues.

[3] In this case, the entire dose is the dose a person would receive over 70 years of exposure. ATSDR chose a 70-year period of exposure to be protective of public health.

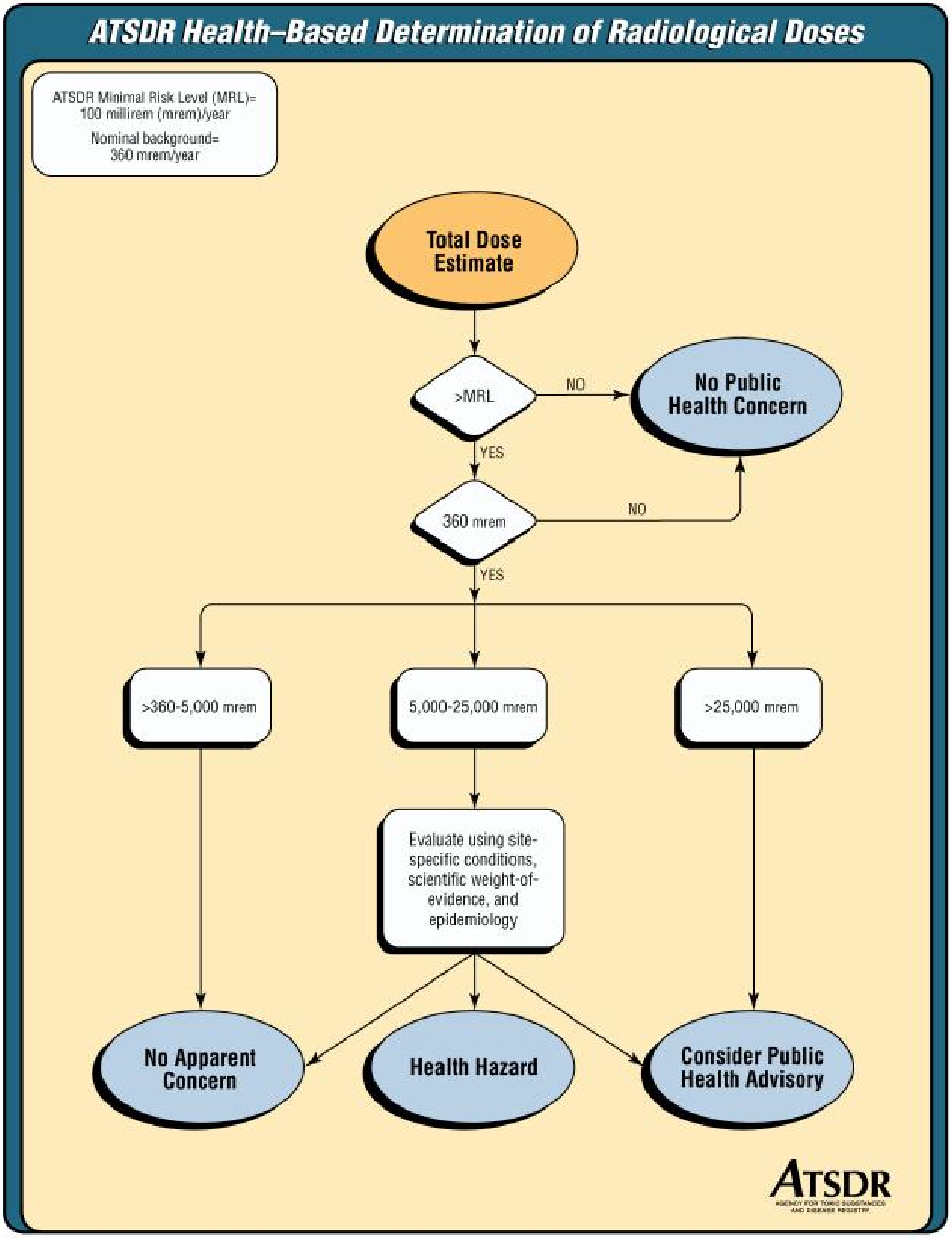
Table 3. ATSDR's Minimal Risk Levels (MRLs) for Uranium

Route	Duration	Form	MRL Value	Dose Endpoint	Source
Inhalation	Intermediate	Soluble	0.0004 mg/m^3	LOAEL; Minimal microscopic lesions in the renal tubules in half the dogs examined were observed at doses of 0.15 mg/m^3.	Rothstein 1949a
Inhalation	Intermediate	Insoluble	0.008 mg/m^3	NOAEL; No adverse health effects were observed in dogs exposed to doses of 1.1 mg/m^3.	Rothstein 1949b
Inhalation	Chronic	Soluble	0.0003 mg/m^3	NOAEL; No adverse health effects were observed in dogs exposed to doses of 0.05 mg/m^3.	Stokinger et al. 1953
Oral	Intermediate		0.002 mg/kg/day	LOAEL; Renal toxicity was observed in rabbits exposed to doses of 0.05 mg/kg/day.	Gilman et al. 1998b
External Radiation	Acute	Ionizing Radiation	400 mrem	NOAEL; The difference of 0.3 IQ point in intelligence test scores between separated and unseparated identical twins is considered the NOAEL.	Burt 1966
External Radiation	Chronic	Ionizing Radiation	100 mrem/year	NOAEL; The annual dose of 360 mrem/year has not been associated with adverse health effects in humans or animals.	BEIR V 1990

Source: ATSDR 1999a, 1999b

Acute duration is defined as less than or equal to 14 days.
Intermediate duration is defined as 15 to 364 days.
Chronic duration is defined as exposures exceeding 365 days.
The no-observed-adverse-effect level (NOAEL) is the highest dose of a chemical in a study, or group of studies, that did not cause harmful health effects in people or animals.
The lowest-observed-adverse-effect level (LOAEL) is the lowest dose of a chemical in a study, or group of studies, that has caused harmful health effects in people or animals.
The MRL level for intermediate-duration oral exposure is also protective for chronic-duration oral exposure. This is because the renal effects of uranium exposure are more dependent on the dose than on the duration of the exposure.
The rabbit is the mammalian species most sensitive to uranium toxicity and is likely to be even more sensitive than humans.
mg/m^3: milligram per cubic meter
mg/kg/day: milligram per kilogram per day
mrem: millirem
mrem/year: millirem per year

Figure 7. ATSDR Health-Based Determination of Radiological Doses



III.B. Public Health Evaluation

ATSDR evaluated past and current exposure to uranium contamination released from the Y-12 plant and found that the levels that people were exposed to were too low to be of health concern for both radiation and chemical health effects.

III.B.1. Past Exposure (1944–1995)

ATSDR used the screening results from the Task 6 report to evaluate past uranium releases to the environment from the Y-12 plant and past uranium exposures to residents living near the Y-12 plant. The Scarboro community located within the city of Oak Ridge was selected as a reference location to estimate concentrations of uranium in the air, surface water, and soil in an off-site area where residents resided during years of past Y-12 plant uranium releases. The Task 6 team identified Scarboro as the reference location using air dispersion modeling, specifically EPA's Industrial Source Complex Short Term (ISCST3) dispersion model, Version 96113 (USEPA 1995 as cited in ChemRisk 1999). Ground-level uranium air concentrations were estimated for a 40 by 47 kilometer grid to quantitatively relate past Y-12 plant uranium release rates to resulting average airborne uranium concentrations at locations surrounding the reservation. Using this method, the Task 6 team was able to identify off-site locations with the highest estimated uranium air concentrations. The Task 6 report stated that "while other potentially exposed communities were considered in the selection process, the reference locations [Scarboro] represent residents who lived closest to the ORR facilities and would have received the highest exposures from past uranium releases…Scarboro is the most suitable for screening both a maximally and typically exposed individual" (ChemRisk 1999). Scarboro represents an established community surrounding the Y-12 plant with the highest estimated uranium air concentrations.

ATSDR evaluated both the radiation and chemical aspects of past uranium exposure. Neither the total radiation dose[4], nor the chemical ingestion and inhalation doses from exposure to

[4] The total radiation dose for past exposures is the sum of both internal and external exposures to the air, surface water, and soil pathways.

uranium released from the Y-12 plant in the past would cause harmful health effects for people living near ORR, including those in the Scarboro community.

III.B.1.a. Past Radiation Effects

ATSDR evaluated whether exposure to past levels of uranium released from the Y-12 plant would cause harmful radiation effects in communities near the Y-12 plant, especially the reference location (the Scarboro community), which is considered the area that would have received the highest exposures. The total past uranium dose received by the reference population (155 mrem, discussed in the next paragraph) is well below levels of health concern and is not expected to have caused any adverse health effects in the past.

During the development of the Task 6 report, uranium radiation doses from the air, surface water, and soil pathways were estimated for the reference location, Scarboro, using a 52-year exposure scenario (Figure 8 shows the exposure pathways evaluated). To evaluate potential radiation health effects to the population in Scarboro, ATSDR adjusted the Task 6 committed effective dose equivalents (CEDEs) to be equivalent to a 70-year exposure (see Table 4).[5] The total past uranium radiation dose received by the reference population, the Scarboro community, from multiple routes of internal and external exposure pathways is a CEDE of 155 millirem (mrem) over 70 years. This total past radiation dose (CEDE of 155 mrem over 70 years) is well below (32 times less than) the ATSDR radiogenic cancer comparison value of a CEDE of 5,000 mrem over 70 years (see Figure 9). ATSDR derived this radiogenic cancer comparison value after reviewing the peer-reviewed literature and other documents developed to review the health effects of ionizing radiation (Appendix D provides more information about ATSDR's derivation of the radiogenic cancer comparison value of 5,000 mrem over 70 years). This radiogenic cancer comparison value assumes that from the intake of uranium, the entire radiation dose (a 70-year dose, in this case) is received in the first year following the intake. ATSDR believes this radiogenic cancer comparison value to be protective of human health and, therefore, does not

[5] The Task 6 level II committed effective dose equivalents (CEDEs) were converted from Sievert (Sv) to mrem by multiplying by 10^5. These CEDE values were then multiplied by 1.35 (70 years/52 years) for comparison with the ATSDR radiogenic cancer comparison value, which is based on a 70-year exposure.

expect carcinogenic health effects to have occurred from past radiation doses received from past Y-12 uranium releases.

To evaluate noncancer health effect from the total past uranium radiation dose (CEDE of 155 mrem over 70 years) received by the Scarboro community, an approximation can be made to compare the CEDE of 155 mrem, which is based on 70 years of exposure, to the ATSDR chronic exposure MRL for ionizing radiation (100 mrem/year) which is based on one year of exposure. The CEDE of 155 mrem over 70 years could be divided by 70 years to approximate a value of 2.2 mrem as the radiation dose in the first year which is well below (45 times less than) the 100 mrem/year ATSDR chronic exposure MRL for ionizing radiation (see Figure 9). The ATSDR MRLs are based on noncancer health effects only and are not based on a consideration of cancer effects. The ATSDR MRL of 100 mrem/year for chronic ionizing radiation exposure is derived by dividing the average annual effective dose to the U.S. population (360 mrem/year) by a safety factor of 3 to account for human variability (ATSDR 199b). The average U.S. annual effective dose of 360 mrem/year is obtained mainly from naturally occurring radioactive material, medical uses of radiation, and radiation from consumer products (see Figure 9) (BEIR V 1990 as cited in ATSDR 1999b). This average annual background effective dose of 360 mrem/year has not been associated with adverse health effects in humans or animals (ATSDR 1999b). ATSDR believes the chronic ionizing radiation MRL of 100 mrem/year is below levels that might cause adverse health effects in persons most sensitive to such effects; therefore, ATSDR does not expect noncancer health effects to have occurred from radiation doses received from past Y-12 uranium releases.

Table 4. Total Past Uranium Radiation Dose to the Scarboro Community

Exposure Pathway	Isotope	Committed Effective Dose Equivalents (CEDE) in mrem	Total CEDE for Each Exposure Pathway (mrem)
Sum of doses from the air pathway	U 234/235	34	40
	U 238	6	
Sum of doses from the surface water (EFPC) pathway	U 234/235	27	49
	U 238	22	
Sum of doses from the soil pathway	U 234/235	38	66
	U 238	28	
Total across all media	U 234/235	99	**155**
	U 238	56	

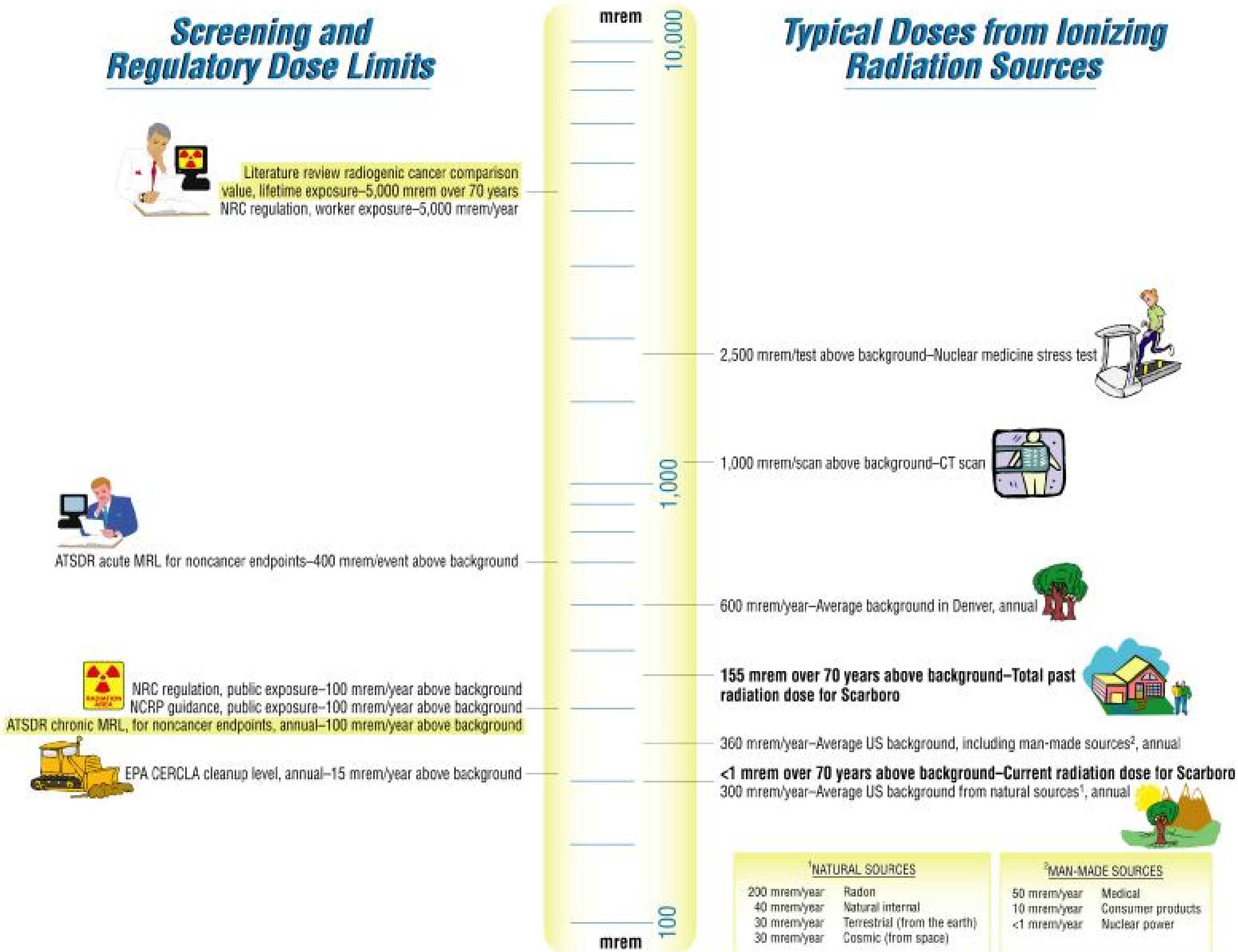
Source: ChemRisk 1999

The Task 6 level II CEDEs were converted from Sievert (Sv) to mrem by multiplying by 10^5. In addition, the values were multiplied by 1.35 (i.e., 70 years/52 years) for comparison with the ATSDR radiogenic cancer comparison value, which is based on a 70-year exposure.

Figure 8. Exposure Pathways Evaluated

1

Figure 9. Comparison of Radiation Doses



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Additionally, it should be noted that several levels of conservatism were built into the Task 6 evaluation of past exposures. The Task 6 values that ATSDR relied on to evaluate past exposures came from a screening evaluation that routinely and appropriately used conservative and overly protective assumptions and approaches, which led to an overestimation of concentrations and doses. Even using these overestimated concentrations and doses, persons in the reference community, Scarboro, were exposed to levels of uranium that are below levels of health concern. Following is a list of conservative aspects in this evaluation.

1. The majority of the total uranium radiation dose (54% of the total U 234/235 dose and 78% of the total U 238 dose) is attributed to frequently eating fish from the EFPC and eating vegetables grown in contaminated soil over several years. If a person did not regularly eat fish from the creek or homegrown vegetables over a prolonged period of time (which is very probable), then that person's uranium dose would likely have been substantially lower than the estimated doses reported in this public health assessment.

2. The Task 6 report noted that late in the project it was ascertained that the Y-12 uranium releases for some of the years used to develop the empirical χ/Q (χ is chi) value may have been understated due to omission of some unmonitored release estimates. This would cause the empirical χ/Q values to be overestimated and in turn would cause the air concentrations to be overestimated.

3. According to ATSDR's regression analysis, the method that the Task 6 team used to estimate historical uranium air concentrations overestimated uranium 234/235 concentrations by as much as a factor of 5. Consequently, airborne uranium 234/235 doses based on this method were most likely overestimated.

4. Using the International Commission on Radiological Protection's dose coefficients tends to overestimate the actual radiation doses due to the built-in conservative assumptions (i.e., selecting variables that typically overestimate the true, but uncertain physical and

biological interactions associated with radiation exposure) (for examples, see Harrison et al. 2001; Leggett 2001).

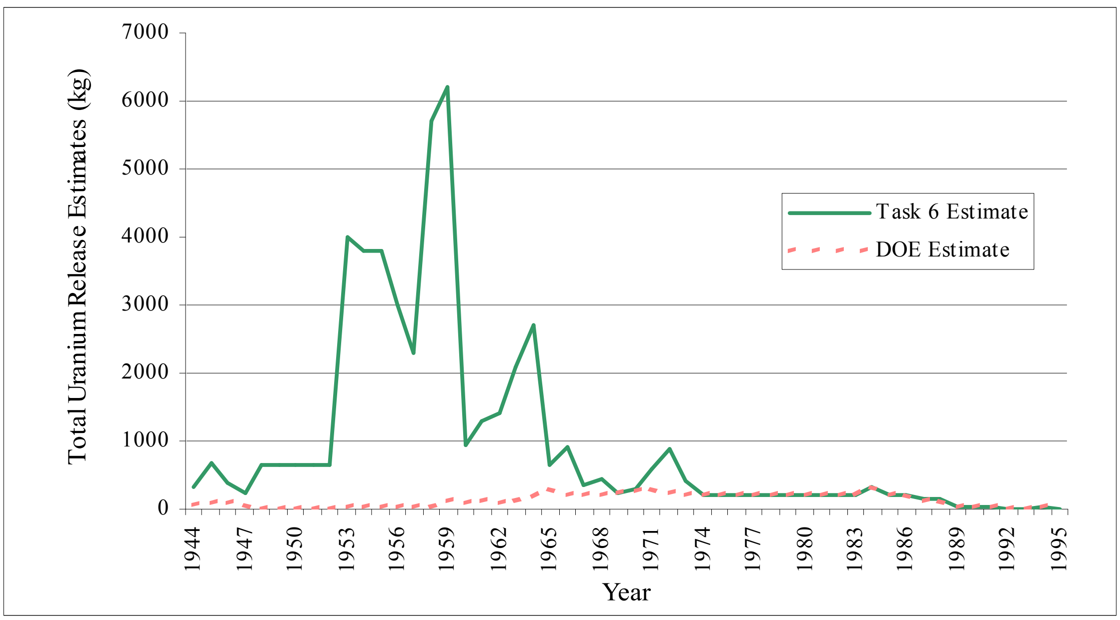
5. In evaluating the soil exposure pathway, the Task 6 team used EFPC floodplain soil data to calculate doses. Actual measured uranium concentrations in Scarboro soil are much lower than the uranium concentrations in the floodplain soil. Consequently, the uranium doses that were estimated for the residents were overestimated because of the use of the higher EFPC floodplain uranium concentrations. The estimated doses would be much lower if they were based on actual measured concentrations in Scarboro.

This conservatism and overestimation, used in the Task 6 evaluation, resulted in overestimation of radiation doses from uranium that the residents of Scarboro were exposed to in the past; however, even those overestimated doses were below levels of health concern. Therefore, Scarboro residents would not be expected to have any adverse health effects from past exposure to uranium. Each past exposure pathway is evaluated separately in the following sections.

<u>Past Air Exposure Pathway</u>

The Task 6 team independently evaluated past Y-12 airborne uranium releases and generated release estimates much higher than those previously reported by DOE (see Figure 10 and Table 5). They attributed the difference to DOE's use of incomplete sets of effluent monitoring data and release documents, along with their use of release estimates based on effluent monitoring data not adequately corrected to account for sampling biases (ChemRisk 1999). It is ATSDR's understanding that DOE and the community have not disputed the release estimates generated by the Task 6 team. Please see Section 2.0 in the Task 6 report for more details about how the airborne uranium release estimates were determined.

Figure 10. Annual Airborne Uranium Release Estimates for the Y-12 Plant



Source: ChemRisk 1999

Table 5. Annual Airborne Uranium Release Estimates for Y-12 Plant (1944–1995)

Year	Task 6 Estimate (kg)	DOE Estimate (kg)	Year	Task 6 Estimate (kg)	DOE Estimate (kg)
1944	310	55	1970	300	259
1945	670	102	1971	580	290
1946	390	102	1972	870	222
1947	250	55	1973	410	206
1948	650	0	1974	210	207
1949	650	0	1975	210	209
1950	650	0	1976	210	207
1951	650	0	1977	210	206
1952	650	0	1978	210	205
1953	4,000	30	1979	210	206
1954	3,800	32	1980	220	218
1955	3,800	32	1981	210	207
1956	3,000	43	1982	210	207
1957	2,300	41	1983	210	208
1958	5,700	41	1984	330	329
1959	6,200	120	1985	210	210
1960	930	99	1986	210	211
1961	1,300	109	1987	150	116
1962	1,400	100	1988	150	116
1963	2,100	103	1989	44*	44
1964	2,700	170	1990	21*	21
1965	640	281	1991	21*	21
1966	920	212	1992	7*	7
1967	340	212	1993	3*	3
1968	440	211	1994	24*	24
1969	250	223	1995	2*	2
			Total	**50,000**	**6,535**

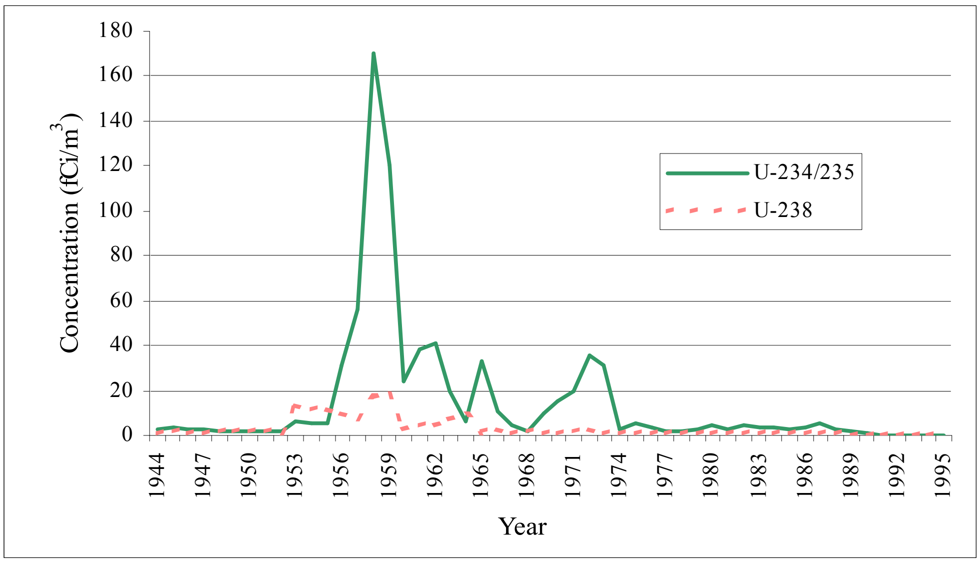
Source: ChemRisk 1999

* Values for 1989 to 1995 were based on releases reported by DOE. Release estimates for these years were not independently reconstructed during the dose reconstruction.

Using Task 6's newly generated annual airborne uranium release estimates for the Y-12 plant from 1944 to 1995 and the measured air radioactivity concentrations from DOE air monitoring station 46, located in the reference location of Scarboro, from 1986–1995 (DOE began monitoring station 46 in 1986), the Task 6 team used an empirical χ/Q (χ is chi) approach to estimate average annual air radioactivity concentrations in Scarboro from the 1944 to 1995 Y-12 plant uranium releases (see Figure 11 and Table 6). The empirical χ/Q is the ratio of measured air radioactivity concentration (air monitoring station 46 data) to release rate (Task 6 annual airborne uranium release estimates). Please see Section 3.0 in the Task 6 report for more details about how the uranium air concentrations were estimated.

The Task 6 team used these average annual U 234/235 and U 238 air radioactivity concentrations based on the empirical χ/Q method to calculated past uranium CEDEs to the Scarboro community via the air exposure pathways. These past uranium CEDEs for each air exposure pathway in Scarboro were summed to calculate the past U 234/235 CEDE of 34 mrem and the past U 238 CEDE of 6 mrem from the air pathway (see Table 4). The total uranium CEDE from the air exposure pathway in Scarboro, after being adjusted to reflect a 70-year exposure, is 40 mrem.

Figure 11. Task 6 Estimated Average Annual Air Radioactivity Concentrations in Scarboro from Y-12 Uranium Releases



Source: ChemRisk 1999

Table 6. Task 6 Estimated Average Annual Air Radioactivity Concentrations in Scarboro from Y-12 Uranium Releases (1944–1995)

Year	U 234/235 (fCi/m^3)	U 238 (fCi/m^3)	Year	U 234/235 (fCi/m^3)	U 238 (fCi/m^3)
1944	2.4	1.1	1970	15	0.91
1945	4.0	2.2	1971	20	1.8
1946	3.0	1.3	1972	36	2.7
1947	2.5	0.81	1973	31	1.2
1948	1.6	2.1	1974	2.7	0.67
1949	1.6	2.1	1975	5.0	0.67
1950	1.6	2.1	1976	3.2	0.67
1951	1.6	2.1	1977	1.6	0.67
1952	1.6	2.1	1978	1.7	0.67
1953	6.5	13	1979	2.3	0.67
1954	5.6	12	1980	4.6	0.71
1955	5.7	12	1981	2.8	0.67
1956	31	10	1982	4.7	0.66
1957	56	7.8	1983	4.0	0.67
1958	170	17	1984	3.4	1.1
1959	120	19	1985	2.7	0.68
1960	24	3.0	1986	3.4	0.69
1961	38	4.2	1987	5.7	0.48
1962	41	4.5	1988	2.9	0.47
1963	20	6.8	1989	1.4	0.024
1964	6.5	8.8	1990	0.77	0.014
1965	33	2.0	1991	0.38	0.063
1966	11	3.0	1992	0.36	0.022
1967	1.9	1.1	1993	0.29	0.0093
1968	2.2	1.4	1994	0.31	0.078
1969	9.4	0.77	1995	0.17	0.0055

Source: ChemRisk 1999

fCi/m^3 is femtocuries per cubic meter. 1 femtocurie equals 1×10^{-15} curies.
Concentrations were estimated using the empirical χ/Q approach.
All values are rounded to two significant figures.

The Task 6 report noted that late in the project it was ascertained that the Y-12 uranium releases for some of the years used to develop the empirical χ/Q value may have been understated (ChemRisk 1999). This would cause the empirical χ/Q values to also be overestimated and in turn would cause the estimated average air radioactivity concentrations in Scarboro to be overestimated (ChemRisk 1999).

ATSDR evaluated the Task 6 methodology for estimating annual average air radioactivity concentrations in Scarboro from Y-12 uranium releases relative to measured uranium air radioactivity concentrations at the DOE air monitoring station 46 in Scarboro from 1986 to 1995.

According to ATSDR's evaluation, the Task 6 empirical χ/Q estimation of the average U 234/235 air radioactivity concentrations for Scarboro from 1986 to 1995 consistently overestimated the measured U 234/235 air radioactivity concentrations in Scarboro from 1986 to 1995 (see Figure 12). In addition, estimated average U 238 air radioactivity concentrations using the Task 6 empirical χ/Q method overestimated or slightly underestimated measured U 238 air radioactivity concentrations (see Figure 13). A detailed discussion of the linear regression evaluation by ATSDR is in Appendix E.

Consequently, the estimated average U 234/235 and U 238 air radioactivity concentrations at Scarboro from 1945 to 1995 Y-12 uranium releases (see Table 6) are most likely overestimated because these concentrations are based on the Task 6 empirical χ/Q value. In addition, the Task 6 team used these likely overestimated average U 234/235 and U 238 air radioactivity concentrations based on the empirical χ/Q method to calculated past uranium CEDEs to the Scarboro community via the air exposure pathways (see Table 7 for a list of air exposure pathways considered by the Task 6 team). As shown in Table 7, the majority of the estimated total radiation dose via the air pathway in Scarboro from Y-12 uranium releases is attributed to inhalation of airborne particles.

Figure 12. Comparison of Average U234/235 Air Radioactivity Concentrations in Scarboro Measured vs. Estimated

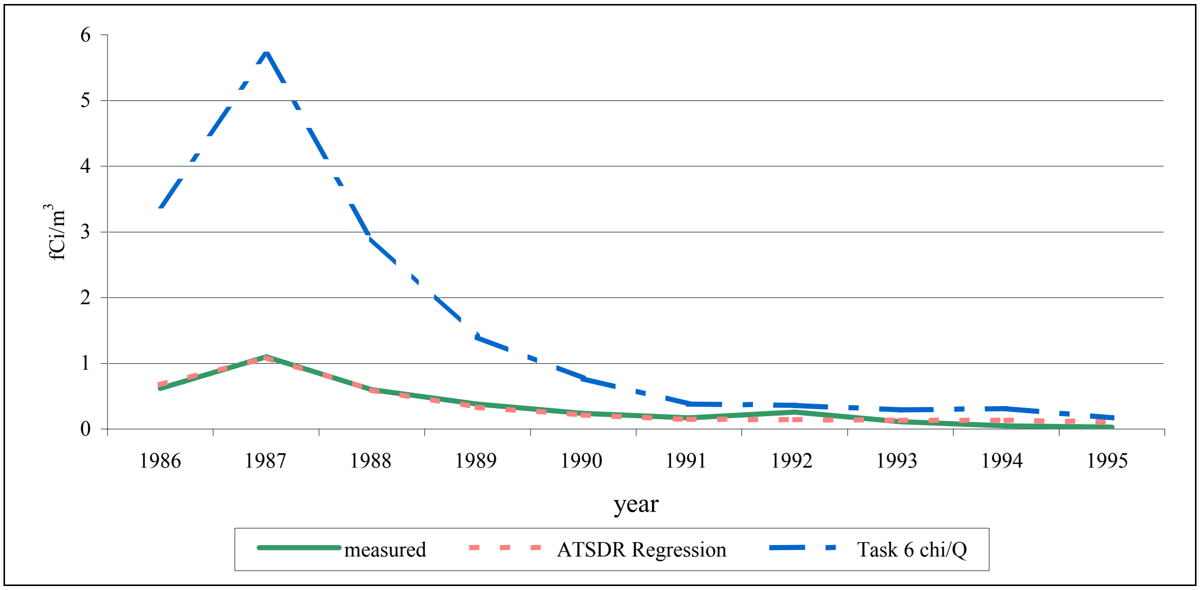


Figure 13. Comparison of Average U 238 Air Radioactivity Concentrations In Scarboro Measured vs. Estimated

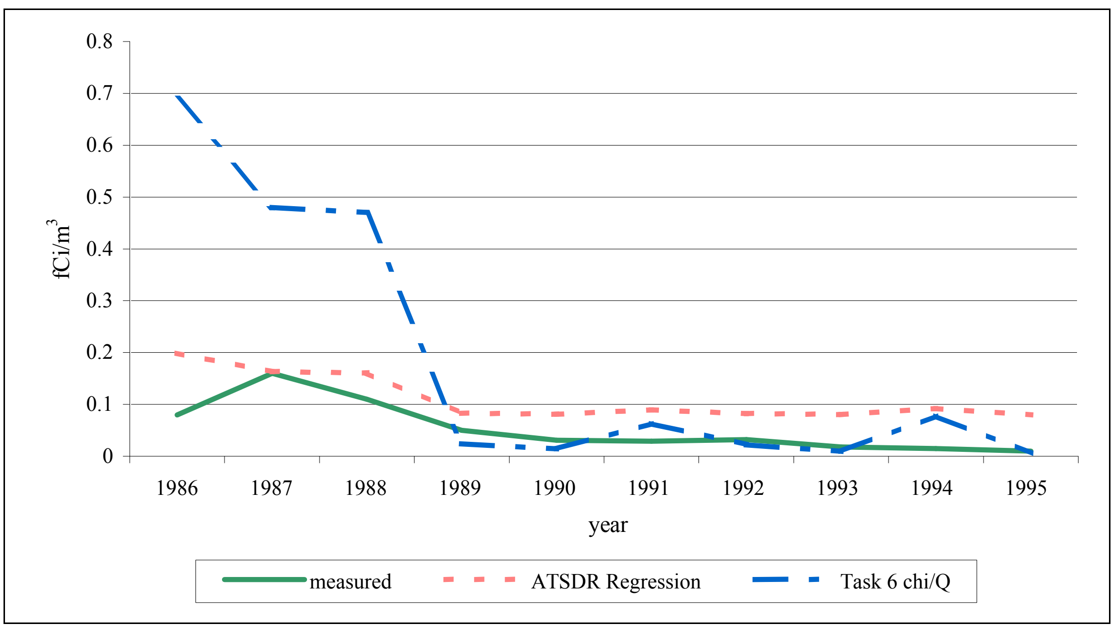


Table 7. Air Pathways Considered by the Task 6 Team

Exposure Pathway to Humans	% Pathway Contributes to Total Radiation Dose	
	U 234/235	U 238
Inhalation of airborne particles	30%	10%
Direct contact with air containing uranium particulates	<1%	<1%
Ingestion of meat from livestock that inhaled airborne particles	<1%	<1%
Ingestion of milk from dairy cows that inhaled airborne particles	<1%	<1%
Consumption of vegetables contaminated with deposited particles	4%	<1%
Consumption of meat from livestock that ate pasture contaminated with deposited particles	<1%	<1%
Consumption of milk from dairy cows that ate pasture contaminated with deposited particles	<1%	<1%

Source: ChemRisk 1999

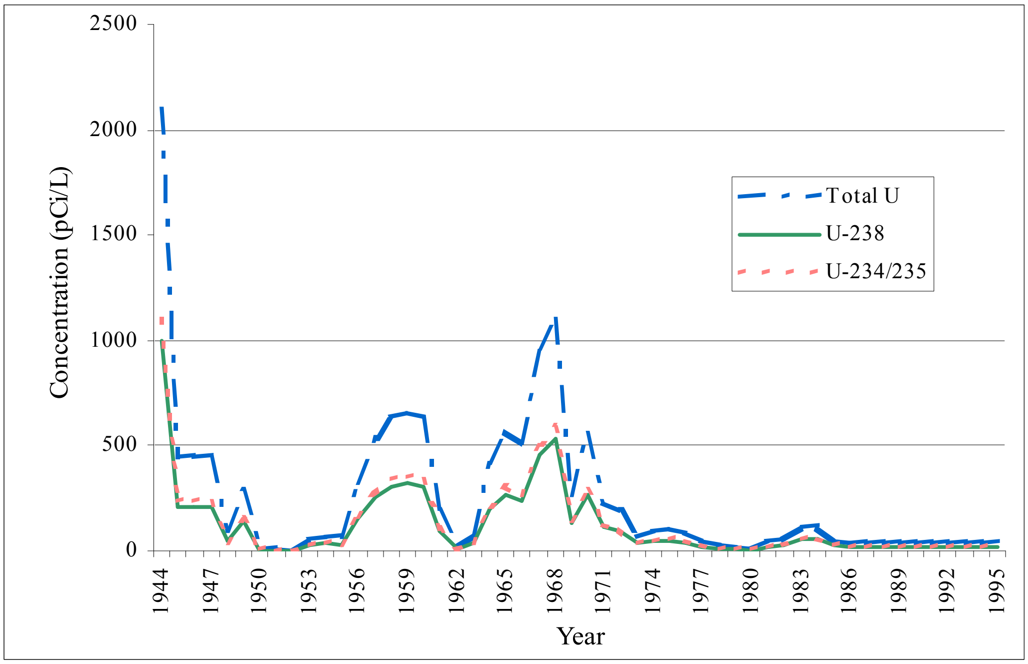
To calculate an estimated uranium radiation dose, the Task 6 team used the latest dose coefficients recommended by the International Commission on Radiological Protection (ICRP) (ChemRisk 1999). Dose coefficients are a combination of factors containing much uncertainty. To compensate for these uncertainties, the ICRP added conservative assumptions to the dose conversion factor values, which resulted in potentially overestimated radiation doses. Please see Appendix F for additional information about the conservatism built into ICRP's dose coefficients (for examples, see Harrison et al. 2001; Leggett 2001).

