Buckman Direct Diversion Project
Independent Peer Review

Final Report

December 3, 2010

Prepared for the
Buckman Direct Diversion Project Board
by ChemRisk, LLC
with AMEC Earth and Environmental

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DISCLAIMER

TABLE OF CONTENTS

FIGURES

TABLES

APPENDICES

1.0 INTRODUCTION

1.1 THE BUCKMAN DIRECT DIVERSION PROJECT

The Buckman Direct Diversion (BDD) is a regional water supply project co-owned by the City of Santa Fe and Santa Fe County, and is one of the largest and most complex non-federal infrastructure projects ever built in Santa Fe County, New Mexico.(1) It diverts water from the Rio Grande to an advanced drinking water treatment plant located southwest of Santa Fe. The water treatment plant will provide up to 60 percent of the annual water supply for more than 100,000 residents of Santa Fe County, and deliver as much as 15 million gallons per day of treated drinking water. Components of the BDD system include a diversion structure on the Rio Grande, a sand removal facility, two raw water booster stations, two treated water pump stations, and 25 miles of pipelines for raw and finished water.

1.2 THE SETTING OF SANTA FE AND THE BUCKMAN DIVERSION SYSTEM

Santa Fe, the capital of New Mexico and the seat of Santa Fe County, is located about 55 miles northeast of Albuquerque in the north central portion of the state. The setting of the BDD system is depicted in Figure 1-1. Water for the BDD system is taken from the Rio Grande at a point on the river's left descending (eastern) bank about 11 miles northwest of the Santa Fe city limits and about 3.5 miles downstream from where New Mexico Route 502 crosses the river at Otowi Bridge. The BDD diversion structure is located about 3 miles east of Los Alamos National Laboratory (LANL), which occupies about 36 square miles of property on the Pajarito Plateau, on the western side of the river, and has operated (under various names) since 1943.

1.3 INITIATION OF THE INDEPENDENT PEER REVIEW

In February of 2002, a formal agreement became effective between the U.S. Forestry Service (USFS), the U.S. Bureau of Land Management (BLM), the U.S. Bureau of Reclamation, and three applicants proposing to build the BDD.(2) The applicants were the City of Santa Fe, Santa Fe County, and Las Campañas − an unincorporated, master-planned community located between Santa Fe and the BDD diversion point (see Figure 1). Three years later, in 2007, the Final Environmental Impact Statement (FEIS) for the BDD Project was issued. In February of 2008, the U.S. Forest Service and the U.S. Bureau of Land Management approved the BDD as the selected alternative by way of publishing a Record of Decision (ROD).(3) After the ROD was announced, individuals and groups were given 30 to 45 days to appeal the decision to the various federal agencies.

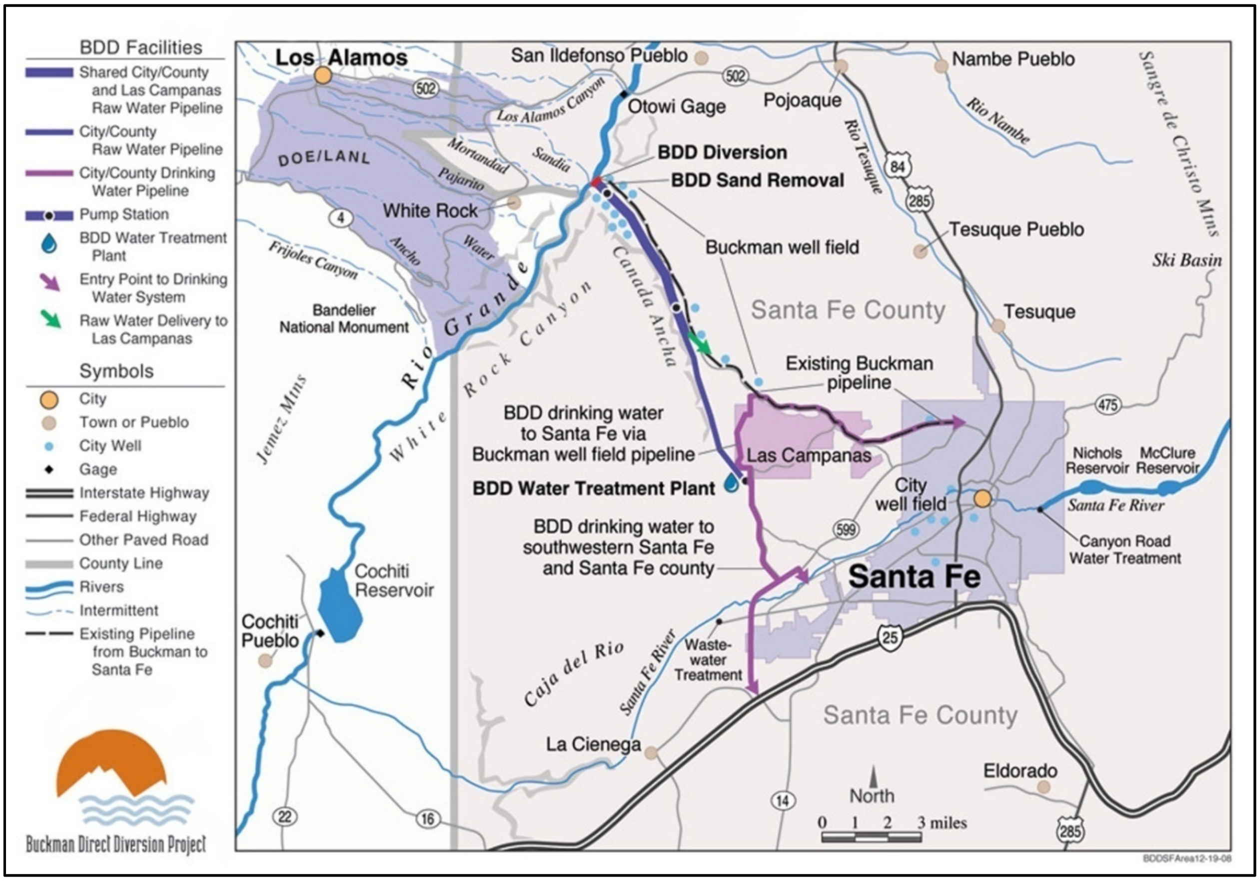


Figure 1-1: The setting of the BDD project

The New Mexico Environmental Law Center filed appeals on behalf of Concerned Citizens for Nuclear Safety (CCNS) and Amigos Bravos. The appeals argued that CCNS and Amigos Bravos had commented on the draft FEIS, stating that the BLM and USFS "failed to adequately evaluate or even consider any of the adverse environmental impacts that could foreseeably result if radionuclides or other water and soil contaminants emanating from the Los Alamos National Laboratory (LANL) were to migrate into the Rio Grande and enter the Buckman Diversion Project."(4) BLM and the USFS had reportedly responded to those comments "with minimal discussion," stating that the impact of such contaminant migration on water quality was "considered speculative." In early May of 2008, the U.S. Forest Service affirmed its ROD for the FEIS on the BDD project.(5) This action signaled that the Forest Service had reviewed all issues raised in the appeals, and had determined that the ROD and FEIS had already sufficiently addressed those issues.

The BDD Board voted unanimously during its October 4, 2007 meeting to request that DOE and LANL fund and implement a number of actions or specific programs to protect public water supplies. In a November 1, 2007 letter to DOE and LANL environmental officials, the Chair of the BDD Board presented the following six requests of LANL:(6)

1. Stop migration of LANL contaminants to the Rio Grande and to groundwater.
2. Properly monitor the transport of legacy contaminants (contaminants from the 1940s-1960s) in both the surface water and groundwater flow systems.
3. Measure the radioactive and toxic contamination of buried sediments containing higher concentrations of post World War II LANL legacy contaminants now buried in the slough (side channel) upstream of the BDD diversion site.
4. Provide an early notification system so the BDD can temporarily stop diversions of any water from the Rio Grande when the Rio Grande is expected to contain elevated levels of contaminants of LANL origin.
5. Monitor the mass of any LANL-origin contaminants diverted with BDD raw water supplies and account for that mass in water treatment plant residuals and treated drinking water.
6. Provide funding for the BDD Board to retain independent peer review by qualified persons with regard to matters of LANL-origin contamination of the public drinking water resources of Santa Fe County and the City of Santa Fe.

After making these requests of LANL, and at the request of Water Quality Town Hall participants in 2008,(7) the BDD sought funding from the DOE for an independent peer reviewer. A $200,000 federal grant was received from the DOE in the fall of 2009. A request for proposals was published on July 17, 2009, and responses were due on September 16, 2009. Responses were reviewed by a panel that included one public member who was appointed by the BDD Project Board. On November, 5th, 2009, the BDD Board approved a $200,000 contract with ChemRisk, LLC (ChemRisk) to perform the Independent Peer Review (IPR), and the work was funded by a DOE grant.

ChemRisk, a leader in human health risk assessment and historical operations at U.S. nuclear weapons plants, subcontracted AMEC Earth and Environmental for its expertise with the hydrology, hydrogeology, and geochemistry of New Mexico. Together, ChemRisk and AMEC make up the IPR team.

1.4 THE GOALS OF THE INDEPENDENT PEER REVIEW

The BDD Board's stated main objective for the IPR was to obtain an independent, overarching analysis and synthesis of existing studies and bodies of information that would support a description (both conceptual and quantitative) of potential tap water health risks and be accompanied by public risk communication deliverables.(8)

More specifically, the independent peer reviewer's work as outlined in the RFP was to include "preparation and presentation of deliverable products that describe, for technical and non-technical audiences, a critiqued synthesis of existing data, information, studies, and published risk assessment analyses regarding exposure and risk to residents of the Santa Fe region from environmental radionuclide, toxic, and hazardous contaminants known to be of LANL-origin and other origins of these contaminants. The work will emphasize the tap water pathway, including the contaminants in Rio Grande water diverted into the BDD and removed by water treatment processes, as previously addressed by Kerry Howe for the BDD Board. The peer reviewer's work includes illustrating the tap water pathway risk by comparison to other pathways and risks. The peer review will quantify, from existing data, information, and studies, and compare, the tap water pathway exposure risk to other pathways of public exposure to LANL-origin contaminants and other natural and man-made radiation exposures. It is the peer reviewer's job to identify and obtain the information that the peer reviewer will analyze, critique, and utilize to prepare the meta-level synthesis described in this RFP." (8)

A peer review can be defined as in-depth critique of assumptions, calculations, extrapolations, alternate interpretations, methodology, and acceptance criteria employed, and of conclusions drawn in the original work.(9) Peer review can confirm or possibly call into question the adequacy of work that has been performed in the past. An effective peer review is expert, independent, external, and technical.

1.5 THE INDEPENDENT PEER REVIEW TEAM

1.5.1 ChemRisk, LLC

ChemRisk, LLC was selected to perform the IPR. ChemRisk is a scientific consulting firm providing state-of-the-art toxicology, industrial hygiene, radiological health, epidemiology and human-health risk assessment services to a wide variety of organizations that confront public health, occupational health, and environmental challenges. ChemRisk scientists have been leaders in the independent investigation of historical operations at U.S. nuclear weapons plants. These investigations have included the Rocky Flats Toxicological Review and Dose Reconstruction prepared for the Colorado Department of Public Health and Environment and the Oak Ridge Dose Reconstruction prepared for the Tennessee Department of Health. Since 1999, ChemRisk has been conducting the Los Alamos Historical Document Retrieval and Assessment (LAHDRA) project for the U.S. Centers for Disease Control and Prevention. For that project, the study team reviewed millions of historical documents at LANL for information relevant to estimating off-site chemical and radionuclide releases and assessing the potential for public health effects from those releases.

Resumes for the IPR team members, many of whom are shown in Figure 1-2, are presented in Appendix 1A.

Tom Widner served as the initial Principal Investigator for the IPR project. Partially through the IPR process, Mr. Widner passed away suddenly. Dr. Brent Finley served as Principal Investigator for the remainder of the IPR process. Dr. Finley is a board-certified toxicologist with 20 years of experience conducting and managing studies involving chemical exposures and human health risk assessment. Throughout his career, he has been involved in preparing more than 400 risk assessments. The project team from ChemRisk also included health physicist and health risk assessor Matthew Le, environmental statistician and health risk assessor Paul Scott, environmental scientist and health risk assessor Erin Shay, and toxicologists Dr. James Keenan and Dr. Kerry Thuett. David Galbraith, M.D., served as an advisor to the project team. Dr. Galbraith is a licensed physician who also has 12 years of life sciences consulting experience. Dr. Dennis Paustenbach, the founder and president of ChemRisk, also served as a senior advisor to the project team. Dr. Paustenbach is a board-certified toxicologist and industrial hygienist with over 25 years of experience in risk assessment, environmental engineering, ecotoxicology, and occupational health.

Figure 1-2: IPR team members at the BDD diversion structure construction site, January 2010. Front: Kerry Thuett, Greg Miller, David Galbraith; Back: Matt Le, Erin Shay, Dawn Kaback, Paul Scott, Tom Widner, and Jim McCord. Not shown: Jim Keenan.

1.5.2 AMEC Earth and Environmental

Scientists with AMEC Earth and Environmental (AMEC) assisted ChemRisk with the IPR. AMEC is a small group of local scientists with the requisite educational backgrounds and close familiarity with the surface water and groundwater hydrology characteristics of a wide variety of settings in New Mexico.

Dr. Jim McCord has more than 28 years of experience in hydrology and water resource investigations. Dr. Greg Miller is a hydrogeologist with 21 years of experience in aqueous geochemistry, geostatistics, surface water and groundwater testing and modeling, and quality assurance. Dr. Dawn Kaback is a geochemist/geological scientist with more than 30 years of experience providing technical and management services for complex environmental and energy issues. Dr. Sorab Panday served as a senior advisor to the IPR team. Dr. Panday has 20 years of experience in water resource modeling, and has developed and applied a variety of models used in that field.

1.6 TASKS ASSIGNED TO THE IPR TEAM

The work performed on the IPR included the following components:

- Interactions with the BDD Board, Project Manager, and project staff
- Review of BDD public communication materials
- Identification and gathering of relevant information
- Analysis and synthesis of information relevant to contamination in the tap water of the Santa Fe region
- Analysis of human exposures and health risks
- Preparation and refinement of project deliverables
- Public meeting planning, conduct, and follow-up

1.6.1 Interactions with the BDD Board, Project Manager, and Project Staff

IPR team members worked with the BDD project management, consultants, and public communications staff initially and at appropriate intervals during the IPR so that the BDD Board would be able to accurately and effectively describe and publicize the team’s engagement, work processes, work products, and conclusions.

The team was also asked to make several presentations to the BDD Board at scheduled public meetings of the Board. Scheduled appearances before the BDD Board included:

- Presentation of the proposed professional services agreement,
- Presentation of the public review draft set of deliverables, and
- Presentation of the response to public comments and the final deliverables.

The IPR team will also provide a letter response to any remaining questions from the BDD Board regarding the final set of deliverables.

1.6.2 Review of BDD Public Communication Materials

One of the initial tasks taken on by IPR team was to review and comment on selected public communication materials that had been prepared and distributed by BDD Staff and contractors. The materials that were reviewed included the following:

- News Releases/Opinions/Letters-to-Editors (2008-2009)
- Direct Technical Testimony of Rick R. Carpenter on behalf of the Buckman Direct Diversion Board before the New Mexico Water Quality Control Commission in the 2009 Triennial Review of Water Quality Standards, August 28, 2009.
- DRAFT Questions and Answers regarding Buckman Direct Diversion and LANL Legacy Contaminants in the Rio Grande, March 26, 2009.
- Howe, K.J. 2008. "Final Report− Effectiveness of the Proposed Santa Fe City/County Water Treatment Plant for Removing Radiological and Other Specific Contaminants." Prepared for the City of Santa Fe and the Buckman Direct Diversion Board. April 15.
- Carpenter, R.R. 2008. "Factual Statement of the Applicants Regarding the New Mexico Environmental Law Center Appeal of the Buckman Direct Diversion FEIS and ROD." Letter from Rick Carpenter to Appeal Deciding Officer, Deputy Regional Forester, Southwestern Region. April 21.
- Montoya, H. 2007. "LANL Contamination of Water Resources in Santa Fe County." "Six Action Steps" letter from the Chair of the Buckman Direct Diversion Board to George Rael of the National Nuclear Security Administration and Susan Stiger of Los Alamos National Laboratory. November 1.
- Gaume, N. 2007. "Buckman Direct Diversion Project− Response to US Fish and Wildlife Service concerns regarding transuranic contaminants and additional potential contaminants of LANL origin at the Buckman Direct Diversion river diversion location." Letter to Sandy Hurlocker, Española District Ranger and BDD EIS Manager. April 23.
- "Town Hall on Water Quality, August 26, 2008." Microsoft PowerPoint presentation supplied as "2008 08 26 BDD PP v2"

- BDD Website Water Quality Sections: “BDD Water Will be Excellent Quality,” “LANL Effects on Rio Grande Water Quality,” “Surface Water Quality,” “BDD Asks LANL to Ensure Water Quality,” “Independent Peer Reviewer,” “Who Regulates LANL,” “Water Quality− Core Sampling Study,” and “FAQs.”

The IPR team reviewed the supplied materials, found them to generally be accurate and appropriate, and identified recommendations for improvement. Items for consideration in those reviews included technical accuracy, timeliness of the included information, suitability of terminology and concepts to the intended audience(s), avoidance of unnecessary complexities, appropriateness of any risk comparisons, degree of referencing external sources of information, effectiveness of using graphical presentations of information, and the extent to which relevant, but potentially opposing, viewpoints are recognized and reflected. The methods and findings of that review were documented in a letter to the BDD staff.

1.6.3 Identification and Gathering of Relevant Information

A comprehensive review of the existing data, reports, and published scientific literature regarding quantification of chemical and radiological contaminants was performed. The major sources of data considered included environmental reports issued by LANL, the RACER database, the LANL water quality database, environmental reports issued by the New Mexico Environment Department (NMED), reports of sampling conducted by the Santa Fe Public Utilities Department, environmental monitoring conducted by Concerned Citizens of Nuclear Safety (CCNS) and other activist groups, the NMED Drinking Water Watch system, and the USGS National Water Information System. These major sources of data are summarized later in this report, along with a discussion of their strengths and weaknesses.

1.6.4 Analysis and Synthesis of Relevant Information

The constituents of interest (COIs) for the IPR were identified and quantified based on reviewing all surface water and storm water analysis results for chemicals and radionunclides in the Rio Grande from 2000 to 2010 from the available databases. The COIs were selected based on examing which analytes had been found to be present above the analytical limit of detection (LOD) for the method in use for samples collected at locations on the Rio Grande that are relevant to releases from Los Alamos Canyon being conveyed to the BDD diversion point. While all radionuclides positively detected in the relevant reach of the river were considered in the risk characterization, only those chemicals positively detected *and* known to have toxic properties were included in the risk characterization.

To characterize the exposure point concentrations for the COIs for this assessment, the United State Environmental Protection Agency (U.S. EPA) software package ProUCL was used.

ProUCL is a program developed by the U.S. EPA to assist with estimating exposure point concentrations, and has the capacity to test the distribution of the data, apply various statistical methods for handling measurements that are below the limit of detection, and estimate mean and 95% UCL concentrations based on the method that is appropriate for the data distribution, sample size, and variance of the data set.(10)

To characterize the most likely sources of COIs that might affect the quality of Rio Grande surface water near the BDD, statistical comparisons were performed of the concentrations measured near the Buckman area to those measured upstream of Otowi Bridge. The analyses of available information and data included an evaluation of past studies of the amounts of COIs of LANL-origin released to the LANL canyons and then into the Rio Grande, the distribution of those contributions over time, comparisons to applicable exposure standards, and comparisons to pathways of public exposure in the Santa Fe region other than tap water ingestion.

Based largely on the work of others, the IPR team also performed analyses of the COIs that were determined to be present in association with sediments in the canyons on LANL property and in the groundwater below LANL. Based on previous work, the IPR team offers some relatively simple analyses of levels of COIs that could be present in the Rio Grande in the future from a major stormflow event and from the discharge of contaminated groundwater to the river near the BDD diversion point.

1.6.5 Analysis of Human Exposures and Health Risks

Several hypothetical exposure scenarios were evaluated. The scenarios differ only in terms of the levels of COIs estimated to be present in the residential tap water at the point of exposure (i.e., the home). The scenarios are as follows:

- COIs are present at levels recently measured in unfiltered and untreated water samples from the Rio Grande.
- Radionuclide COIs are present at levels recently measured in the Rio Grande, except for plutonium, americium, uranium, and gross alpha-emitting radioactivity, which are assumed to be 95% removed by the water treatment processes.
- Radionuclide COIs are present at levels recently measured in the Rio Grande, except for gross alpha-emitting radioactivity and dissolved uranium, which are assumed to be present at levels produced by the Buckman well field as measured by the City of Santa Fe.

The IPR team also assessed the theoretical risk under the assumption that all COIs were present in the Rio Grande at their respective USEPA Maximum Contaminant Levels (or other drinking water standard, if no MCL exists).

The exposure assessment focused on one primary population of interest: a residential user of publicly-supplied drinking water (that is, tap water users). Exposures were evaluated for residents in a variety of age groups. Because chemicals with known mutagenic modes of action may pose higher risks during early life stages, children's age groupings were determined after the COIs were established and a toxicity assessment had been performed. (11-13)

Exposures and health risks were quantified for central tendency scenarios that generally represent typical exposures and upper bound ("reasonable maximum exposure") scenarios in order to provide useful ranges of potential exposure estimates. For each age group, central tendency and upper bound exposure parameters were determined for factors including body weight, duration of residence, tap water ingestion rates, shower duration and frequency, swimming duration and frequency, and home grown produce ingestion rates. The Exposure Factors Handbook (14) and Children's Exposure Factors Handbook (15) were used as the primary sources of exposure parameters, and peer-reviewed literature was also utilized, as appropriate.

Standard U.S. EPA equations were used to estimate the doses [masses of COIs taken in or contacted per mass of body weight per day] for all chemicals and pathways of exposure determined to be of potential concern. Consistent with USEPA's Risk Assessment Guidance for Superfund, lifetime average daily doses (LADDs) were calculated for carcinogenic chemicals, and average daily doses (ADDs) were calculated for non-carcinogenic chemicals, by integrating the exposure parameters and exposure concentrations. (16)

The calculated exposures and health risk estimates were compared to applicable limits and toxicologic benchmarks, and compared to exposures occuring from other sources of the same COIs in the environment (including natural background and fallout from atmospheric weapon testing) and via exposure pathways other than tap water ingestion.

1.6.6 Preparation and Refinement of Project Deliverables

During the course of the IPR, the team will prepare, present, and revise written and graphic risk communication deliverables that will meet potential readers' needs and interests at four levels:

1. Summary for a lay audience,
2. Spanish translation of the summary,
3. Description for the BDD Board, and
4. Documentation for the Board and a technical audience.

This report represents element number 4 of the project deliverables, the detailed documentation. The IPR team will provide preliminary draft and public review draft sets of risk communication deliverables, elicit, consider, and respond to comments, and produce the final set of deliverables before the end of calendar year 2010. When this report is finalized, a summary of the comments and reponses will be provided in Appendix 1B.

1.6.7 Public Meeting Planning, Conduct, and Follow-Up

The IPR team will conduct three public meetings. The first meeting, held on January 14, 2010, was designed to introduce this professional services' effort to the Santa Fe community in order to elicit, understand, and respond to public questions and concerns regarding LANL-origin environmental contamination and the Buckman tap water pathway.

The presentation upon which the initial public meeting was centered can be viewed and downloaded at: http://www.bddproject.org/pdf/01-14-10-BDD-IPR-Public-Meeting-PowerPoint.pdf.

A summary of the initial public meeting, including a summary of the questions and comments offered by attendees, can be viewed and downloaded at: http://bddproject.org/pdf/2010-04-22-BDD-IPR-Meeting-1-Summary.pdf.

The second meeting, held on September 30, 2010, provided an overview of the IPR team's work and draft reports. The third public meeting, scheduled to be held in early December, 2010, will focus on presentation of the final project deliverables and discussion of responses to comments received on the drafts.

2.0 IDENTIFICATION AND GATHERING OF RELEVANT INFORMATION

The IPR team conducted a comprehensive review of existing data, reports, and published scientific literature in order to identify the most useful sources from which to conduct that IPR, as explained in the sections that follow.

2.1 IDENTIFICATION OF RELEVANT INFORMATION SOURCES

2.1.1 Reports Issued by LANL

LANL has performed environmental monitoring on Lab property and on a regional basis since the 1940s.(17) Those efforts expanded significantly around 1970, when publication of environmental surveillance reports began. Published on a semiannual basis for 1971, these reports have been published annually since then, with the quantity of data and analysis presented increasing with each decade.

In addition to the annual surveillance reports, LANL has also published many special reports dealing with ambient monitoring, source emissions, and compliance topics. These include many investigation reports for areas of known or suspected contaminated soils, sediments, surface water, groundwater, and plants and animals.

In recent decades, most environmental samples have been sent to DOE-approved commercial analytical laboratories for analysis. Some have been analyzed on site. Samples are routinely analyzed for radionuclides, metals, general inorganic compounds, volatile organic compounds, semi-volatile organic compounds, and total suspended sediment. Most of the analyses are performed using methods specified by the U.S. Environmental Protection Agency. Commercial laboratories typically analyze the samples in accordance with the "Los Alamos National Laboratory Sample Management Office Statement of Work for Analytical Services and the ESH-18 Addendum."

To identify documents that were relevant to the IPR work, the team utilized:

- DocSleuth, the project information database developed as part of CDC's LAHDRA project(17)
- LANL's Online Catalog (available at http://catalog.lanl.gov/F)
- Documents available via LANL's Environmental programs Web site (http://www.lanl.gov/environment/?4)
- Reference lists provided in relevant documents from the above sources

- Peer reviewed literature identified via searches of PubMed and other online information providers
- Documentation identified by and/or provided by the DOE and LANL points of contact for the IPR

2.1.2 The RACER NM Database

A large portion of the sampling data considered and used in the IPR was obtained from the Risk Analysis, Communication, Evaluation, and Reduction (RACER) database managed by the New Mexico Community Foundation (NMCF) located in Santa Fe, NM. The Internet-based RACER database was a product of the RACER Project, which began in 2003 with the goal of providing a process to inform LANL, state regulators, and the community about chemical and radioactive materials that may be present in the environment as a result of LANL operations.(18) RACER personnel created a Data Analysis Tool (DAT) to provide the public with Web-based access to environmental measurement data collected in and around the LANL site.(19) The DAT allows the user to select data by analysis type, location, data provider (LANL or NMED), analytes, and comparison values (regulatory limits or guidelines). The DAT also allows the user to perform temporal and special analyses and displays of the available data. RACER's DAT tool and its associated Web site were completed in 2009.(19)

The RACER database itself contains over seven million analytical results from environmental monitoring samples collected by LANL and the New Mexico Environment Department (NMED) Oversight Bureau.(18) As previously noted, the database is managed by the NMCF, which has subsequently contracted technical work regarding the database quality assurance and quality control (QA/QC) to the Risk Assessment Corporation (RAC).

NMCF staff have worked with members of the community, tribal governments, and others within NMED and LANL to create and share a tool that could provide information to state and federal regulators, LANL, and the community about the potential sources of public health risk and ecological impacts from LANL operations.(19)

Of most relevance to the BDD IPR, RACER contained 585 surface water or storm water samples collected by LANL and NMED at various locations on the Rio Grande between 1956 and 2010. These samples were analyzed for 578 different chemicals, radionuclides, and contamination indicators (turbidity, pH, etc.) for a total of 33,855 sample contaminant results.

While RACER makes data available that have been provided by LANL or NMED, it also contains results for some samples collected by the U.S. Geological Survey (USGS) and submitted to RACER by LANL. These records have LANL identified as their provider.

Data made available via RACER are classified as to the level of validation that they have received. Because of the limitations of past data collection techniques and analytical methods, older data are typically associated with higher detection limits and greater measurement uncertainties, and may be accompanied by less complete original documentation than newer data. A "Fully Validated" field is provided for each record in RACER, with possible values of Y or N. That field indicates whether or not a result should be considered fully validated or qualified for all uses. A "Y" indicates that the data have been validated according to professional standards and federally accepted validation criteria, or are otherwise qualified for all uses.(20) An "N" indicates that the data are possibly of lower quality, and should be used with caution because the data may be compromised by quality issues (measurement problems, incomplete documentation, etc.).

For example, groundwater, sediment, storm water, and surface water samples collected after January 1, 2000 are judged by LANL to generally be of uniform quality, have validation and analytical laboratory quality codes assigned, and have lower detection limits than most earlier data. Data prior to 2000 generally have higher detection limits and less uniform quality and application of qualifiers.

If data are marked as not fully validated, that does not necessarily mean that they are invalid. They might simply have been collected and analyzed before modern techniques had developed, or resources might not yet have been made available to assemble and review the documentation necessary to validate the data for all uses.

2.1.3 The LANL Water Quality Database

Starting in the fall of 2000, LANL maintained a publically available Water Quality Database (WQDB) that has received relevant environmental measurement data. Until November of 2008, the WQDB was made available to the public via the Internet. On November 6th, 2008, when RACER became available, public access to the WQDB was discontinued.

LANL automatically sends data from the WQDB to RACER weekly.(21) All results for environmental samples that have gone through secondary, independent validation are sent to RACER. Results for samples collected on San Ildefonso Pueblo land, for the City of Santa Fe, or for Los Alamos County are withheld from RACER for an agreed-upon period of time so the owner has an opportunity to review their data; the data are uploaded to RACER after that review period.(21) LANL excludes all field quality assurance/quality control (QA/QC) data from RACER other than field duplicates.

2.1.4 Reports Issued by NMED – Surface Water Quality Bureau

The NMED Surface Water Quality Bureau (SWQB) Monitoring and Assessment Section is responsible for the continual collection, integration, and assessment of water quality data for all lakes and streams in New Mexico. The section collects data and uses them to determine if state surface water quality standards are being met, and to ensure that designated uses are supported.(22)

2.1.5 Reports Issued by NMED – Department of Energy Oversight Bureau

The NMED Department of Energy (DOE) Oversight Bureau is charged with ensuring that activities at DOE facilities in New Mexico are managed and controlled in a manner that is protective of public health and safety and the environment.(23) As part of its mission, the Bureau develops and implements an independent monitoring and oversight program to provide independent evaluations for environmental and public health protection of all media, including air, soils and sediments, groundwater, and surface water.(23) Results of environmental monitoring conducted by NMED are contained within the RACER database.

2.1.6 Reports of Sampling Conducted by the Santa Fe – Sangre De Cristo Water Division

The City of Santa Fe's Sangre de Cristo Water Division (SDCW) publishes an annual water quality report that addresses the source of supply, source water assessment and availability, water quality monitoring results, and drinking water definitions. The annual reports also provide a water quality table that presents a summary of the results of water quality samples taken within that year. Water quality results include data on levels of radiological contaminants, microbial contaminants, organic/inorganic contaminants, and pesticides and herbicides(24).

The Water Division also provided the IPR team with results of groundwater sample analyses for the Buckman wells and the associated 10-million gallon tank between 2003 and 2009.

2.1.7 Information from Concerned Citizens for Nuclear Safety and Other Activist Groups

Data available from applicable reports prepared by various activists groups were considered in this analysis. These reports included:

- *Early Warning: A Radioactive Rio Grande* – A report by The RadioActivist Campaign supported by a Grant from the Citizens' Monitoring and Technical Assessment Fund. The report was prepared as a collaborative effort between The RadioActivist Campaign (TRAC) and the public-interest group Concerned Citizens for Nuclear Safety (CCNS). The study included the collection of samples from along the Rio Grande from the Buckman Wellfield to the Cochiti Dam to determine whether radioactive waste had migrated from LANL via to the Rio Grande via groundwater pathways.(25, 26)

- *Historic and Current Discharges from Lost Alamos National Laboratory: Analysis and Recommendations* – A report prepared by CCNS along with Amigos Bravos that analyzed historic and current discharges to ephemeral and intermittent streams emanating from the Pajarito Plateau, and assessed their potential impacts on human and wildlife health.(27)
- *New Mexico's Right to Know: The Potential for Groundwater Contaminants from LANL to Reach the Rio Grande* – A report prepared by George Rice on behalf of CCNS that analyzed the potential groundwater contamination from LANL reaching the Rio Grande.(28)
- *Comments to the National Academies of Science, "Plans and Practices for Groundwater Protection at the Los Alamos National Laboratory," June 2007 prepublication copy*− Prepared by CCNS and Registered Geologist R. H. Gilkeson.(29)

The NMED Drinking Water Watch System

NMED Drinking Water Bureau provides a publically available, Internet-based application that allows the user to search for water quality information for any of New Mexico's Public Water Systems. The search engine allows the user to search for water quality data by public water supply systems parameters including principal county served, water system type, and primary source water type, as well as by sample type parameters including sample class and sample data collection date.

The USGS National Water Information System

Additional data considered in this analysis were pulled from the U.S. Geological Survey (USGS) National Water Information System. The USGS has collected water-resources data for approximately 1.5 million sites within the U.S, with most data collected from surface water and groundwater sites. Specific to BDD risk analysis, the IPR team considered surface water quality sample analyses available from locations on the Rio Grande upstream and downstream of both LANL and the BDD.

While records in RACER are identified as having been provided by either LANL or NMED, comparison of those USGS data to data in RACER led the IPR team to recognize that practically identical data points were already contained in RACER. After discussions with LANL staff, it was ascertained that surface water samples collected by the USGS from the Rio Grande after the Cerro Grande Fire are indeed contained in RACER with labels that identify LANL as the data provider. Thus, the USGS data used by the IPR were taken from the RACER database as well.

Other Technical Reports and Publications

The IPR team reviewed relevant documents published by other organizations, including:

- The National Academy of Science's 2007 report "Plans and Practices for Groundwater Protection at the Los Alamos National Laboratory: Final Report," prepared by the Committee for the Technical Assessment of Environmental Programs at the Los Alamos National Laboratory, National Research Council.(30)
- Summaries of the testimonies (and associated affidavits and exhibits) of George Rice and Michael Barcelona from the spring, 2010 hearing that dealt with DOE and LANL's application for a hazardous waste permit.(31, 32)
- Relevant documents published by the Institute for Energy and Environmental Research.(33, 34)

2.2 REVIEW, EVALUATION AND CROSS-CHECKING OF DATA SOURCES

2.2.1 Data Sets Used in the Independent Peer Review

Several different data sets of surface water, storm water, and groundwater data were used in the IPR for different purposes, such as risk characterization, comparison of concentration at Buckman to upriver locations, and evaluation of potential impacts from Los Alamos Canyon. These data sets have been collected and analyzed using various sampling methods, different laboratories, different analytical methodologies, and include varying method detection limits. On the whole, because the data included were collected and analyzed after January 1, 2000 and they came from two primary sources (LANL and NMED), for any given radionuclide or chemical it is expected that the data from these two sources will be comparable to each other and of similar quality.

Data Used in the Risk Characterization

For the risk characterization, surface water data from the RACER database from sampling locations along the Rio Grande, groundwater data from the Buckman Well Field Mixing Tank, and groundwater data from the Buckman well field were used to identify the constituents of interest (COIs) and to evaluate the human health risks due to those COIs for different scenarios. Because the focus of the risk characterization is on long-term health risks, storm water data collected at the Buckman Landing and the Otowi Bridge locations collected for temporary storm flow events were not included as data representative for a chronic human health risk assessment.(35, 36)

The specific data sets used for the risk characterization are described below:

<u>Surface water from the Rio Grande near BDD:</u> Unfiltered data collected between January 1, 2000 and February 1, 2010 from the LANL and NMED Buckman and Otowi Bridge sampling locations were used to characterize exposure point concentrations (EPCs) for the risk characterization. If a constituent was detected at the Buckman sampling locations, only the data for the Buckman sampling locations were used, but if a constituent was not detected at the Buckman locations and was detected upstream at Otowi Bridge, data from sampling locations at both locations were used to estimate EPCs. In addition, the unfiltered surface water data from several downriver locations (Mortandad, White Rock, Ancho, and Frijoles) were used in the COI selection process to evaluate chemicals that were only detected at Buckman once during the ten year time period. Table 2-1 summarizes the locations and the time period for which data were available for these locations, and Figure 2-1 shows their locations along the Rio Grande in relation to the BDD intake facility.

Also, the unfiltered surface water for all time periods from the Buckman, Otowi Bridge, Espanola, Chamita, and Embudo sampling locations were used to compare chemical and radionuclide levels between Buckman, Otowi Bridge, and the other upriver locations (Espanola, Chamita, and Embudo) to determine if concentrations at Buckman were significantly higher than those from upriver locations.

<u>Groundwater data from the Buckman Well Fields:</u> To address the use of water from the Buckman Well Field based on current levels of gross alpha radioactivity and dissolved uranium, water samples from the 10 Million-Gallon (MG) tank used to collect and store water from the Buckman wells were used. Seven composited water samples that were collected from 8/12/2002 to 5/29/2009 and analyzed for gross alpha radioactivity and uranium concentration were used. In addition, groundwater data from Buckman wells 1 – 8 collected from 8/16/2001 to 11/24/2009 were used to estimate the radium-226, radium-228, uranium-234, uranium-235/236, and uranium-238 concentrations from the gross alpha concentrations.

Data used for the Upriver/Downriver Comparison

Unfiltered surface water samples collected at 14 sampling locations along the Rio Grande including Buckman (2 locations), Otowi Bridge (6 locations), Espanola (2 locations), and Embudo (2 locations) and along the Rio Chama at Chamita (2 locations) were used. Depending on the location, data collected from 1956 to February 1, 2010 were used.

Data used to Evaluate Future Impacts from LANL Sediments

Unfiltered storm water sampling data from the Los Alamos Canyon sampling location E110 were used to evaluate the future impacts of radionuclides and chemicals to the Rio Grande. Location E110 is the Los Alamos Canyon storm water sampling location closest to the Rio Grande, and data from samples collected at that location on 14 different dates from 8/23/2003 to 1/13/2010 were evaluated for the IPR.

Figure 2-1: Rio Grande sampling locations included in the Peer Review Report. (Sample locations are in blue and BDD intake is a white circle).

2.2.2 Comparison of Available Data Between LANL WQDB and RACER

The RACER database contains over seven million analytical results from environmental monitoring samples collected by LANL and the New Mexico Environment Department (NMED) Oversight Bureau.(18) A part of the scope of the review and analysis of available sampling data, the IPR team compared data housed within the RACER database against the LANL WQDB for the locations where sample results were used as part of the human health risk assessment. The rationale for this review was to ensure the accuracy and completeness between the two water quality databases.

All samples denoted within RACER as being from LANL origin were crosschecked between a spreadsheet containing relevant samples from LANL WQDB results received from LANL staff on May 3, 2010. Upon close inspection of the initial Excel file received from LANL, the IPR team identified sample records with collection dates up to four years in the future. For example, the groundwater sample collected from Buckman Well #1 on July 12, 2006 that was associated with a reported detection of plutonium-238 was described in the file of data extracted from the WQDB as having been collected on July 13, 2010. Upon further inspection between members of the IPR and LANL, the initial Excel spreadsheet was determined to be corrupted, and was not used for further analysis.

Upon receiving a replacement data file from LANL, samples for the Buckman and Otowi Bridge locations were compared between the RACER and LANL databases. The comparison was performed using the unique record identification (URI) field that contains a value that is unique to both entries in RACER and the WQDB. Upon initial review, it was not apparent whether quality assurance (QA/QC) and sample blank results were missing from the RACER database; however, upon further review of both datasets and conversations between the IRP and LANL staff, it was determined that LANL excludes all types of field QA/QC other than field sample blanks from RACER. The reasoning for this exclusion was that currently the RACER software does not distinguish environmental samples from QA/QC samples, so a decision was made to provide only environmental samples to RACER.

Table 2-1: Summary of Rio Grande sampling locations included in peer review report

Sampling Location Name	X (UTM)	Y (UTM)	Data Provider	Data Purpose	Category	Data Available for this Sampling Period After 2000	1990 - 1999	1980 - 1989	1970 - 1979	Before 1970
Rio Grande at Frijoles	386690.33	3957341.6	LANL	COI Selection	Downriver	X				
Rio Grande at Frijoles (bank)	386691.1	3957337.7	NMED-OB	COI Selection	Downriver	X				
Rio Grande at Frijoles (bank)	386691.1	3957337.7	LANL	COI Selection	Downriver	X	X			
Rio Grande at Frijoles (wdth intgrt)	386718.1	3957327.9	LANL	COI Selection	Downriver		X			
Rio Grande at Mortandad	394225.03	3965469	LANL	COI Selection	Downriver	X				
Rio Grande below Frijoles	386539.37	3957127.6	NMED-OB	COI Selection	Downriver	X				
Rio Grande near White Rock	390966.13	3960314.3	LANL	COI Selection	Downriver	X				
Rio Grande at Buckman	395083.03	3966408.5	NMED-OB	Risk Characterization, Upriver Comparison	Buckman	X				
Buckman Diversion SW	395178.7	3966419.3	LANL	Risk Characterization, Upriver Comparison	Buckman	X				
RIO GRANDE AT OTOWI BRIDGE, NM	396887.3	3970658.6	LANL/USGS	Risk Characterization, Upriver Comparison	Otowi	X				
Rio Grande at Otowi (bank)	396900.27	3970662.4	LANL	Risk Characterization, Upriver Comparison	Otowi	X	X	X	X	X
Rio Grande at Otowi (wdth intgrt)	396908.49	3970661.9	LANL	Upriver Comparison	Otowi		X			
Rio Grande at Otowi Upper (bank)	396962.63	3970714.7	LANL	Risk Characterization, Upriver Comparison	Otowi	X	X			
Rio Grande at Otowi Bridge	396962.63	3970714.7	LANL	Risk Characterization, Upriver Comparison	Otowi	X				
Rio Grande at Otowi	NA	NA	LANL	Upriver Comparison	Otowi					X
Rio Chama at Chamita	399877.66	3992635.8	LANL	Upriver Comparison	Upriver	X	X	X	X	X
Rio Chama at Chamita (bank)	399877.69	3992635.7	LANL	Upriver Comparison	Upriver	X				
Rio Grande below Espanola	403271.05	3983460.4	LANL	Upriver Comparison	Upriver	X				
Rio Grande at Espanola	403274.51	3985398.1	NMED-OB	Upriver Comparison	Upriver	X				
Rio Grande at Embudo (bank)	413361.06	4007154	LANL	Upriver Comparison	Upriver	X				
Rio Grande at Embudo	413361.1	4007154.1	LANL	Upriver Comparison	Upriver		X	X	X	X

In addition to field QA/QC samples, data entries corresponding to samples collected on two dates from an Otowi Bridge sampling location were identified in the LANL WQDB, but not in the RACER database. These samples were from a location labeled as “Rio Grande at Otowi Bridge,” and were collected on August 25, 2003 and September 6, 2003. Further discussion with RACER staff indicated that these samples were included in RACER as stormwater samples and were not representative of typical flow conditions. Because of this, these samples were not included in subsequent data sets.

An additional 58 URIs were found within the WQDB, but not in the spreadsheet generated from the RACER database. These 58 entries correspond to Sample IDs CC00081WBOR and CC00081WUOR. Both sample IDs and their respective entries were located within the RACER database; however, the URI did not match the URI appearing in the WQDB entries. LANL staff indicated that the accuracy of these URIs may stem from consolidating the environmental databases into one integrated system, which is underway to better coordinate and serve RACER and other external customers. It was reported that part of this work involves cleaning up of data issues in the old "legacy" databases like the LANL WQDB that were maintained by separate organizations over the years. Further discussions with LANL indicated that the URI’s for these 58 samples corresponded to duplicated entries within the WQDB, and it was suspected that these 58 samples were duplicates identified in RACER and subsequently removed from the database.

Comparison of surface water sample entries taken at the Buckman location was completed last, as the file that was initially received from LANL included no results for surface water samples collected near the Buckman area. After several discussions with LANL staff, it was ascertained that the WQDB query that led to creation of the file sent to the IPR team had only captured surface water sampling locations with "Rio Grande" in their names. Records associated with names such as “Buckman Diversion SW” had not been captured. A replacement data file was provided that included samples collected near Buckman.

Upon review of the Buckman Well data housed within RACER and the WQDB, the IPR team requested detailed data packages for the groundwater sample collected from Buckman Well #1 on July 12, 2006. That groundwater sample was associated with a reported detection of plutonium-238. A data package was received that included 2,608 pages.

On Sept 24, 2007, there were four samples taken at Buckman and analyzed for Pu-239/240. One sample was filtered in the field, another was not, and a field duplicate was taken of each. For the unfiltered samples, the “less than” value for one analysis is a factor of 40 million higher than the “less than” value for the associated field duplicate. Values obtained from contracted laboratories are not altered before entry into RACER, and it is not apparent that an investigation was conducted into the reason for the “less than” values being so drastically different.

3.0 IDENTIFICATION AND CHARACTERIZATION OF THE CONSTITUENTS OF INTEREST

3.1 IDENTIFICATION OF THE CONSTITUENTS OF INTEREST

The potential constituents of interest (COIs) for the IPR human health risk evaluation were first considerd to be all radionuclides and chemicals that were positively detected in the relevant areas of the Rio Grande since the year 2000. This initial list included 287 chemicals and 77 radionuclides. However, the majority of the chemicals detected are either general water quality parameters (pH, dissolved oxygen, total suspended solids, etc.) or elements that lack generally accepted human health toxicity criteria (calcium, potassium, etc.). Such chemicals cannot be evaluated in a human health risk assessment because they do not possess toxicity criteria such as a USEPA reference dose (RfD) or a cancer potency slope factor, or were not a general water quality parameter. In addition, to ensure that the analysis focuses on those COIs that are related to existing sources along the Rio Grande that could impact the BDD, radionuclides and chemicals that were only detected once at the Buckman diversion location or detected at the Otowi Bridge and not detected either upriver or downriver between 2000 and 2010 were not considered to be COIs. Using these guidelines, 15 radionuclide COIs and 35 chemical COIs were identified.

The detection frequencies for each radionuclide and chemical analyzed in Rio Grande surface water samples collected at upriver, Otowi Bridge, Buckman, and downriver sampling locations are presented in Appendix 3A. Table 2-1 identifies the specific sampling locations included in each grouping.

3.1.1 Radionuclide COIs

Table 3-1 identifies all of the radionuclides detected at either the Buckman or Otowi Bridge sampling locations along the Rio Grande. Radionuclide COIs detected at the Buckman sampling locations include:

- Radium-226 and radium-228
- Thorium-228, thorium-230, and thorium-232
- Tritium
- Uranium-234, uranium-235/236, and uranium-238.

Radionuclide COIs not detected at the Buckman sampling locations that were detected at the Otowi Bridge sampling locations include:

- Americium-241
- Lead-214
- Plutonium-238 and plutonium-239/240
- Potassium-40
- Strontium-90.

Table 3-1: Radionuclides detected in Rio Grande surface water

Analyte	Detection Frequencies by Location*	
	Otowi Bridge	Buckman
Americium-241	9/32	0/14
Gross alpha	18/30	25/27
Gross beta	21/22	14/16
Gross gamma	2/18	0/13
Lead-214	2/8	0/1
Plutonium-238	7/24	0/13
Plutonium-239/240	7/24	0/13
Potassium-40	3/21	0/14
Radium-226	3/20	1/11
Radium-228	2/17	3/11
Strontium-90	5/23	0/13
Thorium-228	12/15	6/9
Thorium-230	11/15	4/9
Thorium-232	13/15	7/9
Tritium	14/21	11/11
Uranium-234	24/24	14/14
Uranium-235/236	10/30	7/15
Uranium-238	24/30	14/14

* Detection frequencies include duplicate samples

All of these radionuclides were included as COIs in the subsequent risk characterization. For the radionuclide COIs detected at the Buckman sampling locations, exposure point concentrations were calculated using only samples from the Buckman locations, while for the radionuclide COIs detected at Otowi Bridge locations, but not at the Buckman locations, exposure point concentrations were calculated using samples from both the Buckman and Otowi Bridge locations. This calculation difference was done to ensure that no radionuclides that could potentially impact the BDD were missed because they were not detected during one of the ten sampling events at the Buckman location, even though they were detected at the next sampling location upriver. For the radionuclides detected upriver but not at the Buckman locations, the samples below the limit of detection at the Buckman locations were included in order to account for the impact of their low concentrations at Buckman on the exposure point concentration.

3.1.2 Chemical COIs

Table 3-2 presents all of the chemicals that were detected at either the Buckman or Otowi Bridge locations, as well as flags indicating whether the chemical was not a general water quality parameter, or did not have a toxicity criterion. Chemicals considered to be general water quality parameters and were not included as chemical COIs included:

- Alkalinity as CO_3 and Alkalinity as CO_3 and HCO_3
- Dissolved oxygen
- pH
- Silicon dioxide
- Specific conductance
- Suspended sediment concentration
- Temperature
- Total dissolved solids
- Total Kjeldahl Nitrogen
- Total organic carbon, and
- Turbidity.

Table 3-2: Chemicals detected in Rio Grande surface water

Analyte	Detection Frequencies by Location*		COI Criteria	
	Otowi Bidge	Buckman	Not a General Water Quality Parameter	Has Toxicity Criteria
Acetone	7/19	4/13	Yes	Yes
Alkalinity-CO3	1/11	3/11	No	No
Alkalinity-CO3+HCO3	11/11	11/11	No	No
Aluminum	17/17	15/16	Yes	Yes
Ammonia as Nitrogen	3/11	4/11	Yes	No
Antimony	4/16	0/16	Yes	Yes
Arsenic	11/17	9/16	Yes	Yes
Barium	17/17	16/16	Yes	Yes
Benzo[a]pyrene	0/22	1/14	Yes	Yes
Benzo[g,h,i]perylene	0/22	1/14	Yes	Yes
Beryllium	2/17	1/16	Yes	Yes
Bis(2-ethylhexyl)phthalate	2/22	0/14	Yes	Yes
Boron	16/17	13/14	Yes	Yes
Cadmium	7/16	3/16	Yes	Yes
Calcium	17/17	16/16	Yes	Yes
Carbon Disulfide	0/19	0/13	Yes	No
Chloromethane	0/21	1/13	Yes	Yes
Chromium	11/17	10/16	Yes	Yes
Cobalt	7/17	5/16	Yes	Yes
Copper	10/17	6/16	Yes	Yes
Cyanide, Total	6/23	0/13	Yes	Yes
DDE	0/17	1/13	Yes	Yes
Dibenz[a,h]anthracene	0/22	2/14	Yes	Yes
Endrin Aldehyde	1/17	0/13	Yes	Yes
Fluoride	11/11	11/11	Yes	Yes
Hexachlorocyclohexane, Delta-	1/17	0/13	Yes	Yes
Indeno[1,2,3-cd]pyrene	0/22	2/14	Yes	Yes
Iron	17/17	15/16	Yes	Yes
Lead	15/16	16/16	Yes	Yes
Magnesium	17/17	16/16	Yes	No
Manganese	17/17	15/16	Yes	Yes
Mercury	2/24	0/16	Yes	Yes
Molybdenum	14/17	14/14	Yes	Yes
Nickel	16/17	15/16	Yes	Yes
Nitrate-Nitrite as Nitrogen	11/15	6/11	Yes	Yes
OCDD	1/4	0/0	Yes	Yes
Perchlorate	12/22	11/11	Yes	Yes
Potassium	16/17	16/16	Yes	No
Selenium	4/24	0/16	Yes	Yes
Silicon Dioxide	13/13	11/11	No	Yes
Silver	0/17	1/16	Yes	Yes
Sodium	17/17	16/16	Yes	No
Strontium	17/17	14/14	Yes	Yes
Sulfate	11/11	11/11	Yes	No
Thallium	5/16	1/16	Yes	Yes
Tin	0/17	0/14	Yes	Yes
Total Kjeldahl Nitrogen	10/15	7/13	No	No
Total Organic Carbon	11/11	13/13	No	No
Total Phosphate as Phosphorus	7/11	7/11	Yes	No
Total polychlorinated biphenyls (PCBs) as homologues	4/10	2/10	Yes	Yes
Uranium	16/16	15/15	Yes	Yes
Vanadium	17/17	16/16	Yes	Yes
Zinc	15/17	11/16	Yes	Yes

* Detection frequencies include duplicate samples

Chemicals that were not general water quality parameters, but were not included as COIs because they did not have toxicity criteria included:

- Ammonia as nitrogen
- Calcium
- Chloride
- Magnesium
- Phosphorus
- Potassium
- Sodium
- Sulfate, and
- Total Phosphate as Phosphorus.

The following chemicals were detected only once at either the Buckman or Otowi Bridge sampling locations, were not detected at any upriver or downriver locations from 2000 to 2010, and were not included as COIs:

- Benzo(a)pyrene
- Benzo(g,h,i)perylene
- Dibenz(a,h)anthracene
- Endrin aldehyde
- Indeno(1,2,3,c,d)pyrene, and
- Methyl ethyl ketone.

After applying these criteria, the chemical COIs that were detected at the Buckman locations include:

- Acetone
- Aluminum
- Ammonia
- Arsenic
- Barium
- Beryllium
- Boron
- Cadmium
- Chloromethane
- Chromium
- Cobalt
- Copper
- DDE
- Fluoride
- Iron
- Lead
- Manganese
- Molybdenum
- Nickel
- Nitrate-nitrite as nitrogen
- Perchlorate
- Polychlorinated biphenyls
- Silver
- Strontium
- Uranium
- Vanadium
- Zinc

Because polychlorinated biphenyls (PCBs) are a class of 209 organic compounds with 1 to 10 chlorine atoms attached to biphenyl (a molecule composed of two benzene rings), they are typically evaluated as a mixture of chemicals for risk assessment. Because PCBs can be evaluated as an Aroclor mixture, PCBs were characterized as total PCBs. The total PCB concentration for each sample was estimated as the sum of PCB homologue group concentrations (total monochlorobiphenyl, total dichlorobiphenyl, total trichlorobiphenyl, total tetrachlorobiphenyl, total pentachlorobiphenyl, total hexachlorobiphenyl, total heptachlorobiphenyl, total octachlorobiphenyl, total nonachlorobiphenyl, and total decachlorobiphenyl).

The chemical COIs that were not detected at Buckman but were detected at the Otowi Bridge locations include:

- Antimony
- Bis(2-ethylhexyl)phthalate
- Cyanide
- δ-Hexachlorocyclohexane
- Mercury
- Octachlorodibenzo-p-dioxin (OCDD)
- Selenium
- Thallium

All of these chemicals were included as COIs in the subsequent risk characterization. For the chemical COIs detected at the Buckman sampling locations, exposure point concentrations were calculated using only samples from the Buckman locations, while for the chemical COIs detected at Otowi Bridge locations, but not at the Buckman locations, exposure point concentrations were calculated using samples from both the Buckman and Otowi Bridge locations. This calculation difference was done to insure that no chemicals that could potentially impact the BDD were missed because they were not detected during one of the ten sampling events at the Buckman location, even though they were detected at the next sampling location upriver. For the radionuclides detected upriver but not at the Buckman locations, the samples below the limit of detection at the Buckman locations were included in order to account for the impact of their low concentrations at Buckman on the exposure point concentration.

3.1.3 Pharmaceuticals and Personal Care Products

Pharmaceuticals and Personal Care Products (PPCPs) include a wide variety of personal health and hygiene products, such as medicines, insect repellents, sunscreens, perfumes, soaps, fragrances, and lotions. Their uses include preventing and combating disease, alleviating symptoms from illness and injury, personal comfort, grooming, and cosmetic purposes. These products can be found at almost any drug or convenience store, are used by millions of individuals on a daily basis, and have the potential to enter the environment through domestic sewage and other sources. Other PPCPs are pharmaceuticals, including painkillers, lipid (cholesterol) regulators, antiseptics, chemotherapy agents, antibiotics, and hormones.

3.1.4 Endocrine Disrupting Compounds

Some environmental contaminants are considered to be endocrine disrupting compounds (EDCs), meaning that they have the potential to affect hormone production in the body. EDCs are not produced by the body, but mimic or "antagonize" natural hormones produced within the body. The endocrine system is a complex network of glands and hormones that regulate many essential biological functions, including growth, development, reproduction, and metabolism. These compounds have the potential to alter normal endocrine function within the organism. The most commonly known EDCs are "estrogenic" compounds (such as DDT).

3.1.5 How Prevalent are Pharmaceuticals in the Rio Grande?

Pharmaceuticals and EDCs have been detected in surface water throughout the United States. Kolpin et al. (2002) measured concentrations of various pharmaceuticals, hormones, and other organic wastewater contaminants in streams across the U.S. The authors concluded that "measured concentrations are generally low and rarely exceed drinking water guidelines, drinking-water health advisories, or aquatic-life criteria." (37)

Between 2000 and 2003, the state of New Mexico tested sewage effluent and surface water throughout the state for pharmaceuticals - - specifically for the presence of 38 of the most commonly prescribed medications in the U.S. For the Rio Grande, samples were collected upstream at Espanola (sewage sludge) and the Pilar and the Buckman Crossing locations (surface water). Almost all of the pharmaceuticals were not detected; the authors reported the presence of the anti-epileptic drug phenytoin (Dilantin) at a concentration of 300 ng/L in the sewage effluent in Espanola, and amitriptyline (Elavil, Endep) at a concentration of 30 ng/L at Buckman Crossing. These values are similar to, or lower than, the measured concentrations in treated water from other parts of the U.S. (37,38)

These findings are not surprising. The waters of the Rio Grande upstream of Santa Fe would not be expected to be particularly contaminated with pharmaceuticals, personal care products, or endocrine disrupters, because there are no metropolitan areas near the upper Rio Grande. It is the largely populated communities and their associated commerce and industry that contribute to the majority of such contaminants in water supplies.

3.1.6 Should Water Users be Concerned about PPCPs in the Rio Grande?

Dr. Kerry Howe discussed the presence of amitriptyline in Rio Grande water in his report on the effectiveness of the Santa Fe City/County water treatment facility.(38) Howe explained that "[a]t a rate of ingestion of drinking water of 2 L/day for 70 years, this concentration corresponds to a lifetime intake of 1.5 mg," which he then compared to the typical amitriptyline adult dose ranging from 40 to 150 mg daily.(39, 40) This analysis means that if the treatment facility were unable to remove amitriptyline, the intake by a resident of Santa Fe over an entire lifetime would be 100 times less than one day's-worth of a therapeutic dose for this drug.(40)

The most susceptible populations to toxicity in general are embryos, fetuses, and developing young. Research indicates that teratogenic effects (birth defects) have been shown in mice, rats, and rabbits at doses of amitriptyline equal to or greater than 28 mg/kg/day (41-45). This dose is equivalent to nine times the maximum recommended human dose of 150 mg/day, or 3 mg/kg/day for a 50 kg patient. Based on Dr. Howe's calculation of a lifetime intake of 1.5 mg total, we conclude that the concentrations of amitriptyline measured in the Rio Grande near Santa Fe are in no way high enough to warrant concern, even for the most sensitive populations.

3.1.7 COIs that are Classified as Endocrine Disrupting Compounds

Of the analytes detected in surface water from the Rio Grande near the BDD, those considered to be potential EDCs include:

- DDE,
- perchlorate, and
- PCBs, as well as
- heavy metals, such as lead, cadmium, and mercury.

The potential EDC risks associated with these particular compounds, as they relate to consumption of tap water from the BDD, are discussed in Section 5.

3.2 CHARACTERIZATION OF CONCENTRATIONS OF THE CONTAMINANTS OF INTEREST IN SANTA FE TAP WATER

3.2.1 Recent Measurements in the Rio Grande

The data set used for this evaluation included data from the RACER database collected after January 1, 2000 to February 1, 2010 for sampling locations along the Rio Grande at Buckman and, in some cases, from the nearest upstream stations at Otowi Bridge. For both the radionuclide and chemical COIs, there were two types of data sets used: one data set for those COIs that were detected at the Buckman locations, and one for those COIs that were not detected at the Buckman locations, but were detected at the Otowi Bridge locations. The first data set included only data collected from the Buckman locations, while the second included data collected from both the Buckman and Otowi Bridge locations. Figure 3-1 shows the Buckman and Otowi Bridge sampling locations, along with the locations of the BDD intake facility and Los Alamos Canyon.

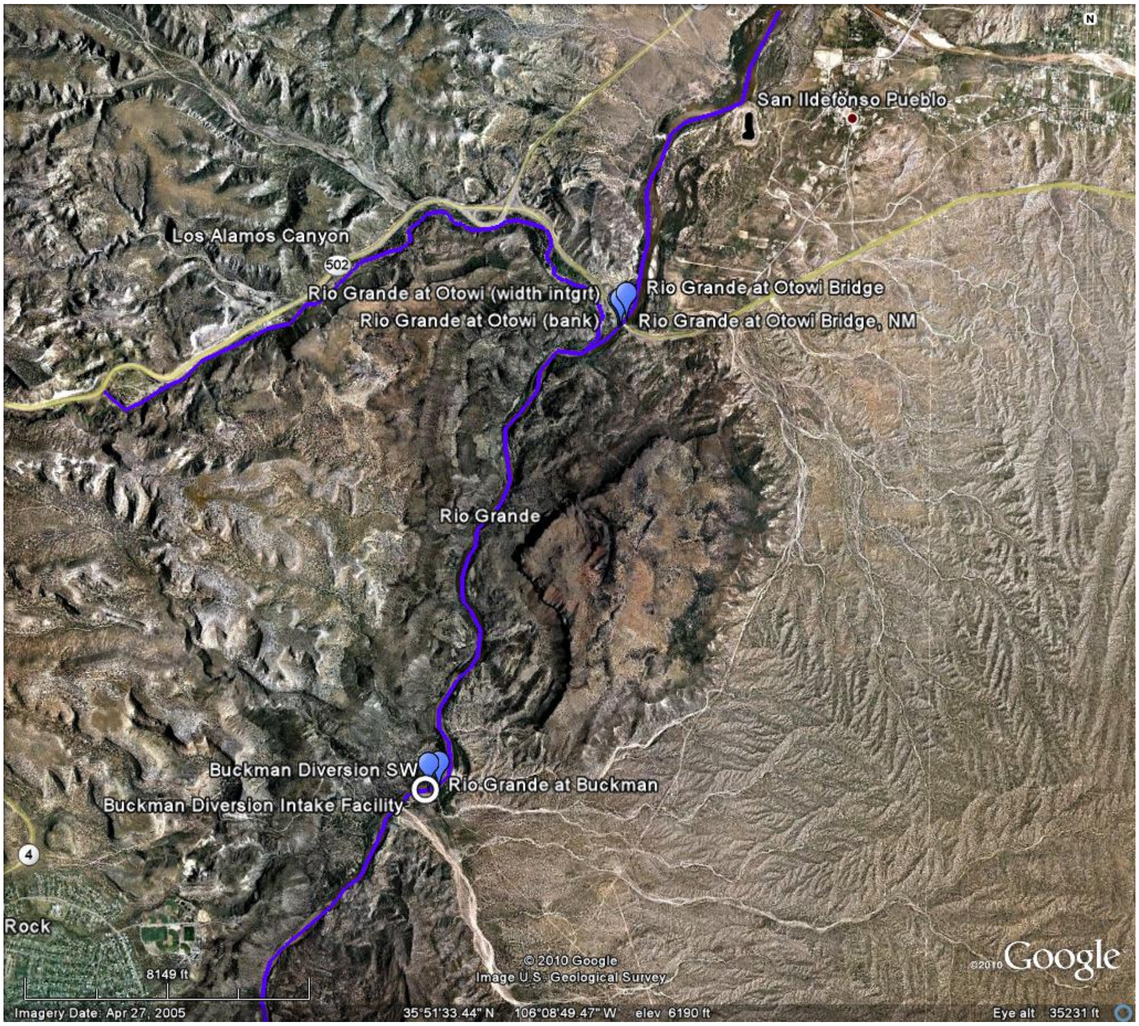


Figure 3-1: Buckman and Otowi Bridge sampling locations used to estimate EPCs

Data Processing

Several steps had to be taken in order to get the data into an appropriate format to estimate EPCs. First, many of the sampling locations and sampling dates included field duplicate samples collected for quality control purposes that have to be accounted for in the EPC calculation. Second, for some chemicals, the limits of detection are much higher than the highest detection, and the data sets for these chemicals had to be adjusted to account for this bias. Finally, due to the correction for background, some of the radionuclide concentrations had negative values that had to be adjusted before EPCs were calculated.

For sample locations and dates that included duplicate samples, the original analysis and the duplicate analyses were combined using the following procedure:

- If the concentration for the original and duplicate analyses were all above the limit of detection (LOD), the sample value was set equal to the average across all of the samples;
- If the concentrations for the original and all of duplicate analyses are below the limit of detection, the sample value was then set equal to the lowest LOD;
- If the concentration for either the original or one of the duplicate analyses was above the limit of detection and the other values were below the limit of detection, the sample value was set equal to the average of the detected values and treated as a detection in ProUCL.

Because some analytes had samples with limits of detection much greater than the maximum detected concentration, the data sets for these radionuclides and chemicals were adjusted by deleting the samples with LODs greater than the maximum detected value. This adjustment was done for two reasons. First, samples with LODs greater than the maximum detection do not provide any additional information about surface water concentrations because actual chemical concentration for a sample below the LOD can be any value between the LOD and zero. If the actual detected concentrations in other samples are less than the LOD for that sample, that sample confirms what is known based on the detected concentrations; that is, the concentrations are below the LOD. Second, including samples with a LOD greater than the maximum detected concentration will unnecessarily bias the EPCs high, and, depending on the difference between the maximum detection and the LOD, this bias could be extremely high.

Because of the random nature of radioactive decay and the common practice of subtracting background count rates for radiometric analyses, the sample values for some of the radionuclides were less than one. Because negative values for radionuclide concentration can lead to the calculation of negative average and upper confidence limit (UCL) surface water concentrations, the negative sample values were replaced with the minimum detectable activity (MDA) for that particular radionuclide, and sampled and treated as a value below the limit of detection. For some radionuclides measured in some samples, no MDA was listed in the RACER database. In this case, the average MDA for those samples with listed MDAs was used. Table 3-3 lists the radionuclides that had negative values for at least one sample, the number of negative values with no listed MDA, and the average MDA estimated from those negative samples with MDAs.

Table 3-3: Radionuclides with at least one negative sample value

Radionuclide	Number of Negative Samples with No MDA[a]	Average MDA for Samples with MDAs Listed (pC/L)
Americium-241	3	8.5
Plutonium-238	19	0.034
Plutonium-239/240	15	0.037
Potassium-40	2	70
Radium-226	0	All negative samples had an MDA
Strontium-40	1	0.4
Uranium-235	0	All negative samples had an MDA

[a] These samples could include duplicate samples as well as original measurements.

Estimates of Recent Concentrations

To estimate the central tendency (CT) and reasonable maximum exposures (RME) EPCs for the radionuclides and chemical COIs for this assessment, the USEPA software package ProUCL was used. ProUCL is a program developed by the USEPA to assist with estimating exposure point concentrations. It is capable of testing the distribution of the data, applying various statistical methods for handling measurements that are below the limit of detection, and estimating mean and 95% UCL concentrations based on the method appropriate for the data distribution, sample size, and variance of the data set.(10)

For the CT EPC, the data distribution was determined (normal, gamma, lognormal, or unknown), and the distribution-appropriate average concentration was estimated. For the calculation of the average concentration, the distribution-appropriate regression on order statistics (ROS) method(10) for the handling of values below the LOD was used. For the ROS method, ProUCL fits a linear regression model of the detected vales of the dataset to the assumed distribution and replaces the values below the LOD with values extrapolated from the linear regression. This method is recommended over the more typical substitution methods (i.e., using one-half of the detection limit) for handling data below the LOD.

For the RME EPC, ProUCL was used to estimate a distribution and data set appropriate upper confidence limit of the mean concentration (UCL) for each radionuclide and chemical COI. Many of the methods used by ProUCL to estimate UCLs include their own robust methods for the handling of values below the LOD, such as the Kaplan-Meier (KM) method, and these were used to estimate the UCLs. If ProUCL could not estimate a UCL due to an insufficient number of detected samples or total number samples, the maximum detected concentration was used for the RME EPC. In addition, if the UCL exceeded the maximum detected concentration, the maximum concentration was used as the RME EPC.

Tables 3-4 and 3-5 present the CT and RME EPCs for the radionuclide and chemical COIs estimated using ProUCL.

Table 3-4: Summary of radionuclide exposure point concentrations (pCi/L) for Rio Grande near Buckman[a]

										Exposure Point Concentration	
Analyte	**Number of Samples**	**Number of Detections**	**Minimum**	**Maximum**	**Arithmetic Mean**	**Arithmetic Standard Deviation**	**Distribution**	**UCL Type**	**UCL**	**CT**	**RME**
Americium-241[b]	31	6	1.75E-04	6.94	0.296	1.294	Not Normal	95% KM (t) UCL	0.725	0.296	0.725
Lead-214[b]	5	3	2.15	5.18	4.524	0.328	Not Normal	95% KM (t) UCL	4.966	4.524	4.966
Plutonium-238[b]	19	6	0	0.0106	0.0022	0.00247	Not Normal	95% KM (t) UCL	0.00264	0.0022	0.00264
Plutonium-239/240[b]	23	5	0.0013	0.009	0.0025	0.0023	Not Normal	95% KM (t) UCL	0.00323	0.0025	0.00323
Potassium-40[b]	8	2	2.98	19.8	7.1	7.4	Not Normal	95% KM (t) UCL	18.6	7.1	18.6
Radium-226	9	1	0.144	1.2	0.598	0.307	Not Normal	Not Calculated	NC	0.598	1.2
Radium-228	9	2	0.237	1.41	0.805	0.214	Lognormal	95% KM (t) UCL	0.991	0.805	0.991
Strontium-90[b]	31	5	0.003	2.23	0.11	0.401	Not Normal	95% KM (t) UCL	0.277	0.11	0.277
Thorium-228	7	4	0.0678	0.301	0.156	0.085	Lognormal	95% KM (t) UCL	0.239	0.156	0.239
Thorium-230	7	3	0.0738	0.466	0.135	0.158	Lognormal	95% KM (t) UCL	0.297	0.135	0.297
Thorium-232	7	5	0.0394	0.22	0.118	0.066	Lognormal	95% KM (t) UCL	0.171	0.118	0.171
Tritium	8	8	13.92	22.29	17.38	2.581	Lognormal	95% KM (Percentile Bootstrap) UCL	19	17.38	19
Uranium-234	11	11	0.567	2.11	1.272	0.491	Lognormal	95% Student's-t UCL	1.54	1.272	1.54
Uranium-235/236	9	5	0.0189	0.0907	0.0491	0.0189	Lognormal	95% KM (t) UCL	0.0583	0.0491	0.0583
Uranium-238	11	11	0.379	1.6	0.849	0.344	Lognormal	95% Student's-t UCL	1.037	0.849	1.037

[a] Data set includes samples from Buckman locations only unless otherwise noted.

[b] Data set includes samples from Buckman and Otowi Bridge locations due to lack of detections at Buckman and detections upstream at Otowi Bridge.

NC or Not Calculated: UCL is not calculated because there are too few detections. The maximum is used instead of the UCL for the RME.

Table 3-5: Summary of chemical exposure point concentrations (µg/L) for Rio Grande near Buckman[a]

Analyte	Number of Samples	Number of Detections	Minimum	Maximum	Arithmetic Mean	Arithmetic Standard Deviation	Distribution	UCL Type	UCL	Exposure Point Concentration	
										CT	RME
Acetone	3	3	1.3	4.2	2.5	1.1	Not Determined	Not calculated	NC	2.5	4.2
Aluminum	11	10	443	6100	2474	2001	Lognormal	95% KM (Percentile Bootstrap) UCL	3497	2474	3497
Ammonia	9	5	11.48	182	46.06	46.92	Lognormal	95% KM (BCA) UCL	86	46	86
Antimony[b]	8	4	0.26	0.6	0.378	0.11	Lognormal	95% KM (Percentile Bootstrap) UCL	0.50	0.38	0.50
Arsenic	11	6	1.5	6.8	3.0	1.5	Lognormal	95% KM (t) UCL	4.0	3.0	4.0
Barium	11	11	49	213	93	47	Gamma	95% Approximate Gamma UCL	120	93	120
Beryllium	2	1	1.0	1.0	1.0	N/A	Not Determined	Not calculated	NC	1.0	1.0
Bis(2-ethylhexyl)phthalate[b]	4	2	0.99	4.5	2.5	1.8	Not Determined	Not calculated	NC	2.5	4.5
Boron	10	9	15	46	31	8.6	Lognormal	95% KM (Percentile Bootstrap) UCL	36	31	36
Cadmium	2	2	0.0938	2.189	0.67	0.64	Not Determined	Not calculated	NC	0.67	2.2
Chloromethane	1	1	0.43	0.43	0.43	N/A	Not Determined	Not calculated	NC	0.43	0.43
Chromium	11	7	1.793	15	4.8	3.9	Lognormal	95% KM (Percentile Bootstrap) UCL	7.1	4.8	7.1
Cobalt	4	4	0.811	5.8	2.6	1.6	Not Determined	Not calculated	NC	2.6	5.8
Copper	11	4	1.576	13	4.4	3.1	Lognormal	95% KM (t) UCL	6.5	4.4	6.5
Cyanide[b]	29	4	1.5	10	1.8	2.5	Lognormal	95% KM (t) UCL	4.0	1.8	4.0
DDE	1	1	0.0076	0.0076	0.0076	N/A	Not Determined	Not calculated	NC	0.0076	0.0076
Fluoride	9	9	189	509	354	82	Lognormal	95% KM (Percentile Bootstrap) UCL	399	354	399
Hexachlorocyclohexane, Delta-[b]	1	1	0.0086	0.0086	0.0086	N/A	Not Determined	Not calculated	NC	0.0086	0.0086
Iron	11	11	332	8050	2280	2341	Gamma	95% Approximate Gamma UCL	4175	2280	4175
Lead	11	11	0.55	16	4.1	5.3	Gamma	95% Approximate Gamma UCL	8.4	4.1	8.4
Manganese	11	11	35	395	133	132	Gamma	95% Approximate Gamma UCL	228	133	228
Mercury[b]	32	2	0.02	0.28	0.09	0.034	Not Determined	95% KM (t) UCL	0.11	0.090	0.11
Molybdenum	10	10	2.0	6.9	4.5	1.5	Lognormal	95% KM (Percentile Bootstrap) UCL	5.3	4.5	5.3
Nickel	11	11	1.7	16	4.8	4.2	Gamma	95% Approximate Gamma UCL	7.5	4.8	7.5
Nitrate-Nitrite as Nitrogen	9	5	12	227	79	77	Lognormal	95% KM (t) UCL	142	79	142
OCDD[b]	4	1	4.20E-06	1.40E-04	4.05E-05	6.64E-05	Not Determined	Not calculated	NC	4.0E-05	1.4E-04
Perchlorate	9	9	0.057	0.11	0.070	0.014	Lognormal	95% KM (BCA) UCL	0.078	0.070	0.078
Total PCBs as homologues	9	2	1.18E-04	6.85E-04	2.26E-04	1.85E-04	Lognormal	95% KM (t) UCL	5.5E-04	2.3E-04	5.5E-04
Selenium[b]	11	4	0.82	3.1	1.6	1.09	Lognormal	95% KM (t) UCL	2.7E+00	1.6	2.7
Silver	1	1	0.11	0.11	0.11	N/A	Not Determined	Not calculated	NC	0.11	0.11
Strontium	10	10	188	432	280	61	Lognormal	95% KM (Percentile Bootstrap) UCL	314	280	314
Thallium[b]	25	6	0.030	2.2	0.30	0.50	Lognormal	95% KM (t) UCL	0.53	0.30	0.53
Uranium	11	11	1.4	4.0	2.5	0.92	Lognormal	95% Student's-t UCL	3.0	2.5	3.0
Vanadium	11	11	3.9	16	8.9	4.1	Lognormal	95% Student's-t UCL	11	8.9	11
Zinc	11	9	4.3	51	12	13	Lognormal	95% KM (BCA) UCL	20	12	20

[a] Data set includes samples from Buckman locations only unless otherwise noted.

[b] Data set includes samples from Buckman and Otowi Bridge locations due to lack of detections at Buckman and detections upstream at Otowi Bridge.

Not Determined: Distribution was not determined because there was an insufficient number of detected values to test for the distribution.

NC or Not Calculated: UCL is not calculated because there are too few detections. The maximum is used instead of the UCL for the RME.

N/A: Standard deviation is not calculated because the number of distinct samples is less than 3.

3.2.2 Recent Measurements in the Rio Grande, Taking into Account Postulated Removal of Some Contaminants by the BDD Water Treatment System

The IPR team was instructed to include in its assessment a scenario that reflects consumption of drinking water containing levels of contaminants recently measured in the Rio Grande, but reflecting 95% removal of plutonium, americium, uranium, and gross alpha radioactivity by the water treatment plant.

The BDD water treatment system includes a series of conventional and advanced water filtration and treatment, and is noted to be a system with an efficiency greater than those commonly used across the nation.(46) Conventional water treatment includes coagulation, flocculation, and sedimentation. Advanced water treatment includes passing water through a series of membrane filters, as well as through ozone reactors and granular activated carbon contactors. The BDD project staff has prepared various graphics and descriptions of the proposed water treatment system.(46)

Background Information about Radionuclide Removal

A study by Gafvert, et al. (47) reported results of the concentration of radionuclides before and after filtration via conventional coagulation-flocculation and sand filtration. Salts of trivalent aluminum and iron were used as coagulants, forming the precipitates $Al(OH)_3$ and $Fe(OH)_3$. These precipitates capture suspended particles, colloids, and dissolved molecular compounds, making them suitable for water purification. Activity concentrations for thorium (except Th-228) uranium, plutonium, and polonium decreased after passing through the filtration systems (47). It was suspected that co-precipitation of thorium, uranium, plutonium, and polonium with $Fe(OH)_3$ could explain the decrease in their activity after passing through the filtration process. For uranium, a pre-filter sample indicated that ~50% of the uranium activity was associated with particles larger than 1 μm.(47) Later, it was reported that the general trend for uranium and thorium was for $Fe(OH_{)3}$ precipitate to have a slightly lower removal efficiency than Al(OH)3 precipitate.(47)

Cesium only exists in the Cs(I) oxidation states. Moreover, it is reported that over 99% of cesium in solution is present as the Cs^+ cation.(38) Several studies reported that coagulation/flocculation was found to be completely ineffective at removing Cs-137, regardless of pH,(38, 47, 48) due to the strong tendency of cesium to be in an aqueous phase.(48) In terms of cesium's sorption into sediment, the evidence indicates that sorption is dependent on the sediment type.(38) Because of this variable behavior, coagulation/flocculation may not be an efficient mode for removal of cesium.

In a report regarding the proposed filtration efficiencies of the proposed BDD treatment plant, Dr. Kerry Howe(38) reported that uranium, plutonium, and americium have similar chemistry with respect to aqueous speciation and water treatment. He further noted that each exists in three or four oxidation states:

- Uranium – U(IV), U(V), U(VI)
- Plutonium – Pu(III), Pu(IV), Pu(V), Pu(VI)
- Americium – Am(III), Am(IV), Am(V), A m(VI)

Uranium reportedly exists in U(VI) oxidation state under oxidation conditions such as those present in the Rio Grande. Am(III) is the only oxidation state that occurs in nature. Pu(V) and Pu(VI) oxidation states exist in nature.

Dr. Howe notes that based on modeling of the aqueous chemistry or the Rio Grande, it was apparent that uranium was entirely complexed, "with over 99 percent of U(IV) present as $Ca_2UO_2(CO_3)_{3(aq)}$ and $CaUO_2(CO_3)_3^{-2}$, and the remaining less than one percent present as $UO_2(CO_3)_2^{-2}$ and $UO2(CO_3)_3^{-4}$." (38)

Dr. Howe described that there is substantial evidence indicating that uranium, plutonium, and americium bind strongly to soil. He noted that William Graf (49) reports that the concentration of uranium in sediments in the Rio Grande were 1000 times greater than that in the aqueous phase. Howe stated that "because actinides attached preferentially to sediments, any treatment process that removes particles will be an effective treatment process for uranium, plutonium, and americium." (38)

Estimated Concentrations in Treated BDD Tap Water

To account for the 95% decrease in concentration for selected radionuclides due to the water treatment technology that will be in use, the previously calculated CT and RME EPCs for americium-241, plutonium-238, plutonium-239/240, uranium-234, uranium-235/236, and uranium-238 were adjusted by a multiplicative factor of 0.05 (that is, reduced by 95%). All other radionuclide and chemical COIs were not adjusted for water treatment. Table 3-6 presents the EPCs for all the radionuclide COIs, including the adjustment for water treatment for the americium, plutonium, and uranium isotopes.

3.2.3 Recent Measurements in Water from the Buckman Well Field

Until the BDD is completed, the three sources of water available to the City and County of Santa Fe area are the City well field, the Buckman well field, and the Canyon Road water treatment plant that treats water from the Santa Fe River reservoirs.(50) Over pumping of the groundwater wells is resulting in damage to the underground aquifer. Even in the best of years, the Santa Fe River reservoirs can only supply about half of the water needs of the region.(50)

The Buckman well field is a system of wells located northwest of the city along the eastern side of the Rio Grande, as shown in Figure 3-2.

Table 3-6: Summary of radionuclide exposure point concentrations (pCi/L) for Rio Grande near Buckman[a] adjusted for impact of water treatment on select radionuclides

										Exposure Point Concentration	
Analyte	Number of Samples	Number of Detections	Minimum	Maximum	Arithmetic Mean	Arithmetic Standard Deviation	Distribution	UCL Type	UCL	CT	RME
Americium-241[b,c]	31	6	8.75E-06	0.347	0.0148	0.0647	Not Normal	95% KM (t) UCL	0.036	0.0148	0.036
Lead-214[b]	5	3	2.15	5.18	4.524	0.328	Not Normal	95% KM (t) UCL	5.0	4.524	4.966
Plutonium-238[b,c]	19	6	0	0.00053	0.00011	0.00012	Not Normal	95% KM (t) UCL	0.000132	0.00011	0.000132
Plutonium-239/240[b,c]	23	5	6.50E-05	0.000	0.0001	0.000115	Not Normal	95% KM (t) UCL	0.0001615	0.000125	0.0001615
Potassium-40[b]	8	2	2.98	19.8	7	7	Not Normal	95% KM (t) UCL	18.6	7.1	18.6
Radium-226	9	1	0.14	1.2	0.60	0.31	Not Normal	Not Calculated	NC	0.598	1.2
Radium-228	9	2	0.24	1.41	0.81	0.21	Lognormal	95% KM (t) UCL	0.991	0.805	0.991
Strontium-90[b]	31	5	0.0030	2.23	0.11	0.40	Not Normal	95% KM (t) UCL	0.277	0.11	0.277
Thorium-228	7	4	0.068	0.301	0.16	0.085	Lognormal	95% KM (t) UCL	0.239	0.156	0.239
Thorium-230	7	3	0.074	0.466	0.14	0.158	Lognormal	95% KM (t) UCL	0.297	0.135	0.297
Thorium-232	7	5	0.039	0.22	0.12	0.066	Lognormal	95% KM (t) UCL	0.171	0.118	0.171
Tritium	8	8	14	22.29	17	2.6	Lognormal	95% KM (Percentile Bootstrap) UCL	19	17.38	19
Uranium-234[c]	11	11	0.028	0.1055	0.064	0.025	Lognormal	95% Student's-t UCL	0.077	0.0636	0.077
Uranium-235/236[c]	9	5	0.0009	0.004535	0.0025	0.000945	Lognormal	95% KM (t) UCL	0.002915	0.002455	0.002915
Uranium-238[c]	11	11	0.0190	0.08	0.042	0.0172	Lognormal	95% Student's-t UCL	0.05185	0.04245	0.05185

[a] Data set includes samples from Buckman locations only unless otherwise noted.

[b] Data set includes samples from Buckman and Otowi Bridge locations due to lack of detections at Buckman and detections upstream at Otowi Bridge.

[c] Concentrations for this radionuclide are assumed to be decreased by 95% after water treatment.

NC or Not Calculated: UCL is not calculated because there are too few detections. The maximum is used instead of the UCL for the RME.

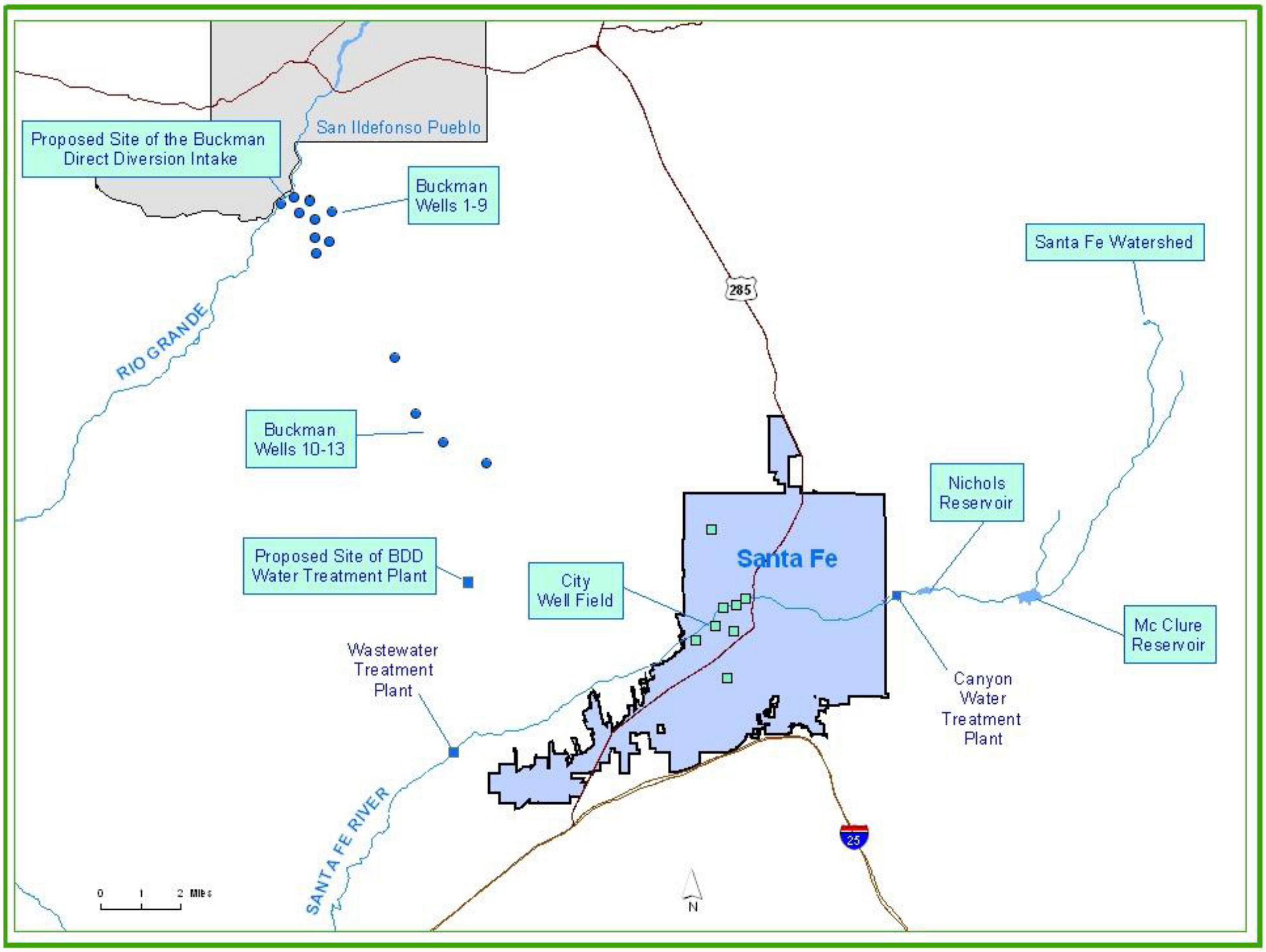


Figure 3-2: Locations of water sources for the Santa Fe region

Drinking water quality compliance for radionuclides under the Safe Drinking Water Act is measured for each set of water sources that share a common "point-of-entry" to the distribution system. The Buckman Well 10 Million-Gallon (10 MG) tank outlet is the point of entry for water from the Buckman wells to the Santa Fe water distribution system, as the outlet of the 4 MG finished water tank will be the point-of-entry for water from the BDD system. The location of the Buckman Well tank is shown in Figure 3-3.

The IPR team was instructed to include in their health risk assessments a scenario that addresses using water that contains mean values of gross alpha radioactivity and dissolved uranium produced by the Buckman well field as measured by the City at the point-of-entry to the public water distribution system and reported for federal Safe Drinking Water Act compliance.

The USEPA's Radionuclides Rule was promulgated on December 7, 2000. The Rule required that water suppliers collect and analyze four quarterly samples from each compliance point during the period between 2004 and 2007. Meeting this requirement was accomplished for the Buckman Tank compliance point as follows:(51)

- The sample collected and submitted on December 1, 2004 is a composite of 4 samples collected in 2004, which satisfied the initial compliance monitoring.
- For reasons unclear to IPR team, on September 21, 2007, NMED collected the final of another set of quarterly composite samples from the Buckman tank.
- Between 2004 and 2008, eight samples were collected and composited into two and analyzed satisfying the initial compliance monitoring.

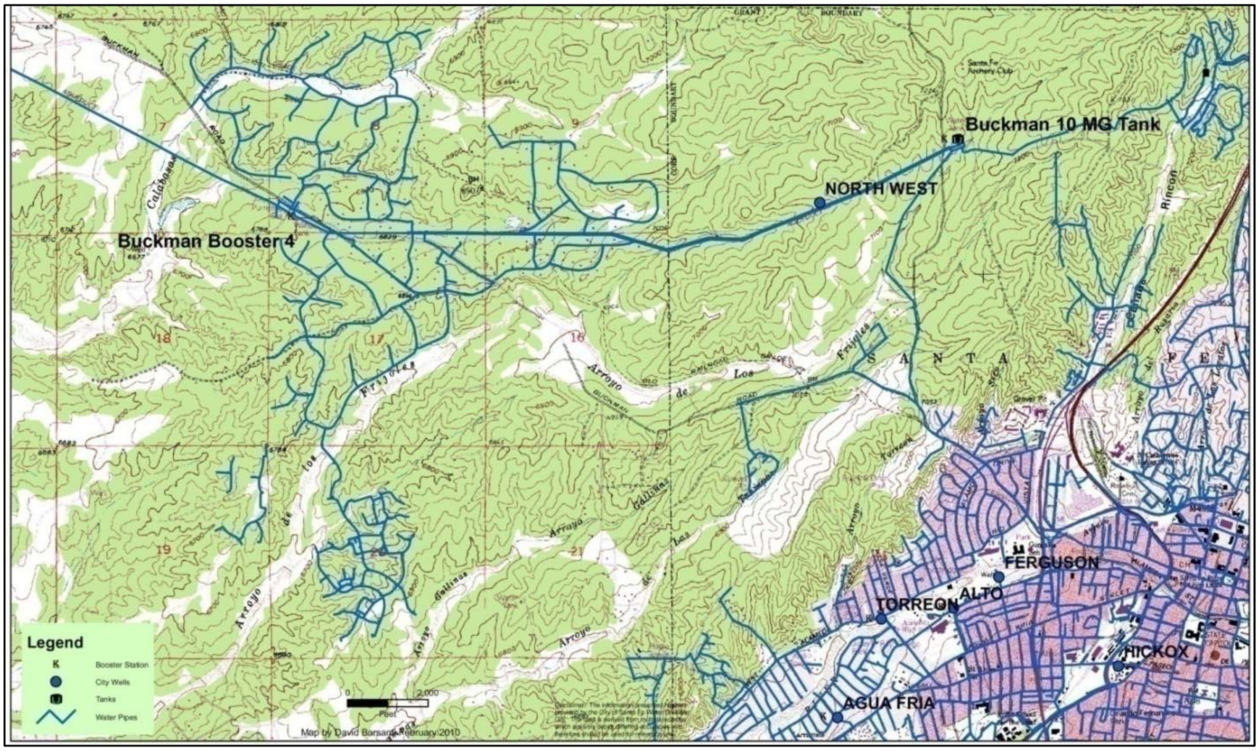


Figure 3-3: Locations of components of the Santa Fe water supply system, including the Buckman Well 10 MG tank

The Rule specifies a sequential analysis scheme to determine compliance:

- The samples had to be analyzed for gross alpha radioactivity and radium-228.
- If gross alpha exceeded 5 pCi/L, the sample had to be analyzed for radium-226.
- If gross alpha exceeded 15 pCi/L, the sample had to be analyzed for uranium.

Because health risk assessment for radionuclides requires knowledge of the identity of the specific radionuclides that are present in the environmental media, the IPR team used measurements from the Buckman Well tank to quantify the magnitudes of the radioactivity present and attributed them to specific radionuclides based on nuclide-specific analyses performed on samples taken from the Buckman Well tank and from the Buckman wells.

Attribution of Gross-Alpha and Total Uranium Concentrations to Specific Radionuclides

As part of the routine monitoring required for the Safe Drinking Water Act, seven samples have been collected since 2002 from the tank and consistently analyzed for gross alpha concentration [with uranium-natural reference and with americium-241 reference (pCi/L)], gross beta concentration (pCi/L), radium-226 activity (pCi/L), and uranium mass concentration (μg/L). In addition, some of these samples were also analyzed for their radium-228, uranium-234, and uranium-238 content. However, because the radium and uranium isotopes have not been consistently analyzed, the concentrations of radium-226, radium-228, uranium-234, uranium-235/236, and uranium-238 were estimated for the IPR analysis based on the gross alpha concentrations and the total uranium mass contribution.

As a first step, the uranium mass concentrations were converted from μg/L to pCi/L by multiplying by a specific activity value of 0.67 pCi/μg. This estimated uranium activity was then subtracted from the corresponding gross alpha concentration with natural uranium reference to estimate the activity for alpha emitters other than uranium. For this evaluation, it was assumed that radium was the only other alpha emitter.

To estimate the concentrations for the two radium isotopes, radium-226 and radium-228 and the three uranium isotopes, uranium-234, uranium 235/236, and uranium-238, the proportion of each isotope's activity relative to the total activity of the element is needed. While the water in the tank was not consistently analyzed for all of the isotopes of radium and uranium of interest, the groundwater samples from the individual Buckman field wells have been analyzed for the radium and uranium isotopes of interest on a consistent basis from 2001 to the present. The data for these wells was taken from the RACER database, and duplicate samples were processed the same way as the Rio Grande surface water data. The groundwater data from the Buckman wells for the radium and uranium isotopes are presented in Appendix 3A (Tables 3A-3 and 3A-4, respectively).