Past Surface Water Exposure Pathway

The closest surface water body to the reference location, Scarboro, is EFPC, which originates from within the Y-12 plant boundary, flows through the city of Oak Ridge, and confluences with Poplar Creek (ChemRisk 1999). EFPC passes about 0.4 miles to the northeast of the populated area of Scarboro at its closest point (ChemRisk 1999). EFPC represents the most credible source of surface water exposure for Scarboro residents (ChemRisk 1999). Public access to the creek exists after it leaves the reservation. However, the creek appears to be too shallow for swimming, although some areas, are suitable for wading and fishing.

To calculate annual average uranium radioactivity concentrations in EFPC from 1944 to 1995, the Task 6 team divided the annual waterborne uranium release estimates from the Y-12 plant by the EFPC annual flow rate (see Figure 14 and Table 8). Please see Section 3.3 in the Task 6 report for more details about how the uranium surface water concentrations were determined.

Figure 14. Average Annual Uranium Concentrations in EFPC Surface Water



Source: ChemRisk 1999

The Task 6 team then calculated estimated CEDEs via the EFPC surface water exposure pathways. The total past uranium CEDE from EFPC surface water exposure pathways, after being adjusted to reflect a 70-year exposure[6], is 49 mrem (see Table 4). As shown in Table 9, the majority of the exposure to uranium is attributed to frequently eating fish from EFPC (24% of the total U 234/235 dose and 35% of the total U 238 dose). It is ATSDR's understanding that EFPC is not a very productive fishing location and very few people actually eat fish from the creek. If a person did not frequently eat EFPC fish over a prolonged period of time, the person's uranium radioactivity dose from the surface water pathway would be expected to be substantially lower than the estimated radioactivity doses reported in this public health assessment.

[6] The total past uranium CEDEs for the EFPC surface water pathway from the Task 6 report were multiplied by 1.35 (70 years/52 years) for comparison with ATSDR's comparison values.

Table 8. Average Annual Uranium Concentrations in East Fork Poplar Creek Surface Water (1944–1995)

Year	Total Uranium (pCi/L)	U 238 (pCi/L)	U 234/235 (pCi/L)	Uranium (mg/L)	Year	Total Uranium (pCi/L)	U 238 (pCi/L)	U 234/235 (pCi/L)	Uranium (mg/L)
1944	2,100	1,000	1,100	3.0	1970	560	270	290	0.79
1945	450	210	240	0.63	1971	230	110	120	0.32
1946	450	210	240	0.63	1972	190	92	100	0.27
1947	450	210	240	0.63	1973	71	34	37	0.099
1948	99	47	52	0.14	1974	99	47	52	0.14
1949	290	140	150	0.41	1975	104	50	55	0.15
1950	9.1	4.3	4.8	0.013	1976	87	42	46	0.12
1951	6.2	2.9	3.3	0.0088	1977	48	23	25	0.067
1952	0.0070	0.0033	0.0037	0.000010	1978	26	12	14	0.036
1953	61	29	32	0.085	1979	23	11	12	0.033
1954	71	34	37	0.099	1980	9.9	4.7	5.2	0.014
1955	68	32	36	0.095	1981	44	21	23	0.062
1956	320	150	170	0.45	1982	54	25	28	0.075
1957	540	260	280	0.76	1983	110	54	60	0.16
1958	640	300	340	0.89	1984	110	54	60	0.16
1959	660	320	350	0.93	1985	50	24	26	0.070
1960	640	300	340	0.90	1986	42	20	22	0.058
1961	200	93	100	0.27	1987	42	20	22	0.058
1962	14.8	7.0	7.8	0.021	1988	42	20	22	0.058
1963	80	38	42	0.11	1989	42	20	22	0.058
1964	420	200	220	0.59	1990	42	20	22	0.058
1965	570	270	300	0.79	1991	42	20	22	0.058
1966	510	240	270	0.71	1992	42*	20*	22*	0.058*
1967	970	460	510	1.4	1993	42*	20*	22*	0.058*
1968	1,100	530	590	1.6	1994	42*	20*	22*	0.058*
1969	270	130	140	0.38	1995	42*	20*	22*	0.058*
EFPC Average Concentrations (1944–1995)							**121**	**134**	**0.36**

Source: ChemRisk 1999

*Assumed same concentration as 1991.
All values are rounded to two significant figures.

Table 9. Surface Water Pathways Considered by the Task 6 Team

Exposure Pathway to Humans	% Pathway Contributes to Total Radiation Dose	
	U 234/235	U 238
Incidental ingestion of EFPC water	<1%	<1%
Ingestion of meat from livestock that drank water from EFPC	<1%	<1%
Ingestion of milk from dairy cows that drank water from EFPC	2%	3%
Consumption of fish from EFPC	24%	35%
Immersion in EFPC water	<1%	<1%

Source: ChemRisk 1999

As with the air pathway, to calculate an estimated uranium radiation dose for the surface water pathway, the Task 6 team used the conservative dose coefficients recommended by the ICRP (ChemRisk 1999). Consequently, the radiation doses are most likely overestimated. Please see Appendix F for additional information about the conservatism built into ICRP's dose coefficients (for examples, see Harrison et al. 2001; Leggett 2001).

Past Soil Exposure Pathway

At the beginning of the Task 6 dose reconstruction, uranium soil data from the reference location, Scarboro, were not available. In its place, uranium soil data from the EFPC floodplain were used as a surrogate for past uranium radioactivity concentrations in Scarboro soil (ChemRisk 1999). The Task 6 team used the average soil concentrations of U 234/235 and U 238 collected from EFPC floodplain between the Y-12 boundary and EFPC MILE 8.8 to estimate past uranium radioactivity doses via the soil pathways in Scarboro. Please see Section 3.4 in the Task 6 report for more details about how uranium concentrations in soil were determined.

The Task 6 report noted that the use of uranium concentrations in EFPC floodplain soil to represent uranium concentrations in Scarboro soil, which is outside of the floodplain, probably introduced conservatism (ChemRisk 1999). The Task 6 report also noted that the uranium concentrations in EFPC floodplain soil, which were available at that time, were not sufficient to support a defensible analysis of average or typical exposure to members of the Scarboro community during the years from the community's inception to the present (ChemRisk 1999).

The Task 6 team estimated past uranium radiation doses by using uranium radioactivity concentrations in EFPC floodplain soil to calculate estimated CEDEs via the soil exposure pathways to residents of Scarboro. The total past uranium CEDE from the soil pathway, after being adjusted to reflect a 70-year exposure[7], is 66 mrem (see Table 4). As shown in Table 10, the majority of the past uranium radiation dose (30% of the total U 234/235 dose and 43% of the total U 238 dose) for the soil pathways is attributed to frequently eating vegetables grown in contaminated floodplain soil over a prolonged period of time. If a person did not frequently eat homegrown vegetables over a prolonged period of time, the person's uranium dose from the soil pathway would have been substantially lower than the estimated doses reported in this public health assessment.

Table 10. Soil Pathways Considered by the Task 6 Team

Exposure Pathway to Humans	% Pathway Contributes to Total Radiation Dose	
	U 234/235	U 238
Inhalation of resuspended dust	2%	3%
Ingestion of soil	<1%	1%
Consumption of meat from livestock that ingested soil	<1%	<1%
Consumption of milk from dairy cows that ingested soil	<1%	1%
Consumption of vegetables grown in contaminated soil	30%	43%
Consumption of meat from livestock that ate pasture grown in contaminated soil	<1%	<1%
Consumption of milk from dairy cows that ate pasture grown in contaminated soil	<1%	1%
External exposure to contaminated soil	3%	<1%

Source: ChemRisk 1999

Toward the end of the Task 6 project (in May 1998), 40 soil samples from the Scarboro community were collected by the Environmental Sciences Institute at FAMU (FAMU 1998). In 2001, EPA collected six soil samples from the Scarboro community to validate the 1998 FAMU results (EPA 2002b). An independent review by Auxier & Associates (Prichard 1998) of the Task 6 report and the report generated by FAMU noted that aerial deposition of uranium was the

[7] The total past uranium CEDEs for the EFPC floodplain soil pathway from the Task 6 report were multiplied by 1.35 (70 years/52 years) for comparison with ATSDR's comparison values.

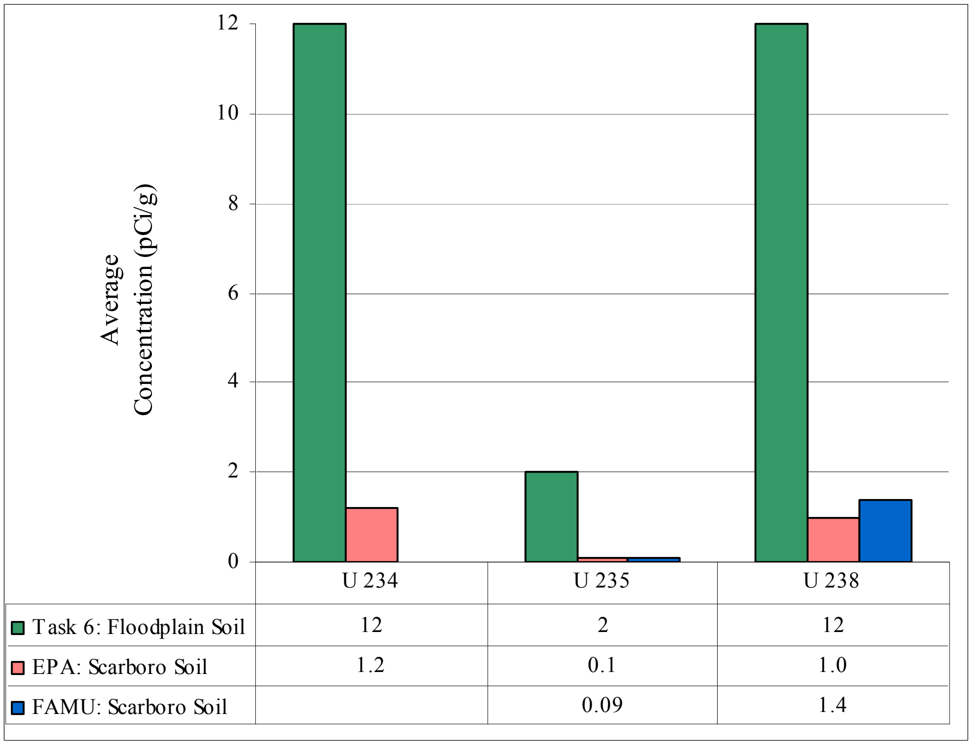
primary source of uranium contamination in Scarboro soil, rather than the transportation of EFPC floodplain soils for use as fill. It was concluded that the radioactivity concentrations of uranium within the Task 6 report (based on EFPC floodplain soil samples) are inconsistent with the radioactivity concentrations of uranium observed in Scarboro soils and that the Task 6 assumptions are unlikely to accurately represent past uranium radioactivity concentrations in Scarboro soil (Prichard 1998). Additionally, technical reviews of the Auxier report, the Task 6 report, and the report generated by FAMU noted that the use of actual Scarboro soil data is preferable to the reliance on floodplain soil data. However, the reviewers cautioned using the FAMU data to estimate past exposure without additional research into the environmental distribution of uranium in the area[8]. Appendix G contains a summary of the technical reviewers' comments.

Based on the FAMU and EPA uranium soil data, the actual uranium radioactivity concentrations in Scarboro soil were much lower than the uranium radioactivity concentrations from the EFPC floodplain soil that the Task 6 team used as a surrogate. As shown in Figure 15 and Table 11, the actual uranium radioactivity concentrations in Scarboro soil are approximately 8 to 22 times less than the EFPC floodplain soil concentrations. Consequently, if the uranium radioactivity concentrations from Scarboro soil were used to estimate the past uranium radioactivity doses instead of the EFPC floodplain soil, the total past uranium CEDE of 66 mrem for the soil exposure pathway in Table 4 would have been significantly lower.

As with the air and surface water pathways, to calculate an estimated uranium radiation dose for the soil exposure pathway, the Task 6 team used the conservative dose coefficients recommended by the ICRP, causing the radiation doses to be overestimated (ChemRisk 1999). Please see Appendix F for additional information about the conservatism built into ICRP's dose coefficients.

[8] The mobility of uranium in soil and its vertical transport (leaching) to groundwater depend on the form of uranium and the properties of the soil, as well as the amount of water available (ATSDR 1999a). The sorption of uranium in most soils is such that it may not leach readily from soil to groundwater; the migration is typically quite local (ATSDR 1999a). In addition, the predominant chemical form of uranium released into the air from the Y-12 plant was highly insoluble uranium oxide (ChemRisk 1999). Leaching is not expected to be a major loss mechanism for insoluble materials, which bind tightly to soil particles (Prichard 1998).

Figure 15. Comparison of the Average Uranium Radioactivity Concentrations EFPC Floodplain Soil vs. Scarboro Soil



Sources: ChemRisk 1999, EPA 2002b, FAMU 1998

FAMU did not analyze for U 234.

Table 11. Comparison of Average Uranium Radioactivity Concentrations EFPC Floodplain Soil vs. Scarboro Soil

		Average U 234 Concentration (pCi/g)	Average U 235 Concentration (pCi/g)	Average U 238 Concentration (pCi/g)
Task 6: Floodplain Soil		12	2	12
EPA: Scarboro Soil		1.2	0.1	1.0
FAMU: Scarboro Soil		not available	0.09	1.4
How much lower are the soil radioactivity concentrations in Scarboro than the EFPC floodplain?	Task 6 vs EPA	10 times	20 times	12 times
	Task 6 vs FAMU	not available	22 times	8.6 times

Sources: ChemRisk 1999, EPA 2002b, FAMU 1998

III.B.1.b. Past Chemical Effects

ATSDR evaluated whether exposure to past levels of uranium released from the Y-12 plant would cause harmful chemical effects in communities near the Y-12 plant, especially the reference location (the Scarboro community), which is considered the area that would have received the highest exposures. Based upon the chemical toxicity of uranium, residents living near the ORR were not exposed through inhalation of air or ingestion of surface water and soil to harmful levels of uranium in the past.

Past Exposure via Inhalation

Using the average air concentrations generated by the Task 6 team (converted from radioactivity values to mass units[9]), ATSDR calculated the average air concentrations of total uranium in Scarboro for each year from 1944 to 1995 and compared them to the ATSDR MRL for inhalation of insoluble uranium (see Table 12). All the average air concentrations of uranium in Scarboro are less than 1% of the ATSDR MRL. As shown in Figure 16, the average annual air concentrations of total uranium are well below the inhalation MRL of 0.008 mg/m^3 for every year. Values below the MRL are not of health concern, so they do not warrant any further evaluation. Additionally, as noted previously in the past radiation effects section, the uranium air concentrations are most likely overestimated. Therefore, ATSDR concludes that residents living near Oak Ridge were not exposed to airborne uranium at levels that would cause harmful chemical effects.

[9] Each individual isotope (U 234, U 235, and U 238) has a separate and distinct half life and mass. Therefore, one can convert the activity of each individual isotope using its specific activity expressed as curies of radioactivity per gram of pure radionuclide (0.331 pCi/µg for U 238, 0.34 pCi/µg for U 234, 0.0154 pCi/µg for U 235). To convert the radioactive measurement of the isotope to grams, one divides the radioactive measurement by its specific activity while ensuring the units of measurement are consistent.

Table 12. Estimated Average Annual Air Concentrations of Uranium in Scarboro

Year	Total Uranium Concentration (mg/m^3)	Is the concentration above the MRL?	Percent of MRL	Year	Total Uranium Concentration (mg/m^3)	Is the concentration above the MRL?	Percent of MRL
1944	3.2×10^{-6}	no	0.04%	1970	2.9×10^{-6}	no	0.04%
1945	6.6×10^{-6}	no	0.08%	1971	5.7×10^{-6}	no	0.07%
1946	3.8×10^{-6}	no	0.05%	1972	8.2×10^{-6}	no	0.10%
1947	2.5×10^{-6}	no	0.03%	1973	4.0×10^{-6}	no	0.05%
1948	6.4×10^{-6}	no	0.08%	1974	2.1×10^{-6}	no	0.03%
1949	6.4×10^{-6}	no	0.08%	1975	2.1×10^{-6}	no	0.03%
1950	6.4×10^{-6}	no	0.08%	1976	2.1×10^{-6}	no	0.03%
1951	6.4×10^{-6}	no	0.08%	1977	2.0×10^{-6}	no	0.03%
1952	6.4×10^{-6}	no	0.08%	1978	2.1×10^{-6}	no	0.03%
1953	4.0×10^{-5}	no	0.50%	1979	2.1×10^{-6}	no	0.03%
1954	3.7×10^{-5}	no	0.47%	1980	2.2×10^{-6}	no	0.03%
1955	3.7×10^{-5}	no	0.47%	1981	2.0×10^{-6}	no	0.03%
1956	2.9×10^{-5}	no	0.36%	1982	2.0×10^{-6}	no	0.03%
1957	2.4×10^{-5}	no	0.30%	1983	2.1×10^{-6}	no	0.03%
1958	5.4×10^{-5}	no	0.68%	1984	3.3×10^{-6}	no	0.04%
1959	6.0×10^{-5}	no	0.75%	1985	2.1×10^{-6}	no	0.03%
1960	9.3×10^{-6}	no	0.12%	1986	2.1×10^{-6}	no	0.03%
1961	1.3×10^{-5}	no	0.16%	1987	1.5×10^{-6}	no	0.02%
1962	1.4×10^{-5}	no	0.17%	1988	1.4×10^{-6}	no	0.02%
1963	2.1×10^{-5}	no	0.26%	1989	1.2×10^{-7}	no	<0.01%
1964	2.6×10^{-5}	no	0.33%	1990	4.7×10^{-8}	no	<0.01%
1965	6.3×10^{-6}	no	0.08%	1991	1.9×10^{-7}	no	<0.01%
1966	9.1×10^{-6}	no	0.11%	1992	7.1×10^{-8}	no	<0.01%
1967	3.3×10^{-6}	no	0.04%	1993	3.2×10^{-8}	no	<0.01%
1968	4.4×10^{-6}	no	0.05%	1994	2.4×10^{-7}	no	<0.01%
1969	2.5×10^{-6}	no	0.03%	1995	2.1×10^{-8}	no	<0.01%

None of the concentrations exceeded the ATSDR inhalation MRL of 0.008 mg/m^3 (i.e., 8.0×10^{-3}) for insoluble uranium.

Figure 16. Estimated Average Annual Air Concentrations of Total Uranium in Scarboro

The air concentration values can be written different ways, for example 1.0E-01 mg/m^3 is the same as 1.0×10^{-1} mg/m^3 and 0.1 mg/m^3.

<u>Past Exposure via Ingestion</u>

The Task 6 team calculated an annual average intake of uranium from 1944 to 1995 through both surface water and soil exposure pathways to residents of Scarboro. They considered (1) incidental ingestion of EFPC water, (2) ingestion of meat from livestock that drank water from EFPC, (3) ingestion of milk from dairy cows that drank water from EFPC, (4) consumption of fish from EFPC, (5) ingestion of soil, (6) consumption of meat from livestock that ingested soil, (7) consumption of milk from dairy cows that ingested soil, (8) consumption of vegetables grown in contaminated soil, (9) consumption of meat from livestock that ate pasture grown in contaminated soil, and (10) consumption of milk from dairy cows that ate pasture grown in contaminated soil (Figure 8 shows the exposure pathways evaluated).

ATSDR used the Task 6 annual average intakes of uranium to calculate past uranium doses for an adult male, adult female, 12-year-old child, and 6-year-old child for each year from 1944 to 1995 (see Table 13). Please see Section *III.A.2. Evaluating Exposures* for an explanation of how ATSDR calculated doses. As shown in Figure 17, the doses for several of the individual years exceeded ATSDR's intermediate-duration oral MRL for chemical toxicity of uranium

(0.002 milligrams per kilogram per day; mg/kg/day). Remember that the MRL is a screening level; values below the MRL are not of health concern and values above are used to determine whether additional evaluation is needed. Therefore, ATSDR further investigated the toxicologic literature to find doses associated with known health effects. The lowest oral (ingestion) dose of uranium that has caused the most sensitive harmful health effect considered to be of relevance to humans was 0.05 mg/kg/day which caused renal (kidney) toxicity in rabbits (ATSDR 1999a). The rabbit is the mammalian species most sensitive to uranium kidney toxicity and is likely to be even more sensitive than humans (ATSDR 1999a). Therefore, ATSDR is comfortable with extrapolating the results from this animal toxicity study to humans. This oral uranium dose of 0.05 mg/kg/day is the minimum lowest-observed-adverse-effect level (LOAEL) that is used by ATSDR to derive the MRL for intermediate-duration oral exposure to uranium. This intermediate-duration oral MRL is also protective for chronic-duration oral exposure because the renal effects of uranium exposure are more dependent on the dose than on the duration of exposure. All the estimated past uranium doses from ingestion of uranium via the soil and surface water pathways in Table 13 and Figure 17 are well below the LOAEL of 0.05 mg/kg/day at which health effects have been observed (renal toxicity observed in rabbits at doses of 0.05 mg/kg/day; ATSDR 1999a). Therefore, ATSDR concludes that residents living near Oak Ridge were not exposed to uranium at levels that would cause harmful chemical effects.

Table 13. Estimated Average Annual Doses from Ingestion of Uranium via the Soil and Surface Water Pathways (1944–1995)*

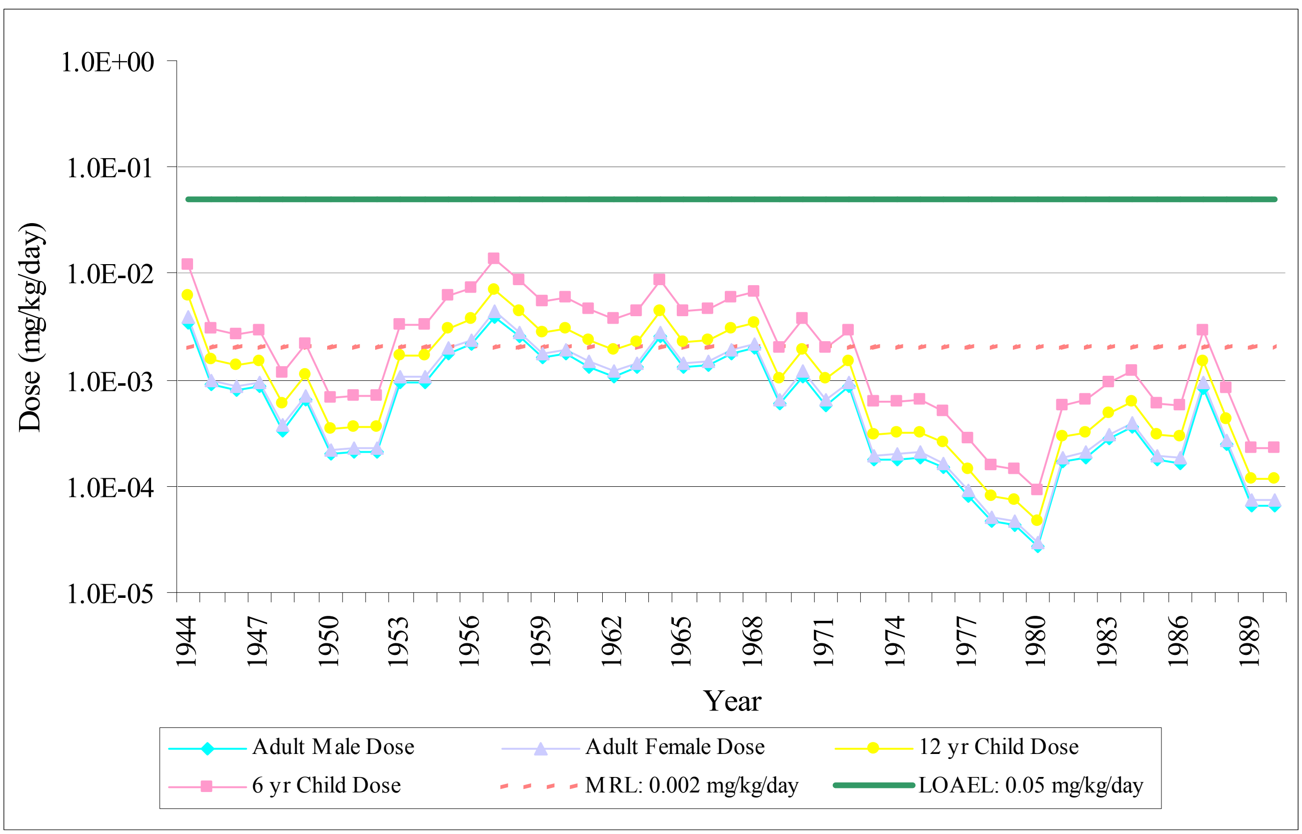
Year	Annual Average Intake (mg/d)	Dose (mg/kg/day)				Is the dose above the MRL?			
		Adult Male	Adult Female	12-yr Child	6-yr Child	Adult Male	Adult Female	12-yr Child	6-yr Child
1944	0.273	3.5×10^{-3}	3.9×10^{-3}	6.1×10^{-3}	1.2×10^{-2}	yes	yes	yes	yes
1945	0.069	8.9×10^{-4}	9.7×10^{-4}	1.5×10^{-3}	3.0×10^{-3}	no	no	no	yes
1946	0.061	7.8×10^{-4}	8.6×10^{-4}	1.4×10^{-3}	2.7×10^{-3}	no	no	no	yes
1947	0.066	8.5×10^{-4}	9.4×10^{-4}	1.5×10^{-3}	2.9×10^{-3}	no	no	no	yes
1948	0.026	3.4×10^{-4}	3.7×10^{-4}	5.9×10^{-4}	1.1×10^{-3}	no	no	no	no
1949	0.050	6.5×10^{-4}	7.1×10^{-4}	1.1×10^{-3}	2.2×10^{-3}	no	no	no	yes
1950	0.015	2.0×10^{-4}	2.2×10^{-4}	3.4×10^{-4}	6.7×10^{-4}	no	no	no	no
1951	0.016	2.1×10^{-4}	2.3×10^{-4}	3.6×10^{-4}	7.1×10^{-4}	no	no	no	no
1952	0.016	2.1×10^{-4}	2.3×10^{-4}	3.6×10^{-4}	7.1×10^{-4}	no	no	no	no
1953	0.075	9.6×10^{-4}	1.1×10^{-3}	1.7×10^{-3}	3.3×10^{-3}	no	no	no	yes
1954	0.075	9.6×10^{-4}	1.1×10^{-3}	1.7×10^{-3}	3.3×10^{-3}	no	no	no	yes
1955	0.139	1.8×10^{-3}	2.0×10^{-3}	3.1×10^{-3}	6.1×10^{-3}	no	no	yes	yes
1956	0.170	2.2×10^{-3}	2.4×10^{-3}	3.8×10^{-3}	7.4×10^{-3}	yes	yes	yes	yes
1957	0.308	4.0×10^{-3}	4.3×10^{-3}	6.8×10^{-3}	1.3×10^{-2}	yes	yes	yes	yes
1958	0.198	2.5×10^{-3}	2.8×10^{-3}	4.4×10^{-3}	8.6×10^{-3}	yes	yes	yes	yes
1959	0.125	1.6×10^{-3}	1.8×10^{-3}	2.8×10^{-3}	5.4×10^{-3}	no	no	yes	yes
1960	0.138	1.8×10^{-3}	1.9×10^{-3}	3.1×10^{-3}	6.0×10^{-3}	no	no	yes	yes
1961	0.104	1.3×10^{-3}	1.5×10^{-3}	2.3×10^{-3}	4.5×10^{-3}	no	no	yes	yes
1962	0.084	1.1×10^{-3}	1.2×10^{-3}	1.9×10^{-3}	3.7×10^{-3}	no	no	no	yes
1963	0.103	1.3×10^{-3}	1.4×10^{-3}	2.3×10^{-3}	4.5×10^{-3}	no	no	yes	yes
1964	0.201	2.6×10^{-3}	2.8×10^{-3}	4.5×10^{-3}	8.7×10^{-3}	yes	yes	yes	yes
1965	0.104	1.3×10^{-3}	1.5×10^{-3}	2.3×10^{-3}	4.5×10^{-3}	no	no	yes	yes
1966	0.108	1.4×10^{-3}	1.5×10^{-3}	2.4×10^{-3}	4.7×10^{-3}	no	no	yes	yes
1967	0.138	1.8×10^{-3}	1.9×10^{-3}	3.1×10^{-3}	6.0×10^{-3}	no	no	yes	yes
1968	0.154	2.0×10^{-3}	2.2×10^{-3}	3.4×10^{-3}	6.7×10^{-3}	no	yes	yes	yes
1969	0.046	5.9×10^{-4}	6.5×10^{-4}	1.0×10^{-3}	2.0×10^{-3}	no	no	no	no
1970	0.085	1.1×10^{-3}	1.2×10^{-3}	1.9×10^{-3}	3.7×10^{-3}	no	no	no	yes
1971	0.045	5.8×10^{-4}	6.4×10^{-4}	1.0×10^{-3}	2.0×10^{-3}	no	no	no	no
1972	0.068	8.7×10^{-4}	9.5×10^{-4}	1.5×10^{-3}	2.9×10^{-3}	no	no	no	yes
1973	0.014	1.8×10^{-4}	2.0×10^{-4}	3.1×10^{-4}	6.1×10^{-4}	no	no	no	no
1974	0.014	1.8×10^{-4}	2.0×10^{-4}	3.1×10^{-4}	6.1×10^{-4}	no	no	no	no
1975	0.015	1.9×10^{-4}	2.1×10^{-4}	3.3×10^{-4}	6.4×10^{-4}	no	no	no	no
1976	0.012	1.5×10^{-4}	1.6×10^{-4}	2.6×10^{-4}	5.1×10^{-4}	no	no	no	no
1977	0.006	8.2×10^{-5}	9.0×10^{-5}	1.4×10^{-4}	2.8×10^{-4}	no	no	no	no
1978	0.004	4.6×10^{-5}	5.1×10^{-5}	8.0×10^{-5}	1.6×10^{-4}	no	no	no	no
1979	0.003	4.3×10^{-5}	4.8×10^{-5}	7.5×10^{-5}	1.5×10^{-4}	no	no	no	no
1980	0.002	2.7×10^{-5}	3.0×10^{-5}	4.7×10^{-5}	9.1×10^{-5}	no	no	no	no
1981	0.013	1.7×10^{-4}	1.8×10^{-4}	2.9×10^{-4}	5.7×10^{-4}	no	no	no	no
1982	0.015	1.9×10^{-4}	2.1×10^{-4}	3.2×10^{-4}	6.4×10^{-4}	no	no	no	no
1983	0.022	2.8×10^{-4}	3.1×10^{-4}	4.9×10^{-4}	9.6×10^{-4}	no	no	no	no

* This table is continued on the following page.

Year	Annual Average Intake (mg/d)	Dose (mg/kg/day)				Is the dose above the MRL?			
		Adult Male	Adult Female	12-yr Child	6-yr Child	Adult Male	Adult Female	12-yr Child	6-yr Child
1984	0.028	3.6×10^{-4}	4.0×10^{-4}	6.2×10^{-4}	1.2×10^{-3}	no	no	no	no
1985	0.014	1.8×10^{-4}	2.0×10^{-4}	3.1×10^{-4}	6.1×10^{-4}	no	no	no	no
1986	0.013	1.7×10^{-4}	1.8×10^{-4}	2.9×10^{-4}	5.7×10^{-4}	no	no	no	no
1987	0.066	8.5×10^{-4}	9.3×10^{-4}	1.5×10^{-3}	2.9×10^{-3}	no	no	no	yes
1988	0.019	2.5×10^{-4}	2.7×10^{-4}	4.3×10^{-4}	8.4×10^{-4}	no	no	no	no
1989	0.005	6.7×10^{-5}	7.3×10^{-5}	1.2×10^{-4}	2.3×10^{-4}	no	no	no	no
1990	0.005	6.7×10^{-5}	7.3×10^{-5}	1.2×10^{-4}	2.3×10^{-4}	no	no	no	no
Number of years the dose is above the MRL (0.002 mg/kg/day)						**5**	**6**	**14**	**24**
Number of years the dose is above the LOAEL (0.05 mg/kg/day)						**0**	**0**	**0**	**0**

Doses were calculated using the following formula: Dose = Intake / Body Weight assuming an adult male weighed 78 kg; an adult female, 71 kg; a 12-year-old child, 45 kg; and a 6-year-old child, 23 kg.
The LOAEL is the lowest-observed-adverse-effect level.
The dose of 0.05 mg/kg/day is the minimal LOAEL from a study in which an increased incidence of renal toxicity (specifically, anisokaryosis and nuclear vesiculation) was observed in New Zealand rabbits. The rabbit is the mammalian species most sensitive to uranium toxicity and is likely to be even more sensitive than humans.

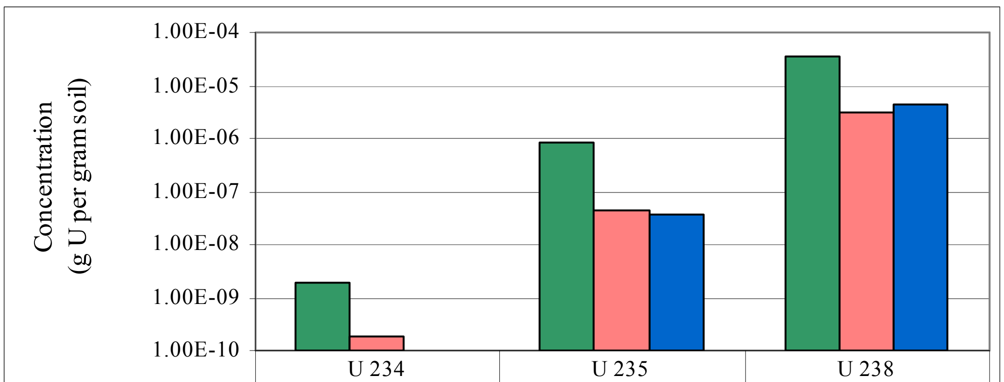
Figure 17. Estimated Average Annual Doses of Uranium via the Soil and Surface Water Pathways



The dose values can be written different ways, for example 1.0E-01 mg/kg/day is the same as 1.0×10^{-1} mg/kg/day and 0.1 mg/kg/day.

For some of the same reasons described previously in the past radiation effects section, the past ingestion doses of uranium (as shown in Table 13 and Figure 17) are overestimated. The annual intakes were calculated using the same overestimated EFPC floodplain soil concentrations in place of actual Scarboro soil concentrations (converted from radioactivity values to mass units[10]). The uranium concentrations in the Scarboro soil are at least 8.6 times less than the EFPC floodplain soil (see Figure 18). Also, the calculated ingestion doses are based on potential exposures from recreating in EFPC, eating fish from EFPC, eating livestock raised in the EFPC floodplain, drinking milk from dairy cows raised in the EFPC floodplain, and eating homegrown vegetables grown in the EFPC floodplain. Livestock is (and was) not allowed within the city limits, and EFPC is not a very productive fishing location. Very few people frequently ate livestock raised in the floodplain, fish from the creek, or vegetables grown in the floodplain over a prolonged period of time. A person's exposure is actually much lower if the person did not frequently engage in these activities over a prolonged period of time.

Figure 18. Comparison of Uranium Concentrations
EFPC Floodplain Soil vs. Scarboro Soil



	U 234	U 235	U 238
Task 6: Floodplain Soil	1.94E-09	8.30E-07	3.60E-05
EPA: Scarboro Soil	1.90E-10	4.38E-08	3.15E-06
FAMU: Scarboro Soil		3.70E-08	4.20E-06

FAMU did not analyze for U 234.
The concentration values can be written different ways, for example 1.00E-04 g U per gram soil is the same as 1.00×10^{-4} g U per gram soil and 0.0001 g U per gram soil.

[10] Each individual isotope (U 234, U 235, and U 238) has a separate and distinct half life and mass. Therefore, one can convert the activity of each individual isotope using its specific activity (0.331 pCi/µg for U 238, 0.34 pCi/µg for U 234, 0.0154 pCi/µg for U 235). To convert the radioactive measurement of the isotope to grams, one divides the radioactive measurement by its specific activity while ensuring the units of measurement are consistent.

Given that the past average annual doses of uranium (shown in Table 13) are overestimated and that they are below levels at which health effects have been observed in the mammalian species most sensitive to uranium toxicity, ATSDR does not expect that people living in communities near the Y-12 plant, including in the reference community (i.e., the residents of Scarboro), have ingested levels of uranium via the soil and surface water exposure pathways that would have resulted in harmful chemical effects.

III.B.2. Current Exposure (1995 to 2002)

This section discusses the current uranium exposures from 1995 to 2002 to residents living near ORR. The Scarboro community was selected as the reference population after air dispersion modeling indicated that its residents were expected to have received the highest exposures (ChemRisk 1999). The Task 6 report stated that "while other potentially exposed communities were considered in the selection process, the reference locations [Scarboro] represent residents who lived closest to the ORR facilities and would have received the highest exposures from past uranium releases…Scarboro is the most suitable for screening both a maximally and typically exposed individual" (ChemRisk 1999). ATSDR determined that current exposures to uranium can include the following pathways: (1) ingestion of soils, (2) ingestion of foods, (3) ingestion of water from nearby creeks, (4) inhalation of air, and (5) external exposure from uranium in soils.

Based on our review of data collected in and around the reference location (Scarboro), ATSDR has determined that the presence of uranium is not a public health concern to people living near the ORR.

III.B.2.a. Current Radiation Effects

ATSDR evaluated whether exposure to the levels of uranium currently being released from the Y-12 plant would cause harmful radiation effects in the reference population, the Scarboro community. The current uranium radiation dose received by the Scarboro community from the air and soil exposure pathways (0.216 mrem) is well below levels of health concern and is not expected to cause adverse health effects.

The current radiation CEDE[11] received by the reference population, the Scarboro community, from exposure to uranium through ingestion of soil and vegetables and inhalation of air is 0.216 mrem over 70 years (see Table 14). This current radiation dose (0.216 mrem) to the residents of Scarboro is well below (23,000 times less than) the radiogenic cancer comparison value of 5,000 mrem over 70 years (see Figure 9). ATSDR derived this CEDE after reviewing the peer-reviewed literature and other documents developed to review the health effects of ionizing radiation (Appendix D contains more information about ATSDR's derivation of the radiogenic cancer comparison value of 5,000 mrem over 70 years). The CEDE assumes that from the intake of uranium, the entire radiation dose (a 70-year dose, in this case) is received in the first year following the intake. ATSDR believes this comparison value to be protective of human health and, therefore, does not expect carcinogenic health effects to have occurred from radiation doses received from current uranium exposures in Scarboro.

To evaluate noncancer health effects from the current uranium radiation dose (CEDE of 0.216 mrem over 70 years) estimated to be received by the Scarboro community, an approximation can be made to compare the CEDE of 0.216 mrem, which is based on 70 years of exposure, to the ATSDR chronic exposure MRL for ionizing radiation (100 mrem/year), which is based on one year of exposure. The CEDE of 0.216 mrem over 70 years could be divided by 70 years to approximate a value of 0.003 mrem as the radiation dose for the first year, which is well below (33,000 times less than) the 100 mrem/year ATSDR chronic exposure MRL for ionizing radiation (see Figure 9). ATSDR MRLs are based on noncancer health effects only and are not based on a consideration of cancer effects. The ATSDR MRL for chronic ionizing radiation exposure is derived by dividing the average annual effective dose to the U.S. population (360 mrem/year) by a safety factor of 3 to account for human variability (ATSDR 199b). The average U.S. annual effective dose of 360 mrem/year is obtained mainly from naturally occurring radioactive material, medical uses of radiation, and radiation from consumer products (see Figure 9) (BEIR V 1990 as cited in ATSDR 1999b). This annual effective dose of 360 mrem/year has not been associated with adverse health effects in humans or animals (ATSDR 1999b). ATSDR believes the chronic ionizing radiation MRL of 100 mrem/year is below levels that might cause adverse health effects in people most sensitive to such effects; therefore, ATSDR does not expect

[11] For current exposure, ATSDR evaluated the radiation dose resulting from internally deposited radionuclides only.

noncancer health effects to have occurred from radiation doses received from current uranium exposure communities near the Y-12 plant.

Table 14. Current Uranium Radiation Dose to the Scarboro Community

Exposure Pathway	Committed Effective Dose Equivalents (mrem)
Inhalation of air in Scarboro	3.95×10^{-2}
Soil ingestion by a 1-year old Scarboro resident	3.97×10^{-2}
Ingestion of vegetables from a private garden	1.37×10^{-1}
Summed Radiation Dose	$\mathbf{2.16 \times 10^{-1}}$

The radiation doses calculated by ATSDR as resulting from the internal deposition of uranium include the background contribution of uranium typically in the body from other natural sources.

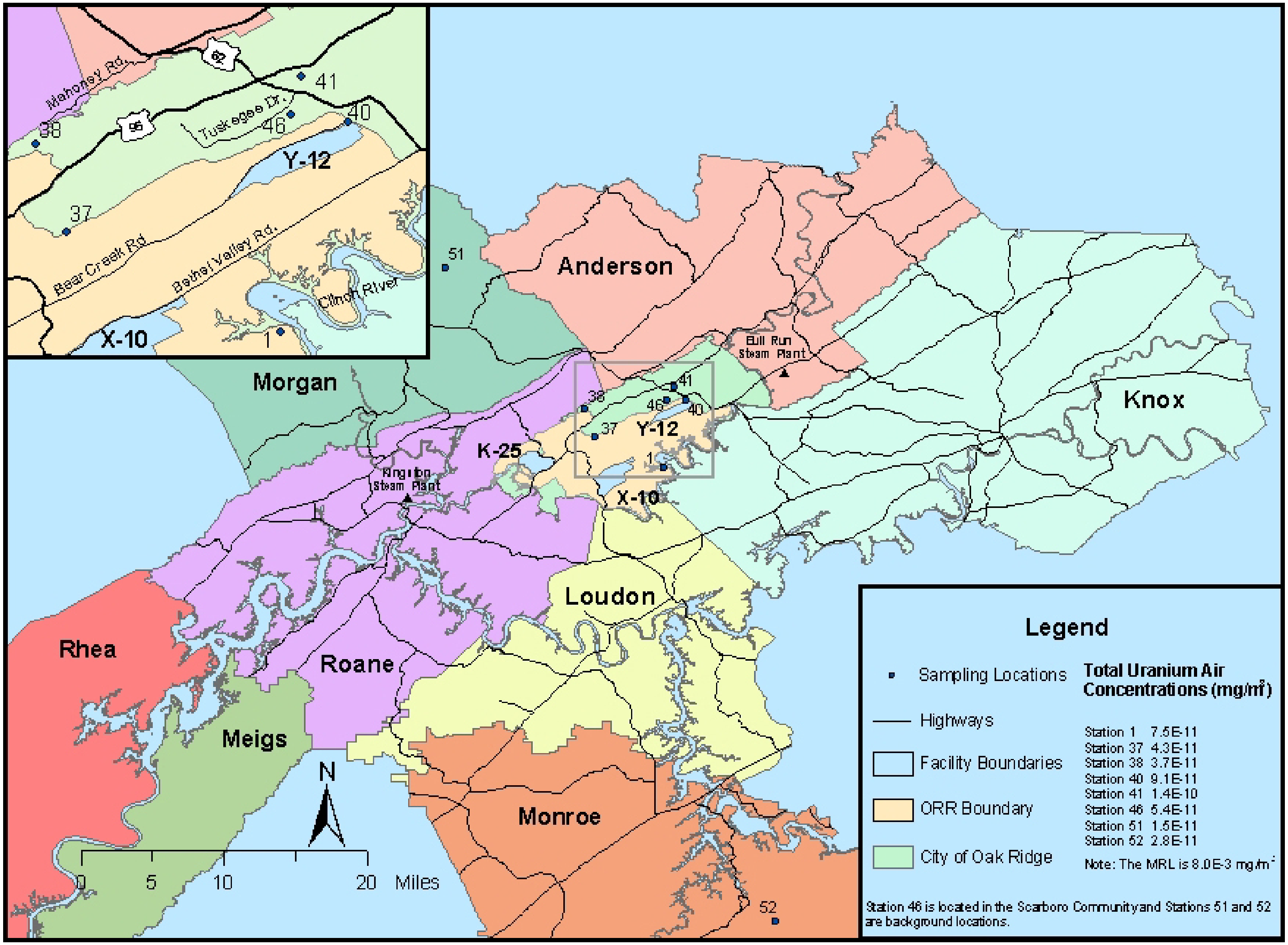
Current Air Exposure Pathway

Operations at the Y-12 plant continue to release materials to the atmosphere. In addition to monitoring the release of uranium from exhaust ventilation systems at the source, DOE has established a series of perimeter air monitoring stations around the reservation, including air monitoring station 46 located in Scarboro west of the Scarboro Community Center. ATSDR reviewed air data accumulated since 1995[12] from four on-site perimeter air monitoring stations, two off-site remote air monitoring stations, and two off-site perimeter air monitoring stations located in Scarboro and the city of Oak Ridge. ATSDR used these values to assess the current radiation impact of inhaling air containing uranium[13] (see Figure 19 for the locations of the air monitoring stations).

[12] ATSDR evaluated data from 1986 to 1991 for Station 41.

[13] Fossil fuel plants, such as coal burning plants, release naturally occurring radioactive materials through their stacks. Because the Bull Run and Kingston Steam Plants are in the vicinity of Oak Ridge, these facilities could be impacting the uranium analyses performed in Oak Ridge. ATSDR could not locate specific information about these plants from the Tennessee Valley Authority. The agency did, however, locate information from a peer-reviewed publication that reported the typical concentrations of uranium in coal ash and fly ash. These values were 4 picocuries per gram (pCi/g) and 5.4 pCi/g, respectively (Stranden 1985).

Figure 19. Locations of Air Monitoring Stations



To estimate the radiation dose, the isotopic activity was evaluated using the appropriate ICRP dose coefficient and a protective inhalation rate. The EPA Exposure Factors Handbook recommends an inhalation rate of 8.7 cubic meters per day (m^3/day) for a child 1 to 12 years of age and an average inhalation rate of 13.25 m^3/day for adults (EPA 1997). For the assessment, ATSDR used a slightly more conservative inhalation rate of 15.25 m^3/day (i.e., 5.5 million liters/year) for adults. Radiation doses resulting from the inhalation pathway are presented in Table 15. As shown in Table 15, people living in the reference location, Scarboro, are expected to inhale sufficient uranium to impart a CEDE of 3.95×10^{-2} mrem.

Furthermore, as the uranium inhaled is considered insoluble, the organ receiving the greatest radiation dose would be the lung. Therefore, ATSDR also calculated radiation doses to the lung. These doses to the lung are not at levels known to cause any adverse health outcomes.

Table 15. Estimated Current Total Radiation Doses from Inhalation of Uranium

Station	Whole Body Dose (mrem)	Lung Dose (mrem)
1 (on-site perimeter monitor)	4.18×10^{-2}	3.47×10^{-1}
37 (on-site perimeter monitor)	2.40×10^{-2}	1.99×10^{-1}
38 (on-site perimeter monitor)	2.13×10^{-2}	1.77×10^{-1}
40 (on-site perimeter monitor)	7.94×10^{-2}	6.59×10^{-1}
41 (city of Oak Ridge)	4.79×10^{-2}	3.98×10^{-1}
46 (Scarboro)	3.95×10^{-2}	3.28×10^{-1}
51 (Norris Dam)	9.31×10^{-3}	7.73×10^{-2}
52 (Fort Loudoun Dam)	1.68×10^{-2}	1.40×10^{-1}

Values are expressed as committed effective dose equivalents (CEDE).
Total uranium doses were calculated using the average concentrations for the data available since 1995, except the doses for Station 41 were calculated using the average concentration for data from 1986 to 1991.

Current Surface Water Exposure Pathway

To evaluate current exposures to uranium through the surface water pathway, ATSDR analyzed available surface water data taken from 1995 to 2002 at off-site locations (Scarboro drainage ditches and Lower EFPC) and for comparison, three on-site locations (Upper EFPC, Bear Creek, and the on-site portion of Lower EFPC after it joins with Bear Creek) (see Figure 20). As shown on Figure 20, the Upper EFPC, located entirely on the reservation, originates and flows through the Y-12 plant to the eastern site boundary and into Lower EFPC. Lower EFPC flows north from the Y-12 plant off site through the business and residential sections of city of Oak Ridge, but does not flow through Scarboro. After flowing through Oak Ridge for about 12 miles, Lower EFPC enters the ORR site again on the western end of the city and joins Poplar Creek, which flows to the Clinch River near the K-25 site. Bear Creek, also located entirely on the site, originates on the western end of the Y-12 plant and flows southwest to join Lower EFPC near the K-25 site. While access to the three on-site locations is restricted, the public has access to the portion of Lower EFPC that flows through the city. However, the creek appears to be too shallow for swimming, and the state has issued a fishing advisory for EFPC that warns the public to avoid eating fish from the creek and to avoid contact with the water. The Scarboro surface water samples were collected in 1998 and 2001 from drainage ditches in Scarboro and analyzed by FAMU and EPA. Also, Scarboro is located at a higher elevation along Pine Ridge than the EFPC floodplain, thus, surface water in Scarboro flows into EFPC.

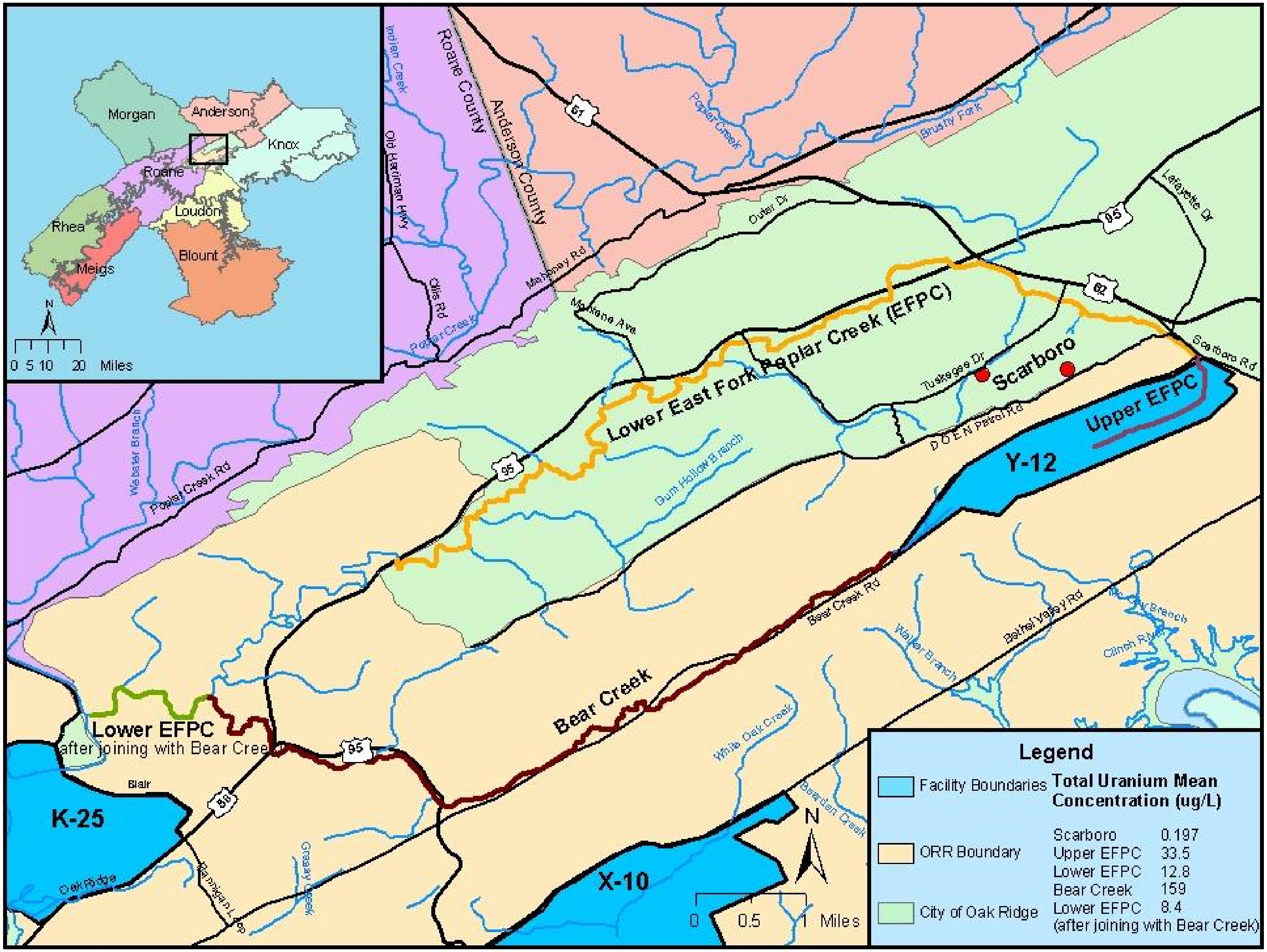
Table 16 shows the mean total uranium concentrations for surface water samples collected from 1995 to 2002 at the two off-site locations and the three on-site locations. The mean uranium concentrations (0.197 µg/L) in surface water from Scarboro ditches are well below (100 times less than) the ATSDR EMEG of 20 µg/L for highly soluble uranium salts (see Table 2). The ATSDR EMEG is a nonenforceable, health-based comparison value developed for screening environmental contaminants for further evaluation. Exposure to concentrations at or below ATSDR's comparison values are not considered to warrant health concern. Even though the mean uranium concentrations are above ATSDR's EMEG of 20 µg/L in Upper EFPC and Bear Creek (on-site locations with access restricted), the mean uranium concentrations decrease to below the EMEG in the off-site portions of Lower EFPC. The total uranium mean concentration in Bear Creek decreases dramatically after joining with Lower EFPC. The total uranium mean concentrations in Scarboro and in the off-site areas of Lower EFPC are below ATSDR's EMEG; therefore, the concentrations of uranium that people might be exposed to are not of health concern.

Table 16. Total Uranium Concentrations in EFPC and Bear Creek

Location	Mean Concentration (µg/L)	Is the mean above the EMEG of 20 µg/L?
Scarboro drainage ditches (off site)	0.197	no
Upper EFPC (on site)	33.5	yes
Lower EFPC (off site)	12.8	no
Bear Creek (on site)	159	yes
Lower EFPC (on site after joining with Bear Creek)	8.4	no

In addition, the mean total uranium concentrations in Scarboro and Lower EFPC are below EPA's maximum contaminant level (MCL) for uranium (30 µg/L). The MCL is the level of a contaminant that is allowed in drinking water. EFPC, however, is not used as a drinking water source. The city of Oak Ridge, including the community of Scarboro, is served by municipal water obtained from the Clinch River (Melton Hill Lake), upstream from the reservation.

Figure 20. Locations of Surface Water Samples



Current Soil Exposure Pathway

In 1997, residents of Scarboro and the local chapter of the National Association for the Advancement of Colored People (NAACP) raised concerns that activities at the Y-12 plant could have produced enriched uranium in Scarboro soils. Enriched uranium contains higher than normal amounts of U 235 as compared to natural uranium and is more radioactive than naturally occurring uranium. The detection and identification of enriched uranium, however, can be difficult in environmental samples, especially because the typical levels of U 235 are low in natural soils. Therefore, enrichment is typically based on the percent by weight of U 235 in the uranium samples, not necessarily by the radioactivity of the sample. In response to the concerns expressed by the residents and the NAACP, FAMU collected soil and water samples for the analysis of uranium and other radionuclides (FAMU 1998).

The results of the FAMU study were released in 1998. In 1999, EPA proposed a study to validate the FAMU results and released a draft of their findings in 2002 (EPA 2002b). Each of these studies only collected samples in the Scarboro community, thus no comparison to other areas of Oak Ridge were made[14]. To address exposure to the soil pathway, ATSDR evaluated soil data recently collected in the reference location, Scarboro. ATSDR compared these Scarboro soil data to national background values, as well as to soil samples collected by DOE for the Background Soil Characterization Project in the Oak Ridge area (DOE 1993). During this background characterization project, DOE collected soil samples from uncontaminated areas on ORR, as well as from areas off site.

[14] ATSDR attempted to locate other background soil sampling data within other areas of the city of Oak Ridge, but as of this writing was unsuccessful. Areas that ATSDR attempted to obtain data from included backgrounds collected for the Atomic City Auto Parts (ACAP) remediation. ACAP is a privately owned company contaminated with materials derived and purchased from Oak Ridge operations. Under consent orders from the state of Tennessee, DOE assumed responsibility for the cleanup of the contaminated areas. In the case of ACAP, environmental media were sampled for U 234, U 235, and U 238. ATSDR was informed by DOE that only one monitoring well and soil boring were collected around ACAP. Therefore, ATSDR does not consider any data derived from this site as representative soil background samples. ATSDR is also trying to locate information related to the CSX Railroad remediation and sampling data collected in the Woodland area of Oak Ridge.

Prior to the nuclear age, background concentration and natural background were identical. After the advent of nuclear weapons, the natural background concentration has been impacted by atmospheric testing. This change of background and natural concentrations now means that there are two separate values, a naturally occurring concentration that is indicated as a pre-nuclear age concentration and a background concentration, which has been impacted by atmospheric testing. To evaluate the presence or absence of enriched uranium, the data are best evaluated on a percent basis. For the purposes of evaluating the radiation dose, however, activity in the form of picocuries (pCi) is necessary.

To evaluate the results of EPA's and FAMU's sampling for public health implications, ATSDR compared the isotopic composition of the uranium in Scarboro soil to the isotopic composition found in naturally occurring uranium. ATSDR also compared the isotope ratio to see if these could indicate elevated uranium, even if the concentrations appeared typical. The EPA isotopic analyses of Scarboro soil indicated that the average radioactivity concentrations were 1.2 picocuries per gram (pCi/g) for U 234, 0.1 pCi/g for U 235, and 1.0 pCi/g for U 238. The isotopic ratio of U 235/U 238 suggested that the radioactivity concentration of U 235 in Scarboro soil was elevated greater than typical concentrations found in nature (see Table 17). Based on an initial observation, the U 235 detected in Scarboro soil appears to be representative of enriched uranium as the isotopic ratio of U 235/U 238 is larger (0.096) than the expected isotopic ratio (0.047) in nature. However, the ratio of the activities can be misleading because the activity of U 235 detected was close to the detection limit and the associated uncertainty of the measurement was large, in some cases 75% of the measured value.

Table 17. Comparison of Uranium Isotopic Ratios
Scarboro Soil to Naturally Occurring Uranium

	U 234	U 235	U 238
Scarboro soil concentration	1.2 pCi/g	0.1 pCi/g	1.0 pCi/g
Isotopic ratio in Scarboro soil	1.16 (U 234/U 238)	0.096 (U 235/U 238)	
Isotopic ratio in nature	0.972 (U 234/U 238)	0.047 (U 235/U 238)	

Source: EPA 2002b

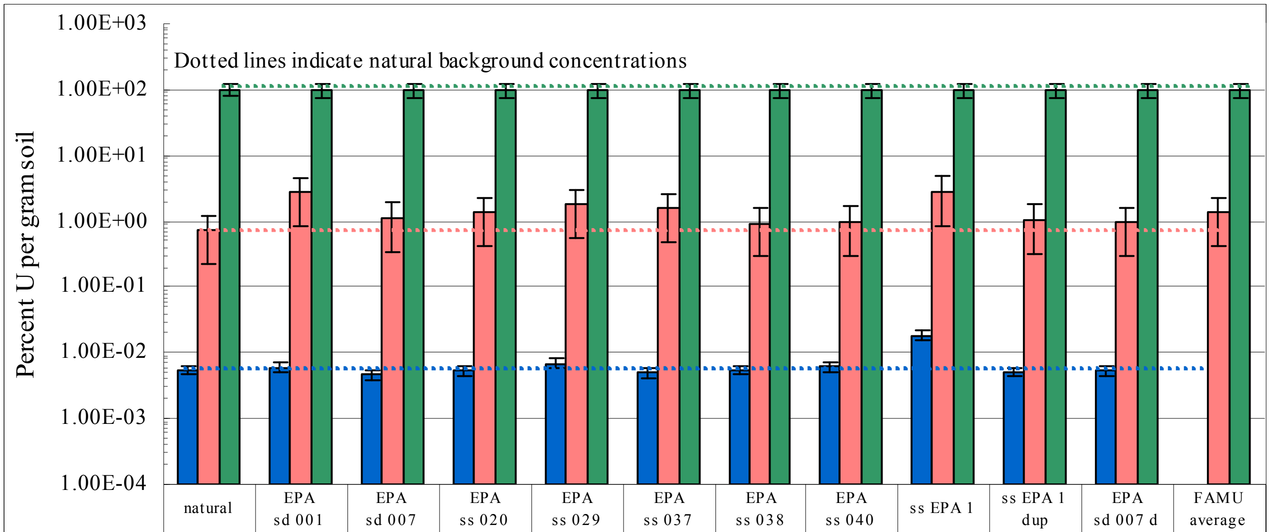
Not shown in the table is the considerable uncertainty in the U 235 measurement. This uncertainty is a function of the amount of U 235 found in nature and the method of analysis.

Therefore, the next step was to determine if the U 235, as a percentage of total uranium, was significantly elevated, which would indicate the presence of enriched uranium. ATSDR converted the measured uranium activity levels obtained from the FAMU and EPA studies to mass units[15]. ATSDR then compared the results of both EPA's sampling efforts (EPA 2002b) and FAMU's (FAMU 1998) sampling efforts to measured soil background concentrations reported by DOE (DOE 1993). ATSDR also compared the results to the established isotopic abundance of the three uranium isotopes. The results of this evaluation are shown in Figure 21. This figure shows the isotopic concentrations of uranium, expressed as a percent of uranium isotopes in soil, in naturally occurring uranium, 10 Scarboro soil and sediment samples from the EPA study, and the average uranium concentrations in Scarboro soil samples from the FAMU study. The dotted lines at 0.005% (U 234), 0.72% (U 235), and 99.2% (U 238) are the concentrations of uranium isotopes found in nature. The error bars represent the uncertainties associated with the analyses of the uranium measurements. The data show that two of the EPA samples (sd 007, ss EPA 1) including the uncertainty, appear to be above the U 235 concentrations found in nature. However, closer evaluation of EPA samples SS EPA 1 and SS EPA 1 dup (a duplicate sample) shows that the uncertainty of these samples is within the range of naturally occurring U 235. Therefore, ATSDR considers only one EPA sample (sd 001) slightly in excess of the naturally occurring concentrations of U 235. Figure 22 compares the uranium isotopic concentrations in naturally occurring uranium to the average uranium isotopic concentrations in soil samples from Scarboro (EPA and FAMU studies) and in background soil samples from uncontaminated areas on and off the ORR (DOE study).

The overall results indicate that the concentrations of uranium detected in the Scarboro community by EPA and FAMU are indistinguishable from the background concentrations of uranium in the area around Oak Ridge. Furthermore, the percentages of uranium in the Scarboro community are essentially identical to the amount of uranium found in nature. However, the Oak Ridge area appears to contain more U 235 than typically found in nature.

[15] To convert the radioactive measurement of the isotope to grams, one divides the radioactive measurement by its specific activity.

Figure 21. Comparison of Uranium Isotopic Concentrations in Natural Uranium, 10 EPA Scarboro Soil Samples, and Average FAMU Scarboro Soil Samples

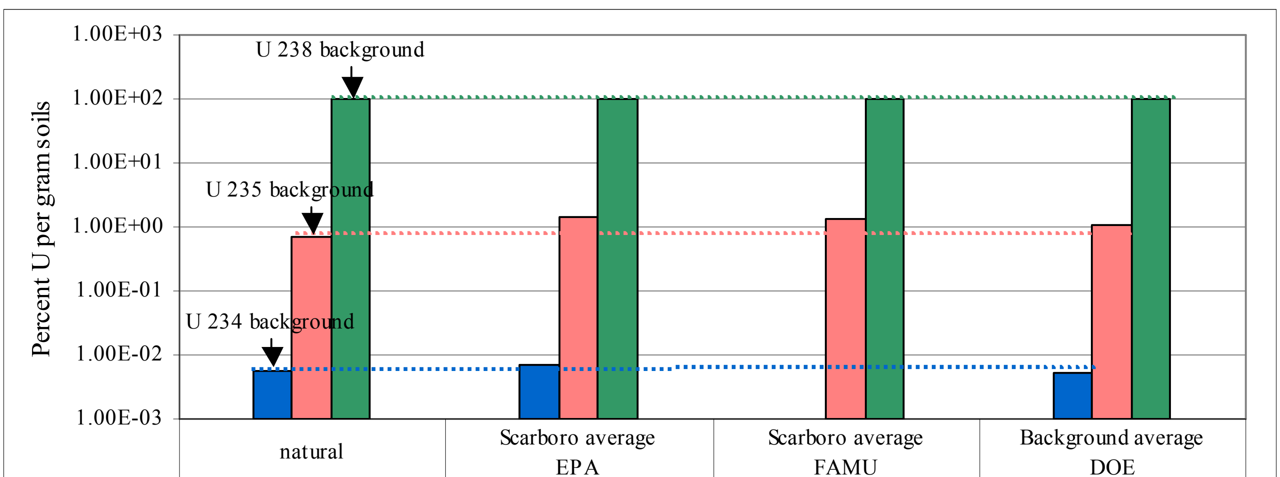


	natural	EPA sd 001	EPA sd 007	EPA ss 020	EPA ss 029	EPA ss 037	EPA ss 038	EPA ss 040	ss EPA 1	ss EPA 1 dup	EPA sd 007 d	FAMU average
U 234	5.50E-03	5.97E-03	4.65E-03	5.45E-03	6.93E-03	4.92E-03	5.52E-03	6.27E-03	1.83E-02	5.13E-03	5.43E-03	1.00E-06
U 235	7.20E-01	2.70E+00	1.12E+00	1.34E+00	1.81E+00	1.54E+00	9.31E-01	9.78E-01	2.80E+00	1.05E+00	9.41E-01	1.37E+00
U 238	9.93E+01	9.73E+01	9.89E+01	9.87E+01	9.82E+01	9.85E+01	9.91E+01	9.90E+01	9.72E+01	9.89E+01	9.91E+01	9.86E+01

Sources: EPA 2002b; FAMU 1998

The isotopic concentration values can be written different ways, for example 1.00E+03 percent U per gram soil is the same as 1.00×10^3 percent U per gram soil and 1,000 percent U per gram soil.

Figure 22. Comparison of the Average Uranium Isotopic Concentrations in Natural Uranium, EPA and FAMU Scarboro Soil Samples, and Background Soil Samples



	natural	Scarboro average EPA	Scarboro average FAMU	Background average DOE
U 234	5.50E-03	6.73E-03	1.00E-06	5.26E-03
U 235	7.20E-01	1.45E+00	1.34E+00	1.08E+00
U 238	9.93E+01	9.85E+01	9.87E+01	9.89E+01

Sources: DOE 1993; EPA 2002b; FAMU 1998

The background average is from the DOE Background Soil Characterization Project, for which soil samples were taken from uncontaminated areas on and off the ORR.
The isotopic concentration values can be written different ways, for example 1.00E+03 percent U per gram soil is the same as 1.00×10^3 percent U per gram soil and 1,000 percent U per gram soil.

Concern has also been expressed that the Scarboro community has been impacted by uranium releases to EFPC. To evaluate this concern, ATSDR evaluated the location and surface elevation of Scarboro and EFPC. Lower EFPC flows north from the Y-12 plant off site through the business and residential sections of city of Oak Ridge, but does not flow through Scarboro. At its closest point, the EFPC passes about 0.4 miles to the northeast of the populated areas of Scarboro (ChemRisk 1999b). Also, Scarboro is located at a higher elevation along Pine Ridge than the EFPC floodplain, and Scarboro does not receive surface water from the EFPC. In addition, ATSDR compared the average uranium isotopic ratios (U 234/U 238; U 235/U 238) of Scarboro soil and EFPC floodplain soil from off-site areas to that of natural occurring uranium. The isotopic ratios are shown in Table 18.

Table 18. Comparison of the Average Uranium Isotopic Ratios in Scarboro Soil, EFPC Floodplain Soil, and Natural Uranium

Location	U 234/U 238	U 235/U 238
Scarboro	4.79×10^{-5}	0.01
EFPC	2.84×10^{-5}	0.004
Natural	5.54×10^{-5}	0.0072

The ratios are based on the percentages of the specific isotopes found in nature, not their radioactivity.

These data suggest that the ratio of U 234/U 238 in Scarboro soil is elevated over the ratio found in EFPC floodplain soils; however, the ratios for both locations are less than the ratio typically found in nature. The ratio of U 235/U 238 in Scarboro soil is not elevated over those found in the EFPC floodplain or in nature. The uranium content in soils within the Scarboro community is representative of uranium found in areas not impacted by Y-12 operations; that is, the soils in Scarboro are not contaminated by atmospheric releases related to ORR operations. Additionally, in 1993, ATSDR scientists released a public health consultation that evaluated the environmental sampling data from EFPC to determine the public health implications of past and current Y-12 plant releases into the creek. ATSDR concluded that the concentrations of uranium and other radionuclides detected in soil, sediment, surface water, and fish from EFPC were not present at levels of public health concern (ATSDR 1993b).

Soil Ingestion Pathway

Typically, the proportion of a population exposed to contaminated soils is identified by estimating the area of contaminant dispersion and then determining the population within the contaminated area. Furthermore, the population can be characterized by identifying individuals who are more likely to ingest soil (i.e., children). However, the entire population in the contaminated area may ingest some soil. People incidentally (accidentally) ingest soil when they use their hands to handle food that they eat, smoke cigarettes, or put their fingers in their mouths because soil or dust particles can adhere to food, cigarettes, and hands. Children are particularly sensitive because they are likely to ingest more soil than adults. Displaying hand-to-mouth behavior is a normal phase of childhood and therefore they have more opportunities to ingest soil than adults do.

For the purposes of this assessment, ATSDR evaluated soil ingestion for Scarboro children (assuming they incidentally ingest 100 mg/day) and their resulting uranium CEDEs over a period of 70 years. For this scenario, ATSDR chose dose coefficients for an infant as these would result in the highest dose to a child who might ingest soils at various ingestion rates. Furthermore, as the uranium ingested is considered insoluble, the organ receiving the greatest radiation dose would be the bone (see Table 19). Therefore, ATSDR also calculated uranium CEDEs to the bone and whole body. These radiation doses to the bone and whole body are well below the ATSDR radiogenic cancer comparison value of 5,000 mrem over 70 years and are not at levels known to cause any adverse health outcomes.

Table 19. Uranium Radiation Doses Following Soil Ingestion by a 1-year old Scarboro Resident at Each Sample Location

Sample Location	Bone (mrem)	Whole body (mrem)
S. Benedict 1	4.37×10^{-1}	3.05×10^{-2}
S. Dillard	6.02×10^{-1}	4.17×10^{-2}
S. Fisk	5.96×10^{-1}	4.15×10^{-2}
Parcel	6.27×10^{-1}	4.38×10^{-2}
S. Benedict 2	6.12×10^{-1}	4.25×10^{-2}
Spellman	7.34×10^{-1}	5.11×10^{-2}
Hampton	5.56×10^{-1}	3.88×10^{-2}
Bennett Lane	3.85×10^{-1}	2.73×10^{-2}
Average	$\mathbf{5.69 \times 10^{-1}}$	$\mathbf{3.97 \times 10^{-2}}$

The dose is the CEDEs expected to be received over a period of 70 years following an intake. It is based on the ingestion of 100 milligrams of soil daily for the course of one year.

Ingestion of vegetables grown near the Y-12 plant

When uptake into plants is possible, the identification of populations that are exposed or potentially exposed through consumption of contaminated plants is evaluated. Because of the chemical nature and solubility in water, uranium oxides, the form of uranium released from the Y-12 plant, are not taken up by plants readily (Dreesen et al. 1982; Moffett and Tellier 1977 as cited in ATSDR 1999a). The uptake, called the concentration ratio (CR), is expressed as a ratio of uranium in soil to the amount of uranium in plants. The concentration ratio is dependent on the soil and type of plant, with recommended values ranging from 0.002 to 0.017 (LANL 2000; NCRP 1999). For example, if a kilogram of soil contains a microgram of uranium, a kilogram of plant material may contain 0.002 to 0.017 micrograms of uranium.