For each sample in which both radium isotopes were detected or all three uranium isotopes were detected, the percent contribution of each isotope to the total concentration was calculated. Only detected values were used because of the large range of uncertainty associated with estimating percent contributions when one sample is less than the LOD, especially if the LOD for one isotope is greater than the detected value for the other isotope. The arithmetic mean percent contributions were then used to determine the individual isotope activities for radium and uranium.

Only one sample from the Buckman wells had detections of both radium-226 and radium-228, a sample collected from Buckman well 6 on March 4, 2009. Based on the data from this sample, the percent contributions used for radium-226 and radium-228 were 37% and 63%, respectively. The average percent contributions based on the 42 samples that had detections for all three uranium isotopes for uranium-234, uranium-235/236, and uranium-238 are 61%, 3%, and 36%, respectively.

Table 3-7 presents the estimated concentrations for the radium and uranium isotopes for the Buckman tank estimated from the gross alpha and uranium mass concentrations.

Because radium-226, radium-228, uranium-234 and uranium-238 were measured in some of the tank water samples, the estimated concentrations were compared to the measured concentrations from the tank to determine how well the estimation procedure did. The estimated radium and uranium concentrations are compared to the measured data in Table 3-8. For the radium isotopes, the estimation method is not that accurate based on a comparison of radium-226 concentrations to the estimated values for the same samples. For radium-226, the estimated concentrations are a factor of 7 to 11 times greater than the measured data. For uranium-234 and uranium-238, the estimated concentrations are much closer to the measured values for the three samples for which these isotopes were analyzed, with the uranium-234 estimates being between a factor of 0.76 to 1.3 of the measured uranium-234 concentrations and with the uranium-238 estimates being between factors of 1.1 to 1.3 times greater than measured uranium-238. In general, the estimation method tends to provide fairly accurate estimates of the uranium isotope concentrations, but large overestimates of the radium isotope concentrations.

The estimated values from Table 3-7 were used in ProUCL to calculate CT and RME EPCs using the same methods as the Rio Grande surface water discussed previously. Table 3-9 summarizes the CT and RME EPCs for radium-226, radium-228, uranium-234, uranium-235/236, and uranium-238.

Table 3-7: Estimated Ra-226, Ra-228, U-234, U-235, and U-238 concentrations for the Buckman Well Field mixing tank

Date	Page No. from "Tank Entry Point" PDF	Gross Alpha (Am ref)	Gross Alpha (U_{nat} ref)	Estimated Gross Alpha without Uranium	Uranium (mass conc)	Estimated Gross Alpha for Uranium	Ra-226 (Estimated)	Ra-228 (Estimated)	U-234 (Estimated)	U-235 (Estimated)	U-238 (Estimated)
		pCi/L	pCi/L	pCi/L	µg/L	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L
8/12/2002[a]	1	22	30	*0.0*	54	*36*	0.00	0.00	33	1.6	19
1/30/2003	*2*	23	33	*1.9*	47	*31*	0.71	1.2	29	1.4	17
3/17/2003	*3*	7.6	10	*4.1*	9.0	*6.0*	1.5	2.6	5.5	0.27	3.2
4/7/2003	*4*	7.5	9.6	*3.6*	9.0	*6.0*	1.3	2.2	5.5	0.27	3.2
12/1/2004	*7*	9.1		*4.0*	7.5	*5.0*	1.5	2.5	4.6	0.23	2.7
9/21/2007	*15*	7.1	9.3	*3.3*	9	*6.0*	1.2	2.1	5.5	0.27	3.2
5/29/2009	*17*	7.4	7.4	*0.97*	9.6	*6.4*	0.36	0.61	5.9	0.29	3.5

Gross alpha (U_{nat} reference) includes uranium.

Per USEPA, to estimate the uranium component, multiply the U mass conc by 0.67

That conversion factor is based on the 1:1 activity ratio of U-234 and U-238 that is characteristic of naturally occurring uranium.

[a] Estimated Gross Alpha without Uranium set equal to zero because difference between estimated uranium activity and gross alpha activity is less than zero.

Table 3-8: Estimated Ra-226, Ra-228, U-234, U-235, and U-238 concentrations for the Buckman Well Field mixing tank

Date	Page No. from "Tank Entry Point" PDF	Gross Alpha (Am ref)	Gross Alpha (U_{nat} ref)	Estimated Gross Alpha without Uranium	Uranium (mass conc)	Estimated Gross Alpha for Uranium	Ra-226 (Estimated)	Ra-228 (Estimated)	U-234 (Estimated)	U-235 (Estimated)	U-238 (Estimated)
		pCi/L	pCi/L	pCi/L	µg/L	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L	pCi/L
8/12/2002[a]	1	22	30	*0.0*	54	*36*	0.00	0.00	33	1.6	19
1/30/2003	*2*	23	33	*1.9*	47	*31*	0.71	1.2	29	1.4	17
3/17/2003	*3*	7.6	10	*4.1*	9.0	*6.0*	1.5	2.6	5.5	0.27	3.2
4/7/2003	*4*	7.5	9.6	*3.6*	9.0	*6.0*	1.3	2.2	5.5	0.27	3.2
12/1/2004	*7*	9.1		*4.0*	7.5	*5.0*	1.5	2.5	4.6	0.23	2.7
9/21/2007	*15*	7.1	9.3	*3.3*	9	*6.0*	1.2	2.1	5.5	0.27	3.2
5/29/2009	*17*	7.4	7.4	*0.97*	9.6	*6.4*	0.36	0.61	5.9	0.29	3.5

Gross alpha (U_{nat} reference) includes uranium.

Per USEPA, to estimate the uranium component, multiply the U mass conc by 0.67

That conversion factor is based on the 1:1 activity ratio of U-234 and U-238 that is characteristic of naturally occurring uranium.

[a] Estimated Gross Alpha without Uranium set equal to zero because difference between estimated uranium activity and gross alpha activity is less than zero.

Table 3-9: Summary of estimated radionuclide exposure point concentrations (pCi/L) for Buckman Well Field

Analyte	Number of Samples	Minimum	Maximum	Arithmetic Mean	Arithmetic Standard Deviation	Distribution	UCL Type	UCL	Exposure Point Concentration	
									CT	RME
Radium-226	7	0	1.5	0.94	0.60	Not Normal	95% Student's-t UCL	1.4	0.9	1.4
Radium-228	7	0	2.6	1.6	1.0	Not Normal	95% Student's-t UCL	2.3	1.6	2.3
Uranium-234	7	4.6	33	13	12	Unknown	95% Chebyshev (Mean, Sd) UCL	33	13	33
Uranium-235/236	7	0.23	1.6	0.62	0.61	Unknown	95% Chebyshev (Mean, Sd) UCL	1.6	0.62	1.6
Uranium-238[a]	7	2.7	19	7.5	7.4	Unknown	95% Chebyshev (Mean, Sd) UCL	20	7.5	19

a Estimated UCL exceeded the maximum detected concentration so RME was set equal to the max.

3.3 DRINKING WATER REGULATIONS AND OTHER GUIDELINES

The COIs were compared to drinking water criteria, which exist in the form of both enforceable regulations and guidelines. The primary criteria considered for this comparison were the USEPA Maximum Contaminant Levels (MCLs), which are legally enforceable drinking water standards for public drinking water systems. For COIs that do not have MCLs, other drinking water guidelines were used for comparison purposes.

3.3.1 USEPA Drinking Water Standards

Public drinking water quality in the U.S. is regulated by the USEPA under the Safe Drinking Water Act (SDWA). As a result of this program, the USEPA established the National Primary Drinking Water Regulations (NPDWR), which are drinking water standards for over 70 contaminants of potential concern in drinking water. The NPDWRs include both enforceable (Maximum Contaminant Levels; MCLs) and non-enforceable health goals (Maximum Contaminant Level Goals; MCLGs). MCLs are mandatory levels defined as "the highest level of a contaminant that is allowed in drinking water."(52) Non-enforceable levels are called maximum contaminant level goals (MCLGs), which are defined as concentrations of chemicals at which "no known or anticipated adverse effect on the health of persons occurs and which allows an adequate margin of safety."(53) In addition, the USEPA has established National Secondary Drinking Water Regulations, which are non-enforceable, recommended guidelines for chemicals that may cause cosmetic effects (such as skin or tooth discoloration) or aesthetic effects (such as taste, odor, or color) in drinking water.

A reference dose (RfD) is an estimate of the amount of a chemical that a person can be exposed to on a daily basis that is not anticipated to cause adverse health effects over a person's lifetime. For non-carcinogenic chemicals, the MCLGs are calculated using a simple equation that incorporates the chemical-specific the oral RfD, the body weight, and drinking water ingestion rate for an adult (70 kg; 2 L/day), and a relative source contribution factor of 20% (which assumes that only 20% of an adult's total daily intake of a chemical is from drinking water).(53) For chemicals that are known or probable human carcinogens, the MCLG is set equal to zero, and the MCL is set at the lowest concentration that can be measured on a routine basis (that is, a Practical Quantitation Limit). MCLGs for chemicals determined to be possible human carcinogens are calculated according to the method used for non-carcinogens (that is, based on an RfD, if one is available), and then a factor of 10 is incorporated to provide additional margin.(53) Subsequent to the MCLG calculation, MCLs are set equal to or as close to the MCLG as is feasible, considering best available treatment technology and taking cost into consideration.

To assure compliance with the MCLs, public water suppliers (PWS) must collect and analyze drinking water samples in accordance with analytical methods and sampling schedules set by the EPA. Depending upon the chemical class and the drinking water source (that is, groundwater and/or surface water), samples are typically collected from a PWS between one and four times per year.(54) While an MCL is referred to as a "maximum level," compliance for more frequently monitored chemicals is determined by comparing annual average concentrations to the MCL (that is, not the maximum concentration).

In addition to the regulated contaminants that are part of the NPDWRs, the US EPA has also developed a list of unregulated contaminants (Contaminant Candidate List 3; CCL3) that are known or anticipated to occur in public water systems and may require future regulation.(52) This list consists of 104 chemicals or chemical groups that the EPA will further evaluate and determine which have sufficient information for the US EPA to make a regulatory determination. The EPA will encourage research for chemicals that lack sufficient information.

3.3.2 New Mexico Drinking Water Standards

The SDWA allows individual states to set and enforce their own drinking water standards, as long as they are not less stringent than national standards. In New Mexico, the NMED Drinking Water Bureau was granted primacy authority by the USEPA to directly oversee its PWSs, and relies upon the MCLs as their drinking water standards.(55)

3.3.3 Other Drinking Water Criteria

Various other sources of health-based drinking water criteria that have been developed by the USEPA and state environmental organizations are readily available. As such, the sources listed below were used to identify drinking water criteria for those COIs for which MCLs have not been developed.

- **NMED Tap Water Screening Levels** were developed for residential exposures based on an adult who is exposed to household water via ingestion and inhalation of volatiles. They are based on a target risk of 1 in 100,000 for carcinogens and a hazard quotient of 1 for non-carcinogens.(56)
- **USEPA Regional Tap Water Screening Levels (RSLs)** were developed similarly to NMED's Tap Water Screening Levels, but use a target risk of 1 in 1 million for carcinogens (USEPA, 2010).
- **Preliminary Remediation Goals for Radionuclides (PRGs)** for tap water are calculated in the same manner as the RSLs, however, they consider both children and adult residents.(57)

- **Drinking Water Equivalent Levels (DWELs)** are set by the USEPA. They are lifetime exposure concentrations considered protective of adverse, non-cancer health effects, assuming that all of the exposure to a contaminant is from drinking water. The RfD set by USEPA for a contaminant is multiplied by body weight and divided by daily water consumption to obtain the compound's DWEL.(90)
- **Lifetime Health Advisories (Lifetime HAs)** are concentrations of chemicals in drinking water that are not expected to cause any adverse non-carcinogenic effects for a lifetime of exposure. The Lifetime HA is based on exposure of a 70-kg adult consuming 2 liters of water per day.(58)
- **Secondary Drinking Water Regulations (SMCLs)** are non-enforceable Federal guidelines regarding cosmetic effects (such as tooth or skin discoloration) or aesthetic effects (such as taste, odor, or color) of drinking water.(58)

The MCLs and other drinking water criteria for the radionuclide and chemical COIs were compiled and are presented in Tables 3-10 and 3-11, respectively. These tables present the process used to select the relevant drinking water criteria for each COI. This process entailed using the MCLs as the selected drinking water criteria, and the lowest available health-based criteria for COIs without MCLs.

Table 3-10: Selection of relevant drinking water criteria for radionuclides*

(All concentrations in uCi/L)

Detected Analyte	USEPA Drinking Water Criteria		Selected Drinking Water Criteria[c]	
	MCL[a]	EPA Superfund PRGs[b]	Value	Source
Americium-241	--	5E-07	5E-07	b
Lead-214	--	1E-04	2E-04	b
Plutonium-238	--	4E-07	4E-07	b
Plutonium-239	--	4E-07	4E-07	b
Potassium-40	--	2E-06	2E-06	b
Radium-226	5E-06 (Ra-226+Ra-228)	5E-06	5E-06	a
Radium-228		5E-08		
Strontium-90	--	9E-07	9E-07	b
Thorium-228	--	5E-08	5E-07	b
Thorium-230	--	5E-07	6E-07	b
Thorium-232	--	5E-07	5E-07	b
Tritium	--	1E-04	2E-04	b
Uranium-234	--	7E-07	7E-07	b
Uranium-235	--	7E-07	8E-07	b
Uranium-238	--	7E-07	8E-07	b

*Drinking water criteria were obtained for all COIs in the Santa Fe River. When availble, EPA MCLs were utilized as the drinking water criteria. When MCLs were unavailable, the lowest value from other health-based criteria was selected, as indicated.

[a] USEPA 2009 (http://www.epa.gov/waterscience/criteria/drinking/dwstandards2009.pdf).

[b] USEPA Preliminary Remediation Goals (PRGs) Calculator (accessed November, 2010); (Consider residential child and adult ingestion exposures).

[c] Superfund PRGs (accessed May, 2010); http://epa-prgs.ornl.gov/radionuclides/. Considers residential adult ingestion exposures, as well as inhalation for tritium and Radium-226.

[c] PRGs were used for all radionuclide COIs that do not have an MCL.

[e] Exludes uranium and radon isotopes.

-- Not available.

Table 3-11: Selection of relevant drinking water criteria for chemicals[a]
(All concentrations in ug/L)

Analyte	USEPA Drinking Water Standards and Health Advisories					NMED Tap Water Screening Level[d]	USEPA Regional Screening Levels (RSLs)[e]	Selected Drinking Water Criteria[a]	
	National Primary Drinking Water Regulations[b]			Health Advisories (HAs)[c]					
	MCL	MCLG	SMCL	DWEL	Lifetime HA			Value	Source
Acetone	--	--	--	--	--	5,480	21,800	5,480	NMED
Aluminum	--	--	50 to 200	--	--	36,500	36,500	36,500	RSL/NMED
Ammonia	--	--	--	30,000	--	--	--	30,000	DWEL
Antimony	6	6	--	10	6	15	15	6	MCL
Arsenic	10	0	--	10	--	0.44	0.045	10	MCL
Barium	2,000	2,000	--	7,000	--	7,300	7,300	2,000	MCL
Beryllium	4	4	--	70	--	73	73	4	MCL
Bis(2-ethylhexyl)phthalate	6	0	--	700	--	47	4.8	6	MCL
Boron	--	--	--	7,000	6,000	7,300	7,300	6,000	Lifetime HA
Cadmium	5	5	--	20	5	18	18	5	MCL
Chloromethane	--	--	--	100	30	15	188	15	NMED
Total Chromium	100	100	--	100	--	--	--	100	MCL
Cobalt	--	--	--	--	--	730.00	11	11	RSL
Copper	1,300	1,300	1,000	--	--	1,460	1,460	1,300	MCL
Cyanide	200	200	--	800	200	730	730	200	MCL
DDE	--	--	--	--	--	1.95	0.20	0.20	RSL
Fluoride	4,000	4,000	2,000	--	--	2,190	1,460	4,000	MCL
Delta HCH	--	--	--	--	--	--	0.037	0.037	RSL
Iron	--	--	300	--	--	11,000	25,600	11,000	NMED
Lead	15	0	--	--	--	--	--	15	MCL
Manganese	--	--	50	1,600	300	1,720	876	50	SMCL
Mercury	2	2	--	10	2	--	0.57	2.0	MCL
Molybdenum	--	--	--	200	40	183	183	40	Lifetime HA
Nickel	--	--	--	700	1,000	730	730	700	DWEL
Nitrite	1,000	1,000	--	--	--		3,650	1,000	MCL
OCDD	--	--	--	--	--	--	--	0.00068	RAIS
Perchlorate	15	--	--	25	15	--	26	15	MCL
Total PCBs	0.5	0	--	--	--	--	--	0.50	MCL
Selenium	50	50	--	200	50	183	183	50	MCL
Silver	--	--	100	200	100	183	183	100	Lifetime HA
Strontium	--	--	--	20,000	4,000	21,900	21,900	4,000	Lifetime HA
Thallium	2	0.5	--	--	--	2.4	--	2	MCL
Uranium	30	0	--	20	--	--	110	30	MCL
Vanadium	--	--	--	--	--	37	184	37	NMED
Zinc	--	--	5,000	10,000	2,000	11,000	11,000	2,000	Lifetime HA

[a] Drinking water criteria were obtained for all COIs in the Santa Fe River. When available, EPA MCLs were utilized as the drinking water criteria. When MCLs were unavailable, the lowest value from other health-based criteria was selected, as indicated.

[b] National Primary Drinking Water Regulations are legally enforceable standards that apply to public water systems.(86)

[c] Health Advisories (HA). An estimate of acceptable drinking water levels for a chemical substance based on health effects information; a Health Advisory is not a legally enforceable federal standard, but serves as technical guidance to assist federal, state, and local officials.(90)

[d] The NMED SSLs are based on a 1 x 10^{-5} target risk for carcinogens, or a hazard quotient of 1 for noncarcinogens.(88)

[e] USEPA Regional Screening Levels for tap water (RSLs).(146)

MCL: Maximum Contaminant Level. The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to the MCLG as feasible using the best available analytical and treatment technologies and taking cost into consideration. MCLs are enforceable standards.

SMCL: Secondary Drinking Water Regulations. Non-enforceable federal guidelines regarding cosmetic effects (such as tooth or skin discoloration) or aesthetic effects (such as taste, odor, or color) of drinking water.

MCLG: Maximum Contaminant Level Goal. A non-enforceable health goal set at a level at which no known or anticipated adverse effect on the health of persons occurs and that allows an adequate margin of safety.

DWEL: Drinking Water Equivalent Level. A lifetime exposure concentration protective of adverse, non-cancer health effects, which assumes that all of the exposure to a contaminant is from drinking water.

RAIS: Risk Assessment Information System; Department of Energy's (DOE's) Oak Ridge Operations Office (ORO).

-- No associated value.

3.4 COMPARISON OF COIS TO DRINKING WATER CRITERIA

The average concentrations of the COI were compared to the selected drinking water criteria; these data are presented in Tables 3-12 and 3-13. These tables show that for all of the 50 COIs, with the exception of U-234, the untreated and unfiltered water river are below the MCLs and other drinking water criteria. In the case of U-234, this radionuclide is associated with regional background levels, which is discussed later in this report.

Table 3-12: Comparision of radionuclide COIs to drinking water criteria

(All concentrations in uCi/L)

Radionuclide	Exposure Point Concentrations (uCi/L)		
	Selected Drinking Water Criteria	Central Tendency (CT)[a]	Is CT > Drinking Water Criteria?
Americium-241	5E-07	3E-07	No
Lead-214	2E-04	5E-06	No
Plutonium-238	4E-07	2E-09	No
Plutonium-239	4E-07	3E-09	No
Potassium-40	2E-06	7E-06	Yes[b]
Radium-226	5E-06	6E-07	No
Radium-228		8E-07	No
Strontium-90	9E-07	1E-07	No
Thorium-228	5E-07	2E-07	No
Thorium-230	6E-07	1E-07	No
Thorium-232	5E-07	1E-07	No
Tritium	2E-04	2E-05	No
Uranium-234	7E-07	1E-06	Yes
Uranium-235	8E-07	5E-08	No
Uranium-238	8E-07	8E-07	No

[a] Average concentration: CT Central Tendency exposure parameter (i.e., average, or typical exposure).

[b] Although the EPC for this COI is greater than the drinking water criteria, it was not detected at the Buckman sampling location.

Table 3-13. Comparision of chemical COIs to drinking water criteria

	Exposure Point Concentrations		
BDD Analyte	Selected Drinking Water Criteria	Central Tendency (CT)[a]	Is CT > Drinking Water Criteria?
Acetone	5,480	2.5	No
Aluminum	36,500	2474	No
Ammonia	30,000	46.06	No
Antimony	6.0	0.378	No
Arsenic	10	2.966	No
Barium	2,000	93.04	No
Beryllium	4.0	1	No
Bis(2-ethylhexyl)phthalate	6.0	2.5	No
Boron	6,000	30.69	No
Cadmium	5.0	0.669	No
Chloromethane	15	0.425	No
Total Chromium	100	4.761	No
Cobalt	11	2.608	No
Copper	1,300	4.442	No
Cyanide	200	1.8	No
DDE	0.20	0.00758	No
Fluoride	4,000	353.9	No
Delta HCH	0.037	0.00859	No
Iron	11,000	2280	No
Lead	15	4.144	No
Manganese	50	133.1	No*
Mercury	2.0	0.09	No
Molybdenum	40	4.503	No
Nickel	700	4.804	No
Nitrite	1,000	79.36	No
OCDD	0.00068	0.000040475	No
Perchlorate	15	0.0701	No
Total PCBs	0.50	0.00022582	No
Selenium	50	1.56	No
Silver	100	0.11	No
Strontium	4,000	280	No
Thallium	2.0	0.296	No
Uranium	30	2.544	No
Vanadium	37	8.885	No
Zinc	2,000	12.3	No

*The lowest of the drinking water criteria available for manganese is identified here; however, this figure is a secondary MCL, and is not a health-based criterion. The next lowest drinking water criterion for manganese is 876 ug/L, which is a USEPA RSL.

3.5 NEW MEXICO SURFACE WATER QUALITY

New Mexico has established water quality standards for surface water that are used to designate surface water uses and to set criteria for attainment of those uses (*Standards for Interstate and Intrastate Surface Waters* - 20.6.4 NMAC). These standards are developed by the NMED and approved by the USEPA under the Clean Water Act, which is an act that establishes the structure for regulating the discharge of pollutants into U.S. surface waters and the associated water quality standards. These standards have been recently updated and became effective on December 1, 2010.

Included in the proposed standards are newly developed water quality criteria for six radionuclides of LANL-origin: americium-241, cesium-137, plutonium-238, plutonium-239/240, strontium-90, and tritium. These new criteria are specific to the reach of the Rio Grande that includes the BDD water intake structure. They are applicable to the public water supply use for monitoring and public disclosure purposes, and are not enforceable standards. These standards are health-based, and were developed using Federal Guidance Report 13, which is the current USEPA methodology for estimating theoretical cancer risks from low-level exposure to radionuclides. These standards are based on a 70-kg adult who consumes two liters of water per day, and a target risk of 1 in 100,000. Similar to the EPA and NMED drinking water regulations, these criteria are for comparison to an average yearly drinking water concentration.

While not to be confused with drinking water standards, it is worth noting that the NMED surface water criteria for these six radionuclides are greater than the drinking water criteria utilized by the IPR team. A comparison is provided in the table below.

Radionuclide	IPR Drinking Water Criteria[a] (pCi/L)	New Mexico Surface Water Criteria (pCi/L)
Americium-241	0.51	1.9
Plutonium-238	0.40	1.5
Plutonium-239/240	0.39	1.5
Strontium-90	0.95	3.5
Tritium	160	4,000
Cesium-137[a`]	1.7	6.4

[a] The PRGs were used as the drinking water criteria by the IPR team for these radionuclides. Although cesium-137 was not a not a COI in this assessment, it is included here for comparison purposes.

3.6 CHARACTERIZATION OF SOURCES OF THE COIS

3.6.1 Sources of COIs in the Rio Grande

COIs in the Rio Grande have originated from a number of sources, including forms of the material that occur in nature; human activities conducted at Los Alamos, LANL, or other urban and industrial areas in the watershed; and above-ground testing of nuclear devices that occurred widely between 1945 and 1980. Some COIs appear to be dominantly of natural origin; others were generated by or enhanced by human activities, and others appear from a mixture of natural and anthropogenic sources.

3.6.1.1 Naturally Occurring Materials

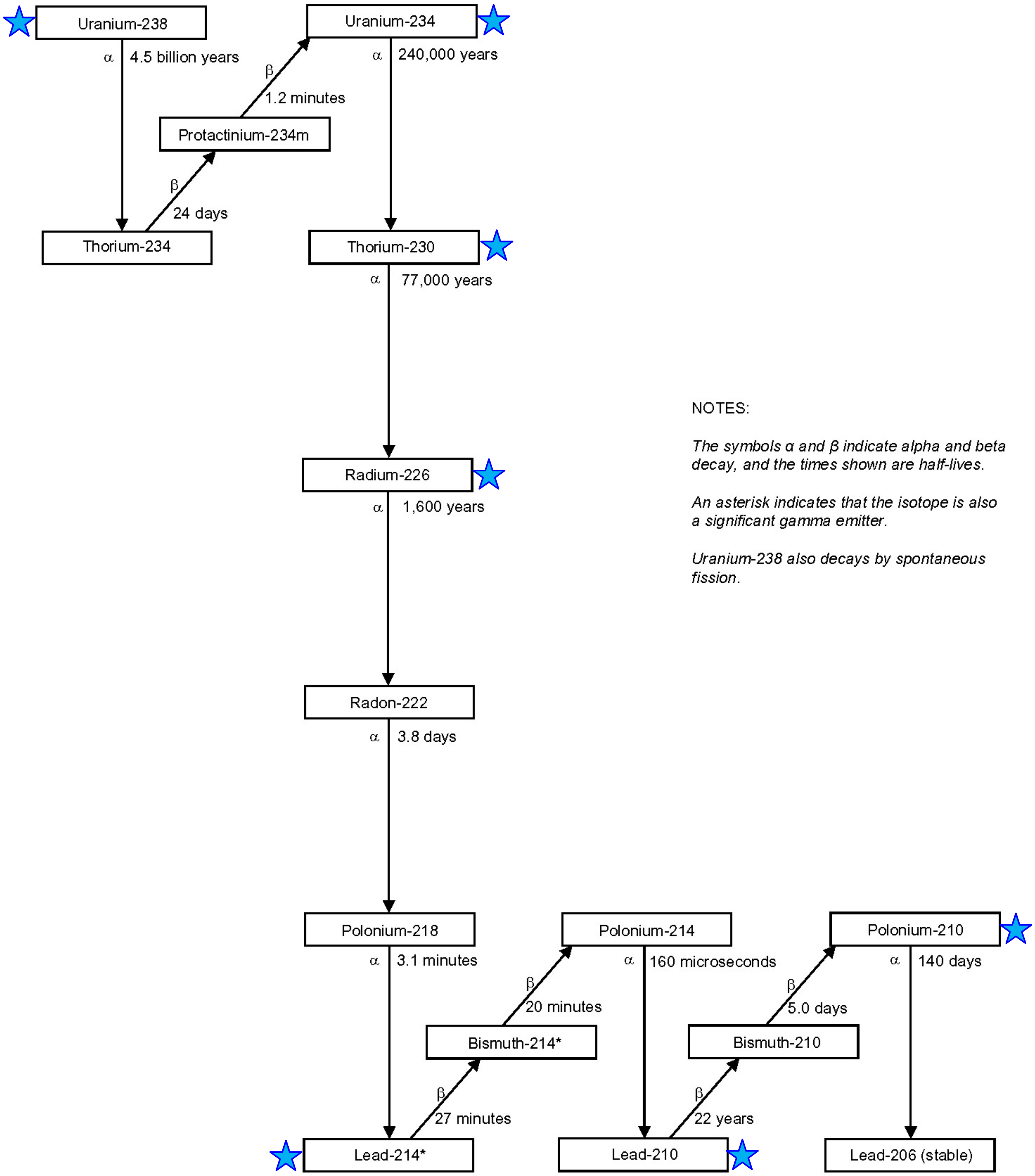
Many of the analytes measured in the Rio Grande are elements that occur naturally in the earth's crust; these include the COIs aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, led, manganese, mercury, molybdenum, nickel, selenium, silver, strontium, thallium, tin, uranium, vanadium, and zinc. Occurrences of these elements in surface waters can result from leaching and/or erosion of natural deposits, but their presence in environmental media can also be enhanced by human uses of the elements and compounds of these elements for industrial or urban uses. Examples would include using chromium compounds as corrosion inhibitors in cooling water systems, and using mercury to extract gold and silver from mined ores.

Radioactive material has existed in air, rocks, water, and plants since the Earth's formation. Over the last century, naturally occurring radioactive materials have been mined and processed for use in medicine, power generation, weapons, consumer products, and industry. These naturally occurring radioactive materials, often referred to as NORM, include those radionuclides present or produced naturally within the environment. Naturally occurring radionuclides can either occur singly within the environment (such as potassium-40) or within the uranium, thorium, and actinium decay series or chains.(59) Each of these decay series starts with a "primordial" radionuclide that was formed when the earth was formed (the U-238, U-235, and Th-232 for which the series are named), passes through a series of disintegrations in which isotopes of various elements are formed, and ends with stable isotopes that decay no further (lead-206, -207, and -208). Isotopes occurring in these decay chains, along with potassium-40, account for most of the background radiation dose to which humans are exposed.(59)

As shown in Figures 3-4 through 3-6,(60) radioactive isotopes of uranium, thorium, radium, polonium, and lead that are COIs occur in the uranium and thorium decay series.(61)

3.6.1.2 Fallout from Above-Ground Nuclear Testing

Between 1945 and 1980, the United States and other countries conducted over 500 atmospheric tests of nuclear weapons.(62) As a consequence of these tests, radioactive fission and activation products in the form of particles and gases were dispersed throughout the atmosphere; radioactive fallout resulted across the earth's surface, and some of that contamination is still present today in soils, surface waters, plants, and animals. While roughly 200 radionuclides are produced during fission, many decay away quite quickly, but a few dominate the potential residual health risk to exposed populations. These include strontium-90, cesium-137, and plutonium-239/240. Radioactive iodine, specifically I-131, has been found to be the radionuclide of greatest concern in terms of public health risks after a nuclear test,(62) but that nuclide has an eight day half-life, and does not remain present after several months have passed.



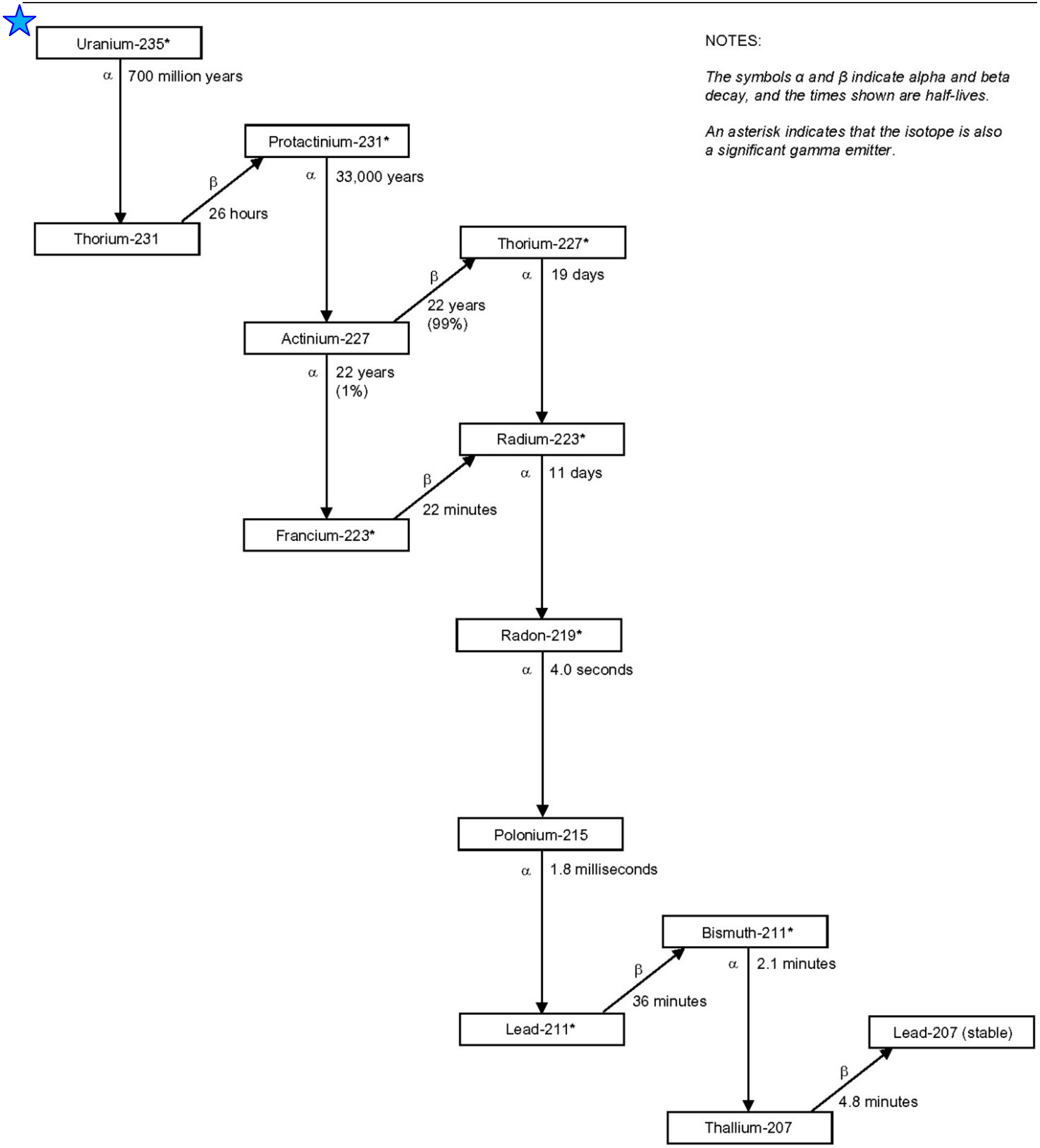
NOTES:

The symbols α and β indicate alpha and beta decay, and the times shown are half-lives.

An asterisk indicates that the isotope is also a significant gamma emitter.

Uranium-238 also decays by spontaneous fission.

Figure 3-4: Natural decay series: uranium-238. Radionuclides that are contaminants of interest for the IPR assessments are marked with a star symbol.



NOTES:

The symbols α and β indicate alpha and beta decay, and the times shown are half-lives.

An asterisk indicates that the isotope is also a significant gamma emitter.

Figure 3-5: Natural decay series: uranium-235. Radionuclides that are contaminants of interest for the IPR assessments are marked with a star symbol.

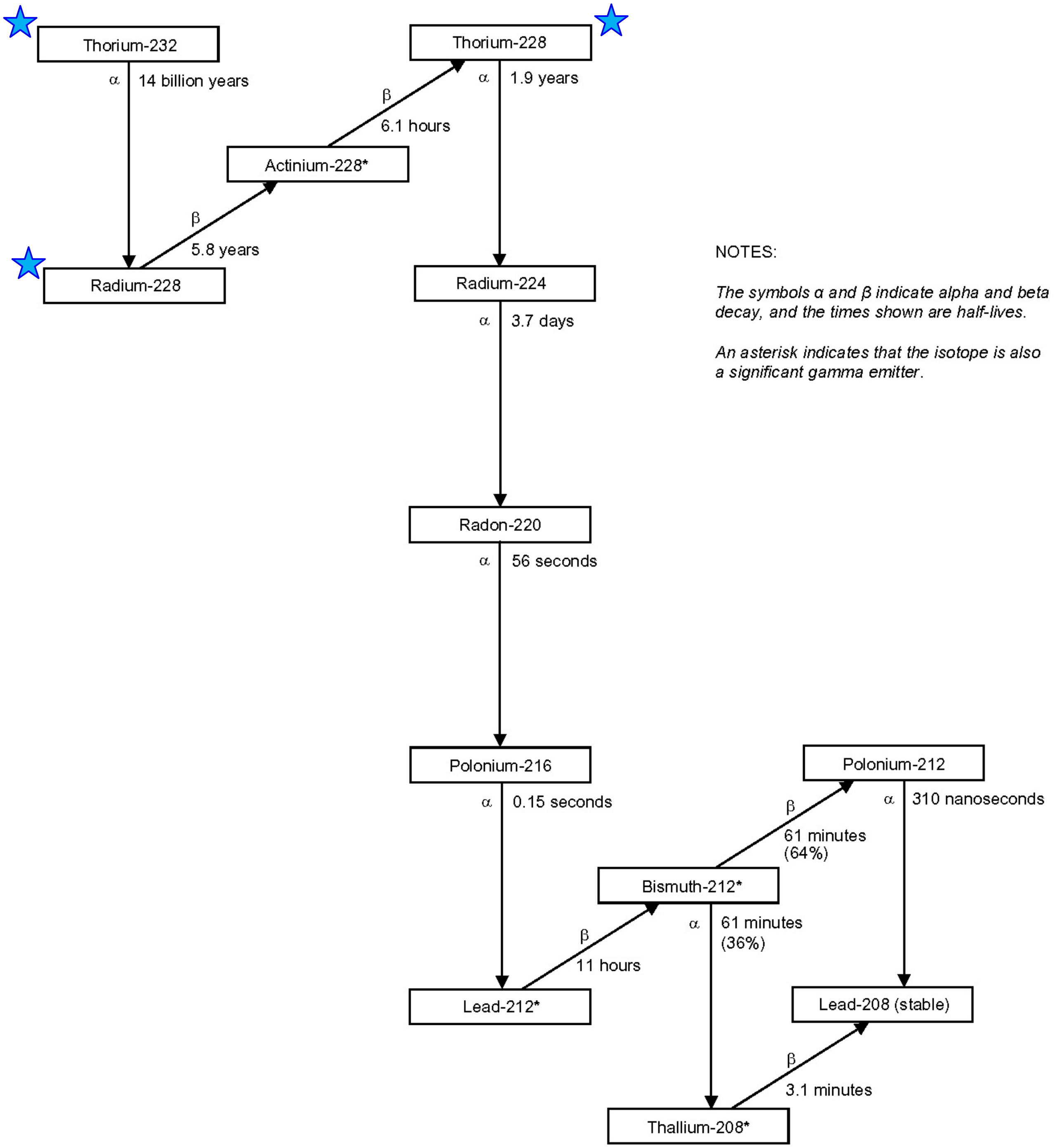


Figure 3-6: Natural decay series: thorium-232. Radionuclides that are contaminants of interest for the IPR assessments are marked with a star symbol.

3.6.1.3 COI Sources at LANL

"Project Y" was born as part of the Manhattan Project to create the first atomic weapons. LANL's activities expanded after the war into diverse areas, including thermonuclear weapon design, high explosives development and testing, weapons safety, nuclear reactor research, waste disposal and incineration, chemistry, criticality experimentation, tritium handling, biophysics, and radiobiology.(17) Operations at Los Alamos have taken place in land divisions called Technical Areas, or TAs, that are located across 36 square miles of Lab property. In terms of the Lab's contribution of contamination to local canyons and into the Rio Grande, there are a number of historical operations or facilities that environmental investigations have identified as most significant:(63)

- Untreated waterborne radioactive wastes released to the South Fork of Acid Canyon from 1944 to 1951 and from the TA-45 treatment plant from 1951 to 1964. LANL has indicated that these are thought to be the primary sources of radionuclide contamination in Acid and Pueblo Canyons (primarily Pu-239/240). Average concentrations of Am-241, Pu-239/240, Sr-90, and U-234 are highest in reach ACS in the South Fork of Acid Canyon, and Cs-137 is also present there above background concentrations.
- A TA-21 outfall into DP Canyon that received waste from industrial waste treatment plants from 1952 to 1986 (Cs-137 and Sr-90), which LANL views as the most important source of contaminants in upper Los Alamos Canyon. Average concentrations of Cs-137 are highest in DP Canyon down-canyon from the 21-011(k) outfall, and Am-241, Pu-239/240, Sr-90, and possibly U-234, are also above background concentrations down-canyon from this outfall.(63)
- A septic tank outfall on the south rim of Acid Canyon in the 1940s (Pu-239/240, PCBs). The SWMU 0-030(g) outfall into Acid Canyon is a recognized source for Am-241 and Pu-239/240 contamination of sediments.
- The former Pueblo Canyon waste water treatment plant on the south rim of Graduation Canyon above Pueblo Canyon (mercury and DDT).
- Contaminated hillsides in the Original Technical Area along Los Alamos Canyon (radionuclides and metals, including mercury). Hillside 137 in upper Los Alamos Canyon below TA-1 is a recognized source for Pu-239/240 in canyon sediments.
- The Omega West Reactor in TA-2, which operated from 1956 to 1993 and leaked tritium to the alluvial groundwater.
- Leach fields at TA-2 (Cs-137 and Sr-90).
- Absorption beds within Material Disposal Area (MDA) V on DP Mesa that received liquid waste effluent from laundry operation and sometimes overflowed into Los Alamos Canyon (plutonium).
- Impoundments at TA-53 (inorganic chemicals, organic chemicals, radionuclides).

- A solid waste management unit (SWMU) at TA-61 (PCBs).
- A septic tank outfall from TA-31's east receiving yard (PCBs).
- An ash pile from a former incinerator at TA-73 (inorganic and organic chemicals).

3.6.1.4 COI Sources from Urban Area and Forests

Some COIs are often found in urban areas, including compounds that are found in motor oil, gasoline, diesel fuel, asphalt, road salt, PCBs, heavy metals, and pesticides.(64-68) PAHs are frequently associated with motor vehicle usage and asphalt, and runoff from roads often contains metals, including cadmium, chromium, copper, lead, nickel, and zinc.(64-68)

Arsenic, cadmium, chromium, cobalt, manganese, and mercury have been measured in relatively high concentrations in some or all of the reaches of upper Acid and DP Canyons, and have also been reported in urban runoff.(63)

The insecticide DDT was used in aerial spraying in the Sante Fe National Forest in 1963, most likely in the upper parts of the Los Alamos and Pueblo Canyon watershed.(63) DDT was likely also used by Laboratory grounds crews and Los Alamos residents until it was banned in 1972.(63)

Various naturally occurring inorganic chemicals (such as barium, cobalt, and manganese) and anthropogenically created fallout radionuclides (including cesium-137, plutonium-239,240, and strontium-90) were concentrated in ash created in the May, 2000 Cerro Grande Fire at levels exceeding that of background sediments before the fire, and the transport of ash has resulted in elevated levels of these materials in post-fire sediment deposits in the canyons.(63) Arsenic, chromium, selenium, and zinc are also higher in post-fire sediment than in pre-fire sediment in some reaches of Los Alamos and Pueblo Canyons, but not in all.(63)

3.6.2 Comparisons of Upriver versus Downriver COI concentrations

To evaluate the impact of LANL-related constituents on the water quality of the Rio Grande near the Buckman Diversion, the COI concentrations detected near Buckman sampling locations were compared to those from sampling locations further upriver on the Rio Grande or on the Rio Chama. Because sampling methods and data sources have changed over time, the comparisons between sampling locations were done differently for different time periods.

3.6.2.1 Data Evaluation

Data from samples collected at 14 sampling locations along the Rio Grande including Buckman (2 sampling locations), Otowi Bridge (6 locations), Espanola (2 locations), and Embudo (2 locations) and along the Rio Chama at Chamita (2 locations). Rio Chama at Chamita is the closest sampling location to the confluence of the Rio Chama and Rio Grande. Table 2-1 lists all of the sampling locations included in this analysis along with their Universal Transvers Mercator (UTM) coordinates and the data provider associated with each location. For the comparisons, these locations were grouped into three sampling location categories: Buckman, Otowi Bridge, and Upriver. The Upriver grouping included the Espanola, Chamita, and Embudo sampling locations.

All of the historical sample analysis results for the locations listed in Table 2-1 were included in this analysis. Because of changes in sampling and analysis methods over time, the sampling locations were evaluated for five different time periods that include: samples collected after 2000; between 1990 and 1999; between 1980 and 1989; between 1970 and 1979; and before 1970. Because samples were collected from the Buckman locations only after 2000, all comparisons performed for the other four time periods were only between the Otowi Bridge and Upriver locations.

For this comparison, the COIs included in the comparisons for each time period were selected based on the following criteria:

- The constituent had to have been measured in at least three samples, as defined by location and sampling date in all of the categories included in the comparisons.
- For the after 2000 sampling time period, a constituent was included if it was detected in at least one sample collected from the Upriver Category and from either the Buckman or Otowi Bridge categories.
- For the other four sampling time periods, a constituent was included if it was detected in at least one sample from the Otowi Bridge and the Upriver categories.

Table 3-14 lists the radionuclides and Table 3-15 lists the chemicals that were included. Overall, the highest number of contaminants included was for the time period after 2000, and the number included in each time period decreased over time. Gross alpha, gross beta, plutonium-238, plutonium-239/240, and tritium were the most consistently included radionuclides, and uranium was the only chemical that was included in more than two time periods.

In general, duplicate samples, samples with LODs greater than the maximum concentration, and negative values for the radionuclides were handled in the same way as the data used to estimate the exposure point concentrations. However, because there were no data available on the MDA for samples included in RACER after 1980, radionuclide samples from the 1970 to 1979 and before 1970 time periods that had negative results were excluded from the comparisons for those time periods.

For this analysis, the data distribution was determined (normal, gamma, lognormal, or unknown) for each data set, and the distributions appropriate regression on order statistics (ROS) method

(10) for the handling of values below the LOD was used. For the ROS method, ProUCL fits a linear regression model of the detected values of the dataset to the assumed distribution and replaces the values below the LOD with values extrapolated from the linear regression. This method is recommended over the more typical substitution methods (i.e., using one-half of the detection limit) for handling data below the LOD. Because the majority of constituent data sets across time periods had lognormal distributions and the other data sets did not fit either a normal, gamma, or lognormal distribution, the lognormal ROS method was used for samples with values below the LOD.

Table 3-14: Results of Kruskal-Wallis or Wilcoxon rank sum tests for significant differences in radionuclide concentration between Buckman, Otowi Bridge, and Upriver locations[a]

Radionuclide	Kruskal-Wallis or Wilcoxon Rank Sum Test p Value by Time Period				
	After 2000	1990 - 1999[b]	1980-1989[b]	1970-1979[b]	Before 1970[b]
Americium-241	0.356[b]	0.457	NA	NA	NA
Cesium-137	NA	NA	0.509	0.41	NA
Gross Alpha	**0.019**	0.167	0.191	0.224	0.145
Gross Beta	**0.029**	0.489	0.527	0.973	0.137
Plutonium-238	0.914[b]	0.075	0.682	0.548	NA
Plutonium-239/240	0.817[b]	0.479	0.463	0.617	0.569
Radium-226	0.121	NA	NA	NA	NA
Radium-228	0.146	NA	NA	NA	NA
Strontium-90	0.078[b]	0.445	NA	NA	NA
Thorium-228	**0.005**	NA	NA	NA	NA
Thorium-230	0.242	NA	NA	NA	NA
Thorium-232	0.073	NA	NA	NA	NA
Tritium	0.134	0.469	0.764	0.958	NA
Uranium-234	0.167	NA	NA	NA	NA
Uranium-235/236	0.479	NA	NA	NA	NA
Uranium-238	0.102	NA	NA	NA	NA

P values in bold indicate a significant difference between at least two of the sampling locations at a 95% confidence level.

a Upriver locations include the Rio Grande at Embudo, Rio Grande at Espanola, and Rio Chama at Chamita.

b Data from the Buckman locations were not available for these radionuclides or for these time periods; thus comparisons are only between Otowi Bridge and Upriver locations using the Wilcoxon Rank Sum test.

Table 3-15: Results of Kruskal-Wallis test for significant differences in chemical concentration between Buckman, Otowi Bridge, and Upriver locations[a]

Chemical	Kruskal-Wallis Test p Value by Time Period				
	After 2000	1990–1999[b]	1980–1989[b]	1970–1979[b]	Before 1970[b]
Acetone	**0.001**[c]	NA	NA	NA	NA
Aluminum	0.277	0.165	NA	NA	NA
Arsenic	0.518	NA	NA	NA	NA
Barium	0.575	0.053	NA	NA	NA
Boron	0.313	0.068	NA	NA	NA
Cadmium	0.208	NA	NA	NA	NA
Chromium	0.601	0.468	NA	NA	NA
Copper	**0.038**	NA	NA	NA	NA
Lead	0.423	0.394	NA	NA	NA
Total PCBs	0.187[c]	NA	NA	NA	NA
Strontium	0.167	0.199	NA	NA	NA
Uranium	**0.04**	**2.04E-04**	0.337	0.453	**0.012**
Vanadium	0.664	0.915	NA	NA	NA
Zinc	0.154	0.668	NA	NA	NA

P values in bold indicate a significant difference between at least two of the sampling locations at a 95% confidence level.

a Upriver locations include the Rio Grande at Embudo, Rio Grande at Espanola, and Rio Chama at Chamita.

c Data form the Upriver locations were not available for this chemical; thus comparisons are only between Buckman and Otowi Bridge locations.

3.6.2.2 Statistical Methods

To evaluate any differences between the three sample locations categories (Buckman, Otowi Bridge, and Upriver) for each of the five time periods, the data for each constituent and sampling location by sampling time period were evaluated graphically using box plots. The box plots for each constituent by sampling time period are presented in Appendix 3B. A box plot is a way of graphically depicting groups of numerical data by displaying the following characteristics: the 5th percentile, which forms the bottom whisker; the 25th percentile, which forms the bottom of the box; median, which is the line shown in the middle of the box; the 75th percentile, which forms the top of the box; and the 95th percentile, which defines the top whisker.(69, 70) Any samples with concentrations less than the 5th percentile or greater than the 95th percentile are shown as asterisks outside the whiskers, and concentrations less than the 2nd percentile or greater than the 98th percentile are shown as circles. Because the majority of these data have lognormal distributions, the y axis of the box plots is in a logarithmic scale.

To determine if there were any statistical differences among the three sampling locations, nonparametric statistical methods for determining differences in the medians between the sampling locations were used. Nonparametric methods were used because several of the data sets had undefined distributions and the majority of contaminants had detection frequencies for some of the sampling locations that were below 50%. The methods used included the Kruskal Wallis test, which is a nonparametric version of a one way analysis of variance and the Wilcoxon Rank Sum test, which is the two sample comparison equivalent of the Kruskal Wallis test (69, 71). The use of rank sum nonparametric methods will help minimize any biases due to differences in the LOD between sampling locations. All testing was performed at a 95% confidence level.

For the data sets in the after 2000 time period that had data for all three sampling locations, the Kruskal-Wallis test was performed. If the Kruskal-Wallis test indicated that at least one pair of sampling locations had medians that were significantly different at a 95% confidence level, the pairwise differences between the three sampling locations were evaluated using the Wilcoxon Rank Sum test with Holm – Bonferroni correction to account for the multiple comparisons.(72, 73) The Wilcoxon Rank Sum test was performed for the data sets in the after 2000 time period that did not have data for all three sampling locations, and for the data sets in the other four time periods.

3.6.2.3 Results

The results of the Kruskal-Wallis and Wilcoxon Rank Sum tests by time period and radionuclide are presented in Table 3-14, and the results for the chemicals are presented in Table 3-15. Only three radionuclides, gross alpha, gross beta, and thorium-228, had at least one significant difference in medians among the three sampling locations ($p<0.05$), and then only for the after

2000 time period. There were no significant differences in the radionuclide concentrations measured at Otowi Bridge compared to the upriver locations for the data collected before 2000. Three chemicals − acetone, copper, and uranium − had at least one significant difference among the three sampling locations for the after 2000 time period. Uranium concentrations were also significantly different for the 1990 -1999 and before 1970 time periods.

Table 3-16 presents the results of the pairwise comparisons for each of these contaminants for the time periods when significant differences occurred. Table 3-17 presents the number of samples, detection frequency, median, 5th percentile, and 95th percentile of the constituent data by sampling location and time. For gross alpha in the after 2000 time period, the only significant pairwise difference is between the Buckman and upriver locations. However, based on the box plot for gross alpha, the concentrations of gross alpha appear to be increasing downstream of the upriver location with a median at the upriver locations of 2.5, at the Otowi Bridge location of 4.0, and at the Buckman location of 4.8 pCi/L. While not significant, the p value for the comparison between the Otowi Bridge and upriver locations is 0.073, which is fairly close to 0.05.

For gross beta, the only significant pairwise difference is between the Otowi Bridge and the upriver locations (p=0.021). Based on the box plots for this constituent in the after 2000 time period, the Otowi Bridge gross beta concentrations appear higher than those at Buckman and at the other upriver locations. Thorium-228 shows a pattern similar to gross beta, but with a higher median concentration for the Otowi Bridge location than either the Buckman or upriver locations. For thorium-228, the significant differences are between Buckman and the upriver locations (p=0.04) and between Otowi Bridge and upriver locations (p=0.002).

For acetone, there were no detections of acetone at the upriver locations in the after 2000 time period, so there was only one comparison between the Buckman and the Otowi Bridge locations. Based on the Wilcoxon Rank Sum test, acetone concentrations are significantly different between the Buckman and Otowi Bridge locations (p=0.001). Based on the box plot, the median acetone concentration at the Otowi Bridge location (3.7 µg/L) is higher than that at Buckman (1.8 µg/L). However, the detection frequencies for these two locations for acetone are fairly low: 30% for Buckman, and 41% for Otowi Bridge.

For copper, the only significant difference is between the Buckman and Otowi Bridge locations (p=0.01). Based on the box plots, the median copper concentration at Otowi Bridge (5.5 µg/L) is higher than the median at Buckman (2.7 µg/L).

Table 3-16: Results of pairwise comparisons of radionuclide and chemical concentrations between Buckman, Otowi Bridge, and Upriver locations[a] for radionuclides and chemicals that had significant differences based on the Kruskal Wallis Test

	Holm-Bonferroni Corrected Wilcoxon Rank Sum p value by Pairwise Comparison		
Radionuclide/Chemical	Buckman versus Otowi Bridge	Buckman versus Upriver	Otowi Bridge versus Upriver
Gross Alpha	0.156	0.021	0.073
Gross Beta	0.456	0.156	0.021
Thorium-228	0.242	0.04	0.002
Copper	0.01	0.484	0.467
Uranium	0.697	0.013	0.024

P values in bold indicate a significant difference between at least two of the sampling locations at a 95% confidence level.

a Upriver locations include the Rio Grande at Embudo, Rio Grande at Espanola, and Rio Chama at Chamita.

Table 3-17: Summary of radionuclide and chemical concentrations between Buckman, Otowi Bridge, and Upriver locations for radionuclides and chemicals that had significant differences based on the statistical tests

Radionuclide/ Chemical	Sampling Period	Buckman					Otowi Bridge					Upriver				
		N	Detection Frequency	Median	5th Percentile	95th Percentile	N	Detection Frequency	Median	5th Percentile	95th Percentile	N	Detection Frequency	Median	5th Percentile	95th Percentile
Gross Alpha	After 2000	12	92%	4.8	1.6	26	19	79%	4.0	0.80	56	13	69%	2.5	0.80	8.9
Gross Beta	After 2000	11	91%	5.5	0.87	24	22	96%	6.7	0.92	281	13	92%	4.3	0.70	13
Th-228	After 2000	7	57%	0.05	0.006	0.28	16	81%	0.19	0.006	30	6	17%	0.006	0.006	0.059
Acetone	After 2000	10	30%	1.8	1.1	3.4	17	41%	3.7	1.6	10	NA	NA	NA	NA	NA
Copper	After 2000	11	36%	2.7	0.76	8.8	16	63%	5.5	1.1	161	3	67%	2.3	1.3	12
Uranium	After 2000	11	100%	2.4	1.4	3.8	15	100%	2.2	1.0	13	3	67%	0.77	0.53	1.3
Uranium	1990 - 1999	NA	NA	NA	NA	NA	16	100%	2.5	1.0	3.4	21	95%	1.2	0.70	2.5
Uranium	Before 1970	NA	NA	NA	NA	NA	16	76%	2.6	0.55	4.7	21	68%	1.4	0.30	6.4

NA: Data were not included for this sampling location and period due to either lack of samples or lack of detected concentrations.

For uranium, there are significant differences between the Buckman and upriver locations (p=0.013) and the Otowi Bridge and upriver locations (p=0.024) for the after 2000 time period, but no significant differences between the Buckman and Otowi Bridge locations (p=0.697). The median uranium concentrations for Buckman (2.4 µg/L) and Otowi Bridge (2.2 µg/L) are similar compared to the median concentration for the upriver locations (1.2 µg/L). This trend continues for the 1990 – 1999 time period for which the median concentration at Otowi Bridge (2.5 µg/L) is significantly different than that at the upriver locations (1.2 µg/L) at a 95% confidence level (p=0.0002). For the 1980 – 1989 and 1970 – 1979 time periods, there were no significant differences in median uranium concentration between Otowi Bridge and the upriver locations. The differences in concentration between the two locations appear again in the before 1970 time period (p=0.012) with the median concentration at Otowi Bridge of 2.6 µg/L and at the upriver locations of 1.4 µg/L.

In general, the majority of COIs measured at the Buckman locations are present at concentrations that are not significantly different than regional background levels measured upriver at the Espanola, Embudo, and Chamita sampling locations. The radionuclide COIs that are due to background sources based on this comparison include: americium-241, plutonium-238, plutonium-239/240, radium-226, radium-228, strontium-90, thorium-230, thorium-232, tritium, uranium-234, uranium-235/236, and uranium-238. The chemical COIs that are present at the Buckman diversion or Otowi Bridge locations at concentrations not significantly different than the upriver locations include: aluminum, arsenic, barium, boron, cadmium, chromium, lead, total PCBs, strontium, vanadium, and zinc.

In addition, several COIs with significant differences between the Buckman diversion, Otowi Bridge, and upriver locations show a significant decrease in concentration at the Buckman diversion or Otowi Bridge relative to the upriver samples. These COIs include: gross beta, thorium-228, acetone, and copper. This decrease indicates that these COIs are present below regional background levels.

Only gross alpha concentration in samples collected after 2000 at the Buckman diversion and Otowi Bridge locations and the uranium concentrations at the Buckman diversion and Otowi Bridge for several time periods including samples collected after 2000 are significantly higher than those found at the upriver locations. However, gross alpha and uranium concentrations at the Buckman diversion location are not significantly different than those at Otowi Bridge. This comparison indicates, then, that under baseflow conditions, there are no COIs that are above regional background levels.

3.6.3 Analyses of COI Compositions or Isotopic Ratios

The process of Thermal Ionization Mass Spectroscopy (TIMS) allows for the quantification of the isotopic composition of the plutonium present in environmental samples by measuring the relative abundance of atoms for the isotopes plutonium 240 and plutonium 239. The plutonium 240:239 atom ratio can be used to distinguish the components of global fallout and plutonium of LANL origin by comparing the ratios to the one for global fallout of 0.18 and the range for weapons production of 0.01 – 0.07.(74) The procedures for TIMS analysis of plutonium were developed by the Los Alamos Clean Chemistry and Mass Spectroscopy Laboratory, and has been applied by NMED in their characterization of distribution of radionuclides in sediments in the northern Rio Grande.(74)

Table 3-18: Results of TIMS analyses of Rio Grande sediments

Station Description	^{240}Pu:^{239}Pu Atom Ratio	LANL Component (%)
Santa Clara		
5–31 cm (hand augured)	0.16	5
Canada Ancha		
0–31 cm (hand augured)	0.21	0
101–110 cm (hand augured)	0.09	39
162–186 cm (hand augured)	0.09	38
213–229 cm (hand augured)	0.02	99
Pajarito		
31–46 cm (hand augured)	0.12	24
Water		
0–31 cm (outcrop A)	0.11	29
91–101 cm (outcrop A)	0.15	8
Frijoles		
31–61 cm (hand augured)	0.08	47
122–152 (hand augured)	0.13	18

These results indicate that directly downstream of Los Alamos Canyon at Canada Ancha near the BDD the impact of the transport of LANL-contaminated sediment from Los Alamos Canyon is minimal in the surface sediments, but that the contribution from LANL does increase with depth. Based on these data, the main source of Pu-239/240 near the BDD under current conditions is most likely from global fallout, rather than from LANL, while the contributions from LANL in the past were much higher than they are currently.

4.0 REVIEW OF PLUTONIUM DISCHARGE TO AND LOSS FROM LANL CANYONS: 1943 TO PRESENT

The IPR team was tasked with examining publications that have estimated the history, inventory, and movement of plutonium released to the LANL canyons, and the fate of that plutonium in the Rio Grande. Plutonium released to the canyons is bound to sediments by chemical and physical processes. Little plutonium is transported as material dissolved in water; it is transported by flowing water moving contaminated sediments from the canyons to the Rio Grande. Research has been conducted to answer questions regarding the concentration, inventory, and ultimate fate of plutonium on sediments in the LACW, and the Rio Grande, for several decades. This section reviews that work with the objective of summarizing the body of work and identifying uncertainties in the two key components of LANL plutonium fate, sediment plutonium inventory, and sediment transport.

4.1 PLUTONIUM INVENTORY IN SEDIMENTS

The concentration of plutonium (plutonium-239/240) in sediments is very important, but is only part of the picture of plutonium at LANL and in the Rio Grande. The plutonium inventory, which includes the total mass of plutonium bound to sediments and its location, is critical to understanding the risk from plutonium. Plutonium inventory, when combined with hydrologic and erosion analysis tools and appropriate field data can be used to predict past and future discharges of plutonium to the Rio Grande.

The amount of plutonium released in the past to Los Alamos and Pueblo canyons is not well known. One starting point for estimating inventory could be the amount of plutonium released to the canyons in the period 1945 through the mid 1980s, but the value is highly uncertain.(75) The greatest plutonium release to Pueblo Canyon is known to have taken place from TA-45 as untreated liquid discharge over the period 1943 through 1950.(76) This initial period of TA-45 operation also has the greatest uncertainty in the amount of plutonium discharged because discharge volumes and radioisotope concentrations were not measured. From 1951 through 1964, TA-45 discharge was gauged and treated and plutonium concentration was measured, decreasing uncertainty for that time period. Discharge from TA-45 ended in 1964.

In Upper Los Alamos Canyon, TA-1 and TA-21 were responsible for the additional plutonium discharges.(76) TA-1 discharged an unknown amount of plutonium from the mid 1940s to the mid 1950’s to Upper Los Alamos Canyon. TA-21 discharged treated effluent containing plutonium from 1965 to 1985 to DP Canyon, flowing to Los Alamos Canyon. Sediment sampling indicates that TA-1 is responsible for most of the plutonium contamination in Upper Los Alamos Canyon. Overall, TA-45 was the source for most all of the plutonium-239/240 discharged to the Los Alamos-Pueblo Canyon watershed and Lower Los Alamos Canyon. TA-1 and TA-21 made lesser, but significant, contributions solely to Los Alamos Canyon.

The current inventory of plutonium in Los Alamos sediments depends on how much plutonium was released to the sediments in wastewater discharge, and on the quantity and timing of sediment transport out of the canyons by snowmelt and storm flow. The storm-driven discharge of contaminated sediment to the Rio Grande has been measured on only a few occasions in the 65 years of laboratory operations. Discharge events that reach the Rio Grande are infrequent on an annual basis, but are not known completely because of infrequent historical monitoring. The loss rate for contaminated sediments from the canyons is known imprecisely; quoting Reneau (1998):(76) “The largest uncertainty concerning the transport of contaminated sediments in the Los Alamos Canyon watershed is the actual sediment transport rate…” Estimates of plutonium release or inventory rely on assumptions with varying degrees of empirical support. Investigations made by Reneau and others since that time(77-79) have extended the understanding of sediment transport at LANL, greatly reducing the uncertainty in contaminated sediment transport. New observations tend to conflict with older assumptions.

Estimates of plutonium inventory have been made by two methods. The first method maps location and volumes of river geomorphological components, and samples the sediment for plutonium concentration to calculate an inventory. The second method uses various sediment transport models to predict the transport of plutonium based on estimated releases, and compares the modeled concentrations to observed sediment plutonium concentrations. If the match between observed and predicted concentrations is good, the model may be suitable for inventory estimation. Sediment transport models generally include a way to estimate transported sediment mass, or inflow and outflow, over a selected reach. The product of modeled sediment mass and the modeled or the observed plutonium concentration is the modeled plutonium inventory. Table 4-1 summarizes the published inventories for plutonium in Los Alamos sediments and the method of determination. If an estimate of input concentration was used to estimate inventory, it is included in Table 4-1. Without considering the influence of global fallout on plutonium concentration or inventory, the amount of plutonium transported to the Rio Grande is obtained by subtracting the current inventory from the total amount of plutonium discharged to the Los Alamos Canyon watershed.

The variation in calculated sediment inventories is high when the oldest estimates are compared to the most recent inventories. As investigations have progressed, sampling out-of-the-active channel sediments has increased. With more extensive sampling, the inventory has also increased. Given the detail of the most recent post-Cerro Grande investigations, it is unlikely that these latest estimates are low. Additionally, the full inventory of contaminants at depth in the sediments has yet to be determined.(79)

Table 4-1: Plutonium-239/240 inventories in Los Alamos watershed sediments (mCi)

Author(s)	Inventory Date	Upper Los Alamos Reaches LA-1, LA-2, LA-3	Pueblo Canyon Inventory Reaches P-1, P-2, P-3, P-4	Lower Los Alamos Canyon Reaches LA-4, LA-5	Total Inventory - Los Alamos Canyon Watershed	Plutonium in Wastewater Release Estimate
Stoker et al. 1981(80)	: ThNE	NE NE	595.2[a] 235.2[b]	35.8[a] 9.83[b]	631 ± 298[a] 246[b]	170
Lane et al. 1985(75)	1980	1.24-1.24	85.78-439.19	19.15-183.47	106.17-624.24	150-3000
Graf 1993, 1994(81, 82)	NA	NE	NE	NE	NE	196.2-4546.2
Graf 1996(83)	1993	2	818	180	1000	1000
Reneau et al. 1998(84-86)	1998	21.94	407.9	27.73	429.84	
Reneau et al. 2004(87)	2000	NE	1075	NE	1075+	NE

[a] Arithmetic mean

[b] Geometric mean

NE - Not Estimated

NA - Not Applicable

The most likely inventory in Pueblo Canyon appears to be greater than 1000 mCi. The inventory in Upper and Lower Los Alamos Canyon is probably two orders of magnitude lower. Lane's model(75) shows a loss to the Rio Grande of 20-80% of the estimated values for total LANL plutonium input to the system, highest losses occurring with highest inputs (Table 4-1). Graf's 1996 best-fit model of Pueblo Canyon streambed sediment concentrations is matched to a plutonium input of 100 Mg of sediment at a concentration of 10,000 fCi/g, indicating a total input of 1000 mCi of plutonium. Graf's 1996 estimates of total inventory based on field measurements match his suggested total input to the system (1000 mCi), implying no loss to the Rio Grande. The closeness of Graf's 1996 inventory estimate to that of Reneau's for 2000 indicates that Graf's Riverine Accounting and Transport (RAT) model is probably not a reliable predictor of sediment transport in the ephemeral LANL canyons.

4.2 SELECT HISTORY OF INVESTIGATIONS

The transport of plutonium contaminated sediment at LANL was first noted in 1946 over 11 km, the full length of Pueblo Canyon.(77) Within a few years of plutonium discharge to Acid Canyon, sediment transport processes began to move plutonium to the Rio Grande. The rapid transport of contaminated sediments away from discharge locations was cited as the reason that radiologic hot spots did not develop in the canyons.(88) The importance of sediment transport processes for distributing plutonium was cited through the 1970s and 80s, particularly the importance of clays and clay-sized particles, which retain more plutonium by weight than do larger, coarser-grained stream sediments.(88-91) Because plutonium is strongly associated with soil and sediment, and degrades little on a human time-scale, detailed understanding of the nature of erosion, deposition, and sediment transport in streams, rivers and reservoirs in Northern New Mexico is critical to understanding where the LANL plutonium has gone, and where it remains. Because of that interest, detailed evaluation of the climatic, hydrologic, and geomorphic controls on sediment-bound plutonium transport from the discharges to the Rio Grande began at LANL.

Scientific examination and publication regarding sediment transport processes in the sporadically-flowing canyons of Los Alamos spans over forty years. The study of storm flow in ephemeral canyons is difficult, because, by definition, these canyons do not flow constantly, and they have wide ranges in characteristics for individual flood events. Ephemerally flowing canyons are the source of the flash floods of southwestern and cowboy lore. LANL canyons are the subject of much study because of the plutonium, and much of the sediment science effort is possible because of the presence of the plutonium itself. Plutonium-contaminated sediments act as a tracer for stream sediment movement and measurement of dilution by uncontaminated sediments. The tracer is not perfect; plutonium inputs to the system from global fallout complicate interpretation, and recently developed specialized methods are needed to sort out fallout plutonium from LANL plutonium.

It is a principle of science to use simplifying assumptions when there are insufficient data, understanding, or no need to robustly support a complex evaluation. It is also a principle that science builds on previous work, refining, refuting, and adding detail to topics that are the subjects of continuing study. Forty years of sediment transport evaluation in Los Alamos canyon reflects both of those scientific processes. Often in science there is a political or social trigger event that focuses resources and talent on solving a particular problem. It was just such a trigger event that brought about the heightened interest in sediment transport at Los Alamos: the Cerro Grande Fire of 2000.(92) The fire greatly altered the hydrology of the Los Alamos Canyon watershed, with post fire erosion, flooding, and increased contaminant transport expected. Physical modifications to the watershed, such as dams and siltation basins, were undertaken in 2000-2003 with some efforts continuing to this day. The watershed was instrumented with flow gauging, meteorology, and automated streamflow samplers. Special studies regarding sediment transport were undertaken by LANL, NMED, and the USGS. The detailed and extensive data collection effort post-Cerro Grande filled data gaps and resolved some of the assumptions held and questions raised by earlier researchers.

Early quantitative evaluations from field-based studies of radioisotopes in stream sediments and storm flow are represented by:

- Select publications by William D. Purtymun (with others) from 1966 through 1990;
- A plutonium in sediment inventory resulting from sampling and grain-size analysis;(91)
- A general modeling approach for contaminated sediment transport advanced by Leonard J. Lane (with others) in 1985; and,
- Integration of historic, geomorphologic, hydrologic, and climatic factors (among others) into a unified understanding of plutonium transport in the LANL canyons and the Rio Grande by William L. Graf.(49, 93, 94)

Following Graf’s series of publications, LANL continued more detailed investigations of plutonium in sediments in the Los Alamos and Pueblo Canyons, since the early publications revealed uncertainties just as as they resolved problems. The geomorphic approach to classifying sediments and channel features demonstrated by Graf to locate LANL contaminated sediments in the Rio Grande was extended to Pueblo and Los Alamos canyons by Reneau with others,(76, 95, 96) and new contaminated sediment inventories were calculated. These were the last major detailed publications on sediment transport and inventory in Los Alamos and Pueblo canyons (exclusive of annual LANL-wide Environmental Surveillance Reports) prior to the Cerro Grande fire.

4.3 SIGNIFICANT ASSUMPTIONS IN EARLY WORK

All scientific work relies on assumptions to some degree. The early work on sediment transport at Los Alamos and in the Rio Grande had to make numerous assumptions in order to accomplish meaningful studies. The objective here is not to explore all of the assumptions used in the early work; instead, we examine certain key assumptions that are common to the work of early investigators in light of contemporaneous and later publications, present the differences, and draw inferences from the differences. The selected key assumptions common to early work are:

- Only sediments smaller than 0.0625 mm are rapidly transported as suspended flow.
- Canyon bed load sediments are coarse sediment particles greater than 0.0625 mm that merge with the slowly transportable Rio Grande bed load.
- The highest plutonium concentrations are found in fine-grained sediments, but coarse sediments hold the majority of the inventory of plutonium.
- A few large storms are responsible for most of the sediment transport in the Los Alamos Canyon watershed.
- All sediment contributions to suspended and bed load sediment transport come from within the canyon channels.

Each of these assumptions is addressed individually below.

4.3.1 Only Sediments Smaller than 0.0625 mm are Rapidly Transported as Suspended Flow

It is generally understood that the smallest particles of sediment are transported the farthest and easiest by water. This phenomenon is reflected in the grade-school experiment in which dirt is shaken with water in a jar, and students then observe that large particles settle quickly, while the finest particles of clay remain suspended in the water for hours to days. Earth scientists have classified sediments into fractions based on size (Table 4-2). The observation that plutonium concentrations in silt and clay size fractions were markedly higher, and the knowledge that they were easily transportable, resulted in many investigators relying on the assumption that the suspended sediment was composed only of silt and clay sized particles.

Table 4-2: Grain size classification under the Udden-Wentworth System

Name	Size Range (mm)
Granules- Fine Gravel	2–4
Very Coarse Sand	1–2
Coarse Sand	0.5–1
Medium Sand	0.25–0.5
Fine Sand	0.125–0.250
Very Fine Sand	0.0625–0.125
Silt and Clay	≤0.0625

In 1971, Purtymun stated that with respect to size analysis of 63 samples of stream channel alluvium "the silt and clay size fraction makes up about 5% of the channel alluvium and is subject to suspended transport by storm runoff, which leaves the coarse materials behind to move at a slower rate as bed material".(89) Purtymun noted a quandary(90) concerning the suspended sediments, in that they are composed "mostly of the silt- and clay-sized fractions," even though there are "only small amounts of silt and clay" in the channel sediments. Table I from this report reveals that the average of five suspended sediment samples had 65% of the particles larger than 0.062 mm, with 6% of the suspended sediment being very coarse sand (1-2 mm). This conflicting information was presented without explanation. The 1981 study by Stoker suggests that the transportable "fine" sediments are composed of clay, silt, very fine and fine sand sizes. Stoker uses a different sediment classification scheme than the one in Table 4-2, with slightly larger grain sizes in each class (i.e., very coarse sand is 1.17-2.36 mm for Stoker, vs. the 1-2 mm in the Udden-Wentworth system).

Currently, sediment transport fractions are commonly divided into suspended load, and bed load components. Bed load is the material that is moved along a river bed by rolling and pushing (traction load), and saltation, usually at a velocity much less than that of the river. Bed load is usually composed of sands and pebbles, but when the water level is high and the current strong, boulders may be moved. Suspended load is when fluid forces that tend to keep particles in solution are strong enough to overcome gravitational forces that are trying to settle the particle out of water. There is a transitional zone in which material is moving between suspended and bed load. In reality, there are not sharp divisions between suspended load and bed load, and materials that are suspended can rapidly become part of the bed load as stream conditions change. Wash load is material that is washed into the stream channel by runoff.

The need for sharp divisions between bed load and suspended load is largely for conceptual reasons, but does help reduce the complexity of sediment transport calculations. As such, the 1985 sediment transport modeling effort(75) made a sharp division at 0.063 mm between suspended load and bed load. Graf uses the same numerical cut-off value when describing suspended and bed load in the canyons and the Rio Grande.(49, 97) In Graf's RAT model conceptualization of plutonium transport(49, 97) suspended load sediments are also <0.063 mm, are not considered by the model in calculating plutonium transport, and all sediments >0.063 mm are solely bed load.

More recent work in the LANL canyons has recognized that sediment fractions to 0.5 mm are commonly transported as suspended load. (76-79, 95, 96) Early observations in DP canyon found coarse sands transported as suspended sediments(90) at flows lower than 4.2 cfs, a very moderate discharge rate for an ephemeral stream in stormflow. Later studies of snowmelt driven runoff found that very fine sand was common at moderate flows from 0.5 to 6.2 cfs.(98) Using a 0.063 mm size cut off for suspended sediments in Los Alamos canyons is not well supported. The result of selecting this cut off is that rapid transport of coarse sediments is not considered, and that early sediment transport models are based on the assumption that coarse sediment inventories are not depleted by channel scour and suspended transport.

4.3.2 Canyon Bed Load Sediments are Coarse Sediment Particles Greater than 0.0625 mm that Merge with the Slowly Transportable Rio Grande Bed Load

It follows from the discussion above that "coarse" sediments defined as bed load for the Los Alamos watershed in early studies have been, and continue to be, transportable as suspended sediments,(78, 79) meaning that some coarse grained sediments can be transported to the Rio Grande from the Los Alamos watershed as suspended sediments in addition to bed load. There have been questions as to the fate of coarse sediments in the Rio Grande. Graf is the only early pre-Cerro Grande investigator to address sediment transport in the Rio Grande at Otowi. In his 1993 and 1994 works he states that "bed load sediments are sand and gravel in the Rio Grande (sand with particle diameters between 63 microns and 2 mm, gravel greater than 2 mm). They bounce, roll, and creep along the bed at the base of the flow. At flood discharges, the larger amounts of energy available permit the transport of sand in suspension."(93,94) Much of Graf's discussion of transport in the Rio Grande is based on this assumed condition-- that only flood flow will transport sediments with a particle size greater than 0.063 mm in the suspended load.

The USGS conducted extensive studies on sediment transport in the 1950s and 1960s. Publications in its professional paper series included work on the Rio Grande. From 1958 through 1962, the USGS collected suspended sediment samples from the Otowi Gage on the Rio Grande.(99) The work determined that substantial amounts of sand size fractions are transported at moderate flows at Otowi. The 53-year flow record at Otowi indicates that the 50% occurrence rate flow (one half of flows are higher than this number, one half are less) is about 900 cfs. Grain-size analysis of suspended sediment at 1000 cfs discharge was near 25% coarse sand. These findings indicate that moderate discharge in the Otowi reach has transported significant volumes of sand in the suspended load, in the time period where the greatest flux and concentration of plutonium was moving to the Rio Grande.

Another USGS study in the same series looked at vertical distribution of suspended sediment in the Rio Grande at Bernalillo, Bernardo, and Socorro,(100) and found that medium sand was suspended in flow at a range of flow rates and channel geometries. These studies far to the south are important because they demonstrate that a decade before the closure of Cochiti Reservoir, slowly transportable bed load sediments as defined by Graf are, in reality, rapidly transportable suspended sediments as confirmed by observation. It is probable that Graf's analysis of contaminated sediment transport in the Rio Grande has underestimated the mobility of "coarse" sediments. Coarse sediment mobility also explains why surveillance sampling rarely detected a LANL signature in Rio Grande bed load samples. Sediments to 1.0 mm are rapidly transported by moderate flows in the Rio Grande; bed load contamination in the Rio Grande was not detected because Los Alamos 'bed load' is suspended and transported away on introduction to the river, or by the next moderate increase in flow.

4.3.3 The Highest Plutonium Concentrations are Found in Fine Sediments, But Coarse Sediments Hold the Majority of the Plutonium Inventory

This assumption has been a central theme for all but the most recent investigations into contaminated sediment transport and contaminant inventory. As sampling activities in Pueblo Canyon have expanded, more and more flood plain samples have been obtained. Floodplains contain more silt and clay than channel deposits, and all post-1942 floodplains downstream of outfalls are contaminated with plutonium. Additional investigation has resulted in more accurate assessment of contaminant distributions, greatly increasing the inventory in upper Pueblo Canyon over previous investigations.(78) Contaminated coarse sediments still dominate the lower reaches of Pueblo Canyon, but, overall, 61% of the plutonium is in the fine sediments.(78) Revision in sediment distribution and transport characteristics may require a revision in risk perception. Early models indicated that risk was low, because most of the plutonium mass was in coarse sediments, which transport more slowly. The current model posits that coarse sediments transport more rapidly than previously assumed, and more of the plutonium mass is in easily transportable fine sediments than was previously believed.

4.3.4 A Few Large Storms are Responsible for Most of the Sediment Transport in the Los Alamos Canyon Watershed

General principles hold that the amount of sediment discharge for a stream increases non-linearly with discharge, equal increases in discharge produce ever larger amounts of sediment, and large storms happen less often than small ones. A more accurate estimate of sediment load as proportional to discharge measures these parameters and determines which storms are most efficient at transporting sediment. Early sediment transport calculations assume the first principles are true; testing of these assumptions could not realistically be undertaken without the presence of the post-Cerro Grande watershed instrumentation and data processing. Recent workers have determined that, on the scale of decades, events that occur at least once a year are responsible for 70% of the sediment transport, and events with a reoccurrence period of 10 years or more are responsible for less than 5% of the sediment transport.(78)

Graf's approach to sediment transport during the period of greatest release of plutonium to the canyons was based on the timing of large flood events on the plateau. New information on the importance of less extreme events to sediment transport suggests that plutonium transport in the canyons and to the Rio Grande in the mid 1940s through the early 1960s would be greater than estimated using only "floods." Removal of much larger amounts of contaminated sediments from LANL during this period would mean that total releases would need to be on the high end of the range found in Table 4-1 to accommodate known inventory and post-Cerro Grande measured sediment and plutonium transport rates.(74, 101, 102)

4.3.5 All Sediment Contributions to Suspended and Bed Load Sediment Transport Come from Within the Canyon Channels

Prior to post-Cerro Grande research activities, the source of all of the fine sediment found in canyon storm flow and runoff was believed to be derived from erosion and weathering of the canyon materials themselves. Observations following the fire noted substantial components of fine sediments brought into the canyons by the overland flow called the wash load.(78) Prior work had made no allowances for wash load contributions to suspended sediments from mesa and highland erosion. It is uncertain if this neglect of the wash load would have measurable impacts on plutonium transport calculations prior to the fire, but it is probably quite important to account for this portion of the sediment budget moving forward.

4.4 SUMMARY

Investigations into plutonium transport on sediments contaminated by wastewater discharge at LANL have been ongoing since 1946. In the 1960s through the 1990s evaluation of sediment-bound plutonium transport on and off LANL property relied on a number of assumptions that were necessarily employed because available data limited the methods that could be employed, and uncertainty was high. Because of the intensity and breadth of sediment transport and contaminant inventory investigations conducted after the Cerro Grande fire, many of the assumptions used in the past have been replaced with more precise, less uncertain methods and knowledge. Evaluation of the assumptions used in the past indicates that pre-Cerro Grande investigations:

- Underestimated the contaminant inventory remaining on site;
- Underestimated the amount of contaminated sediment transported to the Rio Grande; and,
- Underestimated the amount and rate of contaminated sediment transport down the Rio Grande.

5.0 HUMAN HEALTH RISK ASSESSMENT

5.1 EXPOSURE ASSESSMENT

Exposure assessment is the process of estimating the magnitude, frequency, and duration of human exposure to a chemical or radionuclides in the environment. This process considers the nature and size of potential 'receptor populations' (that is, persons of interest who may come into contact with an agent), and the uncertainties associated with each variable.(103) Accordingly, this section describes the ways in which Santa Fe residents may utilize tap water, and the plausible pathways by which they may be exposed to chemicals and radionuclides present in their tap water. It is important to point out that while the exposures evaluated here are hypothetical (that is, the EPCs are not actual water concentrations measured at the tap), they do represent reasonable estimates of exposure in the absence of true tap water data.

The exposure assessment has been conducted in accordance with USEPA exposure and risk assessment guidance.(11, 16, 104-109) Additionally, consideration was given for site-specific residential concerns, as they were applicable to USEPA risk assessment (public meetings). While there are fundamental differences in the way that chemical and radionuclide exposures are expressed, the general exposure assessment approach below is used for both chemicals and radionuclides:(16)

1. Characterize Potential Exposures
    a. Identify Potential Exposure Pathways
    b. Identify Potential Exposure Populations
2. Estimate Exposure Concentrations
3. Quantify Exposures

5.1.1 Identification of Relevant Exposure Pathways- Chemicals

The USEPA defines chemical exposure as "contact between an agent and the visible exterior of a person (e.g., skin and openings into the body)."(110) Although several potential pathways may exist, usually not all are complete. In order for a chemical exposure pathway to be complete, the following conditions must exist:

- There must be a source and a mechanism of chemical release to the environment;
- There must be an environmental transport medium (such as air or water);
- There must be a point of human contact with the medium; and
- There must be an exposure route at the contact point (such as inhalation, ingestion, or absorption).

In accordance with USEPA guidance, exposure estimates were quantified for central tendency (CT) and reasonable maximum exposures (RME) in order to provide a range of potential exposure estimates.(111)

Exposure pathways can be determined by environmental conditions (such as location of media), by the potential for an agent to transfer from one environmental medium to another (such as from tap water to homegrown vegetables), and by the general activities of the potentially exposed population (such as amount of water ingested and frequency of an activity). Each pathway describes a unique mechanism by which a population or an individual may be exposed.

Various potentially complete exposure pathways were considered for this evaluation; however, specific focus is on those pathways that are expected to be both complete and relevant with respect to potential tap water-related human exposures. Primary residential exposures are those involving direct contact with tap water. Such pathways include tap water ingestion and dermal contact via hand washing, bathing, or swimming.

Additionally, secondary exposures may occur when contaminants are transported from tap water to a second exposure medium. There are two physical processes by which the COIs could be transported from tap water to other relevant exposure media: 1) uptake into locally grown produce, and 2) volatilization or aerosolization into air. As such, secondary exposures to chemicals from tap water can occur via consumption of homegrown (or locally grown) produce if agents are transferred to plants that are watered with tap water. If an agent volatilizes from tap water or is aerosolized to a significant degree, then inhalation can also be a plausible exposure pathway.

Table 5-1 below summarizes the complete and relevant exposure pathways for the chemical COIs considered in this analysis. Regardless of whether a pathway is considered primary or secondary, each of these exposure pathways constitute a complete exposure pathway that is evaluated in the chemical risk evaluation.

The following exposure pathways are most likely to be associated with infrequent or minimal levels of human exposure, and were therefore not quantified in this analysis:

- Irrigation/sprinklers
- Household washing
- Washing bicycle or car
- Bathing children outside of a bathtub
- Firefighting

Table 5-1: Exposure pathways evaluated for chemicals

Residential Tap Water Uses Considered	Potential Exposure Pathway	Complete Exposure Pathway? Volatile Chemicals[a]	Complete Exposure Pathway? Non-Volatile Chemicals	Relevant age Groups
Tap water as drinking water (includes cooking with tap water)	Ingestion	✓	✓	All
Watering home- or locally grown produce	Ingestion	✓	✓	> 1 year
Taking a bath	Inhalation	✓	--	All
	Dermal uptake	✓	✓	
Showering	Inhalation	✓	✓	All[a,b]
	Dermal uptake	✓	✓	
Hand washing	Dermal uptake	✓	✓	> 1 year
Swimming and/or hot tub use	Inhalation	✓	--	All[c]
	Dermal uptake	✓	✓	

[a] Five of the 42 COIs are considered volatile: acetone, chloromethane, cyanide, mercury and methyl ethyl ketone.

[b] Children under the age of six typically take baths rather than showers; therefore only the RME shower scenario is evaluated for this age group.

[c] Although children under the age of one are not expected to swim frequently, they were conservatively evaluated in this assessment.

✓ Pathway is complete.

-- Pathway is not complete.

In utero or early postnatal exposure scenarios are not explicitly quantified in this assessment. However, for those COIs for which the sensitive non-carcinogenic health endpoint is based on reproductive or developmental effects, an *in utero* exposure scenario is intrinsically evaluated within the residential risk assessment. This is because there are various layers of safety built into the risk assessment process. It is a goal of the USEPA to develop non-carcinogenic toxicity criteria (RfDs and RfCs) that are protective of all known health endpoints for a particular chemical, and that are not expected to cause any adverse effects, even in the most susceptible sub-populations. Therefore, USEPA toxicity criteria represent health-protective exposure levels that are much lower than the levels at which an adverse health effect was first observed in an animal study, or lower than the levels that caused no adverse effect at all.

In utero exposures are most often evaluated for reproductive and/or developmental effects. While not all chemicals are known to cause reproductive or developmental effects, for those COIs for which the sensitive non-carcinogenic health endpoint is based on reproductive or developmental effects, an *in utero* exposure scenario is intrinsically evaluated within the residential risk assessment. For chemicals associated with potential reproductive or developmental effects, but for which a different health endpoint was determined to be more sensitive, the resultant toxicity criteria are inherently protective of effects associated with *in utero* exposures.

5.1.2 Identification of Relevant Exposure Pathways- Radionuclides

While potential exposures to radionuclides are generally similar to those for chemicals, differences in exposure between the two agents exist due to physical-chemical behavior differences.

Radiation exposure can occur via "internal exposure," which involves the intake of a radionuclide via ingestion or inhalation. However, dermal absorption is generally not a significant exposure pathway for radionuclides, and is typically not considered in radiological risk assessments.(16) Dissimilar to chemical exposures, however, exposure to radiation may also occur from immersion in a medium containing radioactive materials (such as immersion in water), or from being in the proximity of a medium that contains a radionuclide. Exposure pathways evaluated for radionuclides are identified in Table 5-2.

Table 5-2: Exposure pathways evaluated for radionuclides

Residential Tap Water Uses Considered	Potential Exposure (Type/Pathway)	Complete Exposure Pathway?	Relevant Age Groups
Tap water as drinking water (includes cooking with tap water)	Internal/Ingestion	✓	All
Watering home- or locally grown produce	Internal/Ingestion	✓	> 1 year
Taking a bath	Internal/ Inhalation	✓ [a]	All
	External Exposure	✓	
Showering	Internal/ Inhalation	✓	All[b]
	External Exposure	✓	
Hand washing	--	--	--
Swimming and/or hot tub use	Internal/ Inhalation	✓ [a]	> 1 year
	External Exposure	✓	

[a] Of the 17 radionuclides of interest, only tritium is considered to be volatile, and is evaluated as such.

[b] Children under the age of six typically take baths rather than showers; therefore only the RME shower scenario is evaluated for this age group.

✓ Pathway is complete.

--Although this pathway was evaluated for chemical exposures, it is insignificant for radionuclides.

Each of the potentially relevant exposure pathways is described in more detail in the following sections, along with the associated exposure parameters and equations used to calculate intake and external exposure.

5.1.3 Identification of Relevant Exposure Populations for Chemicals

As has been discussed, this assessment has been specifically conducted to evaluate potential tap water exposures for a resident living in Santa Fe. As such, a resident is the sole exposure population for this analysis. In a chemical risk assessment, residential exposures are evaluated separately for adults and children, and the estimates are summed to determine lifetime exposures.

Recent USEPA guidance recommends that children be evaluated by age groupings that best reflect how their behavioral and physiological factors are expected to change with age. (12, 13, 15, 111) The USEPA defines a child or youth as being under the age of 21, expressed as "0 to <21 years."(12) Age groupings are expressed using the "<" symbol, meaning "up until."(15, 111) In other words, exposures for a child/youth range from birth up until the child's 21st birthday (that is, 0 to < 21 years, for a total of 21 years). As another example, the infant age group of 0 to < 1 year includes exposures from birth up until the 1st birthday.(12, 111) The breakdown of children's age groups used in this evaluation is also harmonious with USEPA guidance for evaluating children's risks to carcinogens.(11, 106) Chemicals that are carcinogenic via a mutagenic mode of action necessitate applying additional safety factors for children <2 years old, and for children between the ages of 2 and 15 years old (that is, 2 to < 16 years).

Accordingly, seven different age groups are evaluated for the chemical risk assessment. These age groups correspond to behavioral differences in tap water-related exposures, account for differences in physiological factors, and account for the necessary adjustments for mutagenic carcinogens. While there is no prescribed age group for an adult, a residential adult is generally considered to be between the ages of 21 and < 70 years old.(111) A summary of the age groups identified for the chemical risk assessment is included in Table 5-3 below.

In accordance with USEPA guidance for chemical risk assessments, residential exposures were estimated according to age group, wherein both males and females in a particular age group are evaluated together as one population.(16, 105, 111) Therefore, the exposure parameters (such as body weight, ingestion rates, etc.) utilized to quantify exposures represent average values that correspond to the male and female population combined.

5.1.4 Exposure Populations for Radionuclides

The age groups considered for radiological risk evaluations are different than those for chemicals. The FGR 13 risk coefficients, which are discussed in the Toxicity Assessment section, correspond to six basic ages at intake: birth, 1 year of age, 5 years of age, 10 years of age, 15 years of age and adults.(112) For this analysis, age groups were identified that correlate with both the risk coefficients in FGR 13, as well as the age groups used for chemical risk assessment. Similar to USEPA chemical risk assessment guidance, ICRP-103 recommends the use of a 70-year lifetime for the general public (i.e., residents). (113) A summary of the age groups evaluated in the assessment of exposure (and risk) for both chemicals and radionuclides is presented in Table 5-3 below.

Table 5-3: Exposure groupings: Residential age groups evaluated for the chemical and radionuclide risk assessments

General Age Group Classification	Chemical Risk Evaluation (years of age)	Radionuclide Risk Evaluation (years of age)
Infant	<1	0–4
Toddler	1–2	
	3–5	
Child	6–10	5–14
	11–15	
Teen/young adult	16–20	15–24
Adult	21–70	25–70
Lifetime	0–70	0–70*

*The lifetime exposure group represents a lifespan of birth until 70 years of age. The risk coefficients used to evaluate this age group are based on a lifespan of birth to 110 years of age, as discussed above.

In accordance with FGR 13, the radiological risk assessment involves quantifying exposures for each age group using gender-specific exposures factors when available. (112) Exposure factors were therefore developed for males and females separately for each age group. These factors were created in order to coincide with the risk coefficients developed for radionuclides, which account for the variation in the usage differences that may be associated with age and gender, and also characterize the differences in radiological cancer rates between men and women.

5.1.5 Estimation of Exposure Point Concentrations (EPCs)

An exposure point concentration (EPC) is a concentration of a chemical or radionuclide in a medium of interest (e.g., tap water, vegetables) to which a receptor is estimated to be exposed. The EPC is the primary variable distinguishing CT from RME exposures in this evaluation.

For this evaluation, EPCs were determined for the four tap water exposure scenarios that were previously defined in Section 3. The tap water concentrations established for each scenario were used as the EPCs for the primary exposure pathways (that is, ingestion of tap water and dermal contact with tap water via hand washing, bathing, and swimming), and used to determine the EPCs for secondary exposure pathways (such as concentrations in produce and concentrations in air while bathing and swimming).

For the evaluation that assumed that each COI was present at the concentration corresponding to its MCL, the tap water EPCs for both chemicals and radionuclides were set equal to USEPA MCL or other relevant drinking water criteria when MCLs were not available. The drinking water criteria selected for each radionuclide and chemical of interest were identified in Tables 3-10 and 3-11, respectively.

5.1.6 Equations and Factors for Quantification of Exposures

Potential health hazards associated with chemical and radionuclide exposure are related to the degree of uptake or “dose” received upon exposure. Dose estimates are based on concentrations of chemicals or radionuclides in tap water, and exposure assumptions that describe the rate and frequency to which an individual might directly (such as in primary pathways) or indirectly (secondary pathways) come into contact with them. This section presents the equations used to estimate the potential doses for each complete exposure pathway, and describes the relevant exposure parameters and the estimated exposure concentrations.

Conservatisms Inherent in this Assessment

All of the exposure scenarios evaluated in this assessment represent chronic exposures, as exposures were assumed to occur over a lifetime. Because activity patterns vary over a person’s lifetime, it is unlikely that an individual would consistently be exposed to each of the pathways evaluated in this assessment every day of the year, throughout his or her lifetime. For example, it is common for people to travel outside of their hometown for at least two weeks per year, during which time they would not be exposed. Additionally, the CT and RME estimates for current residence time range from 8 to 12 years and 26 to 32 years, respectively.(111) Activity factors such as vacations and residential tenure in Santa Fe have not been factored into this evaluation.

Also, many of the exposure factors used to describe the scenarios evaluated in this assessment (such as consumption rates for water or homegrown produce) represent “doers,” not general population averages or per capita values. There are other conservatisms incorporated into the risk assessment that are specific to each pathway, and that are discussed in the sections that follow. For these reasons, this evaluation is defined as conservative.

Exposure Factors

While there are differences in the methodologies used to conduct radiological and chemical risk (and exposure) evaluations, the same sources were used to determine the relevant exposure parameters for each assessment. The primary source of exposure parameters for this assessment is the USEPA’s *Exposure Factors Handbook* (EFH); however, other sources were also consulted.(111) The exposure parameters provided in EFH reflect revisions made to the *Child-Specific Exposure Factors Handbook*, which was updated and published in 2008 (from 2002). As such, EFH provides the most updated information regarding both adult and childhood exposure parameters.

Age- and gender-specific exposure factors were determined according to the age groupings presented in Table 5-3 (above). Some of the data presented in EFH were collected prior to the issuance of USEPA's *Guidance on Selecting Age Groups for Monitoring and Assessing Childhood Exposures to Environmental Contaminants* and, as such, the age groups (and exposure parameters) are not entirely consistent with recent guidelines.(12) When exposure parameters were not available for a specific age grouping, they were averaged (time-weighted) across the relevant ages in order to determine a point value for that age group. The development of the exposure parameters (for all scenarios) is presented within the Section 5 Appendices, and is summarized in the sections that follow.

Although the EPC is the primary distinguishing variable between CT and RME exposures, for certain exposure pathways, it was also deemed relevant to include CT and RME exposure parameters. For example, both CT and RME ingestion rates were established for the tap water ingestion pathway, since it was expected to be the most significant exposure pathway for this risk evaluation. The exposure parameters utilized for each exposure pathway evaluated in this risk evaluation are discussed in more detail below.

It should be noted that the USEPA warns against using all upper bound exposure parameters so as to avoid unrealistic over-estimates of exposure.(111, 114) USEPA guidance additionally recommends that care be taken when estimating body weights for an exposure population so that they are consistent with the population parameters used in the exposure analysis. Body weights are directly correlated with other physiological factors (such as water consumption rates and skin surface area), and while using a body weight that is "high" might seem appropriate for upper bound estimates, it is actually less conservative, since the intake parameters are averaged over a larger number, leading to a smaller dose estimate.

Exposure Factors that are Common to All Scenarios

<u>Fraction Placeholders (F; unitless)</u> - For each exposure pathway, a fraction placeholder was incorporated into the dose equation; however, it was assumed to be 1(unity). This placeholder could be used to account for 1) a "fraction from contaminated source" and/or 2) a chemical- and exposure route-specific "bioavailability fraction."(16) Using a fraction of 1 assumes that, for the intake being evaluated, 100% originates from the Santa Fe tap water. It has also been assumed that all chemicals are 100% bioavailable once taken into the body (this concept is further discussed in the Toxicity Assessment section).

<u>Body weight (BW; kg)</u> – The body weights shown in Table 5-4, which are averages over each age group, were obtained from the EFH.(15, 111)

Table 5-4: Body weights by age group

Age Group (years of age)	Body Weight (kg)
<1	7.8
1–2	12.6
3–5	18.6
6–10	31.8
11–15	56.8
16–20	71.6
21–70	80

Exposure Duration (ED; years) - The Exposure Duration is the number of years over which an exposure occurs. For a residential risk assessment, the exposure duration is equal to the number of years included in each age grouping. The ED values used are shown in Table 5-5.

Table 5-5: Exposure durations by age group

Age Group (years of age)	Exposure Duration (years)
<1	1
1–2	2
3–5	3
6–10	5
11–15	5
16–20	5
21–70	49
Lifetime	70

Averaging time (AT$_{\text{NC or C}}$; days) - The Averaging Time is equal to the number of days in the Exposure Duration for non-carcinogens, and the total number of days in a 70-year lifetime for carcinogens. The values used are shown in Table 5-6.

Table 5-6: Averaging times

Age Group (years)		Ingestion and Dermal (days)	Inhalation (hours)
<1	"ADD"	365	8,760
1–2		730	17,520
3–5		1,095	26,280
6–10		1,825	43,800
11–15		1,825	43,800
16–20		1,825	43,800
21–70		17,885	429,240
Lifetime	"LADD"	25,550	613,200

Calculating Doses for Ingestion and Dermal Contact (ADDs and LADDs)

In accordance with USEPA guidance, standard equations were used to calculate doses for the ingestion and dermal pathways.(15, 16, 105, 107, 111) For non-carcinogenic chemicals, doses are calculated as average daily doses (ADDs), and for carcinogenic chemicals, doses are calculated as lifetime average daily doses (LADDs).(16) The primary difference between the calculation of ADDs and LADDS is the "averaging time" over which exposure is assumed to occur; for non-carcinogens, the averaging time and exposure duration are one in the same, while for carcinogens, the averaging time is assumed to be a lifetime of 70 years, regardless of the exposure duration.

The dose equations used in this evaluation are based on the following basic exposure equations: (111, 114)

$$(1) \qquad \textit{Potential Dose} = EPC \times IR \times ED$$

where:
Potential Dose = The potential dose for intake
EPC = COI concentration in medium (such as tap water, food)
IR = Intake rate (such as rate of ingestion, dermal contact)
ED = Exposure duration

$$(2) \qquad Dose = \frac{(Potential \quad Dose)}{(BW \times AT)}$$

where:
Dose = Average Daily Dose (ADD) for non-cancer effects or Lifetime Average Daily Dose (LADD) for carcinogenic effects
BW = Body Weight
IR = Averaging Time

From the dose equation above, various exposure route-specific dose equations can be derived by substituting the potential dose with specific assumptions.

Exposure Concentrations for Inhalation (EC_{NC} and EC_C)

Historically, inhalation doses have been quantified in the same manner as dermal and oral doses (that is, as ADDs/LADDs). This quantification requires converting inhalation toxicity criteria into reference doses and slope factors for the risk quantification step. However, this methodology is no longer recommended for the evaluation of inhaled contaminants. As such, the present inhalation risk evaluation was conducted according to the updated inhalation dosimetry methodology presented in RAGS (Risk Assessment Guidance for Superfund) Part F, wherein Exposure Concentrations are calculated for non-carcinogens (EC_{NC}) and carcinogens (EC_C).(107) ECs are time-weighted average concentrations derived from a measured or modeled EPC in air, which has been adjusted based on the characteristics of the exposure scenario being evaluated.(107) A "dose" is not calculated, *per se*; rather, the EC represents the deposited/delivered dose and physiochemical characteristics of the inhaled contaminant.(107) This methodology conservatively assumes that 100% of the deposited dose remains in the respiratory tract; respiratory clearance mechanisms are not considered.

5.1.6.1 Ingestion Exposure Pathways—Ingestion of Tap Water

The primary use exposure of Santa Fe tap water is for potable water consumption. For this analysis, drinking water exposures were quantified for a tap water consumer. A "consumer" population essentially represents a population whose sole source of intake is from the source under consideration; in this case, a tap water consumer utilizes Santa Fe tap water as his or her sole source of potable water. Consumer tap water ingestion rates are inherently higher than "per capita" rates, as per capita rates represent an average intake for all persons in a population, including those who do not use tap water as a drinking source.

The following equation was used to estimate ingestion doses:

$$\text{ADD or LADD} = \frac{\left(EPC_{TW} \times CF1 \times IR_{TW} \times F_{TW} \times ED \times EF_{TW}\right)}{\left(BW \times AT_{NCorC}\right)}$$

where:

ADD = Average Daily Dose (mg/kg-day)
LADD = Lifetime Average Daily Dose (mg/kg-day)
EPC_{TW} = Exposure Point Concentration– tap water (µg/L)
CF1 = Conversion Factor 1 (0.001 mg/µg)
IR_{TW} = Tap Water Ingestion Rate (L/d)
F_{TW} = Fraction Placeholder for Tap Water
EF_{TW} = Exposure Frequency for Tap Water (days/year)
ED = Exposure Duration (years)
BW = Body Weight (kg)
AT_{NC} = Averaging Time (days)
AT_C = Averaging Time (days)

Both CT and RME exposure values were determined for tap water ingestion rate, using the values presented in the EFH.(111) These values are presented in Table 5-7.

Table 5-7: Tap water ingestion rates for CT and RME exposure scenarios

Age Group (age in years)	Tap Water Ingestion Rates (L/day)	
	CT	RME
<1	0.50	1.11
1-2	0.33	0.90
3-5	0.42	1.1
6-10	0.48	1.3
11-15	0.65	1.7
16-20	0.84	2.3
21-70	1.2	2.7

These ingestion rates include water ingested directly from the tap as drinking water, as well as water ingested indirectly as part of food and beverage preparation (such as infant formula, coffee, tea, frozen juices, soups, gelatin, etc.). The exposure frequency for drinking tap water was assumed to be every day of the year (that is, 365 days/year).

5.1.6.2 Ingestion of Home- or Locally Grown Produce

The potential exists for a Santa Fe resident to ingest COIs in home or locally grown produce watered with Santa Fe tap water. Intake of home/locally grown produce varies according to factors such as region, age, urbanization, and race. As such, for this exposure pathway, consideration was given to intakes for home/locally grown produce that best represents the Santa Fe area, based on available information.

According to the Santa Fe Master Gardener Association and the Santa Fe Farmers Market and Santa Fe Farmers Market Institute,(115, 116) some of the more common types of produce grown in the Santa Fe area include:

- Various greens and leafy vegetables (such as lettuce, spinach, arugula, sprouts, etc.)
- Potatoes
- Carrots
- Onions
- Garlic
- Mushrooms
- Peppers (such as chili, bell, shishito)
- Tomatoes
- Beets

- Beans
- Turnips
- Squash (such as summer, winter, zucchini)

In addition to these vegetables, apples are also common to the area, and are available year-round. Of the types of produce common to the Santa Fe area, the IPR team estimated that roughly 65% are grown above ground, and 35% are grown below ground (such as root produce). This information was used to determine the EPCs for the vegetables.

The equation used to quantify exposures for ingestion of home/locally grown produce is provided below. The produce intake rates provided in the EFH are in units of g/kg-day; thus, using these data to calculate potential dose does not require the body weight factor to be included in the denominator of the ADD equation.

$$ADD\ or\ LADD = \frac{\left(EPC_{veg} \times CF2 \times IR_{veg} \times F_{veg} \times ED \times EF_{veg}\right)}{\left(AT_{NCorC}\right)}$$

where:

ADD = Average Daily Dose (mg/kg-day)
$LADD$ = Lifetime Average Daily Dose (mg/kg-day)
EPC_{veg} = Exposure Point Concentration–homegrown produce (mg/kg)
$CF2$ = Conversion Factor 1 (0.000001 kg/mg)
IR_{veg} = Ingestion Rate for homegrown produce (mg/kg-day)
F_{veg} = Fraction Placeholder for homegrown produce
EF_{veg} = Exposure Frequency for tap water (days/year)
ED = Exposure Duration (years)
AT_{NC} = Averaging Time (days)
AT_{C} = Averaging Time (days)

Ingestion rates for “home-produced” foods were derived using information and guidance from the EFH.(111) First, the recommended total vegetable ingestion rates were identified for per capita intakes (average intakes across the U.S. population) and consumer (average intakes for persons consuming only), and used to represent the CT and RME scenarios, respectively. Because these values represent ingestion of vegetables from all sources (i.e., both home- and commercially-produced), they were then multiplied by a ‘fraction of vegetable intake that is home-produced.’(111) For the CT estimate, a fraction of 0.057 was used, which represents the fraction of vegetable intake that is home-produced for persons living in the western region of the United States (including New Mexico, Arizona, California, Colorado, Idaho, Montana, Nevada, Oregon, Utah, Washington, and Wyoming). For the RME scenario, a fraction of 0.173 was used, which represents the fraction of vegetable intake that is home-produced for persons in the U.S. who have produce gardens. The resulting ingestion rates are provided in Table 5-8 below.

Table 5-8: Ingestion rates for home/locally grown produce (mg/kg-day)

	Age Group (age in years)						
	< 1	1–2	3–5	6–10	11–15	16–20	21–70
CT	--	393	336	254	180	165	170
RME	--	1,194	1,021	709	502	502	516

These ingestion rates do not explicitly represent intake of locally grown apples. However, this is thought to be offset by using vegetable ingestion rates for *total* vegetables consumed by individuals, such that the ingestion rates are overestimates for the amount of home/locally grown vegetables ingested that are specific to the Santa Fe area. Furthermore, information regarding fraction of home-grown produce intake is not available specifically for apples.(15, 111)

This exposure pathway was not evaluated for children under the age of one year. Consumption rates for consumers of home grown produce are not provided for this age group in the EFH, which reports that the diets of these consumers differ markedly from other household members, who are not assumed to consume any portion of home-produced food brought into the home.(15, 111)

The exposure frequency for ingestion of home/locally-grown produce was assumed to be every day of the year (that is, 365 days/year).

5.1.6.3 Dermal Exposure Pathways—Dermal Absorption While Hand Washing

While this pathway represents only a small portion of the total potential exposures, it was considered because it is expected to have a high potential frequency of occurrence within a residential population. The doses associated with dermal uptake due to hand washing were calculated as follows:

$$\text{ADD or LADD} = \frac{(EPC_{TW} \times CF1 \times CF3 \times F_{hands} \times SSA_{hands} \times Kp \times ED \times EF_{TW} \times ET_{handwash})}{(BW \times AT_{NCorC})}$$

where:

ADD = Average Daily Dose (mg/kg-day)
LADD = Lifetime Average Daily Dose (mg/kg-day)
EPC_{TW} = Exposure Point Concentration for tap water (μg/L)
CF1 = Conversion Factor 1 (0.001mg/μg)
CF3 = Conversion Factor 3 (0.001 L/cm^3)
F_{hands} = Fraction Placeholder for hand washing

SSA_{hands} = Skin Surface Area of hands (cm^2)
K_p = Permeability Coefficient (cm/h)
ED = Exposure Duration (years)
EF_{TW} = Exposure Frequency for tap water (events/year)
$ET_{handwash}$ = Hand Washing Exposure Time (hours/event)
BW = Body Weight (kg)
AT_{NC} = Averaging Time (days)
AT_C = Averaging Time (days)

Hand washing frequency was estimated from information provided in the EFH.(111) Children between the ages of 0 and 1 year were not evaluated for this scenario, since the frequency with which they wash their hands is extremely low.(111) Exposure frequencies were estimated for CT and RME exposures, and are summarized in Table 5-9 below. Best estimates were derived for central tendency hand washing based upon the ranges presented in EHF for "doers," and were multiplied by a factor of two in order to derive the RME exposure frequencies. Similar to the "consumer" described above, a "doer" is a person who regularly washes his or her hands (that is, the values do not incorporate information for those persons who do not wash their hands).

Table 5-9: Exposure times for hand washing

	Age Group (age in years)						
	<1	1–2	3–5	6–10	11–15	16–20	21–70
Events/day	--	4	4	4	4	4	7.5
Days of exposure:	--	350	350	350	350	350	350
Events/year- CT	--	1,400	1,400	1,400	1,400	1,400	2,625
Events/year- RME	--	2,800	2,800	2,800	2,800	2,800	5,250

Mean values for skin surface area of the hand were obtained from EFH and are presented in Table 5-10.

Table 5-10: Skin surface areas for the hands (cm^2)

Age Group (age in years)						
<1	1–2	3–5	6–10	11–15	16–20	21–70
211	300	450	540	840	990	980

Lastly, determining the dose of a chemical received via the skin requires knowing the rate at which the chemical will pass the skin barrier, or the 'dermal permeability coefficient' of the compound in water. RAGS Part E was used as the primary source for obtaining permeability coefficients; when values were unavailable, they were obtained from the RAIS database.

Depending on their physical-chemical properties, certain organic chemicals have limited permeability in water (i.e., they are hydrophobic). Such chemicals are poorly absorbed by the skin, and are unlikely to constitute a dermal risk via skin absorption. Hydrophobic chemicals can be identified by their log octanol-water partition coefficients ($\log K_{OW}$s); it is generally accepted that chemicals with $\log K_{OW}$ values of greater than five are hydrophobic.(117) The following four COIs have $\log K_{OW}$ values greater than five, and were therefore not evaluated for the dermal exposure routes in this risk assessment: bis(2-ethylhexyl)phthalate, DDE, OCDD and total PCBs. A summary of the chemical-specific permeability coefficients utilized is provided within the Section 5 Appendices.

5.1.6.4 Dermal Absorption While Bathing

For reasons of simplicity, and in order to be conservative, a single equation was used to estimate dermal uptake due to showering or taking a bath.

$$\text{ADD or LADD} = \frac{(EPC_{TW} \times CF1 \times CF3 \times F_{TW} \times SA_{body} \times K_P \times ED \times EF_{bathe} \times ET_{bathe})}{(BW \times AT_{NCorC})}$$

where:
ADD = Average Daily Dose (mg/kg-day)
$LADD$ = Lifetime Average Daily Dose (mg/kg-day)
EPC_{TW} = Exposure Point Concentration for tap water (µg/L)
$CF1$ = Conversion Factor 1 (0.001mg/µg)
$CF3$ = Conversion Factor 3 (0.001 L/cm^3)
F_{TW} = Fraction Placeholder for bathing
SA_{body} = Total Body Skin Surface Area (cm^2)
K_p = Permeability Coefficient (cm/h)
ED = Exposure Duration (years)
EF_{bathe} = Bathing Frequency (days/year)
ET_{bathe} = Time Spent Bathing (hours/day)
BW = Body Weight (kg)
AT_{NC} = Averaging Time (days)
AT_C = Averaging Time (days)

It was assumed that an individual will take either a bath or a shower. In order to represent both potential bathing options, the mean recommended exposure times for taking a bath were used, since they are longer than the recommended times for taking a shower.(111) These values are presented in Table 5-11 below.

Table 5-11: Exposure frequency for bathing—dermal (hours per day)

Age Group (years of age)						
<1	1–2	3–5	6–10	11–15	16–20	21–70
0.32	0.38	0.40	0.40	0.42	0.55	0.28

An exposure frequency of 365 days per year was used for this assessment.

The total body surface area was assumed to be in contact with the water, and the age-specific default values for mean skin surface area shown in Table 5-12 were used in the dose calculations.

Table 5-12: Skin surface areas for the whole body (cm^2)

Age Group (years of age)						
<1	1–2	3–5	6–10	11–15	16–20	21–70
3,992	5,300	7,600	10,800	15,900	18,400	19,450

As noted above, the chemical-specific permeability coefficients are provided within the Section 5 Appendices.

5.1.6.5 Dermal Absorption While Swimming or Using a Hot Tub

For reasons of simplicity and in order to be conservative, a single equation was used to estimate dermal uptake due to swimming in a pool or hot tub filled with Santa Fe tap water. This equation is as follows:

$$\text{ADD or LADD} = \frac{(EPC_{TW} \times CF1 \times CF3 \times F_{TW} \times SA_{body} \times K_P \times ED \times EF_{swim} \times ET_{swim})}{(BW \times AT_{NCorC})}$$

where:

ADD = Average Daily Dose (mg/kg-day)
LADD = Lifetime Average Daily Dose (mg/kg-day)
EPC_{TW} = Exposure Point Concentration for tap water (µg/L)
CF1 = Conversion Factor 1 (mg/µg)
CF2 = Conversion Factor 2 (L/cm^3)
F_{TW} = Fraction Placeholder for tap water
SA_{body} = Total Body Skin Surface Area (cm^2)
K_p = Permeability Coefficient (cm/h)
ED = Exposure Duration (years)
EF_{swim} = Exposure Frequency for swimming (months/year)
ET_{swim} = Time Spent in Swimming Pools (hrs/months)

BW = Body Weight (kg)
AT_{NC} = Averaging Time (days)
AT_C = Averaging Time (days)

The total body surface areas presented above were used for this equation, and the chemical-specific permeability coefficients are provided within the Section 5 Appendices. Based on meteorological data, it was conservatively estimated that individuals may swim in outdoor pools for five months out of the year, when the average maximum temperature is greater than 70 degrees F (from May through September); as such, five months/year was used as the CT exposure frequency).(118) Because it is possible for residents to swim in indoor pools year-round, an exposure frequency of 12 months/year was used for the RME scenario. Swimming exposure times were obtained from EFH, and represent the mean recommended swimming exposure times.(119)

Table 5-13: Exposure times and frequencies: Swimming

	Age Group (years of age)						
Parameter (units)	<1	1 to 2	3 to 5	6 to 10	11 to 15	16 to 20	21 to 69
ET_{Swim} (hours/month)	1.6	1.8	2.5	2.5	2.4	2.4	0.74
EF_{Swim} – CT (months/year)	6	6	6	6	6	6	6
EF_{Swim} – RME (months/year)	12	12	12	12	12	12	12

5.1.6.6 Inhalation Exposure Pathways-- Inhalation While Bathing

For reasons of simplicity and in order to be conservative, a single equation was used to estimate inhalation exposures to COIs while showering or taking a bath:

$$EC_{NC} \text{ or } EC_C = \frac{(EPC_{air-bathe} \times CF1 \times F_{bathe} \times ED \times EF_{bathe} \times ET_{bathe})}{(AT_{NCorC})}$$

where:

EC_{NC} = Exposure Concentration (mg/m^3)
EC_C = Exposure Concentration (mg/m^3)
$EPC_{air\text{-}bathe}$ = Exposure Point Concentration for air (µg/m^3)
$CF1$ = Conversion Factor 1 (0.001 mg/µg)
F_{air} = Fraction Placeholder for air
ED = Exposure Duration (years)
EF_{bathe} = Exposure Frequency for inhalation (days/year)
ET_{bathe} = Showering or Bathing Time (hours/day)
AT_{NC} = Exposure Concentration (number of hours in exposure duration)
AT_C = Averaging Time for carcinogens (number of hours in 70 years)

Individuals may inhale COIs that are volatile while showering or taking a bath. Additionally, they may inhale non-volatile COIs, which may become aerosolized while taking a shower. As noted in Table 5-1, children under the age of six typically take baths rather than showers; this age group was therefore only evaluated for the RME shower inhalation scenario. As such, for the CT scenario, children under six were assumed to only be exposed to volatile chemicals while taking a bath (that is, they were not exposed to non-volatile COIs via shower aerosolization).

The exposure times for the inhalation-while-bathing scenario represent the entire time that a person remains in the bathroom as the time relates to bathing; in other words, the exposure times include the time during which an indivdual is bathing, as well as the time he or she remains in the bathroom subsequent to bathing. The exposure times are presented below, and represent the mean inhalation exposure times.(111)

Table 5-14: Exposure frequencies: Bathing—Inhalation (hours/day)

Age Group (age in years)						
<1	1 to 2	3 to 5	6 to 10	11 to 15	16 to 20	21 to 69
0.37	0.43	0.47	0.47	0.55	0.75	0.28

5.1.6.7 Inhalation While Swimming or Using a Hot Tub

For reasons of simplicity and in order to be conservative, a single equation was used to estimate inhalation of COIs while swimming in a pool or hot tub filled with Santa Fe tap water. The equation is as follows:

$$EC_{NC} \text{ or } EC_C = \frac{(EPC_{air-swim} \times CF1 \times F_{air-swim} \times ED \times EF_{swim} \times ET_{swim})}{(AT_{NCorC})}$$

where:

EC_{NC} = Exposure Concentration (mg/m^3)
EC_C = Exposure Concentration (mg/m^3)
$EPC_{air-swim}$ = Exposure Point Concentration for air (µg/m^3)
CF1 = Conversion Factor 1 (0.001 mg/µg)
$F_{air-swim}$ = Fraction Placeholder for air-swim
ED = Exposure Duration (years)
EF_{swim} = Exposure Frequency for inhalation (days/year)
ET_{swim} = Showering or Bathing Time (hours/day)
AT_{NC} = Exposure Concentration (number of hours in exposure duration)
AT_C = Averaging Time for carcinogens (number of hours in 70 years)

Because water in a swimming pool is not aerosolized in the manner of a shower, it was only relevant to quantify exposures to volatile COIs for this scenario. Although children under the age of one are not expected to swim frequently, they were conservatively evaluated in this assessment. The exposure times and frequencies used for the dermal-contact–with-COIs-while-swimming scenario were also used for the inhalation scenario.

5.2 RISK CHARACTERIZATION FOR CHEMICALS

The risk characterization provides a quantitative and qualitative discussion of the potential health hazards associated with exposures to the COIs. Both non-carcinogenic and carcinogenic health effects are addressed. Non-carcinogenic health effects are characterized by comparing estimated exposures to the maximally "acceptable" exposures, and carcinogenic health risks are characterized with respect to theoretical excess cancer risks that may trigger a regulatory concern.

5.2.1 Non-Carcinogenic Hazard Evaluation

Non-Carcinogenic Hazard Quotients- Ingestion and Dermal Contact
Non-carcinogenic hazards are characterized using the hazard quotient (HQ) approach.(16) For ingestion and dermal contact exposures, the HQ is the ratio of the calculated average daily dose (ADD) to the maximally acceptable "safe" dose (that is, the USEPA's reference dose, or RfD):

$$HQ = \frac{ADD}{RfD}$$

where:
HQ = Hazard Quotient (unitless)
ADD = Average Daily Dose (mg/kg-day)
RfD = Reference Dose (mg/kg-day)

For inhalation exposures, the non-carcinogenic HQs are characterized as the ratio of the calculated exposure concentration (EC_{NC}) to the maximally acceptable concentration (i.e., the USEPA's reference concentration, or RfC):

$$HQ = \frac{EC_{NC}}{RfC}$$

where:
HQ = Hazard Quotient (unitless)
EC_{NC} = Exposure Concentration (mg/m^3)
RfC = Reference Concentration (mg/m^3)

Because different chemicals may cause similar adverse health effects, it is often appropriate to combine HQs associated with different substances. The most precise manner in which to characterize non-carcinogenic health risks is via a hazard index (HI). The HI is the sum of hazard quotients for substances that affect the same target organ or organ system (e.g., lung, kidney, liver) or result in the same health endpoint (e.g., respiratory irritant).(120-123) HIs were calculated for each target organ or organ system as follows:

$$HI = HQ_1 + HQ_2 + ... + HQ_n$$

where:
HI = Hazard Quotient (unitless)

Information regarding the target organ effects of chemicals has been summarized by various sources; this information was reviewed to determine the target organs/systems relevant to the COIs for this assessment, and is presented within the Section 5 Appendices.(57, 124-126) An HI of 1.0 or less will not likely result in adverse non-cancer health effects over a lifetime of exposure.

5.2.2 Carcinogenic Risk Evaluation

Carcinogenic health risks are defined in terms of the probability that an individual will develop cancer as the result of exposure to a given chemical at a given concentration.(16) The incremental probability of developing cancer (that is, the theoretical excess cancer risk) is the additional risk above and beyond the cancer risk an individual would face in the absence of the exposures characterized in this risk assessment.

For ingestion and dermal contact exposure pathways, the theoretical excess cancer risk (CR) is based on lifetime average daily doses, and is calculated as follows:

$$CR = LADD \times SF$$

where:
CR = Theoretical Excess Cancer Risk
$LADD$ = Lifetime Average Daily Dose (mg/kg-day)
SF = Cancer Slope Factor $(\text{mg/kg-day})^{-1}$

For inhalation exposures, the theoretical excess cancer risks are calculated as follows:

$$CR = IUR \times EC_C$$

where:
CR = Theoretical Excess Cancer Risk
IUR = Inhalation Unit Risk $(\mu\text{g/m}^3)^{-1}$

EC_C = Exposure Concentration for Carcinogens ($\mu g/m^3$)

The risks due to exposure to carcinogens are summed for each chemical and pathway, regardless of the carcinogenic mode of action. Typically, cancer risks in the range of 1×10^{-6} to 1×10^{-4} are considered acceptable.(122, 127)

5.3 LEAD EVALUATION

Lead risk assessments are conducted using a different methodology than that used for a typical chemical risk assessment. For lead, biokinetic models developed by USEPA are used to predict blood lead (PbB) levels based on anticipated exposures, which are then compared to USEPA default PbB levels of concern.(128, 129) A lead risk assessment also differs from a chemical risk assessment in that it is focused solely on evaluating children under the age of seven, since they are considered the most sensitive and relevant age group with respect to residential lead exposures.(128-130)

In accordance with USEPA guidelines, the Integrated Exposure Uptake Biokinetic Model for Lead in Children (IEUBK) was used to predict exposure-related PbB levels for children under the age of seven.(128-130) This model is recommended for evaluating chronic residential exposures, such as those being evaluated in this assessment.(131) It is worth noting that there are additional USEPA-advocated methods for evaluating lead exposures. The Adult Lead Model (ALM), for example, can be used for adults in non-residential exposure scenarios (such as occupational). The ALM is similar to the IEUBK model; however, it is more limited in function, since it considers adult exposures to lead in soil and dust only.(128, 129, 131) USEPA guidance is also available for addressing intermittent and variable exposures to lead.(132)

The "IEUBKwin" software package for PCs was utilized in this risk assessment. As stated in the User's Guide, "[the IEUBKwin software] utilizes four interrelated modules (exposure, uptake, biokinetic, and probability distribution) to estimate blood lead (PbB) levels in children exposed to lead (Pb)-contaminated media. IEUBKwin allows the user to estimate, for a hypothetical child or population of children, a plausible distribution of PbB concentrations centered on a geometric mean PbB concentration. The geometric mean PbB is predicted from available information about the child's or children's exposure to lead. From this distribution, the model estimates the risk (that is, probability) that a child's or a population of children's PbB concentration will exceed a certain level of concern (typically 10 µg/dL)." (133)

5.3.1 Lead Exposure Assessment

The same exposure pathways evaluated for the chemical risk assessment (as previously discussed) were also evaluated for the lead risk assessment, with the exception of dermal exposures. Exposure to lead via dermal absorption is not considered a significant pathway for the general population, and the IEUBK model does not incorporate a dermal exposure component. As such, this lead assessment incorporates exposure estimates for the following pathways:

- Ingestion of drinking water;
- Ingestion of home/locally-grown produce; and
- Inhalation while bathing.

Because lead is not a volatile chemical, it was evaluated for the inhalation-during-swimming exposure pathway.

Exposure parameters were developed using information from the EFH in the same manner as previously described for the chemical risk assessment, although, as mentioned, the age groups considered for the lead evaluation are different. (111) For the dietary intake pathway (that is, ingestion of home/locally grown produce), the IEUBK model requires inputs in terms of amount of lead ingested (µg) per day. Therefore, for each relevant age group, dietary lead intake (µg/day) was calculated as the product of the exposure point concentration of lead in home-grown vegetables (EPC_{veg}; mg/kg), the vegetable ingestion rate (IR_{veg}; mg/kg-day), the body weight (kg), and a conversion factor (1×10^{-6} kg/mg). As previously discussed, this exposure pathway was not considered for children under the age of one year.

For all other pathways, exposure parameters and exposure point concentrations were entered as separate values. For inhalation exposures, IEUBKwin requires that inhalation rates be entered in units of m^3/day. Bathing inhalation rates were therefore determined by multiplying the inhalation rates for light intensity activities (IR; m^3/minute) by the bathing exposure times (ET; minutes/day). As previously discussed, children under the age of six are more likely to take a bath than a shower; for the CT exposure scenario, then, it was thus assumed that all children take baths only. While children aged six or older may be more likely to take showers, IEUBK model limitations do not allow for this age group to be evaluated differently for inhalation exposures. All age groups for the CT evaluation were therefore assumed to take baths only. Because lead is not volatile, it was not evaluated for CT inhalation exposures while taking a bath. For the RME exposure scenario, children of all ages were assumed to take showers, and were evaluated for potential inhalation exposures via aerosolized shower water.

Input exposure parameters used in the IEUBKwin modeling are shown in Tables 5-15 and 5-16 below.

Table 5-15: Exposure parameters used for the lead evaluation, recent measured concentrations scenario

Age Group (age in years)	Water Ingestion Rate (L/day)		Dietary Lead Intake Home-Grown Produce (µg/day)		Bathing Inhalation Rate (m^3/day)	
	CT	RME	CT	RME	CT	RME
<1	0.47	1.1	--	--	--	0.17
1	0.31	0.89	0.035	0.11	--	0.31
2	0.36	0.91	0.043	0.13	--	0.31
3	0.42	1.1	0.049	0.15	--	0.31
4	0.42	1.1	0.049	0.15	--	0.31
5	0.42	1.1	0.049	0.15	--	0.31
6	0.48	1.3	0.063	0.18	0.31	0.31

Table 5-16: Exposure parameters used for the lead evaluation, MCLs scenario

Age Group (age in years)	Water Ingestion Rate (L/day)		Dietary Lead Intake Home-Grown Produce (µg/day)		Bathing Inhalation Rate (m^3/day)	
	CT	RME	CT	RME	CT	RME
<1	0.47	1.1	--	--	--	0.17
1	0.31	0.89	0.87	2.63	--	0.31
2	0.36	0.91	1.1	3.20	--	0.31
3	0.4	1.1	1.2	3.67	--	0.31
4	0.4	1.1	1.2	3.67	--	0.31
5	0.4	1.1	1.2	3.67	--	0.31
6	0.5	1.3	1.6	4.38	0.31	0.31

In addition to these exposure parameters, the EPCs for lead in tap water and air (while bathing), were input into IEUBKwin.

5.3.2 Toxicity Assessment

EPA's risk assessment for lead is unique because a reference dose for lead is not available. The toxicokinetics (i.e., the behavior of lead in the body including absorption, distribution, metabolism and excretion) of lead have been well studied, however, and the concentration of lead in human blood is most often used as the typical descriptor for assessing lead exposure.

Lead exposure is particularly relevant for children under the age of seven, since they are thought to be the most sensitive age group for potential adverse health effects from lead.(128, 129) The target health endpoint for lead exposure is the central nervous system. Studies have associated subtle neurobehavioral effects with PbB levels of approximately10 µg/dL in children, with population effects becoming clearer and more definite in the range of 30 to 40 µg/dL.(134, 135) Based on a review of the relevant studies, the USEPA has established a PbB level of 10 µg/dL as the level at or above which health effects might occur in children.(128, 129, 136, 137)

Only a fraction of lead that enters the body through the respiratory or gastrointestinal (GI) systems is actually absorbed into the systemic circulation. As such, the IEUBK model incorporates an uptake component that considers the process by which lead is transferred to the blood. Uptake is described as "the quantity of lead absorbed per unit time from portals of entry (gut, lung) into the systemic circulation of blood." (133)

In order for inhalation absorption to occur, lead must be "bioaccessible;" specifically, the lead must be deposited on the alveolar surface of the lung. While airborne particles and aerosols may be inhalable, only particles less than 2.5 µm in size are small enough to penetrate the alveolar region for subsequent absorption into the bloodstream.(136) Particles larger than 2.5 µm are deposited onto cilia in the tracheobronchial and nasopharyngeal regions of the respiratory system prior to reaching the lungs. The IEUBK model therefore uses a default lung bioaccessibility factor of 32%, and assumes that 100% of this fraction is absorbed. This default inhalation bioaccessibility factor is conservative for the purposes of this assessment, since alveolar deposition of aerosolized water droplets generated during a hot-water shower has been found to be 10% or less.(138)

For both tap water and diet-related exposures (that is, vegetable ingestion), IEUBKwin uses a default bioavailability factor of 50%. The absorption of lead in food by infants is considered to be high, ranging from approximately 42 to 53%.(139) Although GI absorption is thought to decrease after infancy, a default value of 50% is nonetheless assumed for all children under the age of seven. For absorption via water ingestion, a default bioavailability factor of 50% is used, and considered to be a plausible value. This factor is based on the assumption that the maximum retention of lead in children likely exceeds 60%, and that absorption is likely to be only somewhat smaller than retention.(139)

5.3.3 Risk Characterization

The IEUBKwin model was used to relate the lead exposure concentrations (that is, lead in tap water, home/locally grown produce, and air while showering) to estimated PbB levels. Using a series of computations, this model combines site-specific estimates of lead intake, accounts for the absorption, distribution, and elimination of lead from a child's body, and predicts a plausible distribution of PbB levels for residential children 0 to 7 years of age.(128)

IEUBK has several exposure modules containing default parameters for air, diet, drinking water, soil/dust, absorption/bioavailability and maternal exposures; however, using site-specific data is encouraged when it is available. Information regarding alternative exposure sources can also be included in a separate exposure module; however, doing so was not relevant for the purposes of this evaluation. The following methods were used for the IEUBKwin modeling:

- Vegetable ingestion rates were converted to µg/day and entered as "dietary intake."
- Bathing inhalation was evaluated using the outdoor inhalation component of the model. Inhalation rates were entered as m^3/day, and the exposure time ("outdoors") was set to 24 hours/day.
- The soil/dust ingestion component was "zeroed out" by entering 0 for the EPC.
- For the infant, the default maternal blood concentration default of 1.0 µg/dL was used, which accounts for lead that may have transferred from the mother to the fetus *in utero.*(132)
- Model defaults for absorption and bioaccessibility were utilized.
- The default geometric standard deviation (GSD) of 1.6 (unitless) was used; the GSD is a measure of the relative variability in PbB levels of children within a given population.

The EPA set a specific goal for lead risk assessment that there should be no more than a 5% chance that any child will have a PbB concentration greater than 10 µg/dL (128-130, 140). The results of the IEUBK modeling are:

Recent Measured Concentrations Scenario:

- CT Exposures: The geometric mean PbB concentration was predicted to be 0.340 µg/dL, and was associated with a 0% chance that PbB levels would exceed the USEPA's level of concern of 10 µg/dL.
- RME Exposures: The geometric mean PbB concentration was predicted to be 1.627 µg/dL, and was associated with a 0.006 % chance that PbB levels would exceed the USEPA's level of concern of 10 µg/dL.

MCLs Scenario:

- CT Exposures: The geometric mean PbB concentration was predicted to be 1.292 µg/dL, and was associated with a 0.001% chance that PbB levels would exceed the USEPA's level of concern of 10 µg/dL.
- RME Exposures: The geometric mean PbB concentration was predicted to be 3.206 µg/dL, and was associated with a 1.6 % chance that PbB levels would exceed the USEPA's level of concern of 10 µg/dL.

In conclusion, the tap water-related exposures to lead are not of concern for residents. These results are not surprising, given that lead levels in the Rio Grande are no greater than regional background levels (as described in Section 3). The input and output files for the IEUBK modeling are presented within the Section 5 Appendices.

5.4 CHARACTERIZATION OF HUMAN HEALTH RISKS FROM RADIONUCLIDE EXPOSURES

Analysis of potential health risks to the public from radionuclide ingestion and inhalation via tap water was determined using USEPA's Federal Guidance Report 13 – *Cancer Risk Coefficients for Environmental Exposure to Radionuclides* (FGR 13). First published in 1999, the FGR 13's intent is to provide numerical factors for estimating the risk of cancer from low-level exposure to radionuclides.(112) These numerical factors, defined as risk coefficients, estimate the probability of radiogenic cancer mortality or morbidity per unit activity inhaled or ingested (internal exposure), as well as the probability or radiogenic cancer mortality or morbidity per unit time-integrated activity concentration in air or soil (external exposure).(112) Only the risk of developing cancer (cancer morbidity) was calculated for this assessment.

FGR 13 provides cancer mortality and morbidity risk coefficients for each radionuclide detected in the Rio Grande for three modes of exposure: direct ingestion of tap water, ingestion of fruits and vegetables grown using tap water, and inhalation of tap water particulates or vapors. Risk coefficients for these internal exposure modes include the contribution to dose from the production of decay chain members in the body after intake of the parent radionuclide, regardless of the ½-lives of the decay chain members.(112) Moreover, for internal exposure modes, a risk coefficient for a given radionuclide is based on the assumption that this radionuclide is the only radionuclide present in the environmental medium. However, for the ingestion and inhalation pathways, for each radionuclide addressed, a separate risk coefficient is provided for each subsequent member of the chain that is of potential dosimetric significance.(112) It is important to note that the guidance report assumes that the concentration of the radionuclide in the environmental medium remains constant.

The health risk assessment portion of the IPR assessments relied upon a supplemental electronic database published by USEPA in 2002, which provides access to detailed numerical data generated in the course of computing the cancer risk coefficients that appear in FGR 13.(141) Each risk coefficient [r] is specific to the radionuclide, environmental medium, and the mode of exposure through that medium. Computing a lifetime cancer risk [R] associated with the intake of or external exposure to a given radionuclide:

$$R = r_R \times I_R$$

where:

R = Lifetime Cancer Risk [unitless]

$r_{[R]}$ = Total Cancer Morbidity Risk Coefficient Specific to the Radionuclide and Mode of Exposure [μCi^{-1}]

I_R = Calculated Intake of Radionuclide [Ci]

FGR 13 stresses that analyses involving the risk coefficients should be limited to estimating prospective risks in hypothetical or large existing populations, or retrospective analyses or risks to large actual populations.(112)

5.4.1 Direct Ingestion of Tap Water or Food Prepared with Tap Water

As previously mentioned, risk coefficients available in FGR 13 were used to calculate the risk of developing cancer from direct ingestion (that is, drinking) of water containing radionuclides. To compute the lifetime intake associated with direct ingestion of tap water for a given radionuclide, the following equation was used:

$$I_R = C_R \times U \times ED$$

where:

I_R =	Calculated Intake of Radionuclide [Ci]
C_R =	Concentration or Radionuclide in tap water [µCi/L]
U =	Age- and Gender-specific Drinking Water Usage Rate [L/day] (Usage rate includes both water drank directly and from food prepared using tap water)
ED =	Exposure Duration [day]

5.4.2 Ingestion of Vegetables Grown Using Tap Water

$$I_R = C_{Vegetable} \times IR \times ED$$

where:

IR = Age- and Gender-specific Ingestion Rate [mg/day]

The radionuclide concentration in homegrown fruits and vegetables due to the watering of a garden using residential tap water were estimated using the following equation: (142)

$$C_{[Vegetable]} = C_{[Radionuclide]} \times \left[Irr_{rup} + Irr_{res} + Irr_{dep}\right]$$

where:

$C_{[vegetable]}$ =	Exposure Point Concentration in homegrown fruits and vegetables (pCi/kg);
$C_{[radionuclide]}$ =	Exposure Point Concentration in tap water (pCi/L);
Irr_{rup} =	Root Uptake from Irrigation Multiplier [L/kg];
Irr_{res} =	Re-suspension from Irrigation Multiplier [L/kg], and
Irr_{dep} =	Aerial Deposition from Irrigation Multiplier {L/kg]

The root uptake multiplier represents the transfer of radionuclides from irrigation water to the homegrown fruit or vegetable via root uptake. This multiplier is calculated using the following equation:

$$Irr_{rup} = \frac{Ir \times F \times Bv_{wet} \times [1 - \exp(-\lambda_B \times t_B)]}{P \times \lambda_B}$$

where:

Ir = Irrigation Rate (L/m^2-day);
F = Fraction of Year when irrigation is occurring (unitless);
Bv_{wet} = Soil-to-plant Wet Uptake Coefficient (unitless);
λ_B = Effective Removal Rate (1/day);
t_B = Time Period of Deposition (days), and;
P = Area Density for the Root Zone (kg/m^2).

Default values were used for *Ir, F*, and *P,* and are presented in Table 5-17.(142) The values for Bv_{wet} are radionuclide specific, and are presented in Table 5-18. The time period of deposition for this assessment was set as equal to 90 days, the default growing season length assumed for this assessment.

Table 5-17: Nonchemical-specific parameter values used to estimate chemical and radionuclide concentrations in homegrown fruits and vegetables

Parameter	Units	Value	Reference
Irrigation rate, I_r	L/m^2-d	3.62	RAIS default value(142); equal to watering 1 inch/week
Irrigation period, F	unitless	0.25	RAIS default value(142); 3-month growing season
Soil leaching rate, λ_{HL}	1/day	2.70E-05	RAIS default value(142)
Decay rate for chemicals for nonradionuclides, λ_i	1/day	0	RAIS default value(142)
Effective removal rate for nonradionuclides, λ_B	1/day	2.70E-05	RAIS default value(142)
Long-term deposition buildup, t_b	days	90	Maximum length of time vegetables and fruits will be available for deposition during growing season
Area density of root zone, P	kg/m^2	240	RAIS default value(142)
Produce plant mass loading rate factor, $MLF_{produce}$	unitless	0.26	RAIS default value(142)
Interception fraction, I_f	unitless	0.0975	Derived using methods from USEPA (2005)(143) for produce and leafy vegetables excluding silage
Translocation factor, T	unitless	1	RAIS default value(142)
Weathering half-life, T_w	days	14	RAIS default value(142)
Decay for removal on produce for chemicals, λ_E	1/day	0.0495	RAIS default value(142)
Plant yield (wet), Y_v	kg/m^2	2	RAIS default value(142)
Above ground exposure time, t_v	days	60	RAIS default value(142)

Table 5-18: Estimation of fruit and vegetable exposure point concentrations for radionuclides (pCi/kg)

Analyte	Exposure Point Concentration (pCi/L)		Decay Rate (1/days)	Effective Removal Rate (1/day)	Removal from Produce (1/day)	Soil-to-Wet Plant Uptake	Root Uptake Multiplier (L/kg)	Resuspension from Irrigation Multiplier (L/kg)	Aerial Deposition from Irrigation Multiplier (L/kg)	Overall Multiplier (L/kg)	Fruit/Vegetable EPC (pCi/kg)	
	CT	RME									CT	RME
Americium-241	0.296	0.725	4.39E-06	3.14E-05	0.050	0.001	3.39E-04	0.088	0.85	0.93	2.76E-01	6.77E-01
Lead-214	4.524	4.966	3.73E+01	3.73E+01	37.3	0.01	1.01E-06	0.000026	0.0012	0.0012	5.47E-03	6.01E-03
Plutonium-238	0.0022	0.00264	2.17E-05	4.87E-05	0.050	0.001	3.39E-04	0.088	0.85	0.93	2.05E-03	2.46E-03
Plutonium-239/240	0.0025	0.00323	7.89E-08	2.71E-05	0.050	0.001	3.39E-04	0.088	0.85	0.93	2.34E-03	3.02E-03
Potassium-40	7.1	18.6	1.48E-12	2.70E-05	0.050	0.300	1.02E-01	0.088	0.85	1.0	7.35E+00	1.93E+01
Radium-226	0.598	1.2	1.19E-06	2.82E-05	0.050	0.04	1.36E-02	0.088	0.85	0.95	5.66E-01	1.14E+00
Radium-228	0.805	0.991	3.30E-04	3.57E-04	0.050	0.04	1.34E-02	0.087	0.84	0.94	7.58E-01	9.33E-01
Strontium-90	0.11	0.277	6.54E-05	9.24E-05	0.050	0.3	1.01E-01	0.088	0.84	1.0	1.14E-01	2.86E-01
Thorium-228	0.156	0.239	9.93E-04	1.02E-03	0.050	0.001	3.24E-04	0.084	0.83	0.92	1.43E-01	2.19E-01
Thorium-230	0.135	0.297	2.47E-08	2.70E-05	0.050	0.001	3.39E-04	0.088	0.85	0.93	1.26E-01	2.77E-01
Thorium-232	0.118	0.171	1.35E-13	2.70E-05	0.050	0.001	3.39E-04	0.088	0.85	0.93	1.10E-01	1.60E-01
Tritium	17.38	19	1.54E-04	1.81E-04	0.050	4.8	1.62E+00	0.088	0.84	2.5	4.43E+01	4.84E+01
Uranium-234	1.272	1.54	7.77E-09	2.70E-05	0.050	0.003	8.47E-04	0.088	0.85	0.93	1.19E+00	1.44E+00
Uranium-235/236	0.0491	0.0583	2.70E-12	2.70E-05	0.050	0.003	8.47E-04	0.088	0.85	0.93	4.59E-02	5.45E-02
Uranium-238	0.849	1.037	4.25E-13	2.70E-05	0.050	0.003	8.47E-04	0.088	0.85	0.93	7.93E-01	9.69E-01

[a] Values from ORNL (2010).

[b] Values from ANL (1993) and NCRP (1989).

Table 5-19: Estimation of fruit and vegetable exposure point concentrations for radionuclides adjusted for water treatment (pCi/kg)

	Exposure Point Concentration (pCi/L)										Fruit/Vegetable EPC (pCi/kg)	
Analyte	CT	RME	Decay Rate (1/days)[b]	Effective Removal Rate (1/day)	Removal from Produce (1/day)	Soil-to-Wet Plant Uptake (unitless)[c]	Root Uptake Multiplier (L/kg)	Resuspension from Irrigation Multiplier (L/kg)	Aerial Deposition from Irrigation Multiplier (L/kg)	Overall Multiplier (L/kg)	CT	RME
Americium-241[a]	0.003195	0.0107	4.39E-06	3.14E-05	0.050	0.001	3.39E-04	0.088	0.85	0.93	2.98E-03	9.99E-03
Lead-210	46.4	80.8	8.51E-05	1.12E-04	0.050	0.01	3.38E-03	0.088	0.84	0.94	4.34E+01	7.56E+01
Lead-214	6.52	11.45	3.73E+01	3.73E+01	37.3	0.01	1.01E-06	0.000026	0.0012	0.0012	7.89E-03	1.39E-02
Plutonium-238[a]	0.0001695	0.000149	2.17E-05	4.87E-05	0.050	0.001	3.39E-04	0.088	0.85	0.93	1.58E-04	1.39E-04
Plutonium-239/240[a]	0.001355	0.00775	7.89E-08	2.71E-05	0.050	0.001	3.39E-04	0.088	0.85	0.93	1.27E-03	7.24E-03
Polonium-210	39.45	62.4	5.02E-03	5.05E-03	0.055	0.001	2.73E-04	0.071	0.78	0.85	3.35E+01	5.30E+01
Potassium-40	16.54	47.03	1.48E-12	2.70E-05	0.050	0.300	1.02E-01	0.088	0.85	1.0	1.71E+01	4.87E+01
Radium-226	0.598	1.2	1.19E-06	2.82E-05	0.050	0.04	1.36E-02	0.088	0.85	0.95	5.66E-01	1.14E+00
Radium-228	0.437	0.991	3.30E-04	3.57E-04	0.050	0.04	1.34E-02	0.087	0.84	0.94	4.11E-01	9.33E-01
Strontium-90	0.131	0.305	6.54E-05	9.24E-05	0.050	0.3	1.01E-01	0.088	0.84	1.0	1.35E-01	3.15E-01
Thorium-228	0.156	0.239	9.93E-04	1.02E-03	0.050	0.001	3.24E-04	0.084	0.83	0.92	1.43E-01	2.19E-01
Thorium-230	0.135	0.297	2.47E-08	2.70E-05	0.050	0.001	3.39E-04	0.088	0.85	0.93	1.26E-01	2.77E-01
Thorium-232	0.118	0.171	1.35E-13	2.70E-05	0.050	0.001	3.39E-04	0.088	0.85	0.93	1.10E-01	1.60E-01
Tritium	17.38	18.95	1.54E-04	1.81E-04	0.050	4.8	1.62E+00	0.088	0.84	2.5	4.43E+01	4.83E+01
Uranium-234[a]	0.0636	0.077	7.77E-09	2.70E-05	0.050	0.003	8.47E-04	0.088	0.85	0.93	5.94E-02	7.20E-02
Uranium-235/236[a]	0.00244	0.002915	2.70E-12	2.70E-05	0.050	0.003	8.47E-04	0.088	0.85	0.93	2.28E-03	2.72E-03
Uranium-238[a]	0.04245	0.05185	4.25E-13	2.70E-05	0.050	0.003	8.47E-04	0.088	0.85	0.93	3.97E-02	4.85E-02

[a] Concentrations for this radionuclide are assumed to be decreased by 95% after water treatment.

[b] Values from ORNL (2010).

[c] Values from ANL (1993) and NCRP (1989).

The effective removal rate is the sum of the radionuclide-specific decay constant (λ_i) and the soil leaching rate (λ_{HL}). The default soil leaching rate of 0.000027 1/days was used, along with decay constants (1/days) presented in Table 5-18. This soil leaching rate is equivalent to a half-life of 70 years.

The resuspension from irrigation multiplier represents the transfer of radionuclides from the resuspension of soil previously impacted by irrigation water to the surfaces of the homegrown fruits and vegetables during the watering. This multiplier is calculated using the following equation:

$$Irr_{res} = \frac{Ir \times F \times MLF \times [1 - \exp(-\lambda_B \times t_B)]}{P \times \lambda_B}$$

where:

MLF = Produce Plant Mass Loading Factor (unitless).

The default value for MLF of 0.26 was used, and this parameter is the mass of soil resuspended per mass of vegetation.

The aerial deposition from irrigation multiplier represents the transfer of radionuclides from irrigation water to the surfaces of homegrown fruits and vegetables. This multiplier is calculated using the following equation:

$$Irr_{dep} = \frac{Ir \times F \times I_f \times T \times [1 - \exp(-\lambda_E \times t_v)]}{Y_v \times \lambda_E}$$

where:

I_f = Interception Fraction (unitless);
T = Translocation Factor (unitless);
λ_E = Decay for Removal of Produce (1/day);
t_v = Above Ground Exposure Time (day), and;
Y_v = Plant Yield in terms of wet weight (kg/m^2)

The default values were used for *T,* λ_E, t_v, *and* Y_v, and are presented in Table 5-17.(142) Because the default value for I_f includes consideration for silage (i.e., grass and other feed for livestock), the value for I_f was adjusted to only include homegrown fruits and vegetables. Based on the method in USEPA (2005), the interception fraction was estimated using the following equation:

$$I_f = 1 - e^{-\gamma \times Y_p}$$

where:
γ = Empirical Coefficient Specific to the Type of Plant.

A consumption weighted average empirical coefficient of 0.0515 was used that accounted for the differences in coefficient between homegrown fruits (γ of 0.0324) and vegetables (γ of 0.0846). The estimated I_f for only homegrown fruits and vegetables is 0.0975. The estimated values for all three multipliers and the central tendency and RME fruit and vegetable concentrations are presented in Table 5-18 for untreated drinking water, and Table 5-19 for treated drinking water.

5.4.3 Estimation of Committed Dose from Intake of Radionuclides in Tap Water

FGR 13 risk coefficients for internal and external exposure modes estimate cancer morbidity or mortality directly from intake, thereby bypassing an estimation of committed dose to organs and tissue or committed effective dose to the whole body. To further characterize exposures to radionuclides from the tap water ingestion pathway, and to enable the IPR team to evaluate exposure from unfiltered and untreated surface water in comparison to exposure to ubiquitous background radiation, the annual whole body effective dose to an adult who ingests tap water, which is the route of greatest exposure, was calculated.

Effective dose is a quantity created by the International Commission on Radiological Protection (ICRP) to represent the dose to which the total body could receive uniformly that would give the same cancer risk from individual organs or tissues receiving the same absorbed dose, accounting for differences in radiosensitivities. (144, 145) Effective dose is the sum of the absorbed doses in tissue and organs multiplied by their respective quality factors to account for the potential for a biological effect (i.e., cancer) resulting from the absorbed dose: (146)

$$H_E = \sum D_T \times w_t$$

where:
H_E = Whole Body Effective Dose [rem]
D_T = Absorbed Dose to Tissue/Organ [Sv]
w_T= Tissue/Organ Weighing Factor based on Radiosensitivity [unitless]

Along with providing risk coefficients, the 2002 CD FGR 13 supplement provides dose coefficients that allow for the calculation of an absorbed dose to a specific type of organ or tissue (equivalent dose), or the sum of the equivalent dose that would result in the same risk from the individual organs or tissues receiving the absorbed dose (effective dose).(141) As with risk coefficients, each dose coefficient [d_r] is specific to the radionuclide, environmental medium, and the mode of exposure through that medium. Computing an annual whole-body effective dose [H_T] associated with the direct ingestion to a given radionuclide in tap water or food prepared with tap water is given by the relationship:

$$H_E = d_{E,R} \times I_R$$

where:
H_E = Whole Body Effective Dose [rem]
$d_{E,R}$ = Effective Dose Coefficient Specific to Each Radionuclide and Mode of Exposure [rem/Ci]
I_R = Calculated Intake of Radionuclide [Ci]

5.4.4 Inhalation of Radionuclides from Tap Water

FGR 13 provides risk coefficients for inhalation in air expressed as the cancer risk per unit activity intake. Risk coefficients are provided for three categories that represent the form of the inhaled materials. The form of the inhaled materials is classified in terms of the rate of absorption from the lungs to the blood using the classification scheme presented in ICRP Report 66. Types F, M, and S represent fast, medium, and slow rates of absorption of material inhaled in particulate form, respectively.(112) However, the intake rate of air is assumed to depend on age and gender.(112) For this analysis, and in accordance with FGR 13 recommendations (as based on the ICRP Report 66), inhalation risk coefficients were based on a moderate rate of absorption (Type M) for all radionuclides except thorium (i.e., thorium-228, -230, and 232), for which a slow rate of absorption (Type S) was used, as recommended.

Lifetime intakes during showering and bathing associated with inhalation of tap water for a given non-volatile radionuclide were calculated using the following equation:

$$I_{Radionuclide} = C_{Radionuclide} \times SF_p \times IR \times ED$$

where:
IR = Age- and Gender-specific Inhalation Rate [m^3/day]
$SF_{particulate}$ = Particulate Slope Factor [(ng/m3)/(mg/L)] (147)

One of the radionuclides, tritium, was considered to be volatile in this assessment. Radionuclide intakes during showering and bathing associated with inhalation of tap water for tritium were calculated using the following equation:

$$I_{Radionuclide} = C_{Radionuclide} \times VF \times IR \times E$$

where:
VF = Volatization Constant [L/m^3]

5.4.5 Direct Exposure to Radiation from Swimming or Bathing in Tap Water

A different approach was necessary to calculate excess cancer risk through direct exposure to radiation from swimming or bathing in tap water. As previously mentioned, FGR 13 provides risk coefficients for external exposure from submersion in air, external exposure from the ground surface, and external exposure from soil contaminated to an infinite depth; however, the guidance does not provide risk coefficients for external exposure from immersion in contaminated water. To calculate risk via this route, the IPR team relied upon Federal Guidance Report 12 *External Exposure to Radionuclides in Air, Water, and Soil* (FGR 12), which tabulates dose coefficients for external exposure to photons and electrons emitted by radionuclides distributed in air, water, and soil (148). These dose coefficients allow for the calculation of an absorbed dose rate to a specific type of organ or tissue (equivalent dose), or the sum of the equivalent dose rates that would result in the same risk from the individual organs or tissues receiving the absorbed dose (effective dose). These dose coefficients assume that the concentrations of the radionuclides are uniform throughout the source region.(148, 149) Specific to the dose coefficients for immersion in contaminated water, the source region is assumed to be infinite in the extent, relative to the paths of associated radiations.(148, 149)

To calculate an equivalent dose for a specific organ or tissue, or to calculate the effective equivalent dose, FGR 12 provides the following relationship, in which the equivalent dose or effective equivalent dose is equal to the dose coefficient, which is specific to the radionuclide and exposure medium, multiplied by the time-integrated concentration of the radionuclide in the exposure medium:

$$H_t = h_t \times \int C(t)dt$$

where:
H_t = Equivalent Dose or Effective Equivalent Dose [Sv]
h_t = Dose Coefficient [Sv per Bq s m^{-3}]
C = Concentration of Radionuclide [Bq or Ci]

The EPC considered in this assessment assumes that the concentration of the contaminant (chemicals and radionuclides) stay constant over the duration of an individual’s exposure; thus, the relationship for calculating absorbed dose becomes:

$$H_t = h_t \times C \times ED$$

where:
ED = Lifetime Exposure Duration [s]

ICRP Publication 60 *Recommendations of the International Commission on Radiological Protection* (ICRP 60) provides nominal probability coefficients for stochastic effects of low level exposures to radiation (Table 3, pg. 22). The report provides both probability coefficients for fatal cancers and non-fatal cancers for the adult worker population and whole population.(150) ICRP 60 provides a total risk of cancer (fatal and non-fatal) for the whole population of 0.06 Sv^{-1}. In 2007, ICRP 60 was superseded by ICRP Publication 103, *The 2007 Recommendations of the International Commission on Radiological Protection.*(113) ICRP 103 provides an updated table for probability coefficients (Table 1, pg. 53), now referred to as risk coefficients, for stochastic effects at low level exposure.(113) Total risk of cancer for the whole population was updated to 0.055 Sv^{-1}.(113)

Using the effective equivalent dose calculated for each radionuclide using FGR 12, excess cancer risk can be calculated using the following relationship:

$$R = H_t \times r$$

where:
R = Risk of Generating Cancer (cancer morbidity)
r = ICRP 103 Nominal Risk Coefficient for Stochastic Effects (.055 Sv^{-1})

5.5 THE STATE OF KNOWLEDGE REGARDING POTENTIAL EFFECTS OF EXPOSURE TO MULTIPLE CONTAMINANTS

A mixture is defined by the USEPA as any combination of two or more chemical substances, regardless of source or of spatial or temporal proximity, that can influence the risk of chemical toxicity in a target population.(151) Humans are rarely, if ever, exposed to just one chemical; however, in toxicology, studies with mixtures are scarce, and an important question for risk assessors is whether the response from a combined exposure can be predicted from the dose-response information available for the individual compounds.

The main public health concerns with mixtures are that interactions of mixture components may lead to toxicities not seen with individual components and that a mixture may be synergistic; that is, its potency may be much greater than expected based on knowledge of the components. In these situations, the mechanism underlying the toxicity of concern includes one or more interactions of mixture components. It should be noted that it is equally as likely that a mixture will have the opposite effect, and the potency of a combination of chemicals will be less than one would expect looking only at single components (antagonistic).

Examples of synergistic mixtures include carbon tetrachloride and ethanol (ethyl alcohol), which are individually toxic to the liver, but together produce much more liver injury than the sum of their individual effects. Another example includes the mixture of insecticidal pyrethroids with piperonyl butoxide. The insecticide activity of pyrethroids increases tenfold when one part piperonyl butoxide is mixed with nine parts pyrethroids.(152) Based on the results of a literature search, none of the potential COI combinations in this risk assessment have known synergistic effects in humans.

Standard regulatory default approaches to mixture risk assessment consider doses and responses of mixture components to be additive.(151) This assumption of additivity is expected to yield generally neutral risk estimates (i.e., neither conservative nor lenient), and are plausible for component compounds that induce similar types of effects at the same sites of action. This assumption underlies the toxic equivalency factor (TEF) or the relative potency factor (RPF) approach (e.g., that used to assess the cumulative risk of dioxins and dioxin-like polychlorinated biphenyls (PCBs), organophosphorus pesticides, *N*-methyl carbamates, or endocrine-disrupting chemicals).

Non-cancer hazards in this assessment were characterized using the hazard quotient approach.(153) The hazard quotient (HQ) is the ratio of the calculated average daily dose (ADD) to the maximally acceptable "safe" dose (that is, the reference dose, or RfD). When assessing mixtures, the sum of HQs for substances that affect the same target organ or organ systems is termed the hazard index (HI).(154) An HI less than one indicates that even sensitive populations are unlikely to experience adverse health effects from the mixture. The key major categories of effects usually considered in risk assessments of mixtures include neurotoxicity, developmental toxicity, reproductive toxicity, immunotoxicity and target organ effects (such as hepatic, renal, respiratory, cardiovascular, gastrointestinal, hematological, musculoskeletal, and dermal/ocular effects). Although higher exposure levels may be required to produce adverse health effects other than the critical effect, the RfD can be used as the toxicity value for each effect category as a conservative and simplifying step.

Carcinogenic health risks are defined in terms of the probability of an individual developing cancer as the result of being exposed to a given chemical at a given concentration.(153) The incremental probability of developing cancer (that is, the theoretical excess cancer risk) is the additional risk above and beyond the cancer risk that an individual would face in the absence of the exposures characterized in this assessment. When assessing mixtures containing multiple suspected or known carcinogens, the risks for each chemical are summed together to determine the total excess cancer risk. In general, the USEPA considers excess cancer risks that are below about 1 chance in 1,000,000 (1×10^{-6}) to be so small that they are negligible. Excess cancer risks ranging between 1×10^{-6} and 1×10^{-4} are generally considered to be acceptable.(155)

5.6 SUSCEPTIBLE SUBPOPULATIONS

Age, developmental stage, and health status can make a difference in exposure and risk posed by exposure to a material, either because of being more or less exposed, or having a greater or lesser biological response to exposures (susceptibility). For example, the risk posed by environmental agents can be greater for various life stages, such as the very young or adults over 65 years. Life stage is an important factor when determining susceptibility for several reasons. Children may be particularly vulnerable because of differences in exposure arising from their behavior (such as crawling on the floor and putting things into their mouths), absorption, or metabolism. Aging may also render individuals more susceptible to adverse effects from a pollutant because, as individuals age, their bodies' ability to defend against, and respond to, injury may diminish. Other sensitive subpopulations may include pregnant women, immunocompromised persons, and people with chronic illnesses. Regulatory agencies have made the protection of sensitive subpopulations law. For example, the Food Quality Protection Act and the 1996 amendments to the Safe Drinking Water Act both call for protection of susceptible subpopulations.

As stated above, this risk assessment utilizes RfDs to assess the risk of individual chemicals and to calculate HQs and HIs. Reference doses, as defined by the USEPA, take into account sensitive subpopulations in several ways. RfD are based on the most sensitive toxic effect found in the most sensitive subpopulations. As an example, for mercury, the RfD is based on reproductive effects in pregnant women. However, often little is known about the toxic effects of a substance at very low chronic doses, such as those addressed in this risk assessment. As such, uncertainty factors (UFs) are used for extrapolations. If there are no appropriate human data, an interspecies UF of 1, 3, or 10 is used. The factors considered when deciding on a specific value include (1) the species tested (type, appropriateness, and range), (2) the toxicological endpoint observed and the likely mechanism of action, (3) the range of response in the species tested, (4) the variability of response among the species tested, and (5) pharmacokinetic differences among the species tested. An intra-species UF of 1, 3, or 10 is also used to address variability among humans. The factors considered when assigning a specific value include (1) the toxicological endpoint observed and the likely mechanism of action, (2) the range of response among humans and subpopulations, and (3) pharmacokinetic differences among individuals.(143) Because the RfD is defined as applicable to “susceptible subgroups,” using UF accounts for uncertainty due to limited information.

5.7 DURATION AND FREQUENCY OF EXPOSURE

For many agents, the toxic effects that follow a single exposure (acute) are very different than those associated with repeated exposure (chronic). For example, one of the primary acute effects of hexavalent chromium exposure is ulceration and perforation of the nasal septum, while chronic inhalation of hexavalent chromium is a known cause of lung cancer. One of the principal tenets of toxicology is that acute toxicological responses are associated with thresholds; that is, there exists a dose below which the probability of an individual responding is zero. The existence of thresholds for chronic effects is less well defined, especially in relation to carcinogenesis. Chronic exposure to a toxic agent may produce some immediate (acute) effects after each administration (if the threshold dose is exceeded) in addition to the long-term, low level, or chronic effects. For chronic toxic effects, then, the most important factor is usually the total dose of the chemical, unless an acute threshold is exceeded.

Another important factor that must be considered when evaluating the potential toxicity of a chemical exposure is the frequency of exposure; specifically, the relationship between the elimination rate, the frequency of exposure, and the threshold of the toxic effects. For example, if the time it takes to eliminate the chemical from the body is shorter than the exposure interval, the toxic threshold dose may never be reached. Conversely, if the exposure interval is longer than the frequency of exposure, the toxic chemical may increase in the body until the toxic threshold is reached. Chronic toxic effects may occur if the chemical accumulates in the body (that is, absorption exceeds biotransformation and/or excretion), if the chemical causes irreversible toxic effects, or if there is insufficient time for the system to recover from toxic damage within the exposure frequency interval.

As discussed above, when considering chronic health effects (including cancer), the total dose of the COI would be considered the most important variable. Additionally, episodic exposure to the COI, such as those predicted due to runoff because of snowmelt or storms, could lead to acute health effects if toxic thresholds are exceeded. However, in the case of COI in Santa Fe's tap water, it is unlikely that any acute thresholds would be reached due to episodic runoff events.

5.8 RESULTS OF THE HUMAN HEALTH RISK ASSESSMENT

As described earlier, several hypothetical exposure scenarios were evaluated. The scenarios differed only in the levels of COIs estimated to be present in the residential tap water at the point of exposure (i.e., the home). These scenarios included 1) concentrations of COIs based on recent measurements in the Rio Grande, 2) concentrations of COIs based on recent measurements in the Rio Grande modified by accounting for 95% removal of certain radionuclides by the BDD treatment system, and 3) concentrations of COIs based on recent measurements of gross alpha radioactivity and uranium in water from the Buckman well field (as measured at the associated 10 MG tank).

The primary purpose of evaluating these various scenarios is to provide a basis of comparison for the estimated health risks associated with untreated Rio Grande water (Scenario #1 above) to other scenarios involving either some level of water treatment (Scenario #2 above) or existing, alternative sources of tap water (Scenario #3). Additonally, the IPR team also assessed the theoretical risk under the assumption that all COIs were present in the Rio Grande at their respective USEPA Maximum Contaminant Levels or other drinking water criteria if no MCL exists (termed the "MCLs" scenario). The purpose of that analysis was simply to provide a benchmark measure of the potential risks associated with consuming maximally acceptable levels of the various contaminants.

The most meaningful results of the health risk assessment are those for the central tendency evaluations, since they are most representative of typical exposures expected from using local tap water, while still being conservative (e.g., assuming a lifetime of daily exposure). We present the results for both CT and RME risk estimates in the tables; however, our discussion of the results is focused on the CT risk estimates. Nonetheless, it is important to note that, in general, the RME risk estimates are only marginally higher than the CT estimates, due to the many conservative assumptions used to derive the CT estimates.

5.8.1 Health Risk Assessment Results for Chemicals

The health risk assessment results for chemicals are summarized in Tables 5-20 through 5-23. The results are broken down by chemical, and are presented based on the Central Tendency and Reasonable Maximum Exposure assessments. Tables 5-20 and 5-21 present cancer risk estimates for chemicals, for the "Recent Measurements" and "MCLs" scenarios, respectively. Tables 5-22 and 5-23 present non-cancer risk estimates for chemicals and the "Recent Measurements" and "MCLs" scenarios, respectively. Those results are broken down by the relevant non-cancer health endpoints, and are presented based on the Central Tendency and Reasonable Maximum Exposure assessments.

As previously mentioned, cancer risks in the range of 1×10^{-6} to 1×10^{-4} are considered acceptable.(122, 127) The figure below graphically depicts the chemical cancer risk assessment results, and shows that, for each individual chemical, the risks fall within the acceptable range.

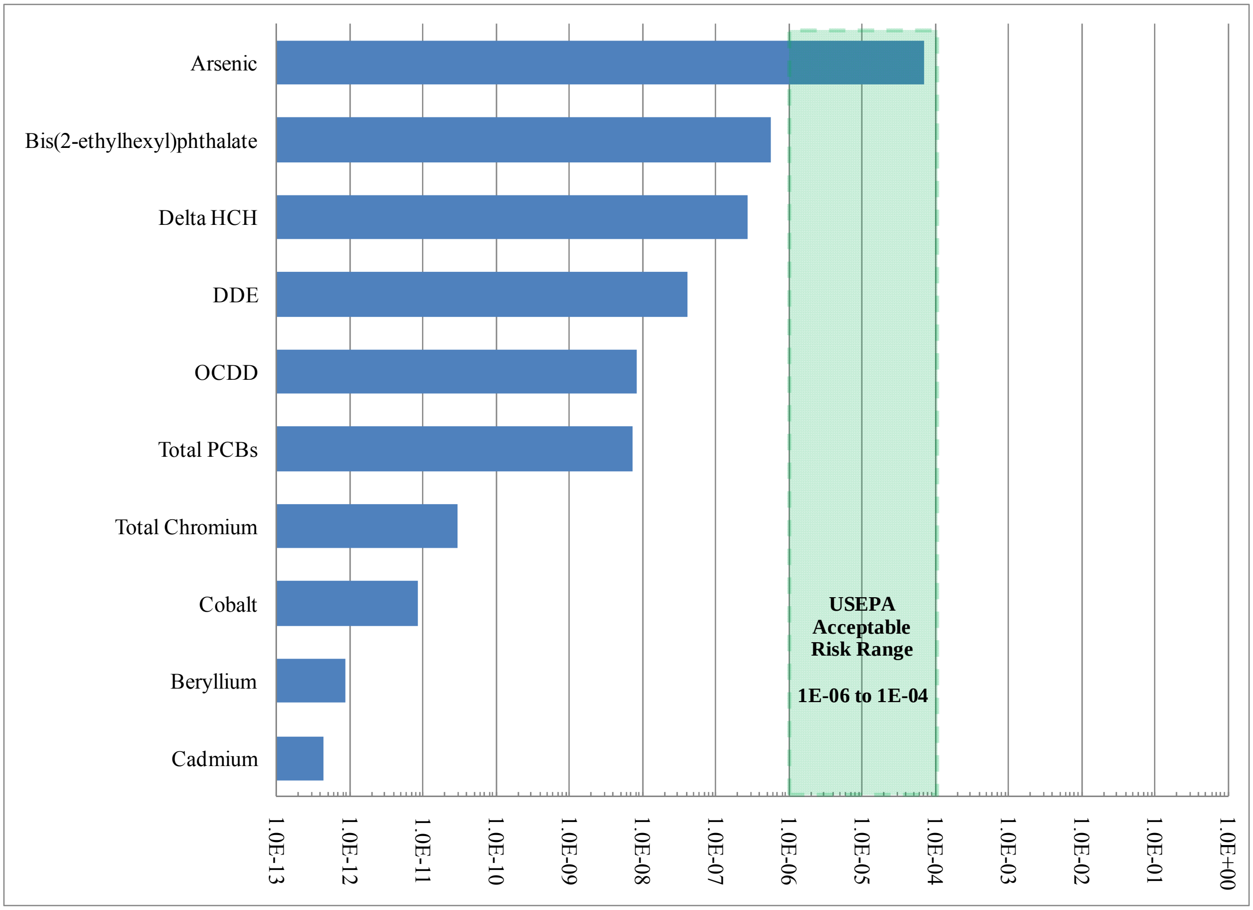


Figure 5-1: Theoretical cancer risks for the chemical COIs

Additional details of the risk assessment results for chemicals can be found in Appendices 5A and 5B. The tables in those appendices include breakdowns by chemical, exposure pathway, and health endpoint for the CT and RME assessments.

5.8.2 Health Risk Assessment Results for Radionuclides

The health risk assessment results for radionuclides are summarized in Tables 5-24 through 5-30. Tables 5-24 through 5-26 present cancer risk estimates for radionuclides for the “Recent Measurements” scenario. Table 5-24 presents the cancer risks broken down by age group and gender for both the CT and RME assessments. Tables 5-25 and 5-26 show the cancer risk estimates for the “Recent Measurements” scenario in more detail, with breakdowns by radionuclide, gender, age group and exposure pathway.

Table 5-27 presents cancer risk estimates for radionuclides for the “MCLs” scenario, broken down by age group and gender for the CT and RME assessments.

Table 5-28 presents cancer risk estimates for radionuclides for the “Water Treatment” scenario, broken down by age group and gender for the CT and RME assessments.

Table 5-29 present cancer risk estimates for radionuclides for the “10 MG Tank” scenario, broken down by age group and gender for the CT and RME assessments.

Table 5-30 presents the annual whole body effective dose estimates for the adult ingestion CT and RME assessments under the “Recent Measurements” scenario.

Those results are broken down by chemical, and are presented based on the Central Tendency and Reasonable Maximum Exposure assessments.

Additional details of the health risk assessment results for radionuclides can be found within the Seection 5 Appendices for the “Recent Measurements,” “MCLs,” “Water Treatment,” and “10 MG Tank” scenarios, respectively. The tables in those appendices include breakdowns by gender, age group, radionuclide, and exposure pathway for the CT and RME assessments.

As previously mentioned, cancer risks in the range of 1 x 10^{-6} to 1 x 10^{-4} are considered acceptable.(122, 127) The figure below graphically depicts the results of the radionuclide cancer risk assessment, and shows that, for each individual chemical, the risks fall within the acceptable range.

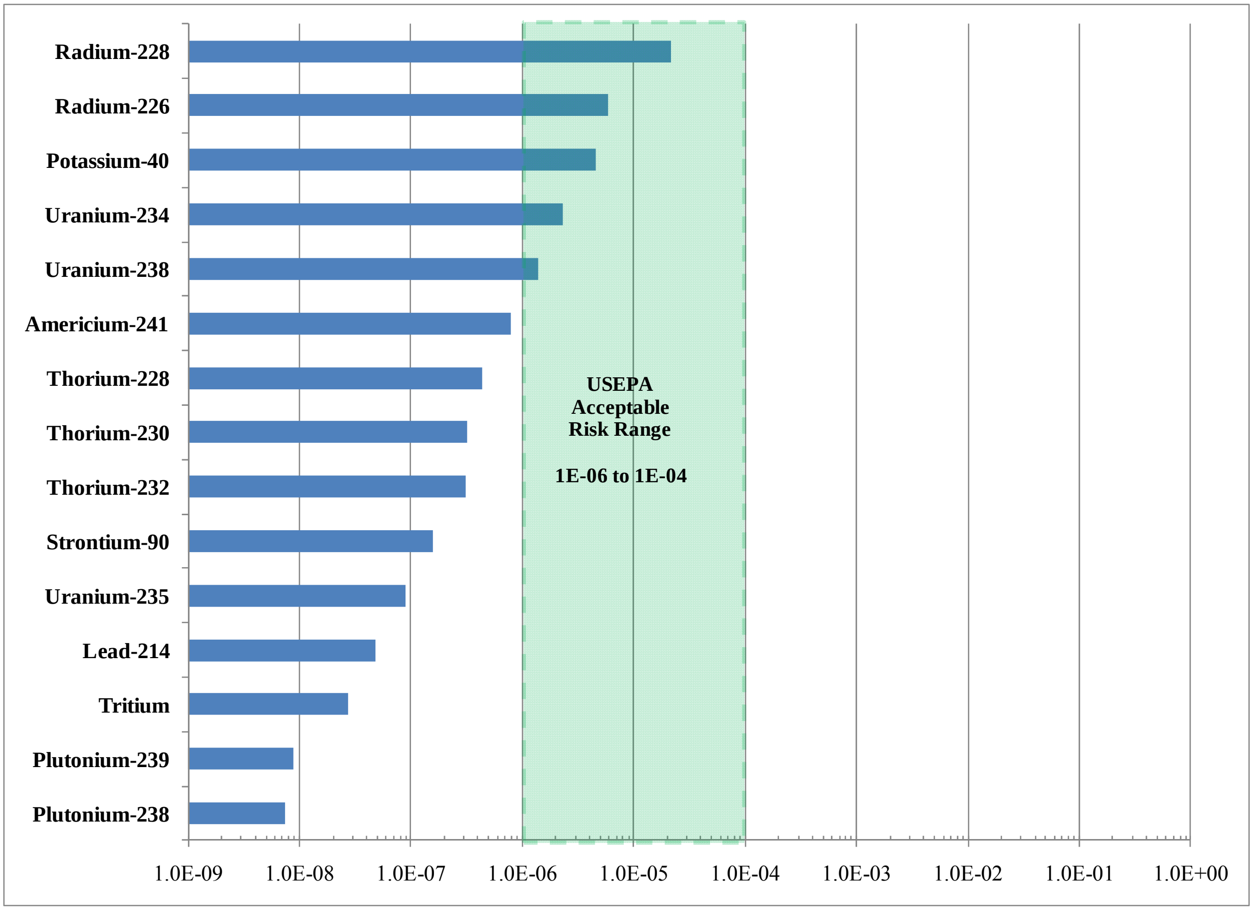


Figure 5-2: Theoretical cancer risks for the chemical COIs

Table 5-20 Chemical Cancer Risk Summary Table EPCs

Analyte	Risk	
	CT	RME
Acetone	--	--
Aluminum	--	--
Ammonia	--	--
Antimony	--	--
Arsenic	7.16E-05	2.24E-04
Barium	--	--
Beryllium	8.63E-13	9.63E-13
Bis(2-ethylhexyl)phthalate	5.60E-07	2.38E-06
Boron	--	--
Cadmium	4.33E-13	1.58E-12
Chloromethane	--	--
Total Chromium	2.97E-11	6.67E-11
Cobalt	8.44E-12	2.09E-11
Copper	--	--
Cyanide	--	--
DDE	4.12E-08	9.73E-08
Fluoride	--	--
Delta-HCH	2.78E-07	6.17E-07
Iron	--	--
Lead*	--	--
Manganese	--	--
Mercury	--	--
Molybdenum	--	--
Nickel	--	--
Nitrite	--	--
OCDD	8.41E-09	6.87E-08
Perchlorate	--	--
Total PCBs	7.22E-09	4.18E-08
Selenium	--	--
Silver	--	--
Strontium	--	--
Thallium	--	--
Uranium	--	--
Vanadium	--	--
Zinc	--	--
Total	**7.24E-05**	**2.28E-04**

Table 5-21: Total risk summary—MCL

	Risk	
Analyte	CT	RME
Acetone	--	--
Aluminum	--	--
Ammonia	--	--
Antimony	--	--
Arsenic	2.31E-04	5.37E-04
Barium	--	--
Beryllium	6.91E-12	3.85E-12
Bis(2-ethylhexyl)phthalate	1.94E-05	1.28E-05
Boron	--	--
Cadmium	6.47E-12	3.61E-12
Chloromethane	--	--
Total Chromium	1.25E-09	9.39E-10
Cobalt	7.12E-11	3.97E-11
Copper	--	--
Cyanide	--	--
DDE	8.04E-06	6.18E-06
Fluoride	--	--
Hexachlorocyclohexane, Delta-	1.29E-06	2.55E-06
Iron	--	--
Lead*	--	--
Manganese	--	--
Mercury	--	--
Molybdenum	--	--
Nickel	--	--
Nitrite	--	--
OCDD	2.09E-06	1.37E-06
Perchlorate	--	--
Total PCBs	1.19E-04	9.18E-05
Selenium	--	--
Silver	--	--
Strontium	--	--
Thallium	--	--
Uranium	--	--
Vanadium	--	--
Zinc	--	--
Total	3.82E-04	6.52E-04

Table 5-22: Non-cancer risk summary for chemicals, infant age group, “recent concentrations” scenario

	Hazard Index	
Health Endpoint	Central Tendency (CT)	Reasonable Maximum Exposure (RME)
Kidney Effects	0.18	0.87
Respiratory Effects	0.27	1.16
Decreased Body/Organ Weight	0.18	0.58
Circulatory/Cardiovascular System Effects	1.31	5.09
Immune System/Thyroid Effects	0.61	2.88
Skin Effects	0.66	1.95
Gastrointestinal Effects	0.26	0.96
Bone/Teeth Effects	0.41	1.02
Hair Loss	0.44	1.55
Liver Effects	0.30	1.17
Gout	0.06	0.15
Reproductive Effects	1.21	4.64
Central Nervous System Effects	1.00	4.34

Table 5-23: Non-cancer risk summary for chemicals, infant age group, "MCLs" scenario

Endpoint	Hazard Index	
	Central Tendency (CT)	Reasonable Maximum Exposure (RME)
Kidney Effects	2.39	5.20
Respiratory Effects	7.46	16.06
Decreased Body/Organ Weight	5.29	11.62
Circulatory/Cardiovascular System Effects	6.76	15.93
Immune System/Thyroid Effects	5.20	11.46
Skin Effects	4.14	9.06
Gastrointestinal Effects	3.29	7.20
Bone/Teeth Effects	4.74	10.43
Hair Loss	3.12	6.82
Liver Effects	2.37	5.22
Gout	0.52	1.14
Reproductive Effects	6.46	14.22
Central Nervous System Effects	5.00	11.01

Table 5-24: Cancer risk summary for radionuclides EPC

Age	Male		Female	
	CT	RME	CT	RME
0–5 Years	8.44E-06	3.43E-05	8.44E-06	3.43E-05
5–15 Years	1.23E-05	5.02E-05	1.23E-05	5.02E-05
15–25 Years	1.18E-05	4.62E-05	1.18E-05	4.61E-05
25–70 Years	1.11E-05	4.24E-05	1.10E-05	4.29E-05
Lifetime (0–70 years)	3.80E-05	1.46E-04	3.79E-05	1.46E-04

Table 5-25: Cancer risk summary MCL

Age	Male		Female	
	CT	RME	CT	RME
0–5 years	5.75E-06	1.51E-05	5.73E-06	1.50E-05
5–15 years	7.36E-06	1.96E-05	7.33E-06	1.95E-05
15–25 years	5.96E-06	1.55E-05	5.79E-06	1.52E-05
25–70 years	1.03E-05	2.60E-05	9.99E-06	2.50E-05
Lifetime (0–70 years)	2.66E-05	6.83E-05	2.58E-05	6.58E-05

Table 5-26: Cancer risk summary—95% removal

Age	Male		Female	
	CT	RME	CT	RME
0–5 years	7.39E-06	3.05E-05	7.38E-06	3.05E-05
5–15 years	1.10E-05	4.55E-05	1.10E-05	4.55E-05
15–25 years	1.09E-05	4.26E-05	1.08E-05	4.25E-05
25–70 years	9.29E-06	3.62E-05	9.27E-06	3.66E-05
Lifetime (0–70 years)	3.36E-05	1.31E-04	3.35E-05	1.30E-04

Table 5-27: Cancer risk summary, Buckman wells

Age	Male		Female	
	CT	RME	CT	RME
0–5 years	1.97E-05	9.96E-05	1.97E-05	9.96E-05
5–15 years	2.81E-05	1.42E-04	2.81E-05	1.42E-04
15–25 years	2.63E-05	1.23E-04	2.62E-05	1.23E-04
25–70 years	2.72E-05	1.33E-04	2.72E-05	1.34E-04
Lifetime (0–70 years)	8.76E-05	4.16E-04	8.76E-05	4.16E-04

5.8.3 Combined Risks for Chemicals and Radionuclides

The total risk from all chemical and radionuclide COIs combined is 1 x 10^{-4}, which falls on the upper end of the acceptable risk range.

6.0 POTENTIAL FUTURE IMPACTS ON THE RIO GRANDE FROM CHEMICALS AND RADIONUCLIDES IN LANL SEDIMENTS AND GROUNDWATER

6.1 OVERVIEW

Environmental contamination at LANL can impact water used by the BDD project if transported to the reach of the Rio Grande above the BDD intake. There are contaminated sediments, surface water, and groundwater present at LANL. Surface water contamination includes suspended sediment discharged with canyon storm-flow. There are known groundwater and surface water pathways for contamination to move from LANL and discharge to the Rio Grande. The location of surface water and groundwater discharge areas pertinent to BDD risk determination is along the reach of the Rio Grande from the confluence of Lower Los Alamos Canyon downstream to the Buckman Direct Diversion intake. Aerial photography indicates that the length of this reach of the Rio Grande is about 5.3 kilometers (3.3 miles), as shown in Figure 6-1.

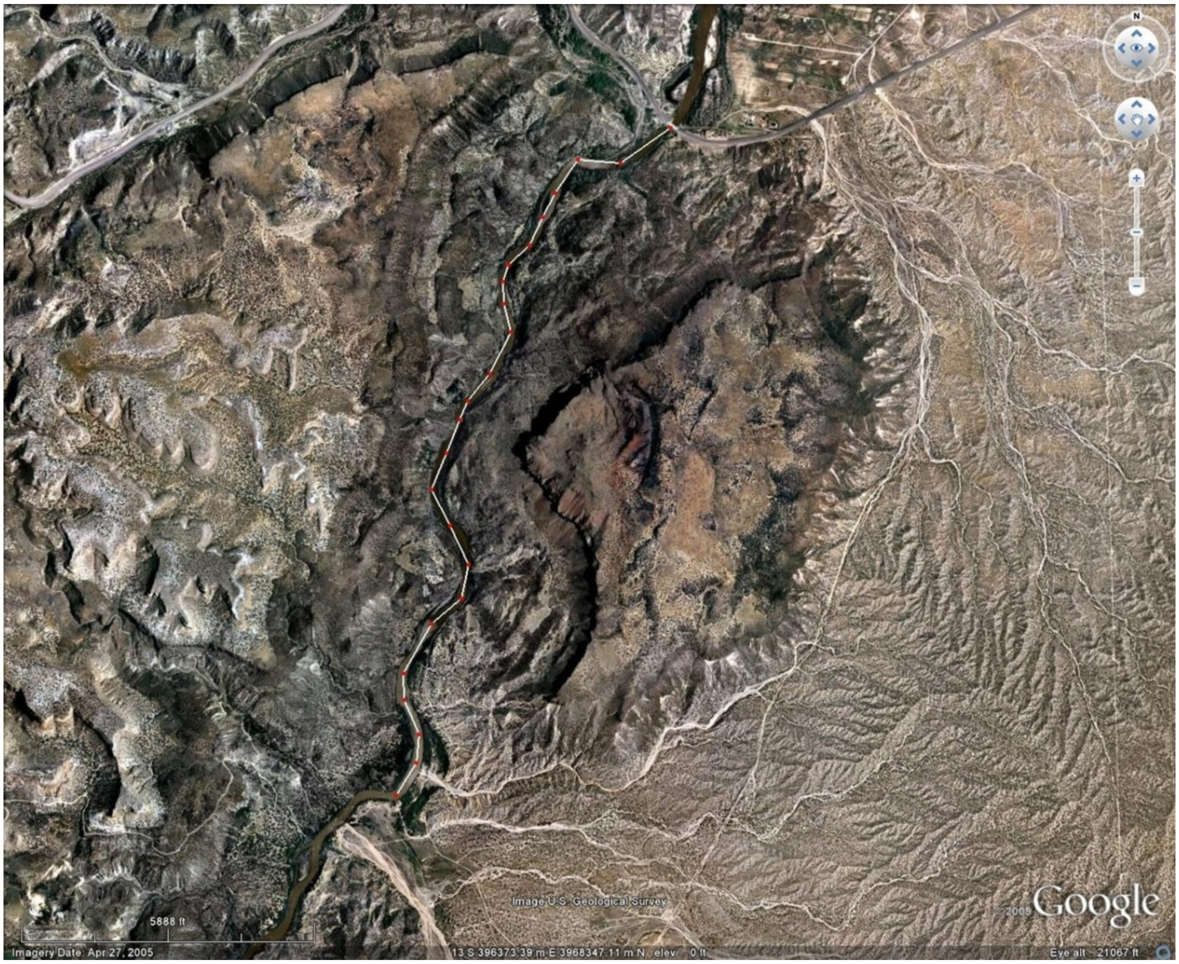


Figure 6-1: The relevant reach of the Rio Grande between the entry of Los Alamos Canyon and the area of the BDD diversion

The report describes the hydrologic pathways for transport of LANL-associated contaminants to the relevant reach of the Rio Grande, as well as historical and current observations of contamination within the watersheds that discharge to this reach. This information on pathways and observed contamination is based entirely on reports and data published by LANL and NMED. This data and information is reviewed and synthesized in order to develop conservative estimates of potential contaminant discharges to the Rio Grande upstream of the BDD project intakes. Section 4 describes our review and synthesis related to the surface water pathway, and Section 5 discusses the groundwater pathway.

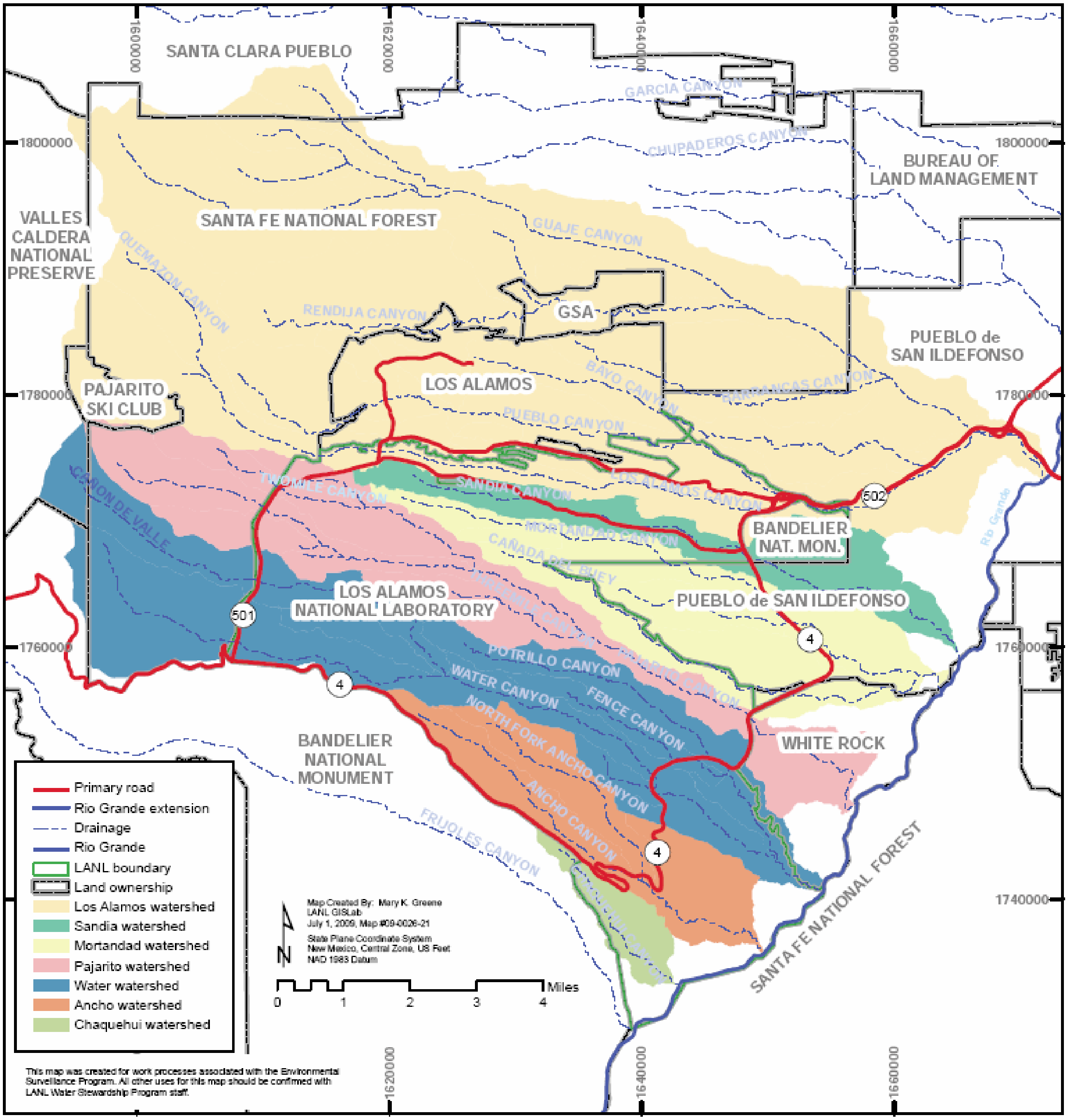
6.2 CONTAMINANT MIGRATION VECTORS AT LANL

For on-site contamination at LANL to pose a risk to the BDD, contaminants must be transported off site to the cited reach of the Rio Grande. Two principal hydrologic vectors, or pathways, exist: surface water and groundwater. The following two subsections describe each of these pathways.