From 1998 to 2000, DOE collected homegrown vegetables from a Scarboro resident and analyzed these foods for radionuclides, including the uranium isotopes. ATSDR analyzed the private garden vegetable data to evaluate the uranium radiation dose a person might receive from the ingestion of these vegetables. The rate of consumption of contaminated plants may differ considerably from the national average for certain populations living near hazardous waste sites. EPA has published a handbook, the Exposure Factors Handbook (EPA 1997), in which regional rates for foods are listed. ATSDR used the food intake parameters specific to the South (see Table 20).

Table 20. Food Ingestion Rates for the Southern United States

Food	Per Capita Intake (g/kg/day)	Standard Error
Total fruit	3.017	0.105
Total vegetable	4.268	0.047
Total meat	2.249	0.025
Homegrown fruits	2.97	0.3
Homegrown vegetables	2.27	0.122
Home-produced meat	2.24	0.194

Source: EPA 1997

g/kg/day: grams per kilogram per day

ATSDR estimates that a person who frequently eats vegetables from a private garden in Scarboro is expected to receive about 0.137 mrem of uranium per year. The summary of this analysis from the ingestion of foods collected from a private garden in Scarboro is provided in Table 21.

Table 21. Radiation Doses from Uranium Following Ingestion of Private Garden Vegetables Grown in Scarboro

Vegetable type	Total Radiation Dose (mrem per gram food)
Leafy	1.87×10^{-3}
Tomatoes	4.34×10^{-5}
Turnips	1.54×10^{-4}
Total per gram food	2.06×10^{-6}
Total following ingestion	1.37×10^{-1} mrem per year

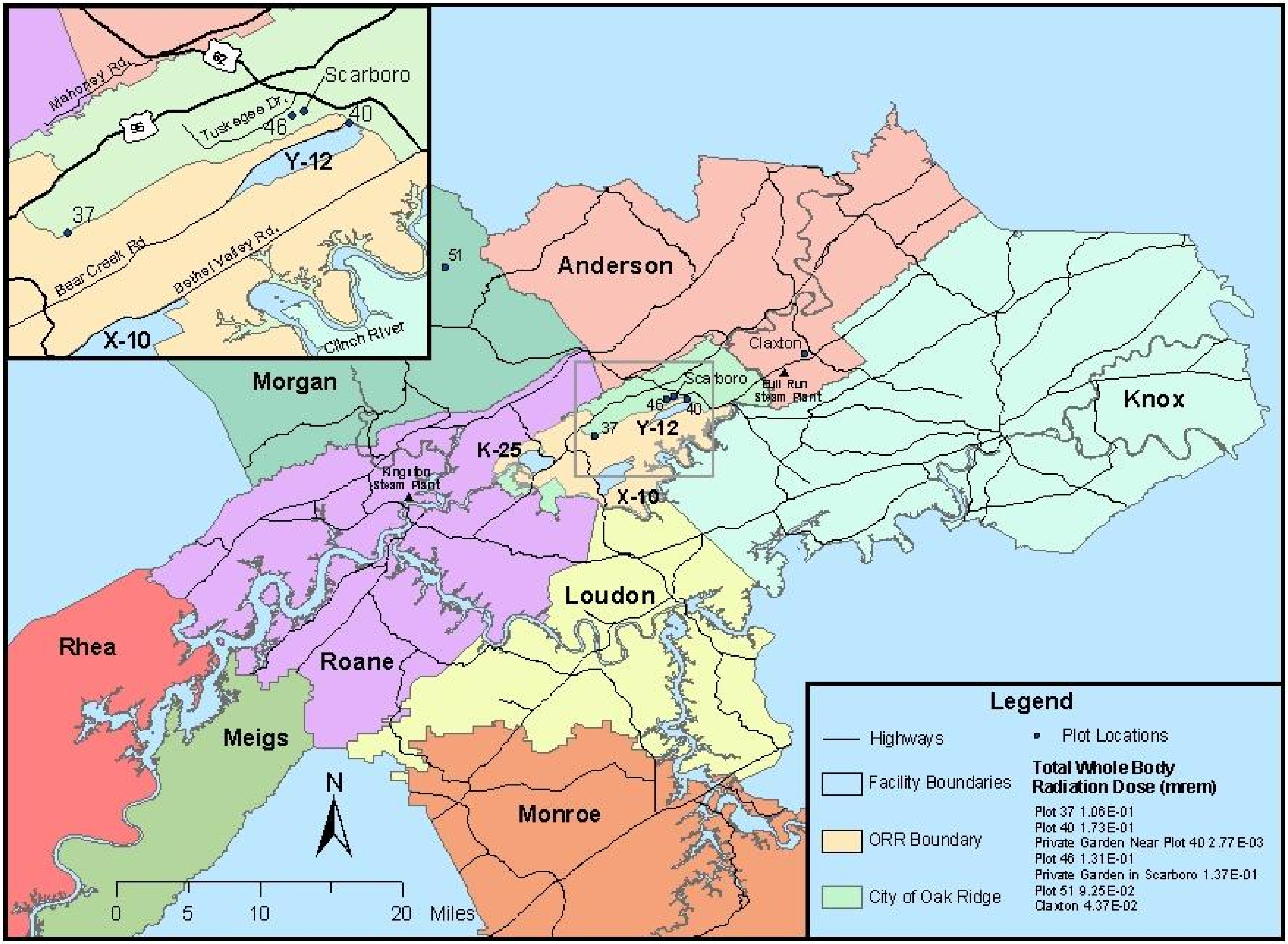
Ingestion is based on an 80-kilogram adult eating 2.27 grams of produce per kilogram of body weight per day for 365 days a year (EPA 1997).

In addition, DOE collects and analyzes vegetables grown in plots near on-site and off-site air monitoring stations and in private gardens (Figure 23 gives sample locations). The vegetables included lettuce, turnips, turnip greens, and tomatoes. These vegetables are analyzed for radionuclides, including the uranium isotopes. ATSDR estimated the annual dose a resident might receive from ingesting equal amounts of these vegetables using the same default values estimated for a Scarboro resident. That is, the typical resident would ingest 2.27 grams of produce per day for each kilogram of their body weight. For these calculations, we used a body weight of 80 kilograms (approximately 176 pounds) and 365 days per year. The estimated average radiation doses from uranium are summarized in Table 22. These results indicate that the produce grown and consumed in the Scarboro community contains essentially the same amount of uranium as produce grown in the outlying areas.

Table 22. Radiation Doses from Uranium Following Ingestion of Garden Vegetables Grown On and Off the Oak Ridge Reservation

Plot Identification Number	Location	Total Whole Body Radiation Dose (mrem)
Plot 37	Monitoring station 37 On site west of Y-12 in the ORR	1.06×10^{-1}
Plot 40	Monitoring station 40 On site near Bear Creek Road and Scarboro Road Intersection	1.73×10^{-1}
Private Garden	Off site near station 40	2.77×10^{-3}
Plot 46	Monitoring station 46 Off site in Scarboro	1.31×10^{-1}
Private Garden	Off site in Scarboro	1.37×10^{-1}
Plot 51	Monitoring Station 51 Off site in Morgan County	9.25×10^{-2}
Claxton	Off site in Claxton	4.37×10^{-2}
	Average ± SD	$9.8 \times 10^{-2} \pm 5.8 \times 10^{-2}$
	Average excluding Plot 46 and Scarboro private garden	8.36×10^{-2}

Figure 23. Locations Where Vegetable Samples Were Grown On and Off the Oak Ridge Reservation



External exposure from uranium in soils

Uranium is a very weak emitter of radiation and is considered a health problem if internalized within the body. A comparison of dose factors using federal guidance documents (EPA 1988, 1993) indicates that uranium in the soil pathway can be removed from any additional evaluation.

III.B.2.b. Current Chemical Effects

ATSDR evaluated whether exposure to the levels of uranium currently being released from the Y-12 plant would cause harmful chemical effects in people living near the Y-12 plant, including the reference population (the Scarboro community). On the basis of the chemical toxicity of uranium, it can be stated that residents living near the ORR are not currently being exposed to harmful levels of uranium through inhalation of air or ingestion of soils, homegrown vegetables, and surface water.

Current Inhalation Exposure Pathway

ATSDR reviewed the air monitoring data accumulated since 1995 in the Scarboro community (Station 46) and air monitoring data accumulated from 1986 to 1991 in the city of Oak Ridge (Station 41). ATSDR used these data to assess the chemical impact of inhaling air containing uranium[16]. These data were compared to data from perimeter air monitoring stations (Stations 1, 37, 38, and 40) on the reservation as well as to background data at remote air monitoring stations (Stations 51 and 52) (Figure 19 shows the locations of the air monitoring stations). For the comparisons, ATSDR converted the isotopic uranium values to mass[17], expressing the activity in

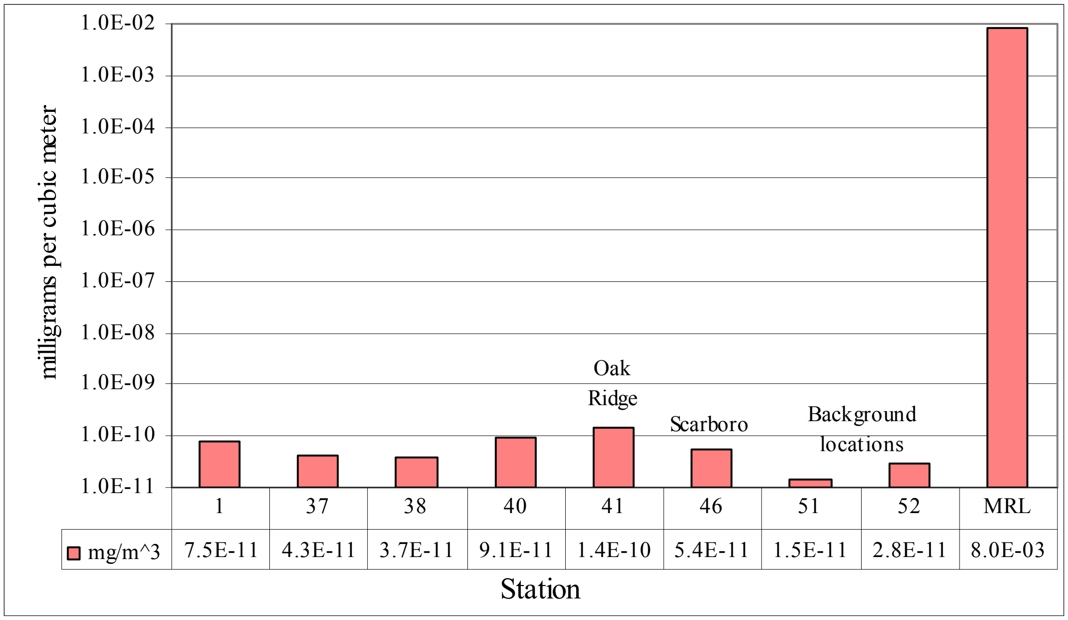
[16] Fossil fuel plants, such as coal burning plants, release naturally occurring radioactive materials through their stacks. Because the Bull Run and Kingston Steam Plants are in the vicinity of Oak Ridge, these facilities could be impacting the uranium analyses performed in Oak Ridge. ATSDR could not locate specific information about these plants from the Tennessee Valley Authority. The agency did, however, locate information from a peer-reviewed publication that reported the typical concentrations of uranium in coal ash and fly ash. These values were 4 picocuries per gram (pCi/g) and 5.4 pCi/g, respectively (Stranden 1985).

[17] Each individual isotope (U 234, U 235, and U 238) has a separate and distinct half life and mass. Therefore, one can convert the activity of each individual isotope using its specific activity expressed as curies of radioactivity per gram of pure radionuclide (0.333 pCi/µg for U 238, 6,187 pCi/µg for U 234, 2.14 pCi/µg for U 235). To convert the radioactive measurement of the isotope to milligrams, one divides the radioactive measurement by its specific activity while ensuring the units of measurement are consistent.

units of milligrams of uranium per cubic meter of air (mg/m^3). The air concentrations of uranium in Scarboro averaged 5.4×10^{-11} mg/m^3 and in the city of Oak Ridge averaged 1.4×10^{-10} mg/m^3 (see Figure 24). The average uranium air concentrations from perimeter monitoring stations on the reservation to the west of Scarboro are about 20% lower than the average concentrations measured in the Scarboro location. The average background uranium air concentrations from the remote air monitoring stations are about 60% lower than that of Scarboro; however, the average concentration from Station 1, located on site near X-10, is about 40% higher than Scarboro. Station 41, located in Oak Ridge near the intersection of South Illinois Avenue and the Oak Ridge Turnpike, has an average concentration about 60% higher than Scarboro. Therefore, ATSDR believes this indicates that a portion of the uranium detected in the air around Scarboro is from the Y-12 plant.

The current air concentrations were compared to ATSDR's intermediate-duration inhalation MRL of 8×10^{-3} mg/m^3 for insoluble uranium. As shown in Figure 24, air concentrations from all stations, including Scarboro, are more than a million times less than the MRL and therefore well below levels that would be expected to cause harmful chemical effects.

Figure 24. Average Uranium Air Concentrations Compared to the MRL



The air concentration values can be written different ways, for example 1.0E-02 milligrams per cubic meter is the same as 1.0×10^{-2} milligrams per cubic meter and 0.01 milligrams per cubic meter.
Values are averages of monitoring station data available from 1995 to present; except the value for Station 41 is an average of data from 1986 to 1991.
Station 46 is in the Scarboro community, and Stations 51 and 52 (located at the Norris and Fort Loudoun Dams, respectively) are monitoring locations that have not been impacted by releases from the ORR. The remaining stations are on the reservation.
ATSDR's MRL is also shown.

Current Ingestion Exposure Pathway

Ingestion of soils

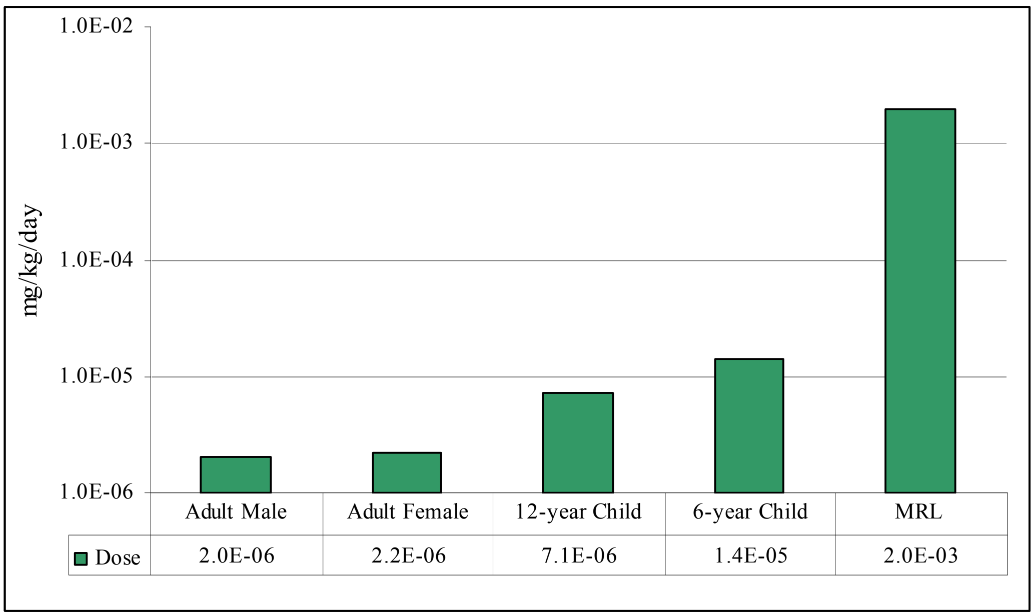
As with the evaluation of radiation effects, ATSDR considered that the entire population of Scarboro incidentally ingests soil. Adults were assumed to incidentally ingest 50 mg of soil/day, whereas children were assumed to incidentally ingest 100 mg/day. For the purposes of the assessment, ATSDR evaluated current doses for an adult male, an adult female, a 12-year-old child, and a 6-year-old child. The results are summarized in Table 23 and Figure 25. Section *III.A.2. Evaluating Exposures* explains ATSDR's method of calculating doses.

Table 23. Uranium Doses from Ingestion of Scarboro Soil

Population	Body Weight (kg)	Intake Rate (mg/day)	Dose (mg/kg/day)
Adult Male	78	50	2.0×10^{-6}
Adult Female	71	50	2.2×10^{-6}
12-year Child	45	100	7.1×10^{-6}
6-year Child	23	100	1.4×10^{-5}
		Ingestion MRL	2.0×10^{-3}

The average soil uranium concentration of 3.19 mg U/kg soil (EPA 2002b) was used in the formula Dose = (Conc. × IR) / BW to calculate the uranium dose from incidental ingestion of soil.

Figure 25. Uranium Dose Following Ingestion of Soil



The dose values can be written different ways, for example 1.0E-02 mg/kg/day is the same as 1.0×10^{-2} mg/kg/day and 0.01 mg/kg/day.

The estimated uranium doses from ingestion of Scarboro soil by all receptor populations are well below the ATSDR MRL for intermediate-duration oral exposure to uranium (0.002 mg/kg/day) (shown in Table 23). The maximum uranium dose to the receptor population (6-year-old child) is approximately 140 times less that the ATSDR MRL. Remember that the MRL is a screening level for which values below are not of health concern. This intermediate-duration oral MRL is also protective for chronic-duration oral exposure because the renal effects of uranium exposure are more dependent on the dose than on the duration of exposure. Therefore, residents of

Scarboro are not currently being exposed to harmful levels of uranium through incidentally ingesting soil.

Ingestion of vegetables grown near the Y-12 plant

Because of its chemical nature and solubility in water, uranium oxide is transported poorly from soils to plants (Dreesen et al. 1982; Moffett and Tellier 1977 as cited in ATSDR 1999a). The uptake varies widely (i.e., concentration ratios range from 0.002 to 0.017; LANL 2000; NCRP 1999) and is dependent on the nature of the soil, the pH, and the concentration of uranium in the soil.

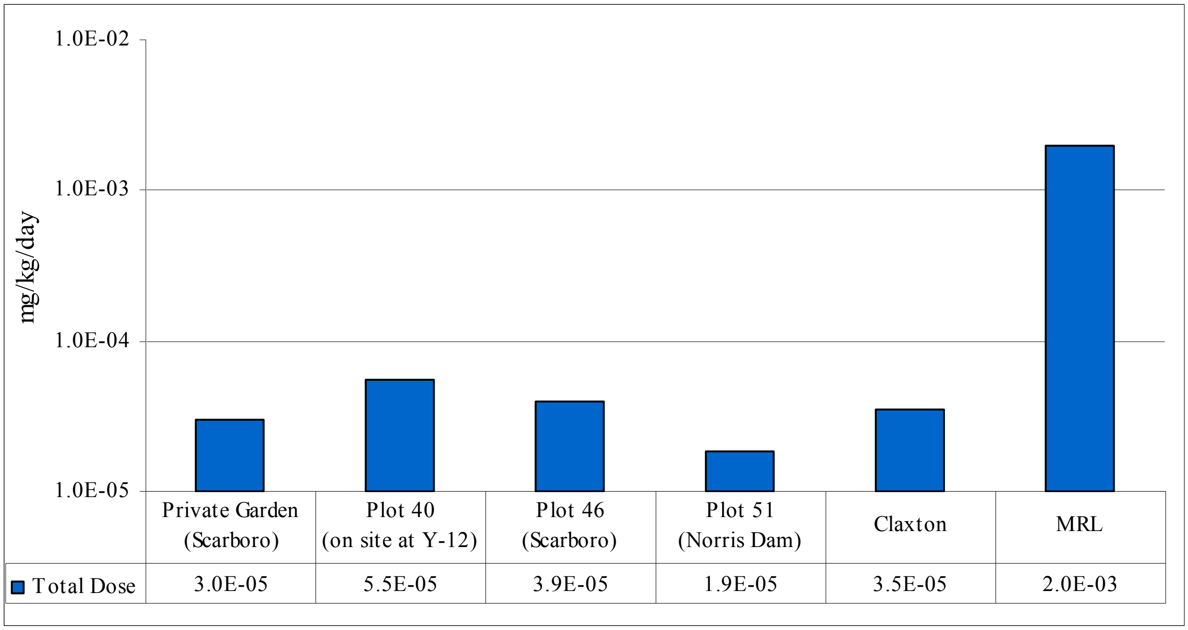
As noted previously in the radiation effects section, DOE collected homegrown vegetables from plots near on-site and off-site air monitoring stations and in private gardens in Scarboro and Claxton and analyzed these foods for the uranium isotopes. ATSDR used food ingestion rates (listed in Table 20) to evaluate the mass intake one might receive from the ingestion of these vegetables. The estimated doses of uranium from ingestion of vegetables from several locations on and around the ORR, including a private garden in Scarboro and a garden grown at air monitoring station 46 (also located in Scarboro), are given in Table 24 and Figure 26.

Table 24. Total Uranium Dose Following Ingestion of Vegetables Grown On and Off the Oak Ridge Reservation

Location	Total Intake (mg/g)	Total Dose (mg/kg/day)
Private Garden (Scarboro)	1.3×10^{-5}	3.0×10^{-5}
Plot 40 (on site at Y-12)	2.4×10^{-5}	5.5×10^{-5}
Plot 46 (Scarboro)	1.7×10^{-5}	3.9×10^{-5}
Plot 51 (Norris Dam)	8.2×10^{-6}	1.9×10^{-5}
Claxton	1.5×10^{-5}	3.5×10^{-5}
	MRL	2.0×10^{-3}

The total uranium doses were calculated by multiplying the total intakes by 2.27 g/kg/day, which is the mean intake of homegrown vegetables for people who live in the South and garden (EPA 1997).

Figure 26. Total Uranium Dose Following Ingestion of Vegetables Grown On and Off the Oak Ridge Reservation



The dose values can be written different ways, for example 1.0E-02 mg/kg/day is the same as 1.0×10^{-2} mg/kg/day and 0.01 mg/kg/day.

ATSDR has established an MRL of 0.002 mg/kg/day for the ingestion of uranium. As shown in Table 24, the total uranium doses from ingestion of vegetables grown in all on-site and off-site locations, including the Scarboro community, are well below the ATSDR MRL for intermediate-duration oral exposure to uranium (0.002 mg/kg/day). The estimated total uranium doses from ingestion of vegetables grown in private gardens in Scarboro are more than 50 times less than the MRL, and therefore ingestion of these vegetables is not of health concern.

Ingestion of water from nearby creeks

EFPC is not used as a drinking water source. The city of Oak Ridge, including Scarboro, is served by municipal water, which must meet specific drinking water quality standards set by EPA. Under the authorization of the Safe Drinking Water Act, EPA has set national health-based standards to protect drinking water and its sources. More information concerning the Safe Drinking Water Act can be found on EPA's website at http://www.epa.gov/safewater or by calling EPA's Safe Drinking Water Hotline at 1-800-426-4791. The total uranium mean concentrations in surface water from Scarboro ditches and Lower EFPC are below EPA's MCL for uranium (30 μg/L). In addition, Table 16 shows that the mean total uranium concentrations for surface water samples collected from Scarboro ditches and Lower EFPC are below ATSDR's EMEG of 20 μg/L. Therefore, the concentrations of uranium that people might be exposed to are not of health concern.

> The MCL is the level of a contaminant that is allowed in drinking water.

IV. PUBLIC HEALTH IMPLICATIONS

Summary of Public Health Implications

ATSDR evaluated past and current off-site exposures to uranium releases from the Y-12 plant for both chemical and radiation health effects. Uranium from the Y-12 plant was released into the air from vents and stacks; uranium was also released into the surface water via East Fork Poplar Creek (EFPC) (ChemRisk 1999).

The Scarboro community represents an established community surrounding ORR where residents resided during the years of uranium releases. The Scarboro community was selected as the reference population after air dispersion modeling indicated that its residents were expected to have received the highest uranium exposures (ChemRisk 1999). The Task 6 report stated that "while other potentially exposed communities were considered in the selection process, the reference locations [Scarboro] represent residents who lived closest to the ORR facilities and would have received the highest exposures from past uranium releases…Scarboro is the most suitable for screening both a maximally and typically exposed individual" (ChemRisk 1999).

As shown in Table 25, all of the exposure pathways evaluated by ATSDR for both radiation and chemical health effects resulted in uranium exposures that were too low to be of health concern. Therefore, the residents living in Scarboro were not exposed to harmful levels of uranium from the Y-12 plant in the past, and they are not currently being exposed to harmful levels of uranium from the Y-12 plant. **Consequently, if the Scarboro community—the population likely to have received the highest uranium exposures from the Y-12 plant—was not in the past and is not currently being exposed to harmful levels of uranium from the Y-12 plant, then other residents living near the Y-12 plant, including those within the city of Oak Ridge, are also not being exposed to harmful levels of uranium.** For more details about each of the pathways evaluated, see Section III.B. Public Health Evaluation.

Table 25. Summary of Public Health Implications from ATSDR's Evaluation of Past and Current Uranium Exposure to Off-Site Populations

Exposure	Effects	Pathway	Notes	Is there a public health concern?
Past	Radiation	Total	The total radiation dose from exposure to uranium via all air, surface water, and soil exposure pathways was estimated to be 155 mrem over 70 years (see Table 4 and Figure 9). This dose is well below (32 times less than) the ATSDR radiogenic cancer comparison value of 5,000 mrem over 70 years. Also, the total radiation dose approximation value of 2.2 mrem per year (based on the 155 mrem over 70 years) is well below (45 times less than) the ATSDR chronic-duration MRL of 100 mrem/year for ionizing radiation.	No
	Chemical	Inhalation	Yearly estimated air concentrations of uranium ranged from 2.1×10^{-8} to 6.0×10^{-5} mg/m^3 (see Figure 16 and Table 12). All concentrations were less than 1% of the intermediate-duration inhalation MRL of 8×10^{-3} mg/m^3 for insoluble forms of uranium.	No
		Ingestion	Yearly estimated uranium doses via all soil and surface water exposure pathways ranged from 2.7×10^{-5} to 1.3×10^{-2} mg/kg/day (See Figure 17 and Table 13). All doses are less than the dose (5×10^{-2} mg/kg/day) at which health effects (renal toxicity) have been observed in rabbits, the mammalian species most sensitive to uranium kidney toxicity.	No
Current	Radiation	Ingestion and Inhalation	The uranium radiation dose from exposure via ingestion of soil and vegetables and inhalation of air is 0.216 mrem over 70 years (see Table 14 and Figure 9). This dose is well below (23,000 times less than) the radiogenic cancer comparison value of 5,000 mrem over 70 years. Also, the approximation value of current radiation dose of 0.003 mrem per year (based on 0.216 mrem over 70 years) is well below (33,000 times less than) the ATSDR chronic-duration MRL of 100 mrem/year for ionizing radiation.	No
	Chemical	Inhalation	Average uranium air concentrations (5.4×10^{-11} mg/m^3 in Scarboro and 1.4×10^{-10} mg/m^3 in the city of Oak Ridge) are well below (more than a million times less than) the intermediate-duration MRL of 8×10^{-3} mg/m^3 for insoluble forms of uranium (see Figure 24).	No
		Ingestion	The estimated uranium doses from ingestion of Scarboro soil (ranging from 2.0×10^{-6} to 1.4×10^{-5} mg/kg/day) were well below (more than 140 times less than) the ATSDR oral MRL of 2×10^{-3} mg/kg/day for uranium (see Table 23). The estimated uranium doses from ingestion of vegetables grown in private gardens in Scarboro are 3.0×10^{-5} and 3.9×10^{-5} mg/kg/day which are more than 50 times less than the oral MRL of 2×10^{-3} mg/kg/day for uranium.	No

ATSDR's evaluations of off-site exposures to uranium released from the Y-12 plant indicate that past exposures are not of health concern and are unlikely to result in adverse health effects. For every exposure pathway evaluated, the doses were too low to be of health concern for both radiation and chemical health effects.

Past Radiation Exposure

For the evaluation of carcinogenic effects of past radiation exposure to uranium releases from the Y-12 plant, ATSDR compared the estimated total radiation dose over 70 years from exposure to uranium in the air, surface water, and soil pathways (presented in the Task 6 report)[18] to the ATSDR radiogenic cancer comparison value of 5,000 mrem over 70 years. The radiation dose expected to be received in the reference community, the Scarboro population, was 155 mrem over 70 years (see Table 4), and accounts for multiple routes of exposure. This radiation dose of 155 mrem is 32 times less than the radiogenic cancer comparison value of 5,000 mrem which ATSDR believes is protective of human health (see Figure 9). Therefore, ATSDR does not expect carcinogenic health effects to have occurred from past off-site exposures to radiation doses received from Y-12 uranium releases. This committed effective dose equivalent (CEDE) value of 5,000 mrem over 70 years was derived by ATSDR after reviewing the peer-reviewed literature and other documents developed to review the health effects of ionizing radiation (see Appendix D for more information about ATSDR's derivation of the radiogenic cancer comparison value of 5,000 mrem over 70 years).

To evaluate noncancer health effect from the total past uranium radiation dose (CEDE of 155 mrem over 70 years) received by the Scarboro community, an approximation can be made to compare the CEDE of 155 mrem, which is based on 70 years of exposure, to the ATSDR chronic exposure minimal risk level (MRL) for ionizing radiation (100 mrem/year), which is based on one year of exposure. The CEDE of 155 mrem over 70 years could be divided by 70 years to approximate a value of 2.2 mrem as the radiation dose for the first year, which is well below (45 times less than) the 100 mrem/year ATSDR chronic exposure MRL for ionizing radiation (see Figures 7 and 9).

[18] The Task 6 values (based on 52 years of exposure) were multiplied by 1.35 (70 years/52 years) for comparison with ATSDR's MRL, which is based on a 70-year exposure.

The ATSDR MRLs are based on noncancer health effects only and are not based on a consideration of cancer effects. MRLs are estimates of daily human exposure to a substance that are unlikely to result in noncancer effects over a specified duration. MRLs are intended to serve only as a screening tool to assist in determining which contaminants should be more closely evaluated in the public health assessment process. Exposure to estimated doses less than the MRL is not considered to be of health concern, and exposure to estimated doses above the MRL does not necessarily mean that adverse health effects will occur—values above require additional evaluation.

- ATSDR derived the chronic-duration, noncancer MRL of 100 mrem/year for ionizing radiation by dividing the average annual effective dose to the U.S. population (360 mrem/year) by three to account for human variability (that is, ATSDR applied an uncertainty factor of 3) (ATSDR 1999b). This annual effective dose to the U.S. population is obtained mainly from naturally occurring radioactive material, medical uses of radiation, and radiation from consumer products (BEIR V 1990 as cited in ATSDR 1999b). The annual effective dose of 360 mrem/year has not been associated with adverse health effects in humans or animals.

ATSDR believes the chronic ionizing radiation MRLs of 100 mrem/year is below levels that might cause adverse health effects in people most sensitive to such effects: therefore, ATSDR does not expect noncancer health effects to have occurred from past off-site exposures to radiation doses received from past Y-12 uranium releases.

Past Chemical Exposure

To evaluate past chemical exposure to uranium releases from the Y-12 plant, ATSDR compared the estimated average annual air concentrations of uranium in Scarboro (generated during the Task 6 evaluation) to ATSDR's intermediate-duration inhalation MRL for insoluble forms of uranium. All the estimated average air concentrations of uranium for each year were less than 1% of the inhalation MRL of 0.008 mg/m^3 (see Figure 16 and Table 12).

- ATSDR derived this MRL from a study in which no adverse health effects were observed in dogs exposed to 1.1 mg/m^3 of uranium dioxide dust (an insoluble form of uranium) (Rothstein 1949b as cited in ATSDR 1999a). Because this no-observed-adverse-effect level (NOAEL) was derived from an intermittent exposure and ATSDR derives inhalation MRLs for continuous exposure, the NOAEL was adjusted to continuous exposure. In addition, because the NOAEL was derived from an animal study, ATSDR converted it to a human equivalency concentration. Then, ATSDR divided the NOAEL of 1.1 mg/m^3 by an uncertainty factor of 30 (3 for extrapolation from animals to humans and 10 for human variability) to calculate the intermediate-duration inhalation MRL.

ATSDR also compared the estimated total uranium dose from ingestion via both the surface water and soil exposure pathways (also generated during the Task 6 evaluation), to ATSDR's intermediate-duration oral MRL for uranium. Remember that MRLs are used only as a screening tool and have built-in uncertainty or safety factors, making these values considerably lower than levels at which health effects have been observed. Even though some of the doses were higher than the MRL, it does not necessarily follow that harmful health effects will occur—values above the MRL indicate that the contaminant should be evaluated further. Because some of the estimated doses were above the MRL, ATSDR further investigated the toxicologic literature to find doses associated with known health effects. The minimum lowest-observed-adverse-effect level (LOAEL) for oral exposure to uranium that has caused the most sensitive harmful health effects considered to be of relevance to humans was 0.05 mg/kg/day, which caused renal (kidney) toxicity in rabbits (Gilman et al 1998b as cited in ATSDR 1999a). The rabbit is the mammalian species most sensitive to uranium kidney toxicity and is likely to be even more sensitive that humans (ATSDR 1999a). Therefore, ATSDR is comfortable with extrapolating the results from this animal toxicity study to humans. All of the estimated total ingestion doses were less than the LOAEL of 0.05 mg/kg/day at which health effects (renal toxicity) have been observed in rabbits; therefore, past exposure via all the surface water and soil exposure pathways is not a health concern (see Figure 17 and Table 13).

- ATSDR derived this intermediate-duration oral MRL from a study in which an increased incidence of renal toxicity (specifically, anisokaryosis and nuclear vesiculation) was observed in New Zealand rabbits exposed to 0.05 mg/kg/day of uranium as uranyl nitrate (Gilman et al. as cited in ATSDR 1999a). ATSDR applied a total uncertainty factor of 30 (3 for use of a minimal LOAEL and 10 for human variability) to calculate the MRL. No adjustment was made for interspecies variation because the rabbit is the mammalian species most sensitive to uranium toxicity and is likely to be even more sensitive than humans. This MRL for intermediate-duration oral exposure is also protective for chronic-duration oral exposure. This is because the renal effects of uranium exposure are more dependent on the dose than on the duration of the exposure.

Additionally, it should be noted that several levels of conservatism were built into this evaluation of past exposures. As mentioned previously, the values that ATSDR relied on to evaluate past exposures (those from the Task 6 report) came from a screening evaluation that routinely and appropriately used conservative and overly protective assumptions and approaches, which led to an overestimation of concentrations and doses. Even using these conservative overestimations of concentrations and doses, the estimated levels of uranium that persons in the reference community, Scarboro, were exposed to were below levels of health concern. Following is a list of conservative aspects in this evaluation.

1. The majority of the total uranium dose (54% of the total U 234/235 dose and 78% of the total U 238 dose) is attributed to frequently eating fish from the EFPC and eating vegetables grown in contaminated soil over several years (see Tables 9 and 10). If a person did not regularly eat fish from the creek or homegrown vegetables over a prolonged period of time (which is very probable), then that person's uranium dose

would likely have been substantially lower than the estimated doses reported in this public health assessment.

2. The Task 6 report noted that late in the project it was ascertained that the Y-12 uranium releases for some of the years used to develop the empirical χ/Q value may have been understated due to omission of some unmonitored release estimates. This would cause the empirical χ/Q values to be overestimated and in turn would cause the air concentrations to be overestimated.

3. According to ATSDR's regression analysis, the method that the Task 6 team used to estimate historical uranium air concentrations overestimated uranium 234/235 concentrations by as much as a factor of 5. Consequently, airborne uranium 234/235 doses based on this method were most likely overestimated (see Figure 12 and Appendix E).

4. Using the ICRP dose conversion factors tends to overestimate the actual radiation doses due to the built-in conservative assumptions (i.e., selecting variables that typically overestimate the true, but uncertain physical and biological interactions associated with radiation exposure) (for examples, see Harrison et al. 2001; Leggett 2001).

5. In evaluating the soil exposure pathway, the Task 6 team used EFPC floodplain soil data to calculate doses. Actual measured uranium concentrations in Scarboro soil are much lower than the uranium concentrations in the floodplain soil. Consequently, the uranium doses that were estimated for the residents were overestimated because of the use of the higher EFPC floodplain uranium concentrations. The estimated doses would be much lower if they were based on actual measured concentrations in Scarboro.

ATSDR's evaluations of off-site exposures to uranium released from the Y-12 plant indicate that current exposures are not of health concern and unlikely to result in adverse health effects. For every exposure pathway evaluated, the doses were too low to be of health concern for both radiation and chemical health effects.