6.2.1 Surface Water Vector

The surface water pathway includes two components: contaminants sorbed to suspended sediments and contaminants dissolved in streamflows. The majority of the surface water discharge to the Rio Grande over the river reach of interest is confined to the Los Alamos - Pueblo Canyon drainage (Figure 6-2). This watershed also includes Acid, DP, Barrancas, Bayo, Guaje, and Rendija Canyons; the latter four canyons are often described in the LANL literature as the North Canyons. Storm discharge to the Rio Grande from overland flow and small unnamed canyons along the 5.3 km reach is assumed to be a small contribution to total flow in the river, and is not considered here.

Surface water contamination at LANL that could move to the Rio Grande and impact BDD is confined to the Los Alamos Canyon watershed (LACW). The flow in the stream channels of the canyons is ephemeral (storm or snowmelt driven), with exception of groundwater discharge to springs, and near-perennial base flow in the lowest elevation stream reaches near the Rio Grande. During storms, dissolved contamination concentrations and mass are significantly less than the amounts associated with suspended sediments. Storms and runoff mobilize and suspend sediments in the LACW. Surface water contaminant transport from LANL is dominantly associated with metals and radionuclides that are sorbed to sediments suspended in the stream flow, which is highly variable.



Map Created By: Mary K. Greene
LANL GISLab
July 1, 2009, Map #09-0026-21

State Plane Coordinate System
New Mexico, Central Zone, US Feet
NAD 1983 Datum

This map was created for work processes associated with the Environmental Surveillance Program. All other uses for this map should be confirmed with LANL Water Stewardship Program staff.

Figure 6-2: Watersheds on LANL property (from Figure 6-1 in LA-14407-ENV)

The concentration and total mass of contaminants on sediments at LANL is decreasing over time due to curtailed waste discharge and disposal, remedial actions, radioactive decay, biodegradation, and off-site transport of sediments removing them from inventory. Mixing with, and dilution by, uncontaminated sediments may be increasing the total volume of contaminated sediments in some stream reaches. While there have been measurable reductions in contaminated sediment inventory in the LACW for the reasons noted above, off-site transport of chemicals and radionuclides in suspended sediment is quantifiable, as illustrated by the results of investigations by NMED and LANL.(27, 63, 74, 101, 156) For example, NMED has indicated that off-site transport results in exceedances of expected background values for plutonium-239/240 in water upstream of the BDD intake.(101) Other compounds are also present in suspended sediments based on previous work by LANL (metals, PCBs, pesticides), but were not quantified at the time of the NMED study. Significant inventories of contaminated sediments remain in the Los Alamos watershed canyons. LANL is making efforts to further quantify off-site transport in the LACW, and is currently undertaking remedial actions to reduce sediment migration.(157)

The sediment-bound contaminants present are variable in type and concentration depending on the stream reach in which they are located. Details can be found in the LANL publications on the canyon investigations,(63, 158) and are not reproduced here. The contaminated sediment inventory is large enough that contaminated sediment discharge from LANL to the Rio Grande has been currently noted, and is expected to continue for decades to come.(63)

6.2.2 Groundwater Vector

There are three potential LANL-sourced groundwater contributions to the contaminant load in surface water upstream of the BDD intake. These potential groundwater contaminant sources are from discharge to the Rio Grande by the Alluvial Aquifer (AA) and associated stream channel base flow, the Intermediate Perched Aquifer (IPA) and the upper portions of the Regional Aquifer (RA). The shallow alluvial aquifer found predominantly in canyon bottoms is strongly coupled to canyon surface water flow.(159) Springs that discharge in the tributary canyons and the key reach of the Rio Grande are associated with the IPA and the RA.(159) The RA is the major water yielding aquifer in the area.(159) The degree of connection between the AA, IPA, and RA is much more variable under LANL than close to the Rio Grande. Acknowledging this complexity of the flow system, the waters in these aquifers ultimately merge before discharging to the river.(159)

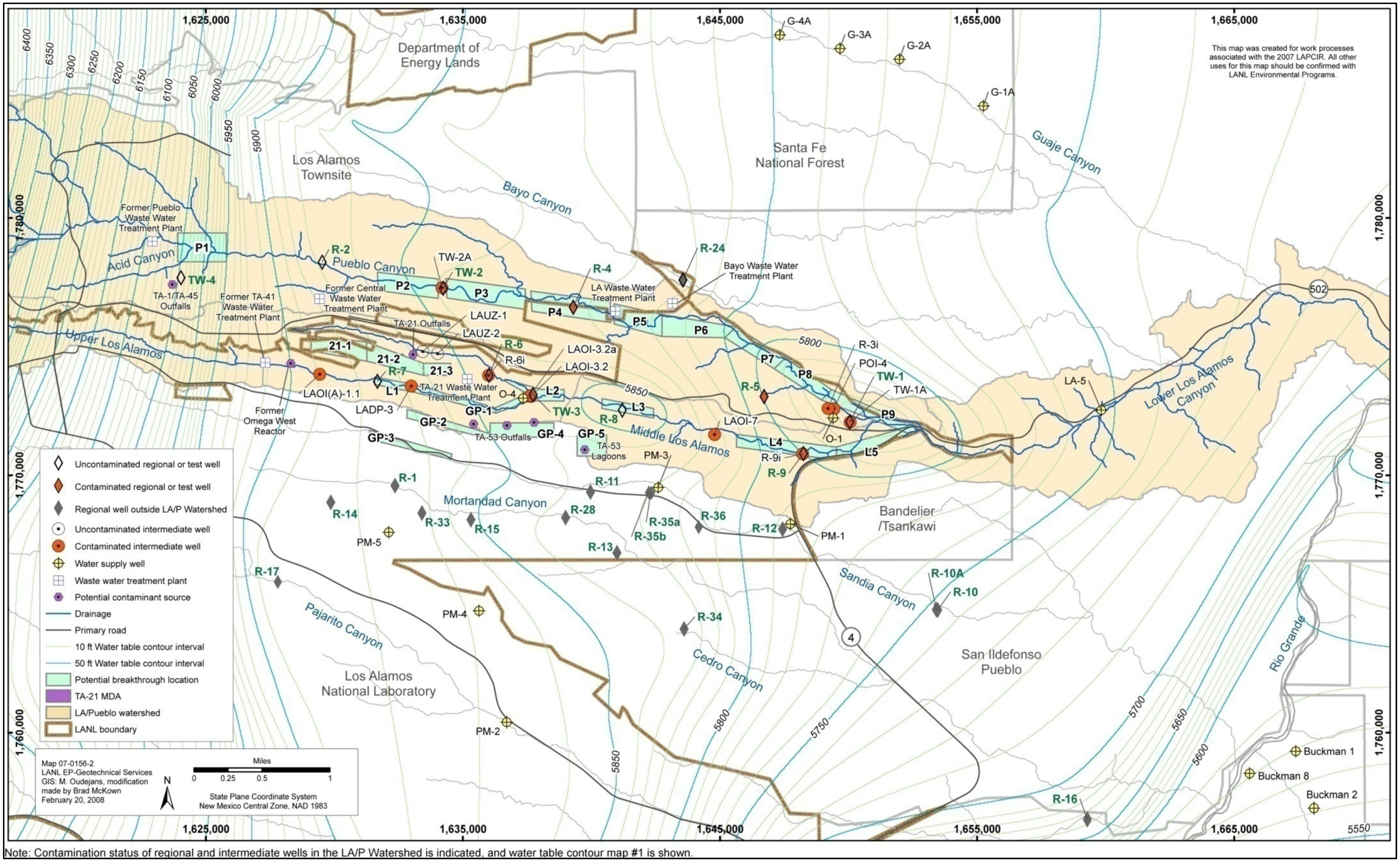
As described earlier, all three aquifers at LANL (AA, IPA, and RA) contain contaminated groundwater. Much of the groundwater in the AA in the LACW watershed moves downstream to discharge to the Rio Grande.(63, 159) Farther up the canyons, the interaction between the AA and the IPA becomes more complex,(160) allowing breakthrough of mobile contaminants to the regional aquifer.(161) LANL acknowledges 22 of these "breakthrough locations" related to Los Alamos and Pueblo Canyon, as depicted in Figure 6-3 (reproduced from Figure 2.0-3 found in LA-UR-08-1105). Similar pathways for contaminant breakthrough to the RA also exist in Mortandad canyons,(162) and it is not unreasonable to assume that they would also be present in Sandia Canyon.(163)

As depicted in Figure 6-3, the measured gradient and flow directions in the RA indicate that the RA under the LACW, Sandia Canyon, and Mortandad Canyon flow to the Rio Grande reach above the BDD.(161) Alternate interpretations of the RA water table surface(161) (see Appendix D in that reference) also depict potential transport of contaminated RA groundwater from the LACW, Sandia Canyon, and Mortandad Canyon to the Rio Grande reach above BDD.

The RA under the LACW, Sandia Canyon, and Mortandad Canyon has broad areas of low hydraulic gradient, consistent with groundwater recharge, as evidenced by the widely spaced lines of equal head depicted in Figure 6-3. Recharge potential is relatively higher in this area,(163) and discharge from treatment facilities has the highest density and volume in this area of the plateau. The combination of breakthrough zones, recharge indicators and measurements, contaminant sources in aquifers overlying the RA, and contamination of the RA by the most mobile constituents found at LANL, indicates that contamination of the RA by LANL has the potential to migrate to the Rio Grande.

Based on its review and synthesis of recent groundwater monitoring data, LANL has recently asserted that much of the contaminated groundwater in the Regional Aquifer is hydraulically and hydrogeologically isolated from the Buckman Well Field.(164) These recent interpretations differ from the 2005 hydrologic synthesis report,(159) which conservatively assumed a strong hydrologic connection between the contaminated areas under LANL to the Buckman well field(159) (see Figure 4-33 in that reference). This example is one of several evolutions of LANL hydrogeologic models and the numerical simulations used to test those models. Given the overall complexity of the system and the continuing acquisition of new data and information, such an evolution in hydrogeologic conceptual models is not unexpected. Similarly, the recent identification of “breakthrough areas” where quasi-vertical contaminant transport to the RA has occurred, or is occurring through preferential flow paths, has the appearance of being novel, but, in reality, is the net result of gradually improving hydrogeologic understanding.(161)

The hydrogeology of the Pajarito Plateau is complex enough without having to consider historic contaminant transport or changes in the hydrologic budget from groundwater withdrawal and waste water treatment plant discharges to canyons. The fact that the groundwater system connection to the Rio Grande through the AA, IPA and RA is only partially understood contributes to uncertainty, and rationally results in heightened public concern.



Note: Contamination status of regional and intermediate wells in the LA/P Watershed is indicated, and water table contour map #1 is shown.

Figure 6-3: Monitoring wells and other features within Los Alamos and Pueblo Canyons (Figure 2.0-3 from LA-UR-08-1105)

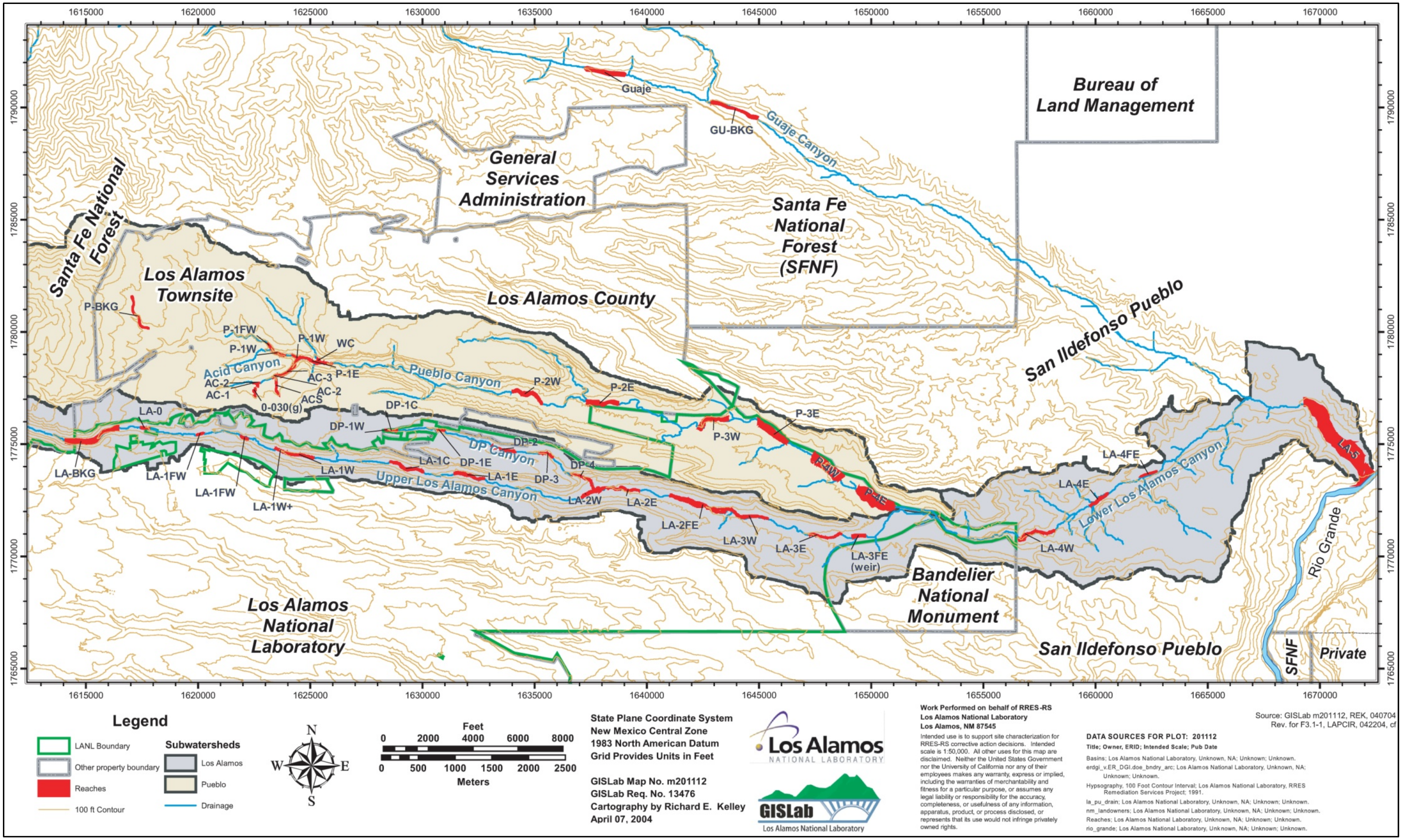
6.3 CONTAMINANT LOCATIONS AT LANL

The following two subsections describe and tabulate findings and observations of contaminated surface water (including suspended sediments) and groundwater associated with LANL sources that can be transported to the relevant reach of the Rio Grande via the pathways described earlier in this report.

6.3.1 Surface Water Contamination

Contaminated bed load sediments with a LANL origin are found in abandoned channels of the Rio Grande between LACW and the BDD intake.(74) Most investigations of contaminated sediments in this reach of the Rio Grande are focused on radionuclide concentrations and PCBs.(165, 166) Using plutonium-239/240 as a metric for LANL sourced contamination, little contaminated sediment has been found to be present at shallow depths (<30 cm) in river-bed sediments or abandoned channels in this reach of the river.(74) Modern characteristics of flow in the Rio Grande are not expected to erode or expose these sediments.(49) Potential impacts at the BDD intake from contaminated suspended sediments will most likely be related to flow and transport from LACW, rather than from erosion of the in-place contaminated Rio Grande bed and channel deposits. It is generally agreed that the greatest concentration of contaminants is found in easily transportable fine-grained sediments.(49, 92, 166, 167)

Sediment contamination in the Los Alamos and Pueblo watershed includes 30 inorganic chemicals, 72 organic chemicals, and 15 radionuclides. Surface water and sometimes interrelated AA groundwater contamination includes 46 inorganic chemicals, 51 organic chemicals, and 11 radionuclides.(63) Sediment contamination in the North Canyons includes 21 inorganic chemicals, 33 organic chemicals, and six radionuclides(158); arsenic is the only groundwater contaminant noted to date in the North Canyons, and is probably of natural origin. Contaminated sediments at LANL in the LACW have been mapped, and the contamination has been characterized in three dimensions. Estimates of the distribution, volume, and mass of contaminants have been made.(63) Contaminated sediment stream reaches in the LACW are assumed to be as mapped by LANL, and are represented in Figure 6-4 (published as Figure 3.1-1 in LA-UR-04-2714(63)); the contaminated and background stream reaches for the North Canyons as depicted in Figure 6-5 (excerpted from Draft LANL Figure 10-0010-01.pdf).



State Plane Coordinate System
New Mexico Central Zone
1983 North American Datum
Grid Provides Units in Feet

GISLab Map No. m201112
GISLab Req. No. 13476
Cartography by Richard E. Kelley
April 07, 2004

Work Performed on behalf of RRES-RS
Los Alamos National Laboratory
Los Alamos, NM 87545

Intended use is to support site characterization for RRES-RS corrective action decisions. Intended scale is 1:50,000. All other uses for this map are disclaimed. Neither the United States Government nor the University of California nor any of their employees makes any warranty, express or implied, including the warranties of merchantability and fitness for a particular purpose, or assumes any legal liability or responsibility for the accuracy, completeness, or usefulness of any information, apparatus, product, or process disclosed, or represents that its use would not infringe privately owned rights.

Source: GISLab m201112, REK, 040704
Rev. for F3.1-1, LAPCIR, 042204, cf

DATA SOURCES FOR PLOT: 201112
Title; Owner, ERID; Intended Scale; Pub Date
Basins; Los Alamos National Laboratory, Unknown, NA; Unknown; Unknown.
erdgi_v.ER_DGI.doe_bndry_arc; Los Alamos National Laboratory, Unknown, NA; Unknown; Unknown.
Hypsography, 100 Foot Contour Interval; Los Alamos National Laboratory, RRES Remediation Services Project; 1991.
la_pu_drain; Los Alamos National Laboratory, Unknown, NA; Unknown; Unknown.
nm_landowners; Los Alamos National Laboratory, Unknown, NA; Unknown; Unknown.
Reaches; Los Alamos National Laboratory, Unknown, NA; Unknown; Unknown.
rio_grande; Los Alamos National Laboratory, Unknown, NA; Unknown; Unknown.

Figure 6-4: Reaches in the Los Alamos and Pueblo Watershed (from LA-UR-04-2714)

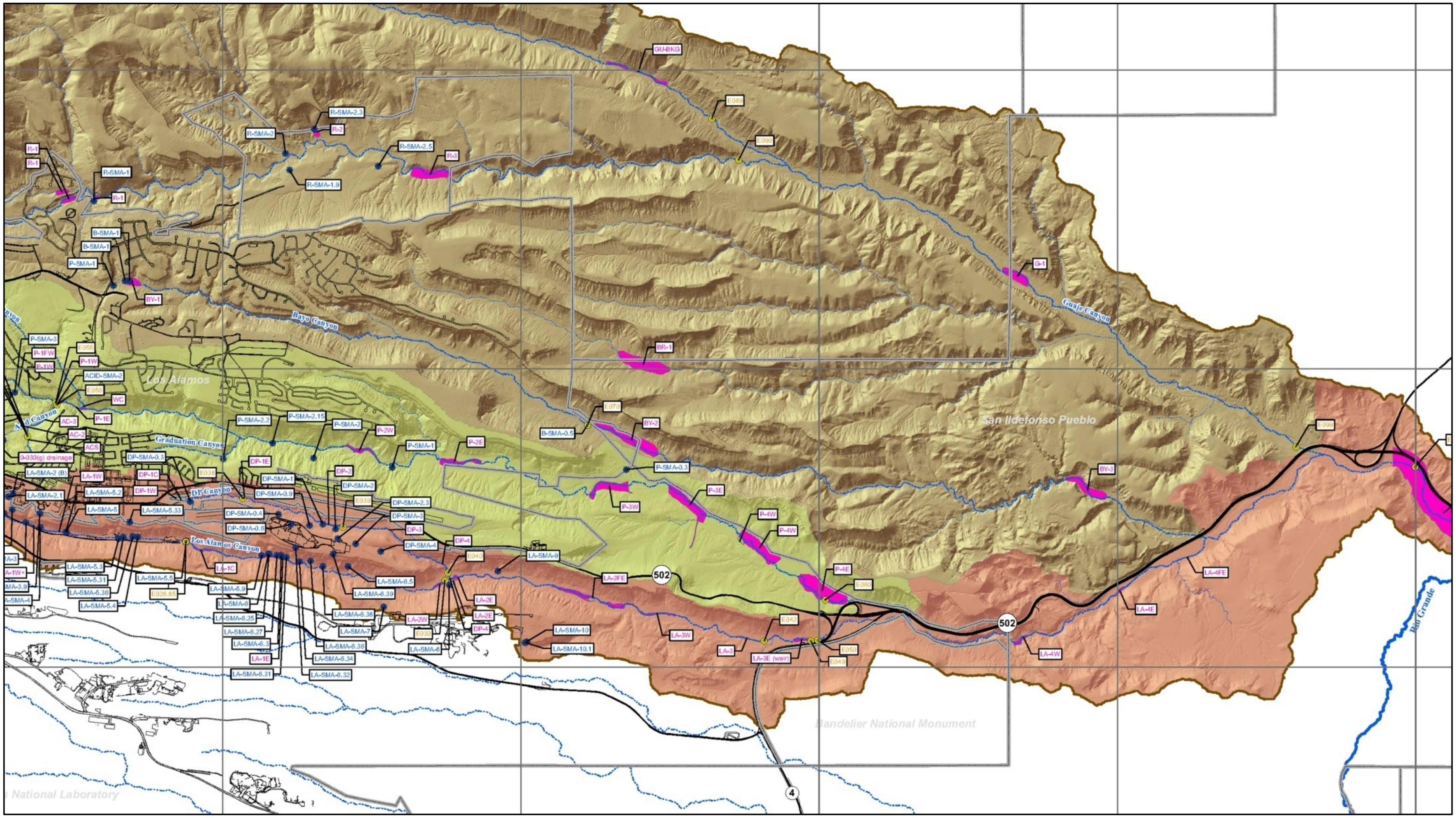


Figure 6-5: Contaminated and background stream reaches of the North Canyons (from Draft LANL Figure 10-0010-01.pdf)

The storm timing and intensity, the canyons affected by storms, the location, contaminant concentration and susceptibility to erosion of sediments are just a few of the controlling factors regulating the flow of contaminated sediments and surface water from LANL to the Rio Grande. Each sediment transport event is unique, resulting from unique antecedent conditions and unique storms. Storm events affect canyons unequally, with many events resulting in no sediment transport or water flow to the Rio Grande at all. Infrequent large events cause significant discharge of contaminated water and sediments to the Rio Grande from the LACW. One of the Cerro Grande fire's effects was to increase the frequency, duration, and magnitude of streamflow in response to precipitation (due to decreased vegetation), an effect that has diminished since the fire, but still persists a decade later. One result of all storm events at LANL is a modification of the sediment-bound contaminant inventory with respect to contaminant concentration and post-storm locations.

In light of the complex hydrology described above and the scope of the IPR effort, a simplified path for calculating impacts at the BDD is needed. Certain observations and limitations are recognized:

- The highest risk at the BDD intake will occur when large amounts of contaminated sediments from LACW are transported to the Rio Grande and the river is at its low-flow condition (minimum dilution).
- Significant changes in surface water flow, suspended sediment concentration, and contaminant concentration take place between the LANL site boundary and the Rio Grande over approximately 6 km (3.7 mi.).
- Monitoring results from surface water storm flow sampling within the LANL boundaries cannot be reliably extended to predictions of surface water discharge at the Rio Grande.
- Contaminant concentrations and distribution of in-place LACW contaminated sediments are not useful for calculating potential in-stream concentrations in the Rio Grande because of the difficulty in predicting their transport.
- In the absence of direct measurement, correlations between concentration of individual contaminants in in-place and suspended sediments may be useful for predicting in-stream concentrations of undetermined contaminants in the Rio Grande.
- Surface water sampling within contaminated LANL canyons is biased towards higher contaminant concentrations than would be expected in the sediments of the lower reaches of LACW.

Given the constraints above, using sediment contaminant data from any point other than from the confluence of LACW with the Rio Grande in order to project Rio Grande contaminant concentrations at the BDD intake would be highly uncertain. By necessity, the IPR relies on data from the E110 surface water monitoring station. Storm flow and contaminant data from this station is very limited.

6.3.2 Groundwater Contamination

Contaminated RA groundwater is found under the LACW, as well as under Sandia Canyon and Mortandad Canyon. As described earlier, there are potential groundwater pathways that can convey contaminated water to the BDD reach of the Rio Grande and/or the capture zone of the Buckman well field. The following paragraphs describe some of the contaminated groundwater observations, and the locations of those observations relative to the BDD. We also describe how LANL's defined groundwater monitoring objectives limit the scope of its characterization efforts, leading to increased uncertainty as to the nature and extent of existing groundwater contamination beneath LANL.

When contaminants are introduced to groundwater, they flow with groundwater. Groundwater flows from areas of higher potential energy (uphill, or up-gradient), to areas of lower potential energy (downhill or down-gradient). In order for a contaminant to be detected in groundwater, detection monitoring wells need to be located down-gradient of the contaminant source. Contaminant plumes in groundwater spread longitudinally (down-gradient) and laterally (cross-gradient). Taking into account plume spreading, if a monitoring well is located in such a manner as to be unable to detect a contaminant from a particular source, that monitoring well is "off-gradient" for that specific source.

The uncontaminated collocated RA monitoring wells R-10 and R-10A (Sandia Canyon) are a minimum of 4.2 km (2.6 miles) from the Rio Grande reach of interest, and, based on current water table elevation maps are off-gradient (will not detect contamination) from Mortandad and Sandia Canyons (Figure 6-3). The uncontaminated RA monitoring well R-16 (Mortandad Canyon) is much closer to the river at ~0.7 km (0.4 mile), but lies downstream of the river reach of interest, and is again off-gradient. Contaminated wells are found in the IPA and the RA (TW-1, R-5, and R-9) as close as 5.55 km (3.45 miles) to the Rio Grande; Sandia and Mortandad Canyon contaminated IPA and RA wells are about 11.3 to 12.9 km (7 to 8 miles) from the closest reach of the river. Contaminated AA wells are found as close as 160 meters (525 feet) to the Rio Grande in Lower Los Alamos Canyon, and contaminated base-flow surface water is found at the discharge of Lower Los Alamos Canyon to the Rio Grande.

LANL has not reported groundwater contamination in the RA monitoring wells closest to the Rio Grande over the river reach of interest; however, RA monitoring wells in the RA along this reach are scarce and/or off-gradient to the BDD reach, with most a large distance from the Rio Grande.

The intent of the LANL groundwater monitoring program under the Consent Order has been described by reviewers and LANL. The descriptions differ:

From the 2007 National Research Council (NRC) report:(30)

> "Under the Consent Order, LANL is to conduct investigations of groundwater in accordance with NMED-approved workplans to fully characterize the nature, vertical and lateral extent, fate, and transport of groundwater contamination originating from the Laboratory to determine the need for, and scope of, corrective action."

From the 2009 Los Alamos and Pueblo Canyons Well Network Evaluation, Revision 1,(161) "Monitoring Objectives:"

> "1. To confidently detect contaminants before their arrival at water-supply wells…
> 2. To confidently detect contaminants before their arrival at a Laboratory boundary…
> 3. To support an understanding of the nature and extent of contamination sufficient to support the evaluation of potential corrective measures.
> *This objective evaluates the contribution of the groundwater-monitoring network to the understanding of the nature and extent of contaminant migration within the regional aquifer. This objective does not have a quantitative metric because the degree to which the nature and extent of contamination must be understood is a function of which remedial alternative, if any, will be employed, and the remedial decision will not come until the CME phase of work."*

There are significant differences in the NRC and LANL descriptions of the intent of LANL groundwater monitoring under the Consent Order. When referring to the nature and extent of plume characterization, NRC states "…fully characterize…," as compared to the less certain "…to support an understanding..." From the perspective of evaluating LANL groundwater risk to the BDD intake, the NRC approach is more definitive and preferable. Other than for chromium in Sandia and Mortandad Canyons, LANL is deferring defining the nature and extent of groundwater contamination with certainty and detail to a later undefined date when Corrective Measures Evaluation (CME) will be initiated.

The current approach to evaluating groundwater contamination at LANL is limited to detection monitoring to identify contaminated groundwater before it leaves the LANL site.(30, 161) As such, one of the features generally common to groundwater contamination investigations, defining the nature and extent of groundwater contamination, is completely absent from LANL reporting.

The importance of LANL's programmatic decision not to create plume maps or conduct plume characterization activities at this time, to the BDD IPR task is easily discernable from inspection of Figure 6-3. At the eastern end of Los Alamos Canyon are three contaminated RA wells: TW-1, R-5, and R-9. These three wells define an area of contamination that has been known to exist for over a decade that is approximately 0.4 miles wide by 0.6 miles long. The closest RA monitoring well between this area and the Rio Grande is miles away and off-gradient. Despite the proximity of this contamination (and other similar areas) to off-site receptors and drinking water supply wells, LANL has yet to define the nature and extent of groundwater contamination (that is, to define the plume center and edges, and the range of concentrations within the plume).

While it is certain that contamination has migrated towards the Rio Grande from the TW-1, R-5, and R-9 area, under the LANL monitoring program it is currently impossible to say if contamination in this area has already migrated to the RA under San Ildefonso Pueblo, to the Rio Grande, or some intermediate distance. Similarly, it is impossible for LANL to definitively state that the TW-1, R-5, and R-9 contaminant detections represent all the contaminants present between TW-1, R-5, and R-9 areas and the Rio Grande, or if the levels of contamination that have been detected at the wells represent the worst, or best, case for contamination of the RA to the east of Los Alamos and Pueblo Canyons.

The lack of data points between contaminated wells and the Rio Grande and the Buckman well field is recognized by LANL, and new wells are proposed,(161) partly in response to public and state criticism of the LANL monitoring plan. The lack of data points does not allow a definitive statement to be made regarding the presence or absence of RA contamination between the easternmost contaminated wells (closest to the river) in the RA and the Rio Grande at this time.

LANL was to complete construction of the "Buckman Sentinel" well in the RA by the end of September 2010.(168) The planned location of the well was unknown to the IPR at the time of this report. This well will be located in such a way as to serve as an early warning for RA contamination migrating to the Buckman Wells; by necessity, it will be between contamination and the Rio Grande above BDD. The degree that this well will reduce the existing uncertainties regarding groundwater contaminant transport to the Rio Grande above BDD, however, is unknown.

As LANL expands its detection monitoring program, it has encountered previously unknown contamination. As an example, the chromium concentrations in R-42, first sampled in October, 2008, have exceeded the concentrations found in proximal RA wells. LANL's best estimates(169) of the concentration found at the R-42 location ranged from 0.0 to 140 ug/L. The concentration in this well was reported to have reached 10 times the MCL of 0.10 mg/L in August, 2009(170) (1000 ug/L), which is about eight times the maximum predicted, and over three times the highest concentration predicted for the plume. This example shows that LANL numerical methods of estimating the nature and extent of contaminant plumes can be unreliable. This example also demonstrates that a detection monitoring program does not provide information as to the limits and extent of contamination, and to the level of uncertainty that it creates. The nearest chromium contaminated RA well, R-28 at approximately 0.25 miles distant, has chromium levels that are half of those found in R-42. Using the chromium values from R-28 results in underestimating risk by a factor of two, as compared to using values from R-42. Again, because plume characterization has not been conducted, it is impossible to say whether the chromium levels in R-42 represent the best or worst case situation with respect to its presence in the RA below Mortandad Canyon.

The contaminants found in groundwater samples are listed in Table 6-1 by canyon area, aquifer, and data source. The source of this data for LACW's AA is LA-UR-04-2714.(63) The sources of the data for LACW's IPA and RA are LA-UR-08-1105(161) and LA-UR-10-1772.(171) The sources for the Sandia Canyon IPA and RA are LA-UR-08-4702,(169) LA-UR-08-0456,(172) and LA-UR-10-0939.(170) The source for the Mortandad Canyon IPA and RA is LA-UR-08-0455(173) and LA-UR-09-4934,(174) and LA-UR-10-0939.(170) Groundwater in the Sandia and Mortandad AA is not considered, since the water does not flow to the Rio Grande reach above BDD, and the IPA is a better indicator of contaminants that will eventually migrate to the RA under these areas than the AA. Filtered and unfiltered samples are used. Contaminants that exceed screening criteria (numerical standard) are listed separately from contaminants with background exceedances that are below screening criteria.

6.4 CONTAMINANT TRANSPORT TO THE RIO GRANDE - SEDIMENT TRANSPORT VECTOR

To determine the concentration of sediment-associated contamination at the BDD withdrawal point, information is needed on:

1. The concentration of sediment-bound contaminants in water discharging from LACW to the Rio Grande.
2. The rate and duration of the sediment-bearing flow from LACW.
3. The amount of flow in the Rio Grande above the mixing point with LACW discharges.
4. The concentration of sediment-bound contaminants in the Rio Grande upstream of the mixing point.

Once concentrations in discharges from the LACW are estimated, calculating the mixing that takes place when Los Alamos Canyon flows allows for estimating a resultant contaminant concentration at the confluence with the Rio Grande. Very little dilution or mixing is expected to occur between the confluence and the BDD intake, and, therefore, the concentrations estimated at the confluence represent a reasonable maximal estimate for the BDD intake. Items 3 and 4 above are better known than items 1 and 2.

Table 6-1: Contaminants found in groundwater samples by canyon and aquifer

Canyon	Aquifer	Contaminants that Exceed Background	Contaminants that Exceed Screening Criteria as Described in LANL Documents	Data Sources
Los Alamos	Alluvial Aquifer and Springs	Radionuclides: americium-241, gross beta, plutonium-239/240, radium-226, radium-228, strontium-90, tritium Organics: acetone, 2-butanone, chloroform, chloromethane, heptachlorodibenzodioxins, methylene chloride Metals: arsenic, iron, manganese Inorganics: chloride, nitrate, perchlorate	Radionuclides: gross beta, strontium-90, plutonium-239/240 Metals: iron, manganese Inorganics: perchlorate	LA-UR-04-2714, Appendix C; Tables C-1.0-13 through C-1.0-15 LA-UR-09-7415; Tables D-1 through D-10 LA-UR-09-3071; Tables D-1and E-1 through E-16 LA-UR-10-1772; Table 1
Los Alamos	Intermediate Perched Aquifer	Radionuclides: tritium, plutonium-238, uranium-235, uranium-238 Organics: bis(2-ethylhexyl)phthalate, phenol Metals: antimony, arsenic, barium, boron, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, molybdenum, nickel, selenium, strontium, thallium, tin, uranium, vanadium, zinc Inorganics: alkalinity, ammonia, bromide, calcium, chloride, fluoride, magnesium, nitrate, nitrite, phosphorous, potassium, silica, perchlorate	Organics: bis(2-ethylhexyl)phthalate, phenol Metals: iron, lead, manganese, nickel Inorganics: perchlorate[a], phosphorous	LA-UR-08-1105; Tables E-1.0-1a through E-1.0-1g LA-UR-09-7415; Tables D-5 through D-10 LA-UR-09-3071; Tables D-1, E-3 through E-7, and E-12 through E-16 LA-UR-10-1772; Table 1

Canyon	Aquifer	Contaminants that Exceed Background	Contaminants that Exceed Screening Criteria as Described in LANL Documents	Data Sources
Los Alamos	Regional Aquifer	Radionuclides: tritium, gross alpha, gross gamma, plutonium-238 Organics: acrolein, benzo(a)pyrene, arochlor-1260 (PCB), phenol Metals: aluminum, antimony, barium, boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, molybdenum, nickel, selenium, thallium, titanium, uranium, vanadium, zinc Inorganics: ammonia, bromide, calcium, chloride, fluoride, magnesium, molybdenum, nitrate, nitrite, phosphorous, potassium, sulfate, total nitrogen, perchlorate	Organics: acrolein, benzo(a)pyrene, arochlor-1260 (PCB), phenol Metals: iron, lead, manganese, nickel, thallium. Inorganics: ammonia, perchlorate[a], phosphorous	LA-UR-08-1105; Table E-1.0-2a through E-1.0-2g LA-UR-09-7415; Table D-5 through D-10 LA-UR-09-3071; Tables D-1, E-3 through E7, and E-12 through E-16 LA-UR-10-1772; Table 1
Sandia	Intermediate Perched Aquifer	Radionuclides: gross alpha, radium-226, radium-228, tritium Organics: Chloroform, chloromethane, 1-4 dioxane, hexachlorodibenzodioxins Metals: Chromium, manganese Inorganics: Perchlorate	Metals: chromium	LA-UR-08-0456 Tables E-5 through E-9 LA-UR-09-4932 Tables E-4 through E-9 LA-UR-10-0939 Tables D-12 and D-16 through D-21 LA-UR-10-1772; Table 1
Sandia	Regional Aquifer	Radionuclides: tritium, radium-226, radium-228 Organics: acetone, bis(2-ethylhexyl)phthalate, 2-butanone, carbon disulfide, chloromethane, 2-hexanone, toluene Metals: arsenic, chromium Inorganics: nitrate, perchlorate	Metals: chromium	LA-UR-08-0456 Tables E-5 through E-9 LA-UR-09-4932 Tables E-4 through E-9 LA-UR-10-0939 Tables D-12 and D-16 through D-21 LA-UR-10-1772; Table 1

Canyon	Aquifer	Contaminants that Exceed Background	Contaminants that Exceed Screening Criteria as Described in LANL Documents	Data Sources
Mortandad	Intermediate Perched Aquifer	Radionuclides: tritium Organics: acetone, 1-4 dioxane, bis(2-ethylhexyl)phthalate Metals: chromium Inorganics: fluoride, nitrate, nitrite, perchlorate	Inorganics: nitrate, perchlorate[a]	LA-UR-08-0455 Tables E-3 through E-8 LA-UR-4934 Tables E-3 through E-8 LA-UR-10-0939 Tables D-6 through D-11 LA-UR-10-1772; Table 1
Mortandad	Regional Aquifer	Radionuclides: tritium, radium-226, radium-228, thorium-230 Organics: acetone, 2-butanone, benzene, chloromethane, 1-4 dioxane, 1-4 dichlorobenzene, heptachlorodibenzofurans, toluene Metals: antimony, chromium Inorganics: nitrate, perchlorate	Organics: benzene Metals: chromium Inorganics: nitrate, perchlorate[a]	LA-UR-08-0455 Tables E-3 through E-8 LA-UR-4934 Tables E-3 through E-8 LA-UR-10-0939 Tables D-6 through D-11 LA-UR-10-1772; Table 1

[a] With reference to the NMED Consent Order value of 4 µg/L.

6.4.1 Surface Water Contaminants and Concentrations

As described earlier, contaminated sediment inventories exist for the LACW, and these contaminated sediments could impact the BDD when transported by storms. While it is possible to use numerical models of sediment transport to predict the concentration, rate and duration of contaminant flux from LANL for various scenarios using the available data, it is beyond the scope of this effort to use sediment concentration data and models to predict fluxes from LANL. For reasons previously presented, we focus on contaminated storm waters discharging to the Rio Grande from LACW. Sampling data considered is limited to unfiltered samples taken from storm flow at the confluence of LACW and the Rio Grande, LANL surface water gauge E110. Two sources of data from this station, LANL and NMED, are used to estimate an upper and lower limit to contaminants associated with suspended sediments at the BDD. It is generally agreed that the presence of chemicals and radionuclides in unfiltered samples at this location is due mainly to their sorption to suspended sediment particles(49, 92, 166, 167) (as opposed to constituents "dissolved" in the water column itself).

The changes in contaminant transport from LANL as a result of the fire were a subject of great public concern and activity at LANL from 2000 through 2004. The effect of the fire, at least on increased stormflow from the canyons, has persisted to this day. While there has been extensive monitoring of the sediments present on-site at LANL, and on-site stormflow, measurement and reporting of storm and contaminant discharge to the Rio Grande, at the Rio Grande (E110) is sporadic and limited.

NMED collected unfiltered "grab" water samples at the E110 gage during a storm event (which began at 2:10 pm) on August 8, 2006, and reported that total $Pu^{239/240}$ concentrations ranged from 270 pCi/L an hour after the storm began (3:30 pm) to 50 pCi/L five hours later (at 8:30 pm). NMED estimated that the total $Pu^{239/240}$ concentrations could have approached 400 pCi/L before the first sample was collected. These values are orders of magnitude higher than the $Pu^{239/240}$ concentration of 1.73 pCi/L determined by LANL for the same storm at the same station reported in RACER. Both LANL and NMED maintain that the $Pu^{239/240}$ values obtained by their respective sampling and analysis are representative of the values discharged during the storm. The reason for the difference is unknown to the IPR team.

NMED calculated the result of mixing this plutonium flow in the Rio Grande; the results (which represent estimates of unfiltered concentrations at the confluence point) ranged from 192-287 pCi/L. While the NMED estimate is orders of magnitude higher than the DOE drinking water screening level of 1.2 pCi/L,(166) plutonium has not been detected downstream of the LACW confluence (at the Buckman location) during baseflow conditions; at a limit of detection of 3×10^{-3} PCi/L. It is important to note that the DOE drinking water screening level applies to measurements of filtered samples (i.e., measurements of "dissolved" chemicals in water samples that have had the suspended particles removed). Hence, comparing unfiltered samples that are known to have elevated concentrations of particles (where a vast majority of the chemical is found) to the DOE "dissolved" screening criteria is of limited utility.

The NMED storm sampling effort only analyzed $Pu^{239/240}$ levels, while the LANL sampling event included numerous chemicals and radionuclides. To calculate a maximum probable "mixed" concentration of those constituents at the Rio Grande confluence point, the multi-analyte LANL flow weighted composite results are normalized to $Pu^{239/240}$ and multiplied by the plutonium flux determined by NMED to determine a range for multi-analyte constituent levels at the confluence with the Rio Grande.

6.4.2 LANL Storm Flow Sampling at E110

The changes in contaminant transport from LANL as a result of the fire were a subject of great public concern and activity at LANL from the year 2000 through 2004. The effect of the fire, at least on increased stormflow from the canyons, has greatly diminished in the period 2007-2009. While there has been extensive monitoring of the sediments and on-site stormflow at LANL, pre and post fire, measurement and reporting of storm and contaminant discharge to the Rio Grande is lacking. During the four years of monitoring of storm flow post-Cerro Grande, LANL sampling of LACW at the Rio Grande (E110) was conducted on one day in 2003.(92, 175, 176)

The RACER database was queried on June 8, 2010 for all surface water flow and analytical data for E110 from January 1, 2004 to the present. Surface water flow data for E110 is not maintained on RACER. Two sampling events were identified in this period that resulted in validated analysis of unfiltered samples of "Storm Runoff" at E110, on July 6, 2006 and August 8, 2008 (Table 6-2). Samples from these two events were analyzed for the Radionuclide, Pesticide/PCB, Metals and General Inorganics analytical groups. Information was not available from RACER regarding the timing or discharge volumes of these storm events, the number of samples composited, or the nature of compositing. LANL has indicated that these samples, while collected by an autosampler, are not composites, but are grab samples.

The data presented in Table 6-2 were reduced to data with confirmed quantification and no quality assurance flags. The common, relatively non-toxic, analytes aluminum, calcium, hardness, magnesium, sodium, and silica are not used further. No differentiation is made as to the type and proportion of contaminants that are attributable to LANL activities, the Cerro Grande Fire, natural background, or non-LANL activities. This reduced data set is normalized to the flow weighted average $Pu^{239/240}$ concentration. The relative percent difference between the plutonium-normalized elemental ratios and averages of those values are calculated where possible. The reduced storm flow contaminant data set and calculations are presented in Table 6-3. The plutonium normalized ratios are used later to estimate peak contaminant concentrations.

6.4.3 NMED Plutonium Flux Measurements

NMED documentation was reviewed to help determine if there were sediment risk or concentration calculations that could be used directly in this effort, or could be used to estimate sediment contaminant concentrations at the diversion point. As with the LANL efforts, there was not a comprehensive evaluation of organic, inorganic, and radionuclide contamination leaving LACW available, but there is work in progress to improve the estimation of flux. NMED also has published a contaminant flux for $Pu^{239/240}$. NMED made flux determinations from direct measurements of concentration and flow, and developed an equation relating stream flow and plutonium concentration.(101)

Table 6-2: Analytical results for all stormwater samples taken by LANL at E110 — January, 2004 through May, 2010

Sample	Collection Date	Analyte Name	Symbol	Result	Units	Lab Qualifier	Field Prep	Sample Description	Comparison Value	Comparison Units	Comparison Type	Comparison Detail
GU060700E11001	7/9/2006	Aroclor 1262	<	0.1	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Aroclor 1260	<	0.1	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Aroclor 1254	<	0.1	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Aroclor 1248	<	0.1	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Aroclor 1242	<	0.1	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Aroclor 1232	<	0.1	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Aroclor 1221	<	0.1	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Aroclor 1016	<	0.1	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Uranium-238	=	57.8	pCi/L	No_Flag	UF	Storm Runoff	0.547	pCi/L	PRG EPA Superfund	Tap water
GU060700E11001	7/9/2006	Uranium-235/236	=	3.39	pCi/L	No_Flag	UF	Storm Runoff		pCi/L	No comparison available	-
GU060700E11001	7/9/2006	Uranium-234	=	57.1	pCi/L	No_Flag	UF	Storm Runoff	0.674	pCi/L	PRG EPA Superfund	Tap water
GU060700E11001	7/9/2006	Tritium	<	-23.6	pCi/L	U	UF	Storm Runoff	144	pCi/L	PRG EPA Superfund	Tap water
GU060700E11001	7/9/2006	Thorium-232	=	19	pCi/L	No_Flag	UF	Storm Runoff	0.471	pCi/L	PRG EPA Superfund	Tap water
GU060700E11001	7/9/2006	Thorium-230	=	17	pCi/L	No_Flag	UF	Storm Runoff	0.523	pCi/L	PRG EPA Superfund	Tap water
GU060700E11001	7/9/2006	Thorium-228	=	20.4	pCi/L	No_Flag	UF	Storm Runoff	0.159	pCi/L	PRG EPA Superfund	Tap water
GU060700E11001	7/9/2006	Strontium-90	=	1.05	pCi/L	No_Flag	UF	Storm Runoff	0.644	pCi/L	PRG EPA Superfund	Tap water
GU060700E11001	7/9/2006	Sodium-22	<	-1.41	pCi/L	U	UF	Storm Runoff	4.95	pCi/L	PRG EPA Superfund	Tap water
GU060700E11001	7/9/2006	Radium-226	<	39.2	pCi/L	No_Flag	UF	Storm Runoff	0.000816	pCi/L	PRG EPA Superfund	Tap water
GU060700E11001	7/9/2006	Potassium-40	=	113	pCi/L	No_Flag	UF	Storm Runoff	1.93	pCi/L	PRG EPA Superfund	Tap water
GU060700E11001	7/9/2006	Plutonium-239/240	=	2.12	pCi/L	No_Flag	UF	Storm Runoff	0.353	pCi/L	PRG EPA Superfund	Tap water
GU060700E11001	7/9/2006	Plutonium-238	=	0.211	pCi/L	No_Flag	UF	Storm Runoff	0.364	pCi/L	PRG EPA Superfund	Tap water
GU060700E11001	7/9/2006	Neptunium-237	<	13	pCi/L	U	UF	Storm Runoff	0.707	pCi/L	PRG EPA Superfund	Tap water
GU060700E11001	7/9/2006	Cobalt-60	<	-0.284	pCi/L	U	UF	Storm Runoff	3.03	pCi/L	PRG EPA Superfund	Tap water
GU060700E11001	7/9/2006	Cesium-137	<	2	pCi/L	U	UF	Storm Runoff	1.57	pCi/L	PRG EPA Superfund	Tap water
GU060700E11001	7/9/2006	Gross beta	=	192	pCi/L	No_Flag	UF	Storm Runoff		pCi/L	No comparison available	-
GU060700E11001	7/9/2006	Americium-241	<	0.352	pCi/L	U	UF	Storm Runoff	0.458	pCi/L	PRG EPA Superfund	Tap water
GU060700E11001	7/9/2006	Gross alpha	=	74.8	pCi/L	No_Flag	UF	Storm Runoff		pCi/L	No comparison available	-
GU060700E11001	7/9/2006	Suspended Sediment Concentration	=	41900000	ug/L	H	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Cyanide, Amenable to Chlorination	<	1.5	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Cyanide, Total	<	1.5	ug/L	UH	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Hardness	=	2260000	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Zinc	=	2140	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Vanadium	=	671	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Thallium	=	10.5	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Sodium	=	26000	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Silver	=	2.4	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Selenium	<	12.5	ug/L	UN	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Potassium	=	132000	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Nickel	=	676	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Molybdenum	<	2	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-

Sample	Collection Date	Analyte Name	Symbol	Result	Units	Lab Qualifier	Field Prep	Sample Description	Comparison Value	Comparison Units	Comparison Type	Comparison Detail
GU060700E11001	7/9/2006	Mercury	<	0.6	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Manganese	=	25200	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Magnesium	=	229000	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Lead	=	735	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Iron	=	573000	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Copper	=	595	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Cobalt	=	311	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Chromium	=	497	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Calcium	=	526000	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Cadmium	=	12	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Beryllium	=	67.8	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Barium	=	10800	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Arsenic	=	105	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Antimony	<	2.5	ug/L	UN	UF	Storm Runoff		ug/L	No comparison available	-
GU060700E11001	7/9/2006	Aluminum	=	758000	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Aroclor 1262	<	0.105	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Aroclor 1260	=	0.3	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Aroclor 1254	<	0.105	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Aroclor 1248	<	0.105	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Aroclor 1242	<	0.105	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Aroclor 1232	<	0.105	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Aroclor 1221	<	0.105	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Aroclor 1016	<	0.105	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Uranium-238	=	42.7	pCi/L	No_Flag	UF	Storm Runoff	0.547	pCi/L	PRG EPA Superfund	Tap water
GU060800E11001	8/8/2006	Uranium-235/236	=	2.58	pCi/L	No_Flag	UF	Storm Runoff		pCi/L	No comparison available	-
GU060800E11001	8/8/2006	Uranium-234	=	38	pCi/L	No_Flag	UF	Storm Runoff	0.674	pCi/L	PRG EPA Superfund	Tap water
GU060800E11001	8/8/2006	Tritium	<	34.6	pCi/L	U	UF	Storm Runoff	144	pCi/L	PRG EPA Superfund	Tap water
GU060800E11001	8/8/2006	Thorium-232	=	18.8	pCi/L	No_Flag	UF	Storm Runoff	0.471	pCi/L	PRG EPA Superfund	Tap water
GU060800E11001	8/8/2006	Thorium-230	=	15.7	pCi/L	No_Flag	UF	Storm Runoff	0.523	pCi/L	PRG EPA Superfund	Tap water
GU060800E11001	8/8/2006	Thorium-228	=	21.3	pCi/L	No_Flag	UF	Storm Runoff	0.159	pCi/L	PRG EPA Superfund	Tap water
GU060800E11001	8/8/2006	Strontium-90	=	9.61	pCi/L	No_Flag	UF	Storm Runoff	0.644	pCi/L	PRG EPA Superfund	Tap water
GU060800E11001	8/8/2006	Sodium-22	<	2.29	pCi/L	U	UF	Storm Runoff	4.95	pCi/L	PRG EPA Superfund	Tap water
GU060800E11001	8/8/2006	Radium-226	=	83.4	pCi/L	No_Flag	UF	Storm Runoff	0.000816	pCi/L	PRG EPA Superfund	Tap water
GU060800E11001	8/8/2006	Potassium-40	=	1140	pCi/L	No_Flag	UF	Storm Runoff	1.93	pCi/L	PRG EPA Superfund	Tap water
GU060800E11001	8/8/2006	Plutonium-239/240	=	1.73	pCi/L	No_Flag	UF	Storm Runoff	0.353	pCi/L	PRG EPA Superfund	Tap water
GU060800E11001	8/8/2006	Plutonium-238	=	0.54	pCi/L	No_Flag	UF	Storm Runoff	0.364	pCi/L	PRG EPA Superfund	Tap water
GU060800E11001	8/8/2006	Neptunium-237	<	47.9	pCi/L	UI	UF	Storm Runoff	0.707	pCi/L	PRG EPA Superfund	Tap water
GU060800E11001	8/8/2006	Cobalt-60	<	-0.241	pCi/L	U	UF	Storm Runoff	3.03	pCi/L	PRG EPA Superfund	Tap water
GU060800E11001	8/8/2006	Cesium-137	=	25.2	pCi/L	No_Flag	UF	Storm Runoff	1.57	pCi/L	PRG EPA Superfund	Tap water
GU060800E11001	8/8/2006	Gross beta	<	4150	pCi/L	No_Flag	UF	Storm Runoff		pCi/L	No comparison available	-
GU060800E11001	8/8/2006	Americium-241	=	0.478	pCi/L	No_Flag	UF	Storm Runoff	0.458	pCi/L	PRG EPA Superfund	Tap water

Sample	Collection Date	Analyte Name	Symbol	Result	Units	Lab Qualifier	Field Prep	Sample Description	Comparison Value	Comparison Units	Comparison Type	Comparison Detail
GU060800E11001	8/8/2006	Gross alpha	=	2290	pCi/L	No_Flag	UF	Storm Runoff		pCi/L	No comparison available	-
GU060800E11001	8/8/2006	Cyanide, Amenable to Chlorination	<	1.5	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Cyanide, Total	=	7.62	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Suspended Sediment Concentration	=	30700000	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Hardness	=	873000	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Zinc	=	921	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Vanadium	=	252	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Thallium	=	0.88	ug/L	J	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Sodium	=	11800	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Silver	<	0.2	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Selenium	<	2.5	ug/L	UN	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Potassium	=	36200	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Nickel	=	227	ug/L	EN*	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Molybdenum	<	2	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Mercury	=	2.1	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Manganese	=	28300	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Magnesium	=	47100	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Lead	=	434	ug/L	E*	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Iron	=	56200	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Copper	=	97.4	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Cobalt	=	207	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Chromium	=	41.3	ug/L	N*	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Calcium	=	272000	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Cadmium	=	9.3	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Beryllium	=	49.1	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Barium	=	6290	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Arsenic	<	15.9	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Antimony	<	0.9	ug/L	JN	UF	Storm Runoff		ug/L	No comparison available	-
GU060800E11001	8/8/2006	Aluminum	=	122000	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Total Suspended Solids	=	89300000	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Perchlorate	<	4	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Cadmium	=	20.6	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Lead	=	1370	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Antimony	<	0.793	ug/L	B	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Thallium	=	10.4	ug/L	E	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Uranium	=	102	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Arsenic	=	159	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Boron	=	187	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Beryllium	=	118	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Molybdenum	<	1.02	ug/L	B	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Tin	<	1.55	ug/L	UN	UF	Storm Runoff		ug/L	No comparison available	-

Sample	Collection Date	Analyte Name	Symbol	Result	Units	Lab Qualifier	Field Prep	Sample Description	Comparison Value	Comparison Units	Comparison Type	Comparison Detail
GU03080E11001	8/23/2003	Strontium	=	4000	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Silver	<	8.19	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Aluminum	=	886000	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Barium	=	16000	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Cobalt	=	549	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Chromium	=	528	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Copper	=	714	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Iron	=	572000	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Manganese	=	76400	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Nickel	=	817	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Selenium	<	22.9	ug/L	U	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Silicon Dioxide	=	142000	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Vanadium	=	551	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Zinc	=	3300	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Total Suspended Solids	=	99400000	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-
GU03080E11001	8/23/2003	Total Suspended Solids	=	128000000	ug/L	No_Flag	UF	Storm Runoff		ug/L	No comparison available	-

Table 6-3: Analytical detections and ratio to plutonium-239/240 at Gage E110

Analyte Name	7/9/2006 Results	8/8/2006 Results	Units	7/9/2006 Ratio to $^{239/240}$Pu	8/8/2006 Ratio to $^{239/240}$Pu	Relative Percent Difference	Average Ratio to $^{239/240}$Pu
Aroclor 1260 (PCB)		0.0003	mg/L		0.00017		0.00017
Silver	0.0024		mg/L	0.00113			0.00113
Arsenic	0.105		mg/L	0.04953			0.04953
Barium	10.8	6.29	mg/L	5.09434	3.63584	33%	4.36509
Beryllium	0.0678	0.0491	mg/L	0.03198	0.02838	12%	0.03018
Cadmium	0.012	0.0093	mg/L	0.00566	0.00538	5%	0.00552
Cobalt	0.311	0.207	mg/L	0.14670	0.11965	20%	0.13318
Chromium	0.497	0.0413	mg/L	0.23443	0.02387	163%	0.12915
Copper	0.595	0.0974	mg/L	0.28066	0.05630	133%	0.16848
Cyanide, Total		0.00762	mg/L		0.00440		0.00440
Iron	573	0.0974	mg/L	270.28302	0.05630		135.16966
Manganese	25.2	28.3	mg/L	11.88679	16.35838	32%	14.12259
Mercury		0.0021	mg/L		0.00121		0.00121
Nickel	0.676		mg/L	0.31887			0.31887
Lead	0.735		mg/L	0.34670			0.34670
Thallium	0.0105		mg/L	0.00495			0.00495
Vanadium	0.671	0.252	mg/L	0.31651	0.14566	74%	0.23109
Zinc	2.14	0.921	mg/L	1.00943	0.53237	62%	0.77090
Gross alpha	74.8	56.2	pCi/L	35.28302	32.48555	8%	33.88428
Gross beta	192	2290	pCi/L	90.56604	1323.69942	174%	707.13273
Americium-241		0.478	pCi/L		0.27630		0.27630
Cesium-137		25.2	pCi/L		14.56647		14.56647
Plutonium-238	0.211	0.54	pCi/L	0.09953	0.31214	103%	0.20583
Plutonium-239/240	2.12	1.73	pCi/L	1	1	0%	1
Radium-226		83.4	pCi/L		48.20809		48.20809
Strontium-90	1.05	9.61	pCi/L	0.49528	5.55491	167%	3.02510
Thorium-228	20.4	21.3	pCi/L	9.62264	12.31214	25%	10.96739
Thorium-230	17	15.7	pCi/L	8.01887	9.07514	12%	8.54701
Thorium-232	19	18.8	pCi/L	8.96226	10.86705	19%	9.91466
Uranium-234	57.1	38	pCi/L	26.93396	21.96532	20%	24.44964
Uranium-235/236	3.39	2.58	pCi/L	1.59906	1.49133	7%	1.54519
Uranium-238	57.8	42.7	pCi/L	27.26415	24.68208	10%	25.97312

Using the discharge/concentration/sediment load relationships developed by NMED and the IPR team's own assumptions regarding the correlation between LANL's Pu$^{239/240}$ concentrations and the concentration of other contaminants of potential concern, the sediment-bound contaminant mass loading into the Rio Grande can be estimated. From Table 6-4 below,(101) it is clear that measured flows and sediment transport estimates are highly variable.

Table 6-4: NMED estimates of storm flows and contaminant transport for 2000 through 2006

Year	Number of Storm Flow Events >10 cfs	Maximum Flow (cfs)	Mean Flow (cfs)	Median Flow (cfs)	Total Plutonium 239/240 Transport (mCi)	Total Suspended Sediment Transport (tons [metric])
2000	6	147	64	50	8.4	1,933
2001	17	1440	145	25	54.3	12,552
2002	17	583	65	16	24.4	5,453
2003	9	749	142	59	28.2	6,606
2004	15	504	71	21	23.6	5,428
2005	4	129	93	101	8.1	1,863
2006	6	1926	387	79	51.1	11,701

6.4.4 Contaminant Discharge Calculation - Surface Water

NMED estimated that a storm in 2006 caused plutonium concentrations in the Rio Grande below the confluence with Los Alamos Canyon to rise to 192 pCi/L, and possibly as high as 287 pCi/L.(74, 101, 156) NMED did not measure the concentration of other contaminants in the LACW stormwater. Empirical relationships between Pu$^{239/240}$ and other sediment-bound contaminants were created from LANL E110 data obtained from RACER for unfiltered samples. The purpose of creating such relationships is to establish proportionality between Pu$^{239/240}$ and other measured contaminant concentrations of suspended sediments at E110 in order to apply to the NMED estimated in-stream concentrations of Pu$^{239/240}$ to estimate suspended concentrations of other constituents. By not discounting the high NMED value, and using a proportionality, an estimate can be obtained for the high range of COI values. This estimate should be used with great caution, as it is based on only three samples (two LANL and one NMED) and relies on an unproven relationship between sediment boud Pu$^{239/240}$ concentrations and other COIs. As error-prone as the estimate may be, it serves as a starting point for evaluation of potential COI concentrations in the Rio Grande from LACW discharge to the Rio Grande.

LACW storm flow is assumed to mix instantaneously with Rio Grande base flow. Corrections for sediment dilution or loss in the distance along the reach above the BDD intake are not used. Using the relationships developed here, and the NMED estimate of 192 pCi/L maximum for sediment-bound Pu$^{239/240}$ in the Rio Grande on August 8, 2006, the following in-stream sediment-bound contaminant concentrations were calculated (Table 6-5). For the purpose of this calculation, dissolved contaminant concentrations are assumed to be negligible as compared to sediment-bound concentrations,(63) and upstream contaminant concentrations are assumed to be zero values.

Table 6-5: Estimated unfiltered contaminant concentrations in the Rio Grande (at the LACW discharge point) as a result of LACW storm flow

Analyte Name	Estimated Concentration Corresponding to 192 pCi/L $^{239/240}$Pu	Units	Range of Concentrations from Rio Grande at Buckman in Surface Water Samples Collected after 2000	Comparison Units
Aroclor 1260 (PCB)	0.033	mg/L	<0.0001	mg/L
Silver	0.217	mg/L	0.00011	mg/L
Arsenic	9.509	mg/L	0.0015–0.0071	mg/L
Barium	838.1	mg/L	0.049–0.214	mg/L
Beryllium	5.795	mg/L	0.001	mg/L
Cadmium	1.059	mg/L	0.00024–0.00079	mg/L
Cobalt	25.57	mg/L	0.001–0.0045	mg/L
Chromium	24.80	mg/L	0.0021–0.016	mg/L
Copper	32.35	mg/L	<0.003–0.013	mg/L
Cyanide, Total	0.846	mg/L	<0.0015	mg/L
Iron	25953	mg/L	0.1–8.8	mg/L
Manganese	2712	mg/L	<0.01–0.4	mg/L
Mercury	0.233	mg/L	<0.000062	mg/L
Nickel	61.22	mg/L	0.0017–0.0167	mg/L
Lead	66.57	mg/L	0.00055–0.0166	mg/L
Thallium	0.951	mg/L	<0.0002–0.00067	mg/L
Vanadium	44.369	mg/L	0.00358–0.017	mg/L
Zinc	148	mg/L	0.00435–0.053	mg/L
Gross alpha	6506	pCi/L	1.9–30.4	pCi/L
Gross beta	135769	pCi/L	<2.22–32.8	pCi/L
Americium-241	53	pCi/L	<0.00243	pCi/L
Cesium-137	2797	pCi/L	<0.165	pCi/L
Plutonium-238	40	pCi/L	$<2.1\times10^{-9}$	pCi/L
Plutonium-239/240	192	pCi/L	$<5.4\times10^{-10}$	pCi/L
Radium-226	9256	pCi/L	<0.146–1.2	pCi/L
Strontium-90	581	pCi/L	<0.0245	pCi/L
Thorium-228	2106	pCi/L	0.0384–0.305	pCi/L
Thorium-230	1641	pCi/L	<0.00934–0.237	pCi/L
Thorium-232	1904	pCi/L	<0.0171–0.022	pCi/L
Uranium-234	4694	pCi/L	0.567–2.12	pCi/L
Uranium-235/236	297	pCi/L	<0.00947–0.0957	pCi/L
Uranium-238	4987	pCi/L	0.375–1.64	pCi/L

The estimated values in Table 6-5 suggest that, during significant storm events, maximum concentrations of suspended chemicals and radionuclides (constituents sorbed to sediment particles) would exceed the levels previously measured in unfiltered samples downstream in the Rio Grande. The estimated constituent concentrations (Table 6-5) are speculative because they are based on an unproven relationship between plutonium and other sediment bound COIs. As described in Section 3 of this report, measured levels of chemicals and radionuclides in the Rio Grande (above and below the LACW confluence) are consistent with regional "background" levels. However, it must also be noted that unfiltered samples from the Rio Grande examined for a range of COIs *during LACW storm events* are lacking.

Nonetheless, the results of the NMED evaluation (101) and the results presented here indicate that storm flow from LACW can result in suspended sediment contaminant concentrations that are much higher than the levels normally present in the Rio Grande. When applying this information to evaluate potential water quality impacts from storm flow events in the future, it is important to keep in mind that:

- An early warning system is being put in place that will allow BDD personnel to cease diversion of water when there is indication of storm flow coming down Los Alamos Canyon. Monitoring data from past episodic releases indicate that elevated concentrations typically flow to the Rio Grande for several hours at the most.
- If any of the storm water contamination were, by some mechanism, to make it into the BDD system, it would encounter a treatment system that is rated as highly effective at removing particle-bound contaminants.

6.5 CONTAMINANT TRANSPORT TO THE RIO GRANDE - GROUNDWATER TRANSPORT VECTOR

A portion of the contamination present in the Rio Grande at the Buckman Diversion is from groundwater discharge to the Rio Grande. Some contamination may be present from LANL activities. To determine the concentration of groundwater-associated contamination at the BDD withdrawal point, information is needed regarding:

1. The concentration of contaminants in groundwater discharging from LANL to Rio Grande reaches upstream of the Buckman Diversion.
2. The rate and duration of the groundwater discharge to the Rio Grande.
3. The amount of flow in the Rio Grande above the mixing point with LANL discharges.
4. The concentration of contaminants in the Rio Grande upstream of the mixing point.

By calculating the mixing ratio between groundwater and the Rio Grande flow, the resultant contaminant concentration at the BDD intake is determined, and the potential impacts from contaminated groundwater can be calculated.

The uncertainty of plume dimensions and concentrations in part guides the approach taken here. Alluding to our previous illustration using RA monitoring wells near the east end of Los Alamos Canyon, without direct and supportable knowledge that contaminants from the TW-1, R-5, and R-9 area are not currently reaching the Rio Grande, we lean toward conservative assumptions. For the purposes of our risk evaluation, we assume that contaminants are reaching the Rio Grande at the highest concentrations greater than screening levels detected in the RA wells closest to the Rio Grande under Los Alamos watershed, or along groundwater flow paths from Sandia Canyon and Mortandad Canyon to the Rio Grande. Even with this significant level of hydrogeochemical conservatism, though, we simply do not have the data to say if our estimate is the worst, or best, possible case.

As described earlier, the three aquifers merge as they approach the Rio Grande channel and floodplain. Mixing of the AA and RA is observed close to the Lower Los Alamos Canyon confluence with the Rio Grande.(159) The size of the AA and IPA discharge area to the Rio Grande is much smaller than the RA discharge area, but the relative contributions and degree of mixing between the aquifers are generally unknown over the river reach of interest, which greatly increases the uncertainty in estimating the contaminant flux to the Rio Grande for this mixed groundwater. Current hydrogeological uncertainty, and public perception, suggests that a highly conservative approach is appropriate for assessing risk at the BDD for the groundwater vector.

6.5.1 Rio Grande Base Flow and Groundwater Discharge Estimates

The 2005 LANL hydrologic synthesis report(159) indicates that January base flow at the Otowi gauge for the period 1983 through 1986 varies from about 11.33 to 50.97 m^3/s (400 to 1800 cfs). This range of base flows is used to calculate the dilution of groundwater discharging to the Rio Grande. The January baseflow gain in discharge over the entire Otowi to Cochiti reach of 41.8 km (25.97 miles) is estimated at 0.368 ± 0.249 m^3/s (13.0 ± 8.8 cfs). Kwicklis et al., estimate the gain over a 30.6 km reach adjacent to LANL to be 8.6 cfs (0.2435 m^3/s or 0.00796 m^3/s/km).(163) The average total groundwater flux to the Rio Grande by all aquifers from the LANL 2005 analysis is 0.0088 m^3/s/km (0.050 ft^3/s/mi), and values by others presented by LANL ranging from 0.009 to 0.023 m^3/s/km are included for comparison.

From above, the total west side of the river groundwater contribution to Rio Grande flow above the BDD at low base flow (11.33 m^3/s) and high groundwater discharge (0.0023 m^3/s/km) is about 0.5 percent of the total flow. The width of the mouth of the Lower Los Alamos Canyon along the Rio Grande is about 220 meters (722 feet), and by length represents about 4.2 percent of the 5.3 km river reach of interest. Assuming that a canyon's alluvial discharge occurs along its entire width helps bound its outflow to the river. The current understanding of groundwater discharge to the Rio Grande is insufficient to split the discharges estimates into components lying east and west of the Rio Grande. For the purpose of this study, we assumed that one-half (50%) of all groundwater discharge to the Rio Grande over the 3.3 km reach is from the west (LANL) side of the river.(163)

6.5.2 Contaminants and Concentrations

As previously discussed, the known contaminated RA and IPA groundwater is some distance removed from the Rio Grande, but there are large uncharacterized areas of the RA between known contaminated groundwater, the Rio Grande, and the Buckman Wells. In order to estimate risk at the BDD intake, the contaminant characteristics of the RA water discharging to the Rio Grande are assumed to be the same as the closest known areas of RA contamination in the LACW, Sandia Canyon, and Mortandad Canyon. (LA-UR-09-7415,(177) LA-14263-MS,(159) and LA-UR-04-2714(63)).

The highest LANL reported values for contaminants in the IPA and RA closest to the Rio Grande under the LACW, Sandia Canyon, and Mortandad Canyon are used as representatives of RA discharge concentrations, which results in a very conservative assumption, and mimics the effect of a very rapid non-reactive groundwater flow path to the Rio Grande from LANL. When these concentrations are applied to all of the estimated contaminated RA discharge to the Rio Grande, an additional conservative assumption is applied.

The AA in Lower Los Alamos Canyon near the Rio Grande has been characterized by sampling of the springs, surface water and AA wells (LLAO-4 and LLAO-5). The highest reported LANL values for contaminants in the AA and base flow surface water(63) are used as representatives of the discharge concentrations from these groundwater sources, which, again, is a highly conservative method.

6.5.3 Travel Time for Contaminated Groundwater

As demonstrated by LANL(159) and George Rice for Concerned Citizens for Nuclear Safety,(178) travel times for groundwater contaminants at LANL are highly variable. Contaminant travel-time is variable because the hydrogeology of the Pajarito Plateau is complex, and there are a wide range of contaminants. Travel times are dependent on the three-dimensional relationship of the release and receptor point, the contaminant of interest, and climate variability in that influences travel-times in near-surface hydrologic systems. Additionally, the hydrogeologic controls on travel time at LANL are highly variable over short distances because of the differences in water transmitting capacity of individual geologic units, and variation within the units themselves. Over longer distances, such as between contaminated groundwater in the canyons and the Rio

Grande reach above the BDD, uncertainty increases again. In general, the location of the leading edge, or center of mass, of groundwater contaminant plumes at LANL is known imprecisely, lending little certainty in selecting a physical starting point for a travel-time calculation. Given these constraints, it is not possible to generalize or calculate reasonably well supported travel-times for LANL contaminated groundwater to reach the Rio Grande above the BDD.

6.5.4 Contaminant Discharge Calculation—Groundwater

A calculation spreadsheet was developed for determining mixing ratios (dilution factors) along the reach of interest under varying Rio Grande base flows and aquifer discharges. The contaminant concentrations used are derived from the tables referred to in Table 1. For the purpose of this calculation, only contaminants that exceeded screening levels were used. Contaminant values for the RA are the highest detected in the aquifer of interest, regardless of the canyon nearest to it. Springs, surface water, AA and IPA values are used interchangeably, with the highest values detected from any of those sources used in the calculations. No dilution or attenuation of any contaminant on any flow path is applied to reduce contaminant concentrations at the discharge to the Rio Grande.

To vary the contribution of the sum of the AA and IPR, alluvial base flow, and springs to total base flow of the Rio Grande, the length of the AA discharge zone and the length of a plume from the RA along the river can be adjusted by the user. The base flow at the Otowi gauge can be varied through its range. For the purpose of the example presented, the combined AA and IPA discharge zone length is set to 10% of the total reach, the RA plume length along the river is set to 50% of the remaining reach, and base flow is set to its low value of 400 cfs. When the flow calculations are linked to contaminant concentrations in groundwater, the concentration at BDD can be determined in a conservative manner.

The results of the calculation of Rio Grande contaminant concentrations are presented in Table 6-6. Upon examination, it is clear that, under very conservative assumptions, all analyzed contaminants of groundwater origin would be diluted to below levels of regulatory concern.

Table 6-6: Estimated concentrations of contaminants of groundwater origin discharging into the Rio Grande above the BDD

Rio Grande Groundwater-Source Contaminants	Concentration at BDD
Inorganics	Concentration (mg/L)
Arsenic	0.000006
Chromium	0.002409
Iron	0.043728
Lead	0.000287
Manganese	0.009243
Mercury	0.000001
Nickel	0.000581
Nitrate	0.036369
Perchlorate	0.000224
Phosphorus	0.000030
Thallium	0.000009
Zinc	0.011133
Radionuclides	Concentration (pCi/L)
Americium-241	0.000032
Plutonium-239,240	0.000642
Strontium-90	0.000803
Gross beta	0.054058
Organics	Concentration (µg/L)
Benzo(a)pyrene	0.0011
Aroclor-1260	0.0024
Acroline	0.0024
Benzo(a)pyrene	0.0024
Bis(2-ethylhexyl)phthalate	0.0952
Phenol	0.0029
Benzene	0.0573

7.0 DISCUSSION AND CONCLUSIONS

7.1 IDENTIFICATION AND GATHERING OF RELEVANT INFORMATION

After a comprehensive review of existing data, reports, and published scientific literature, the IPR team identified the information considered to be the most useful for the purposes of the BDD IPR. Specifically, information obtained from LANL and NMED technical reports and data obtained from the RACER database comprise the basis for this IPR evaluation.

7.2 IDENTIFICATION AND CHARACTERIZATION OF THE COIS

As per the purpose of this evaluation, surface water measurements in the Rio Grande at locations closest to the BDD intake are of primary interest. Detections of constituents at locations upstream and downstream of the Buckman locations were compared to the Buckman dataset, in order to ensure that the COI selection process identified those COIs most likely to be present in Rio Grande, at the BDD intake, on a typical, daily basis.

For all analytes, sufficient data existed for conducting statistical analyses and health risk assessment calculations. For some analytes, the data were relatively sparse (four samples or less), but still sufficient for conservatively estimating risk. The majority of COIs had data for most of the 11 total sampling events at either of the two Buckman locations and 22 total sampling events at any of the four Otowi Bridge locations. Ten of the 35 chemical COIs had exposure point concentrations (EPCs) that were estimated from four samples or less [acetone, beryllium, bis(2-ethylhexyl) phthalate, cadmium, chloromethane, cobalt, DDE, delta-hexachlorocyclohexane, OCDD, and silver]; four of these COIs had EPCs that were based on only one sample (chloromethane, DDE, delta-hexachlorocyclohexane, and silver). The lack of robust sampling data for these chemicals was due to their infrequent detection in baseflow surface water. Additionally, the reported concentrations were often estimated or “J” flagged values that were measured below their respective limits of detection. Because the reasonable maximum exposure (RME) EPCs and, in some cases, the central tendency (CT) EPCs, were set as equal to the maximum detected concentration for these chemicals, their risk estimates will be uncertain, and most likely will overestimate their actual contribution to human health risks.

The primary data utilized in the human health risk assessment for tap water sources represent recent (i.e., within the last ten years) unfiltered, untreated surface water samples obtained during normal, baseflow conditions in the Rio Grande. Any risk estimates made on these data, then, have not factored in the removal effects of water treatment, and, in effect, therefore represent the potential risks of drinking water straight from the Rio Grande.

7.3 COMPARISON OF COIS AT THE BUCKMAN LOCATIONS TO DRINKING WATER CRITERIA

The average concentrations of all 50 radionuclide and chemical COIs at the Buckman sampling locations were below drinking water criteria, with the exception of Uranium-234 (U-234). However, U-234 also exceeds the drinking water guideline used in this evaluation at numerous locations far upstream on the Rio Grande (>12 miles), indicating that regional background levels of U-234 typically exceed the drinking water guideline**.**

This comparison is very conservative because drinking water criteria apply to finished, treated water suitable for consumption, whereas the samples taken from the Rio Grande were untreated and unfiltered. Figures 7-1 and 7-2 show comparisons of the average concentrations for some COIs measured at the Buckman location to the associated drinking water criteria for radionuclides and chemicals, respectively.

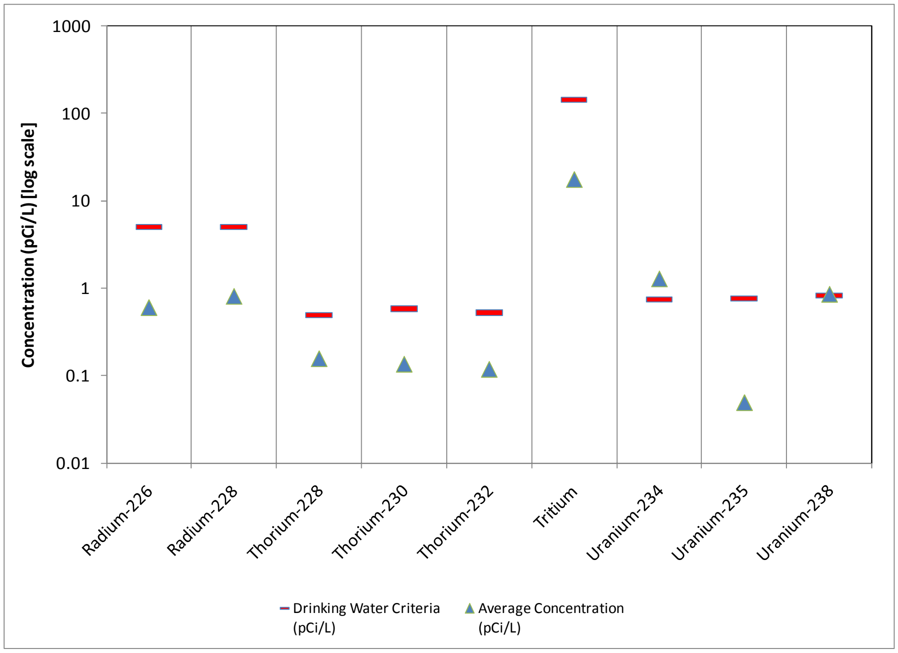


Figure 7-1: Comparison of average surface water concentrations for selected radionuclide COIs to drinking water criteria

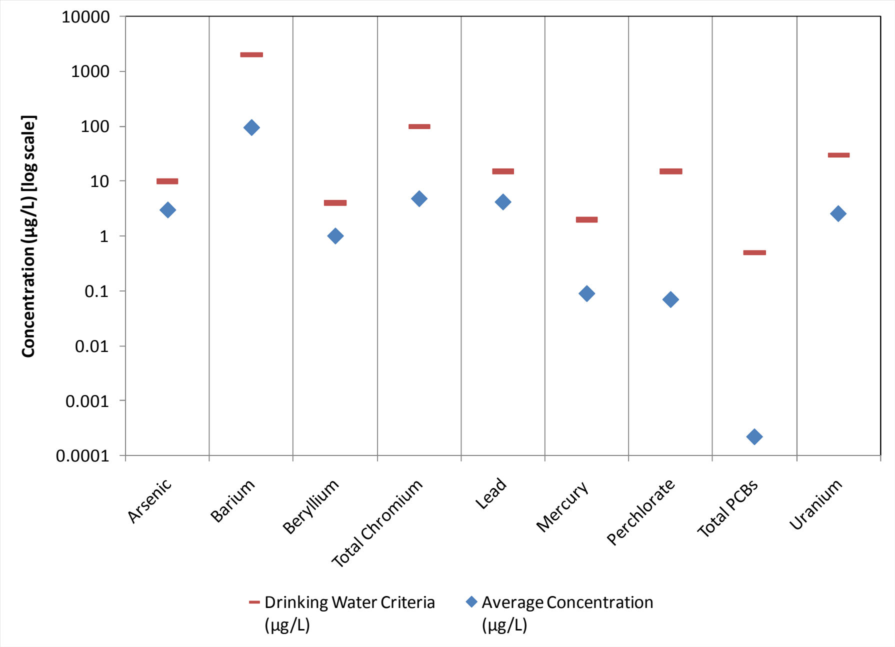


Figure 7-2: Comparison of average surface water concentrations for select chemical COIs to drinking water criteria

7.4 CHARACTERIZATION OF SOURCES OF THE COIS

COIs in the Rio Grande originated from a number of sources, including naturally occurring material, human activities conducted at LANL, human activities associated with other urban and industrial areas in the watershed, and above-ground nuclear device testingthat occurred widely between 1945 and 1980. Some COIs appear to be predominantly of natural origin; others were generated or enhanced by human activities, and others are caused by a mixture of natural and anthropogenic sources. For the purposes of this evaluation, COI sources other than LANL were considered "regional background."

While sediments in some areas of LANL's watersheds and in and near the Rio Grande have accumulated and retained some legacy contamination, measurements of waterborne constituents detected in the Rio Grande in recent years are largely representative of a mixture of chemicals and radionuclides from a variety of natural and anthropogenic sources. To help explore the relative contributions of LANL sources and upriver sources, statistical tests were performed to evaluate the differences in concentrations measured near the Buckman diversion location, Otowi Bridge, and upriver locations on the Rio Grande and the Rio Chama. While the Otowi Bridge is located up-river from where Los Alamos Canyon enters the Rio Grande, comparisons of data from those locations to upriver locations were performed because sample collection near the Buckman only began in 2000. In every case, for each COI, the concentrations downstream of LANL were no greater than those upstream of LANL.

Figures 7-3 and 7-4 present concentration comparisons for some COIs at the Buckman and Otowi Bridge sampling locations.

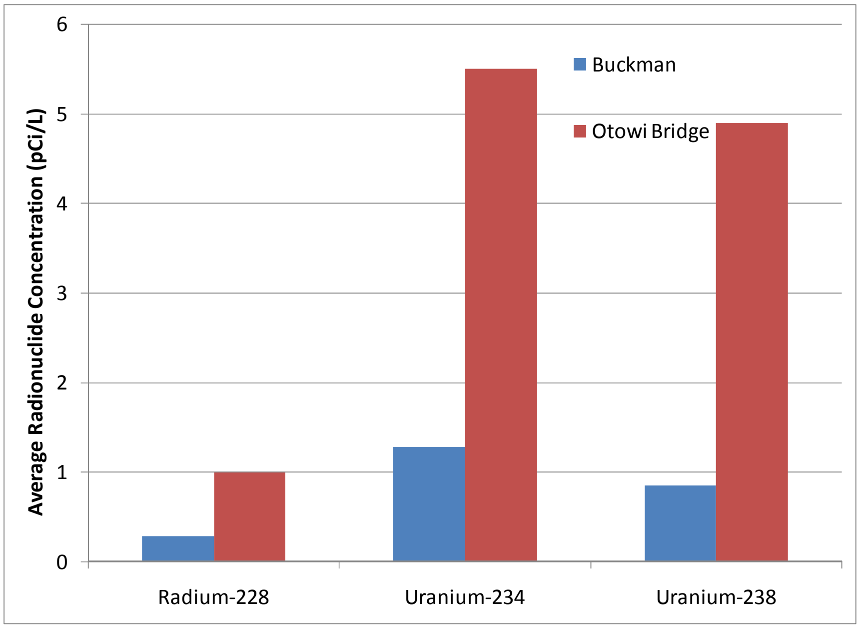


Figure 7-3: Comparison of average concentrations for selected radionuclides at the Buckman and Otowi Bridge locations

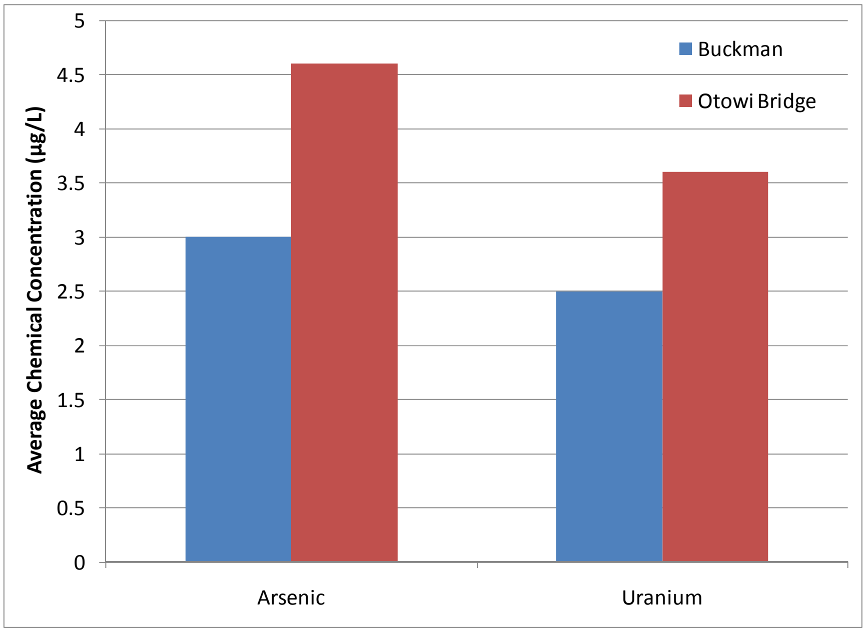


Figure 7-4: Comparison of average concentrations for selected chemicals at Buckman and Otowi Bridge

These figures indicate that LANL does not contribute to the presence of COIs in the Rio Grande during base-flow conditions. They also indicate that the COI levels measured in the Rio Grande are representative of regional background. The regional background levels of all the COIs appear to be due primarily to naturally occurring sources, as opposed to man-made sources, including LANL.

The Thermal Ionization Mass Spectroscopy (TIMS) measurements performed by LANL and NMED(74) have provided useful indications of the relative contributions of LANL sources and weapons testing fallout in terms of the levels of Pu-239/240, Am-241, Cs-137, and Sr-90 recently measured in channel and bank sediments along various areas of the Northern Rio Grande. Based on these measurements, plutonium has been associated with three types of sources: those that predominantly represent weapons testing fallout, those that represent LANL influence, and those for which LANL influence is possible. The largest concentration of contamination of LANL origin in sediments was identified at Caňada Ancha near the Buckman site. While TIMS measurements of sediments provide useful information for understanding the distribution of legacy contamination along the Rio Grande, the lower concentrations of radionuclides that routinely exist in the flowing water of the Rio Grande preclude using the method for surface water samples that would be directly useful for addressing relative contribution of contaminants to water that could be provided through the BDD system.

7.5 REVIEW OF PLUTONIUM DISCHARGE TO AND LOSS FROM LANL CANYONS: 1943 TO PRESENT

The IPR team was tasked with examining work by others who have estimated the history, inventory, and movement of plutonium released to the LANL canyons and its fate in the Rio Grande. Research has addressed the concentrations, inventories, and fates of plutonium on sediments in the Los Alamos Canyon watershed and the Rio Grande for several decades. The IPR team summarized that body of work, and identified uncertainties in two key components of LANL plutonium fate: sediment plutonium inventory and sediment transport.

Estimates of plutonium inventory have been made by mapping locations and volumes of riverbed sediment components and measuring plutonium concentrations to calculate inventories. A second method has used sediment transport models to predict the transport of plutonium based on estimated releases, and then compared the modeled concentrations to observed concentrations.

The early work on sediment transport at Los Alamos and in the Rio Grande had to make numerous assumptions in order to accomplish meaningful studies. The IPR team examined certain key assumptions common to the work of early investigators in light of contemporaneous and later publications. Based on that analysis and on the body of information now available, the IPR team concludes that pre-Cerro Grande Fire investigations:

- Underestimated the contaminant inventory remaining on site;
- Underestimated the amount of contaminated sediment transported to the Rio Grande; and,
- Underestimated the amount and rate of contaminated sediment transport down the Rio Grande.

The degree of underestimation is difficult to quantify. Historical inventory estimates have varied by more than an order of magnitude. Based primarily on the history of revisions in inventory and transport, the *past* underestimation of plutonium inventory in Los Alamos Canyon watershed was at least a factor of two and approached a factor of ten. The transport underestimation depends on the time period, the works being compared, and the underestimation of inventory. Past researchers did not specifically estimate the amount of plutonium transported to, and within, the Rio Grande, except as related to the highly uncertain inventory of the past. Past qualitative approximations of transport to and within the Rio Grande are underestimates, but cannot be assessed quantitatively.

7.6 HUMAN HEALTH RISK ASSESSMENT

The most meaningful results of this health risk assessment are those for the central tendency evaluations, since they are most representative of typical exposures that would be expected from using BDD tap water. Hence, the discussion below focuses on the risk estimated for the central tendency (CT). However, it is important to note that in general, the upper-bound, “reasonable maximal exposure” (RME) risk estimate is only marginally higher than the CT estimate, due to the many conservative assumptions used to derive the CT estimates.

Four different hypothetical exposure scenarios were evaluated in order to provide a basis of comparison for the estimated health risks associated with untreated Rio Grande water; they are discussed below.

7.6.1 Theoretical Cancer Risks Associated with COI Levels Recently Measured in Untreated and Unfiltered Water in the Rio Grande

As defined by the USEPA and other agencies, acceptable increased cancer risk ranges from 1 x 10^{-6} to 1 x 10^{-4}; risks in this range are not of regulatory concern.

Radionuclides - For the 15 radionuclides evaluated, lifetime cancer risks were estimated for males and females based on recent surface water concentrations measured in the Rio Grande. Estimated cancer risk for each radionuclide range from 2.16 x 10^{-5} (for Ra-228) to 7.43 x 10^{-9} (for Pu-238) (Table 5C-2). The total, central tendency, lifetime cancer risk for males and females summed across these 15 radionuclides is 3.80 x 10^{-5}, which is within the US EPA's generally acceptable range of 1 x 10^{-6} to 1.0 x 10^{-4} cancer risk. Only four of the 15 radionuclides demonstrate a slight excess cancer risk above 1.0 x 10^{-6}: K-40 (4.54 x 10^{-6}), Ra-226 (5.93 x 10^{-6}), Ra-228 (2.16 x 10^{-5}), and U-234 (2.32 x 10^{-6}). Cancer risks to females vary only slightly from those estimated for males, with the total, lifetime, central tendency cancer risk for females 0.2% lower than that for males (Table 5C-4). This difference is due to slightly lower risks from ingestion of produce and inhalation while bathing and swimming.

Figure 7-5 below summarizes the theoretical cancer risks radionuclides. It shows that four COIs fall within the USEPA acceptable health risk range: potassium-40 (K-40), radium-226 (Ra-226), radium-228 (Ra-228) and U-234.

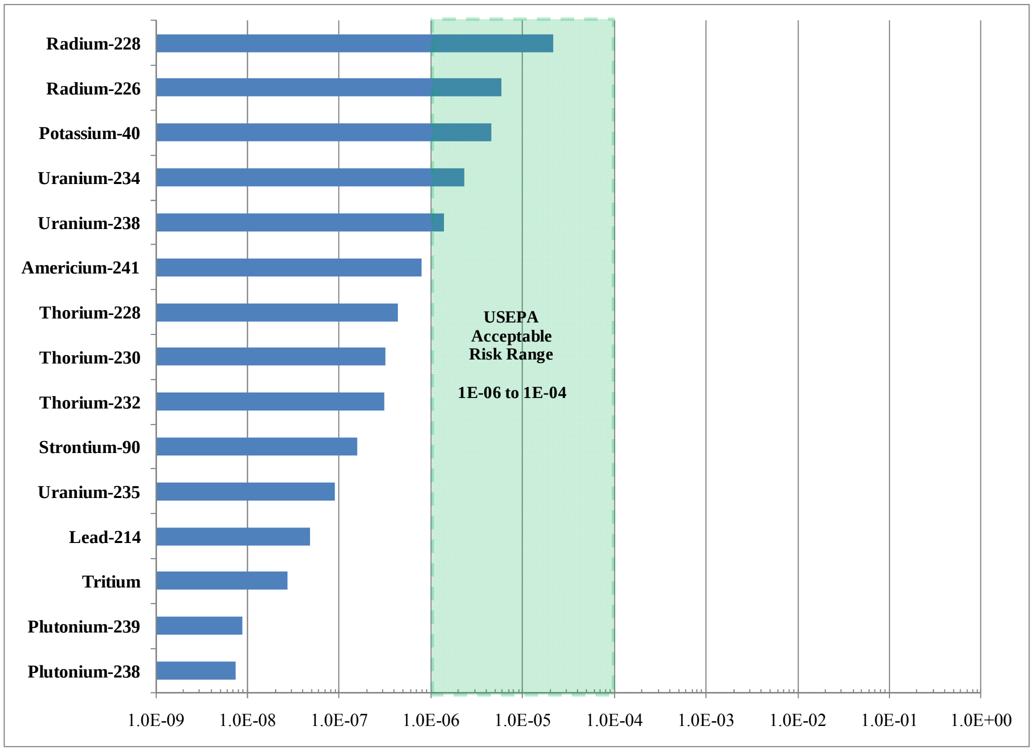


Figure 7-5: Theoretical risks—Radionuclides

Chemicals – Ten of the 35 chemical COIs are potentially carcinogenic. Carcinogenic risks were summed across all relevant exposure pathways for each of the ten carcinogenic COIs. These risk estimates range from 4 x 10^{-13} (for cadmium) to 7 x 10^{-5} (for arsenic) (Table 7-1). The total lifetime cancer risk for all ten COIs is 7 x 10^{-5}, indicating that arsenic is the predominant contributor to total risk. Figure 7-6 below summarizes the theoretical cancer risks of chemicals, shows that only arsenic falls with acceptable health risk range, and that theoretical risks from the remaining chemicals are negligible.