Current Radiation Exposure

To evaluate carcinogenic effects of current radiation exposure to uranium releases from the Y-12 plant, ATSDR calculated the radiation dose (see Table 14) from the following pathways: (1) inhalation of air, (2) ingestion of soils, and (3) ingestion of foods. ATSDR then compared the dose to the radiogenic cancer comparison value. The radiation dose received by the reference population, the Scarboro community, is 0.216 mrem, which is well below (more than 23,000 times less than) the radiogenic cancer comparison value of 5,000 mrem over 70 years (see Figure 9). ATSDR derived this CEDE after reviewing the peer-reviewed literature and other documents developed to review the health effects of ionizing radiation (see Appendix D for more information about ATSDR's derivation of the radiogenic cancer comparison value of 5,000 mrem over 70 years). The CEDE assumes that from the intake of uranium, the entire dose (a 70-year dose, in this case) is received in the first year following the intake. ATSDR believes this value to be protective of human health and, therefore, does not expect that harmful radiation effects from exposure to uranium are occurring currently.

As noted previously, to evaluate noncancer health effects from the current radiation dose (CEDE of 0.216 mrem over 70 years), an approximation can be make to compare the CEDE of 0.216 mrem, which is based on 70 years of exposure, to the ATSDR chronic exposure MRL of 100 mrem/year, which is based on one year of exposure. The CEDE of 0.216 mrem over 70 years could be divided by 70 years to approximate a value of 0.003 mrem as the radiation dose for the first year, which is well below (33,000 times less than) the 100 mrem/year ATSDR chronic exposure MRL for ionizing radiation (see Figures 7 and 9). ATSDR MRLs are based on noncancer adverse health effects only and are not based on a consideration of cancer effects. ATSDR believes the chronic ionizing radiation MRL of 100 mrem/year is below levels that might cause noncancer adverse health effects in persons most sensitive to such effects. ATSDR, therefore, does not expect noncancer health effects to have occurred from radiation doses received from current off-site uranium exposure.

- As noted previously, ATSDR derived the chronic-duration, noncancer MRL for ionizing radiation by dividing the average annual effective dose to the U.S. population (360 mrem/year) by 3 to account for human variability (i.e., ATSDR applied an uncertainty factor of 3) (ATSDR 1999b). This annual effective dose to the U.S. population is obtained mainly from naturally occurring radioactive material, medical uses of radiation, and radiation from consumer products (BEIR V 1990 as cited in ATSDR 1999b). The annual effective dose of 360 mrem/year has not been associated with adverse health effects in humans or animals.

ATSDR compared off-site surface water concentrations of uranium to the EMEG of 20 µg/L. The average uranium concentrations found in surface water from Scarboro ditches (0.197 µg/L) and in surface water of Lower EFPC (12.8 µg/L) are below ATSDR's EMEG and, therefore, not of health concern (see Table 16).

ATSDR also compared Scarboro soil concentrations to natural background concentrations and to background concentrations collected at uncontaminated areas on and around the ORR (see Tables 17,18 and Figures 18, 21, 22). The soil concentrations found in Scarboro are indistinguishable from natural background concentrations.

Therefore, the level of radiation a person receives from current off-site exposures to uranium the air, surface water, and soil (including ingestion of soil and vegetables) would not cause harmful health effects.

Current Chemical Exposure

To evaluate current chemical exposure to uranium releases from the Y-12 plant, ATSDR compared the average air concentrations from several monitoring stations, including ones in Scarboro and the city of Oak Ridge, to the intermediate-duration inhalation MRL for insoluble forms of uranium. The average uranium air concentrations from all of the monitoring stations evaluated, including the ones in Scarboro and the city of Oak Ridge, were well below (more than a million times less than) ATSDR's intermediate-duration inhalation MRL of 0.008 mg/m^3 for insoluble forms of uranium (see Figure 24). The average uranium air concentrations, therefore, are well below levels that would be expected to cause harmful chemical effects.

- As noted previously, ATSDR derived the inhalation MRL from a study in which no adverse health effects were observed in dogs exposed to 1.1 mg/m^3 of uranium dioxide dust (an insoluble form of uranium) (Rothstein 1949b as cited in ATSDR 1999a). Because this NOAEL was derived from an intermittent exposure, and ATSDR derives inhalation MRLs for continuous exposure, the NOAEL was adjusted to continuous exposure. In addition, because the NOAEL derived from an animal study, ATSDR converted it to a human equivalency concentration. Then, ATSDR divided the NOAEL of 1.1 mg/m^3 by an uncertainty factor of 30 (3 for extrapolation from animals to humans and 10 for human variability) to calculate the intermediate-duration inhalation MRL.

ATSDR also compared the doses from ingestion of uranium through the soil pathway (see Table 23 and Figure 25), including ingestion of soil and vegetables from the reference location, Scarboro (see Table 24 and Figure 26), to the oral intermediate-duration MRL of 0.002 mg/kg/day for insoluble forms of uranium. The maximum uranium dose from ingestion of Scarboro soil is approximately 140 times less than the MRL, and the uranium dose from ingestion of vegetables grown in the private gardens in Scarboro are more than 50 times less than the MRL. Therefore, the uranium doses are well below the MRL and not of health concern.

- As noted previously, ATSDR derived this intermediate-duration oral MRL from a study in which an increased incidence of renal toxicity (specifically, anisokaryosis and nuclear vesiculation) was observed in New Zealand rabbits exposed to 0.05 mg/kg/day of uranium as uranyl nitrate (Gilman et al. as cited in ATSDR 1999a). ATSDR applied a total uncertainty factor of 30 (3 for use of a minimal LOAEL and 10 for human variability) to calculate the MRL. No adjustment was made for interspecies variation because the rabbit is the mammalian species most sensitive to uranium toxicity and is likely to be even more sensitive than humans. This MRL for intermediate-duration oral exposure is also protective for chronic-duration oral exposure. This is because the renal effects of uranium exposure are more dependent on the dose than on the duration of the exposure.

EFPC is not used as a drinking water source. The city of Oak Ridge, including Scarboro, is served by municipal water, which must meet specific drinking water quality standards set by EPA. Regardless, the total uranium mean concentrations in surface water collected from Scarboro ditches and in water collected from Lower EFPC are below EPA's maximum contaminant level (MCL) for uranium (30 μg/L). In addition, Table 16 shows that the mean total uranium concentrations for surface water samples collected from Scarboro and Lower EFPC are below ATSDR's environmental media evaluation guide (EMEG) of 20 μg/L. Therefore, the concentrations of uranium that people might be exposed to in surface water are not of health concern.

V. Community Health Concerns

Responding to community health concerns is an essential part of ATSDR's overall mission and commitment to public health. ATSDR actively gathers comments and other information from the people who live or work near the ORR. ATSDR is particularly interested in hearing from residents of the area, civic leaders, health professionals, and community groups. ATSDR will be addressing these community 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 Databas**e specifically designed to compile and track community health concerns related to the site. The database allows ATSDR to record, to track, and to respond appropriately to all community concerns and to document ATSDR's responses to these concerns.

In 2001 and 2002, ATSDR compiled more than 1,800 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 workgroup 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 uranium releases from the Y-12 plant. The following table contains summarized comments, actual comments, and ATSDR's responses. These concerns and responses are sorted by category (health concerns/general, cancer health effects, noncancer health effects, and health concerns/procedural).

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

	Summarized Comment	Actual Comment	ATSDR's Response
Health Concerns/General			
1	A commenter believes that Scarboro is significantly contaminated by U 235.	The U 235 contamination is significant.	ATSDR evaluated past and current exposure to uranium contamination released from the Y-12 plant and determined that in every exposure pathway, the levels of uranium were too low to be of public health concern for both radiation and chemical health effects. ATSDR evaluated whether the levels of U 235 in the soil in Scarboro were significant by comparing the radioactivity concentrations detected in Scarboro by FAMU (1998) and EPA (2002b) to average background levels in the area around Oak Ridge and to background concentrations typically found in nature. ATSDR found that the levels of U 235 that were detected were indistinguishable from background levels when considering the uncertainty associated with the analysis of the uranium measurements. Please see Section *II.B.2.a. Radiation Effects*, Soil, and Figures 18, 21, and 22 for more details about this evaluation. ATSDR also evaluated whether the radioactivity concentrations of uranium detected in the air in Scarboro were higher than those detected at background air monitoring stations. The data indicate that the concentrations in Scarboro are about 60% higher than the remote background locations; however, all of the air concentrations, including those from Scarboro, were well below levels of health concern. Please see Section *III.B.2.b Chemical Effects,* Inhalation, and Figure 24 for additional details.

	Summarized Comment	Actual Comment	ATSDR's Response
2	A commenter believes that facilities on ORR produced plutonium.	ORR facilities were engaged in plutonium production.	A pilot-scale plutonium production plant was built at the X-10 site in 1943 and was operated until November 1963. For more details, please see Section 2.1.1 The Original Mission in the Oak Ridge Health Studies Phase 1 Report, Volume II, Part A: Dose Reconstruction Feasibility Study, Tasks 1 & 2 (ChemRisk 1993a). During Phase 1 of the Oak Ridge Health Studies, the quantity of plutonium released was estimated and determined to not warrant further health study. Plutonium was low in the preliminary ranking of potential hazards. Please see Section 5.4, Relative Importance of Releases from the ORR, and Table 5-11 in the Oak Ridge Health Studies Phase 1 Report, Volume II, Part B: Dose Reconstruction Feasibility Study, Tasks 3&4 (ChemRisk 1993b). These reports are available at the DOE Information Center located at 475 Oak Ridge Turnpike, Oak Ridge, Tennessee. You can also obtain documents from the Information Center at http://www.oakridge.doe.gov/Foia/DOE_Public_Reading_Room.htm or by calling 865-241-4780.

	Summarized Comment	Actual Comment	ATSDR's Response
3	Three commenters requested a careful comparison of Scarboro's contaminant levels with those of other regions of Oak Ridge. Another commenter said that the media perceived Scarboro as a contaminated community. The commenter questioned why the media did not portray as contaminated other parts of Oak Ridge where contaminants have been found.	We would like for environmental tests to be performed on other neighborhoods in Oak Ridge so that it can be determined if the trace levels of uranium contaminants detected in our neighborhood are significantly different from Oak Ridge in general. Do you have any statistics comparing illness in Scarboro and other sections of Oak Ridge? There are no other residential data to compare to Scarboro. It is generally believed by most people who live in Tennessee and perhaps the nation that the Scarboro neighborhood in Oak Ridge, Tennessee, is contaminated with mercury.... The data showed very high levels of mercury contamination in several areas of Oak Ridge; however, the media primarily focused attention on mercury contamination in the Scarboro neighborhood (where no significant mercury was ever found). We would like for those interested in helping our neighborhood with health and contamination issues to be mindful of the psychological, sociological, and economic consequences that result whether contamination issues are real or imaginary.	During this evaluation of Y-12 uranium releases, ATSDR attempted to locate uranium soil sampling data from other areas in Oak Ridge (for example, data from the Atomic City Auto Parts remediation, the CSX Railroad remediation, and sampling data collected in the Woodland area of Oak Ridge), but as of this writing was unsuccessful. ATSDR evaluated whether the levels of uranium in the soil were significantly different in Scarboro by comparing the levels detected in Scarboro by FAMU (1998) and EPA (2002b) to the average background levels in the area around Oak Ridge and to background concentrations typically found in nature. ATSDR found that the levels of uranium that were detected were indistinguishable from background, when considering the uncertainty associated with the analysis of the uranium measurements. Please see Section *II.B.2.a. Radiation Effects*, Soil, and Figures 18, 21, and 22 for more details about this evaluation. ATSDR also evaluated whether the radioactivity concentrations of U 235 detected in the air in Scarboro were higher than those detected at background stations. The data indicate that the concentrations in Scarboro are about 60% higher than the background locations; however, all of the air concentrations, including those from Scarboro, were well below levels of health concern. Please see Section *III.B.2.b Chemical Effects,* Inhalation, and Figure 24 for additional details. ATSDR evaluated past and current exposure to uranium contamination released from the Y-12 plant and determined that in every exposure pathway, the levels of uranium were too low to be of public health concern for both radiation and chemical health effects. ATSDR will be conducting a public health assessment on mercury releases from Y-12, which will evaluate the mercury concentrations in Scarboro.

	Summarized Comment	Actual Comment	ATSDR's Response
4	Three commenters are already certain that Scarboro is seriously contaminated.	We know the soil is contaminated and want someone to prove it. (Just tell us the truth.) There must be something wrong if the government does so many studies, and the newspaper gives it so much attention. Scarboro is the most contaminated residential area.	The Scarboro community was selected as the reference population after air dispersion modeling indicated that its residents were expected to have received the highest exposures (ChemRisk 1999). However, when ATSDR compared the levels of uranium in the soil in Scarboro (FAMU 1998 and EPA 2002b) to levels of uranium naturally occurring in the soil and to average background levels in the Oak Ridge area, it was determined that the uranium radioactivity concentrations in Scarboro were indistinguishable from levels occurring naturally. Please see Section *II.B.2.a. Radiation Effects*, Soil, and Figures 18, 21, and 22 for more details about this evaluation.
5	One commenter believes sirens signify nuclear emergencies at ORR.	The sirens in Y-12 are all nuclear alarms.	The following Web site provides information on warning sirens, the latest news, and other information in case of an emergency at the ORR: http://www.oakridge.doe.gov/emercomm/. The Web site also provides general information about the DOE Emergency Preparedness Program. If you have questions about this program, please visit the Web site or call the DOE Public Affairs Office at 865-576-0885. The sirens are tested at noon eastern time on the first Wednesday of each month. Any other tests and exercises are announced in advance through area newspapers, radio, and television.
6	Three commenters suspect that radioactive wastes are or were secretly dumped around Scarboro.	The SED/AEC dumped "hot" waste from Y-12 in/near Scarboro. Scarboro is a part of ORR, is owned by the government, is leased to the residents, and can be used as a DOE dump at any time. Concerned about the locations of actual and alleged "dumps."	A municipal landfill (on Tuskegee Drive across from Scarboro) and a building material dump site (at the corner of Tuskegee Drive and Tulsa) were present in Oak Ridge in the past. Both sites are currently closed. Neither area was identified as having radioactive wastes during the aerial radiological surveys conducted in the Scarboro area in 1959, 1973, 1980, 1989, 1992, and 1997. Every flyover of Scarboro showed only natural background levels (Carden and Joseph 1998). While this does not preclude the presence of deeply buried wastes in these areas, if present, they most likely are not impacting public health in the Scarboro community because people do not have contact with deeply buried wastes. Designated landfills on the ORR were used for disposal of hazardous wastes and radioactive materials.

	Summarized Comment	Actual Comment	ATSDR's Response
7	Several commenters were concerned about the appearance of their water and whether the water presents a threat to their health.	The drinking water changes color and is sometimes cloudy. Something in water; water was white; how much exposure can an individual have to the water before they are affected by it; things in the water; water not drinkable; problems with water; water quality (thick, milky appearance).	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 one 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 (EPA 1999). The public water supply for Oak Ridge is continually monitored for these regulated substances. 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 is available at the following Web site: http://www.cortn.org/PW-html/2001WaterQualityReport.htm. To ask specific questions related to your drinking water, please call Mr. Bruce Giles, Water and Wastewater Manager, at 865-425-1875 or call EPA's Safe Drinking Water Hotline at 800-426-4791.

	Summarized Comment	Actual Comment	ATSDR's Response
8	Several commenters discussed the Joint Center for Political and Economic Studies' role in the Scarboro community. Two commenters stated that the Joint Center should obtain money for the Scarboro community.	If the Joint Center cannot supply Scarboro with money they should go home. The Joint Center should help Scarboro to write and find grant money. The Joint Center agreement does not require them to explain any past data before 1998. The purpose of Joint Center's Scarboro Community Environmental Study is to address community concerns about environmental monitoring in the Scarboro neighborhood.	Please contact DOE with your concerns about the Joint Center's funding as these comments are not applicable to ATSDR. More information about the Joint Center for Political and Economic Studies can be found at www.jointcenter.org or by calling 202-789-3500.

	Summarized Comment	Actual Comment	ATSDR's Response
9	One commenter asked who will make the official decision about whether or not Scarboro is a contaminated community.	Who makes the official health call?	ATSDR is the principal federal public health agency charged with the responsibility of evaluating the human health effects of exposure to hazardous substances. The agency works in close collaboration with local, state, and other federal agencies, with tribal governments, and with communities and local health care providers. The goal of the agency is to help prevent or reduce harmful human health effects from exposure to hazardous substances. In 1980, the U.S. Congress created ATSDR to implement the health-related sections of the laws that protect the public from hazardous waste and environmental spills of hazardous substances. CERCLA, commonly known as the "Superfund" Act, provided a congressional mandate to clean up abandoned and inactive hazardous waste sites and to provide federal assistance in emergencies involving toxic substances. As the lead agency in the Public Health Service for implementing the health-related provisions of CERCLA, ATSDR is charged under the Superfund Act to assess the presence and nature of health hazards at specific Superfund sites, help reduce or prevent further exposure, and expand the knowledge base about health effects related to exposure to hazardous substances. Under this purview, ATSDR is determining whether hazardous substances in Scarboro represent a public health hazard. For additional information about ATSDR, please visit our Web site at: http://www.atsdr.cdc.gov/. ORRHES was established in 1999, as a subcommittee of the Citizens Advisory Committee on Public Health Service Activities and Research at DOE Sites. The ORRHES provides advice and recommendations to ATSDR and Centers for Disease Control and Prevention (CDC) concerning public health activities and research conducted by ATSDR and CDC at the ORR.

	Summarized Comment	Actual Comment	ATSDR's Response
10	Six commenters questioned the way in which the environmental sampling of Scarboro has been conducted. One commenter suggested that DOE let the citizens of Scarboro determine exactly where sampling is to take place.	Scarboro has a "high" background. The monitor is in the wrong place. They didn't sample the pond where the dump was. They sampled my neighbor's yard, but not my yard. The number of surface water and sediment samples taken should be increased. Our objections in the Scarboro sampling issue include: DOE's shameless refusal to investigate particular areas suggested by Scarboro residents familiar with the DOE's legacy of contamination in their neighborhood. Our objections in the Scarboro sampling issue include: The use of Y-12 as a control against which Scarboro soil was measured to compare contamination levels. Our objections in the Scarboro sampling issue include: The use of the top two inches of soil as a valid sample for soil analysis; the use of only three soil samples sets for analysis.	In 2001, EPA validated the environmental sampling conducted within the Scarboro community by FAMU in 1998 (EPA 2002b; FAMU 1998). ATSDR reviewed the methods and results of the environmental sampling conducted by FAMU and EPA, and found that the procedures were adequate for making public health decisions. Both EPA's and FAMU's reports are available in 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/Foia/DOE_Public_Reading_Room.htm or by calling 865-241-4780. ATSDR evaluated whether the levels of uranium in the soil were significantly different in Scarboro (FAMU 1998 and EPA 2002b) by comparing the levels detected in the soil in Scarboro to levels of uranium naturally occurring in the soil and to average background levels in the Oak Ridge area. ATSDR determined that the uranium concentrations in Scarboro were indistinguishable from levels occurring naturally. Please see Section II.B.2.a. *Radiation Effects*, Soil, and Figures 18, 21, and 22 for more details about this evaluation. When conducting sampling at hazardous waste sites, ATSDR recommends that the initial evaluation of the site include an assessment of probable routes of public exposure/contaminant migration off site, and that the sampling begin at the public exposure points to determine if interim actions are needed to reduce or eliminate public exposure. Contaminated soils may expose individuals who live, play, or work near the site to contaminants at levels of health concern. Ingestion of contaminated surface soil, particularly by children, is a primary concern. Inhalation of contaminated dust and direct dermal contact with contaminated soils also can lead to adverse health effects. Generally, the public is exposed to only the top few inches of soil; therefore, ATSDR has defined surface soil as the top 3 inches. For a public health evaluation, ATSDR needs concentrations of contaminants found in surface soil reported separately from those found in subsurface soil.

	Summarized Comment	Actual Comment	ATSDR's Response
11	Several commenters are concerned about ash and debris settling from the air. Some fear airborne contaminants are related to respiratory health problems.	Scarboro is adjacent to the "incinerator." Fly ash from Y-12 settled over my car. Contamination in air; lots of dust, air stays very smoky, smoggy. Things in air; respiratory problems; respiratory problems in children caused by air pollution from ORR; black air on mother's car after she washed it had to be from the plant; at times the air has a peculiar smell; chest pain during excitation; air pollutants building in the soils nearby; gasoline type fumes.	In 1997 and 1998, CDC, TDOH, and the Scarboro Community Environmental Justice Council conducted a study to determine whether rates of pediatric respiratory illnesses were higher in Scarboro than elsewhere in the United States and to assess whether exposure to various factors increased residents' risk for health problems. The researchers concluded the following: No unusual pattern of illnesses emerged among the children receiving medical exams. The illnesses that were detected were not more severe than would be expected in any community. The findings of the medical exams were consistent with the findings of the community survey. The reported prevalence rate of asthma among children in Scarboro (13%) was higher than the estimated national rate (7% in all children and 9% in black children). However, few studies have been conducted on communities similar to Scarboro, and without asthma prevalence information from these communities, it was not possible to determine whether the prevalence of asthma was higher than would be expected. The Scarboro rate was, however, within the range of rates reported in similar studies throughout the United States and internationally. The reported rate of wheezing among children in Scarboro (35%) was also higher than most national and international estimated rates (which range from 1.6% to 36.8%). The prevalence rates of hay fever and sinus infections in children were comparable to national estimated rates. Because the investigation was not designed to detect associations, and a relatively small group of children was studied, it was not possible to identify causes of the respiratory illnesses. Copies of the report on this study, *An Analysis of Respiratory Illnesses Among Children in the Scarboro Community,* are available in the ATSDR Oak Ridge field office at 1975 Tulane Avenue, Oak Ridge, Tennessee (telephone: 865-220-0295).

	Summarized Comment	Actual Comment	ATSDR's Response
12	Two commenters are concerned about health problems and contamination stemming from employment with DOE.	What did my husband bring home from the plant? Activities at DOE plants have led to worker health problems.	Federal regulations establish requirements for a radiological protection program. Included in the law are requirements for monitoring personnel and the workplace to ensure that contaminants are not taken outside of radiological areas. A DOE Order delineates requirements to ensure worker protection in all environment, safety, and health disciplines. The Atomic Energy Commission established worker health and safety plans through a series of orders. Worker health issues at the plants are a concern to ATSDR; however, those issues are under the purview of NIOSH. For information on NIOSH's occupational energy research program see NIOSH's Web site at www.cdc.gov/niosh/2001-133.html or telephone 513-841-4400.
13	One commenter noted that people have lived along Scarboro Road.	People have lived along Scarboro Road.	To address this comment, ATSDR reviewed available historical U.S. Geological Survey (USGS) maps from 1941, 1953, 1968, 1980, and 1990 to identify buildings located along Scarboro Road. In 1941, prior to ORR being established, eight unidentified buildings (potentially houses) were located along Scarboro Road. By 1953, all but one of these buildings (located at a Y intersection about 1,200 feet north of Bear Creek Road) were removed and one additional structure was added about 1,500 feet south of Bear Creek Road. Both were located west of Scarboro Road on DOE property. In 1968, the structure south of Bear Creek Road was removed, but the one at the Y intersection remained. In addition, a gas station was added north of the intersection of Scarboro Road and Bear Creek Road. No changes along Scarboro Road were noted from the 1968 map to the 1980 and 1990 maps. In addition, ATSDR reviewed a 1945 map of the city of Oak Ridge that shows that Scarboro Road used to run north to the Oak Ridge Turnpike prior to the construction of South Illinois Avenue. According to the USGS map from 1936, seven buildings were located on this portion of Scarboro Road that no longer exists. In 1946, an additional building is shown.
14	One commenter asserted that DOE should buy back any land they have contaminated.	If DOE has contaminated Scarboro land, they must buy it back.	Please contact DOE with your concerns about buying back contaminated land in Scarboro as this comment is not applicable to ATSDR.

	Summarized Comment	Actual Comment	ATSDR's Response
15	Several commenters are concerned about whether Scarboro's creeks, springs, and drainage ditches are contaminated.	The city should cover the contaminated ditches. The springs along the north side of Pine Ridge are contaminated. Groundwater flows from the Y-12 plant to Scarboro. LEFPC flows through the Scarboro community; so does Scarboro Creek. Kids play around the EFPC, when it rains water runs from the EFPC into the yards in community; son swam in the creek as a child; mercury in creek; concerned about water that flows across property; open ditches; children play in water; test the water running through the community; more frequent testing of water; lots of creeks used for drinking water when young; water glows in dark; storm water drains from reservation onto property.	Using the surface water and sediment radioactivity concentrations estimated during Task 6 of the Oak Ridge Dose Reconstruction (ChemRisk 1999), ATSDR evaluated whether past exposure to uranium in the surface water and sediment from EFPC and the floodplain would cause harmful health effects. The estimated doses were below levels of health concern for both radiation and chemical effects. Please see Section ***III.B.1 Past Exposure (1944-1995),*** *Radiation Effects:* Surface Water and Soil; and *Chemical Effects:* Ingestion, for more details about this evaluation. In 1998 and 2001, FAMU and EPA, respectively, sampled surface water and sediment from Scarboro ditches (EPA 2002b; FAMU 1998). In addition, DOE takes bi-monthly surface water samples in EFPC (DOE 1995b). ATSDR evaluated the current surface water data as it pertains to uranium contamination in Section ***III.B.2 Current Exposure***, *Radiation Effects*, Surface Water and Soil. As shown in Table 16, the mean total uranium concentrations in surface water in Scarboro and Lower EFPC are below ATSDR's EMEG and are therefore not of health concern. ATSDR evaluated sediment data with the soil data (see Tables 17 and 18 and Figures 18, 21, and 22). The uranium content of soils/sediment in Scarboro is indistinguishable from natural background levels and is not at a level of health concern.

	Summarized Comment	Actual Comment	ATSDR's Response
16	Several commenters believe that local soil, vegetation, and fish are contaminated. One is concerned because he had been eating these fish before learning that they were contaminated. Two commenters noted that Scarboro's vegetation has an unusual color.	Not allowed to eat fish or touch the water; like to fish; ate fish only to learn later they were contaminated. Vegetables grown in Scarboro are not safe to eat and changed color. What is in the soil? How does it get inside people's body; grass is purplish gold in color, color of flowers has changed; no information on soil testing; soil and water should be tested.	ATSDR received data on vegetable samples collected from gardens from two Scarboro residents. ATSDR calculated radiation and chemical doses following ingestion of vegetables from these gardens. As shown in Tables 21 and 24, the resulting doses are below levels of health concern—it is safe to eat vegetables from private gardens in Scarboro. Please see Section *II.B.2.a Radiation Effects*, Soil*, Ingestion of foods grown in Scarboro,* for more details about ATSDR's evaluation. ATSDR compared the levels of uranium detected in Scarboro soil (EPA 2002b; FAMU 1998) to the average background levels in the area around Oak Ridge and to background concentrations typically found in nature. ATSDR found that the levels of uranium that were detected were indistinguishable from background and are not at levels of health concern. Please see Section *II.B.2.a. Radiation Effects*, Soil, and Figures 18, 21, and 22 for more details about this evaluation. Fish fillet samples collected from EFPC contain mercury and PCBs. However, it is ATSDR's understanding that EFPC is not a very productive fishing location and very few people actually eat fish from the creek. Regardless, in 1993, ATSDR evaluated eating fish from EFPC in a health consultation (ATSDR 1993b). ATSDR concluded that there is no acute health threat to people who eat the fish. However, if people frequently ingest contaminated fish from the creek over a prolonged period, there is a moderate increased risk of adverse effects to the central nervous system and kidneys, and of developing cancer. Copies of the health consultation, entitled *Y-12 Weapons Plant Chemical Releases Into East Fork Poplar Creek,* are available at the ATSDR Oak Ridge field office at 1975 Tulane Avenue, Oak Ridge, Tennessee (telephone: 865-220-0295).

	Summarized Comment	Actual Comment	ATSDR's Response
17	Several commenters want radiation levels to be monitored in Scarboro.	Check for radiation from the plant; radiation spills; radiation levels in Scarboro; should check homes for radon; a lot of people have died; skin allergy; allergies 65% have it; skin rashes on children.	DOE conducts ambient air monitoring in the environment surrounding ORR facilities, including around the Y-12 plant, to measure radiological and other parameters (DOE 1995b). One monitoring station (Station 46) is located in Scarboro, west of the Mount Zion Church on Tuskegee Drive, about 140 meters west of the Scarboro Community Center. This continuous monitoring station has been providing quarterly and annual measurements of uranium in the air since 1986 (ChemRisk 1999).
18	One commenter asked what kinds of health effects would be produced by strontium 90 (Sr-90) exposure.	If Sr 90 were to produce health effects, how would those present themselves?	Because Sr 90 is chemically similar to calcium, it tends to deposit in bone and bone marrow (it is called a "bone seeker"). Internal exposure to Sr 90 is linked to bone cancer, cancer of the soft tissue near the bone, and leukemia (EPA 2002d). Risk of cancer increases with increased exposure to Sr 90. However, Sr 90 was not released from the Y-12 plant in high enough quantities to be a health issue.

	Summarized Comment	Actual Comment	ATSDR's Response
19	Several commenters discussed the scope of substances being investigated in Scarboro. Some requested that scope of environmental sampling be expanded.	Uranium and mercury are the obvious contaminants to detect. What about other radionuclides such as beryllium? Wasn't it used at Y-12? Is the Y-12 nuke slow cooker at Chestnut Ridge security pits included in health effects? I also agree with attendees that the proposed surveillance, in its present proposed form, does not go far enough. Lead, thorium, beryllium, cyanide, acetonitrile, tungsten, and other materials worked at the Y-12 site have been historically "misplaced." At the meeting it was stated by someone in the audience that Strontium-90 and Cesium-137 and other relevant radionuclides should also be measured. The concentration of mercury in the air should be measured, so air samples should be taken also. The concentration of mercury in plants should be measured. Uranium, mercury, iodine, and PCBs have been detected in Scarboro.	ATSDR will continue to evaluate contaminants and pathways of concern to the community surrounding ORR. In addition to this evaluation of uranium from the Y-12 plant, ATSDR is evaluating uranium from the K-25 facility, iodine 131, mercury, White Oak Creek releases in the 1950s, PCBs, fluorides, the TSCA incinerator, and groundwater. ATSDR will also screen data from 1990 to the present to determine whether additional contaminants of concern need to be addressed. While beryllium was used at the Y-12 plant, the form used was not radioactive. In 1998, FAMU collected soil and sediment from Scarboro and analyzed 10% of the samples for 150 organic and inorganic chemicals (FAMU 1998). ATSDR evaluated these data and determined that none of the chemicals that were detected (more than 100 chemicals were not detected) were at concentrations that would cause harmful health effects from exposure to the soil or sediment. ATSDR also evaluated the gamma spectroscopy data collected by EPA in their soil sampling effort in Scarboro (EPA 2002b) and concluded that other radionuclides are not of public health concern. Uranium and thorium are naturally occurring; during their decay, they produce a number of progeny that are gamma emitters. The results indicate that the progeny of uranium 238 and thorium 232 are present in the expected concentrations based on the amount of U 238 reported by EPA and FAMU (EPA 2002b; FAMU 1998). Furthermore, no cobalt 60 (Co 60) was detected, and the concentration of cesium 137 (Cs 137) detected at the sampling locations averaged less than 0.3 pCi/g. In DOE's Background Soil Characterization Project (DOE 1993), the reported concentration of Cs 137 was 2 to 3 times higher than the Scarboro value. This concentration of Cs 137 is not considered to be a public health concern as the resulting radiation dose (estimated from Federal Guidance Report 13 electronic data) following the ingestion of 100 mg of soil, is orders of magnitude below the typical background dose in the Oak Ridge area.

	Summarized Comment	Actual Comment	ATSDR's Response
20	Several commenters suggested that the people of Scarboro need more direct control over environmental sampling activities that go on in their community.	The community, via SCEJOC, should be able to identify and select a contractor to accomplish the tasks needed for the characterization of pollution in the community. Establish clearly that other affected communities in Oak Ridge are invited to sit at the table and collaborate on coordinating activities. The community needs funding to secure its own technical assistance to ensure adequate input into this project.	DOE has primary responsibility for environmental sampling at the ORR.
21	One commenter requested additional information about environmental sampling in the community.	This community needs a Sentinel Health Event evaluation performed immediately. The community needs the data from the secret well monitoring done since the 1980s. The community needs the data from the surface and groundwater studies at Y-12 and K-25, and this data directly impacts the surrounding residents.	This public health assessment evaluates exposure to uranium released from the Y-12 plant. All of the data that ATSDR knows of that pertains the community is included in this report. ATSDR will evaluate uranium from the K-25 facility and the groundwater pathway in the future.

	Summarized Comment	Actual Comment	ATSDR's Response
22	One commenter questioned the value of aerial studies.	As the aerial studies will only reveal large releases (i.e., rare events) why is DOE spending large amounts of funding on this project?	Since the 1950s, aerial radiological surveys have been conducted at DOE facilities to provide data on the total gamma radiation emission rate found on and around its facilities (Carden and Joseph 1998). Not only do these surveys allow for the relatively rapid characterization of large land areas to determine the background levels of radiation, they are also a proven method for identifying areas where the radiation levels significantly exceed background levels of radiation. Because many of the radioactive materials used at Oak Ridge are gamma-emitting elements or decay into gamma-emitting elements, the elevated levels could be associated with Cs 137, Co 60, decay products of SR 90, and decay products of uranium isotopes. In the case of uranium isotopes, if the soil concentrations are not significantly elevated above background levels, then the aerial survey data will be inconclusive; that is, the computer-generated results would not show the presence of elevated levels of uranium. ATSDR has reviewed the existing flyover data for the Scarboro community and the soil survey data. While these aerial radiological surveys aid in identifying contaminated areas, ATSDR does not find the surveys extremely useful in estimating doses or in making health decisions.

	Summarized Comment	Actual Comment	ATSDR's Response
23	Several commenters stated that the people of Scarboro have not been adequately informed about ongoing environmental studies.	DOE has not done an adequate job of informing Scarboro, Oak Ridge, and surrounding communities of these meetings. Our demand is that all policy debates and decisions made on the issues of environmental contamination and its effects include citizens affected by DOE-ORO operations. Should not the result of past studies of past contaminants be more widely made available to the people of Scarboro?	ATSDR is committed to engaging the Oak Ridge community as partners in conceptualizing, planning, and implementing public health activities at ORR, in communicating and discussing results, and in determining appropriate follow-up actions. Throughout the public health assessment process, ATSDR staff have worked with the local community to identify and understand health concerns and to provide opportunities for public involvement. Please see Section ***II.F.1. Summary of ATSDR Activities*** for additional information about ATSDR's community involvement activities. The Oak Ridge Reservation Health Effects Subcommittee (ORRHES) was established in 1999, by ATSDR and CDC to provide advice and recommendations concerning public health activities and research conducted at the ORR. The subcommittee consists of 21 individuals with different backgrounds, interests, and expertise, as well as liaison members from state and federal agencies. The Subcommittee meets periodically in Oak Ridge—community members are always welcome to attend the meetings. To promote collaboration between ATSDR and the communities surrounding the ORR, ATSDR opened a field office in Oak Ridge (located at 1975 Tulane Avenue) in 2001. This field office provides even more opportunities for community members to become involved in ATSDR's public health activities at the ORR. Please contact the ATSDR Oak Ridge field office at 865-220-0295 if you would like to be involved.

	Summarized Comment	Actual Comment	ATSDR's Response
24	Two commenters stated that some people in Scarboro do not participate in meetings because they fear retaliation if they do so.	DOE MUST remember that many people don't attend these meetings because of fear of retaliation on their jobs. Scarboro residents and other Afro-Americans do not participate for fear of retaliation.	All community members are encouraged to talk to any of the ORRHES members about their concerns. Perhaps it would help to know that one of the members is a Scarboro resident and a number of other members are active in the Scarboro community. Please visit the following Web site for more information about the ORRHES and its members: http://www.atsdr.cdc.gov/HAC/oakridge/index.html. Additionally, community members can fill out an *anonymous* Community Health Concerns sheet in ATSDR's field office, located at 1975 Tulane Avenue in Oak Ridge (telephone: 865-220-0295). All concerns are entered into the ATSDR Community Health Concerns Database to ensure that all health concerns are brought to ATSDR's attention and are included in ATSDR's evaluation of potential public health impacts from exposures related to the ORR.
25	One commenter was concerned about ozone levels in Scarboro.	Is ozone concentration monitored? What health effects from ozone?	ATSDR is unaware of any ozone monitoring in Scarboro or the city of Oak Ridge. EPA's Clean Air Act Web site may provide some useful information: http://www.epa.gov/air/oaq_caa.html.
Cancer Health Effects			
26	Several commenters believe that the rate of cancer in Scarboro is unusually high. Some of these people are worried that living near or working at ORR may cause some cancers.	There is a high rate of cancer deaths in Scarboro. Over 80% of people die from cancer; grandfather has spot on lung; husband passed of leukemia; cancer from the plant or the water; husband died of cancer in 1996, worked 39 years at ORR: Everybody around here dies with cancer; Did living here have anything to do with it? Cancer killed 2 brothers, mother, and husband; high rate of breast cancer; cancer possibly due to vegetable garden.	The Public Health Assessment Work Group, as part of the ORRHES, is currently evaluating cancer issues with the TDOH Cancer Registry. This issue will be addressed in the future.