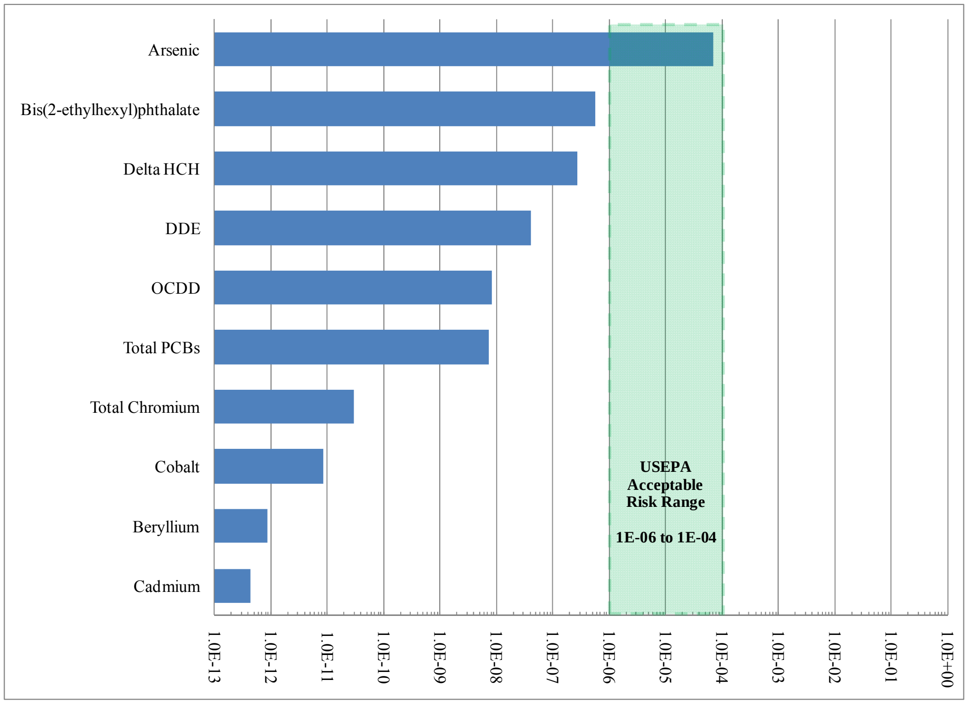


Figure 7-6: Theoretical risks—Chemicals

Combined Risks for Chemicals and Radionuclides - The total risk from all chemical and radionuclide COIs combined is 1 in 10,000, (i.e., increased 0.0001% above the background cancer rate), which is at the upper end of the acceptable risk range. Hence, this analysis indicates that consumption of *unfiltered and untreated* Rio Grande water does not pose an unacceptable cancer risk. Figure 7-7 summarizes the contributions of the different COIs to total risk.

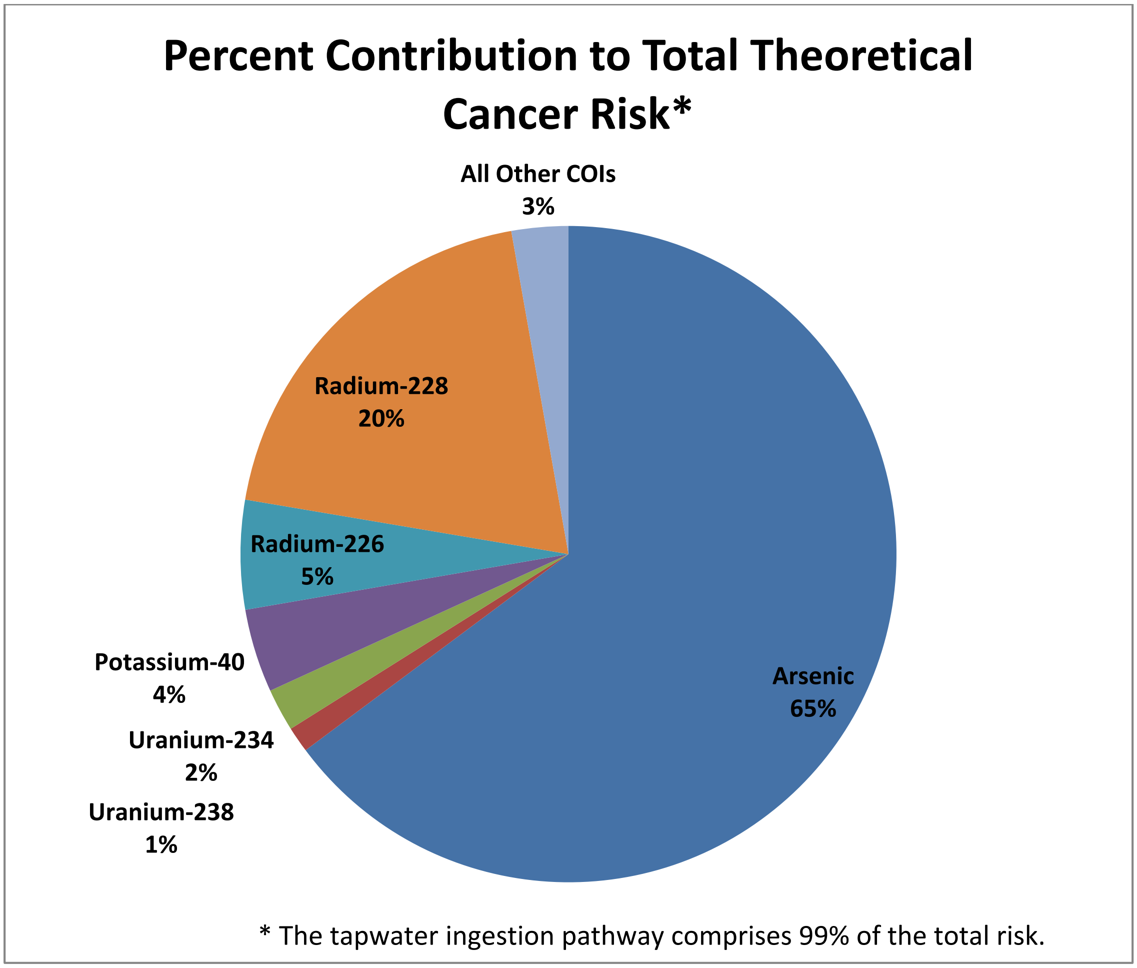


Figure 7-7: Theoretical risks—Radionuclides and chemicals

The primary pathway of exposure for each COI is tap water ingestion; none of the other exposure pathways contribute significantly to the estimated risk.

Arsenic is the primary contributor (65%) to the theoretical risk. It is therefore important to remember that arsenic levels in untreated Rio Grande water are below drinking water criteria and are similar to levels measured regionally and throughout the U.S. Specifically, arsenic is naturally-occurring in soil and rocks, and is released to groundwater and surface water through erosion, dissolution, and weathering. Arsenic is widely distributed in public water systems throughout the U.S., with typical concentrations ranging from one to five µg/L; this range is similar to the concentrations measured in untreated Rio Grande surface water. Furthermore, these theoretical risks are based on *untreated and unfiltered* water samples; in reality, the BDD water treatment plant is expected to effectively remove arsenic.

Similarly, concentrations of Ra-226, and Ra-228 (which comprise 25% of the theoretical risk) at the Buckman sampling locations were always lower than their respective drinking water criteria, and are similar to levels measured elsewhere in the U.S. Ra-226 occurs within the natural decay series for U-238, and Ra-228 occurs within the natural decay series for Th-232. Radium isotopes can reach surface water from a variety of environmental sources essentially by leaching from soil, rocks, and sediment into precipitation and eventually into surface water.

7.6.2 Non-Cancer Risk from Chemical COIs Using Recent Measurements in the Rio Grande

The non-cancer risks for the infant age group are summarized for non-cancer risk, since this group resulted in the highest non-cancer risk estimates. The non-cancer hazards for individual chemicals are summarized in Figure 7-8. The graph below summarizes the estimated non-cancer hazards for individual chemicals.

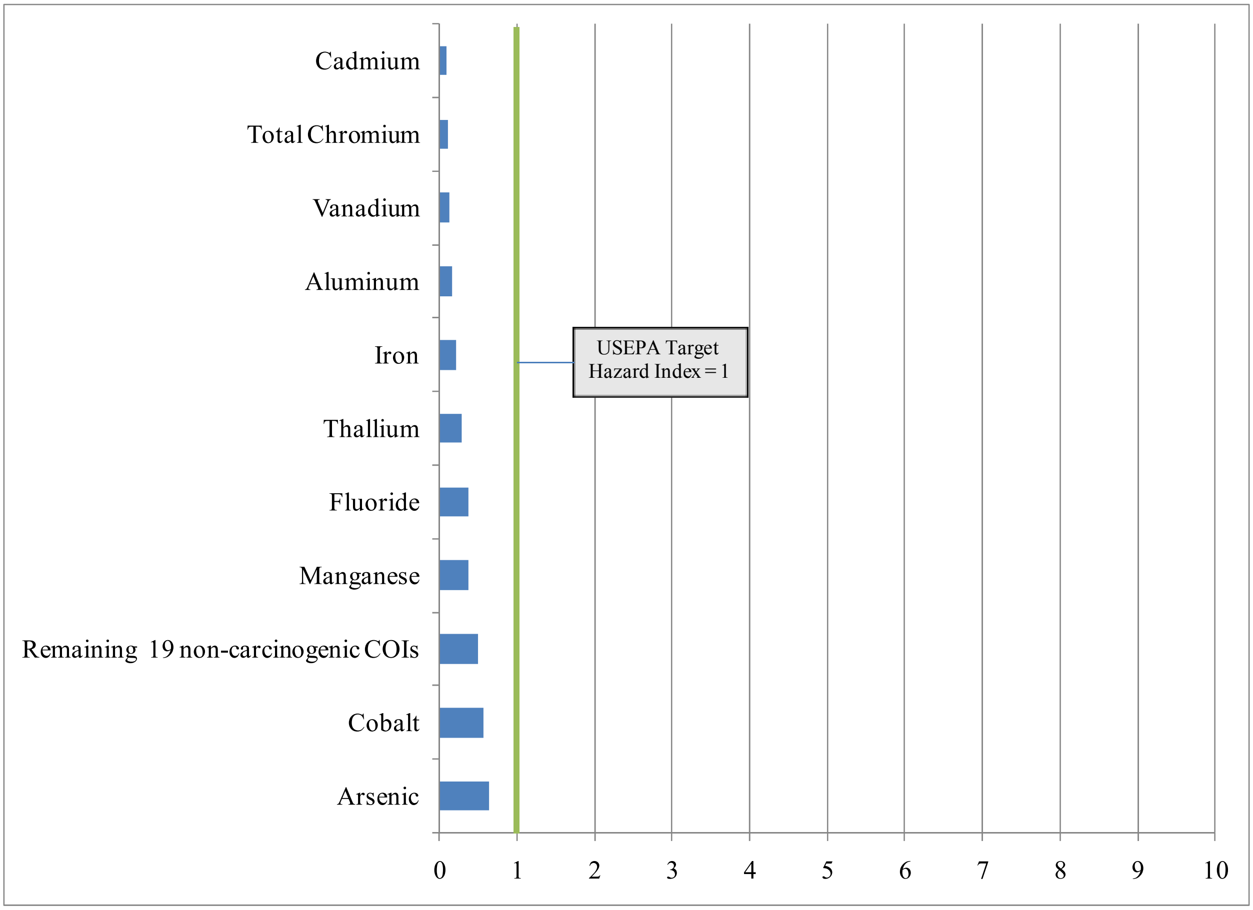


Figure 7-8: Hazard indices—Chemicals

None of these values exceeded 1.0, indicating that there is no non-cancer hazard associated with consuming untreated and unfiltered water from the Rio Grande.

For this the target organ evaluation, the infant age group was the only age group evaluated for which hazard indices exceeded 1.0. The CT hazard indices for chemicals that cause health effects other than cancer range from 0.058 for gout (an acute, inflammatory arthritis) to 1.3 for circulatory/cardiovascular system effects. As expected, the exposure from tap water ingestion dominates the estimated non-carcinogenic health risk estimates. The breakdown of risk contributions for hazard indices greater than 1.0 for infants is:

- Circulatory/Cardiovascular System Effects (Hazard index = 1.3)

Arsenic	48.9%
Cobalt	42.9%
Antimony	4.7%
Nitrite	0.92%
Barium	2.4%
Zinc	0.21%

- Reproductive Effects (Hazard index = 1.2)

Arsenic	52.8%
Cobalt	46.4%
Boron	0.82%

Neither of these hazard index values are indicative of a significant non-cancer hazard associated with consumption of untreated surface water from the Rio Grande. Furthermore, these estimates are associated with consuming *untreated and unfiltered* water from the Rio Grande. Given the expected removal of a substantial portion of these COIs by the BDD water treatment plant, the IPR team believes that there are no non-cancer hazards associated with using tap water provided by the BDD system.

Lastly, none of the COIs are known to have synergistic effects with respect to cancer or non-cancer health endpoints.

7.6.3 Theoretical Cancer Risks Following 95% Removal of Plutonium, Americium, Uranium, and Gross Alpha-emitting Radioactivity

When 95% removal for these isotopes was applied to recent concentrations measured in the Rio Grande, the estimated cancer risks for those isotopes decreased by 95%, as would be expected. However, because other radionuclides that are naturally occurring contribute to the total theoretical cancer risk (K-40, Ra-226, and Ra-228, as discussed above), the radionuclide risk decreases by only approximately 12% in this treatment scenario. In reality, it is expected that the BDD water treatment plant will effectively remove COIs other than just plutonium, americium, and uranium; thus, the overall risk from the radionuclide COIs will likely decrease by much more than 12% (from the untreated scenario above) as a result of water treatment.

7.6.4 Theoretical Radionuclide Cancer Risks Based on Recent Measurements of Gross Alpha Activity and Dissolved Uranium in Buckman Well Water

The estimated radionuclide cancer risk increased about threefold under this assumption [from 3 x 10^{-5} (3 in 100,000) under "current levels" to 9 x 10^{-5} (9 in 100,000) for the Buckman well water assumption], due to the fact that the gross alpha and uranium levels measured in the Buckman well field are higher than in the Rio Grande. Figure 7-9 below compares the total radionuclide risk for each of the three scenarios:

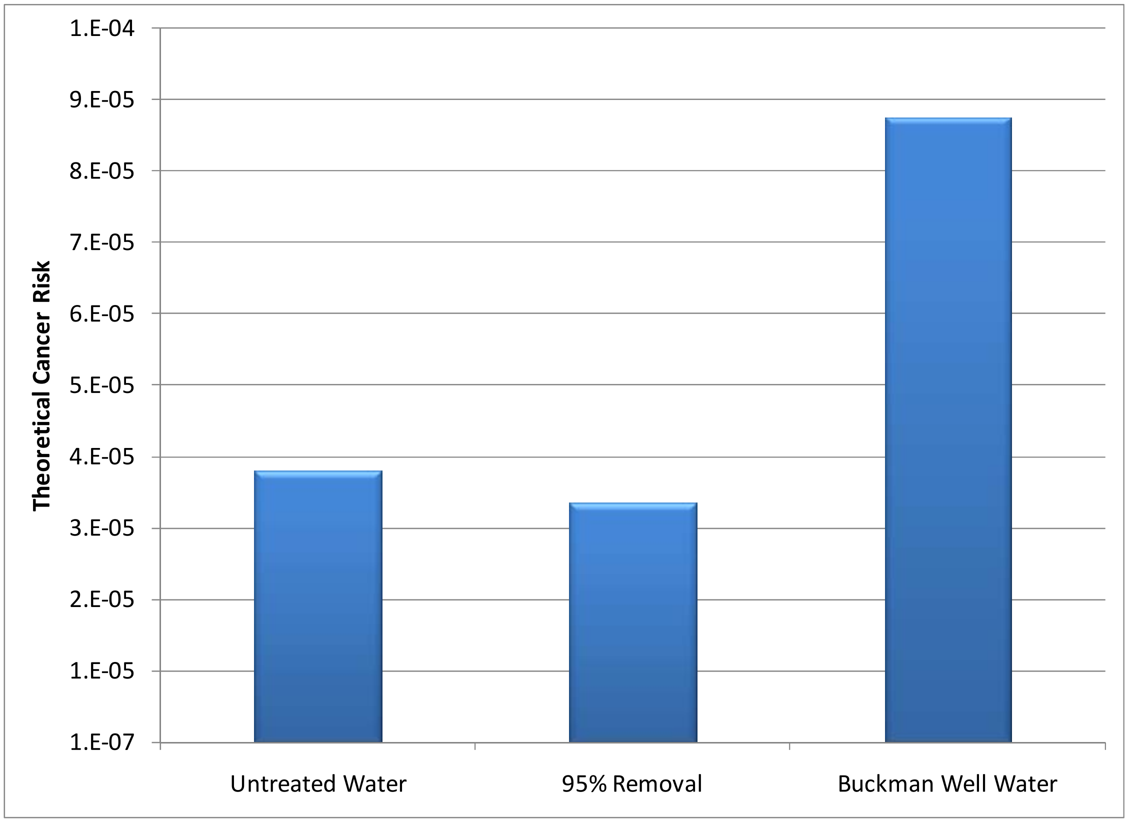


Figure 7-9: Radionuclide risk comparison for untreated water, 95% removal for specific radionuclides, and Buckman well water

The total theoretical cancer risk under this assumption is 3 x 10^{-4}. As before, arsenic ingestion is the primary contributor to the total risk. This scenario is a "worst case" scenario that is highly unlikely to occur, and is included simply for comparison purposes. Figure 7-10 below compares the total risk from "COIs are present at current levels in the Rio Grande" to "COIs are present at drinking water criteria."

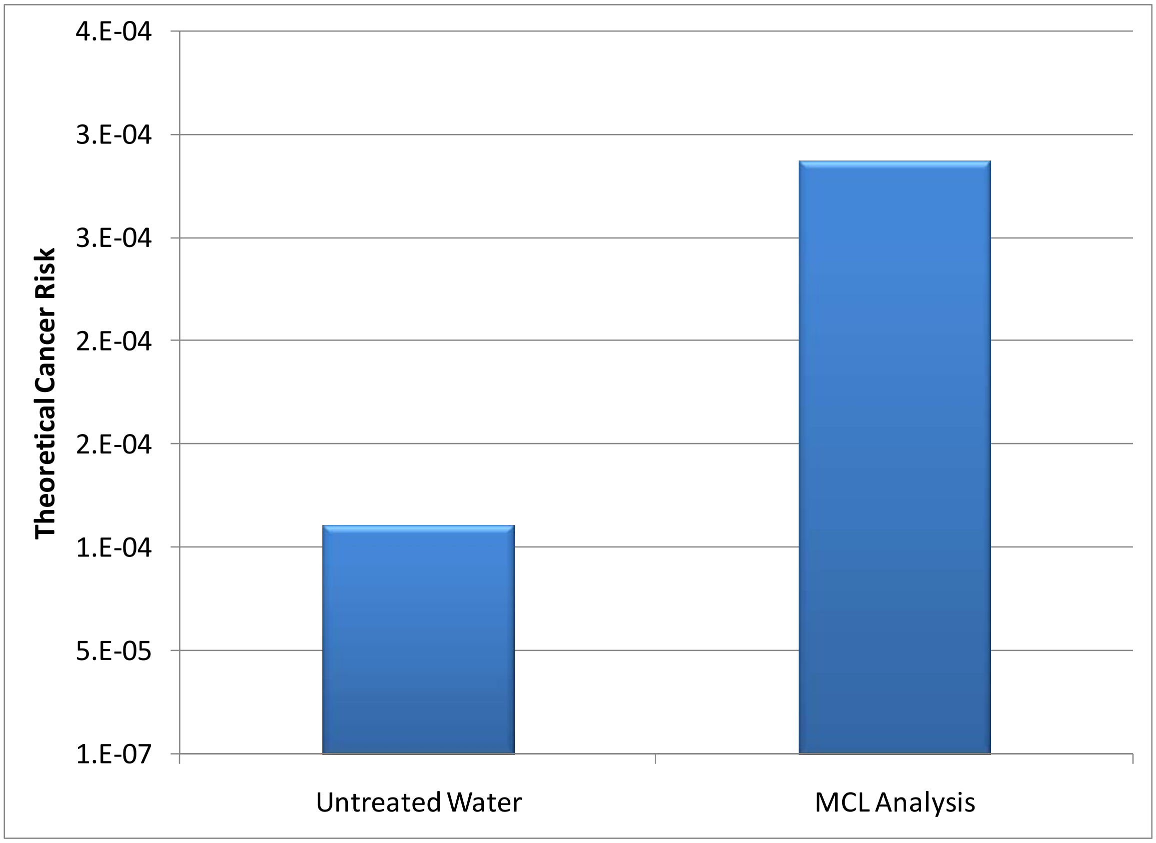


Figure 7-10: Comparison of total risk from "COIs are present at current levels in the Rio Grande" to "COIs are present at drinking water criteria."

7.6.5 Comparison of Theoretical COI Risks to Risks of Everyday Activities

The theoretical cancer risk estimates described above are the probability of getting cancer as a result of exposure to COIs in the Rio Grande (under the assumptions defined in each scenario). The theoretical risks can be put into perspective by comparing them to risks of everyday activities, as illustrated in Figure 7-11.

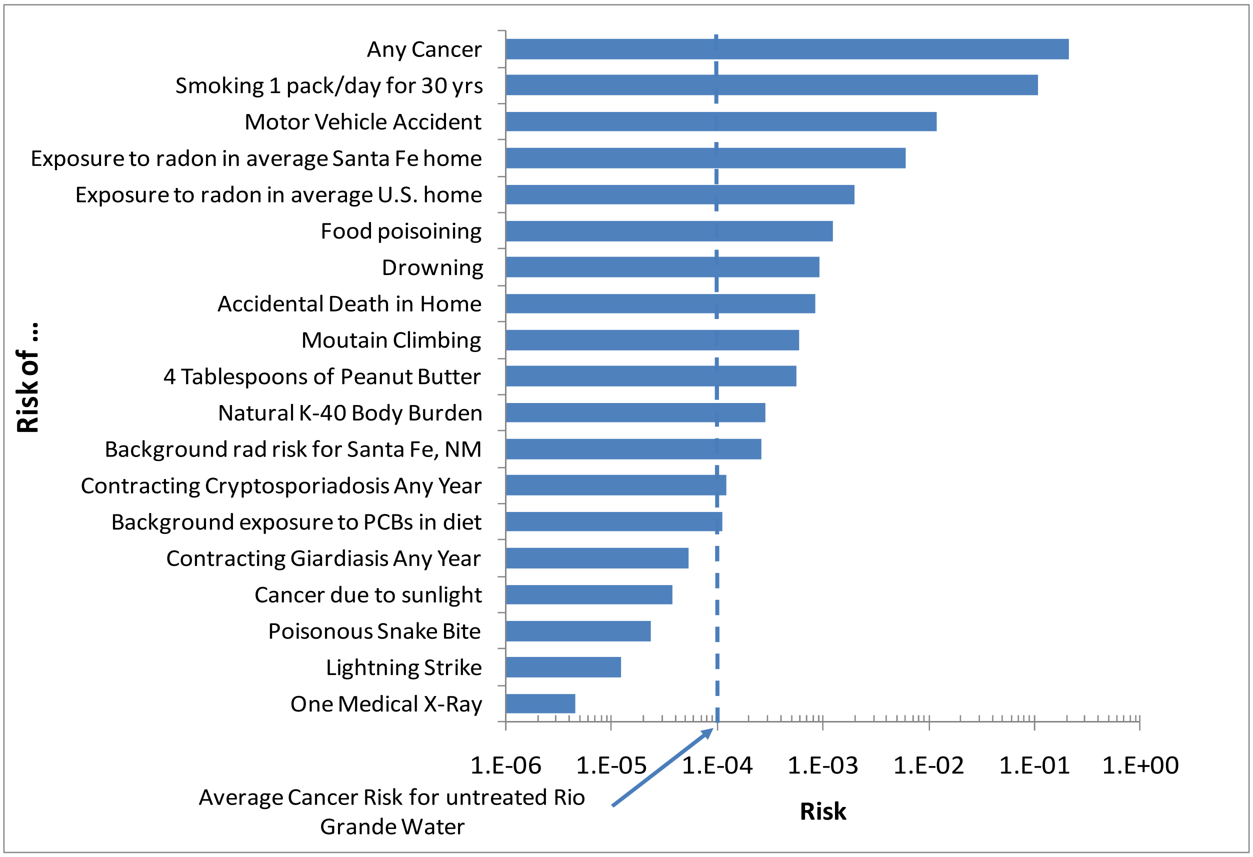


Figure 7-11: Theoretical risks from using BDD water compared to everyday activities

As an example, the theoretical risks associated with consuming untreated and unfiltered Rio Grande water are less than those associated with radon exposure in the typical Santa Fe residence. A more detailed comparison to "everyday risk" is presented below.

7.6.6 Comparison of Radionuclide COI "Effective Doses" to Radiation Doses from Everyday Activities

The IPR team also calculated an annual "effective" radionuclide COI dose for the tap water ingestion pathway. The effective dose can be directly compared to the ubiquitous radionuclide exposures that take place due to naturally occurring radiation or via various diagnostic and therapeutic medical procedures.

In 2009, the National Council on Radiation Protection and Measurements (NCRP) published a report entitled *Ionizing Radiation Exposure of the Population of the United States* (NCRP Report 160). In this report, NCRP estimated that the effective dose per individual in the United States for 2006 was 610 mrem. The two largest contributions to radiation dose are natural background radiation and radiation exposure from diagnostic and therapeutic medical procedures; each contributes to approximately 50% of the total effective dose for the average U.S. citizen. Much smaller contributions (< 1%) are attributable to occupational, industrial, and consumer radiation exposure.

With respect to exposure to ubiquitous background radiation, the NCRP calculated an arithmetic mean of 310 mrem per individual in the United States, and identified the largest contributions of background radiation as internal doses from inhaling radon and thoron gas (228 mrem; 73%); smaller contributions come from cosmic radiation (33 mrem; 11%), as well as internal doses from ingesting naturally occurring radionuclides (29 mrem; 9%), and external exposure to naturally occurring radiation (21 mrem; 7%). To put these findings into perspective, the annual effective radiation dose for an adult ingesting untreated water from the Rio Grande was calculated as 1.6 mrem, over 150 times smaller than the effective dose attributable to natural background for an individual in the United States.

Figure 7-12 compares the effective annual radiation dose from drinking unfiltered Rio Grande water to those associated with various background sources:

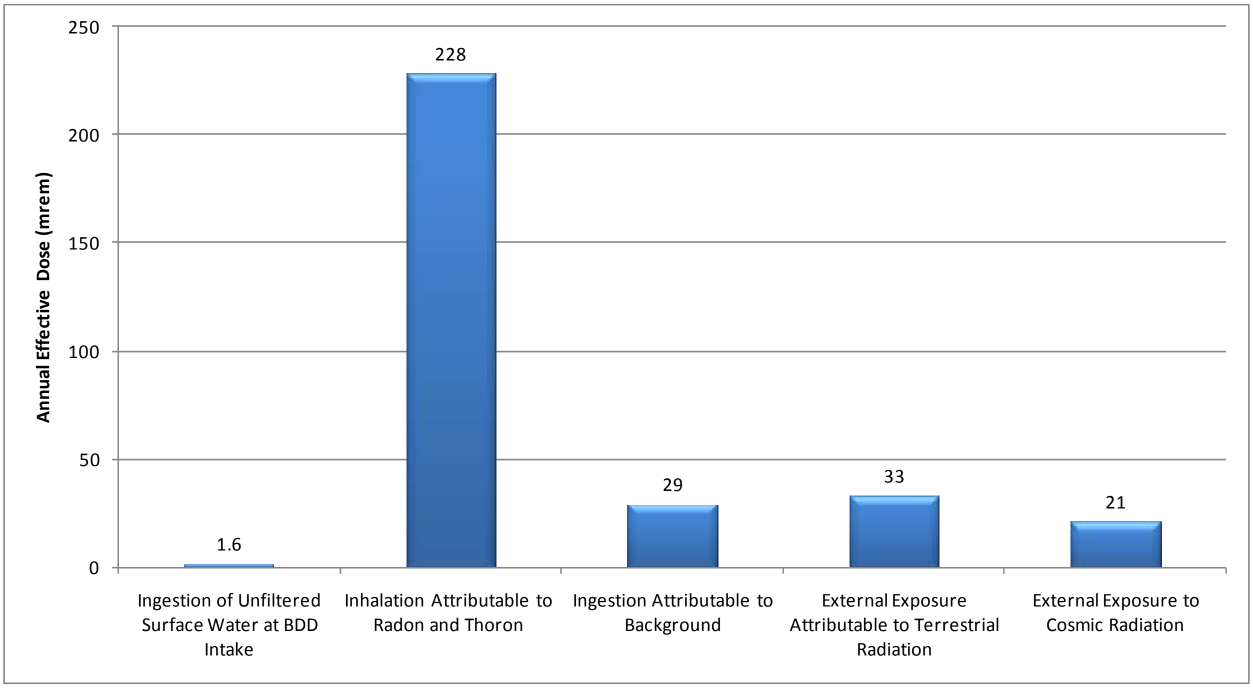


Figure 7-12: Annual effective dose: Comparison of drinking unfiltered Rio Grande water to background sources

Patient exposure to radiation during medical procedures is the other major contributor to the annual effective radiation dose. The annual effective dose from medical procedures was estimated by the NCRP to be 300 mrem, with the largest contributions from computed tomography (CT) scans (147 mrem; 49%), nuclear medicine (77 mrem; 26%), interventional fluoroscopy (43 mrem; 14%), and conventional radiography and fluoroscopy (33 mrem; 11%).

Again, the average effective dose to patients from practical diagnostic and therapeutic procedures are much greater than the annual effective dose for an adult ingesting untreated water from the Rio Grande.

Figure 7-13 compares the effective annual radiation dose from drinking unfiltered Rio Grande water to those associated with various medical sources:

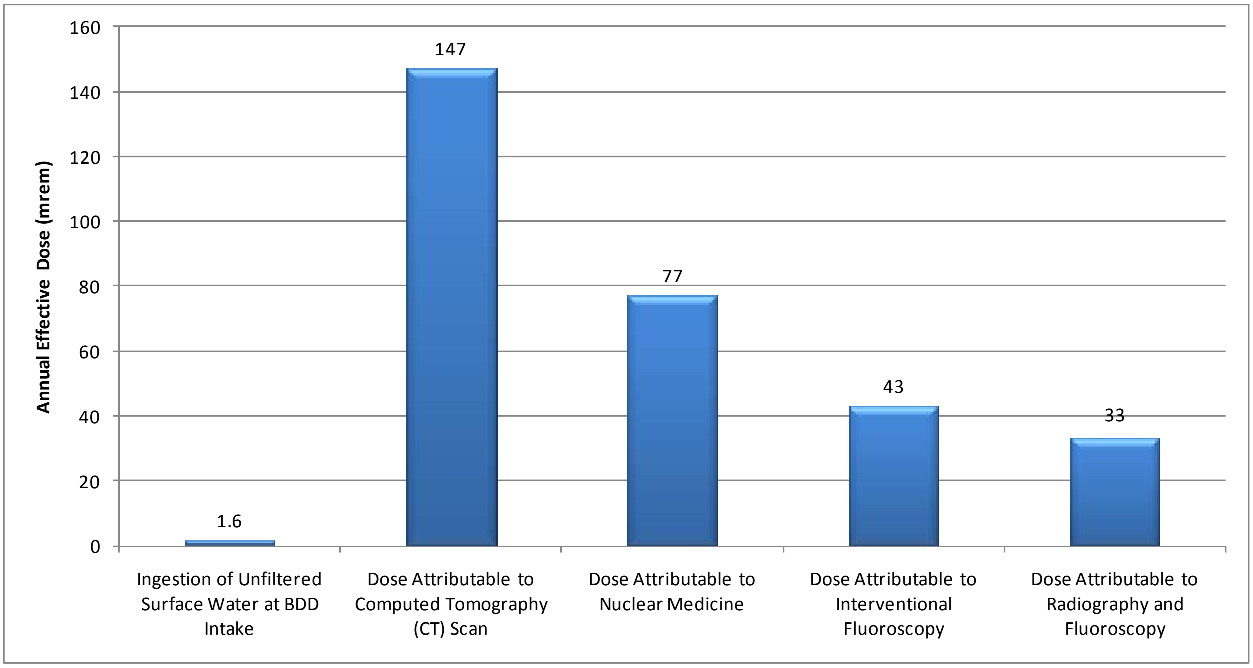


Figure 7-13: Annual effective dose: Comparison of drinking unfiltered Rio Grande water to medical sources

7.6.7 Pharmaceuticals, Personal Care Products, and Endocrine Disrupting Compounds

Because there are no major metropolitan areas in the watershed of the upper Rio Grande, pharmaceuticals have rarely been detected in the Rio Grande, and the detected levels measured to date are too low to be a health concern.

Analyses of personal care products (perfumes, detergents, etc.) have not been conducted in the Rio Grande, but, due to the aforementioned lack of residential development in the upstream watershed, they are not expected to be present in the Rio Grande, and certainly not at levels warranting a health concern.

Some of the COIs considered in this analysis are thought to be potential endocrine disrupting compounds (DDE, perchlorate, PCBs, lead, cadmium, and mercury). Mean levels of these COIs did not exceed their respective drinking water criteria. The risk evaluations performed by the IPR team inherently evlaute the most sensitive (i.e. health-protective) non-carcinogenic health effects associated with each chemical COI, including 13 potential health endpoints ranging from hair loss to central nervous system effects, including those that can be associated with endocrine disruptors, such as developmental effects and immune system/thyroid effects. In no case did the hazard indices for central tendency exposures for any of the age groups (including infants), based on levels recently measured in the Rio Grande exceed 1.0 for health endpoints attributed to those endocrine disrupting compounds. With that being the case, it is unlikely that the levels of endocrine disrupting compounds recently measured in the Rio Grande would lead to any health effects for anyone using BDD tap water, particularly when considering that the BDD water treatment plant is expected to effectively remove many of these compounds.

7.8 POTENTIAL FUTURE IMPACTS ON SANTA FE TAP WATER QUALITY FROM CONTAMINANTS ASSOCIATED WITH LANL SEDIMENTS AND GROUNDWATER

7.8.1 Contaminated Sediment Transport Pathways

Surface sediments in the Rio Grande downstream of the Los Alamos Canyon discharge point do not contain elevated levels of COIs, suggesting that 1) previous Los Alamos Canyon discharges have not resulted in accumulation of contaminated sediments in the Rio Grande; and 2) any contaminated sediments that reach the BDD intake are far more likely to be due to storm-related discharges from LANL than from suspension of Rio Grande bed sediments.

The IPR team developed estimates of COI concentrations that could exist in the Rio Grande at the Los Alamos Canyon confluence during storm events that might result in significant sediment discharge. Estimates indicate that storm events would discharge contaminated sediments into the Rio Grande such that the resulting COI levels in the Rio Grande would exceed normal base-flow levels by several orders of magnitude, for several hours at the most.

An early notification system is being put in place that will allow BDD personnel to cease diversion of water when there is indication of storm flow coming down Los Alamos Canyon. If any of the storm water contamination were, by some mechanism, make it into the BDD system, it would encounter a treatment system highly effective at removing particle-bound contaminants and some dissolved contaminants, such as arsenic and uranium and chromium. Plans for these systems are currently underway, and will be monitored once the BDD system is operational. The IPR team understands that additional stations will be in place that will automatically collect stormflow samples following each runoff event in Los Alamos Canyon. In addition, both NMED and BDD will collect samples from the Rio Grande at Buckman when Los Alamos Canyon stormwater is flowing to the Rio Grande.

7.8.2 Contaminated Groundwater Transport Pathways

Contaminated Regional Aquifer (RA) groundwater is found under the Los Alamos Canyon watershed as well as under Sandia Canyon and Mortandad Canyon. There are potential groundwater transport pathways that can convey contaminated water to the BDD reach of the Rio Grande. LANL has not reported groundwater contamination in the RA monitoring wells closest to the Rio Grande over the river reach of interest; however, RA monitoring wells in the RA along this reach are scarce, and/or off-gradient to the BDD reach, with most located a large distance from the Rio Grande.

The IPR team developed a calculation spreadsheet for determining mixing ratios (dilution factors) along the reach of interest under varying Rio Grande base flows and aquifer discharges. The contaminant concentrations used were derived from those provided in LANL reports for only those contaminants that exceeded screening level. When the flow calculations are linked to contaminant concentrations in groundwater, the concentrations near the BDD system were determined in a conservative manner.

The results indicate that, under very conservative assumptions based on data currently available from LANL, all analyzed contaminants of groundwater origin would be diluted to below levels of regulatory concern.

In summary, stormwater discharge from LANL is episodic, and does not pose a health risk, and *c*ontaminated groundwater at LANL does not impact the water quality at the BDD intake.

7.9 OVERALL CONCLUSIONS OF THE BDD IPR

The overall conclusions of the IPR team can be summarized as follows:

- There is no significant health risk for BDD water system consumers.
- Chemical and radionuclide levels in the Rio Grande are within acceptable drinking water criterias and/or are naturally occurring.
- There is very little if any contribution from LANL to the Rio Grande during normal base-flow conditions.
- Stormwater discharge from LANL does not pose a health risk.
- There are no contributions from LANL groundwater to the Buckman well field.

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Buckman Direct Diversion Project Independent Peer Review

Report Appendices

Prepared for the
Buckman Direct Diversion Project Board
by ChemRisk, LLC
with AMEC Earth and Environmental

APPENDIX 1A-1 – RESPONSES TO COMMENTS RECEIVED

During the independent peer review (IPR) process, the IPR team has released two drafts of the Technical Report, Executive Summary and Community Summary, with each draft updated based on comments received on the draft reports or at public meetings. The initial drafts of the Technical Report, Executive Summary, and Community Summary were sent to the BDD Board and LANL for comment. These comments were considered and second drafts were released for comments from the general public. All comments received were considered in the final versions of the three reports.

Comments received from the BDD Board, LANL, NMED, interested community advocate groups, and the general public have been addressed to the best of our ability in this final report. This appendix provides a summary of the comments received through each comment period and the IPR team's response, broken down by topic (general comments; and comments specific to water quality standards, data selection and use, the chemical risk assessment, the radiological risk assessment, the early warning system and water treatment facility, sediment transport, and groundwater).

Many of the comments received were outside the scope of the IPR. The BDD Board's stated main objective for the IPR was to obtain an independent, overarching analysis and synthesis of existing studies and bodies of information that would support a description (both conceptual and quantitative) of potential tap water health risks and be accompanied by public risk communication deliverables. The IPR scope of work included an emphasis on the tap water pathway and a consideration of all chemicals and radionuclides in Rio Grande water that could be diverted into the BDD. The IPR team was tasked with characterizing the tap water chemical and radionuclide exposures and risks by comparing them to other exposures and risks that occur as part of everyday life. More specifically, the IPR team's work, as outlined in the request for proposals (RFP), was to include the following:

- Preparation and presentation of deliverables that describe, for technical and non-technical audiences, a critiqued synthesis of existing data, information, studies, and published risk assessment analyses regarding exposure and risk to residents of the Santa Fe region from environmental radionuclide, toxic, and hazardous contaminants known to be of LANL-origin and other origins of these contaminants.
- Emphasis on the tap water pathway, including the contaminants in Rio Grande water diverted into the BDD and removed by water treatment processes, as previously addressed by Kerry Howe for the BDD Board.
- Illustration of the tap water pathway risk by comparison to other pathways and risks.

Questions that were out of the scope of the IPR are noted accordingly.

COMMENTS RECEIVED DURING PUBLIC MEETINGS

General Comments

COMMENT: Where can the public access data to prove arsenic is reduced to healthy levels?

> IPR Response: The efficacy of the BDD water treatment plant was outside the scope of the IPR; therefore a quantitative assessment of levels of arsenic after passing through the BDD water treatment plant was not performed. Accordingly, there are no data pertaining to theoretical arsenic reductions available for public review.
>
> The assessment performed by the IPR team focused on levels of arsenic from unfiltered and untreated surface water samples. Based on these samples, the IPR team determined that levels of arsenic in unfiltered and untreated Rio Grande water are below drinking water criteria, and are similar to levels measured regionally and throughout the United States. Moreover, based on the risk assessment that takes into account various conservative assumptions, theoretical cancer risk from exposure to arsenic is within the USEPA acceptable excess cancer risk range of 1 in 1,000,000 to 1 in 10,000.

COMMENT: What is the BDD monitoring protocol?

> IPR Response: The IPR's focus was on review and analysis of existing data, information, studies, and published risk assessment analyses regarding exposure and risk to residents of the Santa Fe region from environmental radionuclide, toxic, and hazardous contaminants known to be of LANL-origin, as well as other origins of these contaminants. Any analysis of the proposed BDD monitoring protocol after implementation of the diversion system and water treatment plant is outside the scope of the IPR.

COMMENT: Does the IPR team plan on working closely with the tribal governments during the project?

> IPR Response: There was not a plan to work with any specific entities outside receiving comments on the preliminary draft reports from the BDD Board and LANL. However, the IPR team worked with members of the community to the extent that was facilitated by holding three public meetings and providing the public the opportunity to review and submit comments on the draft deliverables of the IPR. The objective of the public meetings was to inform the general public (which certainly could include members of tribal governments) about the project, its scope, and findings. The IPR draft deliverables were made available for review and comment from the general public. All comments received were taken into consideration during finalization of the IPR deliverables.

COMMENT: Request for a topographic map showing the locations of the Buckman diversion intake, LACW, and Otowi Bridge was made. The commenter pointed out that various maps are available, but they are hard to interpret and do not provide information that is useful.

> IPR Response: Maps that were deemed useful to the scope of the IPR are presented in all three deliverables of the project.

COMMENT: Request for a schematic of the monitoring samples with respect to filtration, and a diversion location was made.

> IPR Response: Analysis of the monitoring protocol with respect to diversion and filtration was outside the scope of the IPR. As mentioned previously, the IPR's focus was on review and synthesis of existing data, information, studies, and published risk assessment analyses regarding exposure and risk to residents of the Santa Fe region from environmental radionuclide, toxic, and hazardous contaminants known to be of LANL-origin and other origins of these contaminants.

Comments Specific to the Early Warning System and Water Treatment Plant

COMMENT: What chemicals will be removed by the new water treatment facility? How, and how efficiently? What will be done about chemicals that are water soluble? That is, any that will not be removed because of their association with sediment particles.

> IPR Response: Assessment of the efficacy of the BDD water treatment plant was outside the scope of the IPR. Available information on this topic was summarized for the BDD Board by Dr. Kerry Howe in his 2008 report:
>
> - Howe, K.J. 2008. "Final Report− Effectiveness of the Proposed Santa Fe City/County Water Treatment Plant for Removing Radiological and Other Specific Contaminants." Prepared for the City of Santa Fe and the Buckman Direct Diversion Board. April 15, 2008.

COMMENT: What types of filtration mechanisms are used?

> IPR Response: Analysis of the specific filtration and water treatment mechanisms used by the BDD was outside the scope of the IPR; however, the Community Summary presents a schematic, prepared by BDD project staff. The schematic illustrates the conventional and advanced water filtration and treatment mechanisms that have been implemented. Furthermore, available information on those topics was summarized for the BDD Board by Dr. Kerry Howe. More information on the water treatment plant can be found on the BDD project website at www.BDDproject.org.

COMMENT: Will the water treatment remove arsenic?

> IPR Response: The BDD water treatment plant is expected to be effective in removing arsenic; however, quantifying the efficacy of the BDD water treatment plant is outside the scope of the IPR. It is therefore important to remember that arsenic levels in unfiltered and untreated Rio Grande water are below drinking water criteria and are similar to levels measured regionally and throughout the U.S. Arsenic is widely distributed in public water systems throughout the U.S., with typical concentrations ranging from 1 to 5 µg/L; this range is similar to the concentrations measured in untreated Rio Grande surface water.

COMMENT: What thought has been given to unforeseen events such as storms and fires that could potentially negatively affect operation of the BDD?

> IPR Response: Evaluating the efficacy of operational components of the BDD diversion structure and water treatment plant is outside the scope of the IPR. As mentioned throughout the Technical Report, Executive Summary, and Community Summary, an early notification system is being established that will allow BDD personnel to stop diverting Rio Grande water if it is anticipated that the levels of contaminants could become elevated to levels of concern.

COMMENT: Will the health impacts of both drinking the water prior to filtration and after filtration be studied?

> IPR Response: The IPR team evaluated risk from chemical and radiological COIs in unfiltered and untreated surface water samples taken from the Buckman diversion site. While the IPR team did not analyze the efficacy of the water treatment plant, theoretical exposures to radionuclides were also evaluated with and without 95% removal for plutonium, americium, uranium, and gross-alpha emitting radioactivity. The IPR team found that all COI levels in the untreated and unfiltered water samples taken from the Buckman diversion site were less than the USEPA enforceable drinking water standards for tap water. In other words, the COI levels in the Rio Grande meet drinking water standards even before the water is treated. Moreover, the total theoretical cancer risk (all chemicals and radionuclides combined) from use of untreated and unfiltered water samples was 1 in 10,000, which falls within the USEPA acceptable cancer risk range. This estimate far over-states the theoretical cancer risk because it assumes that consumers are drinking untreated and unfiltered water from the Rio Grande.

COMMENT: Will the team be relying on data and reports compiled by Kerry Howe? Have those data been peer reviewed?

> IPR Response: The IPR team relied on existing data, information, studies, and published risk assessment analyses regarding exposure and risk to residents of the Santa Fe region from environmental radionuclide, toxic, and hazardous contaminants known to be of

LANL-origin and other origins of these contaminants. One of many studies reviewed was Dr. Kerry Howe's 2008 report on the efficacy of the BDD water treatment plant. We are not relying on the Howe report and we do not know if his report or the underlying data were peer-reviewed.

COMMENT: How accurate are the costs associated with the operation of the water treatment facility?

> IPR Response: This question is outside the scope of the IPR. The focus of the IPR was on the analysis of exposure and health risk to residents of the Santa Fe region from chemical and radiological contaminants.

COMMENT: How will the water treatment plant dispose of radionuclide and chemical residuals? How will these wastes be handled at the treatment facility?

> IPR Response: Analysis of disposal methods of water treatment residuals was outside the scope of the IPR.

Comments Specific to Data Selection

COMMENT: Specifically, will the team be considering any samples taken at the Cochiti reservoir?

> IPR Response: No. None of the tasks assigned to the IPR team will require use of measurements from Cochiti Reservoir. Cochiti Reservoir receives inputs from sources (including some canyons that drain LANL property) that enter the Rio Grande downriver of the BDD diversion point. Consequently, data from the Cochiti Reservoir area are less useful when evaluating potential exposures from use of tap water provided through the BDD system.

COMMENT: Will the team be using samples taken above the Otowi Bridge?

> IPR Response: Yes. Analytical results of samples taken upriver from the Otowi Bridge were compared to results of samples taken between the entry point of Los Alamos Canyon and the area of the BDD diversion point. These samples were acquired and analyzed as part of the effort to quantify contamination coming from other sources farther upstream in contrast to contamination from LANL sources.

COMMENT: Samples taken around the Otowi Bridge may have been elevated. How will this be addressed? How do these samples affect the BDD project?

> IPR Response: Because the sampling locations at Otowi Bridge are upstream of the discharge point of the LACW, the main source of concentration data used for the risk

assessment are 11 surface water samples collected from the Rio Grande at a LANL sampling location and a NMED sampling location upstream of the Buckman diversion intake. To be health-protective, data from the four Otowi Bridge locations were used for the risk assessment of radionuclides and chemicals that were not detected at the Buckman locations, but that were detected at the Otowi Bridge and at the downstream locations. In general, we consider the Otowi Bridge locations to be representative of natural or anthropogenic regional background concentrations of the COIs. Because these sampling locations are upstream of the LACW, any elevated concentrations are not considered to be LANL related.

COMMENT: Will the team be using data available on the RACER database?

IPR Response: Yes. The IPR team is using data from RACERNM and other sources. A large portion of the sampling data considered and used in the IPR was obtained from the RACER database managed by the New Mexico Community Foundation (NMCF) located in Santa Fe, NM. Of most relevance to the IPR, RACER contained 585 surface and storm water samples collected by LANL and NMED at various locations along the Rio Grande between 1956 and 2010. These samples were analyzed for 578 different chemicals, radionuclides, and contamination indicators (turbidity, pH, etc.) for a total of 33,855 sample contaminant results. Complete details regarding the data used are presented in Section 2 of the Technical Report.

COMMENT: How will the public know that all relevant data are being considered?

IPR Response: The various data sources documented by the IPR and used in the Technical Report are described in Section 2. We believe we have identified all of the relevant available data.

COMMENT: How old, or recent, are the data that will be used in the risk assessment?

IPR Response: Data collected from 2000 to the present was considered in the IPR risk assessment because surface water sampling at the Buckman locations did not begin until after 1/1/2000.

COMMENT: How will data used in the risk analysis be "validated?" Will the team review sampling plans, protocols, chain-of-custody, analytical QA procedures?

IPR Response: The IPR has reviewed documentation regarding the methods, procedures, and practices used in sampling and analysis programs.

COMMENT: Will the peer review team perform qualitative evaluations of these data sources and determine whether they are more or less reliable to be used to assign health risk estimates? The sentiment was expressed that there was considerable variability in quality with respect to data that has already been obtained regarding water quality and contamination. In particular, the speaker voiced the belief that the LANL Water Quality Database was superior in technique and was more representative of actual contaminant levels compared to other data sources, particularly the RACER database, which was felt to not have "qualifiers" or the same degree of data checking and validity compared to the LANL data.

> <u>IPR Response:</u> A comprehensive evaluation of the environmental data reviewed and used by the IPR was beyond our scope of work. Because the RACER database contains LANL, USGS, and NMED surface water and storm water sampling data and we are using data collected from 1/1/2000 to 2/1/2010, we believe these data are of sufficient quality for use in risk assessment, and are comparable with each other. In addition, we compared the data in the LANL Water Quality Database with the data in the RACER database attributed to LANL. The results of this comparison are presented in Section 2 of the Technical Report.

COMMENT: Will the IPR team fully explain their data selection process?

> <u>IPR Response:</u> Yes. The data selection process is described in the IPR report in Sections 2 and 3.

COMMENT: Will the IPR team collect more environmental surveillance data?

> <u>IPR Response:</u> No. The IPR team did not collect new samples or measurements. This was outside the scope of the IPR. Rather, the focus of the IPR was the review and analysis of existing data, information, studies, and published risk assessment analyses addressing risk to residents of the Santa Fe region resulting from environmental exposure to radionuclide, toxic, and hazardous contaminants known to be of LANL-origin, as well as other sources of these contaminants.

COMMENT: Will the IPR team use data from only LANL sources, or other sources too?

> <u>IPR Response:</u> No. The information sources considered and used were not limited to LANL sources.

COMMENT: What is the IPR team's confidence in the data they deem relevant?

> IPR Response: The IPR considers the data that were used to characterize surface water concentrations as part of the risk assessment to be of sufficient quality for use in the risk assessment and that the data are representative of current levels of the COIs in the Rio Grande near the Buckman diversion intake.

COMMENT: Will the team be using sediment and groundwater samples in addition to surface water samples during the assessment?

> IPR Response: The IPR used sediment and groundwater data in a more qualitative fashion to address future impacts from LANL due to sediment and groundwater transport (Section 6 of the Technical Report). Groundwater data from the existing Buckman wells were used indirectly to help estimate radium-226, radium-228, uranium-234, uranium-235, and uranium-238 concentrations from data collected from the Buckman groundwater mixing tank, which is one of the current sources of drinking water for the area.

Comments Specific to Water Quality Standards

COMMENT: A comment was received that NMED WQC is considering reducing standards for the reach of the Rio Grande, and is supposed to release them in mid-October.

> IPR Response: This is correct; the standards have been finalized and became effective on December 1, 2010. This information is included in the IPR Technical Report.

COMMENT: Can the public access data that illustrates specific concentrations of contaminants?

> IPR Response: Aside from the river water data that are summarized in the Technical Report, the public can access the original data utilized in the IPR assessment from the RACER database via the RACER website: http://racernm.com/. Additionally, public water suppliers are required to publish water treatment reports for public informational purposes; the Buckman Regional Water Treatment Plant will be required to do so as well.

COMMENT: Clarify what the components are in regional background. Please explain the philosophy where contamination from nuclear testing becomes part of the regional "natural" background.

> IPR Response: The IPR has not made the statement noted by the commenter, and specifically, does not purport that anthropogenic (manmade) background is part of natural background. "Regional background" includes both natural and anthropogenic sources of chemicals that are ubiquitous in the environment. In the context of the IPR, regional

background is defined as COI concentrations measured in the Rio Grande upstream of where Los Alamos Canyon discharges.

COMMENT: Are CERCLA standards really met for recreational use of the slough area?

> IPR Response: We were asked to evaluate the human health risks associated with tapwater uses of Rio Grande water that enters the BDD diversion intake and evaluation of recreational exposures from soils and sediments near that the intake facility is not within our scope of work

COMMENT: Why are USEPA standards important in this assessment? What do they regulate?

> IPR Response: Under the United States Safe Drinking Water Act, the USEPA sets and enforces the National Primary Drinking Water Regulations (NPDWRs), which are legally enforceable federal standards that apply to public drinking water systems. These standards are referred to as "Maximum Contaminant Levels" and they are mandatory levels defined as "the highest level of a contaminant that is allowed in drinking water," under the Safe Drinking Water Act. USEPA MCLs are the primary benchmark of comparison for chemicals in drinking water in the health risk assessment process. See the previous comment for additional information.

COMMENT: For Cancer Risk, NMED uses $1x10^{-5}$ as a point of departure. Is there benefit in being consistent?

> IPR Response: NMED's point of departure cancer risk of 1×10^{-5} is for the development of drinking water criteria for a *single* chemical or radionuclide. For the purposes of characterizing the risk from multiple chemicals, the risk range of 1×10^{-6} to 1×10^{-4} is typically used.

Comments Specific to Chemical Risk Assessment

COMMENT: Will the team consider PCBs in the Rio Grande sediments and fish?

> IPR Response: No. The purpose of the IPR was to consider potential human health risks associated with exposure to tapwater that has been derived from Rio Grande surface water collected at the Buckman diversion.

COMMENT: Since arsenic is acknowledged as an issue, because it is the driver for increased cancer risk, what provisions are the BDD taking to reduce arsenic levels?

> IPR Response: It is important to remember that the risk assessment is based on "raw" river water concentrations and not concentrations of treated drinking water provided by the Buckman Regional Water Treatment Plant. The public can obtain specific information on how the river water will be treated from the BDD website.

COMMENT: What are MCLs based on?

> <u>IPR Response</u>: In order to set enforceable MCLs, the EPA first derives Maximum Contaminant Level Goals (MCLGs). MCLGs are based on the protection of human health, and the derivation of each MCLG depends upon the health effect(s) associated with each individual chemical. MCLGs are derived to be protective over a lifetime of drinking tap water, and incorporate uncertainty factors to ensure that there will be no known or expected risk to all persons, including sensitive subpopulations. The MCLGs are then further reduced to account for the potential that people may also have opportunities for exposures to chemicals via other pathways (e.g., food ingestion), MCLs are set as close to the MCLGs as feasible after consideration of a number of factors including treatment technologies and cost. The majority of MCLs are equal to their respective MCLGs. For example, the EPA assumes a default MCLG of 0 for known carcinogens. However, because community water suppliers cannot measure concentrations of "zero," the MCL is set to the minimum level that can be detected ("detection limit,").

COMMENT: The IPR team discusses that personal care products, including endocrine disruptors, and synergistic effects were analyzed, but in bullet summary of conclusions, there is nothing said about those issues.

> <u>IPR Response:</u> The IPR team agrees with the comment. A conclusion bullet will be added to the "Overall Conclusions of the Independent Peer Review" section of the Technical Report to address personal care products, including endocrine disruptors.
>
> The following statements were added:
>
> - "It is unlikely that levels of endocrine disrupting compounds recently measured in the Rio Grande would lead to any health effects for anyone using BDD tap water."
> - "Pharmaceuticals have rarely been detected in the Rio Grande, and the detected levels measured to date are too low to be a health concern."

COMMENT: Synergistic effects were only qualitatively assessed.

> <u>IPR Response:</u> The commenter is correct. A literature review was performed to understand whether the COIs had synergistic effects with one another. Based on this review, it was determined that the COIs have no known synergistic effects with respect to cancer or non-cancer health endpoints. Since no synergistic effects were identified, no quantification of such effects is necessary.

COMMENT: How many years are considered in a lifetime exposure?

> IPR Response: For the purposes of residential risk assessments for carcinogens, a lifetime equates to 70 years of daily exposure.

COMMENT: In the list of conclusions of the IPR, please define what a conservative assessment means.

> IPR Response: The term "conservative" now appears later in the Executive Summary and it is defined as an "overestimate of risk."

COMMENT: In the community summary, the statement "the largest contributors to risk are associated with ingesting tap water from food and drink" is unclear. What does this mean?

> IPR Response: The exposure pathway for both chemicals and radionuclides that contributes the most to the total theoretical risk is ingestion of tap water either through food or drink.
>
> Change to Draft Summary: The IPR team will clarify this statement as follows:
>
> "The IPR team determined that ingestion of untreated and unfiltered water contributes the most to the total theoretical risk. Other exposure pathways (bathing, etc.) do not contribute significantly to the theoretical risk associated with…."

Comments Specific to Radiological Risk Assessment

COMMENT: How are the exposure levels applicable for radionuclides with respect to the large age range of 0 to 4 years old?

> IPR Response: The 0 to 4 year old age group radiological is specifically grouped this way to match risk coefficients that have been developed by USEPA's FGR 13 for this age grouping. The IPR team was specifically tasked with using methodology published in FGR 13 when evaluating risk from exposure to radionuclides.

COMMENT: Synergistic effects of chemicals and radionuclides – is there a catalyst for increased risk?

> IPR Response: Theoretical cancer risk was the common denominator to determine the health impact of exposure to consumers from both chemicals and radionuclides. When assessing mixtures that contain multiple suspected or known carcinogens, the risks for each chemical are summed together to determine the total excess cancer risk. Based on the health risk assessment performed by the IPR team, the combined theoretical cancer risk from exposure to chemicals and radionuclides in unfiltered and untreated surface water was 1 in 10,000, which falls within the USEPA acceptable cancer risk range.

COMMENTS RECEIVED FROM THE BDD BOARD AND LANL DURING INITIAL DRAFT REVIEW PERIOD

General Comments

COMMENT: (regarding the Executive Summary) any summary that is 25 pages long is not a summary and will miss the mark for most people hoping to sit down and understand the risk analysis and conclusions in five minutes or so.

> IPR Response: While the IPR team understands that 25 pages are long for a summary document, we feel that such a length was necessary to summarize the amount of material covered in the 300+ page IPR Technical Report. The Community Summary if more appropriate for a five-minute review. To assist the reader with understanding the main findings of the IPR, the conclusions were moved up in the Executive Summary and a table of contents section will be inserted into the document. With this format, the reader will be able to quickly review the main findings of the analysis and skip to the sections he or she is interested in reading further.

COMMENT: The map of the BDD location appearing on page one of the Community Summary is too small.

> IPR Response: The IPR team agrees with the comment. The size of the map was increased.

COMMENT: Figures and should be labeled.

> IPR Response: The IPR team agrees with this comment. Figure numbers and titles were added to all three reports.

COMMENT: It was suggested that an index be added to the Executive Summary. The conclusions and topics or the IPR analysis are difficult to locate. Headings and sub-headings should have different font and size for easier identification.

> IPR Response: The IPR team agrees with this comment. A table of contents was added to the Executive Summary. Additional subheadings appear within the summary to assist the reader in locating specific sections of particular interest.

COMMENT: Regarding the statement in the Executive summary: “In February, 2008, the U.S. Forest Service and the U.S. Bureau of Land Management approved the BDD as the selected alternative by way of publishing a record of decision (ROD).” The failed appeal upholding the ROD should be mentioned.

> IPR Response: The IPR team was aware that the Forest Service had reviewed all issues raised during the appeals process and had determined that the ROD and FEIS had already sufficiently addressed all issues raised. A more detailed summary of the appeals raised, including the ROD issue, is discussed in the Technical Report.

COMMENT: Conclusions of the IPR Assessment should be noted at the beginning of the Community Summary.

> IPR Response: The IPR team agrees with this comment. The bulleted list of overall conclusions was moved closer towards the beginning of the Community Summary.

COMMENT: In the current draft of the Executive Summary, the human health criteria section appears before the sample analysis section. The human health analysis section should appear before sampling.

> IPR Response: The IPR team is somewhat unclear on the intent of this comment. It is standard risk assessment practice to describe the sample data first because all other sections rely on the sampling data.

COMMENT: The Executive Summary notes that the IPR team was tasked with providing risk communication summaries for a lay audience. Two summaries, one for a technical audience and one for a non-technical audience were to be provided.

> IPR Response: The commenter is correct. The sentence was updated to clarify that two summaries of the Technical Report were produced; one for a technical audience (the Executive Summary) and one for a non-technical audience (the Community Summary).

COMMENT: Please clarify who provided funding for the IPR.

> IPR Response: At the request of Water Quality Town Hall participants in 2008, the BDD sought funding from the U.S. Department of Energy (DOE) for an independent peer reviewer. A $200,000 federal grant from DOE was received by the BDD in the fall of 2009. The grant was used to fund an outside contractor to prepare this assessment.

COMMENT: The Executive Summary states **“**water for the BDD system will be taken from the Rio Grande at a point on the river’s left descending (eastern) bank at a location known as Buckman.” A more accurate description may be to just say eastern descending bank, as left is relative to the direction headed.

> IPR Response: The IPR team agrees with this statement. The use of both the “left descending” and “eastern” directional terms is redundant. The recommended change was made in both the Community Summary and Executive Summary.

Comments Specific to Early Warning System and Filtration System

COMMENT: The BDD water treatment process diagram is a good graphic and should be included in the Community Summary; however, the diagram is not referenced in text of this draft. Please provide context on the importance of this diagram?

> IPR Response: The initial draft Community Summary did not specifically refer to the BDD water treatment process diagram within the text; however, various statements within the text mention that untreated water diverted from the Rio Grande will be put through a water treatment system designed to remove many contaminants from the untreated surface water.

COMMENT: The early notification system as use as an additional protective barrier should be mentioned in the Community Summary

> IPR Response: The IPR team agrees with this statement and we presented text to that effect in the section "Impacts of LANL Stormwater and Groundwater." Specifically, the IPR team mentioned that it is estimated that storm events will discharge contaminated sediments into the Rio Grande such that resulting COI levels in the Rio Grande may exceed normal baseflow levels by several orders of magnitude. During such conditions, the early notification system will allow BDD personnel to cease diversion of water when there is indication of storm flow coming down Los Alamos Canyon.

COMMENT: It is noted in the Executive Summary that "BDD treatment plant is expected to remove a substantial portion of these COI's…." Please further define what is meant by expected.

> IPR Response: In response to this comment, the following text was added: "As described in the independent analysis conducted by Dr. Kerry Howe (2008), once the Rio Grande water enters the BDD intake, it will be directed to a sediment removal facility and pump station, and then to a water treatment facility. At the treatment facility, the water will undergo conventional treatment methods including additional sediment removal and disinfection, and advanced treatment methods to further reduce contaminant levels and to polish off the "finished" water. The finished, or treated, water is then subject to water testing and the levels of specific contaminants must be below drinking water standards in order for it to be considered safe to drink. Accordingly, the COI levels used in this analysis are overestimates of the actual amount of COIs in tap water that would be consumed by Santa Fe residents. As such, the risk evaluation is very conservative."

COMMENT: Please discuss significance of untreated vs. treated water.

> IPR Response: The explanation below will be incorporated into the "Identifying the Constituents of Interest (COIs)" section of the Executive Summary:

> *Use of Untreated River Water Data in the Tap Water Risk Assessment*
>
> Any type of water that is used as a drinking water source requires some type of treatment to reduce the levels of suspended particulates, dissolved materials, and biological contaminants before it can be supplied to the public as tap water. Water that has not been treated is referred to as untreated water, or raw water. It is important to recognize that the levels of chemicals and radionuclides used to evaluate the potential health risks in this assessment correspond to raw, untreated water from the Rio Grande.

Comments Specific to Data Selection

COMMENT: The four COIs presented in the figure entitled "Comparison of average concentrations for select chemicals and radionuclides at the Buckman and Otowi Bridge locations" do not seem like the four Los Alamos Canyon COPCs that best substantiate that there is no impact from LANL. Others may be more representative including those found in contaminated sediments from historical releases.

> IPR Response: The four COIs chosen in Figure 2 of the Executive Summary are four of the six COIs that are within the USEPA acceptable range. The other two COIs are radium-226 and potassium-40, and only radium-226 was detected at the Buckman sampling locations. Radium-226 was added to Figure 1 in the Community Summary.

COMMENT: Was the upriver comparison between samples taken at Otowi and the Buckman locations the only evidence used to arrive at the conclusion that concentrations of uranium-234 are not related to releases from LANL?

> IPR Response: Yes. This was the only evidence used to arrive to this conclusion. To evaluate the impact of LANL-related constituents on the water quality of the Rio Grande near the Buckman Diversion, the IPR team compared the COI concentrations detected near Buckman sampling locations to those from sampling locations further upriver on the Rio Grande or on the Rio Chama. These included sample locations at Otowi Bridge, Espanola, Embudo, and a location at Chamita along the Rio Chama. In general, the majority of COIs detected at the Buckman locations are present at concentrations that were not statistically different than levels measured upriver of LANL at the Otowi Bridge, Espanola, Embudo, and Chamita sampling locations. Based on this assessment, the IPR team attributed uranium-234 to non-LANL sources (e.g., regional background or global fallout). The results from this comparison indicate that, under baseflow conditions, LANL's contribution to uranium-234 in the Rio Grande is negligible.

COMMENT: What does "under normal river flow conditions" mean? Why is this important?

> IPR Response: Normal river flow conditions are defined by the IPR team as conditions in the absence of a storm event. This is an important distinction because it is estimated

that storm events will discharge contaminated sediments into the Rio Grande such that resulting COI levels may exceed normal river flow levels by several orders of magnitude. During such conditions, the early notification system will allow BDD personnel to cease diversion of water when there is indication of storm flow coming down Los Alamos Canyon.

COMMENT: The Community Summary notes that results of the comparison between samples taken at Otowi Bridge and the Buckman locations "indicate that LANL has not contributed to COI levels in the Rio Grande under normal river flow conditions." However, one of the major points made earlier in the summary states "LANL as contributed little, if any, chemicals and radionuclides to the Rio Grande during its normal river flow conditions." It is not clear whether LANL has not contributed chemicals or radionuclides or whether LANL has contributed a negligible amount of radionuclides and chemicals.

IPR Response: We agree these statements are not entirely consistent. We have edited this discussion to clarify any confusion.

Change to Community Summary: Clarify statement "Concentrations of this radionuclide [uranium-234] are not related to releases from LANL…" to "the IPR team determined that LANLs contribution of this radionuclide to the Rio Grande is negligible."

Comments Specific to Radiological Risk Assessment

COMMENT: The graph that compares the total radionuclide risk for each of the three scenarios is confusing. Do the values of the risk for each scenario represent a small risk for all scenarios? The Buckman Well scenario value is much higher than the other two scenarios; does this mean the cancer risk is high?

IPR Response: While the Buckman well water assessment theoretical cancer risk is higher than the untreated and treated surface water assessments, the risk itself is within USEPA acceptable limits. To help put all three assessments in perspective, the IPR team used shading to indicate the USEPA maximally acceptable cancer risk range of 1×10^{-6} to 1×10^{-4} excess risk.

COMMENT: For the pie chart within the Executive and Community Summaries that summarizes the contributions of the different COIs to the total risk, perhaps you should draw line from U-234 to the pie shape?

IPR Response: The IPR team agrees with this comment. The contribution of U-234 was unclear on the draft pie chart. It has been updated accordingly.

Comments Specific to Groundwater

COMMENT: the statement “Groundwater entering the Rio Grande from LANL will not impact the water quality at the BDD diversion intake” should be supported with further text.

> IPR Response: The IPR team agrees with this comment and further text was added to support this conclusion. The following text was added to the Community Summary:
>
> Groundwater entering the Rio Grande from LANL will not impact the water quality at the BDD diversion intake because of:
>
> - generally low contaminant concentrations in groundwater,
> - long distances from contamination plumes from the Rio Grande, and
> - the small volume of contaminated groundwater discharge to the river, as compared to Rio Grande flow.

COMMENTS RECEIVED DURING PUBLIC COMMENT REVIEW PERIOD

General Comments

COMMENT: Why is the public comment period so short? Fifteen days is an unreasonable and extremely short period of time to permit the average member of the public who generally lacks technical expertise to review, analyze, and understand the complex data that has been presented in the Community Summary of the Draft Results and in the Executive Summary of the draft results.

> IPR Response: The IPR schedule is set by the BDD Board. The initial IPR schedule was amended due to the untimely passing of the IPR Principal Investigator.

COMMENT: Regarding the Technical Report, Why has the public not been given at least 60 days to review the information and prepare comments?

> IPR Response: As previously mentioned, the IPR schedule is set by the BDD Board. The initial IPR schedule was amended due to the untimely passing of the IPR Principal Investigator.

COMMENT: Why has the full draft report not been made available for review and public comments? The actual data and calculations used in the quantitative carcinogenic risk assessments and the non-carcinogenic hazard index assessments cannot be reviewed without access to the full draft report. Those members of the public that do have technical expertise have been deprived of any ability to fully understand and comment on the core information and methods that the IPR team used to derive their risk assessment estimates.

> IPR Response: The entire drafts of the Technical Report, Executive Summary, and Community Summary were made available during the public review and comment period. These drafts were made available via the BDD project website (www.BDDproject.org) and various public libraries within Santa Fe, NM.

COMMENT: DOE funding paid for the IPR Report through the Buckman Direct Diversion Project Board and so the report comes to the public with corporate indemnification. Having the DOE paying for the IPR team to compile (not gather) data from the year 2000 forward does not an independent peer review make.

> IPR Response: The BDD Board voted unanimously during their October 4, 2007 meeting to request that DOE and LANL fund and implement a number of actions or specific programs to protect public water supplies. In a November 1, 2007 letter to DOE and LANL environmental officials, the Chair of the BDD Board presented six requests of LANL. One of these requests was to provide funding for the BDD Board to retain independent peer review by qualified persons with regard to matters of LANL-origin

contamination of the public drinking water resources of Santa Fe County and the City of Santa Fe. The subsequent grant received by the BDD was used to fund the IPR.

COMMENT: It was suggested that the Executive Summary be included as the first section to the Final IPR Report

IPR Response: The purpose of the Executive Summary was to be a stand-alone document that provided a summary of the findings presented in the Technical Report.

COMMENT: It was suggested that the IPR team eliminate the first sentence from the Community Summary, "There will be no health risk to people drinking BDD Project tap water." and concentrate on the issue of providing water which is EPA-compliant (on an annualized basis). It was emphasized that there is not enough known about the effects of radionuclides on human health.

IPR Response: This statement is one of the overall conclusions of the IPR and is supported by a multitude of evidence presented within the Technical Report. Levels of untreated and unfiltered chemical and radiological COIs were found to be below all enforceable drinking water standards promulgated by the USEPA. Furthermore, results based on conservative chemical and radiological risk assessment guidance prepared by the USEPA indicate that chronic exposure to untreated and unfiltered surface water at the Buckman diversion location during baseflow conditions are within acceptable risk levels.

COMMENT: This report made gross generalizations with the words like "assumption... cannot be assessed quantitatively....."many times. Please find more funding from the DOE to make sure mistakes are not being made that the BDD board will regret.

IPR Response: The overall findings of the IPR that are presented in the Executive Summary and Community Summary are supported by all assessments presented in the Technical Report.

COMMENT: All medical procedures, medications, and research including dentistry, nuclear medicine epigenetic studies, and nanoparticle health impacts will give specific considerations for the pregnant women. This report did not! So the true risk factors for this population have not been addressed.

IPR Response: Developmental effects (risks to the fetus of a pregnant woman) are considered and accounted for in the EPA health criteria that were utilized in the IPR analysis. Hence, risks to the fetus were part of the risk assessment and the results

> indicated no such risks exist even when drinking unfiltered, untreated water from the Rio Grande.

COMMENT: The report analyzes for morbidity, but not mortality.

> IPR Response: The IPR team evaluated cancer and noncancer health endpoints for consumer exposure to unfiltered an untreated surface water samples collected du ring baseflow conditions at the Buckman diversion location. Carcinogenic risk was evaluated using FGR 13 cancer morbidity risk coefficients for radionuclides and USEPA cancer slope factors, which are based on cancer morbidity, for chemicals.

Comments Specific to Early Warning System and Filtration System

COMMENT: Describe the early notification system. How would it operate? What criteria would be used to trigger a decision to cease water diversion during a storm event? What levels of the parameters being monitored will trigger closure of the water treatment plant? At what level will the water treatment plant be placed back on-line?

> IPR Response: Analysis of the early warning system protocol with respect to diversion was outside the scope of the IPR. As mentioned previously, the IPR's focus was on review and synthesis of existing data, information, studies, and published risk assessment analyses regarding exposure and risk to residents of the Santa Fe region from environmental radionuclide, toxic, and hazardous contaminants known to be of LANL-origin and other origins of these contaminants. The IPR did not assess BDD decision-making protocols related to either diversion of filtration of surface water.

COMMENT: Throughout the IPR report there is little recognition given to the projected efficiency of the BDD WTP at reducing the concentrations of the COIs. The only quantitative credit for treatment throughout the report is for one hypothetical exposure scenario in which a 95 % reduction in the levels of plutonium, americium, uranium and gross alpha-emitting radioactivity is assumed. Based on the 0.1 um pore retention in the membrane filters, the 95 % removal for the radionuclides is probably understated.

> IPR Response: As previously mentioned, the IPR did not quantitatively assess the efficacy of the water treatment plant in terms of reduction of risk posed by the chemical and radiological COIs. The 95% removal scenario for plutonium, americium, uranium and gross alpha-emitting radioactivity was a specific request provided in the request for proposals (RFP) prepared for the IPR.

COMMENT: The Final Report "Effectiveness of the Proposed Santa Fe City/County Water Treatment Plant for Removing Radiological and Other Specific Contaminants" by Kerry Howe does not address arsenic. Although I entirely understand why arsenic was not discussed in this report (i.e., essentially it was not detected and when detected in raw samples was below the MCL), recognizing that arsenic has been identified to represent 65 % of the cumulative risk associated with drinking water from the Rio Grande, perhaps a concise Appendix should be added on the presence and treatability of arsenic.

> IPR Response: The commenter is correct; arsenic is the primary contributor (65%) to the theoretical risk. It is therefore important to remember that arsenic levels in untreated Rio Grande water are below drinking water criteria and are similar to levels measured regionally and throughout the U.S. Arsenic is widely distributed in public water systems throughout the U.S., with typical concentrations ranging from 1 to 5 µg/L; this range is similar to the concentrations measured in untreated Rio Grande surface water. As mentioned, these theoretical risks are based on untreated and unfiltered water samples. The BDD water treatment plant is expected to be effective in removing arsenic; however, quantifying the efficacy of the BDD water treatment plant is outside the scope of the IPR

COMMENT: Should the system simply be designed to close the water treatment plant if there is flow from LACW, and therefore no need to monitor chemistry?

> IPR Response: As mentioned previously, analysis of the early warning system protocol with respect to diversion was outside the scope of the IPR. Therefore, the IPR did not evaluate BDD decision-making protocols related to either diversion of filtration of surface water.

COMMENT: Can a reasonable correlation be established between the pollutant(s) of concern and an indicator parameter (such as conductivity or turbidity)?

> IPR Response: While a relationship may exist between turbidity and some of the particulate bound COIs, this type of evaluation was beyond the scope of what the IPR was requested to do.

COMMENT: Will implementation of an early detection program compromise the maximum capacity of the water treatment plant?

> IPR Response: As previously mentioned, the efficacy of the early warning system is outside the scope of the IPR.

Comments Specific to Data Selection

COMMENT: Can you explain why the concentrations from Otowi Bridge are higher than the concentrations at Buckman (See P. 9, Executive Report)? If there is a natural source at Otowi Bridge is it a point source? The data suggest dilution of the COIs between Otowi Bridge and Buckman. If there is a point source at Otowi Bridge can that source of contamination be controlled?

> IPR Response: Because the main source of concentration data used for the risk assessment is 11 surface water samples collected from the Rio Grande at a LANL sampling location and a NMED sampling location upstream of the Buckman diversion intake, it was not within the scope of the IPR to identify the sources of COIs measured at Otowi Bridge. If COI concentrations at Otowi Bridge were equal to or higher than those at Buckman, this was an indication that, for these COIs; the concentrations at Buckman were the same or lower than regional background. This regional background is either due to natural or anthropogenic sources. For most of the COIs, concentrations at Otowi Bridge were also similar or lower than those for sampling locations further upstream at Embudo and Espanola on the Rio Grande and Chamita on the Rio Chama.

COMMENT: It would appear that risk reductions for a number of constituents of interest (COIs) could be quantified and included within the final report.

> IPR Response: Beyond the assumptions in the report regarding percent removal for some of the radionuclides, the determination of the level of COI reduction due to the water treatment system is beyond the scope of the IPR.

COMMENT: Table 3-5 is in portrait format and truncates data. As such, Table 3-5 does not include the Reasonable Maximum Exposure Point Concentrations.

> IPR Response: We agree with this comment and the orientation of the table was corrected.
>
> Change to Report: The orientation of this table has been restored to landscape.

COMMENT: The Total PCB data does not appear to include all available data from RACER for the time period assessed.

> IPR Response: Based on our review of the RACER data for the PCB homologue concentrations, we have included all of the data available in RACER for the time period from 1/1/2000 to 2/1/2010. These data include eight samples from the LANL sampling location (Buckman Diversion SW) and one from the NMED sampling location (Rio Grande at Buckman). One of the LANL samples (9/22/2009) represents a duplicate sample that was processed per Section 3 of the Technical Report.

> Change to Report: The IPR team has added footnotes to the tables of the Technical Report to emphasize that we used the sum of the PCB homologues as our total PCB measure and updated Table 3-2 which shows the detection frequency including duplicates for total PCBs (1/10) rather than for total PCBs as homologues (2/10).

COMMENT: The IPR team attempts to explain the orders of magnitude difference between samples collected by NMED and LANL on August 8, 2006, and attributes the difference to the location where the samples were collected. All of NMED's six samples were collected by an automated ISCO sampler at a fixed sample port location at one hour intervals starting one hour after flow was initiated. NMED repaired the sample line after it was initially damaged by high flows. LANL collected a single sample at the beginning of flow before their sample line was damaged by high flows. Both LANL and NMED samples were collected from the same location. NMED believes that our data is more representative of the contaminant concentrations during the flow event.

> IPR Response: The IPR appreciates NMED's explanation for the differences in the two sets of samples and we will revise the text to include this explanation.
>
> Change to Report: The text has been revised to include the following:
>
> "NMED collected unfiltered "grab" water samples at the E110 gage using an automated ISCO sampler at a fixed sample port location during a storm event (which began at 2:10 pm) on August 8, 2006, and reported that total plutonium-239/240 concentrations ranged from 270 pCi/L an hour after the storm began (3:30 pm) to 50 pCi/L 5 hours later (at 8:30 pm). NMED estimated that the total plutonium-239/240 concentrations could have approached 400 pCi/L before the first sample was collected. These values are orders of magnitude higher than the plutonium-239/240 concentration of 1.73 pCi/L determined by LANL for the same storm at the same station reported in RACER. Both the LANL and NMED samples were collected from the same location using automatic samplers. This difference is related to the difference in location where the water was sampled. The LANL sample was a grab sample from an automated sampler at a fixed depth while the NMED sample was a manually collected grab sample. According to NMED, the difference is due to the fact that they repaired the sample line after it was initially damaged by high flows, while, LANL collected a single sample at the beginning of flow before their sample line was damaged by high flows. While both LANL and NMED samples were collected from the same location, NMED believes that their data are more representative of the concentrations during the flow event."

COMMENT: "*Two sampling events were identified in this period (from Jan 1, 2004 to present) that resulted in validated analysis of unfiltered samples of 'storm Runoff' at E110"* – There are LANL data from 13 sampling events that cover this period in RACER including (2)–2005, (2)–

2006, (2)–2007, (3)–2008, (1)–2009, and (3)–2010. They are found under two different sample location names (Los Alamos Canyon near Otowi Bridge and Los Alamos above Rio Grande). NMED does not store its E110 data in RACER but it is available upon request from San Ildefonso Pueblo. There is NMED data from 13 sampling events at E110 including (3)–2005, (6)–2006, (1)–2008, (2)–2009, and (1)–2010 available from this same time period. Utilizing this additional data, the IPR team may need to modify the results displayed in Table 6-3. Analytical Detections and Ratio to Plutonium-239/240 at Gage E110.

> IPR Response: While the IPR acknowledges that the data mentioned by NMED are currently part of the RACER database, these data were not available in RACER at the time that we performed our evaluation. At the time the IPR performed the evaluation presented in Section 6 of the technical report, the only storm water samples available from RACER were those from the sampling location then labeled "E110 (Los Alamos Canyon near Otowi Bridge)" and now labeled "Los Alamos Canyon near Otowi Bridge" and for the dates 8/23/2003; 7/9/2006; and 8/8/2006. As we have found over the last six months, data are often added to RACER that are not necessarily from recent sampling activity, but rather are from past sampling events that have recently been added to the database. In addition, the sample location referred to as "Los Alamos above Rio Grande" only includes data collected after 2/1/2010, which is the latest date for which sampling data were included by the IPR.
>
> With respect to the NMED data from the 13 events at E110, as stated by NMED, these data are not readily available to the public. In fact, in order to acquire these data, the IPR would have required written permission from the Governor of New Mexico. We were not aware until receipt of your comment that these data could have been requested. We would have requested the data if we knew there was a procedure for obtaining it. As such, we are unable to include them in our evaluation at this time.

COMMENT: With respect to detectable levels of contamination in the RA near the Rio Grande and upstream of BDD, it should be noted that: 1) RA well R-10a, located in lower Sandia Canyon, contains contamination as indicated by above-background concentrations of chloride, sulfate, nitrate, perchlorate, and uranium; and 2) during the early 1990's, the deep production wells LA-1, LA-1B, and LA-2, located in the lower Los Alamos Canyon, contained elevated concentrations of chloride, sulfate, and chromium, and detectable activities of tritium (see LANL's LA-12973-ENV, LA-13047-ENV, and LA-13201-ENV). The presence of tritium at these wells indicates that some fraction of the RA captured by these wells contain a modern component of recharge, with LANL being a likely source. These wells have not been sampled since 1997.

> IPR Response: The IPR acknowledges the observation of historical and present day contamination in the RA beneath Sandia and Los Alamos Canyons. These issues are discussed in Section 6 of the Technical Report.

COMMENT: Are samples collected as grab samples, time-weighted composites, or flow-composites? Are samples collected manually or by an automatic sampler? For each identified sample location (Otowi, Buckman, etc.) are samples collected at one specific location (for example, mid-stream and mid-depth of the Rio Grande) or are aliquots taken across the channel area and then composited?

> IPR Response: It is the understanding of the IPR team that the surface water samples are grab samples collected either manually or by automatic samplers at the designated sampling location. Whether the sample is collected manually or using an automatic sampler is dependent on location and sampling date.

COMMENT: Recognizing the importance of total suspended solids (TSS) in the water column throughout this study, how were samples collected to ensure that the TSS of the sample is representative of the Rio Grande water column?

> IPR Response: While the IPR team understands the importance of TSS, a detailed evaluation of the sampling and analysis methods of the surface water sampling data collected by LANL and NMED included in the RACER database was beyond the scope of what the IPR team was asked to do. We have accepted that these data were collected in the appropriate manner by both LANL and NMED.

COMMENT: The IPR team should have not relied on data gathered by other entities and should have gathered new data for the risk assessment.

> IPR Response: The collection of additional surface water sampling data was beyond the scope of what the IPR team was asked to do. In addition, given the current volume of data collection along the Rio Grande near the Buckman diversion intake by both LANL and NMED, the collection of additional data was not considered necessary.

COMMENT: How can we be safe while drinking water that may wash over 212 unstable contaminated sites in Los Alamos Canyon with heavy metals and radioactive wastes, such as americium, neptunium, plutonium, cesium, strontium, tritium, selenium, hexavalent chromium, PCBs, and perchlorate?

> IPR Response: The IPR acknowledges the concern of the commenter, but based on our evaluation, the health risk to people drinking BDD Project tap water is not of concern.

COMMENT: Are the samples between various databases collected in a similar manner? Are samples preserved in the field consistently?

> IPR Response: It is the understanding the IPR team that standard methods and procedures were used to collect and analyze the data included in the RACER databases and subsequently used by the IPR. One of the reasons for only including data from 1/1/2000 to 2/1/2010 was to insure that data would be comparable. In all cases, these data have been validated per RACER documentation.

COMMENT: There are at least 31 radionuclides identified from Rio Grande upriver from LANL sampling and 22 downriver from LANL radionuclides in Appendix 3A. Yet the risk analysts only consider 15 radionuclides. Where did 31 radionuclides come from if not from LANL operations? If not from LANL, where did five pages listing dozens of dangerous chemicals, upriver and down river from LANL, come from?

> IPR Response: Based on Appendix 3A, only 10 radionuclides were detected in samples at the Buckman location. The additional five radionuclides were included to be health-protective, but were only detected at the Otowi Bridge sampling location and downstream of the Buckman diversion intake. The sampling locations at Otowi Bridge are upstream of the point where Los Alamos Canyon discharges to the Rio Grande so these locations cannot be impacted by storm water and sediment from Los Alamos Canyon and LANL. In addition, there are other canyons that have surface water and sediment impacted by LANL, but they discharge into the Rio Grande downstream of the Buckman diversion intake and consequently do impact water collected from the Buckman diversion.
>
> With respect to other sources of the radionuclides, many of the radionuclides detected upstream can be naturally occurring daughter products of the various radionuclide decay chains. This is discussed further in Section 3 of the Technical Report.

COMMENT: In the absence of a rigorous QA/QC review, a qualifying statement should be presented in the report that the results provided are from different laboratories, may involve different analytical methodologies, have varying method detection limits and practical quantitation limits (PQLs), etc.

> IPR Response: The IPR agrees that a statement should be added to highlight the fact that the data collected from the two sources, LANL and NMED, as well as data collected and analyzed will have some level of uncertainty associated with it due to the differences in sampling and lab methodologies.
>
> Change to Report: The following text has been added to the report:
>
> “Several different data sets of surface water, storm water, and ground water data were used in the IPR for different purposes such as risk characterization, comparison of

> concentration at Buckman to upriver locations, and evaluation of potential impacts from Los Alamos Canyon. These data sets have been collected and analyzed using various sampling methods, different laboratories, different analytical methodologies, and include varying method detection limits. On the whole, because the data included were collected and analyzed after 1/1/2000 and they came from two primary sources (LANL and NMED), for any given radionuclide or chemical it is expected that the data from these two sources will be comparable to each other and of similar quality."

COMMENT: The IPR team could not determine whether some samples were surface or storm events. The report informs the community that "Because of this uncertainty, these samples were conservatively included in the data set used for this evaluation." What is "conservative?

> IPR Response: The text to which the commenter refers is incorrect and did not get updated after further discussions with RACER staff in early August of 2010. These samples were determined to be storm water samples and were not included in the IPR because they were not representative of typical flow conditions, and were located upstream of Los Alamos Canyon and, thus, any LANL discharge to the Rio Grande.
>
> Change to Report: The text in this section of the report was edited to reflect our current understanding of these samples:
>
> In addition to field QA/QC samples, data entries corresponding to samples collected on two dates from an Otowi Bridge sampling location were identified in the LANL WQDB, but not in the RACER database. These samples were from a location labeled as "Rio Grande at Otowi Bridge" and were collected on 8/25/2003 and 9/6/2003. Further discussion with RACER staff revealed that these samples were included in RACER as storm water samples and were not representative of typical flow conditions. Because of this, these samples were not included in subsequent data sets.

COMMENT: It appears that the IPR Team relied upon 1992 Environmental Protection Agency (EPA) Guidance for Data Usability in Risk Assessment (Part A and B) (References 35 and 36.) Data is a crucial issue as it underlies all the risk analyses. We have not had the time necessary to research whether there is an updated methodology that could be used. We question whether an uncertainty analysis was conducted on the conclusions of the IPR report. The science of uncertainty analysis is relatively new and we are concerned that the 1992 Guidance does not include uncertainty analyses methodologies.

> IPR Response: The 1992 EPA Guidance for Data Useability is the most recent guidance available to evaluate data useability. It has been formalized as part of the Risk

Assessment Guidance for Superfund (RAGS) Part D (U.S EPA, 2001) standard tables and reporting guidance.

COMMENT: It may be appropriate to disregard storm water data collected at the Buckman Landing and the Otowi Bridge locations for characterization of long-term health risk assessment for the reasons listed in the report. However, before such a decision is made, an effort should be made to determine the frequency and duration of these increased flow events and to use such information to analyze whether disregarding storm events is appropriate.

IPR Response: Because estimates of cancer risk are averaged over a 70 year lifetime, we do not think that short term increases in COI concentration will have significant impact on the theoretical cancer risk over a 30 year residential exposure duration. But based on your comment we did a simple screening calculation to determine if this would be an issue. Only one of the Rio Grande at Buckman Landing samples, collected on October 11, 2008, showed an increase in concentration over baseflow conditions for the two of COIs with the highest risk (U-234 and U-238) or showed detections when the COI was not detected at Buckman under baseflow conditions (Pu-239/240 and total PCBs). This is also the only Rio Grande at Buckman Landing sample that was collected when the LACW was discharging to the Rio Grande. In general, the concentrations of the select COIs were between 2 to 20 fold higher than those for the surface water sample collected at Buckman under baseflow conditions twelve days earlier (9/29/2008).

Based on Table 6-4 from the Technical Report, which summarizes data from an NMED report (reference 101), NMED reports that the number of storm events ranged over the time period of 2000 to 2006 from 4 to 17. Assuming a worst-case scenario of 17 storm events during a year and that the 20 fold increase in concentration lasts 8 hours, this would lead to an estimated increase in the annual average surface water concentration by a factor of 1.6 {(8624 hrs/8760 hrs) x 1 + (136 hrs/8760 hrs) x 20}. If a median number of storm events of 10 is used, this would lead to an estimated increase of 1.4 in concentration. Thus the subsequent risk estimates would increase by a factor of 1.4 and at most by a factor of 1.6, neither of which is a significant increase in risk, given the level of uncertainty typically associated with human health risk estimates.

Comments Specific to Water Quality Standards

COMMENT: The IPR team did not use the most protective standards. For instance, the IPR team used the federal EPA standard for total chromium of 100 µg/L (micrograms per liter) instead of the more protective New Mexico standard of 50 µg/L.

> IPR Response: The IPR team used the most applicable standards for drinking water. For the protection of human health via tap water ingestion, NMED enforces all MCLs developed by the EPA, including that of 100 µg/L for total chromium. There is no applicable NMED criterion of 50 µg/L for chromium in this case, however, the commenter may be referring to the NMED groundwater standards (http://www.nmcpr.state.nm.us/nmac/parts/title20/20.006.0002.htm). These are not applicable for treated public drinking water.
>
> For comparison purposes, it is worth noting that NMED has also developed health-based Tap Water Screening Criteria for Cr III (55,000 µg/L) and CrIV (110 µg/L), and that the *maximum total chromium* concentration of 15 ppb is below all of the above-noted criteria. It is also worth noting that while the drinking water criteria were compared to the EPCs, this comparison had no bearing on the risk assessment.

COMMENT: The report does put the proper emphasis on the toxicity of arsenic, for which the MCL is still too high to protect public health.

> IPR Response: The reviewer's opinion is noted.

Comments Specific Chemical Risk Assessment

COMMENT: One Commenter noted "Serious concerns with that portion of the report that deals with potential impacts to human health from pharmaceuticals and personal care products (PPCPs) and endocrine disrupting compounds (EDCs). It is apparent that the IPR team did not fully review the rather large amount of information available concerning both the widespread presence of pharmaceuticals in the United States, but also studies focused on New Mexico and particularly the Río Grande. Furthermore, based both on that limited research and an apparent lack of familiarity or concern with the scientific literature on the potential human health impacts of PPCPs and, especially, EDCs, the IPR team draws an unwarranted conclusion that these compounds pose no human health risk."

> IPR Response: Our conclusions on this matter are reasonable. The commenter's concerns regarding EDCs and PPCPs in the U.S. and in New Mexico are noted. This IPR was specifically focused on concentrations of constituents in the Rio Grande that have the potential to be taken in by the Buckman intake structure. As the IPR reports note, there are no major metropolitan areas in the watershed of the upper Rio Grande, pharmaceuticals have rarely been detected in the Rio Grande and the levels that have been measured to date are too low to be a health concern (see section 3.1.5 of the Technical Report). Additionally, chemicals with known endocrine-disrupting capabilities were included as COIs and evaluated in the risk assessment (see section 3.1.7. of the Technical Report).

COMMENT: The IPR report mentions (Section 3.1.5) only two studies of PPCPs and EDCs. The first one, the now-famous US Geologic Survey (USGS) national reconnaissance (2002), did not conduct sampling in New Mexico, although it did identify the widespread presence of PPCPs and EDCs in association with wastewater discharges and areas with high likelihood of agricultural runoff – the areas of concern that prompted the study. The second study is one done by the New Mexico Environment Department (NMED). Why did the IPR team not review other national studies of the presence of PPCPs in waters across the country?

> <u>IPR Response</u>: Other national studies were not reviewed because the purpose of this IRP was to evaluate data that are relevant for the Rio Grande surface water near the Buckman diversion intake. Therefore, it was most relevant to focused on the results of the NMED study; because the USGS survey is considered to be one of the landmark studies on PPCPs, it was also evaluated as means of providing perspective to the NMED results.

COMMENT: If the COIs increase by several orders of magnitude then the instantaneous cancer risks would be expected to increase by orders of magnitude as well. Knowing that the cumulative cancer risk over a 70-year lifetime would increase depending on the frequency and duration of the increased COIs, by what amount would that cumulative risk increase when COIs increase by several orders of magnitude during each storm event?

> <u>IPR Response:</u> Because estimates of cancer risk are averaged over a 70 year lifetime, short term increases in COI concentrations will not have significant impact on the theoretical cancer risk over a 30 year exposure duration. For example, based on Table 6-4 from the Technical Report, NMED reports that the number of storm events range from four to 17 over the time period of 2000 to 2006. Assuming a worst-case scenario of 17 storm events during a year and that a two order of magnitude increase in concentration lasts 2 hours, this would lead to an increase in the annual average surface water concentration by a factor of 1.38 {(8726 hrs/8760 hrs) x 1 + (34 hrs/8760 hrs) x 100}. If a median number of storm events of 10 is used, this would lead to an estimated increase of 1.23 in concentration. Thus the subsequent risk estimates would increase by a factor of 1.23 and at most by a factor of 1.38, neither of which is corresponds to a significant increase in lifetime risk.

COMMENT: The ChemRisk report makes three statements on the health impacts of PPCPs and EDCs (Section 7.6.7):

- Referring to pharmaceuticals: "… the detected levels measured to date are too low to be a health concern";

- Referring to personal care products: "… not expected to be present in the Rio Grande, and certainly not at levels that warrant a health concern";
- Referring to chemicals that could function as EDCs (such as perchlorate, PCBS, etc): that levels detected didn't exceed "mean" drinking water criteria.

It is hard to know what to make of these statements. There are no standards or criteria for pharmaceuticals or personal care products, either for the aquatic environment or for human health.

> IPR Response: The commenter is correct that human health-based drinking water (which is the focus of the IPR) criteria do not exist for pharmaceuticals or personal care products; therefore they were qualitatively evaluated. In addition to the statements above, the Technical Report also informs the reader that pharmaceuticals have rarely been detected in the Rio Grande and that there are no major metropolitan areas in the watershed of the upper Rio Grande. Because of these collective reasons, the IPR Team concludes that pharmaceuticals and personal care products to not warrant a concern. It is also important to remember that river water will undergo treatment prior to reaching consumers.

COMMENT: What specific analyses were done to determine that no synergism or potentiation would exist among the COIs identified in the quantitative risk assessment? The entire question of the synergistic effects of chemical and radionuclide was only briefly mentioned with no current research. This is inadequate. This community and BDD board deserve better for we are the one that will suffer form inadequate peer review.

> IPR Response: Although relatively little is known about the synergism between chemicals, the IPR team performed a search literature search for the COIs and did not identify any known potentiation effects in humans. It should also be noted that it is equally as likely that a mixture will have the opposite effect, and the potency of a combination of chemicals will be less than one would expect looking only at single components (antagonistic).

COMMENT: Did the risk assessment consider the tumor promoting effects of PCBs?

> IPR Response: Yes, the IPR used the current USEPA cancer slope factor for total PCBs. The estimate of cancer slope factor incorporates information on tumor promotion.

COMMENT: What actual pharmaceuticals have been sought and analyzed in water samples collected below the Otowi Bridge?

> IPR Response: As stated in the Technical Report, the current and historical surface water sampling locations included in the IPR have not routinely analyzed samples for pharmaceuticals.

COMMENT: The IPR states that health effects from endocrine disrupting compounds would be unlikely in anyone using the BDD tap water. What analyses were done to arrive at that conclusion? What was the dataset used to arrive at that conclusion?

> IPR Response: The RACER database was used as the source of data for all constituents in the IPR. Some of the chemical COIS have endocrine disrupting effects (see section 3.1.7). They were included as COIs and evaluated along with the other COIs in the risk assessment.

COMMENT: Were chemical contaminants, e.g., pesticides, herbicides, and feed stock hormones, that derive from non-point source agricultural and ranching runoff considered in the risk assessment?

> IPR Response: Except for feed stock hormones, these chemicals were considered in the risk assessment if they were detected in Rio Grande surface water at the Buckman and Otowi Bridge locations and met the criteria in Section 3 for being selected as COIs. If they were not detected in the Rio Grande at those locations over the last ten years, they were not considered to pose a health risk and were not included in the risk assessment.

COMMENT: On page 22 the Executive summary presented Figure 11 and illustrated the "Average Cancer Risk for untreated Rio Grande Water" of 0.0001 on the graph. Is 0.0001 the average risk or is it the total combined risk? An average risk of 0.0001 suggests that there higher risks that are offset by lower risks above and below the mean value of 0.0001—what COI risks above the mean are contributing to the average risk of 0.0001 that was illustrated on Figure 11?

> IPR Response: The average referred to in this figure refers to the level of exposure not to an averaging of risks across chemicals. This average risk in this context means that the risks for each COI are based on typical exposure parameters (tapwater ingestion rates, exposure frequencies, surface water concentrations, etc.). This overall average risk is the sum of the average risks for each COI.

COMMENT: On page 12 of the Executive Summary, showering was identified as an exposure pathway that was evaluated and on page 17, Figure 7 has a footnote that states the ingestion pathway comprises 99% of the total risk. Was the risk from showering calculated based on ingestion of water during showering or on water vapor inhalation during showering or both?

> IPR Response: Shower exposures and risks were quantified for vapor inhalation (for volatile COIs) or for particulate inhalation via aerosolization of water droplets (for non-

volatiles). Ingestion of water while showering is considered “incidental ingestion” and would result in an insignificant exposure.

COMMENT: In what proportion does chromium exist in the Rio Grande water as Cr+3 and as Cr+6, and were carcinogenic risks calculated for chromium?

> IPR Response: For all metals, *total* dissolved concentrations were analyzed for in the Rio Grande (e.g. total chromium). Therefore, the proportion of the total chromium concentration that is Cr+6 vs. Cr+3 is unknown. Because it is unknown, the risks for total chromium were evaluated using the toxicity criteria for Cr+6, which is more conservative.

COMMENT: What metal species were used in the calculation of risks from carcinogenic metals like arsenic and chromium?

IPR Response: For all metals, total dissolved concentrations were analyzed for in the Rio Grande (e.g. total chromium and total arsenic). While USEPA toxicity criteria exist for both Cr+3 and Cr+6, the toxicity criteria for Cr+6 were utilized as Cr+6 is the more toxic of the two chromium species. USEPA’s carcinogenic toxicity criteria for arsenic are based on human exposures to *total inorganic* arsenic in drinking water.

COMMENT: Was the cancer risk from inhalation of water vapor contaminated with As+3 or Cr+6 calculated in addition to the ingestion pathway risk from those carcinogenic metal species?

> IPR Response: In the showering scenario, carcinogenic risks from inhalation of Cr+6 and total arsenic in aesrosolized water droplets were evaluated. Arsenic was evaluated as an oral carcinogen via the tapwater ingestion pathway, however Cr+6 was not evaluated as an oral carcinogen as it is not recognized as one by NMED.

COMMENT: What species of mercury was considered in the risk calculations for mercury? Does mercury in the Rio Grande exist primarily as inorganic mercury or as organic mercury?

> IPR Response: Toxicity criteria for elemental mercury were used. There were no data on methylmercury for surface water along our stretch of the Rio Grande.

COMMENT: The U.S. Environmental Protection Agency (USEPA) cancer risk range of 1 in 10,000 is not as protective as 1 in 1,000,000. The New Mexico Environment Department has chosen 1 in 100,000 as an acceptable cancer risk range. Citizens in NM do not accept that cancer risk willingly as is evident in recent attempts to push the NMED and the NM Water Quality Control Commission to base its water quality standards on the more protective 1 in 1,000,000 risk range.

IPR Response: Comment noted.

COMMENT: The IPR draft report does not consider the effects of run-off pollution to people weighing less than 150 lbs, female, and still developing. Besides the longstanding legacy pollutants that flow downstream from Los Alamos, endocrine-disrupting chemicals that interfere with the hormonal processes controlling the development of all living organisms are particularly troubling. Please broaden your risk studies to include people weighing less than 150 lbs, babies, children and women, and all life in the ecosystem that supports life in our watersheds below Los Alamos.

IPR Response: The IPR is a tap water-based human health assessment, and therefore potential ecological risks were not evaluated. The risk assessment included a variety of age groupings, per U.S. EPA guidelines. Because this has been a common misconception, the IPR team has inserted Table 5-3 from the Technical Report to clarify the age groups that were evaluated. The commenter may also refer to Section 5.1.3 of the Technical Report for additional descriptions of the age groupings and the exposure parameters used to evaluate them.

Table 5-3: Exposure groupings: Residential age groups evaluated for the chemical and radionuclide risk assessments

General Age Group Classification	Chemical Risk Evaluation (years of age)	Radionuclide Risk Evaluation (years of age)
Infant	<1	0–4
Toddler	1–2	
Child	3–5	
	6–10	5–14
	11–15	
Teen/young adult	16–20	15–24
Adult	21–70	25–70
Lifetime	0–70	0–70*

*The lifetime exposure group represents a lifespan of birth until 70 years of age. The risk coefficients used to evaluate this age group are based on a lifespan of birth to 110 years of age, as is discussed above.

COMMENT: Table 5-20 (Cancer Risk Estimates for Chemicals – Recent Measurements) is not included in the draft report.

IPR Response: This was an omission error; the table has been added.

COMMENT: It was requested that the 2008-2009 President's Cancer Panel Annual Report be included which supports the precautionary principle. Please consider the potential health impact of flawed groupings and assumptions can have on this community's most vulnerable.

> IPR Response: The report to which the commenter refers does not provide risk assessment guidance. The EPA methodology that was used in the IPR is common practice and widely accepted in the regulatory risk assessment community.

COMMENT: The exposure assessment does not address increased exposures for people who work with water all the time, such as hotel, restaurant, medical staff, water physical therapists, car wash attendants, and swimming instructors.

> IPR Response: The focus of the IPR has always been on residential tap water use. This is the exposure scenario of most potential concern with respect to tap water use, and ingestion is the pathway of most concern. Our risk assessment confirms that the ingestion pathway constitutes the majority of residential exposure.
>
> For the adult occupational receptors mentioned in the above comment, the dermal pathway is the primary pathway. The combination of exposure factors for these receptors is not expected to result in unacceptable risks. As compared to a resident, while a worker may contact water for longer daily exposure times, they are potentially exposed for 250 days per year or less (vs. the resident exposure time of 350 days per year). Additionally, their exposed skin surface areas will be limited with respect to the residential bathing and swimming scenarios (swim instructors cannot be fully immersed and still instruct), and more akin to the hand washing scenario.

COMMENT: Was exposure to fetuses at the nanoparticle level assessed? Also, the whole question about nanoparticle health risks is totally lacking form a medical point of reference. It is a medical field of research that is exploding. Why is it missing ? Nanoparticle toxins are known to have different epigenetic effects than micro particles at the DNA/RNA levels and during placental blood exchange. Why is this research not included in this report .We used to believe drinking did not harm the fetus now we know it does. Here we are not questioning a recreational beverage we are needing to know if water-a basic need for life-is safe. If the death of a vital member of the team resulted ineffective research then we need more time for the best possible reteach to be provided. This report does not provide this.

> IPR Response: Particles in the nano-sized range have been around since the beginning of time (e.g. soot from fires). *Engineered* nanoparticles are of more recent public interest. There is a growing body of literature that attempts to evaluate exposure to nanoparticles. The exposure pathway having the highest level of interest is inhalation, followed by dermal, and then ingestion.

> In water, nanoparticles quickly form aggregates and/or bind to other materials (e.g. sediment). Therefore, any nanoparticles that may enter the Rio Grande will quickly become part of larger particles which would be captured in the chemical or radionuclide river water analyses, or be filtered from river water prior to it reaching the tap. Aggregates captured as part of the river water analyses would be evaluated in the risk assessment, and would inherently address fetal exposures based on the methods employed in the risk assessment.
>
> There is no evidence to indicate that nanoparticles are present in the Rio Grande at levels that are any different from any other surface water body. Levels of chemicals and radionuclides in the Rio Grande are consistent with regional background levels and/or are below drinking water standards.

Comments Specific to Radiological Risk Assessment

COMMENT: The draft report does not address increased cancer risk to children and women as noted in the findings of the National Research Council in their 2007 report on biological effects of ionizing radiation.

> IPR Response: For the radiological risk assessment, the IPR team's analysis of potential health risk to the public from ingestion and inhalation of radionuclides in tap water was determined by using USEPA's Federal Guidance Report 13 – Cancer Risk Coefficients for Environmental Exposure to Radionuclides (FGR 13). FGR 13 radiogenic cancer risk models used by FGR 13 are both age- and gender-specific. Therefore, exposure factors were developed by the IPR team for males and females separately, for each age group. This is done in order to coincide with the risk coefficients developed for radionuclides, which account for the variation in the usage differences that may be associated with age and gender, as well as characterize the differences in radiological cancer rates between men and women. Appendices 5C-1 through 5C-2 presents a complete breakdown of age-specific exposure parameters and theoretical cancer risk for males and females.

COMMENT: How much Radon was predicted to be inhaled from Radon released from contaminated water during showering or other daily home water uses that would be inhaled not as water vapor but as actual Radon gas or Radon gas (or its decay products) adsorbed on dust particles in the home?

> IPR Response: Radon exposure was not directly assessed by the IPR team. The radiological COIs for the IPR human health risk assessment considered to be all radionuclides that were positively detected in the relevant areas of the Rio Grande since the year 2000. However, cancer risk coefficients published in FGR 13, which the IPR

team relied upon for the radiological risk assessment, consider ingrowth of chain members inside the body. In terms of Radon (Rn-222), its parent radionuclide, Ra-226 was included in the radiological risk assessment, therefore, ingrowth of Rn-222 inside the body was considered. Regarding radon exposure from dust particles in the home, the IPR team did not quantitatively assess cancer risk for other modes of exposure outside of the tap water pathway.

COMMENT: Radon was not listed in the radionuclide COIs listed on P. 7 of the Executive Report yet Radon is a natural decay product of Radium. Why was Radon excluded as a contaminant of concern?

> IPR Response: The radiological COIs for the IPR human health risk assessment considered to be all radionuclides that were positively detected in the relevant areas of the Rio Grande since the year 2000. Radon isotopes did not fit this criteria.

COMMENT: Because the BDD water purification system does not screen out Tritium, citizens need accurate information on the potential amounts of Tritium in our drinking water.

> IPR Response: Tritium was one of the 15 radionuclides evaluated by the IPR. Based on the available data, levels of tritium in unfiltered and untreated surface water samples at the Buckman diversion location fall below drinking water criteria. Furthermore, NMED is currently revising its "Standards for Interstate and Intrastate Surface Waters" (20.6.4 NMAC) to include new water quality criteria for five radionuclides, one of which is tritium. These five standards apply to the stretch of the Rio Grande between Otowi and Buckman only. They are not tap water criteria; instead they are "applicable to the public water supply use for monitoring and public disclosure purposes only." These standards are not yet final; however, the currently proposed values are much higher than the COI levels in the unfiltered Rio Grande samples for tritium. Information on levels of tritum found in untreated and unfiltered surface water samples can be found in Section 3 of the Technical Report.

COMMENT: BDD promoters are saying that these radioactive wastes and horrible toxins can be filtered out before reaching Santa Feans. This is entirely untrue since the exploding of toxic materials in the open air at LANL (like depleted uranium) can create nanoparticles that are too small to be filtered out.

> IPR Response: As mentioned previously, any evaluation of the efficacy of the water treatment plant is outside the scope of the IPR. In response to this comment, however, it should b noted that unfiltered and untreated surface water samples indicate that chemical and radionuclide levels in the Rio Grande are within acceptable drinking water standards. Moreover, the total theoretical increased cancer risk from all chemical and radionuclide

COIs combined is 1 in 10,000, which is within the USEPA acceptable risk range. Hence, this analysis indicates that consuming unfiltered and untreated Rio Grande water does not pose an unacceptable cancer risk.

COMMENT: It is time for the Review Team and risk analysts to retire their cliché that radionuclides occur naturally in the environment so it is permissible for the public to receive more Strontium-90, Cesium-127 or Radium-226 from weapons operations. There is nothing natural about inhaling or drinking a transuranic radionuclide such a Plutonium-239/240 or Americium-241 as some of the 15 radionuclides presented in the report.

IPR Response: Radionuclide COIs in the Rio Grande have originated from a number of sources. These sources include naturally occurring radioactive material (NORM); human activities conducted at LANL; human activities associated with other urban and industrial areas in the watershed; and above-ground testing of nuclear devices that occurred worldwide between 1945 and 1980. To understand the relative contributions of LANL sources and upriver sources, the IPR team performed statistical tests to evaluate the differences in concentrations measured near Buckman, near Otowi Bridge, and at upriver locations on the Rio Grande and the Rio Chama. While the Otowi Bridge is located up-river from where Los Alamos Canyon enters the Rio Grande, comparisons of data from those locations to upriver locations were performed because sample collection near the Buckman only began in 2000. In every case, for each COI, the concentrations downstream of LANL were no greater than those upstream of LANL.

It is important to note that concentrations of all radionuclides found in untreated and unfiltered surface water samples during baseflow conditions, regardless of their origin, were below drinking water standards. Furthermore, results of the radiological risk assessment indicate that theoretical excess cancer risk from the use of untreated and unfiltered surface water at the Buckman diversion location is within, or well below, the USEPA acceptable cancer risk range of 1 in 1,000,000 to 1 in 10,000 for all radionuclides.

COMMENT: The conclusion that "LANL contributes very little, if any, chemicals and radionuclides to the Rio Grande during normal river flow conditions" is not rational. What would the risk analysts consider to be a lot of radionuclides coming from LANL? Are you comparing LANL to bread bakeries or other nuclear weapons facilities?

IPR Response: As mentioned in the response to the previous comment, radionuclide COIs in the Rio Grande have originated from a number of sources, including LANL. To understand the relative contributions of LANL sources and upriver sources, the IPR team performed statistical tests to evaluate the differences in concentrations measured near Buckman, near Otowi Bridge, and at upriver locations on the Rio Grande and the Rio

Chama. While the Otowi Bridge is located up-river from where Los Alamos Canyon enters the Rio Grande, comparisons of data from those locations to upriver locations were performed because sample collection near the Buckman only began in 2000. In every case, for each COI, the concentrations downstream of LANL were no greater than those upstream of LANL.

COMMENT: Table 5-3 does not include distinct columns for the radiological risk for males and females. Lifetime risk is put forth for a person 110 years old contrary to actuarial tables.

> IPR Response: The purpose of Table 5-3 is to present the residential age groups evaluated for the chemical and radionuclide risk assessments. As mentioned in the Technical Report, exposure factors for the radiological risk assessment were developed for males and females separately, for each age group. This is done in order to coincide with the risk coefficients developed for radionuclides, which account for the variation in usage differences that may be associated with age and gender, and also characterize the differences in radiological cancer rates between men and women. Age groups for both males and females are identical; therefore, it was not necessary to include distinct columns for the radiological risk age groupings for males and females.

COMMENT: The standards for safety are based on an adult man. What about children and pregnant women, people with illness and the elderly? Women and girls have a greater risk of cancer when exposed to toxic substances than an adult man. Likewise, children of both sexes have a greater risk of cancer when exposed to toxic substances than adults. The analyses should be redone with these greater risk levels taken into account.

> IPR Response: The standard to which the commenter is referring to is the Reference Man standard published by the International Commission on Radiological Protection (ICRP) in the 1975 ICRP publication (ICRP Report 23). Reference Man was an anatomical model between 20-30 years of age, weighing 70 kg, is 170 cm in height. The Reference Man standard was not used by the IPR team when evaluating exposures and characterizing cancer and noncancer risk for either chemicals or radionuclides. Specific to radionuclides, the radiological risk assessment involved the quantification of exposures and cancer risk for five age groups using gender-specific exposures factors.

COMMENT: I am concerned about reports I have read in Science Magazine about colloid mediated transport of actinides and soluble species of Plutonium oxide. I am concerned that equipment designed for the BDD will not be able to detect these species of contaminant, or remove them.

> IPR Response: The IPR did not quantitatively assess the efficacy of the water treatment plant in terms of reduction of risk posed by the chemical and radiological COIs. The 95%

removal scenario for plutonium, americium, uranium and gross alpha-emitting radioactivity was a specific request provided in the request for proposals (RFP) prepared for the IPR.

COMMENT: The IPR does not address the increased cancer risk for women and children as described in the Biological Effects of Ionizing Radiation, Report No. 7 (BEIR VII) of the National Research Council.

IPR Response: The Health Risks from Exposure to Low Levels of Ionizing Radiation (BEIR VII; Phase 2) report from the National Research Council was prepared to advise the U.S. governmental agencies on the relationship between exposure to ionizing radiation and human health.

The USEPA radiological risk assessment guidance, including FGR 13, are based on scientific data on radiation-induced cancer in humans, including studies of atomic bomb survivors, and of individuals irradiated medically or occupationally. Regarding the methods used by the IPR team to evaluate cancer risk from exposure to radionuclides, the request for proposals (RFP) specifically requested that the IPR rely upon FGR 13.

USEPA's FGR 13 considers age, gender, and organ differences when we recommend limits on human exposure to radiation. The USEPA has indicated that is now examining whether separate male and female risk coefficients should be published for the general population, given the approximate two-fold difference in risk per unit dose estimated in the BEIR VII report; however, USEPA has noted that it's risk coefficients and regulatory actions are "conservative" in that they sum the risks from an entire lifetime exposure, taking into account age-dependent differences in intake, biokinetics, and sensitivity to radiation.

COMMENT: Is the IPR utilizing a 70 or 110-year lifetime for the radiological risk assessment? It is unclear.

IPR Response: A 70-year lifetime exposure is used for both the chemical and radiological risk assessment. FGR 13 provides cancer risk coefficients for intakes of, or exposures to, radionuclides for five age intervals: 0 – 5, 5 - 15, 15 - 25, 25 - 70, and 0 - 110 years. The four partial coefficients represent the risk over the remaining life per unit usage of the environmental medium by the age cohort. The lifetime (0-110 years) risk coefficient is used to calculate risk or radiogenic cancer from chronic exposure over an individual's entire lifetime. For this analysis, age groups were identified that correlate with both the risk coefficients in FGR 13, as well as the age groups used for chemical risk assessment. Similar to USEPA chemical risk assessment guidance, ICRP-103 recommends the use of a 70-year lifetime for the general public (i.e. residents).

COMMENT: The IPR Team did not cite the definitive National Research Council report: the BEIR VII – the Biological Effects of Ionizing Radiation, Report VII, to support the last sentence.

> IPR Response: As mentioned previously, the IPR team relied upon FGR 13 to evaluate risk regarding exposure to radionuclides. The USEPA radiological risk assessment guidance is based on scientific data on radiation-induced cancer in humans, including studies of atomic bomb survivors, and of individuals irradiated medically or occupationally. USEPA's FGR 13 considers age, gender, and organ differences when we recommend limits on human exposure to radiation. The USEPA has indicated that is now examining whether separate male and female risk coefficients should be published for the general population, given the approximate two-fold difference in risk per unit dose estimated in the BEIR VII report; however, USEPA has noted that it's risk coefficients and regulatory actions are "conservative" in that they sum the risks from an entire lifetime exposure, taking into account age-dependent differences in intake, biokinetics, and sensitivity to radiation.

Comments Specific to Stormwater Sediment Transport

COMMENT: On P. 5 the Executive Summary states that storm events could produce "contaminant discharge from LANL into the Rio Grande" and on P. 26 the Executive Summary stated that the team estimated "the resulting COI levels in the Rio Grande will exceed normal base-flow levels by several orders of magnitude." What does "several" mean?

> IPR Response: Several means "two or more". Because the difference between storm and base flow concentrations varies by COI the reader should refer to the full IPR report for COI-specific comparisons to evaluate the context in which "several" is used.

COMMENT: What are the expected surge concentrations of the COIs during storms? What is the expected frequency and water volume of such storm surges? What does a review and analysis of historical meteorological conditions and storm events predict?

> IPR Response: The available data for "surge concentrations" is extremely limited, therefore the universe of expected concentrations is not well known. Prediction of the timing and volume of storm flow from LANL is complex and beyond the scope if the IPR evaluation. IPR recognizes that predicting storm flow is akin to predicting the weather above a specific area of LANL, and as such recognizes the need for the proposed storm flow warning systems for BDD.

COMMENT: Limited data is available for wet weather events in general, and specifically data is lacking to characterize stormwater from LANL. In the absence of such data, the IPR team attempted to estimate stormwater quality from LANL. The results presented on Table 6-5 are speculative extrapolations that do not appear reasonable or practical. Although I intuitively believe that stormwater from LANL does not pose a health risk to the finished water quality from the BDD WTP, the data presented in the IPR Report does not support this conclusion. Additional stormwater sampling and flow-monitoring should be instituted so that actual data results are available and the relative contribution of pollution from LANL can be ascertained.

> <u>IPR Response:</u> The data contained in Tables 6-2 and 6-3 were used to derive the calculations found in Table 6-5; the analysis conducted was not conducted in the absence of data as implied by the commenter. IPR does recognize that the available data is limited. LANL and NMED have both indicated that they believe that their samples and analysis from the same storm event are indeed representative of storm conditions, even though contaminant concentrations differ by three orders of magnitude for Pu $^{239/240}$. IPR cannot resolve that discrepancy in interpretation by LANL and NMED . Part of the stormflow COI concentration *data* used by IPR are LANL measured concentrations that have passed extensive data validation within each respective agency. During one of these storm events NMED collected and analyzed grab samples for Pu$^{239/240}$ concentrations. The NMED concentration was over 100 times more than the LANL concentrations, *for the same storm event*. The existence of this data is not disputable. IPR did not estimate values in absence of data; it used all available data to make an estimate. The analysis relies on one assumption; that Pu$^{239/240}$ sample concentrations can be used to estimate concentrations of other COIs, from the same sample location and storm event. While the commenter may disagree on the basis of intuition, the point of disagreement does not invalidate the data. IPR recognizes that there is limited LANL stormflow data available and believe that additional storm flow monitoring is essential to reducing uncertainty. IPR also believes that data-based analysis is generally superior to intuition.

COMMENT: How are wet-weather samples collected? Do they represent first-flush conditions, are they flow-composited or are they grab samples?

> <u>IPR Response:</u> The preliminary draft IPR analysis relied on the assumption that LANL E110 samples were flow-proportional composite samples and NMED were grab samples. Information obtained since the publication of the preliminary draft indicates that both the LANL and NMED samples are grab samples. The text in the IPR report has been changed to reflect this new information. LANL and NMED consider that the values that they obtained from sampling the same storm are valid. As such, the IPR report now presents the data as a potential range of COI concentrations.

COMMENT: The analysis then assumes that the pollutants in each stormwater sample should be in the same relative ratio. This is a poor assumption for stormwater samples. Stormwater quality in general is characterized as highly variable dependent on the volume and intensity of a storm event, the velocity of the runoff, the sediment transport, etc. The relative % difference calculation on Table 6-3 (which should include calculations for parameters if a sample was not detected) confirms the variability between samples.

> IPR Response: The IPR analysis presents validated LANL grab-sample storm flow data obtained from RACER for two storms sampled at the E110 gauge in 2006 and compares them against validated samples from NMED for one of the storms . All of the available stormflow data is used. The available data indicate what the observed COI ratios, and their variance over two storms are. There is no speculation involved. The two storm event COI ratios to $Pu^{239/240}$ are calculated providing a COI ratio normalized to $Pu^{239/240}$. No more evaluation of variability from storm to storm is possible with the available data. The normalized ratios are averaged to provide a single ratio for calculation for each COI abundance as compared to $Pu^{239/240}$. The IPR clearly states that the available data limits the applicability of the analysis to an estimate.
>
> The IPR team recognizes that more data would provide a better analysis but endeavored to conduct a reasonable analysis using the available data. In order to accomplish the task set out for IPR the requirements for an ideal analysis was not used to suppress what is possible to do with the available data. IPR affirms that its methodology is reasonable given a limited data set and that it is more beneficial to the public to perform the calculation that is possible, rather than stating that no conclusions can be reached because the data set is not ideal.

COMMENT: The concentrations projected in Table 6-5 are not reasonable or practical. Such elevated concentrations would pose a serious concern. While intuitively I do not believe that the stormwater discharges from LANL pose a health risk, the data in Table 6-5 does not support such a conclusion.

> IPR Response: The concentrations projected in Table 6-5 are reasonable calculations to make based on practical considerations of data availability and quality. The data passed a rigorous data review process that includes NMED oversight, and independent NMED and LANL sampling. NMED and LANL have expressed serious concern regarding the implications of the available storm water sampling, and LANL is currently engaged in expensive sediment transport mitigation efforts because of those same serious concerns. Those decisions were based on data, rather than intuition.

COMMENT: A rigorous stormwater sampling and flow-monitoring program at E110 should be instituted so that actual data results are available and the relative contribution of pollution in stormwater from LANL can be ascertained.

> IPR Response: The IPR team agrees that additional sampling and analysis will reduce uncertainty. LANL has replaced the E110 flow structure with an improved design (E109.9) and is implementing a monitoring program.

COMMENT: Do actual stormwater samples confirm that an early detection system is warranted?

> IPR Response: It is the opinion of IPR team that the available data (actual storm water samples) confirm that an early detection system is warranted.

COMMENT: Are the data results from the October 13, 2010 stormwater sampling event available (p. 6-67 of the IPR Report)?

> IPR Response: The IPR team has not seen the results of the October 13, 2009 sampling. This comment should be addressed to NMED for data availability.

COMMENT: Is there an explanation for such elevated aluminum concentrations in all three of the stormwater samples from LANL as presented in Table 6-2?

> IPR Response: When samples containing suspended solids are acidified prior to analysis the acid will dissolve suspended solids (minerals) to some degree. This is the probable source of high aluminum and is supported by observed high iron and silica concentrations that would be derived from a similar mechanism.

COMMENT: There is plenty of evidence that the current processing used on Buckman aquifer water results in some rather high levels of uranium (as high as 29 µg/L) in City water. I would like to see 3rd-party lab testing of raw and treated water once the system is operational.

> IPR Response: This question, while worthy of detailed consideration, is outside the scope of responsibility of the IPR team. This comment is more aptly directed to BDD and NMED.

COMMENT: The IPR is incomplete because it does not address the situation of most concern – when flash floods and snow melt flow over the 212 dump sites in Los Alamos Canyon, picking up and transporting contaminated sediments that flow into the Rio Grande and down the river to the Buckman Direct Diversion Project Site, Cochiti Dam, and the Albuquerque Diversion Site, and places in between, on its way to the Gulf of Mexico.

> IPR Response: The IPR is complete within its scope. The issue of most concern to the study is the concentrations at the BDD, not the concentrations at any point downstream of

that location. The IPR used the available data for LACW discharge into the Rio Grande, above BDD. An analysis of previous publications regarding the commenter's concerns of long distance transport(Graf, 1994) is included in the IPR report.

COMMENT: Stormwater from LANL does pose a health threat. Please remember, ChemRisk only assessed "normal river flow conditions" and not when Los Alamos and Pueblo canyon system are flowing to the Rio Grande carrying contamination from the Manhattan Project and LANL operations in the decades since.

> <u>IPR Response:</u> IPR agrees that ingestion of storm water from LANL would pose an unacceptable risk.

COMMENT: The BDD Report fails to consider the effect of re-suspension of contaminants from the Rio Grande river bed and banks during storm events since the samples were taken at the outfalls.

> <u>IPR Response:</u> The commenter is incorrect. River bed concentrations of COIs are far less than storm flow concentrations. Rio Grande bed load sediments do not present a significant risk factor. Bank erosion COI risk is limited to the "slough" (Graf, 1994). As stated in the report, bank erosion significant enough to erode the slough sediment would only occur during a catastrophic flood that would also result in shut-down of the BDD intake.

COMMENT: What were the sampling procedures for obtaining representative sediment samples?

> <u>IPR Response:</u> The IPR team is unsure if the commenter is referring to suspended, in place, or bed load samples. Evaluation of sampling procedures is beyond the scope of the IPR review. COI data contained in RACER for sediments has passed data validation and review procedures and policies.

COMMENT: The IPR team assumes the two samples collected from the LACW (location E110) are flow weighted composite samples. Has this been confirmed?

> <u>IPR Response:</u> The inference that these are flow weighted composites was derived from sample flags in RACER and inference from a LANL reference document. <u>Subsequent communication with LANL has determined that the referenced samples are grab samples</u>. The outcome of this new information is that both the LANL and NMED samples are known to be grab samples. This raises the uncertainty level of the analysis presented in the Preliminary Draft IPR report. The increased uncertainty is due to the fact that grab

samples from the same storm event exhibit $Pu^{239/240}$ values that differ by three orders of magnitude. The text in the IPR report has been modified to reflect this uncertainty.

COMMENT: The data presented on Table 6-5 is based on extrapolating concentrations from Table 6-3 and normalizing the data based on a NMED sample that had a plutonium concentration of 192 pCi/l. There is not a supportable rationale for making this extrapolation.

> <u>IPR Response:</u> The commenter provides no information as to why the approach taken by IPR is not supportable. IPR is willing to consider and evaluate alternative quantitative methods of how to predict in-stream concentrations of all sediment bound COIs using the only available data, if a stakeholder chooses to conduct that alternative analysis. All the samples used in the analysis have been identified as grab samples, and that NMED and LANL have both expressed that they believe their samples to be representative of the concentrations of COI's found in LACW storm flow. This means that the values and ratios presented in Section 6 of the IPR report represent ranges of contamination; ranges determined from the only data available. Based on the new information that all samples from E110 used in the IPR analysis are grab samples, the text in the IPR report has been modified to indicate that the values expressed are representative of a range of possible values.

COMMENT: NMED has found a significant positive correlation of suspended sediment concentration (SSC) to gross alpha activity in the Rio Grande indicating that SSC and gross alpha activity will increase or decrease proportionally (NMED 2010). Suspended sediment concentration and subsequently gross alpha will increase significantly during storm flows, including those not directly influenced by LANL discharges. The BDD should consider implementing real-time monitoring of turbidity as a surrogate for suspended sediment concentration and using that data to determine when to cease diverting from the Rio Grande under highly turbid conditions. High turbidity may affect the treatment plant performance and ceasing intake under these conditions could prevent the intake of elevated gross alpha levels into the treatment system.

> <u>IPR Response:</u> This comment is not germane to the IPR team review or publications; this comment is suggesting operational policy to the BDD Board. The IPR team has no opinion regarding the mechanics, technologies, and policy by which the BDD will operate its water diversion and treatment facility.

COMMENT: Surface Water Contaminants and Concentrations Page 6-66 – The limit of detection (5.4×10^{-10} pCi/L) may be a typo. A more realistic value is 3×10^{-2} pCi/L or 3×10^{-3} pCi/L.

> IPR Response: The typo has been corrected.

COMMENT: Surface Water Contaminants and Concentrations Page 6-67 – The date referred to in the first sentence is incorrect. The correct date of the samples that were collected is October 13, 2009.

> IPR Response: IPR will change the text to reflect a sampling date of October 13, 2009 rather than the October 13, 2010 date contained in the text. The mistake was typographical.

COMMENT: "However, it must also be noted that unfiltered samples from the Rio Grande during storm events are lacking." – DOE Oversight data from multiple storm events collected in 2009 from the Rio Grande are available in NMED 2010. DOE Oversight Bureau data from four storm events in 2008 collected at Buckman Landing is also available in the RACER database. All of these samples were collected due to regional storm events, and are not due to discharges from lower Los Alamos Canyon.

> IPR Response: The sentence in the report is referring to data collected in the Rio Grande during discharges from LACW. The data provide information on expected background concentrations of a limited suite of contaminants.

COMMENT: Figure 6-3 depicts water table contours in the RA, but does not include flow directions. Such a depiction could be misleading as flow directions do not necessary follow hydraulic gradient due to media anisotropy. Flow directions should not be inferred from water table maps without taking into the account potential deviations due to anisotropy of aquifer formations.

> IPR Response: The IPR team did not annotate LANL figures with flow directions because it is unnecessary to support the risk assessment. As a first principal, use of hydraulic gradient to evaluate principal direction of groundwater flow is completely supportable, LANL water does indeed flow down gradient towards the Rio Grande. When considering hundreds of feet of change in hydraulic head over miles of distance the general trends observed from water table maps are again supportable. It is recognized that aquifer anisotropy can result in flow-path deviation from lines projected normal to head isopleths. It is completely appropriate over the distances involved to use water table maps to suggest approximate flow directions. To accommodate NMED's comment there would need to be data on the measured anisotropy in three-dimensions, and measured contaminant concentrations in those locations – data that NMED knows does not exist. As such, a comment to consider data that does not exist is moot. The methodology used by IPR is conservative; consideration of anisotropy will serve to

reduce concentrations, reducing conservatism. In the context of a conservative risk assessment the NMED comment is moot, as it *decreases* apparent risk.

Groundwater under LANL flows east to the Rio Grande. The IPR team does not believe that consideration of aquifer anisotropy alters the conclusion of easterly flow reached by the IPR team at the flow-scale under consideration. The IPR team does not believe that NMED is suggesting that aquifer anisotropy alters the conclusion of flow from LANL to the Rio Grande, but will be willing to evaluate quantitative studies by NMED or others that suggest alternate hypotheses and actual flow paths, when such studies become available. Until that time, we will rely on water table maps projected through areas devoid of wells or other data collection activities that measure the effects of aquifer anisotropy; there is no alternative available to the IPR team.

COMMENT: The IPR reviewed water table maps for LANL that were created in 2008. The newer, LANL wide water table map in the 2009 Hydrogeologic Site Atlas, which differs from the maps analyzed in the IPR, should also be considered.

IPR Response: All water table maps published by LANL as listed in the bibliography were considered. This includes the 2009 Hydrological Site Atlas. All maps indicate easterly groundwater flow. NMED presents conflicting comments; either water table maps are useful and a reasonable model for groundwater flow over miles of distance at LANL, or they are not. It is the opinion of the IPR team that the use of water table maps to evaluate the *general* direction of groundwater flow at LANL is perfectly appropriate in the context of the IPR tasks.

COMMENT: Contamination in the RA migrates to the Rio Grande as indicated by the presence of contamination at the RA White Rock Canyon springs 3, 3A, 4, 4A, 4AA, 4B and 4C. NMED notes that these springs discharge downstream of the Rio Grande reach that potentially would contribute contamination to BDD.

IPR Response: The IPR team recognizes that the White Rock spring contamination discharges to the Rio Grande. RA contamination does discharge to the Rio Grande. Like NMED, IPR recognizes that White Rock spring contamination has no bearing on discussion of impacts to BDD.

COMMENT: The term off gradient, as used in the IPR, is vague, and should be replaced with terms that take into account locations relative to an original contaminant source, drip point, or delineated contaminant plume.

> IPR Response: The IPR team believes there is adequate discussion of the operationally defined term "off-gradient" in the main report to ensure that the reader understands its context and use. The intended purpose of the discussion is to point out to the reader that there is a very limited number of monitoring points between known contamination, and the germane reach of the Rio Grande. For this purpose, the term meets the intended need. It is beyond the scope of the IPR task to engage in well-by-well discussion, and the need to do so has been eliminated by the conservative approach taken by IPR. If NMED has *specific text* that they believe will reduce the perceived vagueness, IPR will consider its substitution.

COMMENT: How was it arrived at that the hydrologic connection between the west side of the Rio Grande and the Buckman well field is broken?

> IPR Response: The conclusion is based on several studies by LANL that use scientifically accepted methods to evaluate the hydrologic connection between the Buckman well field and near and far portions of the Regional Aquifer. IPR has reviewed the results of those studies and finds the studies to be reasonable and the conclusion reached regarding a lack of hydraulic connection to be well founded. Specifically, we refer to the LANL document LA-UR-10-1239. The conclusions reached in that document were reached by multiple lines of evidence including pumping tests, current and historical water levels, geophysics, geology, and geochemistry.

COMMENT: What has changed from 2005 when there was a connection published by LANL? It was previously stated that 40% of recharge for Buckman is from Pajarito Plateau.

> IPR Response: There have been additional studies conducted that provide new information on the hydrogeology of the subject area.

COMMENT: The report contradicts the reality that storm water flows have increased in the Los Alamos/Pueblo Canyon system since the Cerro Grande fire. The report states:

"One effect of the Cerro Grande fire was to increase the frequency, duration, and magnitude of streamflow in response to precipitation (due to decreased vegetation), an effect that has diminished since the fire but still persists a decade later."

The presentation "Increasing Storm Water Flows Through Pueblo Canyon Since the Cerro Grande Fire," Prepared by David Englert of the New Mexico Environment Department, Department of Energy Oversight Bureau, May 22, 2008 clearly demonstrates the increased frequency and magnitude of peak flows at the E060 gage station in Los Alamos Canyon at the "Y" at the intersection of State Roads 502 and 4 since the Cerro Grande fire. It states: "During the early years of Laboratory operation, in the 40's, 50's, and 60's, intermittent gages and modeled events indicate there were common flood events, but not to the degree seen after the

Cerro Grande fire." Id. Further, at the September meeting of the BDD Board, Steve Veenis, LANS Project Manager, Los Alamos/Pueblo Canyons, presented information about three heavy rain/flash flood events on August 15, 16, and 23, 2010. The August 15 and 23 flash flood storms were measured at the E109.9 gage station, closest to the Rio Grande in Los Alamos and Pueblo Canyon system. On August 15, 2010, a greater than 200 Year/1 Hour storm event occurred around Totavi at the bottom of Los Alamos/Pueblo Canyon. The estimated peak flow was 750 cubic feet per second (cfs) at the E109.9 gage station.

On August 23, 2010 – less than 10 days from the 200-year/1 hour storm event - a 100 Year/1 Hour flash flood event occurred in the same area. On August 23 the estimated peak flow was 780 cfs at the E109.9 gage station. The final draft report should take these two examples into account in the analyses of contaminant transport in the Los Alamos/Pueblo Canyon system.

> <u>IPR Response:</u> The IPR report accurately states the known conditions; the effects have diminished with time, but still persist. Quoting from the NMED document by Englert cited by the commenter: "We had expected the frequent and intense floods after the Cerro Grande fire, but had also expected the frequency and magnitude to diminish **more quickly**." Emphasis added by the IPR team. We consider the differences between the IPR description of post-Cerro Grande stormflow and the NMED description to be in wording but not intent. In fact, as the graphic below from the 2009 LANL ESR indicates, storm flow from LANL has decreased to pre-Cerro Grande levels for calendar years 2007, 2008, and 2009. IPR has again erred on the conservative side indicating that effects have "diminished " when the available data may well indicate that Cerro Grande fire impacts have *disappeared*.

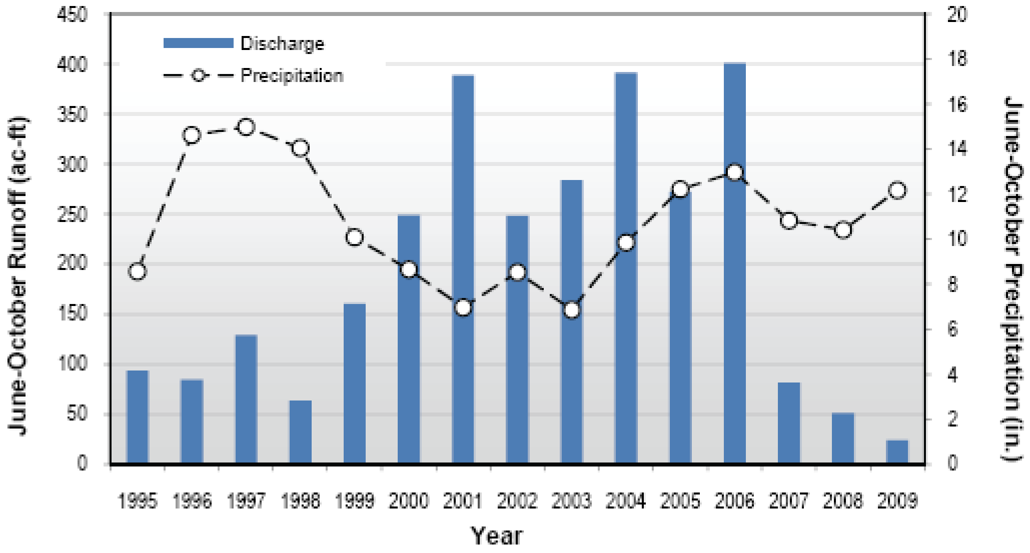


Figure 6-2. **Estimated storm water runoff in LANL canyons (Pueblo Canyon to Ancho Canyon) and precipitation at TA-6 during the months of June through October from 1995 through 2009.**

COMMENT: the Community Summary states that stormwater discharge from LANL does not pose a health risk. The EPA has identified 40 high priority dumpsites in the Los Alamos and Pueblo Canyon system as requiring cleanup in the next three years. For example, PCBs at 37,000 times the New Mexico human health standard were found in stormwater flowing over the dump.

Stormwater from LANL does pose a human health threat. Only "normal river flow conditions" were assessed by the IPR team. It did not address when the Los Alamos and Pueblo Canyon system is flowing to the Rio Grande carrying contamination from the 67-years of LANL operations involving radioactive, toxic and hazardous materials. Further, Los Alamos County does not have a stormwater management plan, so when it rains or snow melts, the large volumes of runoff water could be discharged through pipes directly into the canyons – thereby mobilizing LANL contaminants to the Rio Grande. The unmitigated discharge of stormwater into the canyons provides the power to transport contaminated sediments to the Rio Grande and the BDD Project site. The IPR Team must look at this scenario as well in the final draft report.

> <u>IPR Response:</u> Stormwater impacts to BDD are conveyed through the Rio Grande, at Los Alamos Canyon. The resultant range of COI concentrations as reported by NMED and LANL are presented in the IPR report in Section 6.

COMMENT: regarding the statement, "Contaminated RA [Regional Aquifer] groundwater is found under the LACW [Los Alamos Canyon watershed], as well as under Sandia Canyon and Mortandad Canyon. As described earlier, there are potential groundwater pathways that can convey contaminated water to the BDD reach of the Rio Grande and/or the capture zone of the Buckman well field**"**

LANL is to complete construction of the "Buckman Sentinel" well in the RA [Regional Aquifer] by the end of September 2010. (Reference 168) The planned location of the well was unknown to the IPR at the time of this report. This well will be located in a manner to serve as an early warning for RA contamination migrating to the Buckman Wells; by necessity between contamination and the Rio Grande above BDD. The degree that this well will reduce the existing uncertainties regarding groundwater contaminant transport to the Rio Grande above BDD is unknown. p. 6-62. One sentinel well is a token gesture by DOE and LANL to protect the Buckman Diversion Project and the Buckman Wellfield. More than one sentinel well is needed

Further, DOE/LANL said they were going to install the so-called "Sentinel Monitoring Well for the Buckman" back in 2006. They also told the National Research Council the same thing in 2006. Four or more years have passed with no data about groundwater contamination migrating from LANL waste sites to the Rio Grande and the Buckman Wellfield and Diversion Project at key "sentinel" locations.

> IPR Response: IPR has indicated that the current LANL RA groundwater monitoring network will not detect contamination between the LANL boundary and the BDD reach of the Rio Grande.

COMMENT: Regarding the statement in the Community Summary: "Groundwater entering the Rio Grande from LANL will not impact the water quality at the BDD diversion intake because:

- contaminant concentrations in the groundwater are low"

The above statement is in contradiction with the large amount of groundwater contamination in the regional aquifer as described in the discussion section of the draft Technical Report. In fact, contaminant concentrations in the groundwater are high because large regions of the regional aquifer are contaminated with chromium at concentrations far above the EPA Maximum Contaminant Level (MCL) of 100 ug/L and the New Mexico Drinking Water Standard (DWS) of 50 ug/L. The highest known contamination is at LANL well R-42 at 1000 ug/L – ten times the EPA MCL and 20 times the NMED DWS.

DOE/LANL only reacts to discovery/happenstance of contamination. They are not actively characterizing the nature and extent of the groundwater plumes. The chromium plume was accidentally discovered in January 2004. Almost seven years later, we still do not know the "nature and extent" of the plume as required by statute and regulations.

> IPR Response: While the contamination noted by the commenter exceeds regulatory criteria it is still "low" from the perspective of the concentration of LANL groundwater-sourced contamination that it could cause in the Rio Grande.

COMMENT: The statement in the Community Summary "Groundwater entering the Rio Grande from LANL will not impact the water quality at the BDD diversion intake because:

- There are long distances from the LANL contamination plumes to the Rio Grande"

contradicts text in the Technical Report.

> IPR Response: The IPR team does not believe there is a contradiction.

COMMENT: Regarding the statement in the community summary "groundwater entering the Rio Grande from LANL will not impact the water quality at the BDD diversion intake because

- the volume of contaminated groundwater discharged to the river is very small, as compared to Rio Grande flow.

There is no basis for the above conclusion because the above statements from the Draft IPR Report show there is much uncertainty in:

1. The dimensions of the groundwater plumes flowing to the Rio Grande,

2. The nature and extent of contamination in the plumes, and
3. The distance of the plumes from the Rio Grande.

Another important issue is that LANL and NMED do not have a concern for the presence of large plumes of contaminated groundwater in the regional aquifer over very large regions below LANL. The concern for groundwater contamination in the large LANL watersheds and even at the large LANL waste sites, including Material Disposal Area G, is only to detect the large plumes of contaminated groundwater before the plumes reach the LANL Facility boundary or the nearest public drinking water well.

> IPR Response: There is uncertainty in the factors mentioned by the commenter. The IPR does not believe that these uncertainties overcome or outweigh the minimum 100-1000 fold dilution that occurs when groundwater discharges to the Rio Grande.

COMMENT: The statement made in Section 7 of the Technical Report "there are no contributions from LANL groundwater to the Buckman well field" is contradicted by many statements made throughout the report.

IPR Response: There are no known contaminant contributions from LANL to the Buckman well field. IPR agrees that the statement is overly simplistic and has modified the text accordingly.

Comments Specific to Groundwater

COMMENT: How did the regional aquifer groundwater under Los Alamos Canyon get contaminated?

> IPR Response: The regional aquifer under LANL has been contaminated by a combination of naturally occurring COI's, planned and accidental releases associated with the nature of the DOE mission, and planned and accidental releases associated with municipalities and individuals.

COMMENT: What will be done to monitor migration of the regional aquifer contaminated groundwater plume to determine if groundwater pathways are contaminating the Rio Grande at the BDD site?

> IPR Response: This question, while worthy of detailed consideration, is outside the scope of responsibility of the IPR team. This comment is more aptly directed to NMED, DOE, and LANL.

COMMENT: If contaminated groundwater does migrate to the Rio Grande BDD site how will that affect the risk calculations?

> IPR Response: We have assumed that the *known* most contaminated water under LANL migrates along probable flow paths directly to the Rio Grande and discharges to the Rio Grande at the concentrations detected large distances from the Rio Grande. The assumption is that the highest levels of contamination *do* migrate to the Rio Grande. The risk calculations have used a very conservative assumption that the contaminant concentrations do not decrease during travel to the Rio Grande. The risk calculations are made assuming that contamination *is* discharging to the Rio Grande.

COMMENT: Did the models consider a groundwater point source contamination slightly above or at the BDD site?

> IPR Response: No, the models did not.

COMMENT: A conclusion of the Community report is that: "There are no contributions from LANL's groundwater to the Buckman well field." However, the conclusion is half-baked and lacks real data. The report describes the contaminated groundwater under LANL and then states that the monitoring wells for the regional aquifer are "scarce and/or off gradient … with most located a large distance from the Rio Grande."

> IPR Response: The conclusion is based on several studies by LANL that use scientifically accepted methods to evaluate the hydrologic connection between the Buckman well field and near and far portions of the Regional Aquifer. IPR has reviewed the results of those studies and finds the studies to be reasonable and the conclusion reached regarding a lack of hydraulic connection to be well founded. Specifically, we refer to the LANL document LA-UR-10-1239. The conclusions reached in that document were reached by multiple lines of evidence including pumping tests, current and historical water levels, geophysics, geology, and geochemistry. It is important to recognize that without a hydraulic connection, that the contaminant flow path to the Buckman wells is broken. Within a reasonable degree of scientific certainty, the connection between contaminated LANL groundwater and the Buckman well field is indeed broken. IPR is willing to evaluate quantitative refutation of the LANL findings if said refutation is science and observation based.

COMMENT: The Review Team makes assumptions based on Regional Aquifer (RA) groundwater monitoring wells that have no technical basis for any conclusion because the RA monitoring wells are well known to be defective for monitoring (6-77): "…we assume that contaminants are reaching the Rio Grande at the highest concentrations greater than screening levels detected in the RA wells closest to the Rio Grande under Los Alamos watershed, or along groundwater flow paths from Sandia Canyon and Mortandad Canyon to the Rio Grande."

> IPR Response: We maintain that the IPR analysis is exceedingly conservative in that it will always err on over prediction of groundwater contaminant concentrations that could discharge to the Rio Grande. The IPR had two choices: to use the available data or to not use the available data. Not using the available data means that no analysis of risk is possible for a groundwater contribution to the Rio Grande. We defend the technical basis by which we reached our conclusions.

COMMENT: Contamination could be substantially greater from the Regional Aquifer because LANL's groundwater monitoring wells are defective. The review failed to consider the four EPA Kerr Laboratory reports from 2005 to 2010 regarding RA groundwater monitoring at LANL. The use of bentonite clay and organic drilling fluids has contaminated well screens so that knowledge of contamination is masked by the LANL groundwater monitoring wells. The review has failed to consider statements by the National Research Council, Dr. Michael Barcelona and Registered Geologist Robert Gilkeson for the defective groundwater monitoring well and network at LANL.

> IPR Response: The comment is incorrect. All of the EPA, NRC, Barcelona and Gilkeson reporting on the reasonableness of LANL monitoring has been considered and IPR agrees with their conclusions in principle. By using the highest reported concentrations we have taken a highly conservative approach. None of the reports cited by the commenter speculate or calculate what concentrations could be if the effects of drilling fluids were absent. IPR is no different in that we do not speculate on concentrations, but try to accommodate the uncertainty to the degree possible by a using highly conservative approach to evaluation of LANL groundwater concentration impacts at the BDD intake.

COMMENT: The chromium concentrations in R-42 [Regional Well R-42], first sampled in October 2008, have exceeded the concentrations found in proximal RA [Regional Aquifer] wells. LANL best estimates (Reference 169) of the concentration that would be found at the R-42 location ranged from 0.0 to 140 ug/L [micrograms per liter]. The concentration in this well was reported to have reached 10 times the MCL [EPA drinking water standard set at the maximum contaminant level] of 0.10 mg/L [milligrams per liter] in August 2009 (Reference 170) ([or] 1000 ug/L). This is about 8 times the maximum predicted and over 3 times the highest concentration predicted for the plume. This example shows that LANL numerical methods of estimating the nature and extent of contaminant plumes can be unreliable.

> IPR Response: The commenter has restated a portion of the text from the IPR report. IPR concurs with the findings represented in our report.

COMMENT: Based on review and synthesis of recent groundwater monitoring data, LANL has recently asserted that much of the contaminated groundwater in the RA [Regional Aquifer] is hydraulically and hydrogeologically isolated from the Buckman Well Field. These recent interpretations differ from the 2005 hydrologic synthesis report, which conservatively assumed a strong hydrologic connection between the contaminated areas under LANL to the Buckman well field.

> IPR Response: The commenter has restated a portion of the text from the IPR report. IPR concurs with the findings represented in our report.

COMMENT: The statement in the Community Summary, "There are no contributions from LANL groundwater to the Buckman well field," is contradicted in the draft report.

> IPR Response: Within a reasonable degree of scientific certainty the statement of no contribution is correct. The scientific consensus is that if there is any hydraulic connection it is very poor and would not result in contamination of Buckman well field wells. IPR finds no contradiction.

COMMENT: Early warnings about contaminated groundwater are acknowledged to depend on a Sentinel Monitoring Well that has been promised by LANL since at least 2006 but has not yet been installed. Until it is in place, assertions about its adequacy as an early warning system are premature. Omitted from the Community Summary, this quote appears in the draft report: The degree that this well will reduce the existing uncertainties regarding groundwater contaminant transport to the Rio Grande above BDD is unknown. [Emphasis added.] p. 6-62. To make substantial progress toward safe water and to gain public confidence, uncertainties need to be acknowledged and resolved.

> IPR Response: This commenter's point regarding resolution of uncertainty, while worthy of detailed consideration, is outside the scope of responsibility of the IPR team. This comment is more aptly directed to NMED, DOE, and LANL.

Table 3A-1. Detection Frequencies of Radionuclides Analyzed For in Rio Grande Surface Water

Analyte	Detection Frequencies by Location*			
	Upriver	Otowi Bridge	Buckman	Downriver
Actinium-228	2/12	0/8	0/1	0/5
Aluminum-26	0/2	0/0	0/1	0/1
Americium-241	6/24	6/32	0/14	9/24
Antimony-124	0/10	0/6	0/1	0/5
Antimony-125	0/10	0/6	0/1	0/5
Barium-133	0/8	0/6	0/0	0/4
Beryllium-7	2/12	0/8	0/1	0/5
Bismuth-211	0/8	0/6	0/0	0/4
Bismuth-212	2/12	0/8	0/1	0/5
Bismuth-214	2/12	2/8	0/1	0/5
Cadmium-109	0/10	0/6	0/1	0/5
Cerium-139	0/10	0/6	0/1	0/5
Cerium-141	0/8	0/6	0/0	0/4
Cerium-144	0/10	0/6	0/1	0/5
Cesium-134	2/12	2/8	0/1	0/5
Cesium-137	2/14	1/20	0/14	0/12
Chromium-51	0/10	0/6	0/1	0/5
Cobalt-56	0/2	0/0	0/1	0/1
Cobalt-57	2/12	1/8	0/1	0/5
Cobalt-58	0/2	0/0	0/1	0/1
Cobalt-60	2/14	2/20	0/14	0/12
Deuterium Ratio	0/0	0/0	0/0	2/2
Europium-152	0/10	0/6	0/1	0/5
Europium-154	0/10	0/6	0/1	0/5
Europium-155	0/2	0/0	0/1	0/1
Gross alpha	9/14	13/19	15/16	10/12
Gross alpha/beta	0/0	5/11	10/11	2/2
Gross beta	12/14	21/22	14/16	16/18
Gross gamma	2/8	2/18	0/13	0/9
Iodine-131	0/2	0/0	0/1	0/1
Iodine-133	1/8	0/6	0/0	1/4
Iron-59	0/10	0/6	0/1	0/5
Lead-211	0/8	0/6	0/0	0/4
Lead-212	2/12	0/8	0/1	1/6
Lead-214	2/12	2/8	0/1	0/5
Manganese-54	2/12	1/8	0/1	0/5
Mercury-203	0/8	0/6	0/0	0/4
Neptunium-237	0/10	0/18	0/13	0/11
Neptunium-239	0/8	0/6	0/0	0/4
Niobium-94	0/2	0/0	0/1	0/1
Niobium-95	0/10	0/6	0/1	0/5
Plutonium-238	4/12	6/24	0/13	9/19
Plutonium-239/240	4/12	5/24	0/13	9/19
Potassium-40	2/14	3/21	0/14	1/13
Protactinium-231	0/8	0/6	0/0	0/4
Protactinium-233	0/8	0/6	0/0	0/4
Protactinium-234m	0/10	0/6	0/1	0/5
Radium-223	0/8	0/6	0/0	0/4
Radium-224	0/8	0/6	0/0	1/5
Radium-226	1/14	3/20	1/11	1/7
Radium-228	0/8	2/17	3/11	0/4
Radon-219	0/8	0/6	0/0	0/4
Rhodium-106	0/8	0/6	0/0	0/4
Ruthenium-103	0/8	0/6	0/0	0/4
Ruthenium-106	0/10	0/6	0/1	0/5
Scandium-46	0/2	0/0	0/1	0/1
Selenium-75	0/8	0/6	0/0	0/4
Silver-110m	0/2	0/0	0/1	0/1
Sodium-22	2/14	1/20	0/14	0/12
Strontium-85	0/10	0/6	0/1	0/5
Strontium-90	2/13	5/23	0/13	8/19
Thallium-208	2/12	2/8	0/1	1/6
Thorium-227	0/10	0/6	0/1	0/5
Thorium-228	1/6	12/15	6/9	10/11
Thorium-230	1/6	11/15	4/9	9/11
Thorium-231	0/8	0/6	0/0	0/4
Thorium-232	1/6	13/15	7/9	10/11
Thorium-234	0/10	0/6	0/1	0/5
Tin-113	0/8	0/6	0/0	0/4
Tritium	2/13	13/21	11/11	2/10
Uranium-234	13/13	24/24	14/14	19/19
Uranium-235	1/11	0/6	1/2	1/6
Uranium-235/236	6/10	10/24	6/13	14/18
Uranium-238	13/21	24/30	14/14	19/23
Yttrium-88	0/8	0/6	0/0	0/4
Zinc-65	0/10	0/6	0/1	0/5
Zirconium-95	0/8	0/6	0/0	0/4

* Detection frequencies include duplicate samples but do not include detections less than zero.

Table 3A-2. Detection Frequencies of Chemicals Analyzed For in Rio Grande Surface Water

Analyte	Detection Frequencies by Location*			
	Upriver	Otowi Bidge	Buckman	Downriver
Acenaphthene	0/7	0/22	0/14	0/15
Acenaphthylene	0/7	0/22	0/14	0/15
Acetone	0/4	7/19	4/13	4/13
Acetonitrile	0/2	0/12	0/13	0/6
Acrolein	0/4	0/19	0/13	0/13
Acrylonitrile	0/4	0/19	0/13	0/13
Aldrin	0/4	0/17	0/13	0/8
Alkalinity-CO3	0/0	1/11	3/11	0/0
Alkalinity-CO3+HCO3	0/0	11/11	11/11	0/0
Allyl Chloride	0/2	0/12	0/13	0/6
Aluminum	4/4	17/17	15/16	15/17
Ammonia	0/0	4/4	0/0	6/7
Ammonia as Nitrogen	0/0	3/11	4/11	0/0
Aniline	0/7	0/17	0/14	0/8
Anthracene	1/7	0/22	0/14	0/15
Antimony	0/4	4/16	0/16	5/17
Aroclor 1016	0/6	0/21	0/13	0/11
Aroclor 1221	0/6	0/21	0/13	0/11
Aroclor 1232	0/6	0/21	0/13	0/11
Aroclor 1242	0/6	0/21	0/13	0/11
Aroclor 1248	0/6	0/21	0/13	0/11
Aroclor 1254	0/6	0/21	0/13	0/11
Aroclor 1260	0/6	0/21	0/13	0/11
Aroclor 1262	0/6	0/17	0/13	0/6
Arsenic	1/4	11/17	9/16	11/17
Atrazine	0/2	0/12	0/14	0/4
Azobenzene	0/4	0/14	0/14	0/6
Barium	4/4	17/17	16/16	17/17
Benz[a]anthracene	0/7	0/22	0/14	0/15
Benzene	0/6	0/21	0/13	0/14
Benzidine	0/7	0/22	0/14	0/15
Benzo[a]pyrene	0/7	0/22	1/14	0/15
Benzo[b]fluoranthene	0/7	0/22	0/14	0/15
Benzo[g,h,i]perylene	0/7	0/22	1/14	0/15
Benzo[k]fluoranthene	0/7	0/22	0/14	0/15
Benzoic Acid	0/7	0/17	0/14	0/8
Benzyl Alcohol	0/7	0/17	0/14	0/8
Beryllium	0/5	2/17	1/16	2/15
Bis(2-chloro-1-methylethyl)ether	0/7	0/22	0/14	0/15
Bis(2-chloroethoxy)methane	0/7	0/22	0/14	0/15
Bis(2-chloroethyl)ether	0/7	0/22	0/14	0/15
Bis(2-ethylhexyl)phthalate	3/7	2/22	0/14	2/15
Boron	2/2	16/17	13/14	12/14
Bromide	0/0	0/11	0/11	0/2
Bromobenzene	0/4	0/15	0/13	0/9
Bromochloromethane	0/4	0/15	0/13	0/9
Bromodichloromethane	0/6	0/21	0/13	0/14
Bromodiphenyl Ether, p-	0/7	1/22	0/14	0/15
Bromoform (tribromomethane)	0/6	0/21	0/13	0/14
Bromomethane (Methyl bromide)	0/6	0/21	0/13	1/14
Butanol, N-	0/0	0/11	0/11	0/4
Butyl benzyl phthalate	0/7	0/22	0/14	0/15
Butylbenzene, n-	0/4	0/15	0/13	0/9
Butylbenzene, sec-	0/4	0/15	0/13	0/9
Butylbenzene, tert-	0/4	0/15	0/13	0/9
Cadmium	2/4	7/16	3/16	4/16
Calcium	4/4	17/17	16/16	17/17
Carbon Disulfide	0/4	0/19	0/13	0/13
Carbon Tetrachloride	0/6	0/21	0/13	0/14
Chemical Oxygen Demand	0/0	2/4	0/0	3/6
Chlordane, alpha-	0/4	0/13	0/13	0/3

Analyte	**Detection Frequencies by Location***			
	Upriver	Otowi Bidge	Buckman	Downriver
Chlordane, gamma-	0/4	0/13	0/13	0/3
Chloride	0/0	11/11	11/11	2/2
Chloro-1,3-butadiene, 2-	0/2	0/12	0/13	0/6
Chloroaniline, p-	0/7	0/17	0/14	0/8
Chlorobenzene	0/6	0/21	0/13	0/14
Chloroethane (ethyl chloride)	0/6	0/21	0/13	0/14
Chloroethyl vinyl ether, 2-	0/4	0/9	0/0	0/8
Chloroform	0/6	0/21	0/13	0/14
Chloromethane	0/6	0/21	1/13	1/14
Chloronaphthalene, Beta-	0/7	0/22	0/14	0/15
Chlorophenol, 2-	0/7	0/22	0/14	0/15
Chlorophenyl-phenyl (4-) Ether	0/7	0/22	0/14	0/15
Chlorotoluene, o-	0/4	0/15	0/13	0/9
Chlorotoluene, p-	0/4	0/15	0/13	0/9
Chromium	3/5	11/17	10/16	13/16
Chrysene	0/7	0/22	0/14	0/15
Cobalt	2/5	7/17	5/16	10/16
Copper	3/4	10/17	6/16	9/16
Cresol, o-	0/7	0/17	0/14	0/8
Cresol, p-	0/5	0/16	0/12	0/6
Cresol, p-chloro-m-	0/7	0/22	0/14	0/15
Cyanide, Total	3/14	6/23	0/13	4/14
D, 2,4-	0/0	0/4	0/0	0/5
Dalapon	0/0	0/4	0/0	0/5
DB, 2,4-	0/0	0/4	0/0	0/5
DDD	0/4	0/17	0/13	1/8
DDE	0/4	0/17	1/13	2/8
DDT	0/4	0/17	0/13	1/8
Diamino-4-nitrotoluene, 2,6-	0/2	0/1	0/2	0/2
Diamino-6-nitrotoluene, 2,4-	0/2	0/1	0/2	0/2
Dibenz[a,h]anthracene	0/7	0/22	2/14	0/15
Dibenzofuran	0/7	0/17	0/14	0/8
Dibromo-3-chloropropane, 1,2-	0/4	0/19	0/13	0/13
Dibromochloromethane	0/6	0/21	0/13	0/14
Dibromoethane, 1,2-	0/4	0/19	0/13	0/13
Dibromomethane (Methylene Bromide)	0/4	0/19	0/13	0/13
Dibutyl Phthalate	0/7	0/17	0/14	0/8
Dicamba	0/0	0/4	0/0	0/5
Dichlorobenzene, 1,2-	0/13	0/43	0/27	0/29
Dichlorobenzene, 1,3-	0/13	0/43	0/27	0/29
Dichlorobenzene, 1,4-	1/13	0/43	0/27	1/29
Dichlorobenzidine, 3,3'-	0/7	0/22	0/14	0/15
Dichlorodifluoromethane	0/4	0/19	0/13	0/13
Dichloroethane, 1,1-	0/6	0/21	0/13	0/14
Dichloroethane, 1,2-	0/6	0/21	0/13	0/14
Dichloroethylene, 1,1-	0/6	0/21	0/13	0/14
Dichloroethylene, 1,2-cis-	0/2	0/16	0/13	0/10
Dichloroethylene, 1,2-trans-	0/6	0/21	0/13	0/14
Dichlorophenol, 2,4-	0/7	0/22	0/14	0/15
Dichloropropane, 1,2-	0/6	0/21	0/13	0/14
Dichloropropane, 1,3-	0/4	0/15	0/13	0/9
Dichloropropane, 2,2-	0/4	0/15	0/13	0/9
Dichloropropene, 1,1-	0/4	0/15	0/13	0/9
Dichloropropene, cis-1,3-	0/6	0/21	0/13	0/14
Dichloropropene, trans-1,3-	0/6	0/21	0/13	0/14
Dichlorprop	0/0	0/4	0/0	0/5
Dieldrin	0/4	0/17	0/13	1/8
Diethyl Phthalate	0/7	0/22	0/14	0/15
Dimethylphenol, 2,4-	0/7	0/22	0/14	0/15
Dimethylphthalate	0/7	0/22	0/14	0/15
Dinitroaniline, 3,5-	0/2	0/1	0/2	0/2
Dinitrobenzene, 1,3-	0/4	0/10	0/2	0/11
Dinitro-o-cresol, 4,6-	0/7	0/17	0/14	0/8

Analyte	Detection Frequencies by Location*			
	Upriver	Otowi Bidge	Buckman	Downriver
Dinitrophenol, 2,4-	0/7	0/22	0/14	0/15
Dinitrotoluene, 2,4-	0/11	0/32	0/16	0/26
Dinitrotoluene, 2,6-	0/11	0/32	0/16	0/26
Dinitrotoluene, 2-Amino-4,6-	0/4	0/10	0/2	0/11
Dinitrotoluene, 4-Amino-2,6-	0/4	0/10	0/2	0/11
Dinoseb	0/2	0/16	0/14	0/9
Dioxane, 1,4-	0/2	0/15	0/18	0/7
Diphenylamine	0/7	0/17	0/14	0/8
Diphenylhydrazine, 1,2-	0/3	0/3	0/0	0/2
Dissolved Oxygen	2/2	9/9	9/9	3/3
Endosulfan I	0/4	0/17	0/13	2/8
Endosulfan II	0/4	0/17	0/13	1/8
Endosulfan Sulfate	0/4	0/17	0/13	1/8
Endrin	0/4	0/17	0/13	1/8
Endrin Aldehyde	0/4	1/17	0/13	0/8
Endrin Ketone	0/4	0/13	0/13	0/3
Ethyl Ether	0/0	0/11	0/11	0/4
Ethyl Methacrylate	0/2	0/12	0/13	0/6
Ethylbenzene	0/6	0/21	0/13	0/14
Fluoranthene	2/7	0/22	0/14	0/15
Fluorene	0/7	0/22	0/14	0/15
Fluoride	0/0	11/11	11/11	2/2
Hardness	2/2	16/16	14/14	12/12
Heptachlor	0/4	0/17	0/13	0/8
Heptachlor Epoxide	0/4	0/17	0/13	1/8
Heptachlorodibenzodioxin, 1,2,3,4,6,7,8-	0/0	0/4	0/0	0/5
Heptachlorodibenzofuran, 1,2,3,4,6,7,8-	0/0	0/4	0/0	0/5
Heptachlorodibenzofuran, 1,2,3,4,7,8,9-	0/0	0/4	0/0	0/5
Hexachlorobenzene	0/7	0/22	0/14	0/15
Hexachlorobutadiene	0/11	0/37	0/27	0/24
Hexachlorocyclohexane, Alpha-	0/4	0/17	0/13	1/8
Hexachlorocyclohexane, Beta-	0/4	0/17	0/13	1/8
Hexachlorocyclohexane, Delta-	0/4	1/17	0/13	1/8
Hexachlorocyclohexane, Gamma-	0/4	0/17	0/13	1/8
Hexachlorocyclopentadiene	0/7	0/22	0/14	0/15
Hexachlorodibenzodioxin, 1,2,3,4,7,8-	0/0	0/4	0/0	0/5
Hexachlorodibenzodioxin, 1,2,3,6,7,8-	0/0	0/4	0/0	0/5
Hexachlorodibenzofuran, 1,2,3,4,7,8-	0/0	0/4	0/0	0/5
Hexachlorodibenzofuran, 1,2,3,6,7,8-	0/0	0/4	0/0	0/5
Hexachlorodibenzofuran, 1,2,3,7,8,9-	0/0	0/4	0/0	0/5
Hexachlorodibenzofuran, 2,3,4,6,7,8-	0/0	0/4	0/0	0/5
Hexachloroethane	0/7	0/22	0/14	0/15
Hexahydro-1,3,5-trinitro-1,3,5-triazine (RDX)	0/4	0/10	0/2	0/11
Hexahydro-1,3,5-trinitroso-1,3,5-triazine (TNX)	0/0	0/0	0/2	0/1
Hexahydro-1,3-dinitroso-5-nitro-1,3,5-triazine (DN	0/0	0/0	0/2	0/1
Hexahydro-1-nitroso-3,5-dinitro-1,3,5-triazine (MNX)	0/0	0/0	0/2	0/1
Hexanone, 2-	0/4	0/15	0/13	0/9
Indeno[1,2,3-cd]pyrene	0/7	0/22	2/14	0/15
Iodomethane	0/4	0/15	0/13	0/9
Iron	4/4	17/17	15/16	15/17
Isobutanol	0/2	0/12	0/13	0/6
Isophorone	0/7	0/22	0/14	0/15
Isopropylbenzene (Cumene)	0/4	0/15	0/13	0/9
Isopropyltoluene, 4-	0/4	0/15	0/13	0/9
Lead	4/4	15/16	16/16	15/17
Magnesium	4/4	17/17	16/16	17/17
Manganese	4/4	17/17	15/16	16/17
MCPA	0/0	0/4	0/0	0/5
Mercury	0/14	2/24	0/16	3/20

Analyte	Detection Frequencies by Location*			
	Upriver	Otowi Bidge	Buckman	Downriver
Methacrylonitrile	0/2	0/12	0/13	0/6
Methoxychlor	0/4	0/17	0/13	1/8
Methyl Ethyl Ketone	0/4	1/19	0/13	1/13
Methyl Isobutyl Ketone	0/4	0/15	0/13	0/9
Methyl Methacrylate	0/2	0/12	0/13	0/6
Methyl tertbutyl ether (MTBE)	0/0	0/11	0/11	0/4
Methylene Chloride	0/6	0/21	0/13	1/14
Methylphenol, 3-&4-	0/2	0/1	0/2	0/2
Methylpyridine, 2-	0/5	0/5	0/0	0/4
Molybdenum	1/2	14/17	14/14	11/14
Naphthalene	0/11	0/37	0/27	0/24
Naphthalene, 1-Methyl	0/2	0/12	0/14	0/4
Naphthalene, 2-Methyl	0/7	0/17	0/14	0/8
Nickel	3/4	16/17	15/16	12/16
Nitrate-Nitrite as Nitrogen	0/0	11/15	6/11	4/6
Nitroaniline, 2-	0/7	0/17	0/14	0/8
Nitroaniline, 3-	0/7	0/17	0/14	0/8
Nitroaniline, 4-	0/7	0/17	0/14	0/8
Nitrobenzene	0/11	0/32	0/16	0/26
Nitrophenol, 2 -	0/7	0/22	0/14	0/15
Nitrophenol, 4-	0/7	0/22	0/14	0/15
Nitrosodiethylamine, N-	0/2	0/12	0/14	0/4
Nitrosodimethylamine, N-	0/7	0/22	0/14	0/15
Nitroso-di-N-butylamine, N-	0/2	0/12	0/14	0/4
Nitroso-di-N-propylamine, N-	0/7	0/22	0/14	0/15
Nitrosodiphenylamine, N-	0/0	0/5	0/0	0/7
Nitrosopyrrolidine, N-	0/2	0/12	0/14	0/4
Nitrotoluene, m-	0/4	0/10	0/2	0/11
Nitrotoluene, o-	0/4	0/10	0/2	0/11
Nitrotoluene, p-	0/4	0/10	0/2	0/11
OCDD	0/0	1/4	0/0	1/5
OCDF	0/0	0/4	0/0	0/5
Octahydro-1,3,5,7-tetranitro-1,3,5,7-tetrazocine (HMX)	0/4	0/10	0/2	0/11
Octyl Phthalate, di-N-	0/7	0/22	0/14	0/15
Pentachlorobenzene	0/2	0/12	0/14	0/4
Pentachlorodibenzodioxin, 1,2,3,7,8-	0/0	0/4	0/0	0/5
Pentachlorophenol	0/7	0/22	0/14	0/15
Perchlorate	1/12	12/22	11/11	2/11
PETN	0/2	0/2	0/2	0/2
pH	11/11	27/27	20/20	9/9
Phenanthrene	1/7	0/22	0/14	0/15
Phenol	0/7	0/22	0/14	0/15
Phosphorus	0/0	4/4	0/0	7/7
Potassium	4/4	16/17	16/16	17/17
Propionitrile	0/2	0/12	0/13	0/6
Propylbenzene, n-	0/4	0/15	0/13	0/9
Pyrene	2/7	0/22	0/14	0/15
Pyridine	0/5	0/16	0/14	0/7
Selenium	0/14	4/24	0/16	3/21
Silicon Dioxide	2/2	13/13	11/11	1/1
Silver	1/4	0/17	1/16	1/15
Sodium	4/4	17/17	16/16	17/17
Specific Conductance	10/10	25/25	20/20	8/8
Strontium	2/2	17/17	14/14	14/14
Styrene	0/4	0/19	0/13	0/13
Sulfate	0/0	11/11	11/11	2/2
Suspended Sediment Concentration	6/6	20/20	14/14	10/10
T, 2,4,5-	0/0	0/4	0/0	0/5
TCDD, 2,3,7,8- (Dioxin)	0/0	0/4	0/0	0/5
TCDF, 2,3,7,8-	0/0	0/4	0/0	0/5
Temperature	10/10	14/14	9/9	8/8

Analyte	Detection Frequencies by Location*			
	Upriver	Otowi Bidge	Buckman	Downriver
Tetrachlorobenzene, 1,2,4,5-	0/2	0/12	0/14	0/4
Tetrachloroethane, 1,1,1,2-	0/4	0/19	0/13	0/13
Tetrachloroethane, 1,1,2,2-	0/6	0/21	0/13	0/14
Tetrachloroethylene (PCE)	0/6	0/21	0/13	0/14
Tetrachlorophenol, 2,3,4,6-	0/2	0/12	0/14	0/4
Thallium	0/4	5/16	1/16	7/16
Tin	0/3	0/17	0/14	0/12
Titanium	0/0	0/1	0/0	0/0
Toluene	0/6	0/21	0/13	0/14
Total Dissolved Solids	0/0	11/11	11/11	1/1
Total Kjeldahl Nitrogen	0/0	10/15	7/13	10/12
Total Organic Carbon	0/0	11/11	13/13	5/5
Total Phosphate as Phosphorus	0/0	7/11	7/11	0/0
Total polychlorinated biphenyls (PCBs)	2/2	4/10	2/10	1/1
Total Suspended Solids	10/10	11/11	0/0	11/11
Toxaphene	0/4	0/17	0/13	1/8
TP, 2,4,5- (Silvex)	0/0	0/4	0/0	0/5
Trichloro-1,2,2-trifluoroethane, 1,1,2-	0/4	0/15	0/13	0/9
Trichlorobenzene, 1,2,3-	0/2	0/12	0/13	0/6
Trichlorobenzene, 1,2,4-	0/9	0/34	0/27	0/21
Trichloroethane, 1,1,1-	0/6	0/21	0/13	0/14
Trichloroethane, 1,1,2-	0/6	0/21	0/13	0/14
Trichloroethylene (TCE)	0/6	0/21	0/13	0/14
Trichlorofluoromethane	0/6	0/21	0/13	0/14
Trichlorophenol, 2,4,5-	0/7	0/22	0/14	0/15
Trichlorophenol, 2,4,6-	0/7	0/22	0/14	0/15
Trichloropropane, 1,2,3-	0/4	0/19	0/13	0/13
Trimethylbenzene, 1,2,4-	0/4	0/15	0/13	0/9
Trimethylbenzene, 1,3,5-	0/4	0/15	0/13	0/9
Trinitrobenzene, 1,3,5-	0/4	0/10	0/2	0/11
Trinitrobenzene-1,3,5-triamine, 2,4,6- (TATB)	0/2	0/1	0/2	0/2
Trinitrophenylmethylnitramine	0/4	0/10	0/2	0/11
Trinitrotoluene, 2,4,6-	0/4	0/10	0/2	0/11
Tri-o-cresylphosphate	0/2	0/1	0/2	0/2
Turbidity	10/10	14/14	11/11	7/7
Uranium	2/3	16/16	15/15	15/15
Vanadium	3/4	17/17	16/16	15/17
Vinyl Acetate	0/2	0/12	0/13	0/6
Vinyl Chloride	0/6	0/21	0/13	0/14
Xylene, 1,3-+ Xylene, 1,4-	0/4	0/15	0/13	0/9
Xylene, Mixture	0/2	0/3	0/0	0/3
Xylene, o-	0/4	0/15	0/13	0/9
Zinc	3/4	15/17	11/16	14/16

* Detection frequencies include duplicate samples.

Table 3A-3. Summary of Buckman Well Groundwater Data for Radium-226 and Radium-228

Well	Sampling Date	Concentration (pCi/L)		Percent contribution	
		Radium-226	Radium-228	Radium-226	Radium-228
Buckman 1	10/10/2002	11	< 3.2	NC	NC
	10/22/2003	< 0.37	< 7.3	NC	NC
	5/25/2004	< 0.18	< 2.0	NC	NC
	12/3/2008	0.61	< 0.32	NC	NC
	5/19/2009	< 0.063	0.96	NC	NC
	11/24/2009	1.2	< 0.34	NC	NC
Buckman 2	10/10/2002	14	< 6.3	NC	NC
	10/22/2003	0.46	< 21.3	NC	NC
Buckman 6	3/4/2009	0.46	0.80	37%	63%
	5/19/2009	< 0	0.68	NC	NC
	11/24/2009	1.2	< 0.93	NC	NC
Buckman 8	10/10/2002	< 0.056	< 4.8	NC	NC
	10/22/2003	0.44	< 11	NC	NC
	5/25/2004	< 0.56	< 2.2	NC	NC
	12/3/2008	< 0.15	0.54	NC	NC
	5/19/2009	< 0.43	< 0.60	NC	NC
	11/24/2009	2.2	< 0.46	NC	NC

NC: Percent contribution for radium-226 and radium-228 were not calculated because one or both are reported to be below the LOD.

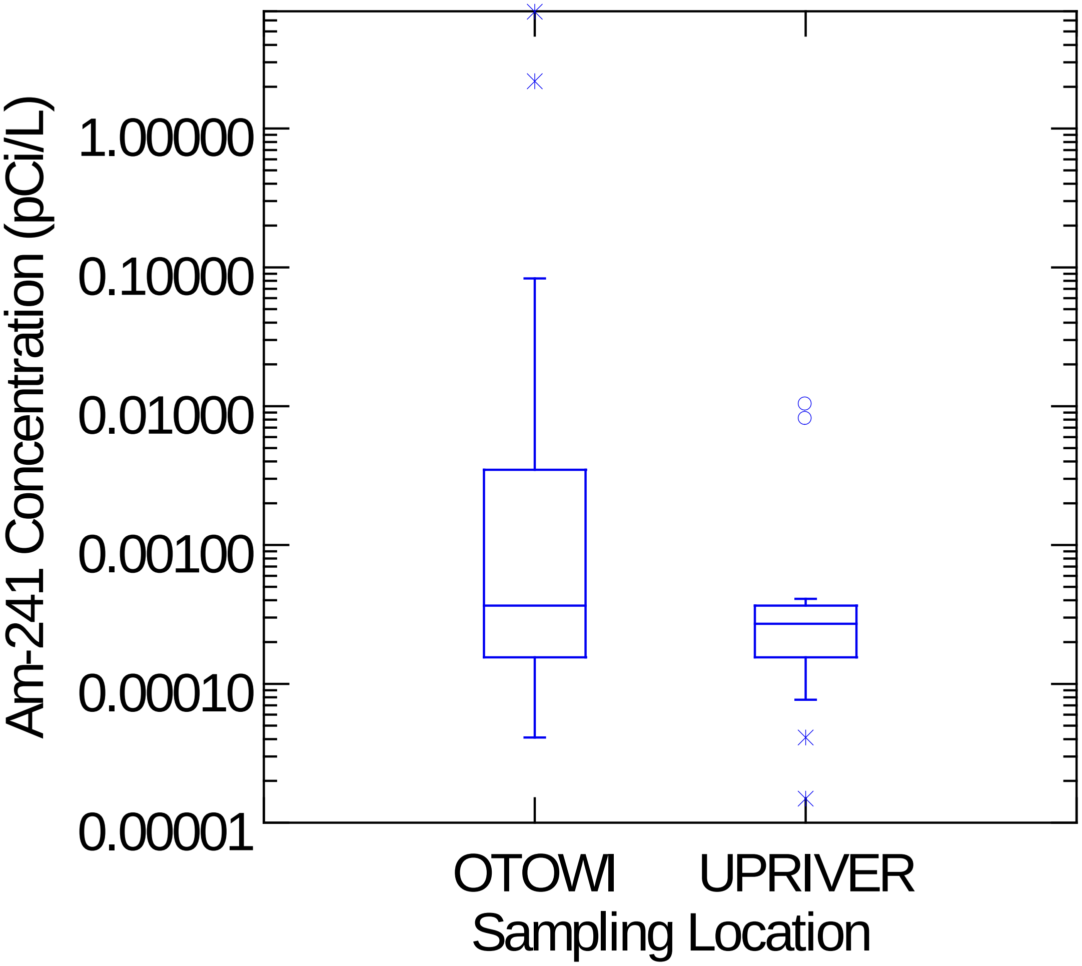
Table 3A-4. Summary of Buckman Well Groundwater Data for Uranium-234, Uranium-235/236, and Uranium-238

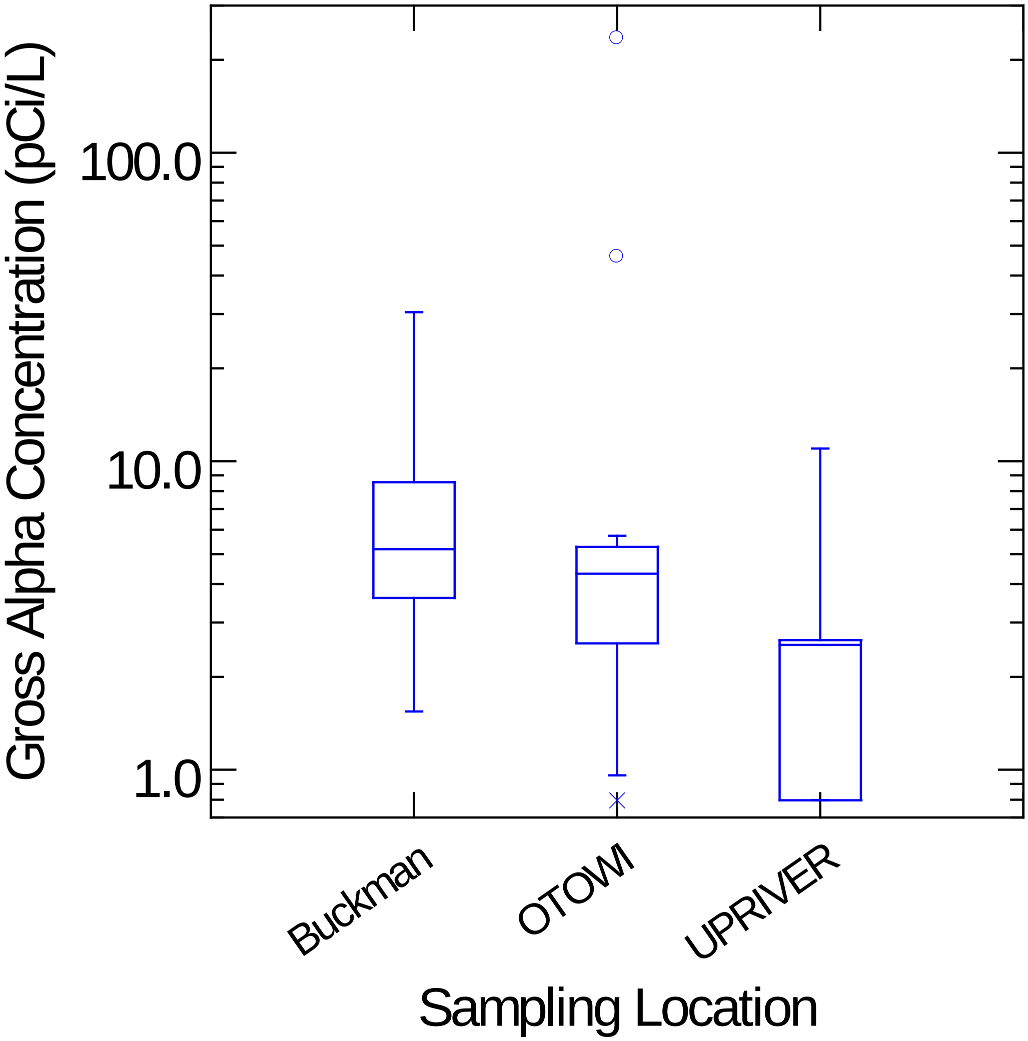
Well	Sampling Date	Concentration (pCi/L)			Percent Contribution		
		Uranium-234	Uranium-235/236	Uranium-238	Uranium-234	Uranium-235/236	Uranium-238
Buckman 1	8/16/2001	3.6	0.13	2.1	62%	2%	36%
	10/31/2001	8.2	0.40	5.5	58%	3%	39%
	10/10/2002	9.3	< 0.084	5.5	NC	NC	NC
	10/22/2003	8.0	0.46	5.5	57%	3%	40%
	5/25/2004	3.6	0.12	2.0	63%	2%	35%
	6/8/2005	5.6	0.25	3.6	59%	3%	38%
	7/12/2006	6.4	0.43	4.0	59%	4%	37%
	9/18/2007	6.4	0.45	4.6	56%	4%	40%
	9/3/2008	7.8	0.36	5.3	58%	3%	40%
	12/3/2008	7.5	0.31	5.1	58%	2%	40%
	5/19/2009	8.0	0.30	5.6	57%	2%	40%
	11/24/2009	9.0	0.31	6.0	59%	2%	39%
Buckman 2	8/16/2001	91	4.2	74	54%	2%	44%
	10/31/2001	13	1.1	6.5	62%	6%	32%
	10/10/2002	96	4.2	144	39%	2%	59%
	10/22/2003	47	5.6	37	52%	6%	41%
	10/26/2004	11	0.34	6.1	63%	2%	35%
	6/8/2005	27	1.7	17	60%	4%	37%
	7/12/2006	35	1.6	27	55%	2%	42%
	9/18/2007	46	3.9	36	54%	5%	42%
Buckman 3	10/31/2001	7.5	0.54	2.6	70%	5%	24%
Buckman 4	10/31/2001	12	0.21	3.0	79%	1%	20%
Buckman 6	10/31/2001	8.8	0.32	1.9	80%	3%	17%
	9/24/2008	5.8	0.28	2.0	72%	4%	24%
	3/4/2009	3.7	0.058	1.4	72%	1%	27%
	5/19/2009	3.8	0.13	1.7	68%	2%	30%
	11/24/2009	6.8	0.067	1.6	81%	1%	19%
Buckman 7	8/16/2001	5.1	0.13	1.7	73%	2%	25%
	10/31/2001	5.7	0.20	1.8	74%	3%	24%
Buckman 8	10/31/2001	7.5	0.24	4.6	61%	2%	37%
	10/10/2002	8.1	< 0.17	4.6	NC	NC	NC
	10/22/2003	7.7	0.80	4.9	57%	6%	37%
	5/25/2004	8.3	0.33	5.0	61%	2%	37%
	6/8/2005	5.6	0.74	4.0	54%	7%	39%
	7/12/2006	9.4	0.34	6.0	59%	2%	38%
	9/21/2007	8.2	0.74	5.0	59%	5%	36%
	9/2/2008	10	0.36	5.8	62%	2%	36%
	12/3/2008	10	0.34	6.0	62%	2%	36%
	5/19/2009	9.8	0.34	6.0	61%	2%	37%
	11/24/2009	9.4	0.31	5.8	61%	2%	38%
Buckman Well 2 New	2/13/2007	20	1.6	33	37%	3%	60%
Buckman Well 8	2/13/2007	8.7	0.20	5.1	62%	1%	37%
				Average:	61%	3%	36%

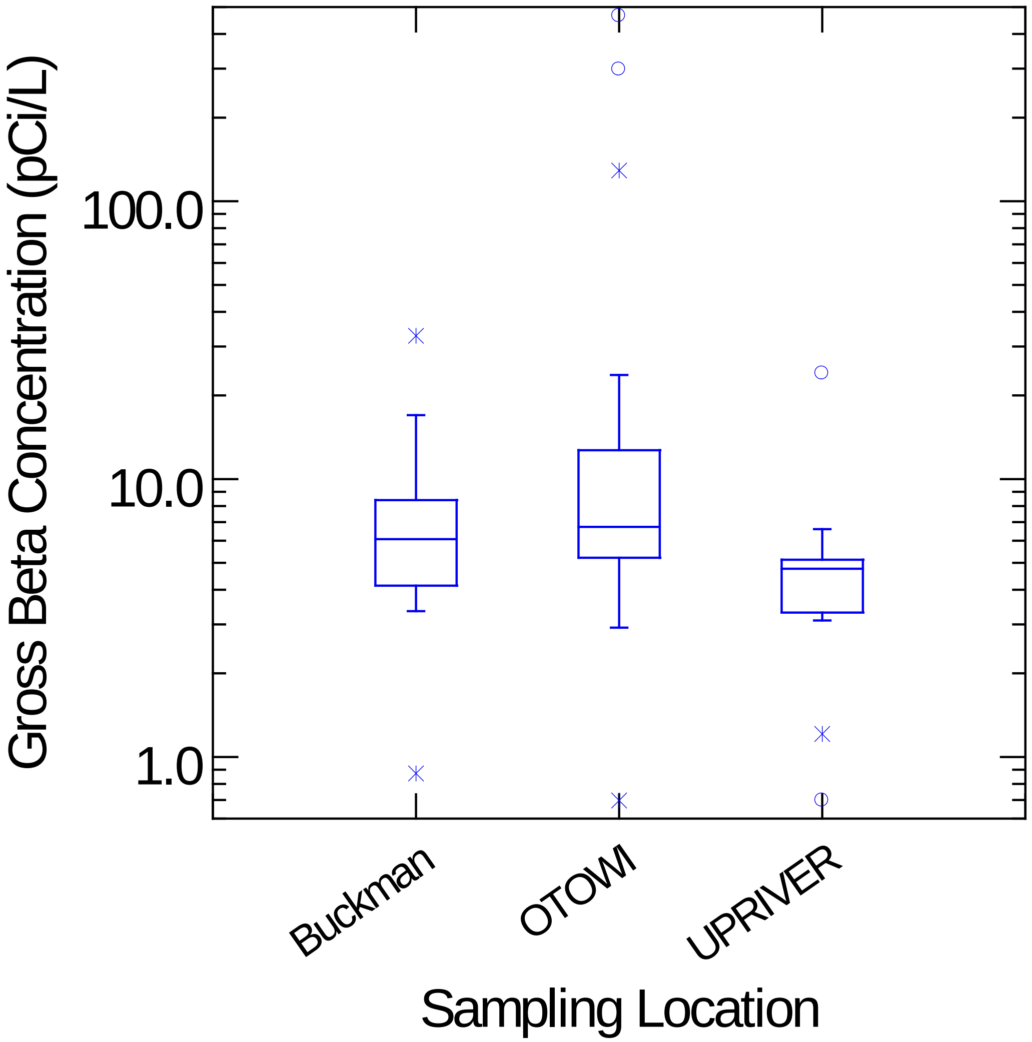
NC: Percent contribution for uranium-234, uranium-235/23 or uranium-238 were not calculated because one or both are reported to be below the LOD.