	Summarized Comment	Actual Comment	ATSDR's Response
Noncancer Health Effects			
27	One commenter was concerned about deformed and retarded babies born in Scarboro.	A lot of deformed and retarded babies were born in Oak Ridge.	Uranium is not known to cause these kinds of health effects. However, ATSDR will also be evaluating the effects from exposure to iodine 131, mercury, White Oak Creek releases in the 1950s, PCBs, fluorides, the TSCA incinerator, and groundwater. Please contact the TDOH with your concerns about a high rate of deformed and retarded babies being born in Oak Ridge.

	Summarized Comment	Actual Comment	ATSDR's Response
28	Several commenters were concerned about the prevalence of asthma among children in Scarboro.	Scarboro children suffer from too much asthma. Asthma; Check people with respiratory problems; 65% of residents have asthma, child up the street has trouble breathing; man had to leave Scarboro because his two boys had trouble breathing.	In 1997 and 1998, CDC, TDOH, and the Scarboro Community Environmental Justice Council conducted a study to determine whether rates of pediatric respiratory illnesses were higher in Scarboro than elsewhere in the United States, and whether exposure to various factors increased residents' risk for health problems. The researchers concluded the following: No unusual pattern of illnesses emerged among the children receiving medical exams. The illnesses that were detected were not more severe than would be expected in any community. The findings of the medical exams were consistent with the findings of the community survey. The reported prevalence rate of asthma among children in Scarboro (13%) was higher than the estimated national rate (7% in all children and 9% in black children). However, few studies have been conducted on communities similar to Scarboro, and without asthma prevalence information from these communities, it was not possible to determine whether the prevalence of asthma was higher than would be expected. The Scarboro rate was, however, within the range of rates reported in similar studies throughout the United States and internationally. The reported rate of wheezing among children in Scarboro (35%) was also higher than most national and international estimated rates (which range from 1.6% to 36.8%). The prevalence rates of hay fever and sinus infections in children were comparable to national estimated rates. Because the investigation was not designed to detect associations, and a relatively small group of children was studied, it was not possible to identify causes of the respiratory illnesses. Copies of the report on this study, *An Analysis of Respiratory Illnesses Among Children in the Scarboro Community,* are available in the ATSDR Oak Ridge field office at 1975 Tulane Avenue, Oak Ridge, Tennessee (telephone: 865-220-0295).

	Summarized Comment	Actual Comment	ATSDR's Response
Health Concerns/Procedural			
29	One commenter suggested that Scarboro was deliberately left out of aerial flyovers for fear of revealing contamination.	Scarboro was left out of the flyovers because it is contaminated.	DOE conducted eight aerial radiological surveys of the ORR between 1959 and 1997. Such flyovers are performed at major DOE facilities nationwide and follow specific procedures. "Broad Area" flyovers cover the entire ORR, while "Focused Area" flyovers cover the three plants, and specific areas of interest due to DOE activities in the area, such as White Oak Creek remediation. Areas off the plant site that show only natural background levels of radiation are not surveyed in "Focused Area" flyovers. The community of Scarboro was included in five "Broad Area" flyovers, and because every flyover showed only background readings, it was not included in two "Focused Area" flyovers. About a third of the Scarboro Community was included in the "Focused Area" flyover of White Oak Creek only because it was on the flight-path for the White Oak Creek survey. Scarboro was not included in "Focused Area" flyovers because it was "not contaminated." Copies of the full report of all radiological flyovers, entitled *Aerial Radiological Surveys of the Scarboro Community,* are available from the Information Center by visiting the following Web site http://www.oakridge.doe.gov/Foia/DOE_Public_Reading_Room.htm or by calling 865-241-4780. Because of this concern, FAMU and EPA performed independent soil sampling of Scarboro. The results of both sampling campaigns confirmed that the levels of uranium would not result in harmful health effects for the people living in Scarboro. For every exposure pathway evaluated, the levels were too low to be of health concern for both radiation and chemical health effects.

	Summarized Comment	Actual Comment	ATSDR's Response
30	One commenter challenged the validity of DOE's Background Soil Study.	The DOE Background Soil Study was done on contaminated soils.	During this evaluation of uranium from the Y-12 plant, ATSDR reviewed Scarboro soil data (EPA 2002b; FAMU 1998), the Background Soil Characterization Project (DOE 1993), and natural background levels. As shown in Figures 18, 21, and 22, there was no significant difference between them. Please see Section *II.B.2.a. Radiation Effects,* Soil for more details about this evaluation. Furthermore, ATSDR compared the results of the Scarboro sampling and the DOE Background Characterization Project to values typically found throughout the country and found no significant difference among the values reported.
31	One commenter challenged the completeness of the Scarboro cancer data.	The Scarboro cancer data supplied by the state is incomplete.	The Public Health Assessment Work Group, as part of ORRHES, is currently evaluating cancer data in counties surrounding the ORR. For more information about the work group's efforts, contact members of ORRHES or the ATSDR Oak Ridge field office (located at 1975 Tulane Avenue, Oak Ridge, Tennessee; telephone: 865-220-0295).

	Summarized Comment	Actual Comment	ATSDR's Response
32	Three commenters expressed their lack of trust in DOE.	What experiments were run on us? What secrets are still being kept? Any DOE-controlled study will lack credibility.	For several decades, DOE and its predecessor agencies have conducted research and production activities at a number of sites across the country, including ORR. These activities involved development and production of nuclear weapons and materials, as well as other nuclear energy-related research. People in communities near and downwind from these sites became increasingly concerned about whether site activities might be affecting their health. In response to these concerns, DOE asked the U.S. Department of Health and Human Services (DHHS) to *independently* investigate the public health implications of its nuclear energy-related activities. DOE formally delegated responsibility for this work to DHHS in two memorandums of understanding issued in 1990. Under a memorandum of understanding between DOE and DHHS, CDC became responsible for analytic epidemiologic research concerning the potential impacts of DOE's energy-related activities. This memorandum of understanding also recognized that ATSDR would be responsible for all public health activities mandated by Superfund. These activities include conducting public health assessments at DOE sites, in addition to other follow-up activities, as appropriate. The ORRHES was established in 1999, as a subcommittee of the Citizens Advisory Committee on Public Health Service Activities and Research at DOE Sites. ORRHES provides advice and recommendations to ATSDR and CDC concerning public health activities and research conducted at ORR. The subcommittee consists of 21 individuals with different backgrounds, interests, and expertise, as well as liaison members from state and federal agencies.
33	One commenter requested greater community control over the selection of environmental contractors.	The Scarboro community should influence the choice of the contractor that will perform the sample collections.	Because ATSDR did not perform environmental sampling in the Scarboro community, this comment is not applicable to ATSDR.

	Summarized Comment	Actual Comment	ATSDR's Response
34	One commenter requested independent analysis and research on mercury from both minority and majority universities.	ORHASP has recognized that mercury speciation is still a problem, but is not going to address it. We must have independent analysis and research performed by both minority and majority universities.	ATSDR will evaluate exposures to mercury during a separate public health assessment, expected to be conducted during 2003.

VI. CHILDREN'S 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. As part of the ATSDR Child Health Initiative, ATSDR is committed to evaluating the special interests of children at sites such as the ORR.

Children living near the ORR are exposed to small amounts of uranium in the air they breathe, in the food they eat, and in the water they play in. However, no cases have been reported where exposure to uranium is known to have caused health effects in children (ATSDR 1999a). It is possible that if children were exposed to very high amounts of uranium, they might have damage to their kidneys, similar to what is seen in adults. However, the levels of uranium in the environment surrounding ORR are too low to cause these kinds of health effects. At this time, the scientific community does not know whether children differ from adults in their susceptibility to health effects from uranium exposure. It is also not known if exposure to uranium has effects on the development of the human fetus. Very high doses of uranium in drinking water can affect the development of the fetus in laboratory animals (one study reported birth defects and another reported an increase in fetal deaths). However, health scientists do not believe that uranium can cause these problems in pregnant women who take in normal amounts of uranium from food and water, or women who breathe the air around a hazardous waste site that contains uranium (ATSDR 1999a).

VII. CONCLUSIONS

Based on a thorough evaluation of past public health activities and available current environmental information, ATSDR has reached the following conclusions:

- ATSDR concludes that the levels of **uranium released from the Y-12 plant in the past and currently would not result in harmful health effects** for either adults or children living near the Y-12 plant, including the city of Oak Ridge and the Scarboro community. ATSDR has categorized this site as having *no apparent public health hazard* from exposure to uranium. ATSDR's category of no apparent public health hazard means that people could be or were exposed, but the level of exposure would not likely result in adverse health effects (definitions of ATSDR's public health categories are included in the glossary in Appendix A).

- Using the results of the Task 6 report, ATSDR evaluated **past uranium exposures** (1944 to 1995) to communities near the Y-12 plant. Despite several conservative parameters, exposure to uranium through both the inhalation and ingestion pathways would result in doses below levels of health concern for radiation and chemical health effects. Therefore, past exposure to uranium poses *no apparent public health hazard*.

    - The total past radiation dose from exposure to uranium via air, surface water, and soil pathways was estimated to be 155 mrem over 70 years, which is well below (32 times less than) the radiogenic cancer comparison value of 5,000 mrem over 70 years. The approximated radiation dose of 2.2 mrem for the first year dose is well below (45 times less than) the ATSDR minimal risk level (MRL) of 100 mrem/year for ionizing radiation.

    - Yearly estimated past air concentrations of uranium ranged from 2.1×10^{-8} to 6.0×10^{-5} mg/m^3, which are less than 1% of the intermediate-duration inhalation MRL of 8×10^{-3} mg/m^3 for insoluble forms of uranium.

- Yearly estimated past doses from exposure to uranium via all soil and surface water exposure pathways ranged from 2.7×10^{-5} to 1.3×10^{-2} mg/kg/day, which are less than the dose (5×10^{-2} mg/kg/day) at which health effects (renal toxicity) have been observed in rabbits, the mammalian species most sensitive to uranium kidney toxicity.

▪ Using available environmental data, ATSDR evaluated **current uranium exposures** (1995 to 2002) to residents living near the Y-12 plant. Exposure to uranium through both the inhalation and ingestion pathways would result in doses below levels of health concern for radiation and chemical health effects. Therefore, current exposure to uranium poses *no apparent public health hazard*.

- The current radiation dose from exposure to uranium through ingestion of soil and vegetables and inhalation of air is 0.216 millirem (mrem), which is well below (more than 23,000 times less than) the radiogenic cancer comparison value of 5,000 mrem over 70 years. The approximated radiation dose of 0.003 mrem for the first year dose is also well below (33,000 times less than) the ATSDR MRL of 100 mrem/year for ionizing radiation.

- Average current uranium air concentrations were 5.4×10^{-11} mg/m^3 in Scarboro and 1.4×10^{-10} mg/m^3 in the city of Oak Ridge, well below (more than a million times less than) the ATSDR intermediate-duration MRL of 8×10^{-3} mg/m^3 for insoluble forms of uranium.

- The estimated uranium doses from ingestion of Scarboro soil (ranging from 2.0×10^{-6} to 1.4×10^{-5} mg/kg/day) are well below (140 times less than) the ATSDR intermediate-duration oral MRL of 2×10^{-3} mg/kg/day.

- The estimated current uranium dose from ingestion of vegetables grown in private gardens in Scarboro (3.0×10^{-5} and 3.9×10^{-5} mg/kg/day) are well below (more than 50 times less than) the oral MRL of 2×10^{-3} mg/kg/day.

- The total uranium mean concentrations in surface water from Scarboro ditches (0.197µg/L) and from off-site areas of Lower East Fork Poplar Creek (12.8 µg/L) are well below ATSDR's health-based comparison value, the environmental media evaluation guide, of 20 µg/L.

VIII. RECOMMENDATIONS

On the basis of the evaluation of past public health activities and the available environmental information, ATSDR recommends the following:

1. ATSDR recommends that the community be informed that ATSDR has evaluated uranium releases from the Y-12 plant on the Oak Ridge Reservation and has concluded that there is no public health hazard associated with past and current releases. ATSDR will work with the Oak Ridge Reservation Health Effects Subcommittee to determine the best way to communicate the results of the evaluation to the people in the community.

IX. PUBLIC HEALTH ACTION PLAN

The public health action plan for the Oak Ridge Reservation (ORR) contains a description of actions taken at the site and those to be taken at the site following the completion of this public health assessment. The purpose of the public health action plan is to ensure that this public health assessment not only identifies potential and ongoing public health hazards, but also provides a plan of action designed to mitigate and prevent adverse human health effects resulting from exposure to harmful substances in the environment. The following public health actions at the ORR are completed, ongoing, or planned:

Completed Actions

- In 1991, the Tennessee Department of Health (TDOH) began a two-phase research project to determine whether environmental releases from ORR harmed people who lived nearby. Phase I focused on assessing the feasibility of doing historical dose reconstruction and identifying contaminants that were most likely to have effects on public health. Phase II efforts included full dose reconstruction analyses of iodine 131, mercury, polychlorinated biphenyls (PCBs), and radionuclides, as well as a more detailed health effects screening analysis for releases of uranium and other toxic substances (a summary can be found in the *Oak Ridge Dose Reconstruction Project Summary Report, Volume 7*).

- In 1992, the U.S. Department of Energy (DOE) conducted a Background Soil Characterization Project in the area around Oak Ridge (DOE 1993).

- In 1993, an ATSDR health consultation, Y-12 Weapons Plant Chemical Releases Into East Fork Poplar Creek, evaluated public health issues related to past and present releases into the creek from the Y-12 plant (ATSDR 1993).

- In 1996, an ATSDR health consultation on the Lower Watts Bar Reservoir evaluated the current public health issues related to the past and present releases into the reservoir from the ORR (ATSDR 1996).

- In 1997, the Centers for Disease Control and Prevention (CDC), the National Center for Environmental Health (NCEH), TDOH, and the Scarboro Community Environmental Justice Council conducted a study to determine whether rates of pediatric respiratory illnesses were higher in Scarboro than elsewhere in the United States, and whether exposure to various factors increased residents' risk for health problems (CDC et al. 1998).

- In 1998, the Environmental Sciences Institute at Florida Agricultural 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 Protections, as well as DOE subcontractors in the Neutron Activation Analysis Group at Oak Ridge National Laboratory and the Jacobs Engineering Environmental Management Team, sampled soil, sediment, and surface water from Scarboro to address community concerns about environmental monitoring in the neighborhood (FAMU 1998).

- In 2001, the U.S. Environmental Protection Agency (EPA) collected samples of soil, sediment, and surface water from the Scarboro community to address community concerns and verify the results of the 1998 sampling conducted by FAMU (EPA 2002b).

Ongoing Actions

- ATSDR will continue to evaluate contaminants and pathways of concern to the community surrounding the reservation. In addition to this evaluation of uranium from the Y-12 plant, ATSDR is evaluating uranium from the K-25 facility, iodine 131, mercury, White Oak Creek releases in the 1950s, PCBs, fluorides, the TSCA incinerator, and groundwater. ATSDR will also screen data from 1990 to the present to determine whether additional contaminants of concern need to be addressed.

- In 1986, DOE installed a continuous air monitoring station (Station 46) in the Scarboro community to provide quarterly and annual air measurements of uranium 234, uranium 235, and uranium 238 (ChemRisk 1999). The station is operated by the Oak Ridge National Laboratory as part of the DOE ORR air monitoring network.

- In 1999, the Oak Ridge Reservation Health Effects Subcommittee (ORRHES) was created under the guidelines and rules of the Federal Advisory Committee Act to provide a forum for communication and collaboration between citizens and the agencies that are evaluating public health issues and conducting public health activities at the ORR. The ORRHES serves as a citizen advisory group to CDC and ATSDR and provides recommendations on matters related to public health activities and research at the reservation. It also provides an opportunity for citizens to collaborate with agency staff members, to learn more about the public health assessment process and other public health activities, and to help prioritize public health issues and community concerns to be evaluated by ATSDR.

Planned Actions

- In 2003, ATSDR will conduct community involvement activities, such as health education, to provide the public with the results of the public health assessment on uranium releases from the Y-12 Plant. Past releases were not a public health hazard to people living near the reservation, and current releases are not a public health hazard to people living near the reservation.

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APPENDICES

APPENDIX A

ATSDR Glossary of Environmental Health Terms

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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.

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

Carcinogen
A substance that causes cancer.

Case-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 followup 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.

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

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

Half-life ($t_{½}$)
The time it takes for half the original amount of a substance to disappear. In the environment, the *half-life* is the time it takes for half the original amount of a substance to disappear when it is changed to another chemical by bacteria, fungi, sunlight, or other chemical processes. In the human body, the *half-life* is the time it takes for half the original amount of the substance to disappear either by being changed to another substance or by leaving the body. In the case of radioactive material, the *half-life* is the amount of time necessary for one half the initial number of radioactive atoms to change or transform into 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 unlikely to pose a measurable risk of harmful (adverse), noncancerous effects. *MRLs* are calculated for a route of exposure (inhalation or oral) over a specified time period (acute, intermediate, or chronic). *MRLs* should not be used as predictors of harmful (adverse) health effects [see **reference dose**].

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.

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 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.

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, sex, 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 (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.

Other Glossaries and Dictionaries

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

APPENDIX B

Summary of Other Public Health Activities

Appendix B

Summary of Other Public Health Activities

Summary of ATSDR Activities

Exposure Investigations, Health Consultations, and Other Scientific Evaluations. ATSDR health scientists have addressed current public health issues and community health concerns related to two areas affected by ORR operations—the EFPC area and the Watts Bar Reservoir area.

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

- *Health Consultation on Proposed Mercury Clean Up Levels, January 1996.* In response to a request from community members and the city of Oak Ridge, ATSDR evaluated the public health impact of DOE's clean-up levels of 180 milligrams per kilogram (mg/kg) and 400 mg/kg of mercury in the EFPC floodplain soil. ATSDR concluded that the clean-up levels of 180 mg/kg and 400 mg/kg of mercury in the soil of the EFPC floodplain would be protective of public health and pose no health threat to adults or children.

- *ATSDR Science Panel Meeting on the Bioavailability of Mercury in Soil, August 1995.* The purpose of the science panel was to identify methods and strategies that would enable health assessors to develop data-supported, site-specific estimates of the bioavailability of inorganic mercury and other metals (arsenic and lead) from soils. The panel consisted of private consultants and academicians internationally known for their metal bioavailability research along with experts from ATSDR, the Centers for Disease Control and Prevention (CDC), EPA, and the National Institute for Environmental Health Science. ATSDR used information obtained from the panel meeting to evaluate the EFPC clean-up level. ATSDR also used the findings to characterize and evaluate soil containing mercury at other waste sites. Three technical papers and an ATSDR overview paper on the findings of the panel meeting were published in the International Journal of Risk Analysis in 1997 (Volume 17:5).

Following are summaries of other ATSDR public health activities involving Watts Bar Reservoir:

- *Community and Physician Education, September 1996*. To follow up on the recommendations in the ATSDR Lower Watts Bar Reservoir Health Consultation, ATSDR developed community and physician education programs on PCBs in the Watts Bar Reservoir. Daniel Hryhorczuk, MD, MPH, ABMT, of the Great Lakes Center, University of Illinois at Chicago, made presentations on the health risk associated with PCBs in fish at a community health education meeting in Spring City, TN on September 11, 1996. In addition, a physician and health professional education meeting for health care providers in the vicinity of the lower Watts Bar Reservoir was held at the Methodist Medical Center in Oak Ridge on September 12, 1996. ATSDR, in collaboration with local citizens, organizations, and state officials, developed an instructive brochure on the TDEC's fish consumption advisories for the Watts Bar Reservoir.

- *Watts Bar Reservoir Exposure Investigation*. In following up on the findings of previous studies and investigations of the Watts Bar Reservoir, including Feasibility of Epidemiologic Studies by the TDOH, ATSDR conducted the exposure investigation with cooperation from the Tennessee Department of Health and the Roane County Health Department. The 1996 exposure investigation was conducted to measure actual PCB and mercury levels in people consuming moderate to large amounts of fish and turtles from the Watts Bar Reservoir, and to determine whether these people are being exposed to high levels of PCBs and mercury. ATSDR published the following three major findings:

    - The exposure investigation participants' serum PCB levels and blood mercury levels are very similar to levels found in the general population.

    - Only 5 of the 116 people tested (4%) had PCB levels that were higher than 20 micrograms per liter (μg/L) or parts per billion (ppb), which is considered to be an elevated level of total PCBs. Of the five participants who exceeded 20 μg/L, four had levels of 20–30 μg/L. Only one participant had a serum PCB level of 103.8 μg/L, which is higher than the general population distribution.

- Only one participant in the exposure investigation had a total blood mercury level higher than 10 μg/L, which is considered to be elevated. The remaining participants had mercury blood levels that ranged up to 10 μg/L, as might be expected to be found in the general population.

Clinical Laboratory Analysis. In June 1992, an Oak Ridge physician reported to the TDOH and the Oak Ridge Health Agreement Steering Panel (ORHASP) that approximately 60 of his patients may have been exposed, either occupationally or from the environment, to several heavy metals. The physician felt that these exposures had resulted in a number of adverse health outcomes (for example, increased incidence of cancer, chronic fatigue syndrome, neurological diseases, autoimmune disease, and bone marrow damage). In 1992 and 1993, ATSDR and the Centers for Disease Control and Prevention's (CDC's) National Center for Environmental Health (NCEH) facilitated clinical laboratory support by the NCEH Environmental Health Laboratory for patients referred by an Oak Ridge physician to the Howard Frumkin, M.D., Dr.PH., Emory University School of Public Health.

Because of patient-to-physician and physician-to-physician confidentiality, results of the clinical analysis have not been released to public health agencies. However, Dr. Frumkin recommended (in an April 26, 1995 letter to the Commissioner of the Tennessee Department of Health) 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 at Oak Ridge. For that reason, I have consistently urged Dr. Reid, each of the patients, and officials of the CDC and the Tennessee Health Department, not to attempt group analyses of these patients."

Review of Clinical Information on Persons Living In or Near Oak Ridge. In addition to the above Clinical Laboratory Analysis, an ATSDR physician reviewed the clinical data and medical histories provide by the Oak Ridge physician on 45 of his patients. The purpose of this review was to evaluate clinical information on persons tested for heavy metals and to determine whether exposure to metals was related to these patients' illnesses. ATSDR concluded that this case series did not provide sufficient evidence to associate low levels of metals with these diseases. The TDOH came to the same conclusion. ATSDR sent a copy of its review to the Oak Ridge physician in September 1992.

Health education. Another essential part of the public health assessment process is designing and implementing activities that promote health and provide information about hazardous substances in the environment.

- *Health Professional Education on Cyanide.* A physician education program was conducted in 1996, to provide information regarding the health impacts of possible cyanide intoxication. The program was intended to assist community health care providers in responding to health concerns expressed by employees working at the East Tennessee Technology Park (formerly the K-25 facility). ATSDR provided the local physicians with copies of the ATSDR Case Studies in Environmental Medicine publication "Cyanide Toxicity," the National Institute for Occupational Safety and Health (NIOSH) final health hazard evaluation, and the ATSDR public health statement for cyanide. Further, ATSDR instituted a system through which local physicians could make patient referrals to the Association of Occupational and Environmental Clinics (AOEC). Finally, ATSDR conducted an environmental health education session for physicians at the Methodist Medical Center in Oak Ridge, Tennessee. The medical staff grand rounds provided the venue for conducting this session. The workshop focused on providing local physicians and other health care providers with information to help them diagnose chronic and acute cyanide intoxication and to answer patients' questions.

- *Workshops on Epidemiology.* At the request of members of the Oak Ridge Reservation Health Effects Subcommittee (ORRHES), ATSDR held two workshops on epidemiology for the subcommittee. The first epidemiology workshop was presented at the June 2001 ORRHES meeting. Ms. Sherri Berger and Dr. Lucy Peipins of ATSDR's Division of

Health Studies provided an overview of the science of epidemiology. The second epidemiology workshop was presented at the December 2001 ORRHES meeting and was designed to help subcommittee members develop the skills needed to review and evaluate scientific reports. In addition, at the August 28, 2001, meeting of the Public Health Assessment Work Group (PHAWG), Dr. Peipins guided the work group and community members through a systematic scientific approach as they critiqued a report by J. Mangano, "Cancer Mortality Near Oak Ridge, Tennessee" (Int. J. of Health Services, V. 24 #3, 1994, p. 521). Based on the PHAWG critique, the ORRHES made the following conclusions and recommendation 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 are the cause of any such alleged anomalies of cancer mortality rates in the general public.
3. The ORRHES recommends to the ATSDR that the Mangano paper be excluded from consideration in the ORR public health assessment process.

- *Health Education Needs Assessment.* Throughout the public health assessment process, ATSDR staff members have gathered concerns from people in the communities around the ORR. Through a cooperative agreement with ATSDR, AOEC began a community health education needs assessment in 2000 to aid in developing a community health education action plan. George Washington University and MCP Hahnemann University are conducting the assessment for the AOEC. The needs assessment will help in planning, implementing, and evaluating the health education program for the site. It will also help health educators identify key people, cultural norms, attitudes, beliefs, behaviors, and practices in the community, which is information that will aid in developing effective health education activities. Information on the needs assessment was presented at several ORRHES meetings.

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 efforts with TDOH, TDEC, NCEH, NIOSH, and DOE. This effort led to the establishment of the Public Health Working Group in 1999, which led to the establishment of 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, in collaboration with the DOE Office of Health Studies, ATSDR and CDC embarked on a process of developing credible, coherent, and coordinated agendas of public health activities and health studies for each DOE site. In February 1999, ATSDR was given the responsibility to lead the interagency group's efforts to improve communication at 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.

Site visits. To better understand site-specific exposure conditions, ATSDR scientists have conducted site visits to the ORR and visited surrounding areas numerous times since 1992. The site visits included guided tours of the ORR operation areas, as well as tours of the local communities to identify how community members might come into contact with environmental contamination.

Summary of TDOH Activities

Pilot Survey. In the fall of 1983, TDOH developed an interim soil mercury level for use in environmental management decisions. CDC reviewed the methodology for the interim mercury level in soil and recommended that a pilot survey be conducted to determine whether populations with the highest risk for mercury exposure had elevated body burdens of mercury. In June and

July 1984, a pilot survey was conducted to document human body levels of inorganic mercury for residents of Oak Ridge with the highest potential for mercury exposure from contaminated soil and fish. The survey also examined whether exposure to mercury-contaminated soil and fish constituted an immediate health risk to the Oak Ridge population. The results of the pilot survey, released in October 1985, suggested that residents and workers in Oak Ridge, Tennessee, are not likely to be at increased risk for having significantly high mercury levels. Mercury concentrations in hair and urine samples were below levels associated with known health effects.

Health Statistics Review. In June 1992, an Oak Ridge physician reported to the Tennessee Department of Health (TDOH) and the Oak Ridge Health Agreement Steering Panel (ORHASP) that he believed approximately 60 of his patients had experienced occupational and environmental exposures to several heavy metals. The physician felt that these exposures had resulted in increased cancer, immunosuppression, chronic fatigue syndrome, neurologic diseases, autoimmune disease, bone marrow damage, and hypercoagulable state including early myocardial infarctions and stroke. In 1992, The TDOH conducted a health statistics review to compare cancer incidence rates for the period of 1988 to 1990 for counties surrounding the Oak Ridge Reservation to rates from the rest of the state. Findings of the review are in a TDOH memorandum dated October 19, 1992, from Mary Layne Van Cleave to Dr. Mary Yarbrough. The memorandum details an Oak Ridge physician's concerns about the health status in the Oak Ridge area. Also available from the TDOH are the minutes and handouts from a presentation given by Ms. Van Cleave at the ORHASP meeting on December 14, 1994.

Health Statistics Review. In 1994 local residents reported that there were many community members with amyotrophic lateral sclerosis (ALS) and multiple sclerosis (MS). The Tennessee Department of Health in consultation with Peru Thapa, MD, MPH, from the Vanderbilt University School of Medicine conducted a health statistics review of mortality rates for amyotrophic lateral sclerosis (ALS), multiple sclerosis (MS), and other selected health outcomes.

TDOH found that because ALS and MS are not reportable diseases, it is impossible to calculate reliable incidence rates. Mortality rates for the period of 1980 to 1992 were reviewed for the 10 counties surrounding the ORR and compared with mortality rates for the state of Tennessee. The following results were reported by the 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 to 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 rates for total deaths, deaths from stroke, deaths from congenital anomalies, and deaths from heart disease were significantly lower for the period from 1979 to 1988. There were no significant differences in the rates of deaths due to cancer, for all sites, in comparison to rates in the rest of state. Rates of deaths from uterine and ovarian cancer were significantly higher than the rates in the rest of the state. The rate of deaths from liver cancer was significantly lower in comparison to the rest of the state.

- For Roane County, the rates of total deaths and deaths from heart disease were significantly lower than the rates in the rest of the state for the period from 1979 to 1988. Although the total cancer death rate was significantly lower than the rate in the rest of the state, the rate of deaths from lung cancer was significantly higher than the rate in the rest of the state. Rates of deaths from colon cancer, female breast cancer, and prostate cancer were also significantly lower than the rates in the rest of the state.

- For Knox County, the rates for total deaths and deaths from heart disease were significantly lower than the rates in the rest of the state. 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 to the rest of the state from 1980 to 1982. This excess in cancer deaths did not persist from 1983 to 1992.

Knowledge, Attitude, and Beliefs Study. A study, coordinated by TDOH, was conducted in an eight-county area surrounding 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. Following is a summary of the findings.

- 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 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-fine 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 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. A health assessment of the East Tennessee region was conducted by TDOH's East Tennessee Region to evaluate the health status of the population, assess the availability and utilization of health services, and develop priorities in planning to use resources. In December 1991, the East Tennessee Region released the first edition of "A Health Assessment of the East Tennessee Region," which included data generally from 1986 to 1990. The second edition, released in 1996, included data generally from 1990 through 1995. A copy of the document is available from the TDOH East Tennessee Region.

Presentation. Dr. Joseph Lyon of the University of Utah gave a presentation to inform the ORHASP and the public of the multiple studies related to the fallout from the Nevada Test Site, including the study of leukemia and thyroid disease. The presentation was sponsored by TDOH and held on February 16, 1995, at the ORHASP public meeting.

Summary of Joint Center for Political and Economic Studies Activities

Scarboro Community Assessment Report. In 1999, the Joint Center for Political and Economic Studies conducted a survey of the Scarboro community to identify environmental and health concerns of the residents. The surveyors attempted to elicit responses from the whole community and achieved an 82% response rate. Additionally, with support from DOE Oak Ridge Operations, the Joint Center has been working with the community since 1998 to help residents articulate their environmental, health, economic, and social needs. Because Scarboro is a small community, the community assessment provided new information about the community that is not available through sources such as the U.S. Census Bureau. It also identified Scarboro's strengths and weaknesses and illustrated the relative unimportance of environmental health issues to other community concerns—environmental and health issues are not a priority for most Scarboro residents; rather the community is more concerned about crime and security, children, and economic development. The Joint Center recommended more active community involvement in city and community planning (Friday and Turner 2001).

APPENDIX C

Toxicologic Implications of Uranium Exposure

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Toxicologic Implications of Uranium Exposure

ATSDR's toxicological profiles identify and review the key peer-reviewed literature that describes particular hazardous substances' toxicologic properties. They also present other pertinent literature, but describe it in less detail than the key studies. Toxicological profiles are not intended to be exhaustive documents, but they do reference more comprehensive sources of specialty information.

In 1999, ATSDR published an updated toxicological profile for uranium (ATSDR 1999a). This document, like all such profiles, succinctly characterizes the toxicologic and adverse health effects information for the hazardous substance it describes. The discussion below is drawn from the updated profile for uranium, except where otherwise noted.

What Is Uranium?

Uranium, a natural and commonly occurring radioactive element, is found in very small amounts in nature in the form of minerals. Rocks, soil, surface and underground water, air, and plants and animals all contain varying amounts of uranium. Typical concentrations in most materials are a few parts per million (ppm). This corresponds to around 4 tons of uranium in 1 square mile of soil 1 foot deep, or about half a teaspoon of uranium in a typical 8-cubic-yard dump truck load of soil (ATSDR 1999a).

Natural uranium is a mixture of three types (or isotopes) of uranium, written as U 234, U 235, and U 238. By weight, natural uranium is about 0.005% U 234, 0.72% U 235, and 99.27% U 238. For uranium that has been in contact with water, the natural weight and radioactivity percentages can vary slightly from these percentages. All three isotopes behave the same chemically, so any combination of the three would have the same chemical effect on your body. But they are different radioactive materials with different radioactive properties. About 48.9% of the radioactivity is associated with U 234, 2.2% is associated with U 235, and 48.9% is associated with U 238 (ATSDR 1999a).

Uranium Use at ORR

One of the industrial processes at the Y-12 plant artificially increased (enriched) the amount of U 235 over and above the enrichment from the K-25 plant. This enrichment process is used to increase the amount of U 235 and decrease the amount of U 238 in uranium. Enriched uranium used for nuclear power plants is typically 3% U 235. Uranium enrichment for nuclear weapons and nuclear propulsion can produce uranium that contains as much as, if not more than, 97% U 235. The uranium left over after enrichment is called depleted uranium. Uranium enriched as at Y-12 is more radioactive than natural uranium, and natural uranium is more radioactive than depleted uranium.

Various types and amounts of uranium compound were used and produced at the Y-12 facility and potentially released to the environment. The chemical forms of uranium used at Y-12 included uranium tetrachloride, uranium oxides in the form of UO_2, UO_3, and U_3O_8, and uranium hexafluoride (ChemRisk 1999). Of these forms, U_3O_8 is most commonly found in nature and chemically is the most stable. Uranium dioxide (UO_2) is the form most used in nuclear reactors; over time, it converts to U_3O_8. The following table gives the water solubility and kidney toxicity of the common uranium compounds used at the Y-12 facility.

Table C-1. Relative Water Solubility and Kidney Toxicity of the Uranium Compounds Used at Y-12

Relative Water Solubility	Relative Toxicity to Kidney	Uranium Compound
Most water soluble	Most toxic	Uranium hexafluoride Uranium tetrachloride
Low water solubility	Low to moderate toxicity	Uranium trioxide
Insoluble	Least toxic	Uranium dioxide Triuranium octaoxide

How Can Uranium Enter and Leave My Body?

Plants and animals can take up uranium. Uranium in soil can be taken into plants without entering into the plants' bodies. Root vegetables (like potatoes and radishes) that are grown in soils with high concentrations of uranium may contain more uranium than other vegetables grown in the same conditions. Uranium can also get into livestock through food, water, and soil. Therefore, uranium is taken into our bodies in the food we eat, the water we drink, and the air we breathe. But it does not stay in the body long—it is eliminated quickly in urine and feces.

What we take in from industrial activities is in addition to what we take in from natural sources. When you breathe uranium dust, some is exhaled and some stays in your lungs. The size of the uranium dust particles and how easily they dissolve determines where in the body the uranium goes and how it leaves your body. Uranium dust can consist of small, fine particles and coarse, big particles. The big particles are caught in the nose, the sinuses, and the upper part of your lungs; from there, they are blown out or pushed to the throat and swallowed. The small particles are inhaled down to the lower part of your lungs. If they do not dissolve easily, they stay there for years. (Most of uranium's radiation dose to the lungs comes from these small particles.) Given these solubilities, the International Commission on Radiological Protection has grouped uranium compounds into three classes, as shown in the following table (ICRP 1993, 1995).

Table C-2. Types of Uranium Compound According to Their Solubilities

	Type F	Type M	Type S
Initial Dissolution Rate (per day)	100	10	0.1
Representative Uranium Compounds	Hexafluoride, tetrafluoride; pure trioxide form (UO_3)	Tetrafluoride, trioxide, octoxide (U_3O_8) (dependent on process)	Octoxide, dioxide (UO_2)

Uranium particles can also gradually dissolve and go into your blood. If the particles dissolve easily, they go into your blood more quickly. When you eat foods and drink liquids containing uranium, most of it leaves within a few days in your feces and never enters your blood. A small portion does get into your blood, which carries it throughout your body. Some of the uranium in your blood leaves your body through your urine within a few days, but the rest stays in your bones, kidneys, or other soft tissues. A small amount of the uranium that goes to your bones can stay there for years. Most people have very small amounts of uranium, about 1/5,000th of the weight of an aspirin tablet, in their bodies, mainly in their bones.