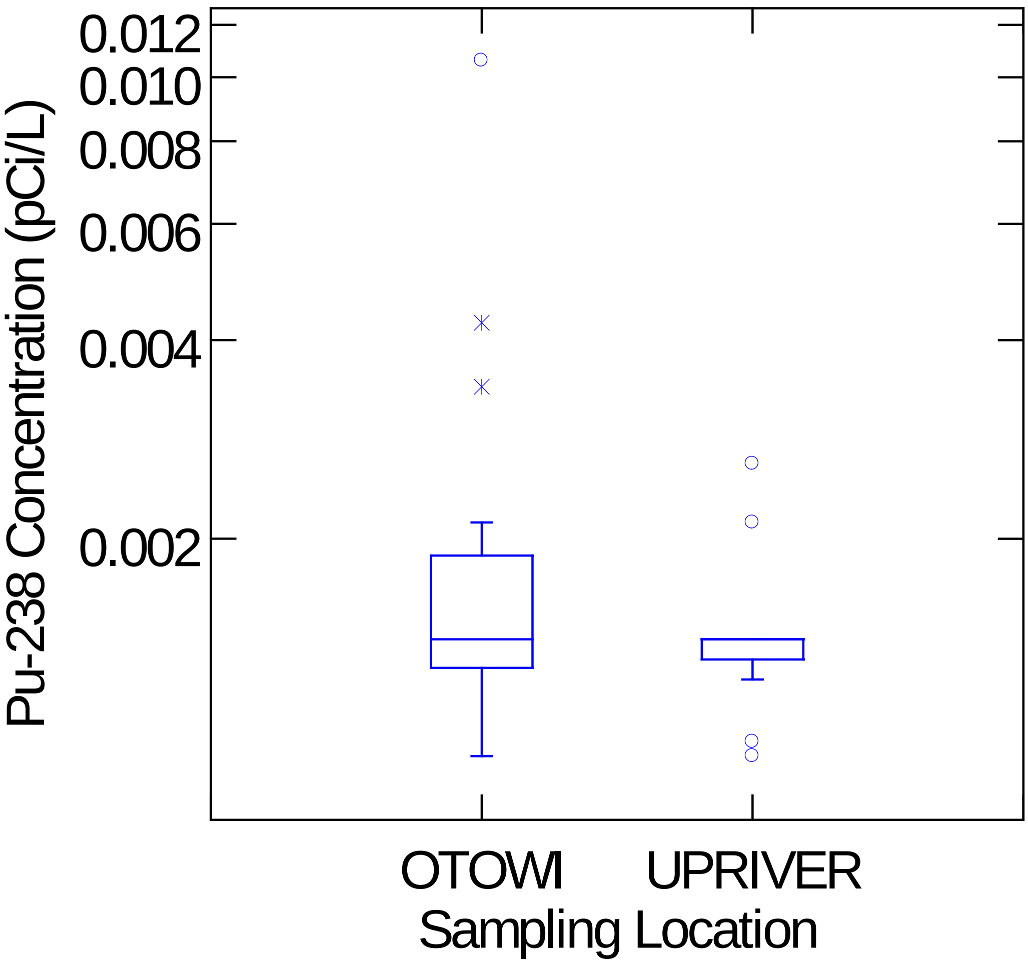
Appendix 3B. Box Plots for the Comparison of Buckman, Otowi Bridge, and Upriver Locations.

<u>Samples collected after 2000 - Radionuclides</u>

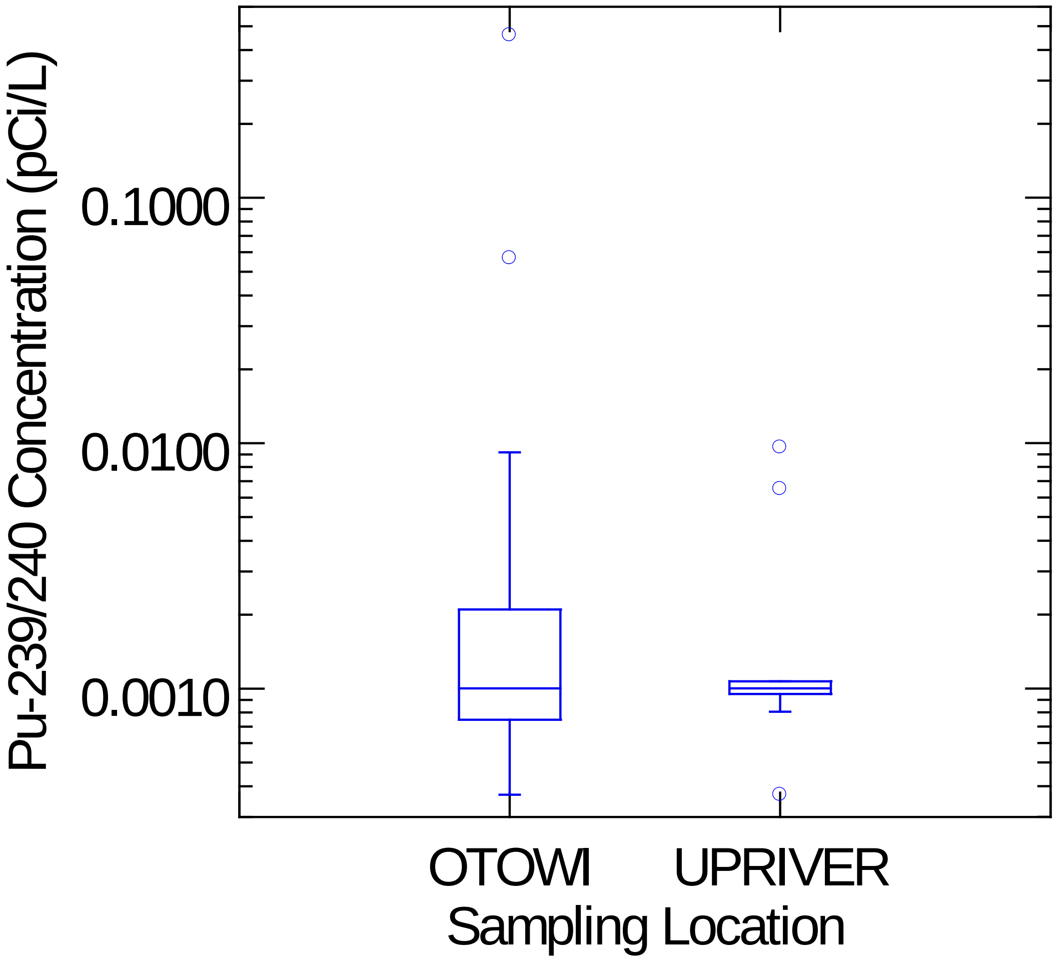


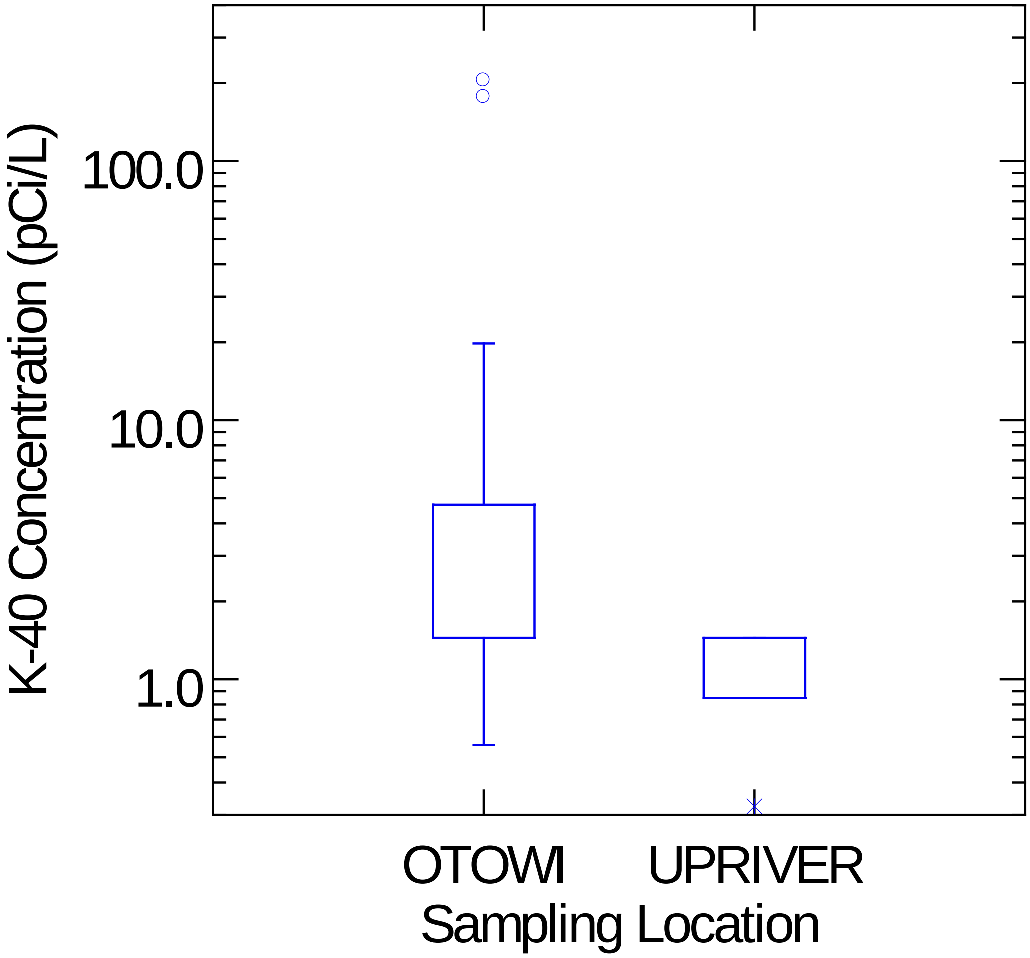

Gross Alpha Concentration (pCi/L)
100.0
10.0
1.0
Buckman
OTOWI
UPRIVER
Sampling Location

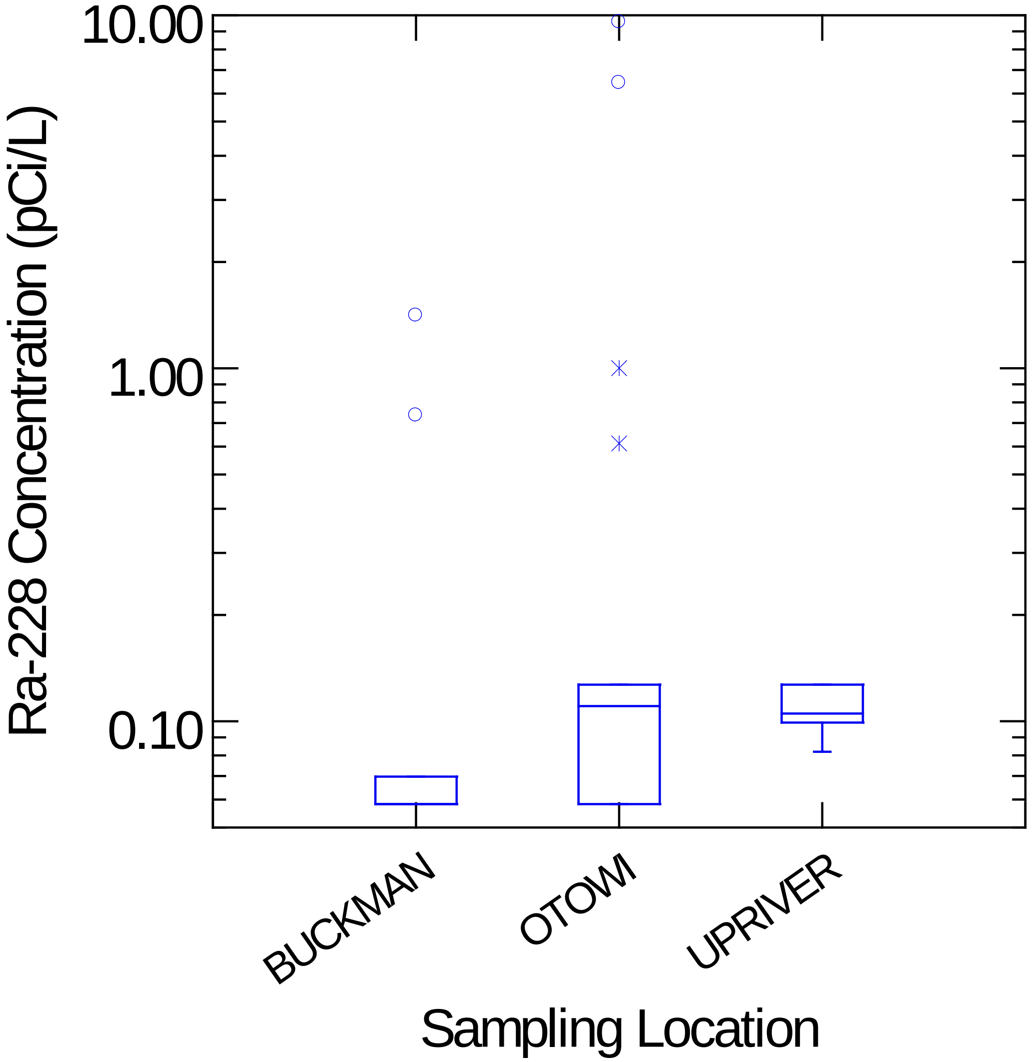

Gross Beta Concentration (pCi/L)
100.0
10.0
1.0
Buckman
OTOWI
UPRIVER
Sampling Location

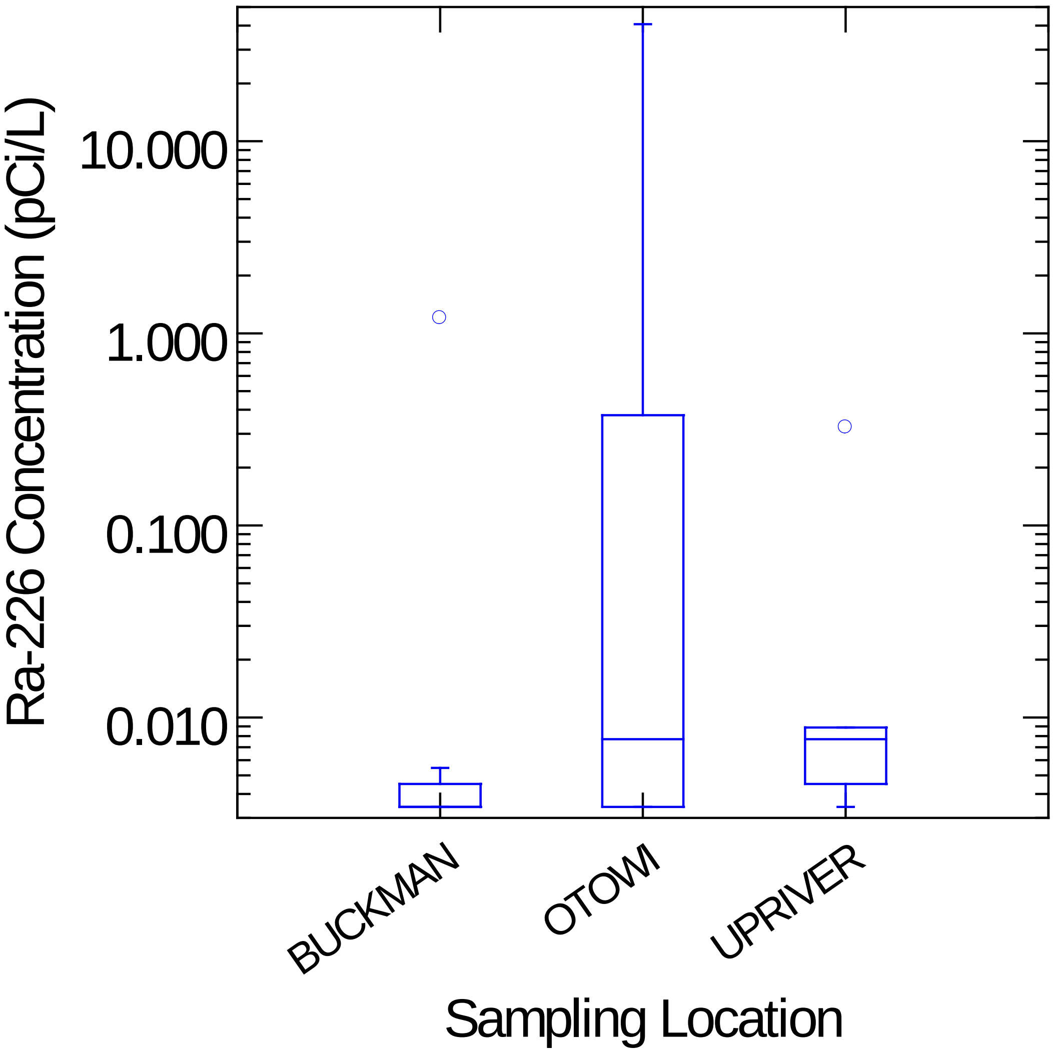


Pu-238 Concentration (pCi/L)
0.012
0.010
0.008
0.006
0.004
0.002
OTOWI
UPRIVER
Sampling Location

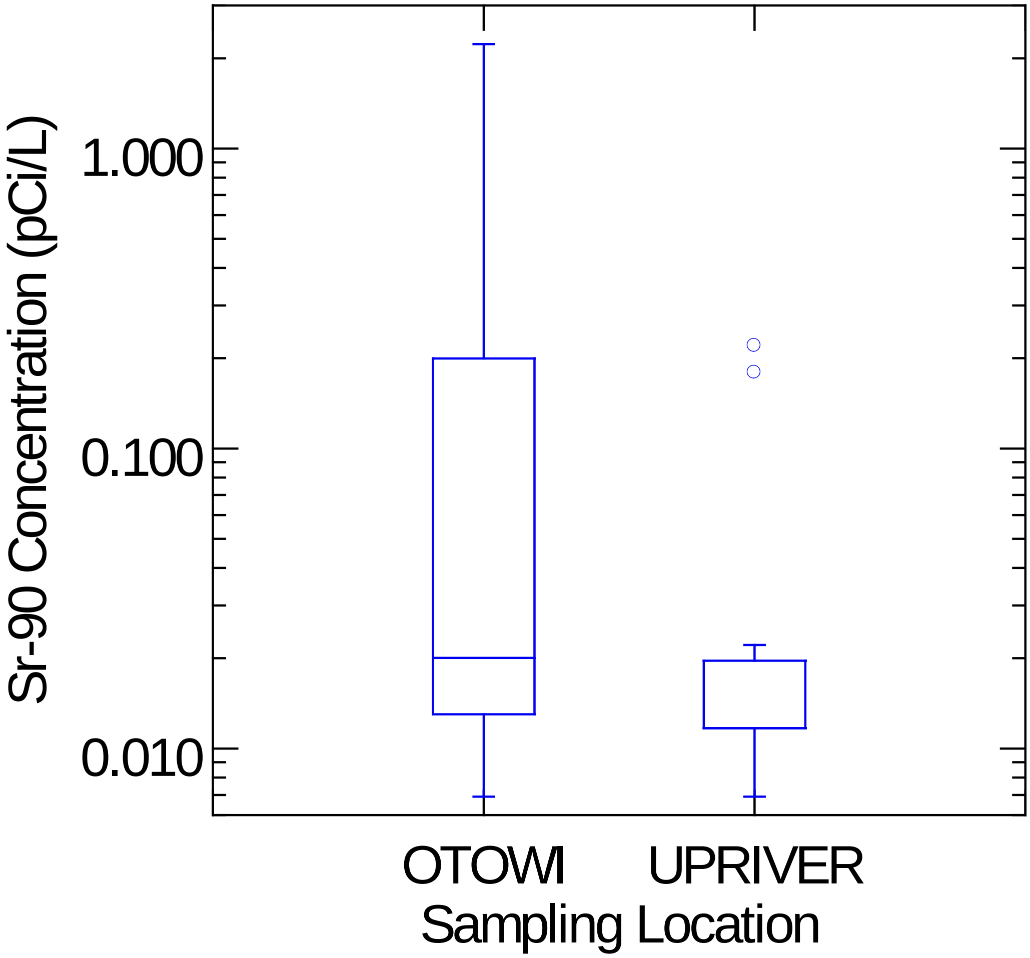

Pu-239/240 Concentration (pCi/L)
0.1000
0.0100
0.0010
OTOWI
UPRIVER
Sampling Location

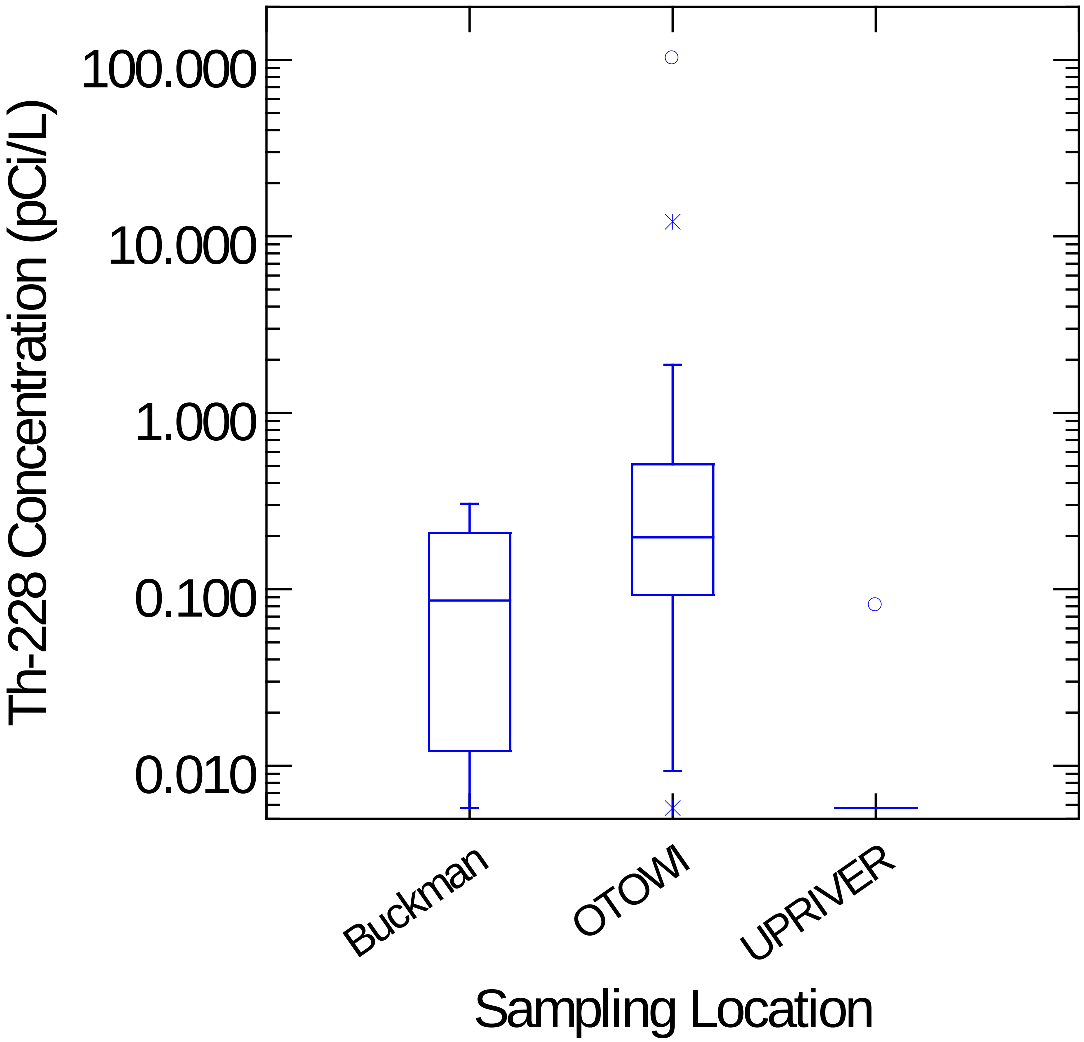

K-40 Concentration (pCi/L)
100.0
10.0
1.0
OTOWI
UPRIVER
Sampling Location

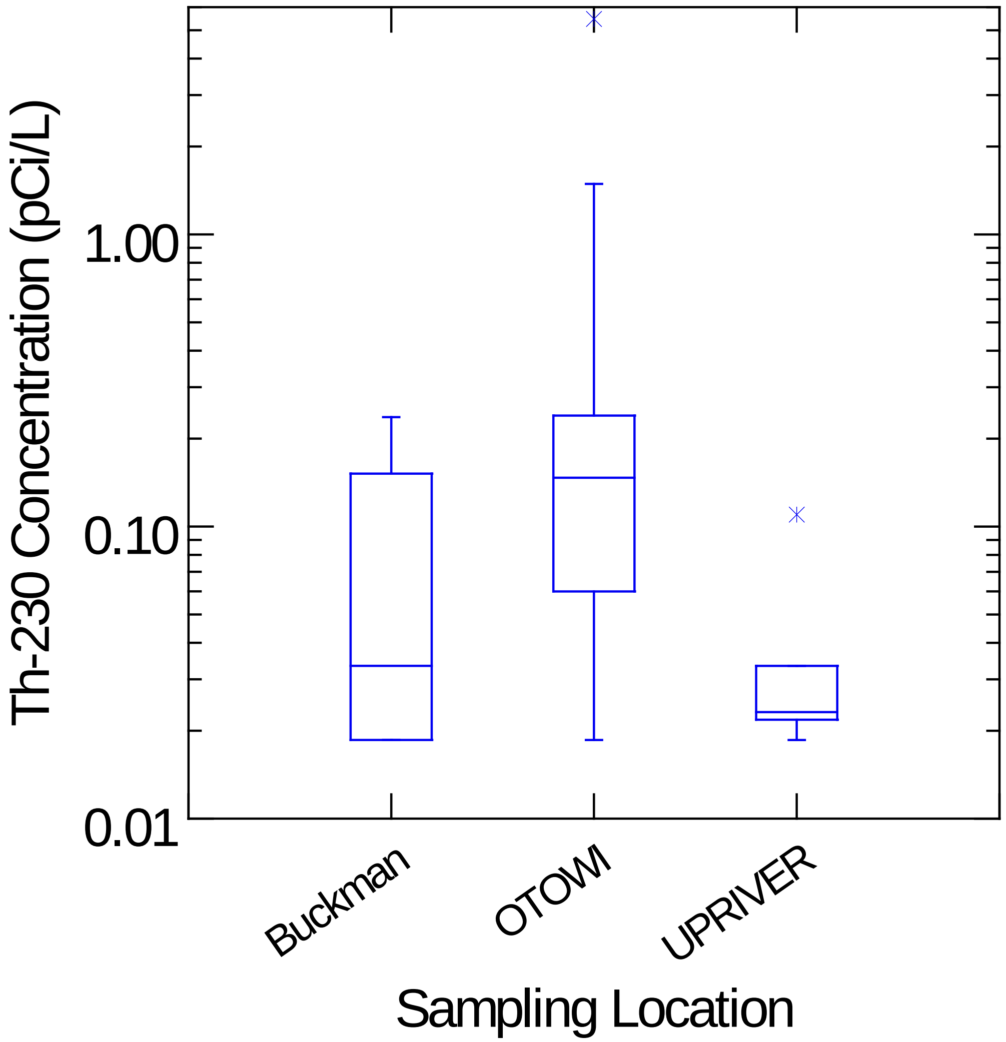

10.00
1.00
0.10
Ra-228 Concentration (pCi/L)
BUCKMAN
OTOWI
UPRIVER
Sampling Location

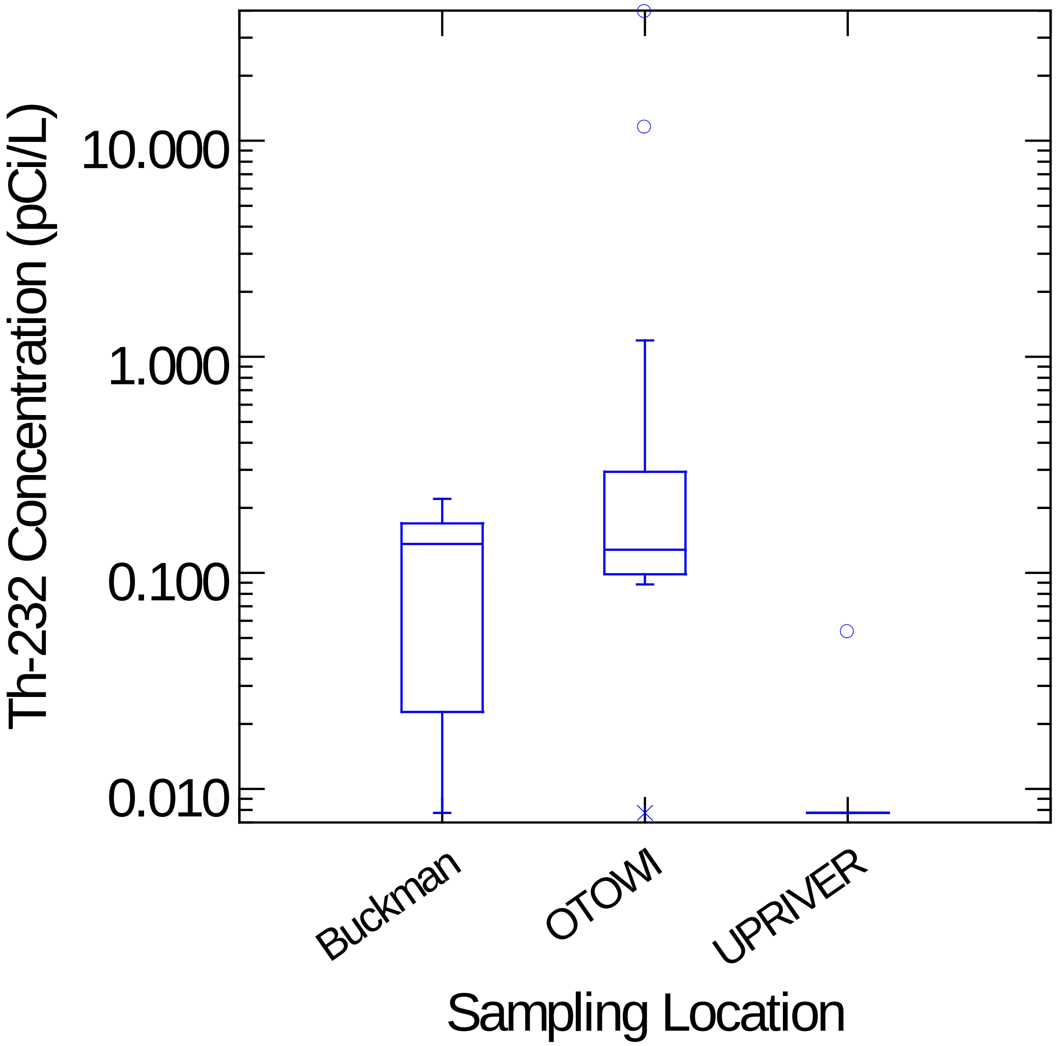


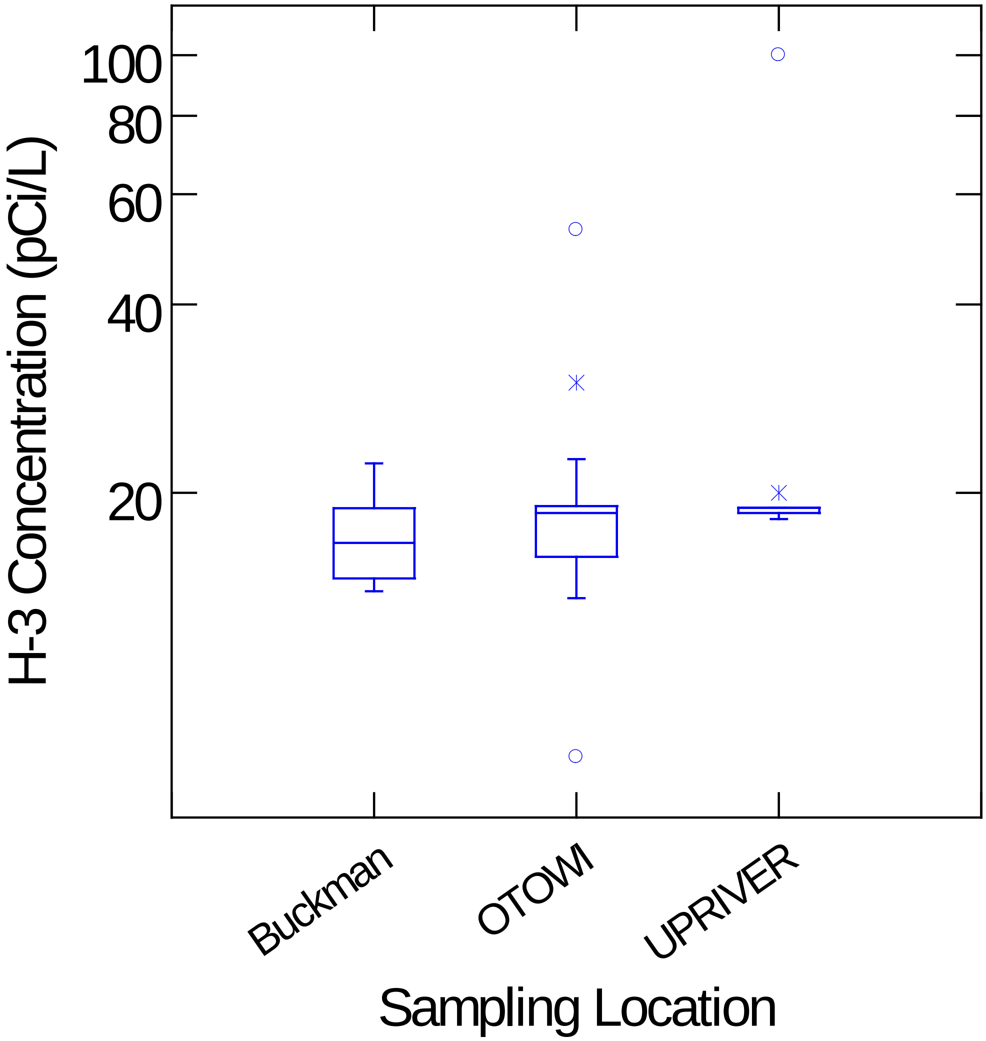
Ra-226 Concentration (pCi/L)
10.000
1.000
0.100
0.010
BUCKMAN
OTOWI
UPRIVER
Sampling Location

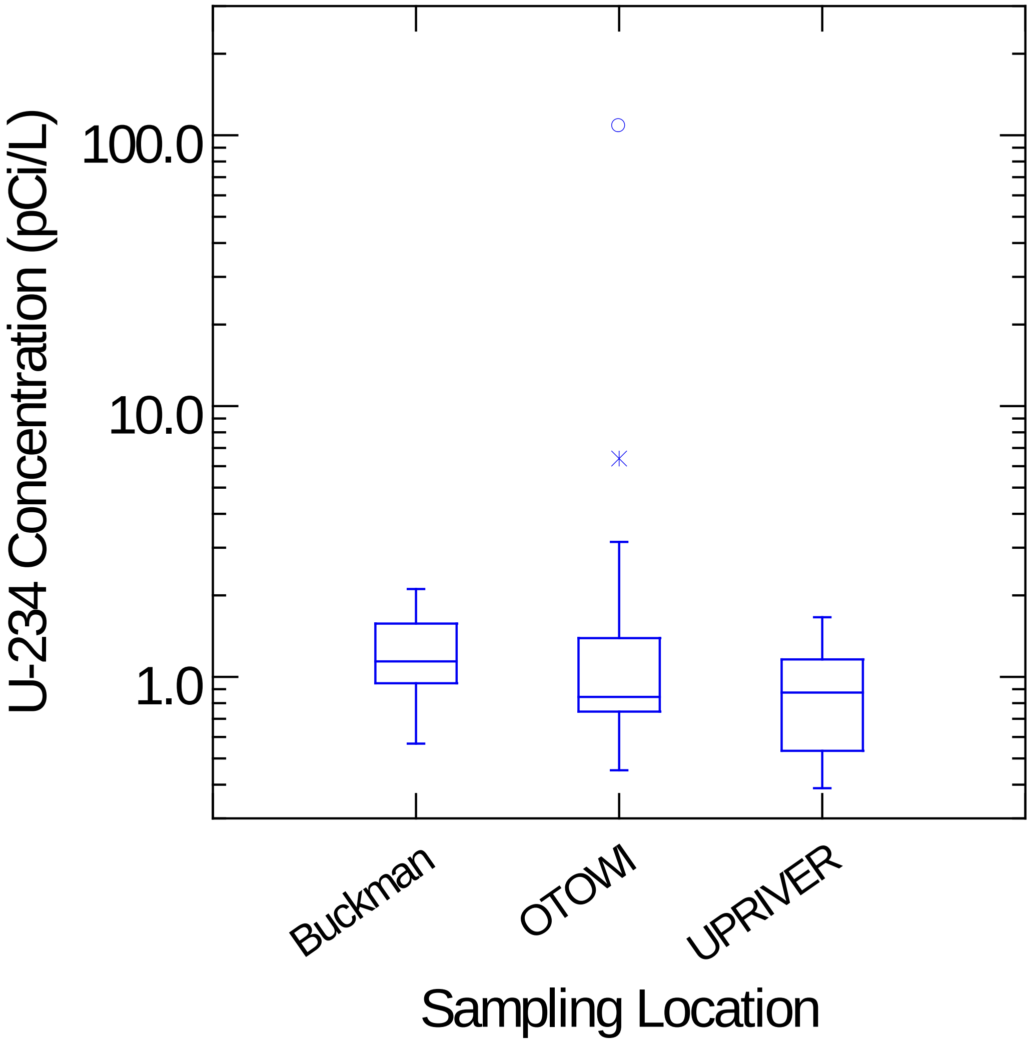

Sr-90 Concentration (pCi/L)
1.000
0.100
0.010
OTOWI
UPRIVER
Sampling Location

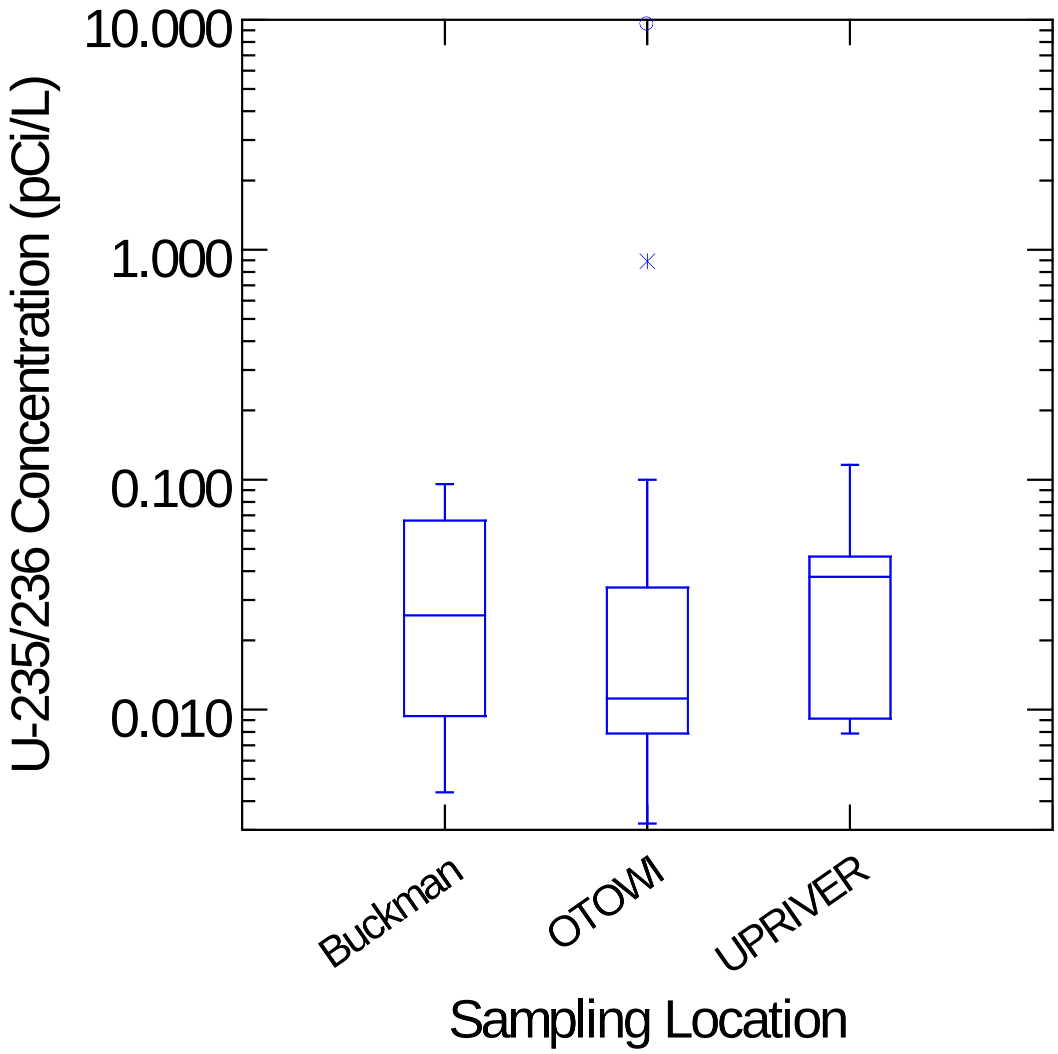

Th-228 Concentration (pCi/L)
100.000
10.000
1.000
0.100
0.010
Buckman
OTOWI
UPRIVER
Sampling Location

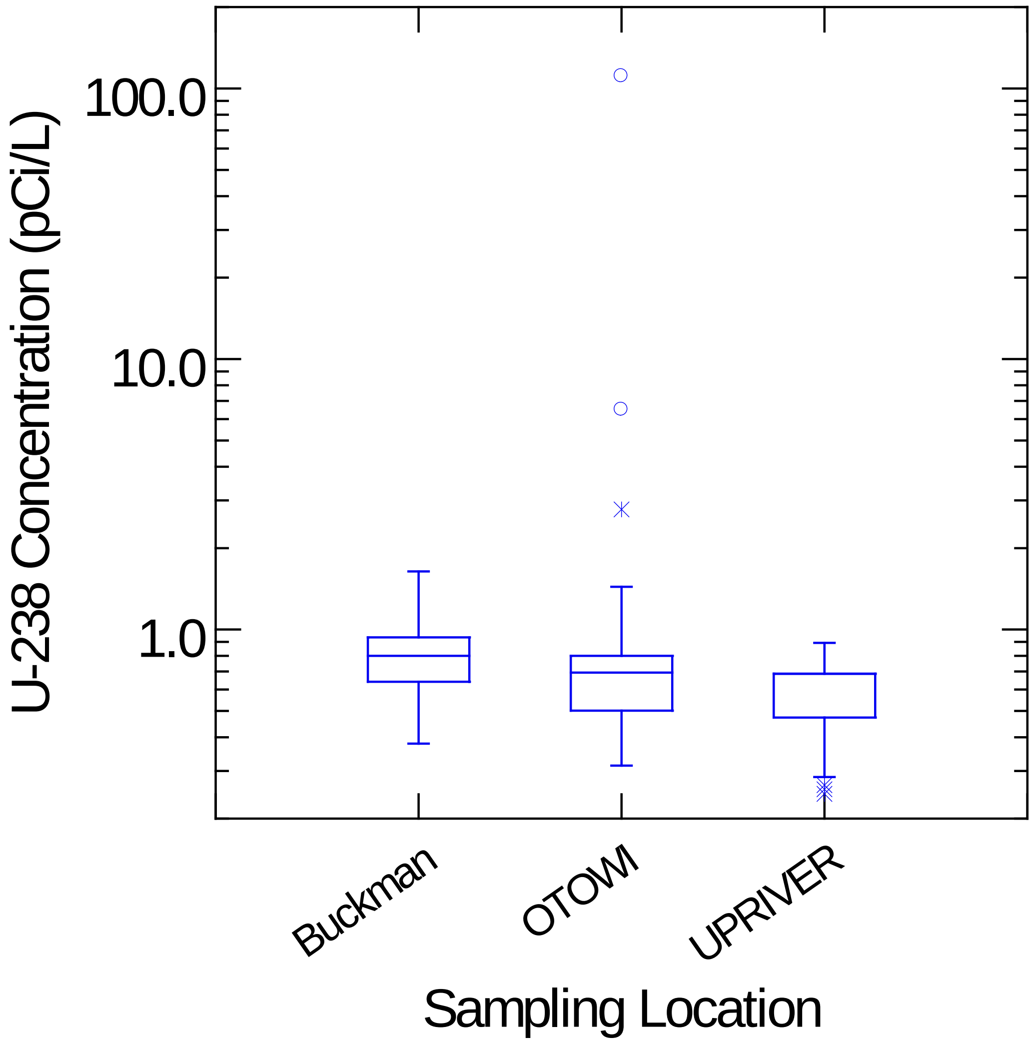

Th-230 Concentration (pCi/L)
1.00
0.10
0.01
Buckman
OTOWI
UPRIVER
Sampling Location


Th-232 Concentration (pCi/L)
10.000
1.000
0.100
0.010
Buckman
OTOWI
UPRIVER
Sampling Location

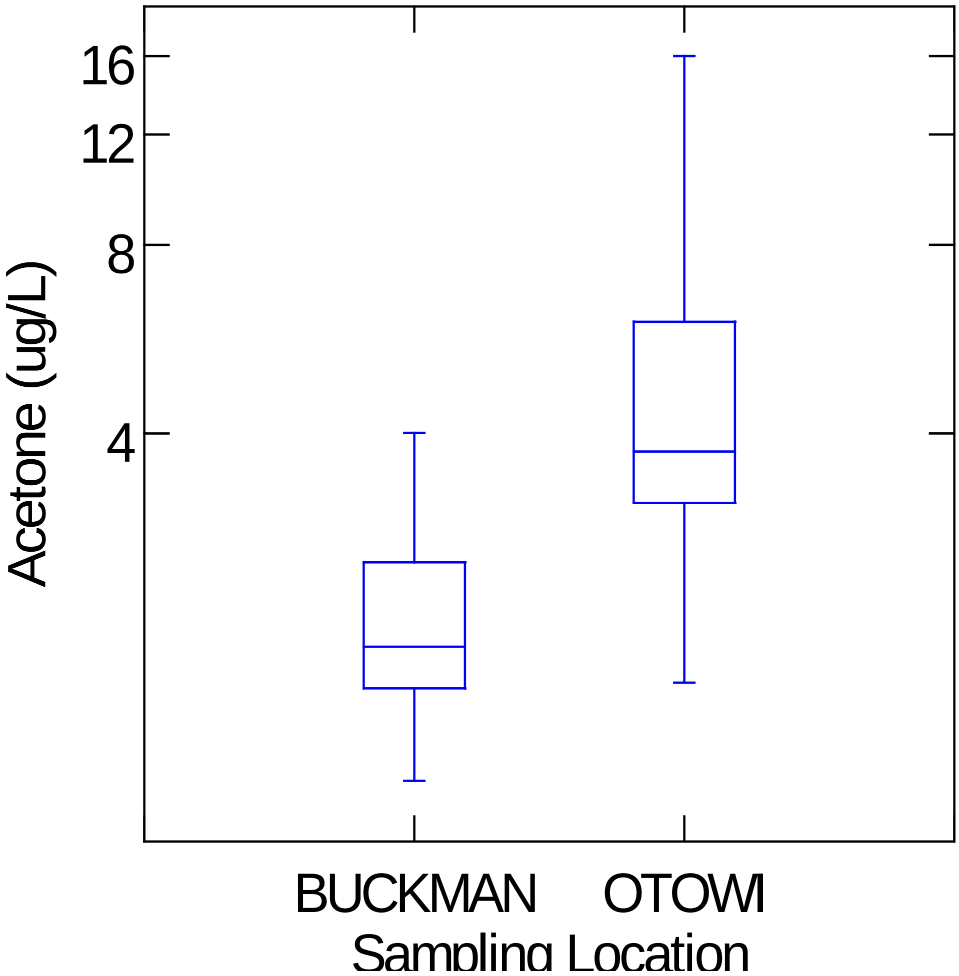

H-3 Concentration (pCi/L)
100
80
60
40
20
Buckman
OTOWI
UPRIVER
Sampling Location

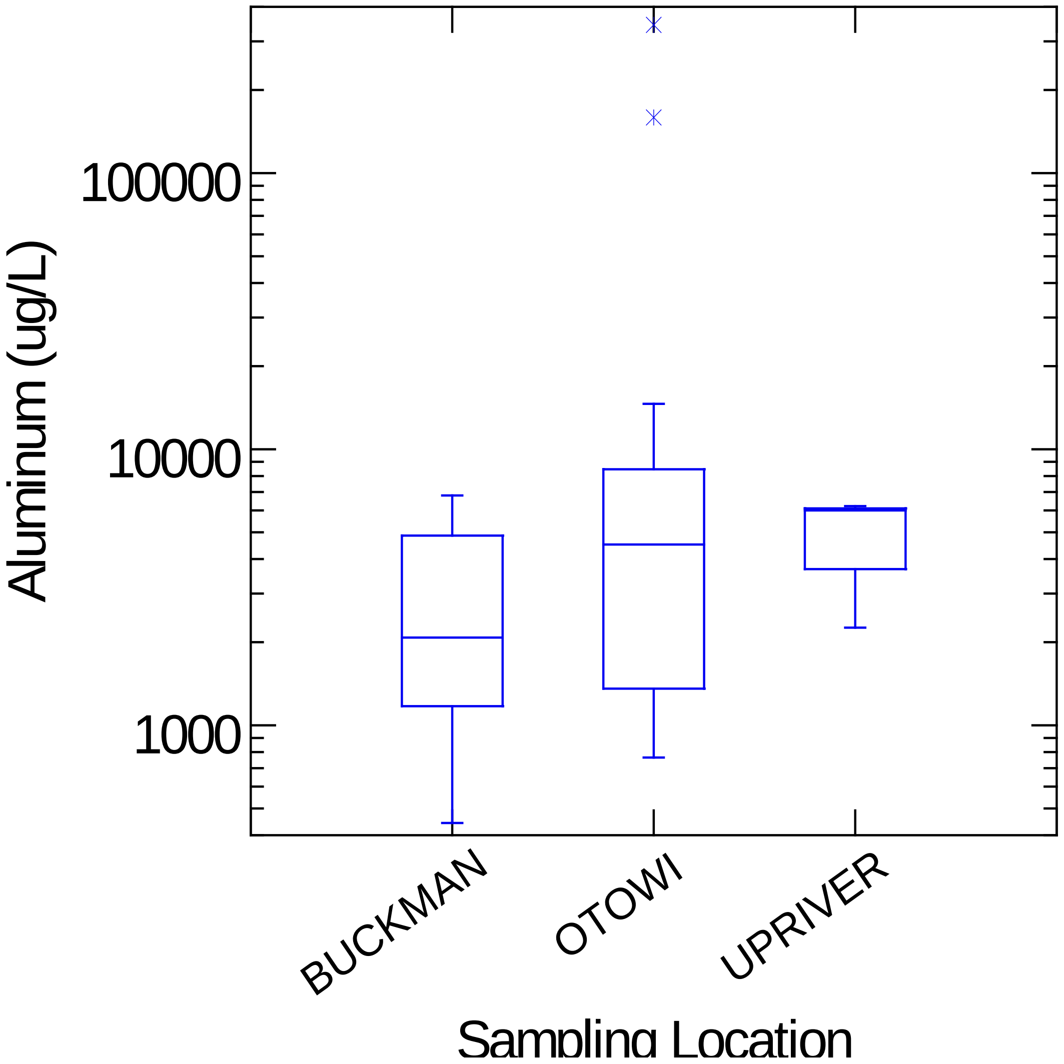

U-234 Concentration (pCi/L)
100.0
10.0
1.0
Buckman
OTOWI
UPRIVER
Sampling Location

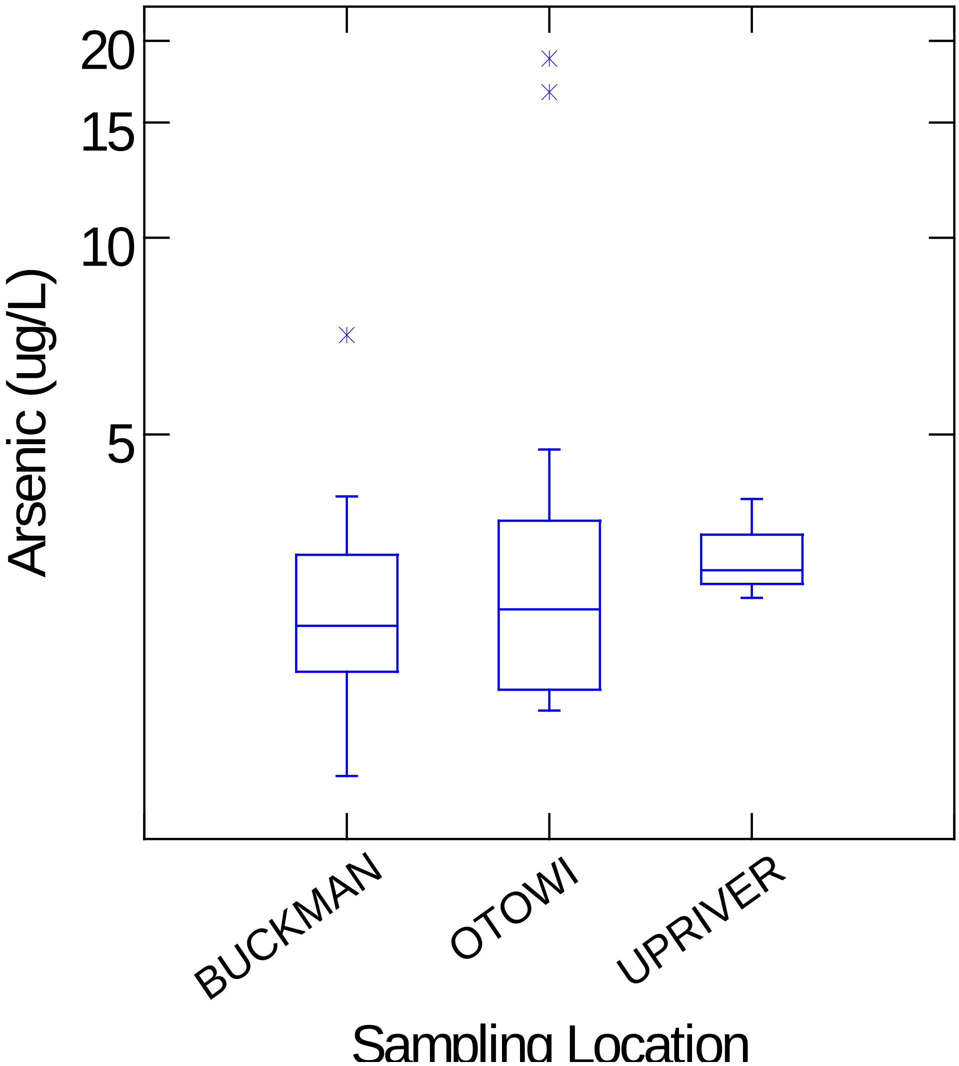

10.000
1.000
0.100
0.010
U-235/236 Concentration (pCi/L)
Buckman
OTOWI
UPRIVER
Sampling Location

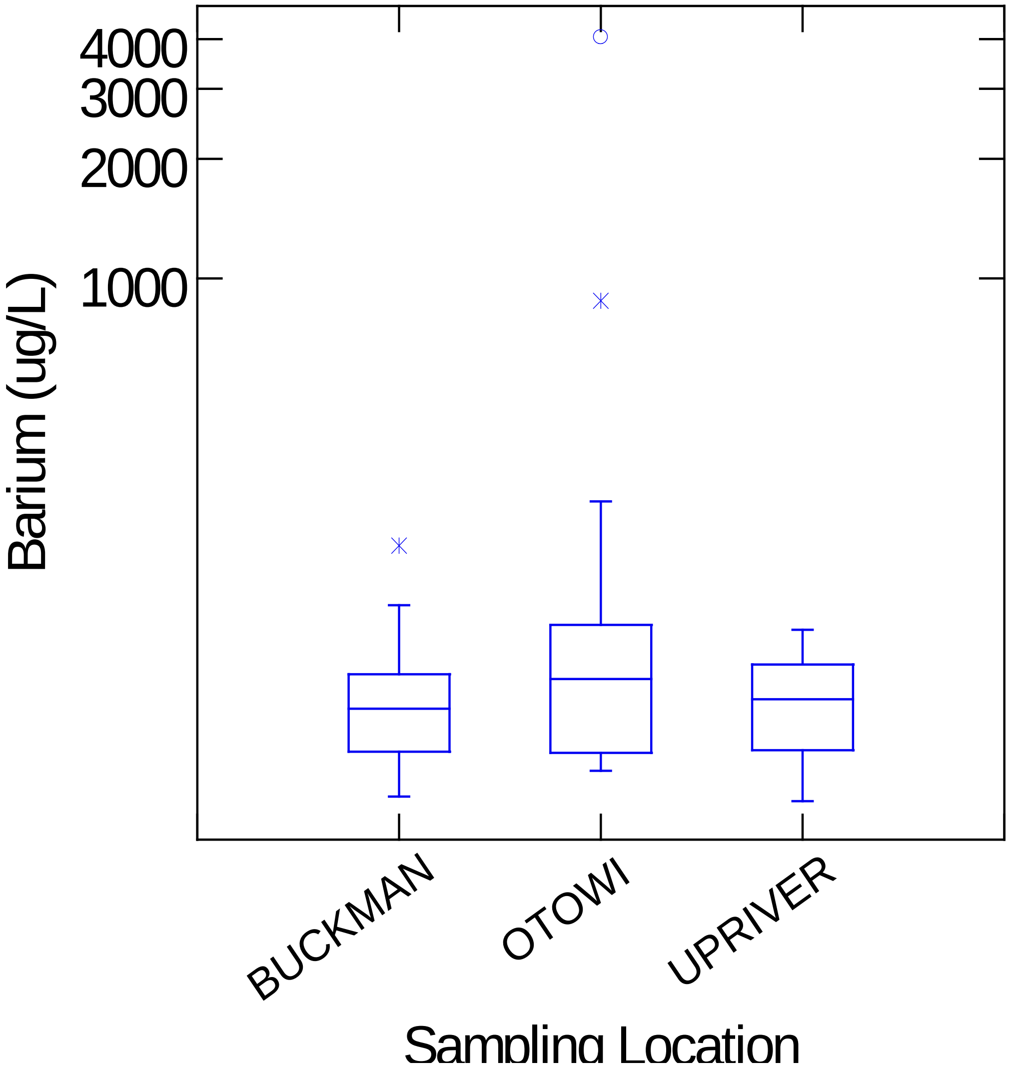

U-238 Concentration (pCi/L)
100.0
10.0
1.0
Buckman
OTOWI
UPRIVER
Sampling Location

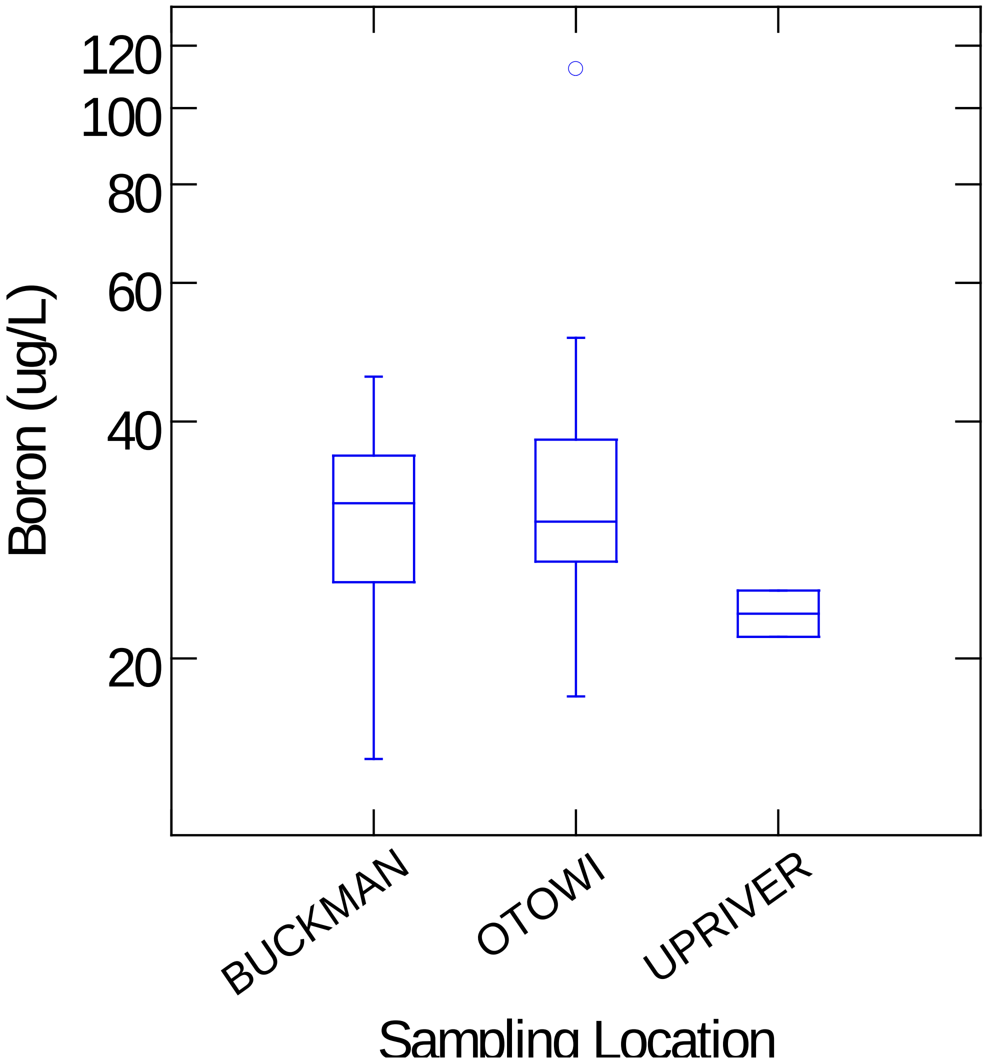
Samples collected after 2000 - Chemicals

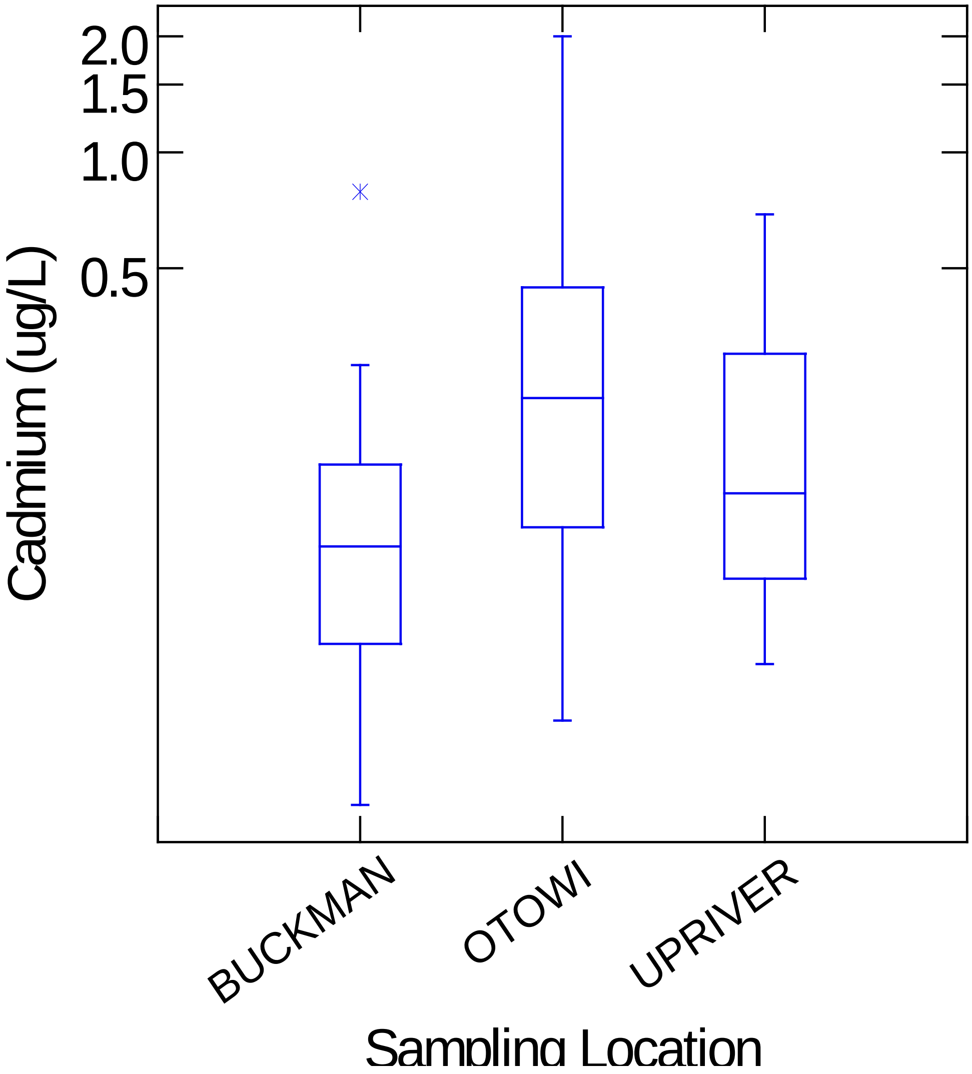


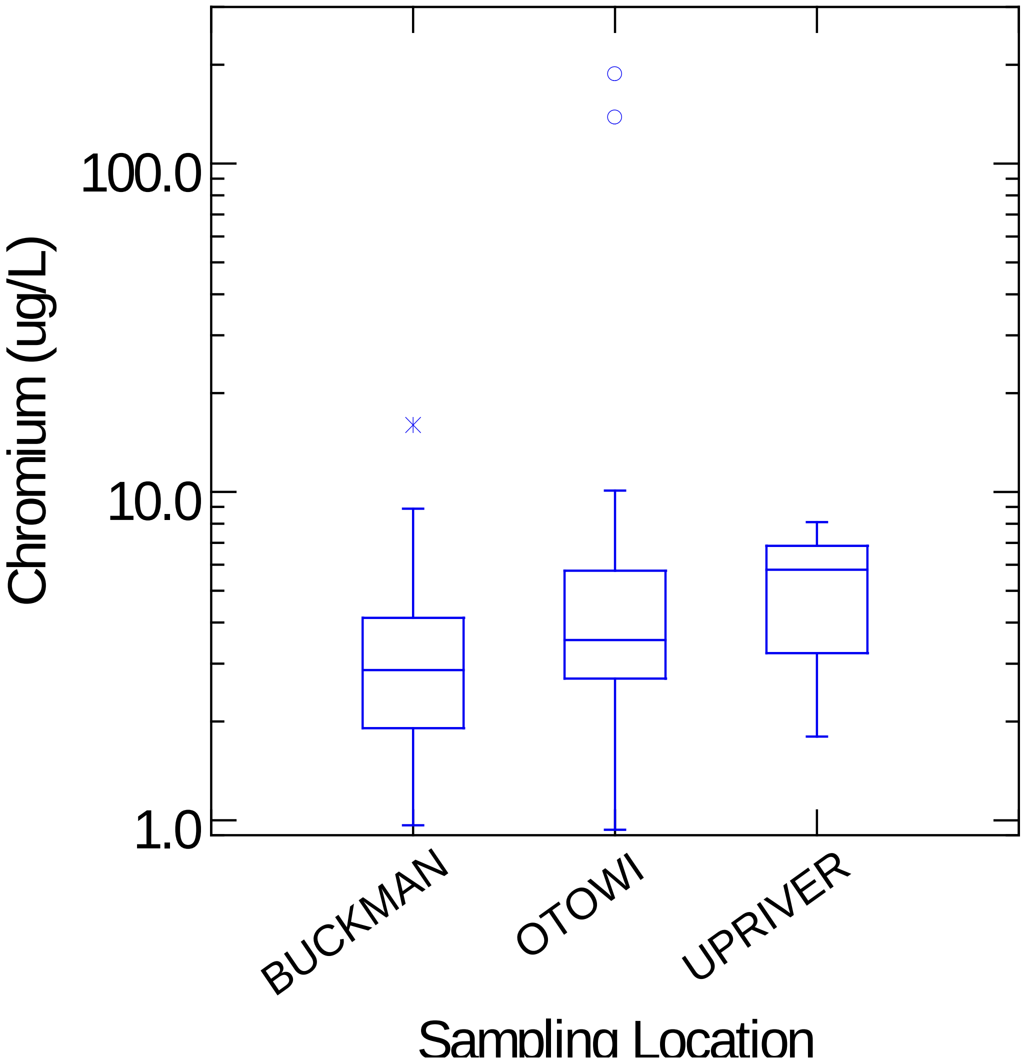

Aluminum (ug/L)
100000
10000
1000
BUCKMAN
OTOWI
UPRIVER
Sampling Location


20
15
10
5
Arsenic (ug/L)
BUCKMAN
OTOWI
UPRIVER
Sampling Location

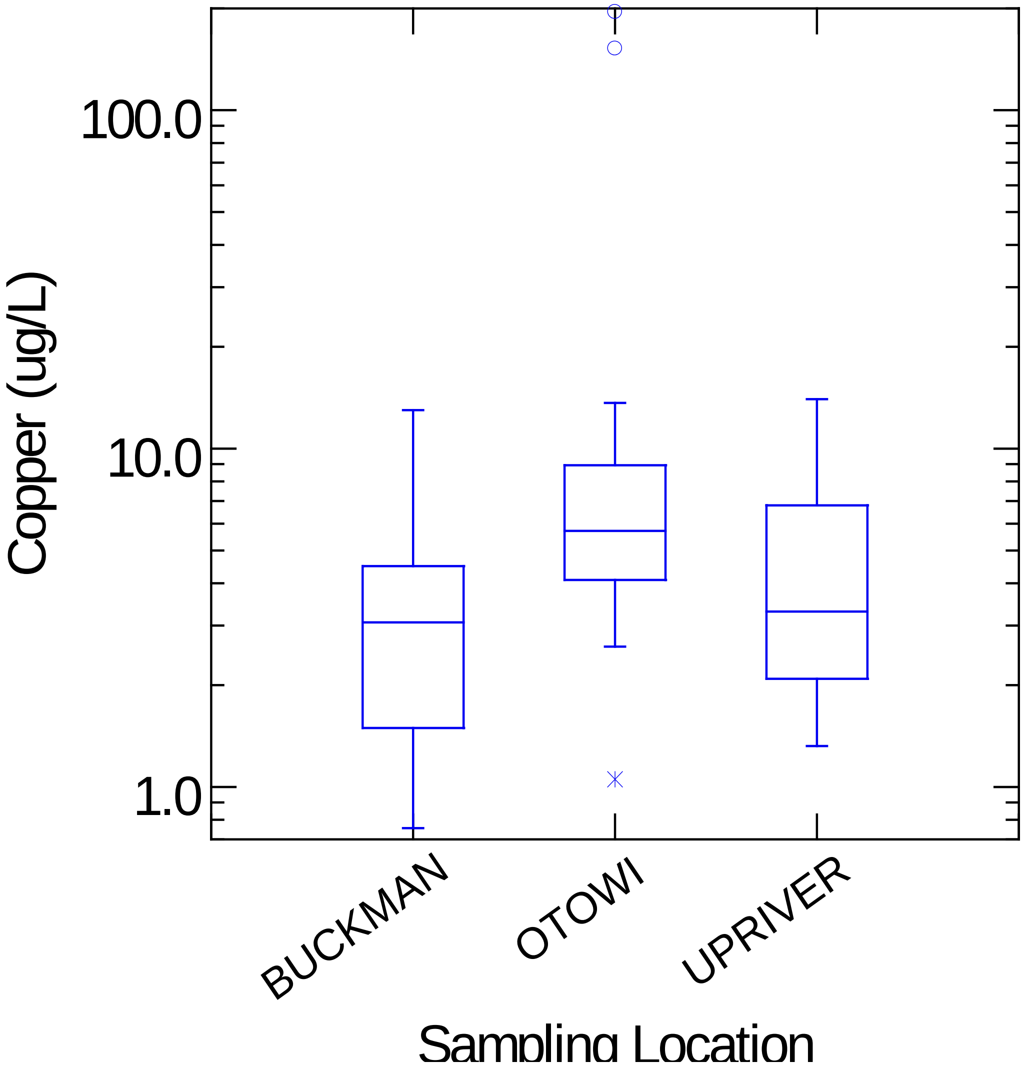

4000
3000
2000
1000
Barium (ug/L)
BUCKMAN
OTOWI
UPRIVER
Sampling Location

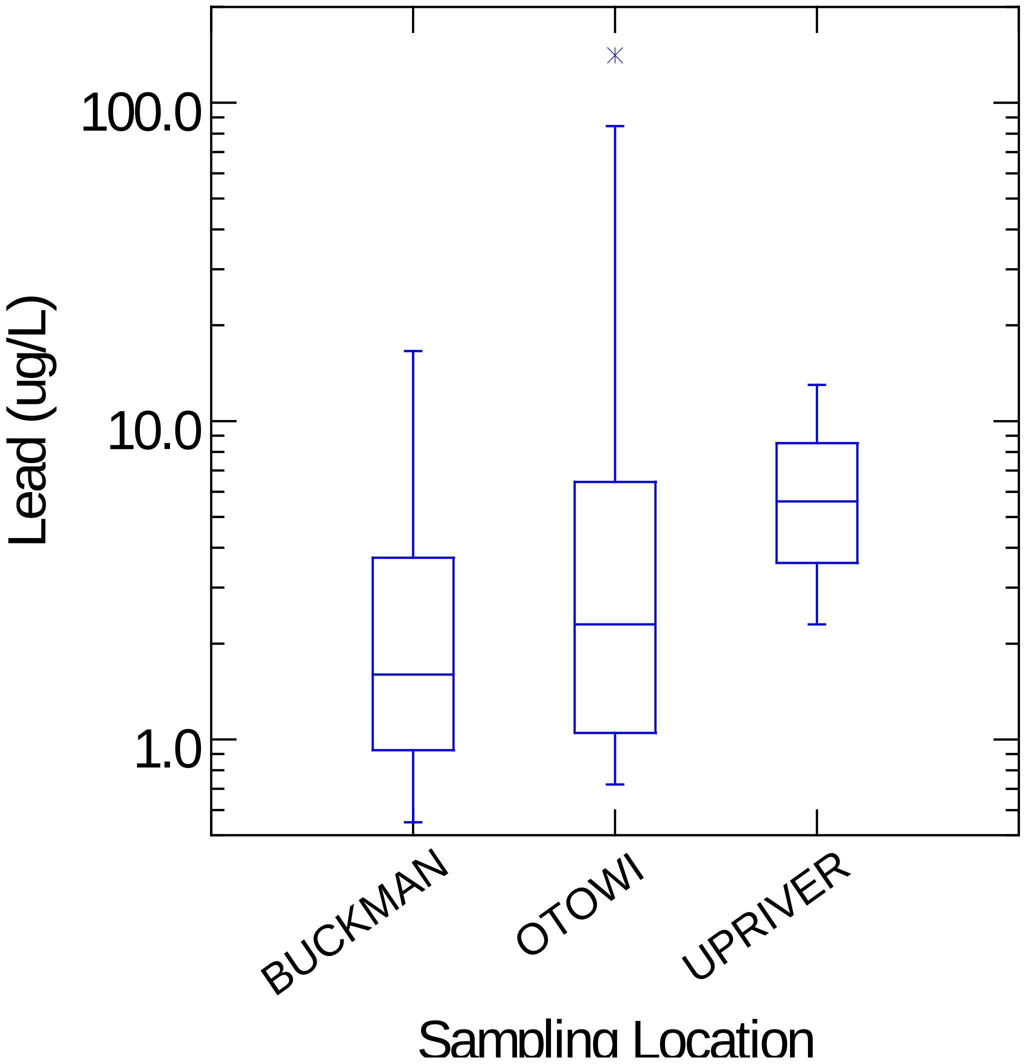

120
100
80
60
40
20
Boron (ug/L)
BUCKMAN
OTOWI
UPRIVER
Sampling Location

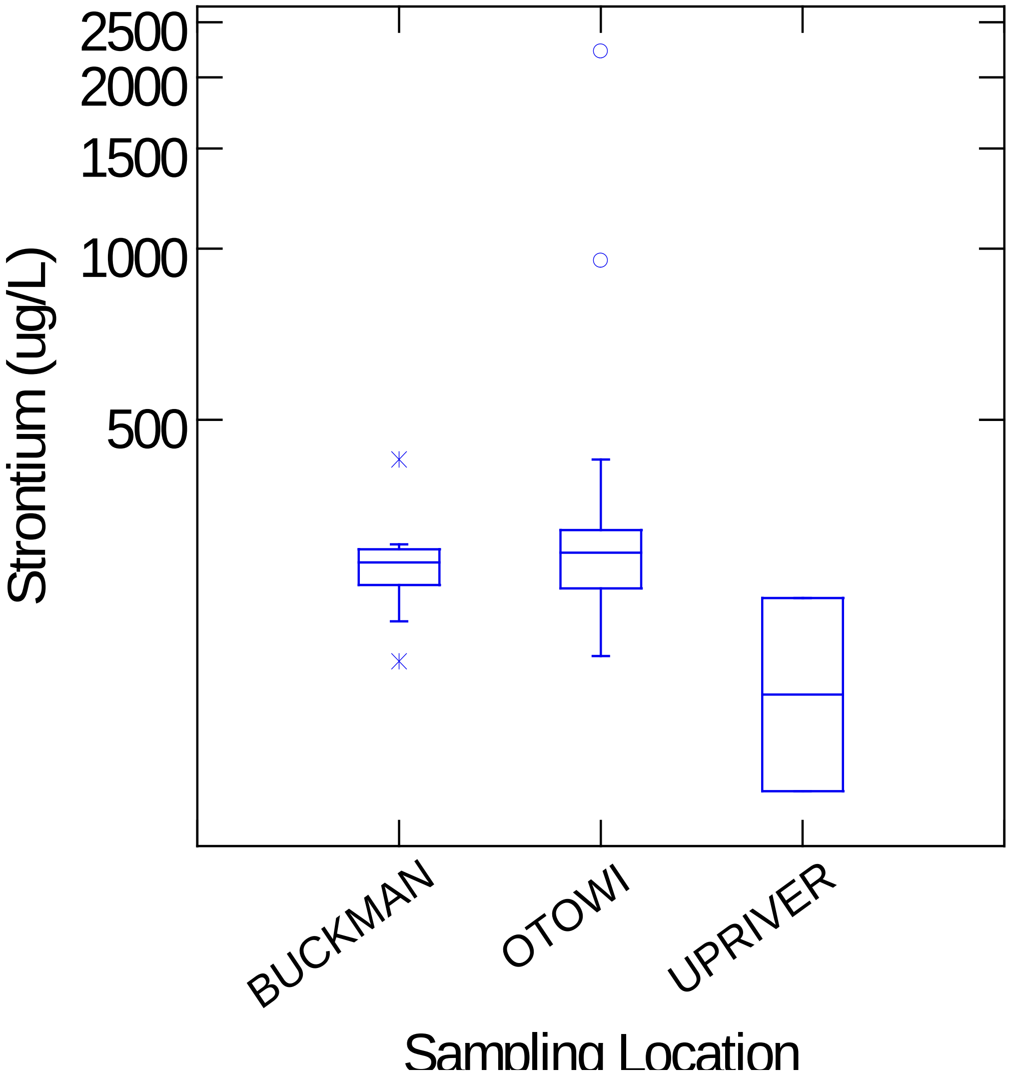

2.0
1.5
1.0
0.5
Cadmium (ug/L)
BUCKMAN
OTOWI
UPRIVER
Sampling Location

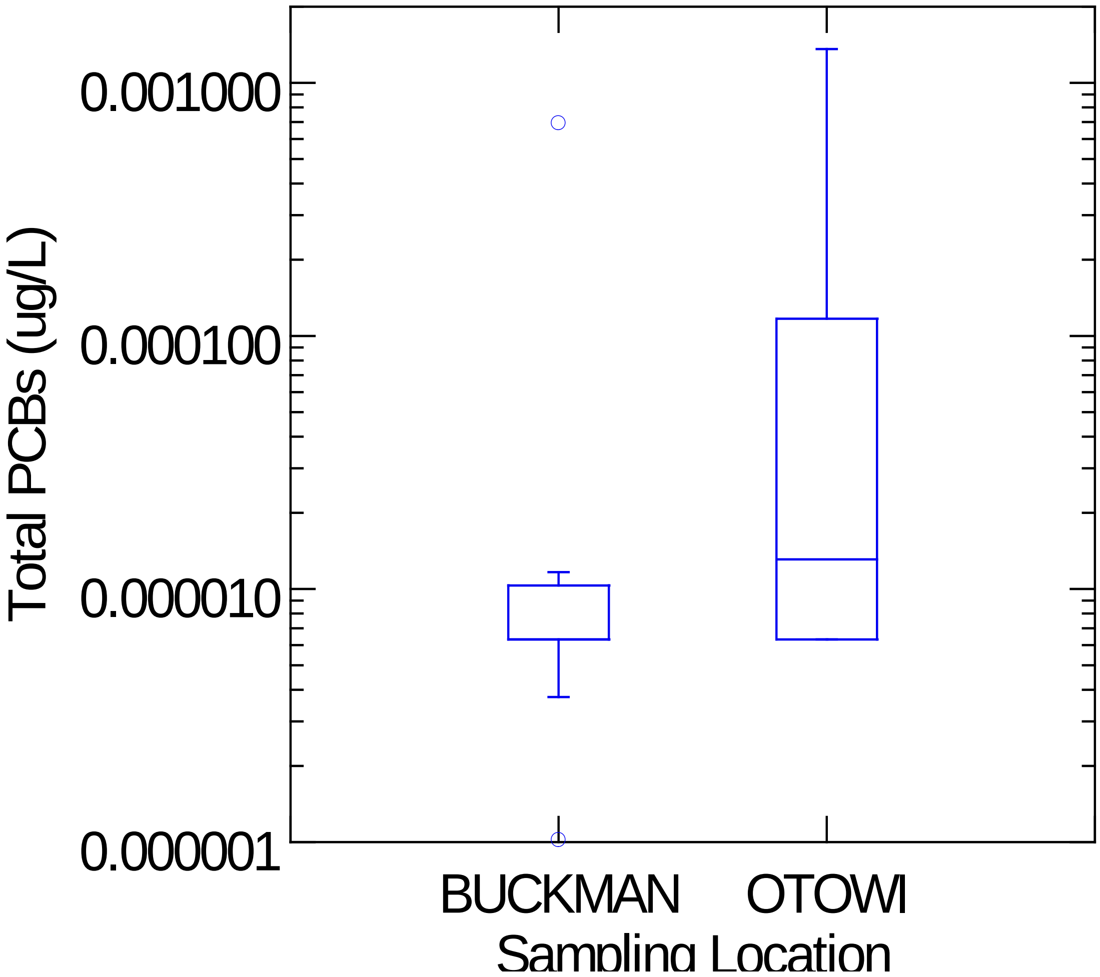


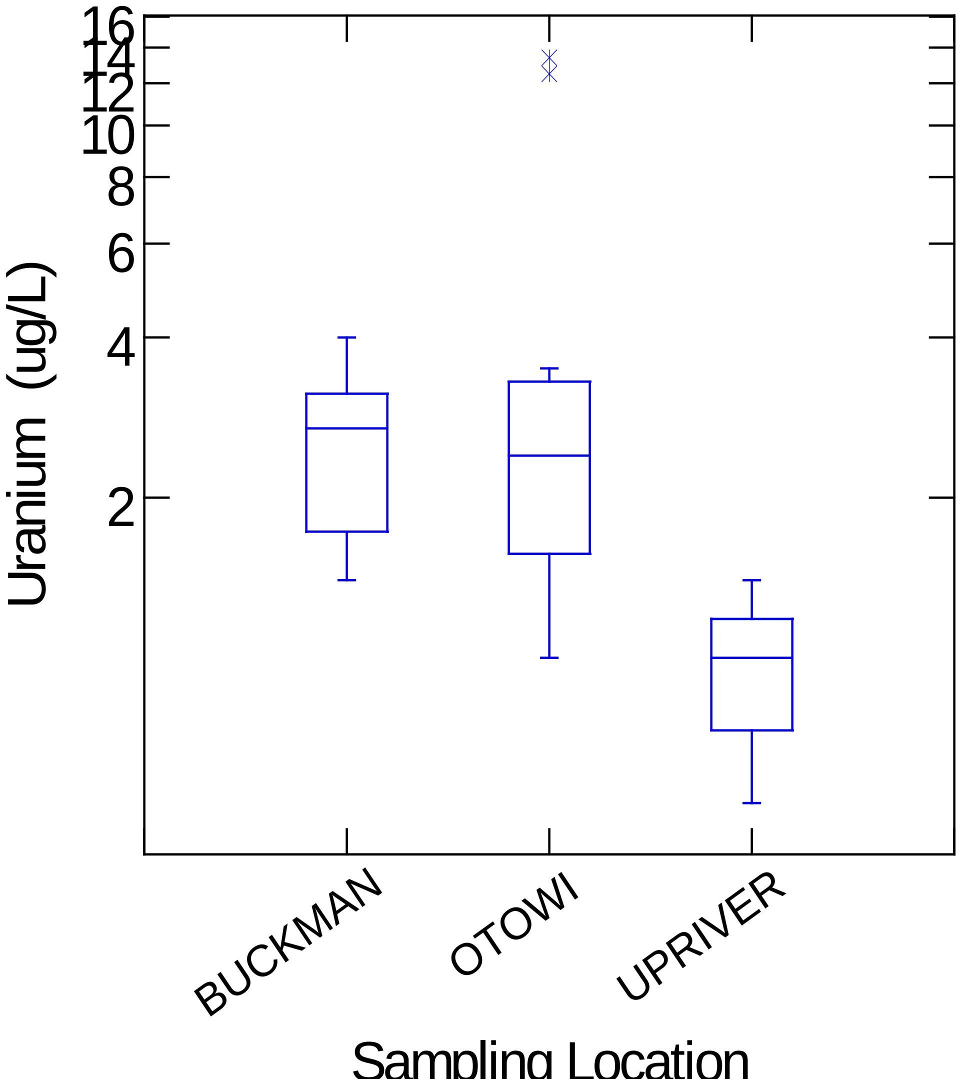
100.0
10.0
1.0
Chromium (ug/L)
BUCKMAN
OTOWI
UPRIVER
Sampling Location

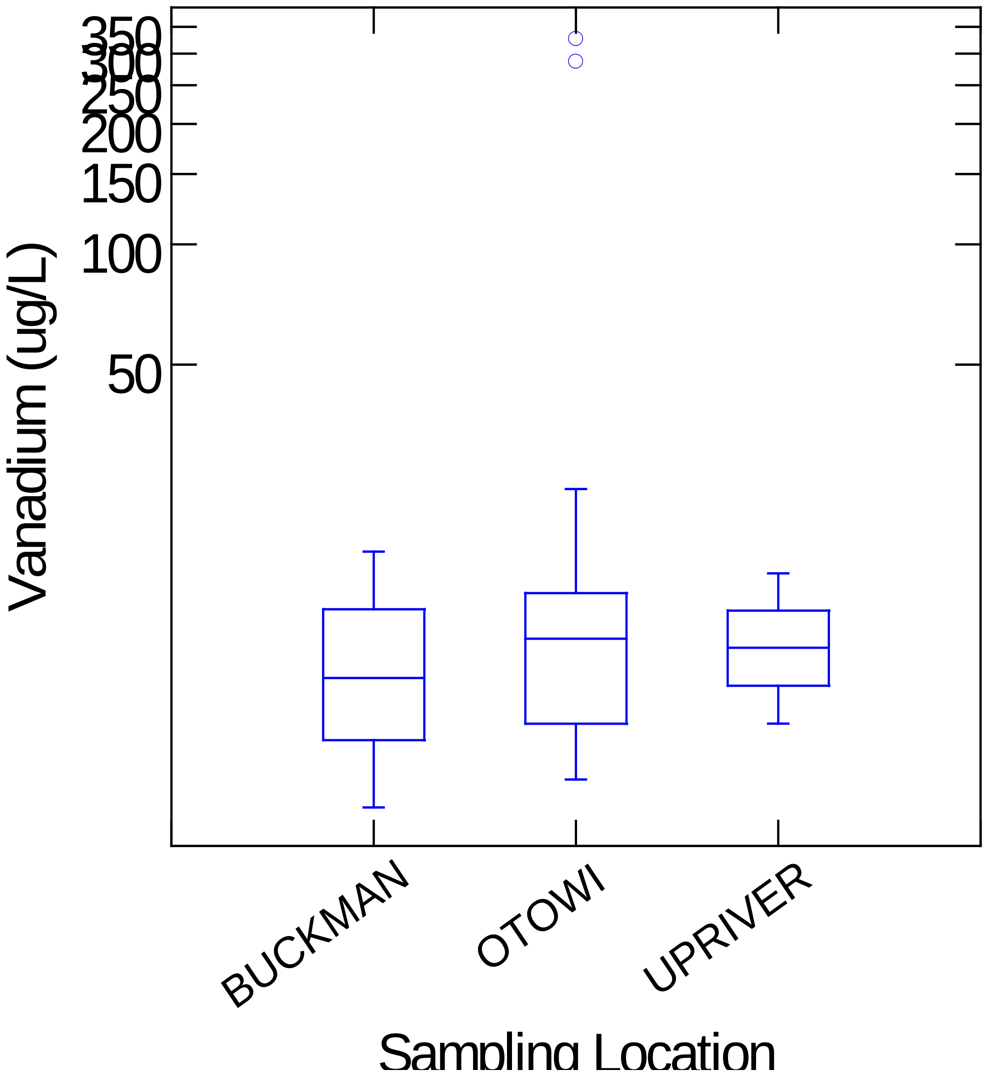

100.0
10.0
1.0
Copper (ug/L)
BUCKMAN
OTOWI
UPRIVER
Sampling Location


100.0
10.0
1.0
Lead (ug/L)
BUCKMAN
OTOWI
UPRIVER
Sampling Location

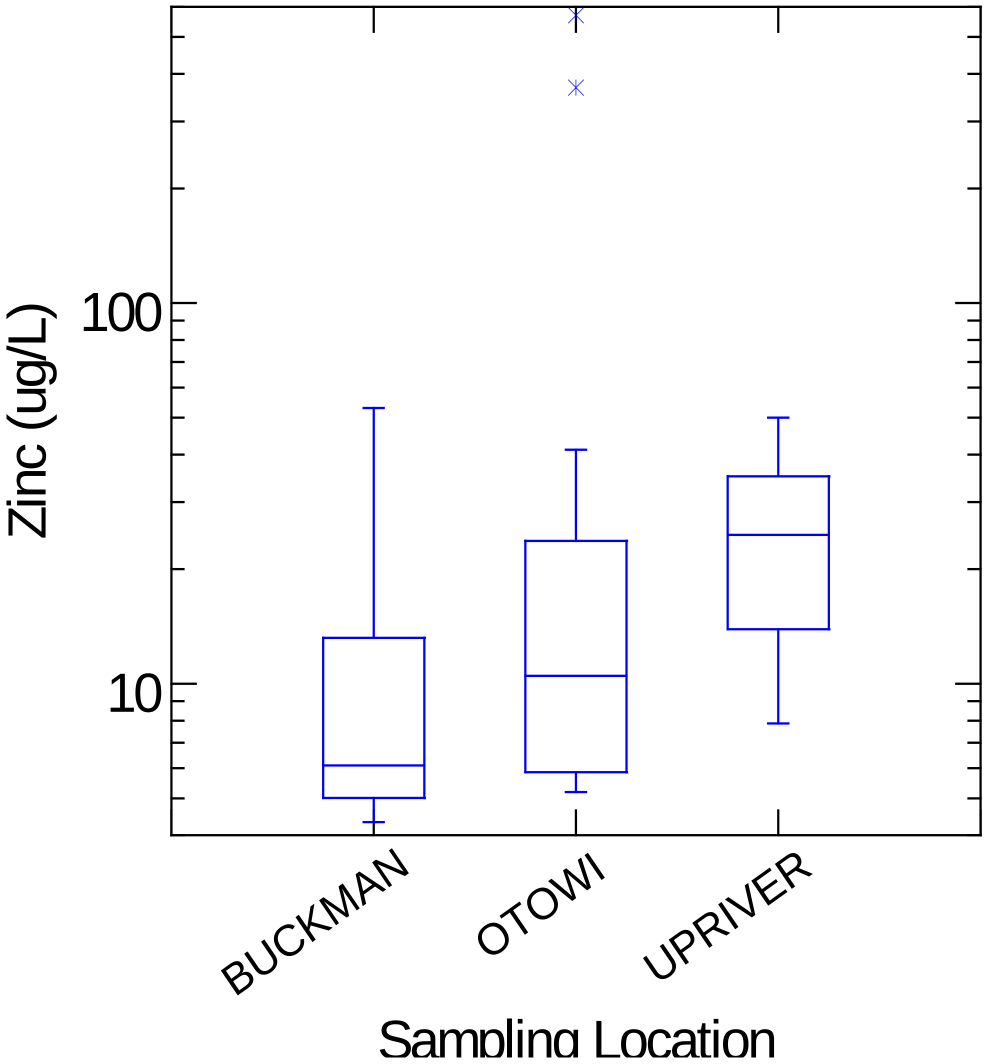

2500
2000
1500
1000
500
Strontium (ug/L)
BUCKMAN
OTOWI
UPRIVER
Sampling Location


Total PCBs (ug/L)
0.001000
0.000100
0.000010
0.000001
BUCKMAN
OTOWI
Sampling Location