How Can Uranium Affect My Health?

Although uranium is weakly radioactive, most of the radiation it gives off cannot travel far from its source. If the uranium is outside your body (in soil, for example), most of its radiation cannot penetrate your skin and enter your body. To be exposed to radiation from uranium, you have to eat, drink, or breathe it, or get it on your skin (ATSDR 1999a).

Scientists have never detected harmful radiation effects from low levels of natural uranium, although some may be possible. However, scientists have seen chemical effects. A few people have developed signs of kidney disease after taking in large amounts of uranium (e.g., one man ingested 131 milligrams per kilogram of uranyl acetate in a suicide attempt; see Pavlakis et al. 1996 as cited in ATSDR 1999a). Animals have also developed kidney disease after they have been treated with large amounts of uranium. It is possible that intake of a large amount of uranium will damage your kidneys.

There is also a chance of getting cancer from any radioactive material like uranium. Again, natural and depleted uranium are only weakly radioactive, and their radiation is not likely to cause cancer. No human cancer of any type has ever been seen as a result of exposure to natural or depleted uranium (ATSDR 1999a). Although several studies of uranium miners found that they were more likely to die from lung cancer, it is difficult to say whether uranium exposure caused these cancers: while they were being exposed to the uranium, the miners were also being exposed to known cancer-causing agents (tobacco smoke, radon and decay products, silica, and diesel engine exhaust). The studies attributed the cancers to exposure to these agents and not to uranium exposure.

The National Academy of Sciences' Committee on the Biological Effects of Ionizing Radiation (BEIR IV) reported that eating food or drinking water that has normal amounts of uranium will most likely not cause cancer or other health problems in most people (National Research Council 1988). The Committee used data from animal studies to estimate that a small number of people who steadily eat food or drink water containing larger-than-normal quantities of uranium could get a kind of bone cancer called a sarcoma. The Committee reported calculations showing that if a million people steadily ate food or drink water containing about 1 picocurie of uranium every day of their lives, one or two of them would have developed bone sarcomas after 70 years, based on the radiation dose alone. However, we do not know this for certain because people normally ingest only slightly more than this amount each day, and people who have been exposed to larger amounts have not been found to get cancer. We do not know if exposure to uranium causes reproductive effects in people. Very high doses of uranium have caused reproductive problems (reduced sperm counts) in some experiments with laboratory animals. Most studies show no effects (ATSDR 1999a).

How Can Uranium Affect Children?

Children are also exposed to small amounts of uranium in air, food, and drinking water. However, no cases have been reported in which exposure to uranium was known to have caused health effects in children. Children exposed to very high amounts of uranium might have damage to their kidneys like that seen in adults. We do not know whether children differ from adults in their susceptibility to health effects from uranium exposure. It is not known if exposure to uranium has effects on the development of the human fetus. Very high doses of uranium in drinking water can affect the development of the fetus in laboratory animals. One study reported birth defects and another reported an increase in fetal deaths. However, we do not believe that uranium can cause these problems in pregnant women who take in normal amounts of uranium from food and water, or who breathe the air around a hazardous waste site that contains uranium (ATSDR 1999a).

Is There a Medical Test to Determine Whether I Have Been Exposed to Uranium?

There are medical tests that can determine whether you have been exposed by measuring the amount of uranium in your urine, blood, and hair. Urine analysis is the standard test. If your body takes in a larger-than-normal amount of uranium over a short period, the amount of uranium in your urine may be increased for a short time. Because most uranium leaves the body within a few days, normally the amount in the urine only shows whether you have been exposed to a larger-than-normal amount within the last week or so. If the intake is large or if higher-than-normal levels are taken in over a long period, the urine levels may be high for a longer period of time. Many factors can affect the detection of uranium after exposure. These factors include the type of uranium you were exposed to, the amount you took into your body, and the sensitivity of the detection method. Also, the amount in your urine does not always accurately show how much uranium you have been exposed to. If you think you have been exposed to elevated levels of uranium and want to have your urine tested, you should do so promptly while the levels may still be high. In addition to uranium, the urine could be tested for evidence of kidney damage, through tests for protein, glucose, and nonprotein nitrogen, which are some of the chemicals that can appear in your urine because of kidney damage. Though such tests could determine whether you have kidney damage, they would not tell you if uranium in your body caused that damage: several common diseases, such as diabetes, also damage the kidneys (ATSDR 1999a).

What Recommendations Has the Federal Government Made to Protect Human Health?

Federal agencies have set limits for uranium in the environment and workplace. In 1991, the U.S. Environmental Protection Agency established a maximum contaminant level for uranium in drinking water of 20 micrograms per liter (µg/L). In December 2003, the maximum contaminant level for uranium will increase to 30 µg/L. The National Institute of Occupational Safety and Health and the Occupational Safety and Health Organization have established a recommended exposure limit and a permissible exposure limit of 0.05 milligrams per cubic meter for water-soluble uranium dust in the workplace. The Nuclear Regulatory Commission has set uranium release limits of 0.06 picocuries per cubic meter in air and 300 picocuries per liter in water (or approximately 438 µg/L).

APPENDIX D

ATSDR's Derivation of the Radiogenic Cancer Comparison Value

APPENDIX D

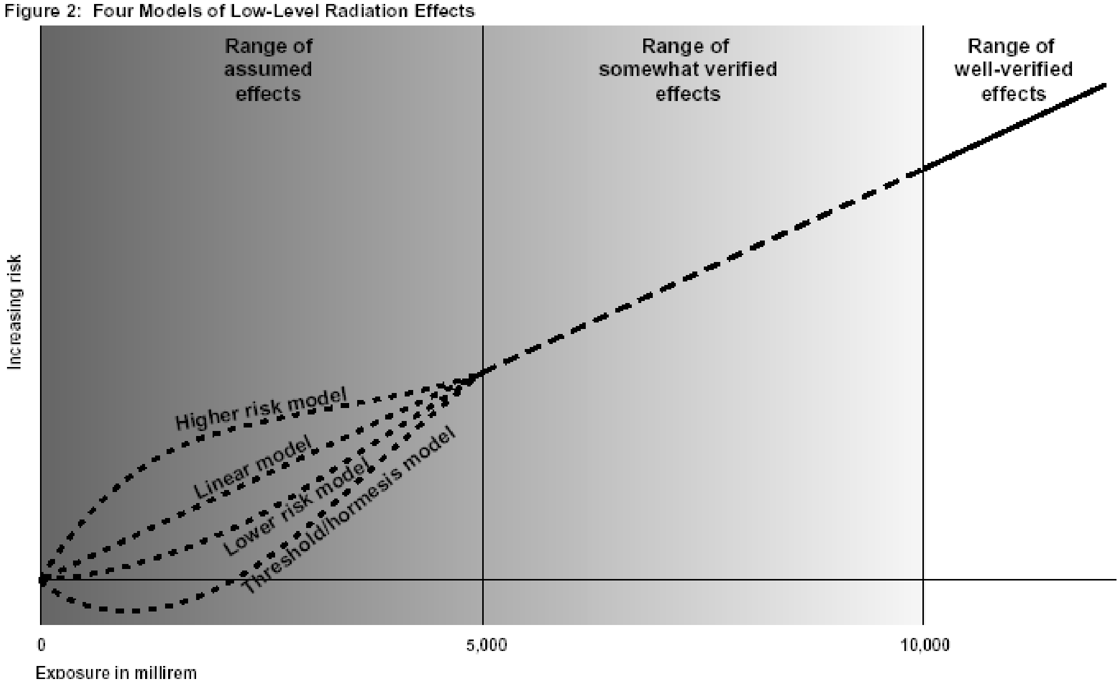
ATSDR's Derivation of the Radiogenic Cancer Comparison Value

For the evaluation of radiation doses at Oak Ridge, ATSDR used the concept of committed effective dose equivalent (CEDE). The CEDE is a calculated dose arising from the one-time intake of radiological uranium, with the assumption that the entire dose (a 70-year dose, in this case)[19] is received in the first year following the intake. The value used by ATSDR for the radiogenic cancer comparison value is 5,000 millirem (mrem) over 70 years. ATSDR derived this value after reviewing the peer-reviewed literature and other documents developed to review the health effects of ionizing radiation.

In 1994, the General Accounting Office (GAO) released a report reviewing the U.S. radiation standards and radiation protection issues (GAO 1994). The GAO further refined their results in 2000 (GAO 2000). According to the later report, "conclusive evidence of radiation effects is lacking below a total of about 5,000 to 10,000 mrem, according to the scientific literature," which was also the consensus of experts they interviewed (GAO 2000).[20] The GAO then developed the following figure from their analysis. The figure shows the representative knowledge base of radiation effects in relation to radiation dose. Besides the four possible dose response curves indicated on the figure, it also shows that at a dose of 10,000 mrem (which is equal to 10 rems or 0.1 sieverts; "rems" is abbreviated as "rem" and "sieverts" is abbreviated as "Sv") or more, the data are conclusive with respect to health effects from radiation exposure. Between 10 rem and 5 rem, the data are not clear as to the health effects. Below 5 rem the effects are not observed, only assumed to occur. Therefore, the risk associated with a dose that approaches background, 0.36 rem/year (360 mrem or 3.6 millisieverts [mSv]) is essentially impossible to measure.

[19] In this case, the entire dose is the dose a person would receive over 70 years of exposure. ATSDR chose a 70-year period of exposure under the assumption that a member of the public would be exposed over an entire lifetime.
[20] Expert organizations estimate risks associated with radiation doses at these levels using complex models of existing data. Here, for example, is an estimate from a 1990 study by a National Academy of Sciences committee called BEIR V: at the 90% statistical confidence interval, out of 100,000 adults exposed to 100 mrem a year of radiation over a lifetime, anywhere from 410 to 980 men and 500 to 930 women might die of cancer caused by the exposure. This confidence interval assumes the validity of the linear model and reflects the uncertainty of inputs to the model.

Figure 2: Four Models of Low-Level Radiation Effects



The National Council on Radiation Protection and Measurement (NCRP), in their Report 136 on linear non-threshold issues, reevaluated the existing data on the dose-response of ionizing radiation and the health effects associated with exposures to ionizing radiation (NCRP 2001). Their evaluation focused on "the mutagenic, clastogenic (chromosome-damaging), and carcinogenic effects of radiation." As in other reviews, the NCRP found no conclusive evidence to reject the linear no-threshold model for radiation dose response. One result of these reviews, however, is that the NCRP stated that for cell systems receiving "low-LET [Linear Energy Transfer] radiations the lowest dose at which a statistically significant increase of transformation over background has been demonstrated is 10 mGy." (10 mGy, or milligrays, are equivalent to a radiation dose of 1 rad.) Animal studies, meanwhile, show variation in the dose-response curves. Accordingly, page 210 of the NCRP report states that "the available information does not suffice to define the dose-response curve unambiguously for any neoplasm in the dose range below 0.5 Sv." Note that the NCRP also stated that other data on induction of neoplasms and life shortening in mice were not inconsistent with a linear response. Thus, there is uncertainty in the response to the types of radiation, the endpoint under investigation, and the animal system being studied.

According to the NCRP, similar dose responses occur in humans, as evidenced by many studies. However, many of these studies were atomic bomb survivor studies—the doses and dose rates involved were very different from the doses and rates typically observed at hazardous waste sites. The NCRP states that in the bomb survivors, induction of leukemia appears to be linear-quadratic; however, the studies on which that statement is based began at least 5 years after the bombing, so they may have missed the initial wave of leukemia. Overall, the induction of solid cancers has a linear nonthreshold (LNT) component as low as 50 mSv (5,000 mrem). Other radiation studies show a possible increase in fetal cancer following an exposure of 10 mGy and increased thyroid cancer following irradiation during childhood following a dose of 100 mSv (10,000 mrem).

The adverse health effects from acute exposures to radiation have been well defined through studies of atomic bomb survivors, medical accidents, and industrial accidents. But this document is concerned with health effects associated with low-dose chronic exposures to ionizing radiation. These health effects are more difficult to define, characterize, and discuss. ATSDR's experience at sites contaminated with radioactive materials shows that chronic exposures are incremental in comparison to background. In the United States, background consists of naturally occurring radon (54%), terrestrial and cosmic radiation (8% each), and radiation from natural internal sources (11%). The remainder (19%) is associated with medical exposures and consumer products (ATSDR 1999b). The typical average background radiation in the United States is 3.6 mSv (360 mrem) per year. Excluding medical and consumer products, the average background is about 300 mrem (3 mSv).

Exposures Associated with Background Radiation

ATSDR could not identify any peer-reviewed studies that show that background-level radiation is harmful. In fact, there are portions of the globe where the background is higher than in the typical area in the United States. According to the United Nations, the world's background radiation can vary from below 1 mSv (100 mrem) to above 6.4 mSv (640 mrem), or higher, per year. For example, in an area in China where elevated levels of natural background radiation are found, studies have shown a significant increase in chromosomal aberrations; however, no increases in adverse health effects have been observed in the 20 or more years this area has been studied. Other areas in the world where there are high background radiation levels are India, Brazil, and Iran. An area in Iran called Ramsar has verified doses as high as 130 mSv per year (1,300 mrem).[21]

Incremental Exposures Above Background Radiation

Many studies have attempted to show a cause and effect from low-level chronic radiation exposure. In these studies, low dose can be defined as doses in excess of 10 mSv (1,000 mrem). No studies exist for exposures or doses below this limit. For many of these low-dose epidemiological studies, researchers used the standardized mortality ratio (SMR). The Society for Risk Analysis defines the SMR as "the ratio of observed deaths in a population to the expected number of deaths as derived from rates in a standard population with adjustment of age and possibly other factors such as sex or race."

An English study of over 95,000 radiation workers whose collective dose from external radiation was about 3,200 man Sv (3,200/95,000 = 34 mSv or 3,400 mrem) only took into account external radiation exposure and dose. The results showed that the SMR for all cancers was less than 1 (Kendall et al. 1992).

A later study by Cardis and coworkers included 95,000 nuclear industry workers in the United States, Canada, and the United Kingdom. The study participants were monitored for external radiation exposure (mostly gamma) and were employed for at least 6 months. In all, there were 15,825 deaths, of which 3,976 were from cancer. The authors found no evidence of a dose response and mortality association from all causes or from all cancers. Of the cancer types,

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[21] ATSDR used several data sources in developing this section: Internet searches, the *Health Physics* journal, and United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) reports.

leukemia (except for chronic lymphocytic leukemia and multiple myeloma) showed a significant association with cumulative external radiation dose (Cardis et al. 1995).

In a cohort study to determine if radiation workers' children were at risk of developing leukemia or other cancers before they reached 25 years of age, Roman and coworkers included 39,557 children of male workers and 8,883 children of female workers. The study suggested that the incidence of cancer and leukemia among children of nuclear industry employees is similar to that in the general population. The SMR for all cancers and leukemias for each sex of the worker was less than 1 (Roman et al. 1999).

In conclusion, ATSDR believes that its reasoning in using a radiogenic cancer comparison value of 5,000 mrem over 70 years is protective of human health at Oak Ridge.

APPENDIX E

Measured vs. Estimated
Average Annual Uranium Air Radioactivity Concentrations
at ORR Air Monitoring Station 46 in Scarboro

Appendix E

Measured vs. Estimated Average Annual Uranium Air Radioactivity Concentrations at ORR Air Monitoring Station 46 in Scarboro

Task 6 of the Oak Ridge Health Studies Phase II (ChemRisk 1999) included an extensive assessment of uranium air emissions from the Y-12 facility and an attempt to estimate historic uranium air radioactivity concentrations in Scarboro from 1944 to 1995 based on the annual airborne uranium release estimates for Y-12 from 1944 to 1995. This section of the public health assessment compares the estimated uranium air radioactivity concentrations (1985 to 1995) in Scarboro to the uranium air radioactivity concentrations measured in Scarboro between 1986 and 1995.

The DOE perimeter air monitoring station 46 in Scarboro has been in operation since 1986. The Task 6 report evaluated the environmental monitoring procedures and methods used for that sampling. The Task 6 report concluded that the "procedures and methods that have been used to collect and analyze air samples for uranium concentrations at the Scarboro location were deemed by the project team to be of adequate quality for use in the Scarboro χ/Q [chi/Q] evaluation presented below. The methods employed by ORNL are consistent with industry standards and are capable of producing reliable estimates of uranium concentrations in Scarboro."

Given the Task 6 conclusion about air sampling at station 46, ATSDR assumes that the measured uranium air concentrations at Scarboro, beginning in 1986, are a reliable basis for calculating uranium air exposures and doses to the Scarboro community. Uranium air concentrations at Scarboro from 1944 to 1985 are unknown and must be estimated. If the 1986 to 1995 annual airborne release estimates for Y-12 and the 1986 to 1995 measured air concentrations in Scarboro are correlated, the correlation will provide a quantitative basis for estimating historic annual average air radioactivity concentrations (1944 to 1995) at Scarboro from the annual airborne uranium release estimated for Y-12 between 1944 and 1995.

The Task 6 study used the correlation between the measured Scarboro air concentrations (1986 to 1995) and the estimated Y-12 airborne uranium emissions (1986 to 1995) to create a multiplying factor (termed "an empirical χ/Q"). This χ/Q is simply the ratio of an observed (measured) annual average uranium air concentration in Scarboro to the estimated airborne uranium releases from Y-12 for the same year.[22] As there were 10 years (1986 to 1995) of observed annual average air concentrations in Scarboro and Y-12 airborne emission rates at the time of the Task 6 report, the χ/Q multiplier corresponding to the 95th upper confidence limit of the mean was used.

Figure E-1 shows the annual average U 234/235 air concentrations calculated using the Task 6 χ/Q multiplier relative to the measured Scarboro air concentrations for 1986 to 1995. The figure shows that the χ/Q estimation of Scarboro air concentrations overestimates the measured air concentrations by up to a factor of 5. Consequently, airborne uranium doses to Scarboro residents calculated from χ/Q concentration estimates were probably also overestimated by a factor of up to 5.

Figure E-1 also shows Scarboro air concentrations estimated using linear regression of Y-12 airborne emissions and measured air concentrations. This is a different method of estimating Scarboro air concentrations from Y-12 emissions data. As the air concentrations estimated using linear regression directly overlie the measured air concentrations in Figure E-1, this method appears to be a better estimator of historic Scarboro air concentrations than the χ/Q method.

The linear regression relationship is illustrated in Figure E-2. This method plots the measured air radioactivity concentrations (in femtocuries per cubic meter, or fCi/m^3; 1 femtocurie equals 1×10^{-15} curies) with the Y-12 uranium airborne emissions and draws a best fit straight line through the plotted points. The linear regression is the equation of the best fit line. The correlation coefficient (shown as R^2 in Figure E-2) is a measure of the strength of association between the air concentrations and emissions. The perfect correlation between factors would be 1. The

[22] χ represents the average annual Scarboro uranium concentration; Q represents the annual Y-12 uranium emissions. Multiplying the historic Y-12 emissions (Q) by the χ/Q term results in an estimate of the historic Scarboro air concentration, or χ.

coefficient of 0.9657 between Scarboro air concentrations and Y-12 U 234/235 emissions indicates that the linear regression is a very reliable estimator of historic Scarboro air radioactivity concentrations.

The regression equation (Figure E-2) for estimating historic Scarboro air radioactivity concentrations from Y-12 emissions is:

$$y = 1.7059x + 0.0784$$

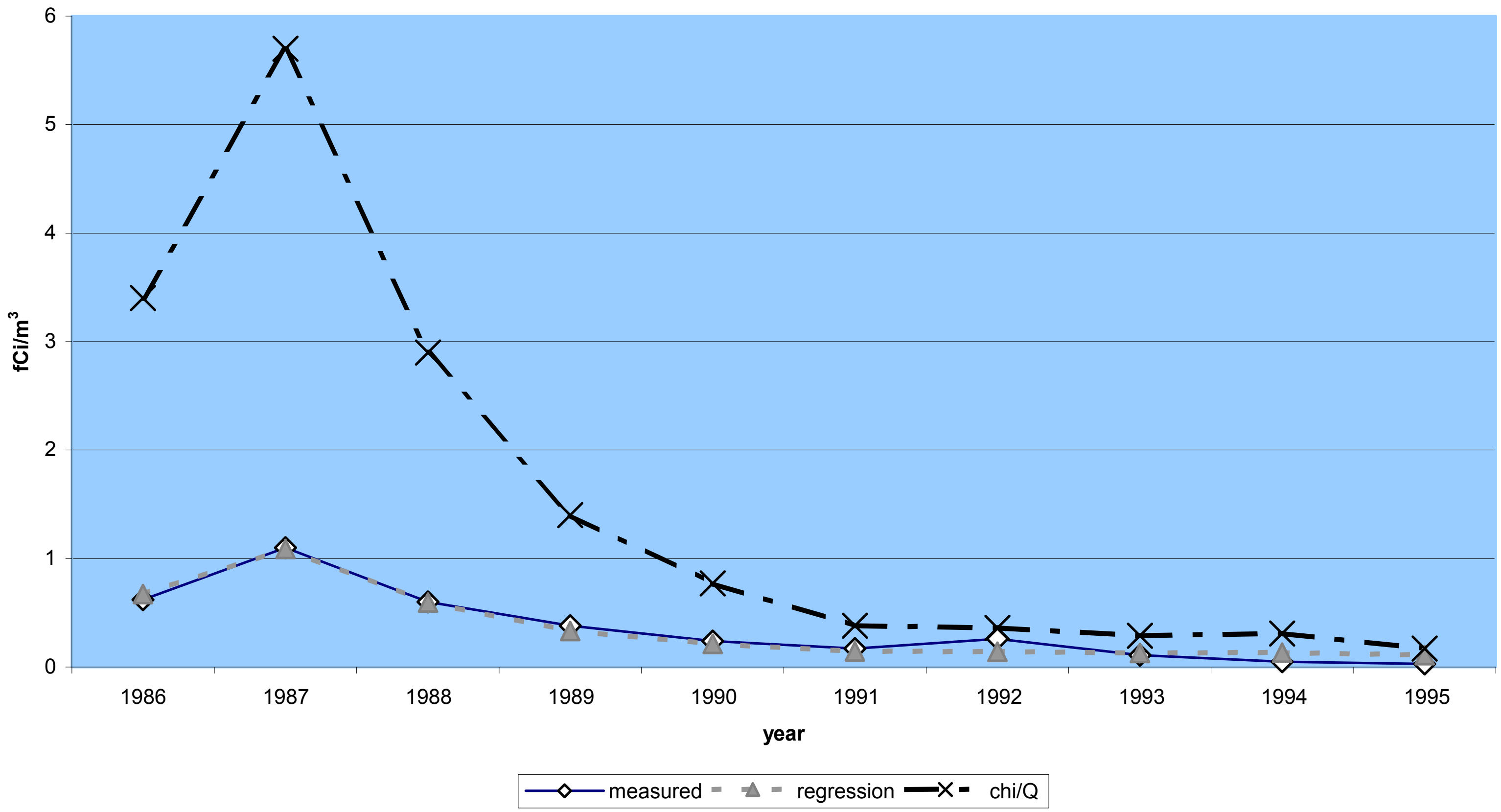
Where: y = the estimated Scarboro air radioactivity concentration in fCi/m^3
x = the Y-12 uranium emission rate in curies

The equation above is based on correlation of U 234/235 release rates (Y-12 emissions) and measured U 234/235 air concentrations.

Figure E-3 shows the relationship between U 238 airborne emissions and measured air concentrations. Although this relationship also shows a positive correlation, it is a much weaker association: the correlation coefficient (R^2) is only 0.6377 and there is much greater scatter of the plotted points relative to the best fit regression line. Consequently, the regression equation based on U 238 emissions and measured Scarboro air concentrations is not considered a reliable estimator of historic air concentrations.

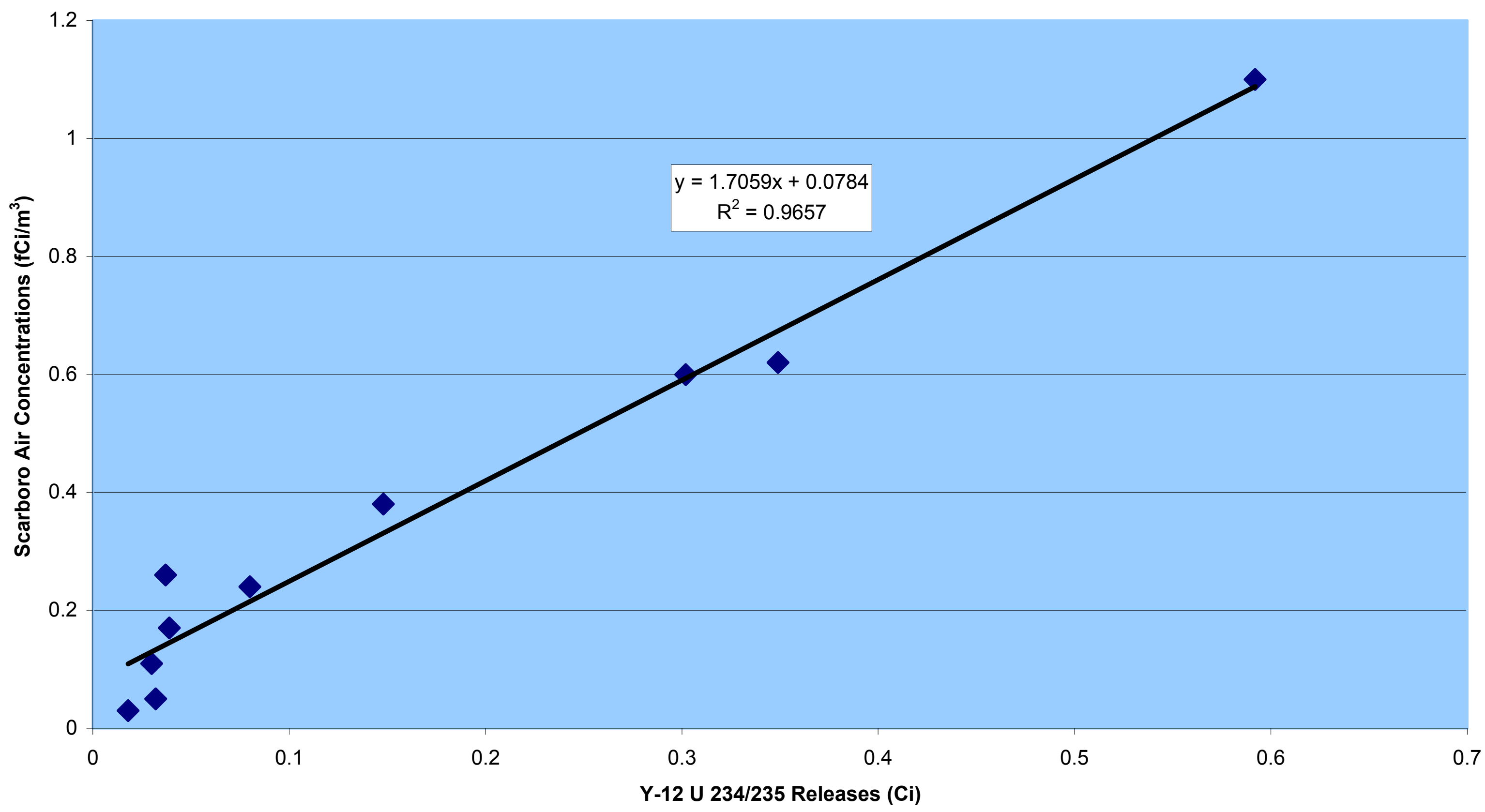
Figure E-4 shows measured and estimated U 238 air concentrations in Scarboro based on the χ/Q and linear regression methods. In this case, the U 238 concentrations are estimated using the U 234/235 regression equation (Figure E-2). The χ/Q estimates show little correspondence with the measured concentrations and either greatly overestimate or underestimate the measured U 238 concentrations. The concentrations estimated using the linear regression method correspond much more closely to the measured U 238 concentrations and never underestimate the measured values. Consequently, airborne U 238 doses to Scarboro residents based on the historic χ/Q concentrations will most likely overestimate, and in some cases underestimate, actual doses.

Figure E-1. Measured vs. Estimated U 234/235 Air Concentrations for Scarboro



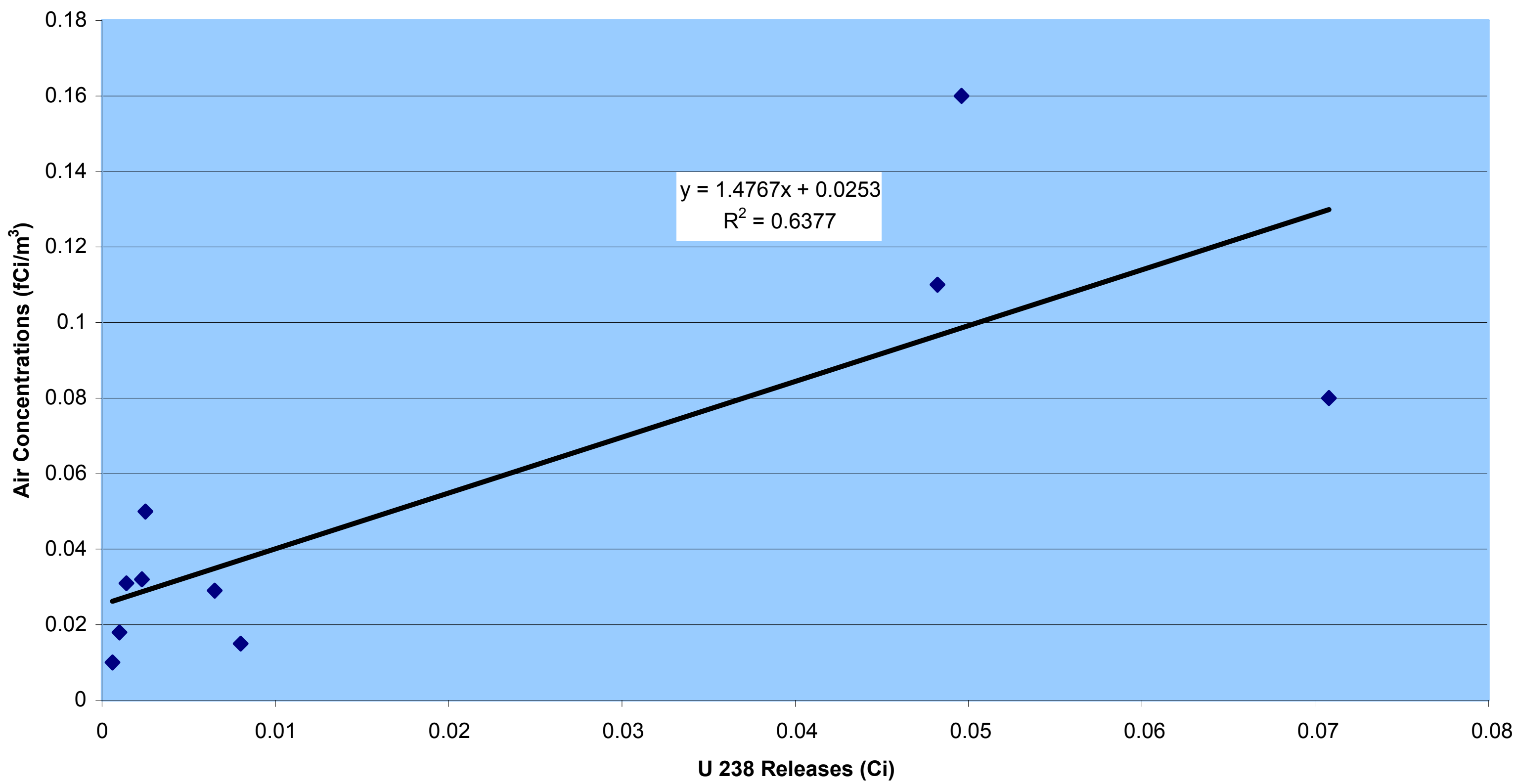
Concentrations estimated using the Task 6 χ/Q method overestimate measured concentrations in Scarboro by a factor of up to 5. Air concentrations estimated using linear regression of measured U 234/235 air concentrations in Scarboro and Y-12 airborne U 234/235 emissions have a much closer agreement with measured air concentrations.

Figure E-2. Airborne U 234/235 Releases Estimates for Y-12 vs. Measured Uranium Air Concentrations in Scarboro



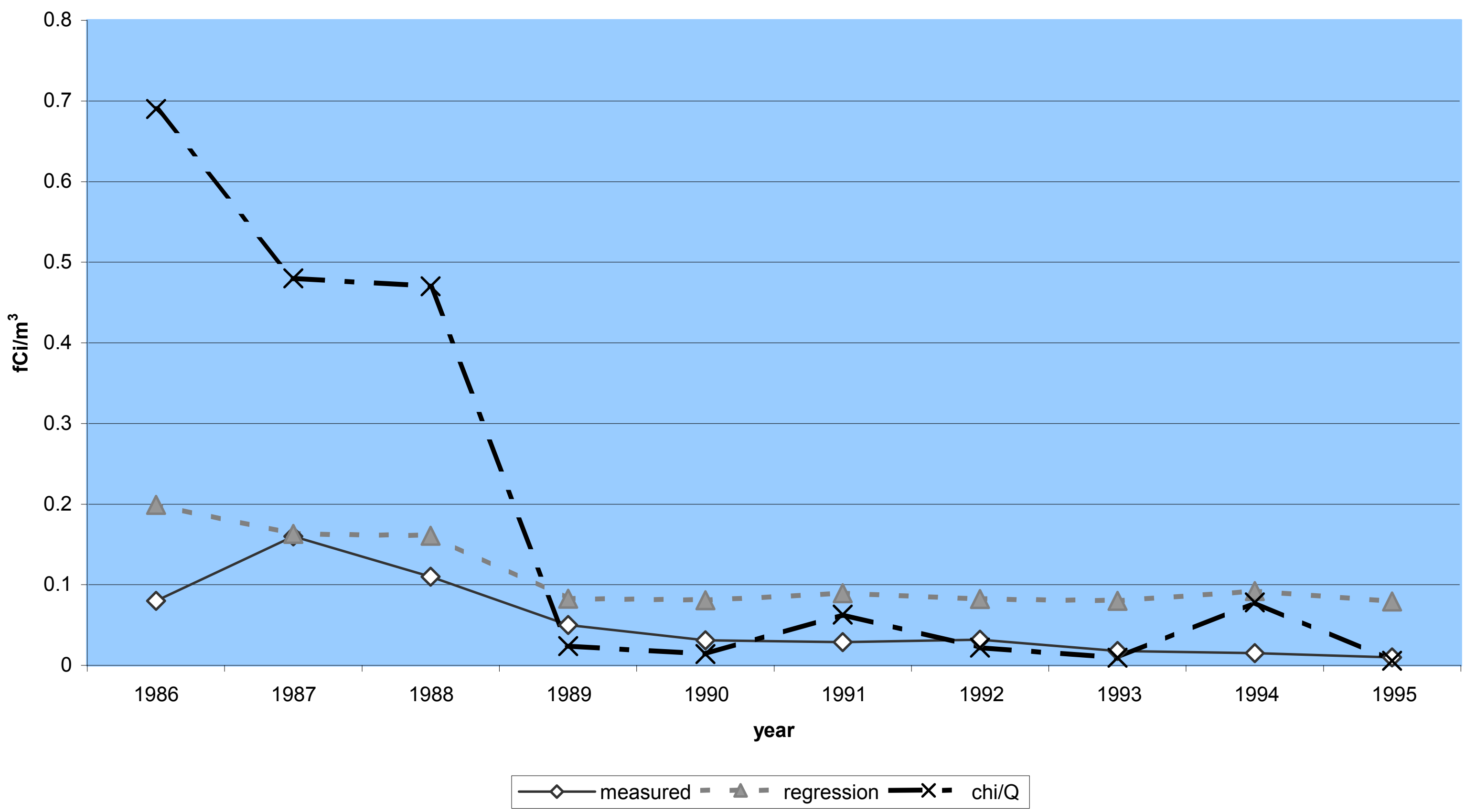
Linear regression between measured Scarboro U 234/235 air concentrations (annual average in fCi/m^3) and Y-12 U 234/235 airborne emissions (in curies) for the years 1986 to 1995. The correlation coefficient (R^2) of 0.9657 indicates a strong positive relationship and the regression equation ($y = 1.7059x + 0.0784$) is a reliable estimator of historic Scarboro air concentrations.

Figure E-3. Airborne U 238 Releases Estimates for Y-12 vs. Measured Uranium Air Concentrations in Scarboro



Linear regression between measured Scarboro U 238 air concentrations (annual average in fCi/m^3) and Y-12 airborne U 238 releases (in curies) for the years 1986 to 1995. The correlation coefficient (R^2) of 0.6377 indicates a weak positive relationship and that the regression equation (y = 1.4767x + 0.0253) is a poor estimator of historic Scarboro air concentrations.

Figure E-4. Measured vs. Estimated U 238 Air Concentrations for Scarboro



Concentrations estimated using the Task 6 χ/Q method overestimate or underestimate measured concentrations in Scarboro. Air concentrations estimated using linear regression of measured U 234/235 air concentrations in Scarboro and Y-12 airborne emissions of U 234/235 have a much closer agreement with measured air concentrations in Scarboro.

APPENDIX F

A Conservative Approach in Radiation Dose Assessment
Issues Associated with Being Protective or Overestimating Radiation Doses

APPENDIX F

A Conservative Approach in Radiation Dose Assessment
Issues Associated with Being Protective or Overestimating Radiation Doses

Research has shown there is little evidence of harm associated with exposure to ionizing radiation at or below the limits recommended by the International Commission on Radiological Protection (ICRP).

Most of the observed data showing adverse health effects related to radiation exposure come from high-dose, high-dose-rate exposures. Therefore, the ICRP's initial goal in setting dose limits was to prevent the directly observable, nonmalignant, not necessarily cancerous effects of such exposures. As the science of radiation protection advanced, the ICRP modified its dose limits to reduce the incidence of cancer and detrimental heredity effects resulting from exposure to radiation (ICRP 1991).

Estimation of Radiation Dose

Radiation dose is a function of the energy from radiation, the amount of radiation absorbed, and the mass of the material absorbing the radiation. The energy of radiation is well known, being derived from first principles of physics. The amount of radiation absorbed is based either on estimated measurements of energy transfer or, in the case of human exposures, on models called phantoms that are used to estimate the shapes, sizes, and masses of organs. Using mathematical models called transport models, one estimates the amount of radiation absorbed by these phantoms. These data are then applied to realistic human data. The ICRP has reviewed and prepared publications discussing tissue masses, ethnicity issues, composition, age, and sex from medically derived information. The masses of human organs used, therefore, are best estimates. Because of these variabilities, the ICRP established a standardized human, the "reference man."

ICRP Dose Coefficients

In its earlier publications, the ICRP only concerned itself with radiation exposure to workers. Following the events associated with the nuclear reactor accident at Chernobyl, the ICRP expanded its role to include members of the public. To characterize exposure to members of the public, ICRP Publication 56 (ICRP 1990) stated, one must have a good understanding of age dependency, biokinetics, anatomical, and physiological data.

The ICRP has developed factors called dose coefficients, dose conversion factors (DCF), which can be used for the purposes of dose assessment. These DCF values are a combination of factors containing much uncertainty. To compensate for this uncertainty, the ICRP added conservative assumptions to the DCF values; accordingly, they may overestimate radiation doses. As radioactive materials decay and emit particles and/or waves, the energy emitted can interact with matter. This interaction has been assigned a weighting factor (called the radiation weighting factor, W_R). The ICRP selected the W_R to be representative of values that are broadly compatible with the dosimetric quantity of Linear Energy Transfer, or LET. The LET estimates the number of ionizations produced by radioactive emissions along their paths as they traverse matter. Although based on the energy of the particular particle, the ICRP selected one specific value (1) for beta particles and gamma radiation and another value (20) for alpha particles based on the energy distribution curves.

For radiation effects on tissues, the ICRP also established a tissue weighting factor (W_T), which is based on the organ and tissue contribution to overall health and incidence of cancers, also based on the “reference man” concept and rates of disease in the population. The weighting factors range from 1% for bone surfaces and skin to 20% for the gonads. Except in the case of radiation effects to the breast, the sexes differ little in response to ionizing radiation. The factors are also used to establish probabilities, based on latency periods, of fatal cancers and non-fatal or hereditary effects in the whole population and in workers. This is a concept of detriment that the ICRP defines as a “measure of the total harm that would eventually be experienced by an exposed group and its descendants as a result of the group’s exposure to a radiation source.”

Accordingly, the ICRP established coefficients for detriment following exposure to ionizing radiation as shown in Table F-1.

Table F-1. ICRP Detriment Coefficients

	Fatal Cancers	Non-Fatal	Hereditary Effects	Total
Adult Workers	0.0004 per rem	0.00008 per rem	0.00008 per rem	0.00056 per rem
Population	0.0005 per rem	0.0001 per rem	0.00013 per rem	0.00073 per rem

Biokinetic Models

After radioactive materials are ingested or inhaled, they are absorbed and distributed throughout the body. The degree of absorption depends on the chemical form of the material; the ICRP has grouped the compounds into general categories based on solubilities in water or body fluids. Furthermore, the ICRP divided the human body into compartments into or out of which the materials are transported, or where they are stored for extended time periods. The models explaining radioactive materials' movement relative to compartments are based on autopsy studies, human volunteers, and animal studies, with adjustments for the "reference man" incorporated. After reviewing these studies, the ICRP selected coefficients for rates of absorption, transit times, and storage times in the organs of interest. In many cases, the variables selected are an overestimation of the true but uncertain biological function.

Summary

The establishment of a series of dose coefficients or dose conversion factors involves much uncertainty in the parameters leading to the calculation of the coefficient. Because of human variability, a standardized human commonly called a "reference man" is used to estimate the radiation dose.

Typical dose assessments use dose coefficients to estimate the radiation dose to a given population. Many of these assessments do not use site-specific information such as demographics or inhalation and ingestion rates. ATSDR, in its evaluation of the radiation doses associated with the Oak Ridge Reservation, has used site-specific parameters and variables more related to the Southern life style than to the human population.

APPENDIX G

Summary of Technical Review Comments

on the

Oak Ridge Health Studies
Oak Ridge Dose Reconstruction—Task 6 Report

Volume 5: 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

FOREWORD

As provided for by the 1991 Tennessee Oversight Agreement between the state of Tennessee and the U.S. Department of Energy (DOE), the Tennessee Department of Health conducted the Oak Ridge Health Studies. The Oak Ridge Health Studies are independent state evaluations of hazardous substances released from the DOE Oak Ridge Reservation (ORR) since its creation. The purpose of the studies is to evaluate whether off-site populations were exposed to chemical and radiological releases from ORR and to assess the risk posed by off-site exposures. The Oak Ridge Health Studies include six dose reconstruction reports: one each on iodine, mercury, polychlorinated biphenyls (PCBs), uranium, and radiological releases into the White Oak Creek, and a screening-level evaluation of additional potential materials of concern. The Oak Ridge Health Agreement Steering Panel provided technical oversight of work performed by contractors (i.e., ChemRisk Division, McLaren/Hart Environmental Services, Inc.; SENES Oak Ridge, Inc.; and Shonka Research Associates) to conduct the Oak Ridge Health Studies.

The Agency for Toxic Substances and Disease Registry (ATSDR) is having each of the Phase II Oak Ridge Health Studies documents reviewed by a group of technical experts to evaluate the quality and completeness of the studies and to determine if the studies provide a foundation for follow-up public health actions or studies. ATSDR will use the information from the Oak Ridge Health Studies, as well as data from the technical reviews and other studies, to develop public health assessments for the ORR. The public health assessments will assess the overall public health impact on off-site populations and determine which follow-up public health actions or studies are indicated.

PURPOSE OF TECHNICAL REVIEW

Introduction

Using the findings of the September 1993 Oak Ridge Health Studies Phase I Report—Dose Reconstruction Feasibility Study, the Tennessee Department of Health developed six dose reconstruction reports in July 1999. The subject of this technical review is the report entitled *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*; hereafter referred to as "the report" or "the uranium report." Some reviewers also refer to the report as the "Task 6 document." The report focuses entirely on uranium dose reconstruction and risk assessment. The main text of the report contains the overall approach, an extensive source term analysis, and an estimation of uranium concentrations in the environment. It concludes by considering the health implications (expressed as screening indices) of these concentrations. The appendices to the report contain supporting data and documents, including detailed discussions, calculations, and analyses concerning uranium present in the areas surrounding Oak Ridge Reservation (ORR).

The December 1999 report of the Oak Ridge Health Agreement Steering Panel (ORHASP), entitled *Releases of Contaminants from Oak Ridge Facilities and Risks to Public Health,* hereafter referred to as the "steering panel document," was also reviewed. ORHASP prepared the steering panel document to compile, in a condensed format accessible to the general public, the results of the uranium report with those of a series of analogous reports that reconstruct the release of other contaminants from the ORR: iodine 131, mercury, PCBs, and other radionuclides.

Finally, reviewers considered two recently released documents dealing with uranium contamination near ORR. The conclusions of these documents were not available until after the uranium document was finalized. The first document, *Scarboro Community Environmental Study,* is a collection of sampling data obtained by scientists from the Florida Agricultural and Mechanical University (FAMU) during a site visit to the town of Scarboro (a small community neighboring on ORR). It will be referred to hereafter as the "FAMU study." The second document, *Scarboro Community Sampling Results: Implications for Task 6 Environmental Projections and Assumptions,* is a report developed by Auxier & Associates that analyzes the results of FAMU's study. It will be referred to hereafter as the "Auxier report." Reviewers were asked to comment on what effect the FAMU study and the Auxier report may have on the conclusions of the uranium document.

Review Process

The purpose of this technical review was to determine if the uranium report provides a foundation on which the Agency for Toxic Substances and Disease Registry (ATSDR) can base follow-up public health actions or studies. ATSDR contracted with Eastern Research Group, Inc., (ERG) to select four expert reviewers to technically review the uranium report: Melvin Carter, Nolan Hertel, Ronald Kathren, and Fritz Seiler. The four reviewers read the entire dose reconstruction document on uranium releases, including appendices and the appropriate sections of the steering panel document ("Summary," "Screening Analysis for Uranium and Other Contaminants" [pp. 51–55], "Technical Issues," "Procedural Issues," and "Recommendations and Discussions"). The reviewers also read and considered both the FAMU study and the Auxier report in preparation for commenting on the uranium report.

Appendices A through D of the full report contain reviewer comments in their entirety, listed alphabetically by author. The appendices are not included in this public health assessment, however, copies of the full report can be obtained by calling ATSDR at 1-888-42-ATSDR or writing to:

ATSDR
Division of Health Assessment and Consultation
Attn: Chief, Program Evaluation, Records, and Information Services Branch, E-60
1600 Clifton Road, N.E., Atlanta, Georgia 30333

Charge to Reviewers

ATSDR charged the technical reviewers to comment on whether the study results were scientifically valid and applicable to public health decision-making and to provide recommendations necessary to strengthen the report's study analyses. Reviewers considered and commented on the report's study design and scientific approaches; its methods of data acquisition, analyses, and statistical reliability; and the scientific interpretations made by the study authors. Reviewers evaluated whether the conclusions and recommendations of the uranium report were substantiated and developed on the sole basis of the information in the documents. ATSDR specifically asked reviewers to critique:

- Study design and scientific approaches
- Methods of data acquisition, analyses, and statistical reliability
- Completeness of data and analyses
- Model validation
- Conformance with current scientific consensuses; internal consistency of methodologies
- Dose validation
- Data gaps
- Bias
- Clarity and thoroughness (e.g., is there enough information to draw conclusions and make public health decisions?)

ATSDR asked reviewers to comment on any and all technical aspects of the dose reconstruction study and how the report might be improved. Each reviewer assessed the dose reconstruction by responding to the study outline below.

1. Source Term and Environmental Concentration Estimates

a. Comment on the quality, completeness, and reasonableness of the estimates of the source terms (releases to air and water) and environmental concentrations (air, water, and soil).

b. In the absence of soil data from the Y-12 reference location (Scarboro community), the authors used uranium concentrations in sediments from the East Fork Poplar Creek floodplain to evaluate the soil exposure pathways. However, in 1998, the Environmental Sciences Institute at FAMU and its contractual partners conducted the Scarboro Community Environmental Study, in which soil, sediment, and surface water samples from the Scarboro community were analyzed for uranium.

Please review the radiological analyses in the *Scarboro Community Environmental Study* by FAMU and the *Scarboro Community Sampling Results: Implications for Task 6 Environmental Projections and Assumptions* by Auxier & Associates, Inc. Comment on whether the 1998 uranium concentrations from Scarboro soil could be used to estimate committed effective dose equivalents, annual average intake, and kidney burdens for the period 1944–1990 in Scarboro. Reviewers may benefit from an on-line bibliography on Cs 137 soil studies available at http://hydrolab.arsusda.gov/cesium137bib.htm.

2. Uncertainty and Sensitivity Analysis

a. Comment on the quality and completeness of the statistical approaches, uncertainty analysis, and sensitivity analysis.

b. Comment on the appropriateness and reasonableness of parameters, assumptions, distribution functions, and qualifiers used to estimate the Level II screening indices, committed effective dose equivalents, annual average intakes, uranium kidney burdens, and hazard index. Do the authors provide sufficient details and justification for independent evaluation and verification?

c. Do the distribution functions appropriately describe the variability of the parameters?

d. Comment on the quality of available data and identify where important data are unreliable, incomplete, or absent.

e. Comment on the degree of reliability and statistical uncertainty in the estimates of committed effective dose equivalents, annual average intakes, uranium kidney burdens, and hazard index.

f. Comment on the limitations of interpreting these estimates.

3. Health Effects/Public Health

a. Comment on quality and completeness of the screening indices, committed effective dose equivalents, annual average intakes, uranium kidney burdens, and the hazard index.

b. Are the screening indices, committed effective dose equivalents, annual average intakes, uranium kidney burdens, and the hazard index appropriately determined?

c. Are the appropriate decision guide (1×10^{-4} cancer risk), the oral reference dose (RfD), and toxicity threshold criteria for uranium kidney burdens used to estimate the potential health impact from uranium exposures?

d. Given the uncertainties, are the committed effective dose equivalents, annual average intakes, and uranium kidney burdens at sufficient levels to be a significant human health problem? If so, explain. Which reference populations might be at significant risk? What are the potential or likely health consequences?

e. Are adverse health effects likely to be statistically detectable?

f. Is the hazard index an appropriate indicator of possible health effects?

g. Are the screening decision tree and criterion appropriate to determine the need for further study?

h. Given the uncertainties, is there a need for a more detailed study with full uncertainty analysis to estimate the potential health impact from uranium exposures? Explain.

i. Is there sufficient information to identify and carefully define by one or more distinguished characteristics a population at significant increased risk? Such distinguishing characteristics might be for example age, sex, ethnicity, geographic area, time period, dietary habits, or lifestyle characteristics.

j. Is the dosimetric and exposed population information appropriate for epidemiologic planning and decisions?

SUMMARY OF REVIEWER COMMENTS

I. Executive Summary

Three of the four reviewers commented on the overall quality of the uranium report. These three reviewers agreed that the report met basic methodological standards and that, while it was not a complete analysis of possible uranium exposure near ORR, it was "a good first pass." Reviewers praised the report in terms such as these: "technically sound and applicable to decision-making," "supported by and developed on the basis of information in the reports," and "no major or significant problems with respect to the study design or the scientific approaches used." One reviewer affirmed that most of the work described in the study conformed with "established and generally accepted techniques." One reviewer applauded the efforts of the Oak Ridge Health Assessment Steering Panel (ORHASP) in developing the report, calling it logically constructed and "state-of-the-art." Overall, the reviewers agreed that the screening assessment is adequate for public health decision-making. However, they felt that additional modifications are required for an adequate past dose reconstruction to be completed.

Two of the four reviewers commented that the report is somewhat lacking in uncertainty or sensitivity analysis. One reviewer indicated that the study did conduct some uncertainty analyses, but they were limited in scope and non-quantitative. The consequence of this lack is that the report does not characterize the error ranges of its quantitative estimates as fully as reviewers would have liked. Two reviewers pointed out that the estimates made in the report tend to be on the conservative side—one expects, therefore, that (when in error) the report would tend to *overestimate* the extent to which exposure to uranium is a problem in the Oak Ridge area. Further refinements to the study are likely to reveal that uranium exposures are actually *lower* than those currently estimated.

Two reviewers noted that the large difference between the new source term estimates and the earlier estimates provided by DOE raise concerns about the underlying reliability of either estimate. One reviewer was surprised that the study authors, after having determined that actual release levels for 1987 and 1988 were 30% greater than those DOE had reported, were willing to accept DOE's release estimates for the years between 1989 and 1995 at face value. The reviewers indicated that their concerns about the source terms estimates would probably be resolved if a full uncertainty analysis were performed for the relevant calculations.

One reviewer was somewhat skeptical of the reported mass distribution for emitted airborne uranium particles. The reviewer suspected that the actual mass distribution of emissions contained a higher percentage of higher-mass particles than that which was recorded by the monitoring equipment. This issue is important to evaluating the public health consequences of the uranium release because higher-mass particles are less likely to be absorbed in the lung than lower-mass particles are.

One of the reviewers noted that the study makes no effort to differentiate between anthropogenic and background concentrations of airborne uranium, while conceding that background levels would probably prove to be insignificant. Another reviewer, however, encouraged further work to quantify the contribution of radioisotopes originating from coal-burning power plants in the area.

Two reviewers considered the basic appropriateness of the report's use of χ/Q calculations to correlate historical uranium releases from the Y-12 facility and historical air concentrations in the Scarboro area. Both reviewers agreed that, at a basic level, this kind of calculation was appropriate for estimating past airborne uranium concentrations in Scarboro. One of these reviewers cautioned, however, that the usefulness of the χ/Q calculations depends on the assumption that there has been no significant change in the sizes of emitted uranium particles between the times when χ/Q data were collected and the times when the χ/Q ratio is being used to estimate airborne uranium concentrations.

Two reviewers disagreed about whether or not the tracer dispersion study suggested in Recommendation #4 of the Steering Panel Report was warranted. One reviewer suggested that this experiment *was* warranted, citing the sparse distribution of air monitoring stations in the Oak Ridge area (which leave many gaps in coverage) and the continuing uncertainty about how effectively Pine Ridge acts as a barrier between the air around ORR and the air around Scarboro.

The other reviewer thought that tracer release studies seemed somewhat excessive and suggested that, as an alternative, the existing χ/Q calculations be re-worked, making use of additional historical weather data, where available.

The reviewers, as a whole, found the treatment of waterborne uranium transport somewhat cursory, and had a range of unanswered questions and concerns in regard to it.

Two reviewers felt that the uranium report's use of sediment samples as a surrogate for uranium soil sampling data was unacceptable. A third reviewer stated that the analogy between soil and sediment data *might* be acceptable but nevertheless praised the actual soil data collected by FAMU as clearly preferable to this analogy. Other reviewers called for further soil sampling in the Oak Ridge area, particularly subsurface soil core sampling.

All four reviewers expressed confidence in the soil sampling data collected by researchers from FAMU. One reviewer considered them clearly superior to the uranium report's sediment data for use in public health decision-making. Three reviewers called for additional uranium monitoring in strategic locations where one might expect past releases of uranium to have accumulated: in sediments behind dams, on flood plains, and around lakes and swamps. Two reviewers also called for soil core samples at depths of up to 1 meter, noting that one would not expect to find significant uranium accumulation near the soil surface (where FAMU collected its samples).

One reviewer concluded that the reference locations selected seemed appropriate but another questioned the report's degree of emphasis on the town of Scarboro as an area of primary public health concern. The reviewer indicated that Scarboro seems to have been chosen as a primary public health concern for the Y-12 uranium releases simply because it is the closest community to the facility. This conclusion, the reviewer stated, is premature and might be modified by further analysis of population distribution, wind patterns, and surface water features in the Oak Ridge area. The reviewer noted that, even if it were determined that uranium exposure was higher in Scarboro than in any other community, overall risk to the public health might still be greater in another town with lower exposure levels but a larger population.

Three reviewers agreed that epidemiological investigation of the Scarboro community was unlikely to produce a statistically significant finding, given the limited screening results of the "likely magnitude of the risk." One reviewer cautioned, however, that the uranium report did not contain enough information about Scarboro to answer questions about the value of further epidemiological study or the possible existence of vulnerable subpopulations.

One reviewer noted that the report, despite its lack of uncertainty analysis, does support the conclusion that ORR uranium exposure has had no *detectable* health effect on persons living in Scarboro. This is not the same as saying that there has been no health effect—the same reviewer said there was a reasonable likelihood that a few cases of cancer in Scarboro were caused by uranium exposure. Even if this were the case, however, there would probably be no statistically valid way to distinguish those cases caused by ORR emissions from those which were not.

II. Review of Documents' Overall Quality

Uranium Report

Three of the four reviewers commented on the overall quality of the uranium report. These three reviewers agreed that the report met basic methodological standards and that, while it was not a complete analysis of possible uranium exposure near ORR, it was "a good first pass." Reviewers praised the report in terms such as these: "technically sound and applicable to decision-making," "supported by and developed on the basis of information in the reports," "no major or significant problems with respect to the study design or the scientific approaches used." One reviewer affirmed that most of the work described in the study conformed with "established and generally accepted techniques." One reviewer applauded the efforts of the Oak Ridge Health Assessment Steering Panel (ORHASP) in developing the report, calling it logically constructed and "state-of-the-art."

Two of the four reviewers commented that the report is somewhat lacking in uncertainty or sensitivity analysis. One reviewer indicated that the study did conduct some uncertainty analyses, but they were limited in scope and non-quantitative. The consequence of this lack is that the report does not characterize the error ranges of its quantitative estimates as fully as reviewers would have liked. Two reviewers pointed out that the estimates made in the report tend to be on the conservative side—one expects, therefore, that, (when in error) the report would tend to *overestimate* the extent to which exposure to uranium is a problem in the Oak Ridge area. Further refinements to the study are likely to reveal that uranium exposures are actually *lower* than those currently estimated.

Other general limitations of the report, as asserted by the reviewers, are that:

- The evaluation of uranium concentrations in soil was not covered in depth; one reviewer noted that it almost seemed incidental to the rest of the report.

- The report lacked background information on how operations data from ORR were obtained, evaluated, and interpreted.

- The report's data were limited to effluent monitoring and included no environmental monitoring data.

- The report fails to adequately differentiate natural and anthropogenic uranium levels in the Oak Ridge area. One reviewer emphasized the importance of this distinction, stating that natural background concentrations must not be mixed in with anthropogenic concentrations for the purposes of risk assessment.

- The report is overly weighted toward gauging the radiological effects of uranium exposure. It should have placed more focus on the chemical toxicity of uranium.

FAMU Study

All four reviewers expressed confidence in the soil sampling data collected by researchers from Florida Agricultural and Mechanical University. One reviewer considered them clearly superior to the uranium report's sediment data for use in public health decision-making. Another stated that the new measurements have "changed the picture completely." Although they applauded FAMU's research efforts, the reviewers were cautious about using the FAMU data to estimate past exposure without additional research into the environmental distribution of uranium in the Oak Ridge area. Three reviewers called for additional uranium monitoring in strategic locations where one might expect past releases of uranium to have accumulated: in sediments behind dams, on flood plains, and around lakes and swamps. Two reviewers also called for soil core samples at depths of up to 1 meter, noting that one would not expect to find significant uranium accumulation near the soil surface (where FAMU collected its samples).

Auxier Report

Three reviewers commented on the Auxier report, describing its analysis and overall conclusions as compelling. Two reviewers stated that it presented convincing evidence that the FAMU soil sampling data are superior to the sediment samples used as surrogates for soil data in the uranium report. One reviewer indicated that the Auxier report convinced him that uranium soil concentrations are 10 to 100 times lower than the values listed in the ORHASP uranium report. Another reviewer praised the Auxier report's study of U 235/U 238 activity ratios in soil samples, which indicated to him that at least *some* anthropogenic uranium is present in Scarboro's soil (probably originating from the Y-12 facility). The reviewer described the Auxier report as "valuable work" that will "add the kind of information which will be needed for a risk assessment."

Steering Panel Report

Two reviewers commented briefly on the overall quality of the steering panel report. One reviewer praised its clarity and thoroughness and stated that it "reached reasonable conclusions and made sound and useful recommendations." The other reviewer noted that, in general, it seemed overly pessimistic in its summary of the uranium report's results.

III. Review of Source Term Estimates

Two reviewers approved of the basic methods used to estimate uranium releases from ORR, calling them reasonable. A broad concern surrounding the estimates, however, was a lack of statistical information about the uncertainties associated with the monitoring data (or lack of such data). One reviewer emphasized that he did not fault the research team for not finding more data, as he recognized that they were constrained by the limits of their archival records. His concern was rather that the team had not adequately expressed the limits of their knowledge in statistical terms.

In particular, reviewers sought more information about the assumptions and justifications used in the source term estimates than was available to them in the text of the uranium report. One reviewer stated that he was unable to evaluate the appropriateness and reasonableness of the source term estimates (and hence of derivative dose estimates) because of this lack of information.

Two reviewers expressed disappointment that no quantitative information is available on over a third of the reported releases of uranium from the K-25 facility. One of these reviewers was puzzled that the study authors chose to treat these data gaps as periods of zero release rather than develop a probability distribution function (PDF) to address their uncertainty. The second reviewer was troubled by this understatement of K-25 releases, given that the report did not attempt to estimate the extent of that understatement. A third reviewer cautioned, however, that it is in fact proper to assign zero values to periods with data gaps if there is truly no information upon which a PDF could be developed.

Two reviewers noted that the large difference between the new source term estimates and the earlier estimates provided by DOE raises concerns about the underlying reliability of interpreting ORR operations and monitoring data. For example, one reviewer wanted additional assurance that uranium releases have not been “double counted” (i.e., counted once in the release reports and again in the monitoring data).

One reviewer was surprised that the study authors, after having determined that actual release levels for 1987 and 1988 were 30% greater than those DOE had reported, were willing to accept DOE's release estimates for the years between 1989 and 1995 at face value.

One reviewer was somewhat skeptical of the reported mass distribution for emitted airborne uranium particles. After considering the configuration of the monitoring equipment used in ORR's stacks, the reviewer suspected that monitoring results may have been erroneously skewed in favor of recording smaller particles. The reviewer suspected that the actual mass distribution of emissions contained a higher percentage of higher-mass particles than that which was recorded by the monitoring equipment. This issue is important to evaluating the public health consequences of the uranium release because higher-mass particles are less likely to be absorbed in the lung than lower-mass particles are.

One reviewer was of the opinion that release estimates of depleted and natural uranium (as opposed to enriched uranium) were particularly uncertain. This uncertainty, the reviewer believed, could affect the *chemical* (as opposed to radiological) health consequences of Oak Ridge residents' uranium exposure.

One reviewer noted that there was very little data available about the release of uranium to surface water from the S-50 facility (in comparison to amount of information available on the Y-12 and K-25 releases). The reviewer qualified the significance of this lack of data, also noting that the overall magnitude of the S-50 release was low, so it would not have much effect on the overall uranium source term.

IV. Review of the Estimation and Measurement of Environmental Uranium Concentrations

Airborne Transport of Uranium

Two reviewers considered the basic appropriateness of the report's use of χ/Q calculations to correlate historical uranium releases from the Y-12 facility and historical air concentrations in the Scarboro area. Both reviewers agreed that, at a basic level, this kind of calculation was appropriate for estimating past airborne uranium concentrations in Scarboro. One of these reviewers cautioned, however, that the usefulness of the χ/Q calculations depends on the assumption that there has been no significant change in the sizes of emitted uranium particles between the times when χ/Q data were collected and the times when the χ/Q ratio is being used to estimate airborne uranium concentrations. The reviewer suggested that further studies ascertain the validity of this assumption.

Two reviewers disagreed about whether or not the tracer dispersion study suggested in Recommendation #4 of the Steering Panel Report was warranted. One reviewer suggested that this experiment *was* warranted, citing the sparse distribution of air monitoring stations in the Oak Ridge area (which leave many gaps of coverage) and the continuing uncertainty about how effectively Pine Ridge acts as a barrier between the air around ORR and the air around Scarboro. The other reviewer thought that tracer release studies seemed somewhat excessive and suggested that, as an alternative, the existing χ/Q calculations be re-worked along the following lines:

- *Use historical wind rose information, when available.* This reviewer noted that days of peak release from Y-12 do not always match days of peak uranium concentrations around Scarboro. The reviewers attributed this occasional lack of correlation to wind conditions that did not favor transport of particulate uranium from ORR to Scarboro. With this in mind, the reviewer suggested that future research efforts might attempt to evaluate Oak Ridge–area uranium concentrations as a function of both ORR release levels *and* specific wind conditions. The reviewer suggested that this might be a particularly worthwhile exercise for periods of known high releases, such as the five days in 1965 when uranium hexafluoride was released from K-25 as part of a fire test.

- *When historical wind rose information is not available, use 5-year average data.* The reviewer was somewhat puzzled by the report's use of meteorological conditions from 1987 to represent "average" weather. The reviewer suggested the report could be improved if 5-year meteorological averages were used instead.

- *Characterize uncertainty of uranium releases for years upon which χ/Q is based.* The reviewer pointed out that if ORR's uranium releases were underestimated in the years upon which χ/Q was based, the χ/Q value would itself be overestimated. Therefore, further information about the reliability of release estimates during those years will shed light on the reliability of χ/Q.

One of the reviewers noted that the study makes no effort to differentiate between anthropogenic and background concentrations of airborne uranium. That reviewer conceded that background levels would probably prove to be insignificant, but another reviewer encouraged further work to quantify the contribution of radioisotopes originating from coal-burning power plants in the area.

The one reviewer who considered the study's use of an ISCST3 dispersion model to estimate the transport of uranium from the K-25/S-50 and X-10 facilities confirmed that the study's methods were appropriate.

Waterborne Transport of Uranium

Three reviewers provided comments pertaining to the concentration of uranium in the East Fork Poplar Creek and Clinch River. Two of these reviewers noted that the results presented are derived from flow rates and concentrations at discharge points. One reviewer wondered if the report's analysis took into account the partitioning of uranium from water into sediment. Another reviewer noted that the absence of the raw data (i.e., the actual flow and concentration data at discharge points) upon which the results were based hampered his evaluation of those results. In particular, the reviewer noted that the reported uranium discharges to the East Fork Poplar Creek seemed "unreasonably high"; he required additional data and analysis before he would vouch for their accuracy.

The reviewers, as a group, found the treatment of waterborne uranium transport somewhat cursory. They had a range of unanswered questions and concerns in regard to it:

- Why did the report use a single annual volume for East Fork Poplar Creek instead of taking seasonable variation into account?

- Why was it assumed that waterborne uranium is at a natural level of enrichment?

- How likely is it that significant quantities of enriched uranium entered local water bodies via soil runoff?

- What is the background level of uranium in the Clinch River and East Fork Poplar Creek?

Concentration of Uranium in Soil and Sediment

Two reviewers agreed that the uranium report's use of sediment samples as a surrogate for uranium soil sampling data was unacceptable. A third reviewer stated that the analogy between soil and sediment data *might* be acceptable, but nevertheless praised the actual soil data collected by FAMU as clearly preferable to this analogy. Other reviewers called for further soil sampling in the Oak Ridge area, particularly subsurface soil core sampling. One reviewer argued that uranium levels in sediment should not be used as an indication of uranium levels in soil because uranium's provenance differs depending on its location:

- The level of uranium present in soil is a function of:

    — The natural prevalence of uranium ore (background uranium) in the region.

    — The deposition of airborne uranium particles onto the soil surface.

- The level of uranium present in sediment is a function of:

    — Groundwater leaching uranium out of soil and into rivers and lakes.

- — The deposition of airborne uranium particles onto the surface of the covering water body.
- — The partitioning of dissolved uranium from water to sediment.

Two reviewers found the FAMU data suggested that contamination of surface soil with uranium in the Oak Ridge area is less serious than previously thought. One reviewer said that the data show that uranium in the soil is close to natural levels of enrichment and concentration. Another said that the data show that the soil exposure pathway for uranium is less significant than previously thought. A third reviewer pointed out that he was not surprised that surface soil concentrations of uranium are near background levels—he expects that if elevated soil concentrations of uranium exist, they would exist further *below* the soil surface.

V. Reviewers' Conclusions and Recommendations for the Use of the Report in Public Health Decision-Making

Exposure and Dose Estimates

Two reviewers considered the methodology used in the uranium study to establish screening indices and compute effective doses. Both reviewers agreed the methodology used was appropriate and consistent with standard practice. Two other reviewers noted that the report was quite conservative in its use of correction factors.

One reviewer noted that although the lack of uncertainty analysis in the uranium report made it difficult to evaluate the reliability of the report's conclusions, he would guess that the report's exposure and dose estimates are accurate to within an order of magnitude. This reviewer also flagged a possible exposure pathway (the transfer of uranium from contaminated water to produce to human consumption) that was excluded from consideration in the report without explanation. Another reviewer held the opinion that the uranium dose estimates were accurate to a factor of 2 and were probably overestimates.

Two reviewers considered the appropriateness of the reference locations chosen to gauge the potential public health consequences of uranium releases from ORR. One reviewer concluded that the reference locations selected seemed appropriate, but the other questioned the report's degree of emphasis on the town of Scarboro as an area of primary public health concern. The reviewer indicated that Scarboro seems to have been chosen as a primary public health concern for the Y-12 uranium releases simply because it is the closest community to the facility. This conclusion, the reviewer stated, is premature and might be modified by further analysis of population distribution, wind patterns, and surface water features in the Oak Ridge area. The reviewer noted that, even if it were determined that uranium exposure was higher in Scarboro than in any other community, overall risk to the public health might still be greater in another town with lower exposure levels but a larger population.

One reviewer referred to the FAMU study's use of the RESRAD model. The reviewer noted that this model is appropriate only if residual soil contamination is the only source of uranium exposure, a situation that may be true at current emissions levels but was not necessarily the case in the past. The reviewer also sought more information about: (1) why the RESRAD model used default parameters instead of site-specific parameters and (2) why certain RESRAD exposure pathways, such as well water and livestock uptake, were eliminated from consideration.

Use of the Report by ATSDR for Public Health Purposes

The three reviewers who spoke to the issue of the uranium report's public health application agreed that the report is adequate for public health decision-making; however, it does not, at present, provide a reliable reconstruction of past uranium doses in the Oak Ridge area. The reviewers, however, affirmed the study's value as a suitable foundation for follow-up studies. One reviewer considered the report useful only as a first-order approximation of actual doses, but suggested that it could be used in cautious preliminary public health work—along with the caveat that it may have underestimated the degree of uncertainty inherent in its estimates.

Three reviewers agreed that epidemiological investigation of the Scarboro community was unlikely to produce a statistically significant finding, given the limited screening results of the "likely magnitude of the risk." One reviewer cautioned, however, that the uranium report did not contain enough information about Scarboro to answer questions about the value of further epidemiological study or the possible existence of vulnerable subpopulations.

One reviewer noted that the report, despite its lack of uncertainty analysis, does support the conclusion that ORR uranium exposure has had no *detectable* health effect on persons living in Scarboro. This is not the same as saying that there has been no health effect: the same reviewer said there was a reasonable likelihood that a few cases of cancer in Scarboro were caused by uranium exposure. Even if this were the case, however, there would probably be no statistically valid way to distinguish those cases caused by ORR emissions from those which were not.

Directions for Further Work

The reviewers had three principal recommendations for improving the quality of the uranium report in preparation for using it in public health decision-making:

- *Add/improve uncertainty and sensitivity analyses.* Three reviewers indicated that more work needs to be done to characterize the extent and significance of the lack of knowledge pertaining to past uranium exposures in the Oak Ridge area. As a guide, one reviewer suggested that future investigators develop probability distribution functions, develop reasonable estimates to fill in gaps in release data, and perform a sensitivity analysis to evaluate how uncertainty in the study's input data creates uncertainty in the study's output. One reviewer also recommended that uncertainty calculations be done separately for systematic and random errors.

- *Develop dynamic models to further characterize the fate of past uranium releases.* Two reviewers emphasized the need to measure uranium concentrations in *core* samples of soil from the Oak Ridge area. These measurements should be part of a broader research effort aimed at identifying how uranium has moved through the Oak Ridge environment after its release. For example, one reviewer asked future investigators to determine where and by what means past releases of uranium have accumulated. Another reviewer emphasized that most such analyses would have to make use of *dynamic* (as opposed to equilibrium) models. This is because ORR uranium releases prior to 1974 varied significantly from year to year and cannot be properly modeled with equilibrium models.

- *Continue searching for site-specific historical information.* One reviewer suggested that investigators collect additional site-specific information about the Oak Ridge area, such as information about the agricultural practices common there during the period in question. The reviewer also suggested that investigators continue to attempt to uncover additional archival information relating to uranium releases from ORR.