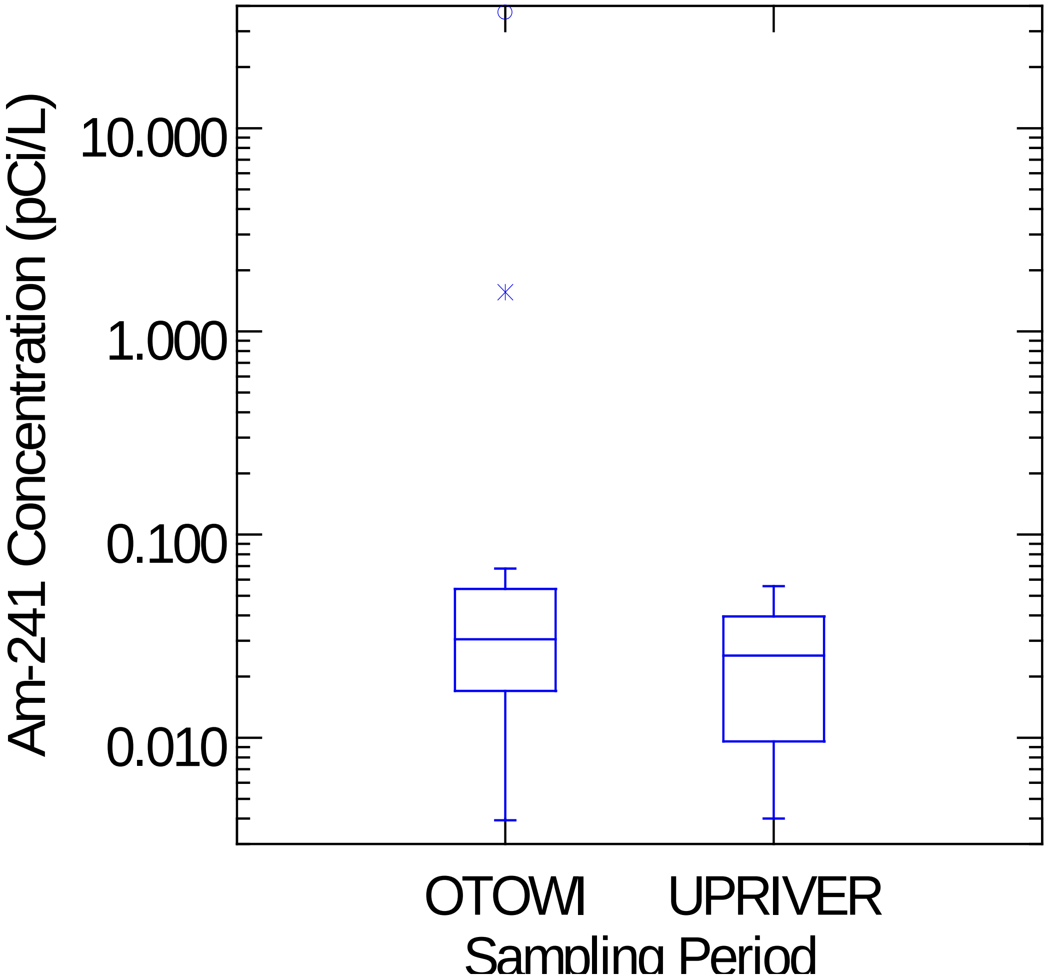

16
14
12
10
8
6
4
2
Uranium (ug/L)
BUCKMAN
OTOWI
UPRIVER
Sampling Location

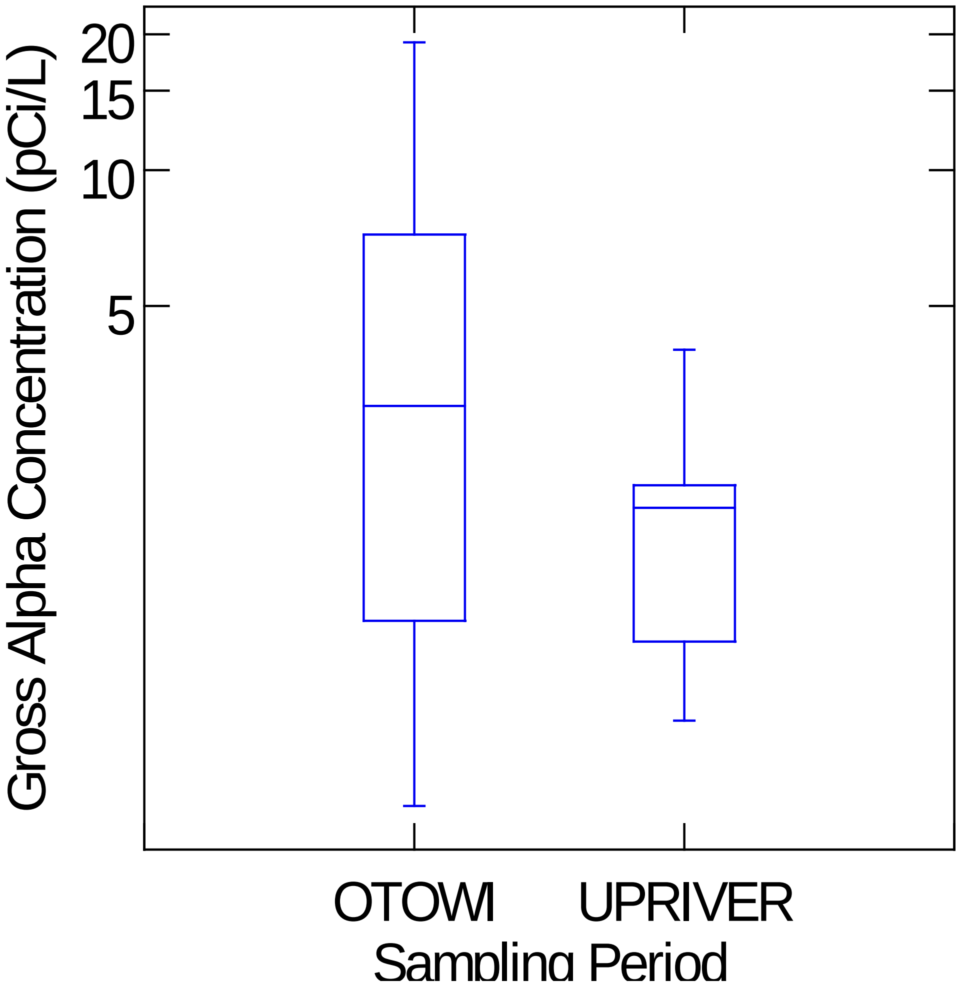


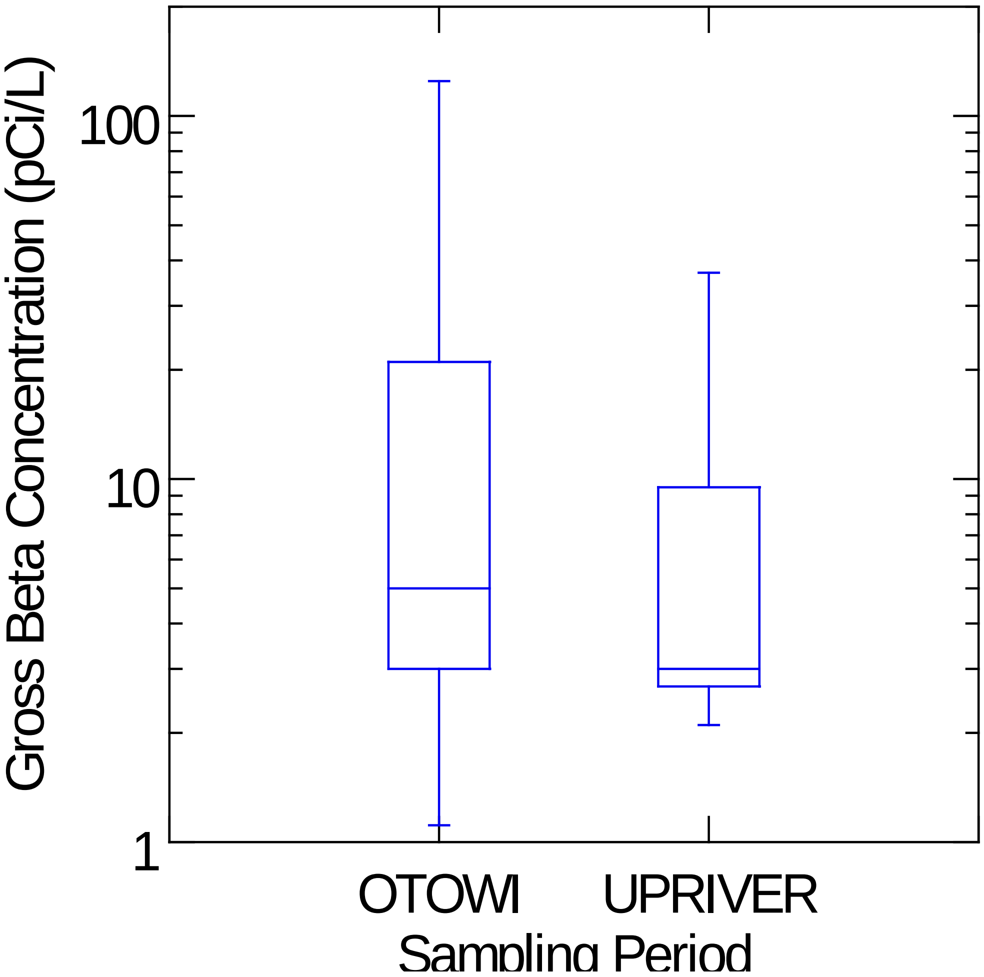
350
300
250
200
150
100
50
Vanadium (ug/L)
BUCKMAN
OTOWI
UPRIVER
Sampling Location

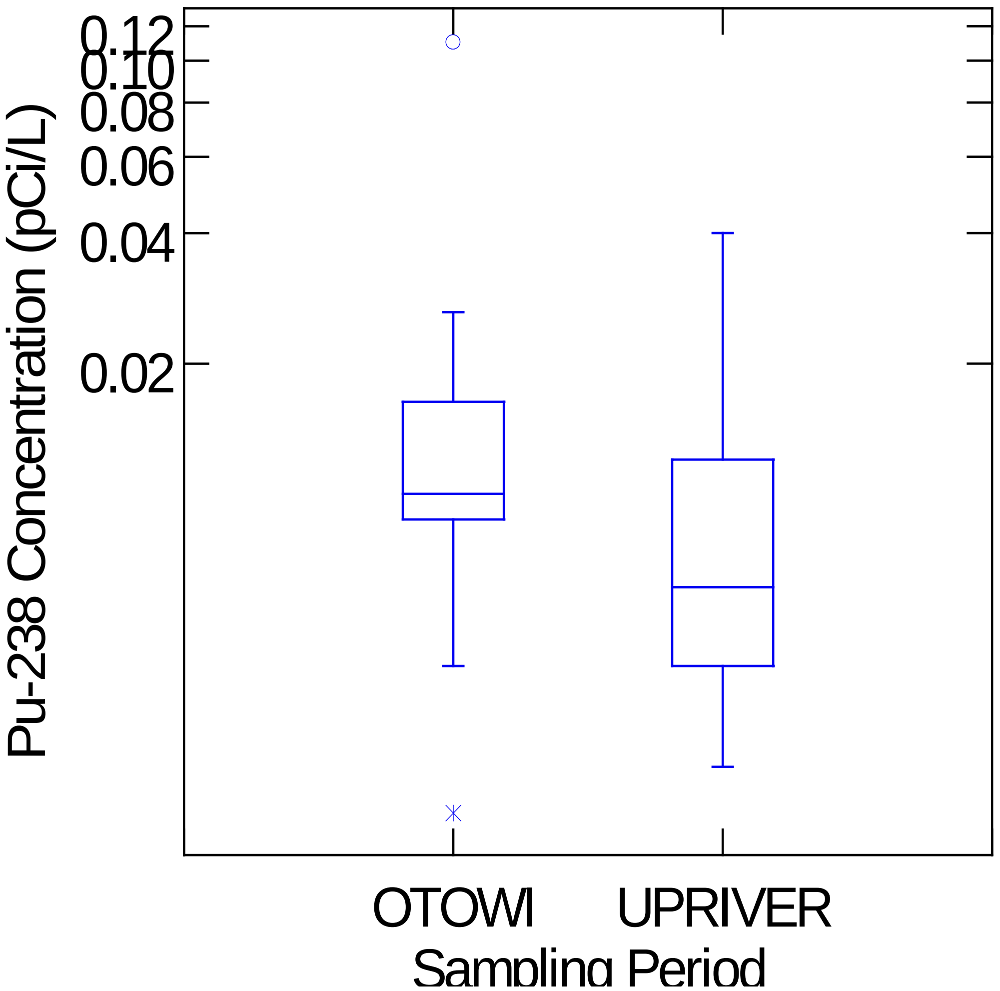

Zinc (ug/L)
100
10
BUCKMAN
OTOWI
UPRIVER
Sampling Location

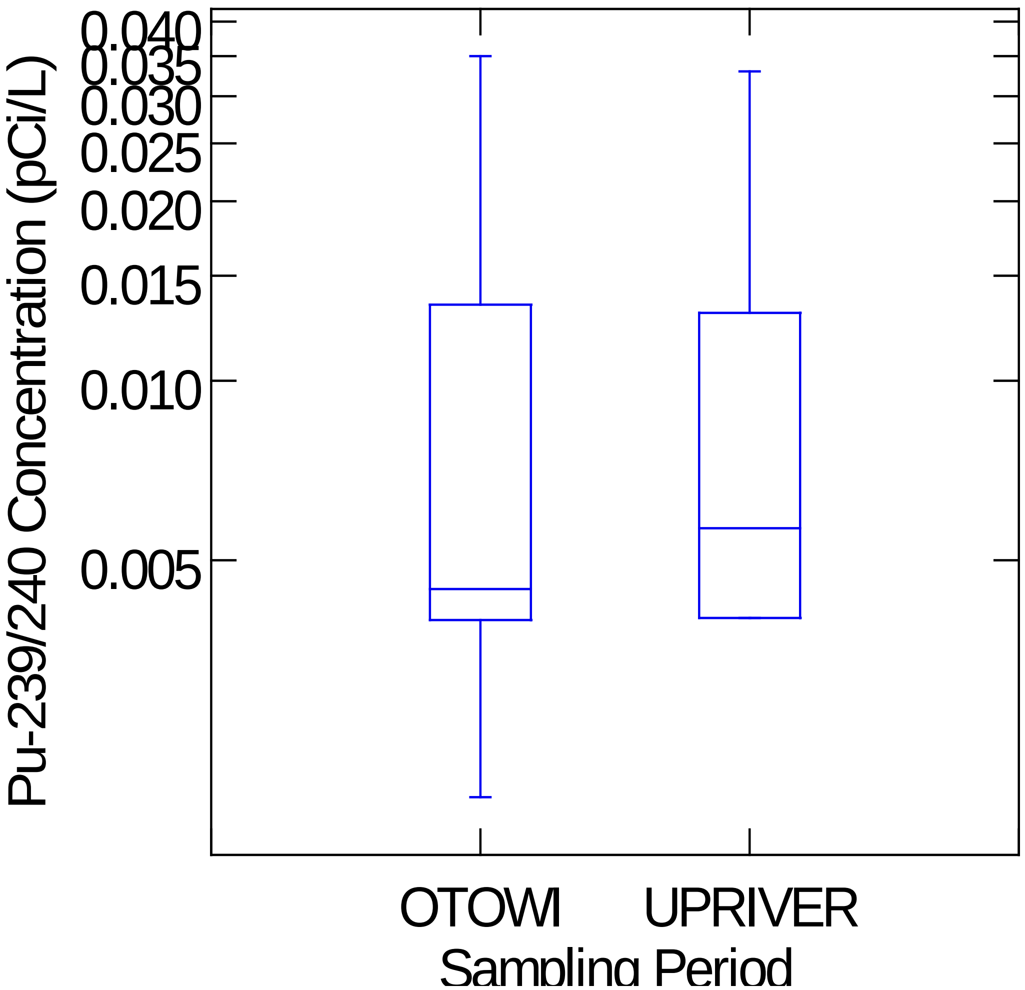
Samples collected between 1990 – 1999 - Radionuclides

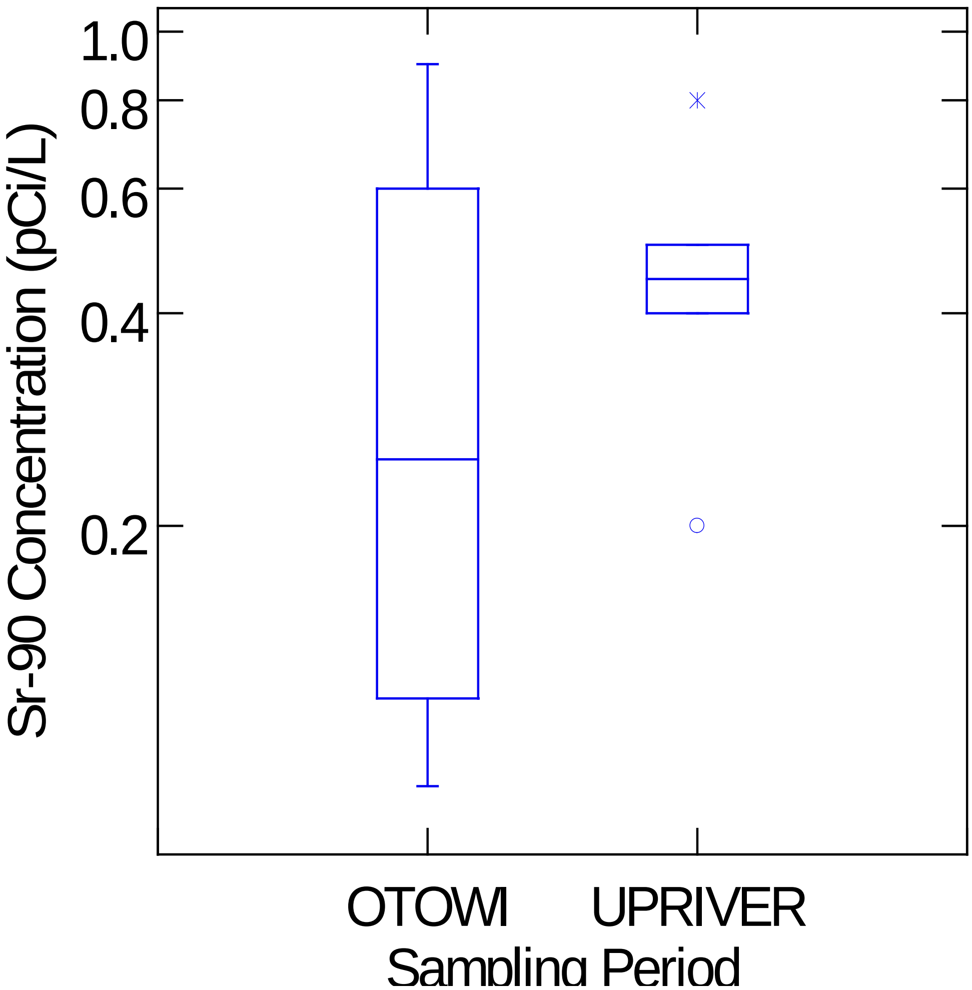


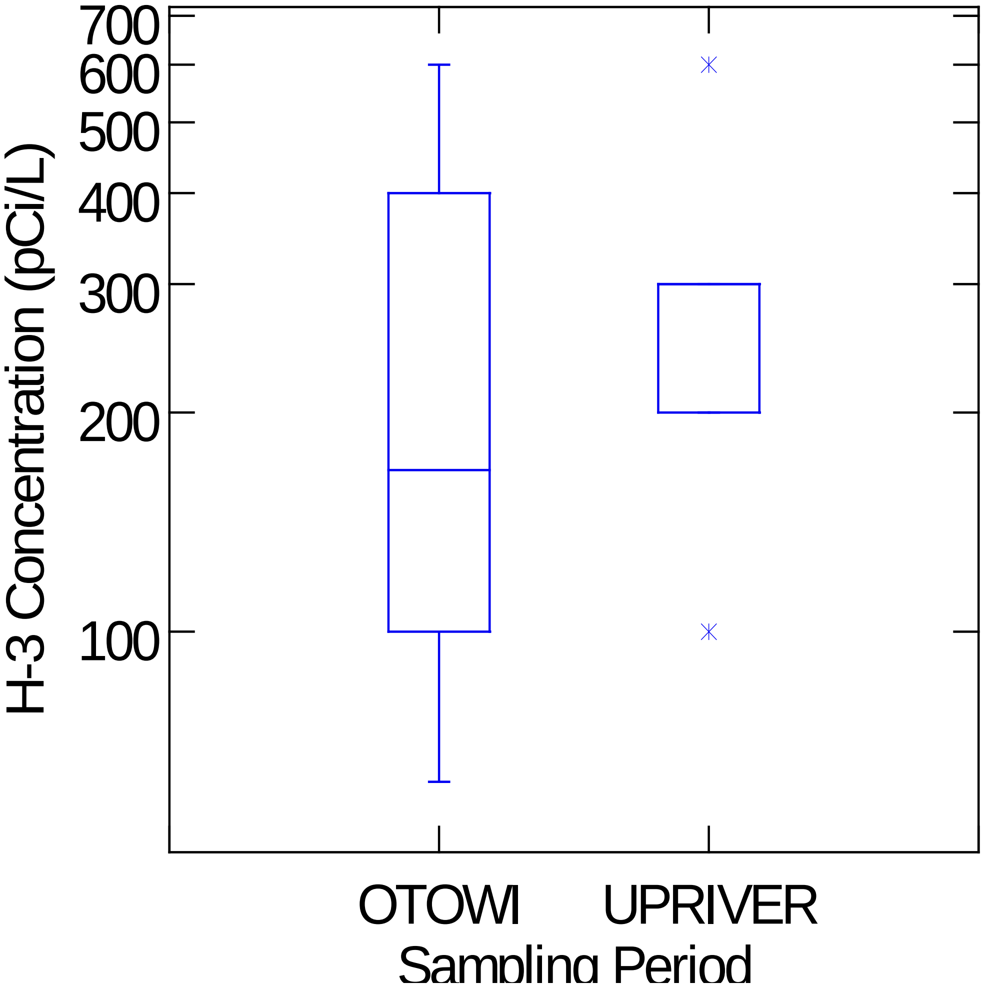

Gross Alpha Concentration (pCi/L)
20
15
10
5
OTOWI
UPRIVER
Sampling Period


Gross Beta Concentration (pCi/L)
100
10
1
OTOWI
UPRIVER
Sampling Period


0.12
0.10
0.08
0.06
0.04
0.02
Pu-238 Concentration (pCi/L)
OTOWI
UPRIVER
Sampling Period

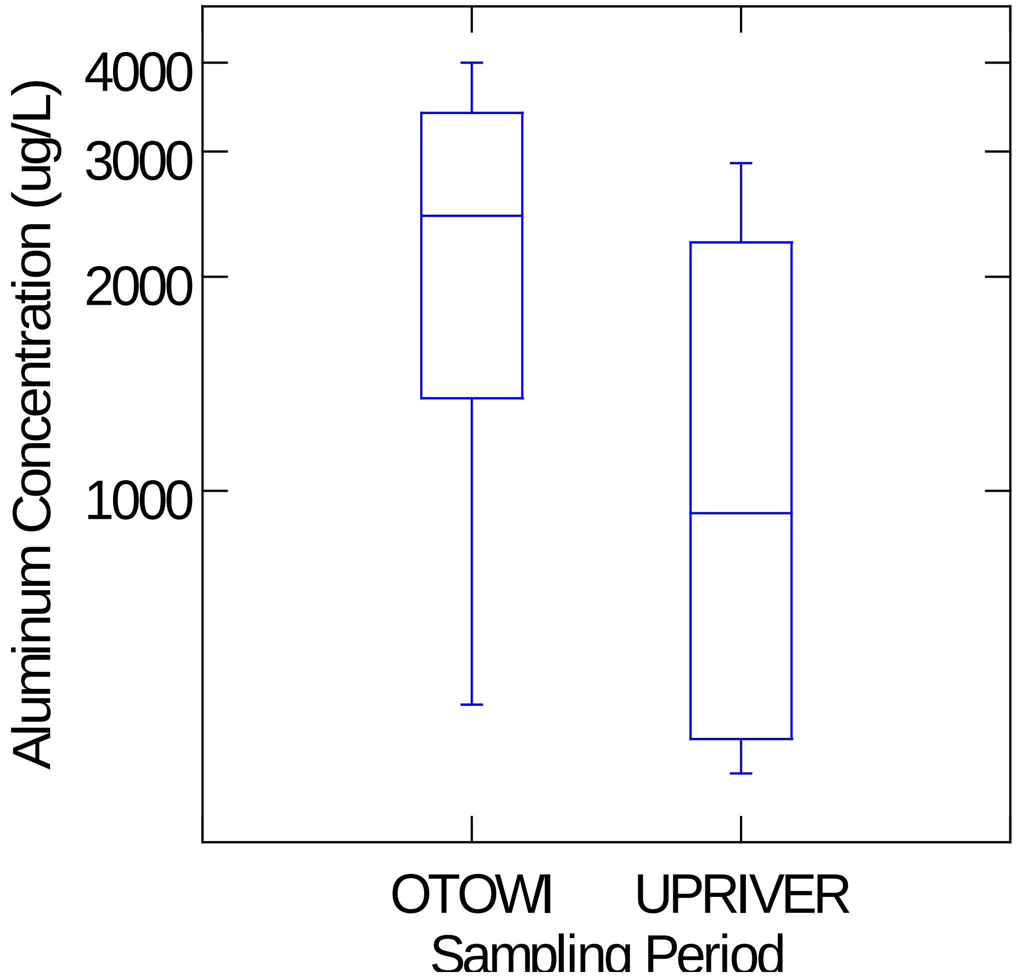

0.040
0.035
0.030
0.025
0.020
0.015
0.010
0.005
Pu-239/240 Concentration (pCi/L)
OTOWI
UPRIVER
Sampling Period

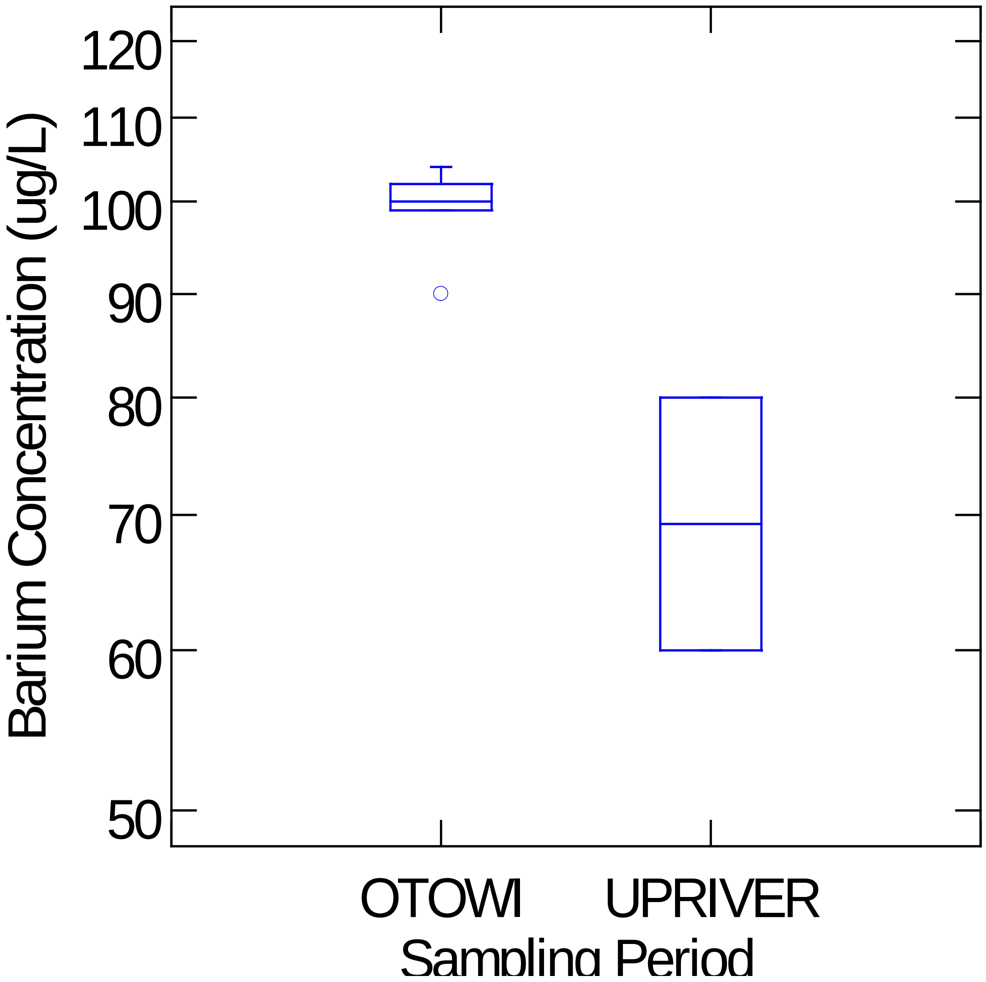

1.0
0.8
0.6
0.4
0.2
Sr-90 Concentration (pCi/L)
OTOWI
UPRIVER
Sampling Period

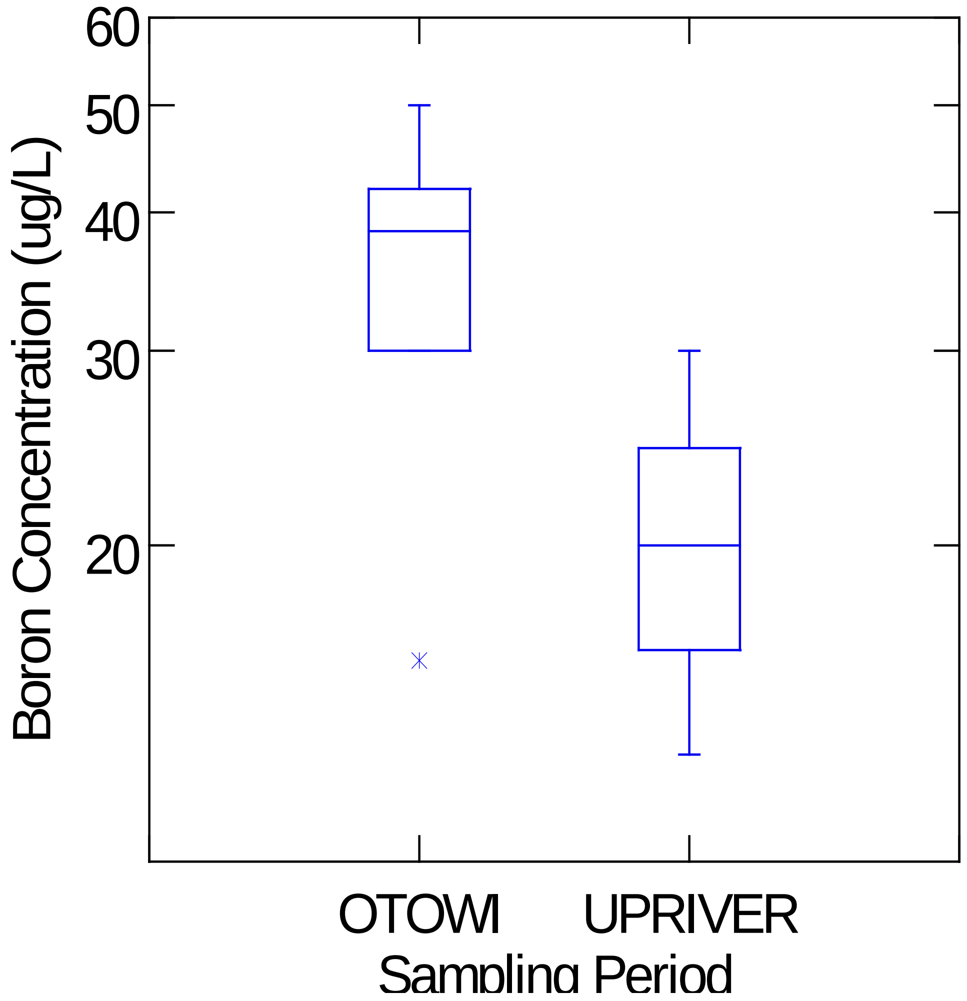


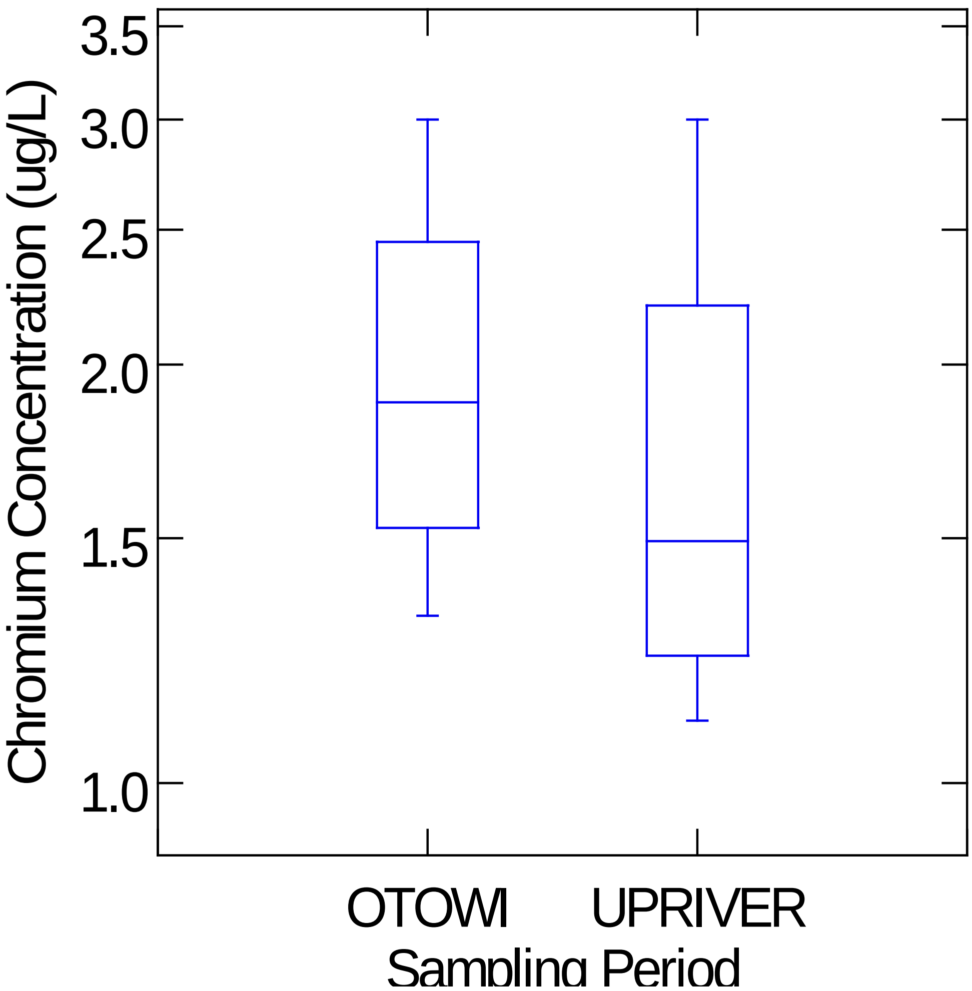
H-3 Concentration (pCi/L)
700
600
500
400
300
200
100
OTOWI
UPRIVER
Sampling Period

Samples collected between 1990 – 1999 - Chemicals

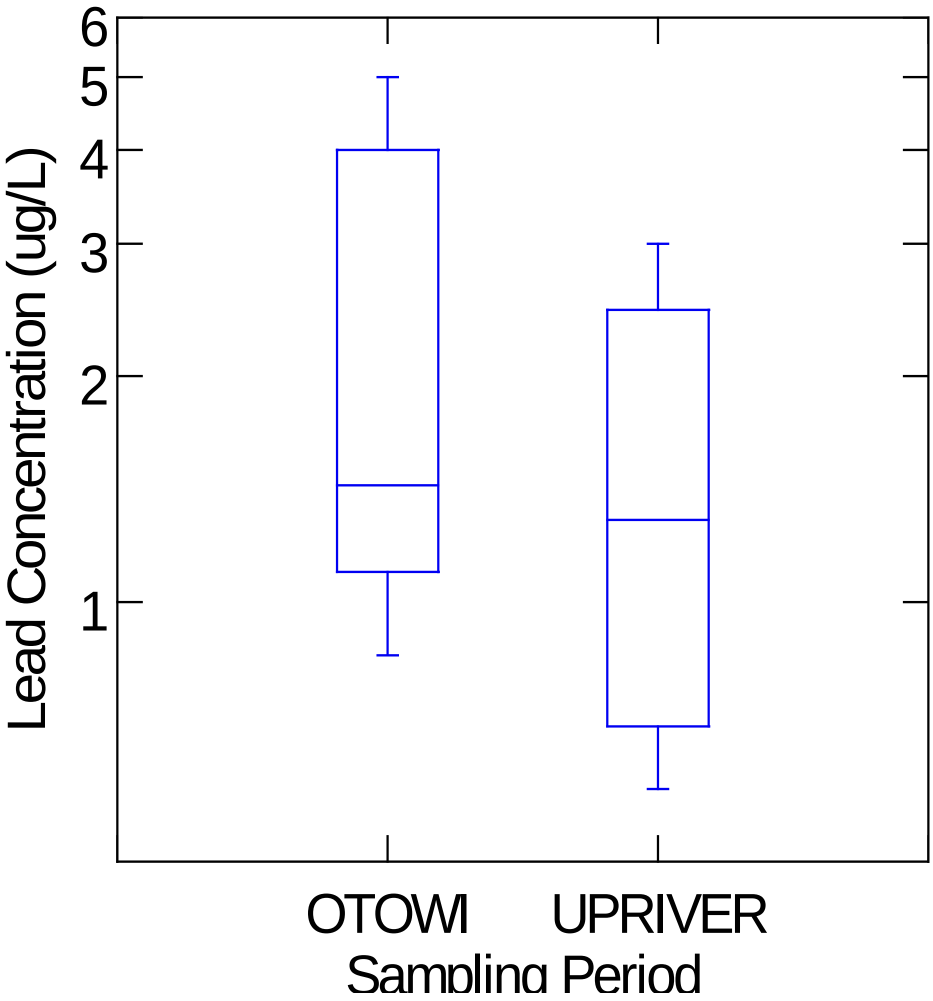


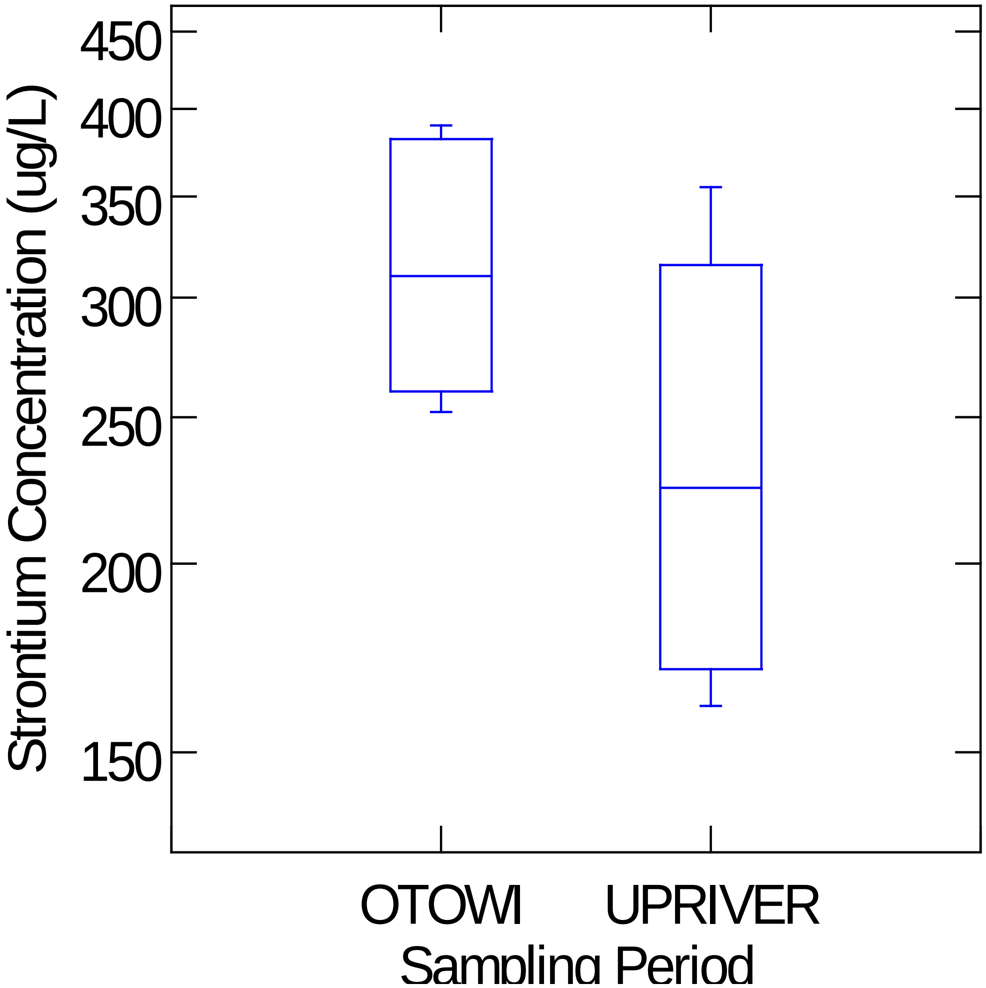

Barium Concentration (ug/L)
120
110
100
90
80
70
60
50
OTOWI
UPRIVER
Sampling Period

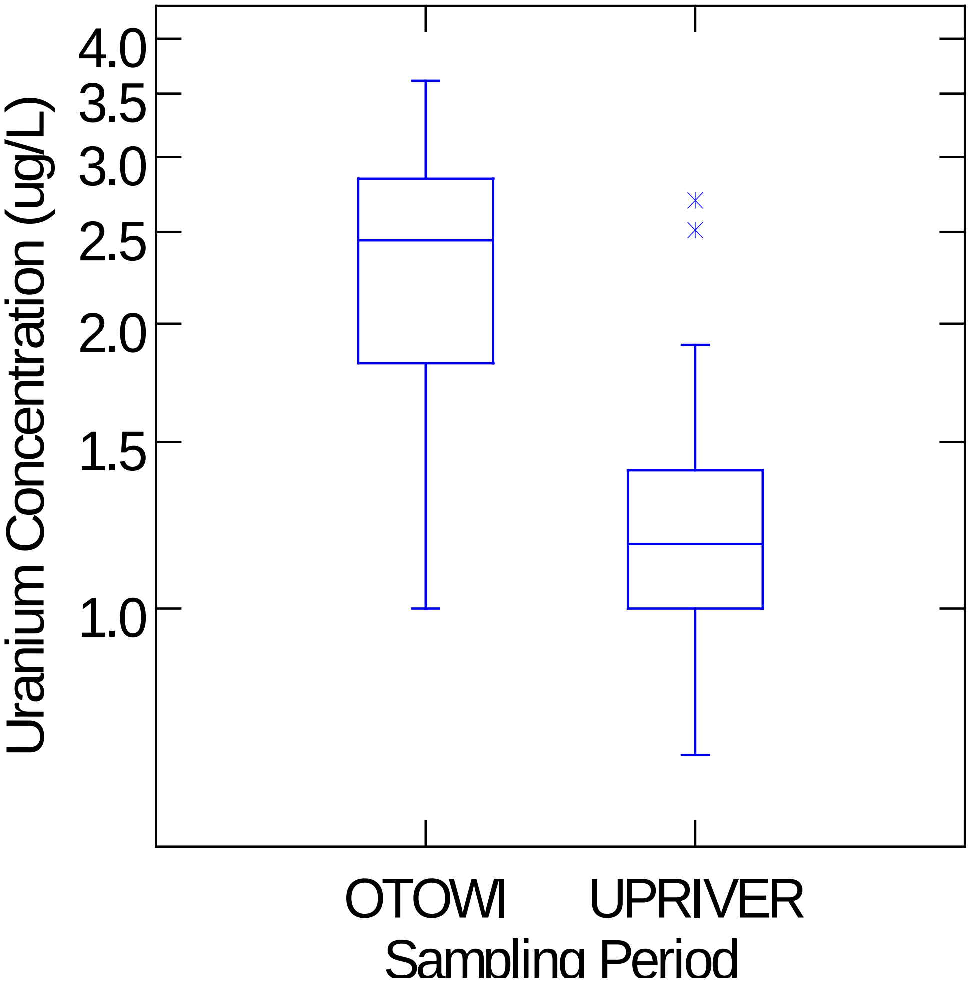

60
50
40
30
20
Boron Concentration (ug/L)
OTOWI
UPRIVER
Sampling Period

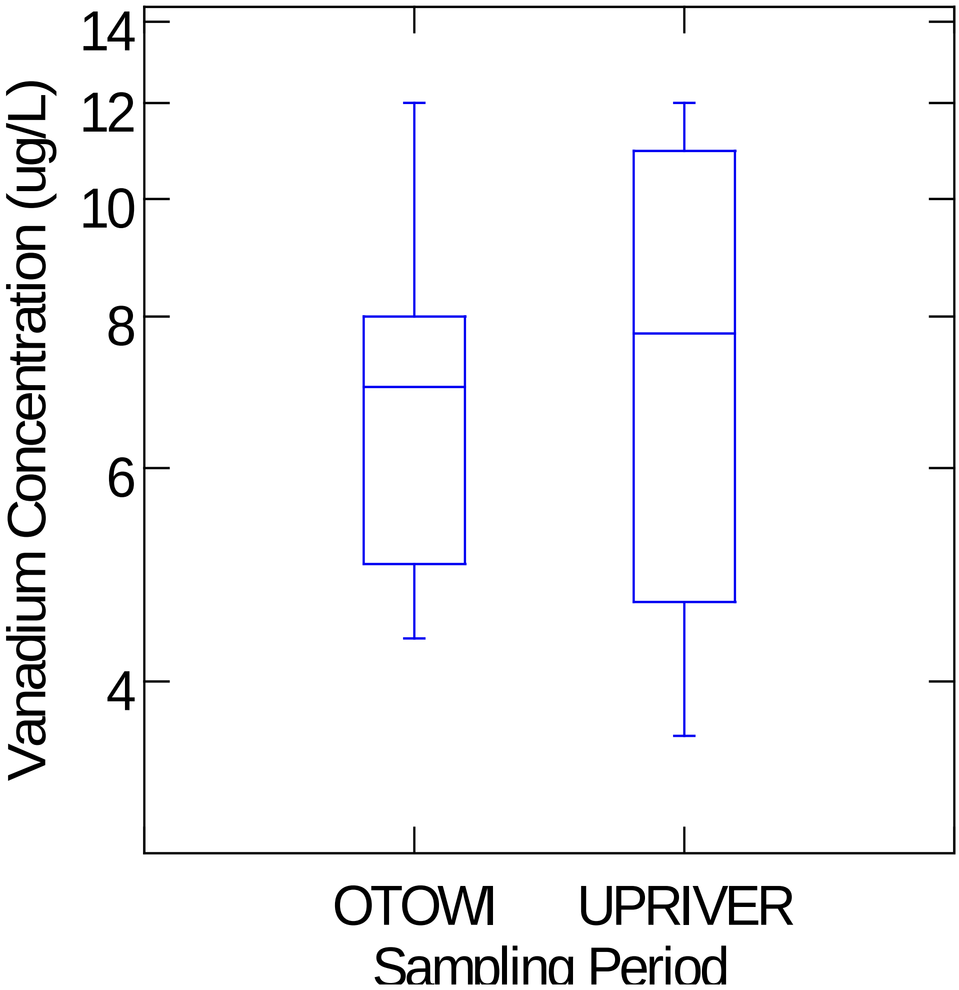


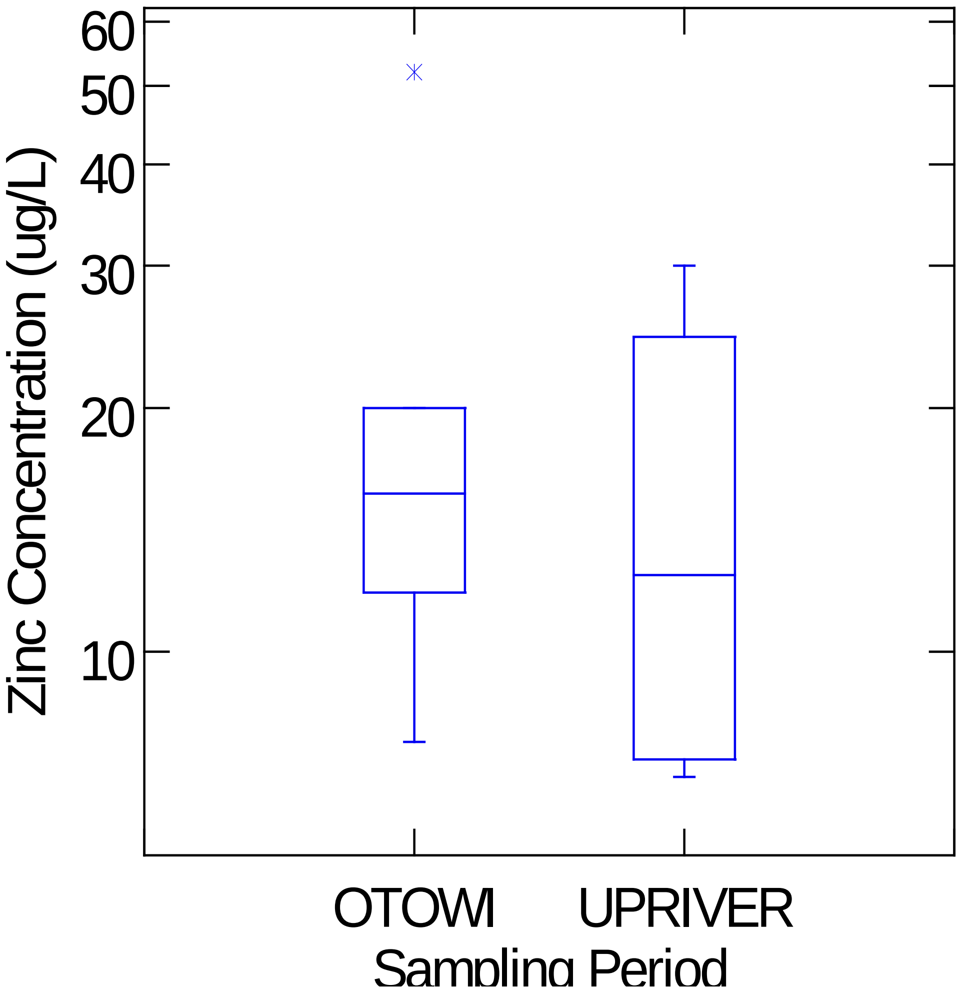
3.5
3.0
2.5
2.0
1.5
1.0
Chromium Concentration (ug/L)
OTOWI
UPRIVER
Sampling Period


6
5
4
3
2
1
Lead Concentration (ug/L)
OTOWI
UPRIVER
Sampling Period

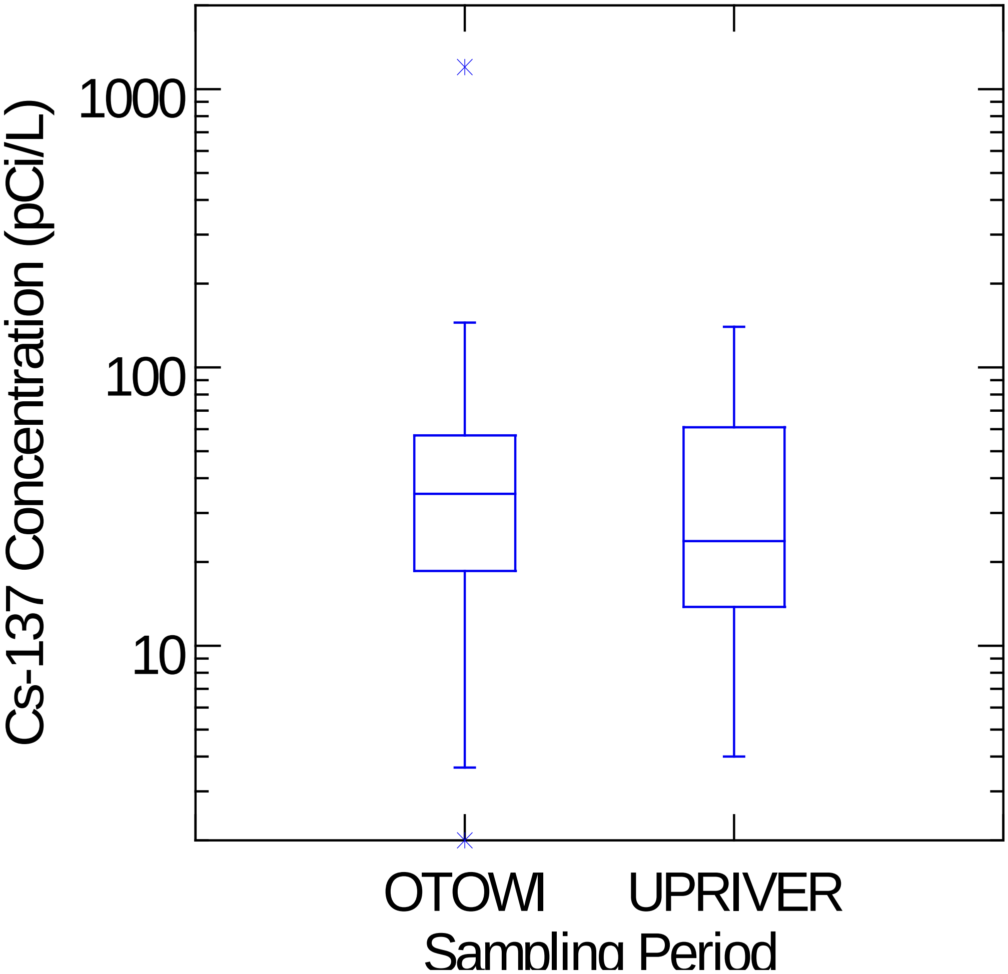

450
400
350
300
250
200
150
Strontium Concentration (ug/L)
OTOWI
UPRIVER
Sampling Period

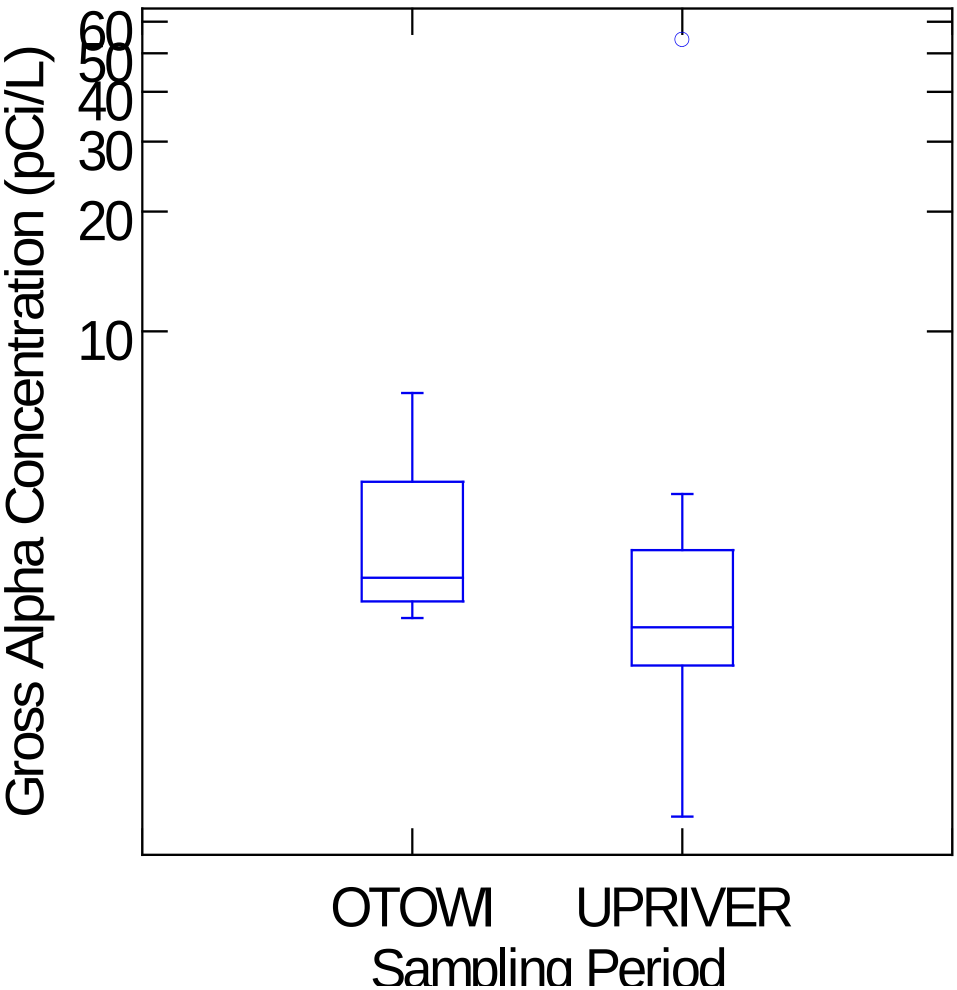

4.0
3.5
3.0
2.5
2.0
1.5
1.0
Uranium Concentration (ug/L)
OTOWI
UPRIVER
Sampling Period

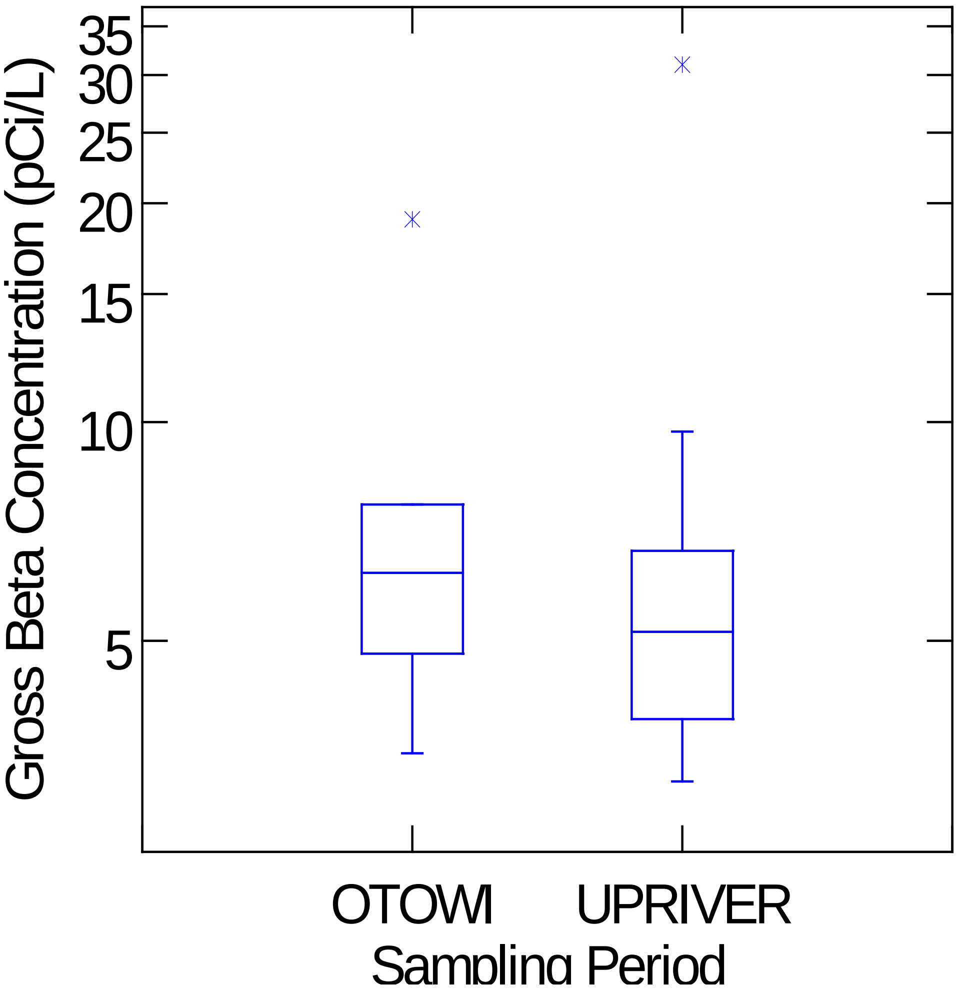

14
12
10
8
6
4
Vanadium Concentration (ug/L)
OTOWI
UPRIVER
Sampling Period

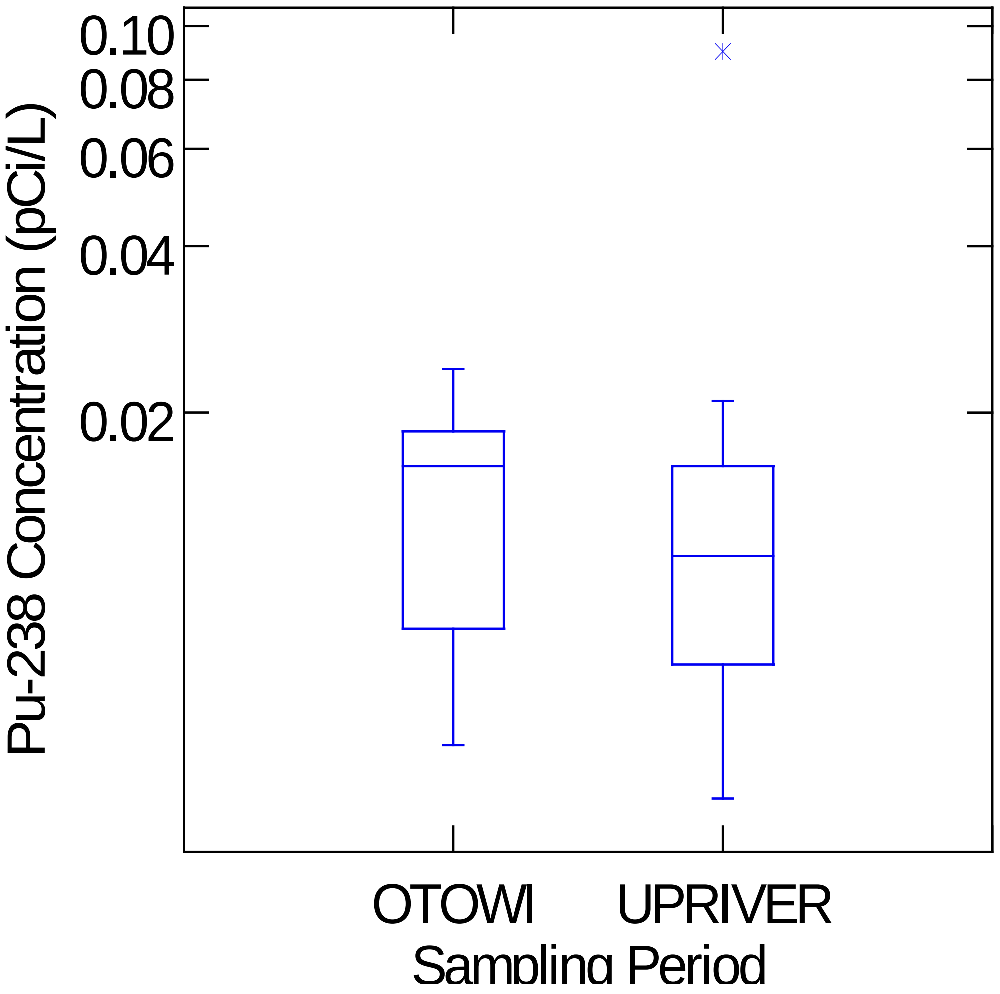

Zinc Concentration (ug/L)
60
50
40
30
20
10
OTOWI
UPRIVER
Sampling Period

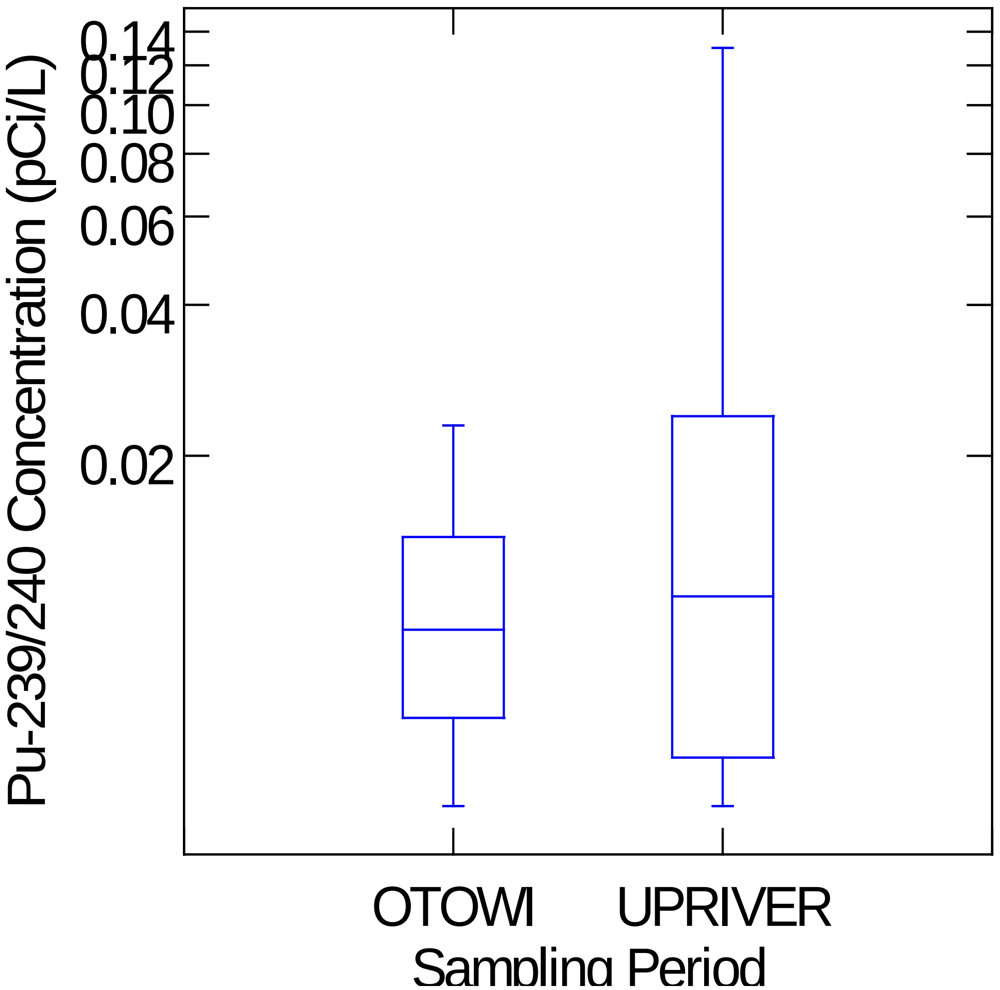
Samples collected between 1980 – 1989 – Radionuclides and Chemicals

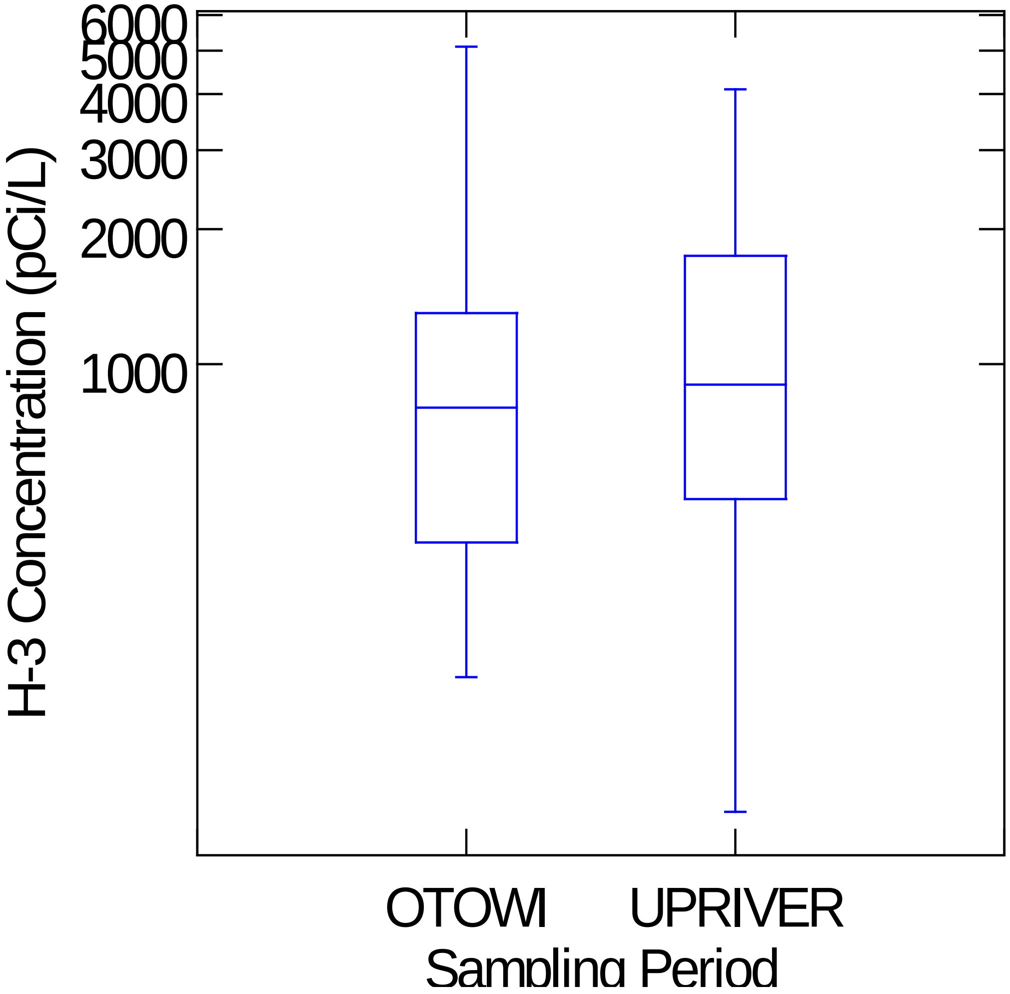



Gross Alpha Concentration (pCi/L)
60
50
40
30
20
10
OTOWI
UPRIVER
Sampling Period

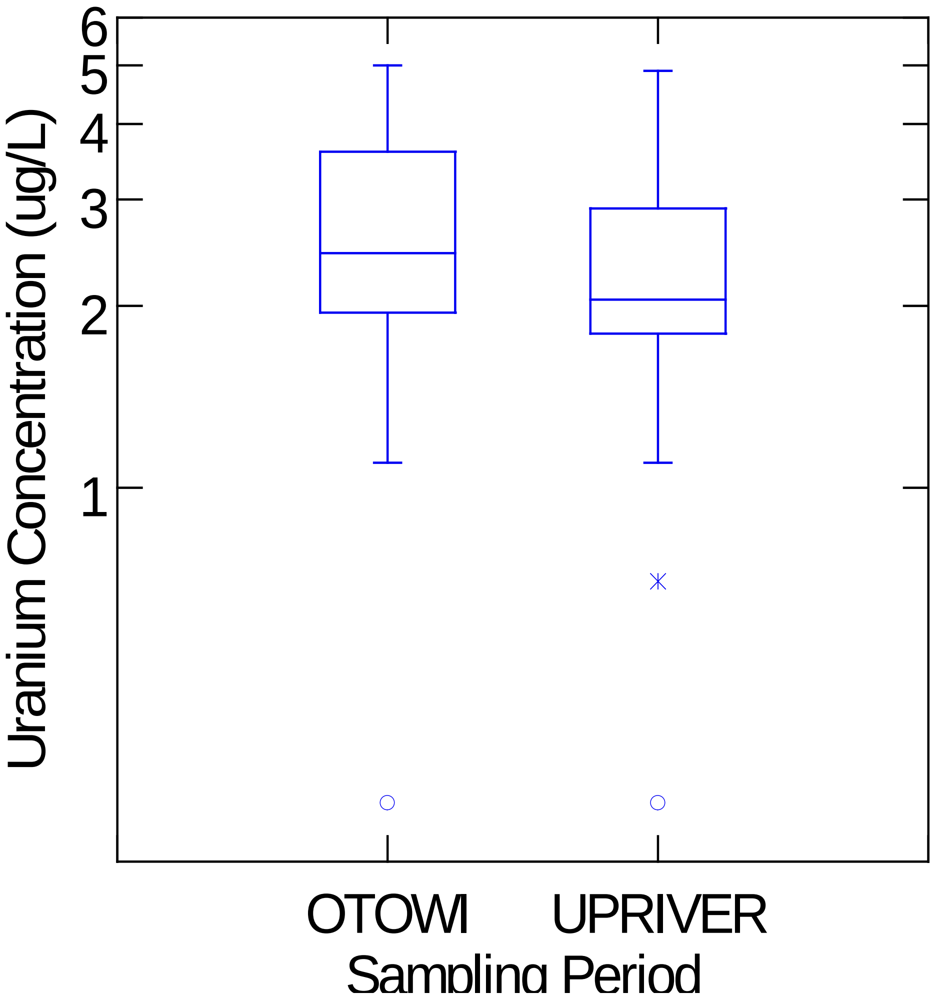

Gross Beta Concentration (pCi/L)
35
30
25
20
15
10
5
OTOWI
UPRIVER
Samplina Period


0.10
0.08
0.06
0.04
0.02
Pu-238 Concentration (pCi/L)
OTOWI
UPRIVER
Sampling Period

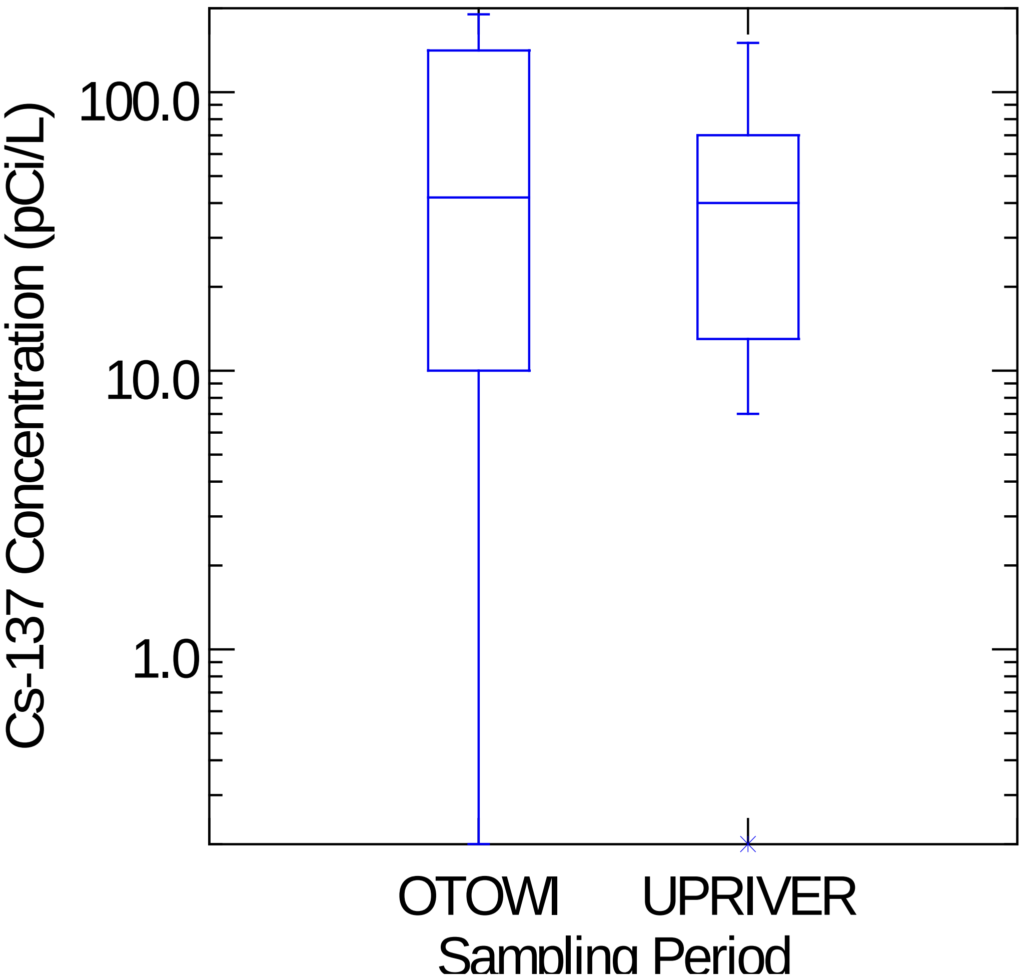

Pu-239/240 Concentration (pCi/L)
0.14
0.12
0.10
0.08
0.06
0.04
0.02
OTOWI
UPRIVER
Sampling Period

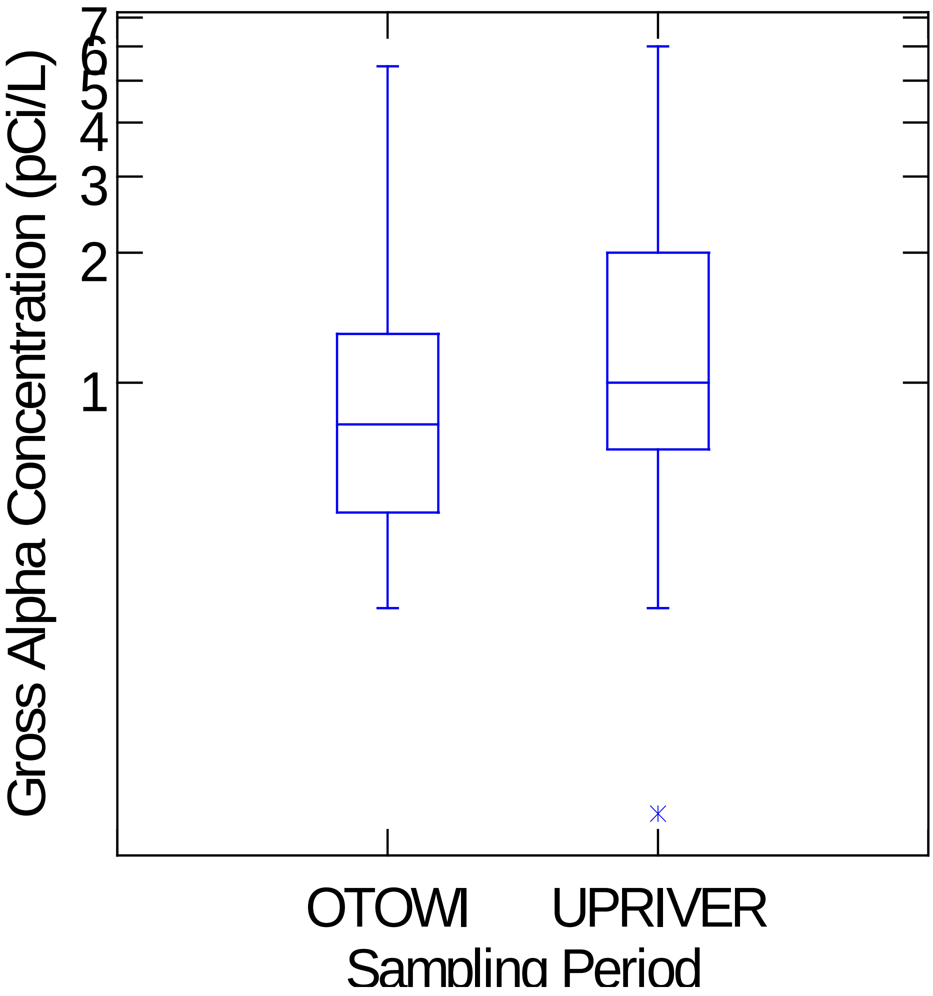


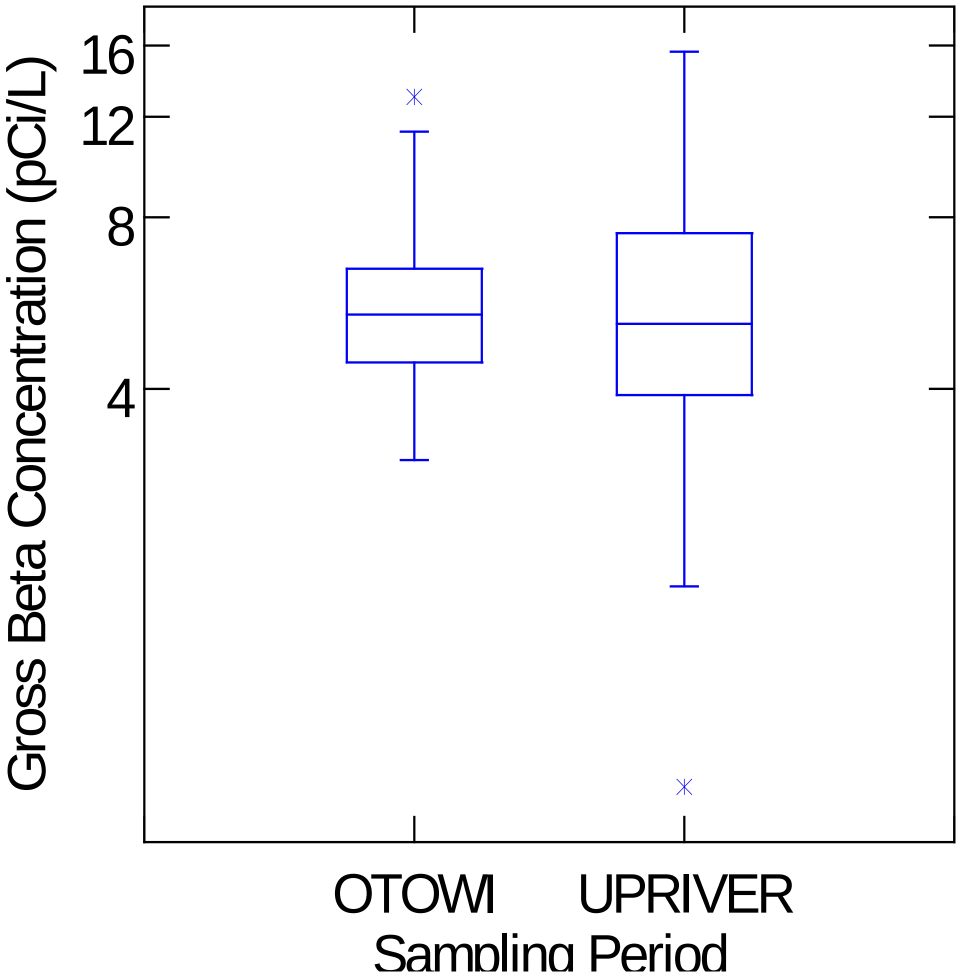
6000
5000
4000
3000
2000
1000
H-3 Concentration (pCi/L)
OTOWI
UPRIVER
Sampling Period

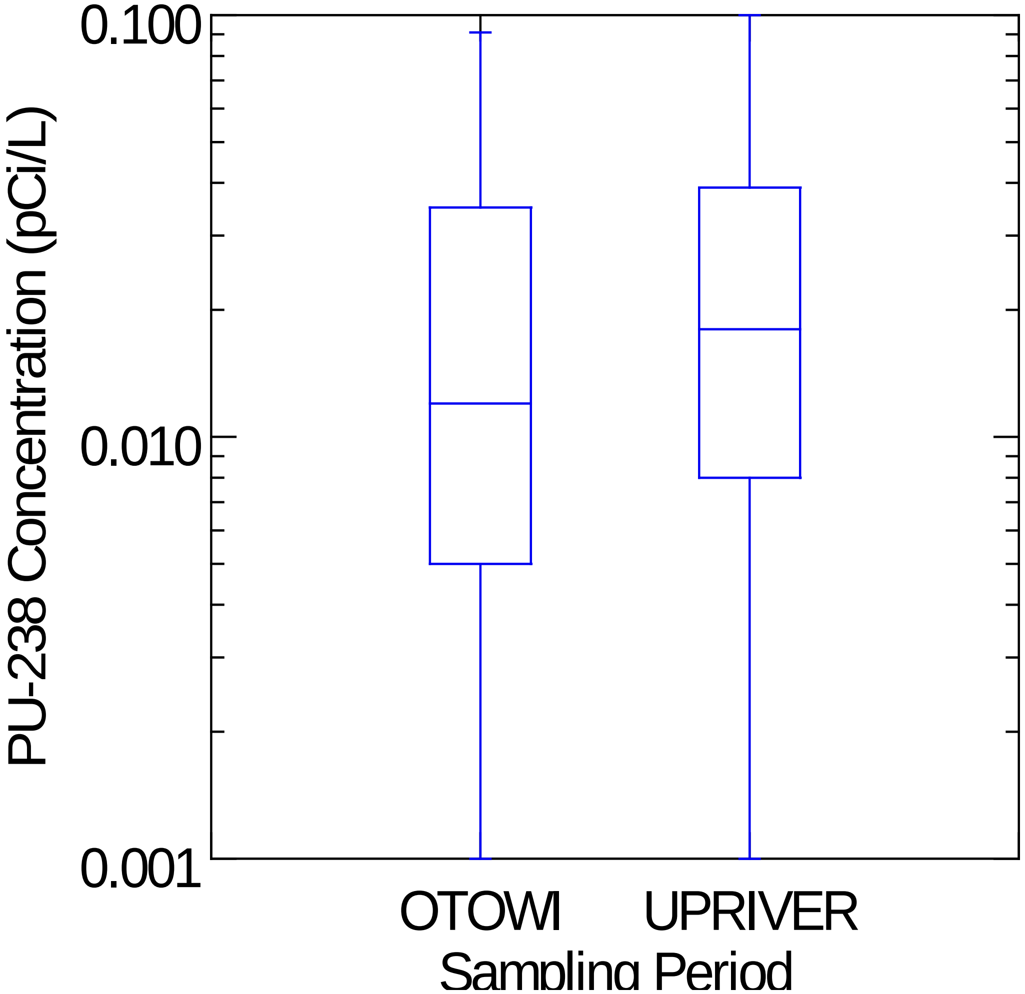

6
5
4
3
2
1
Uranium Concentration (ug/L)
OTOWI
UPRIVER
Sampling Period

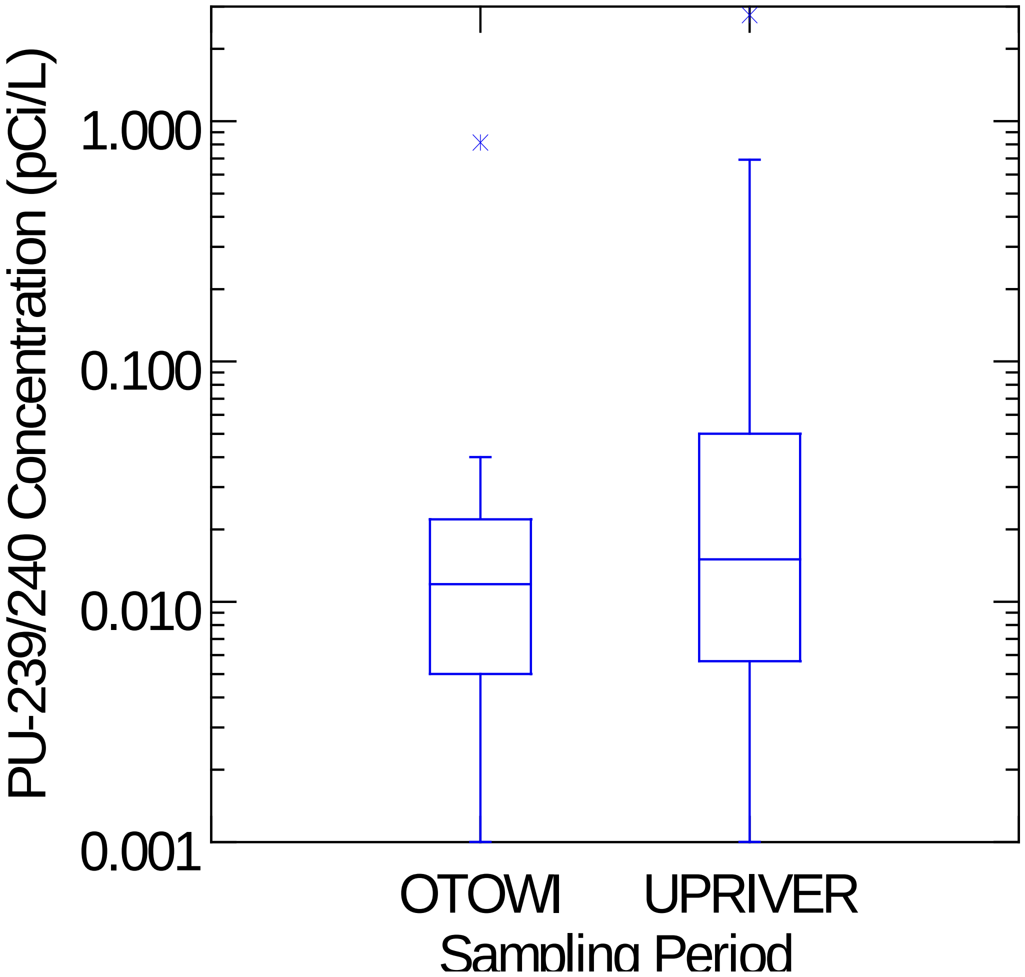
Samples collected between 1970 – 1979 – Radionuclides and Chemicals




Gross Alpha Concentration (pCi/L)
7
6
5
4
3
2
1
OTOWI
UPRIVER
Sampling Period


Gross Beta Concentration (pCi/L)
16
12
8
4
OTOWI
UPRIVER
Sampling Period


0.100
0.010
0.001
PU-238 Concentration (pCi/L)
OTOWI
UPRIVER
Sampling Period


PU-239/240 Concentration (pCi/L)
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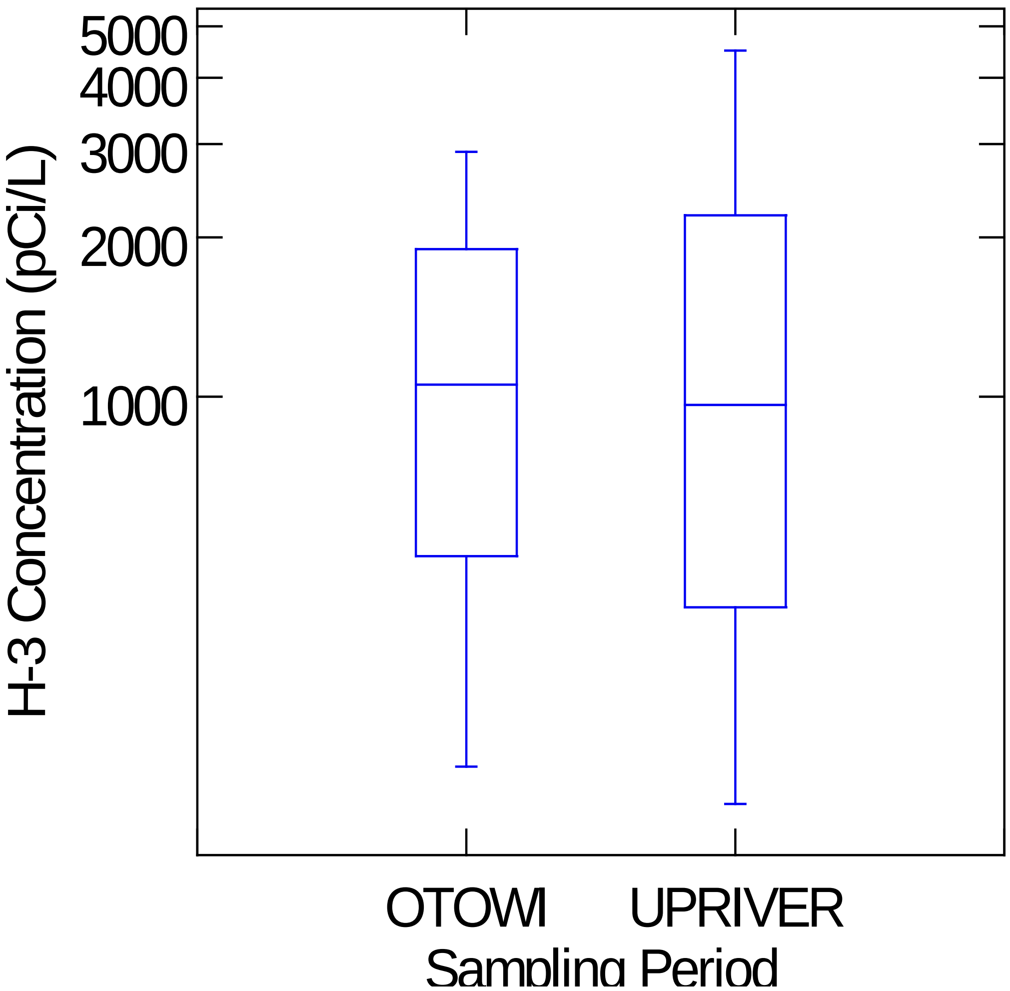
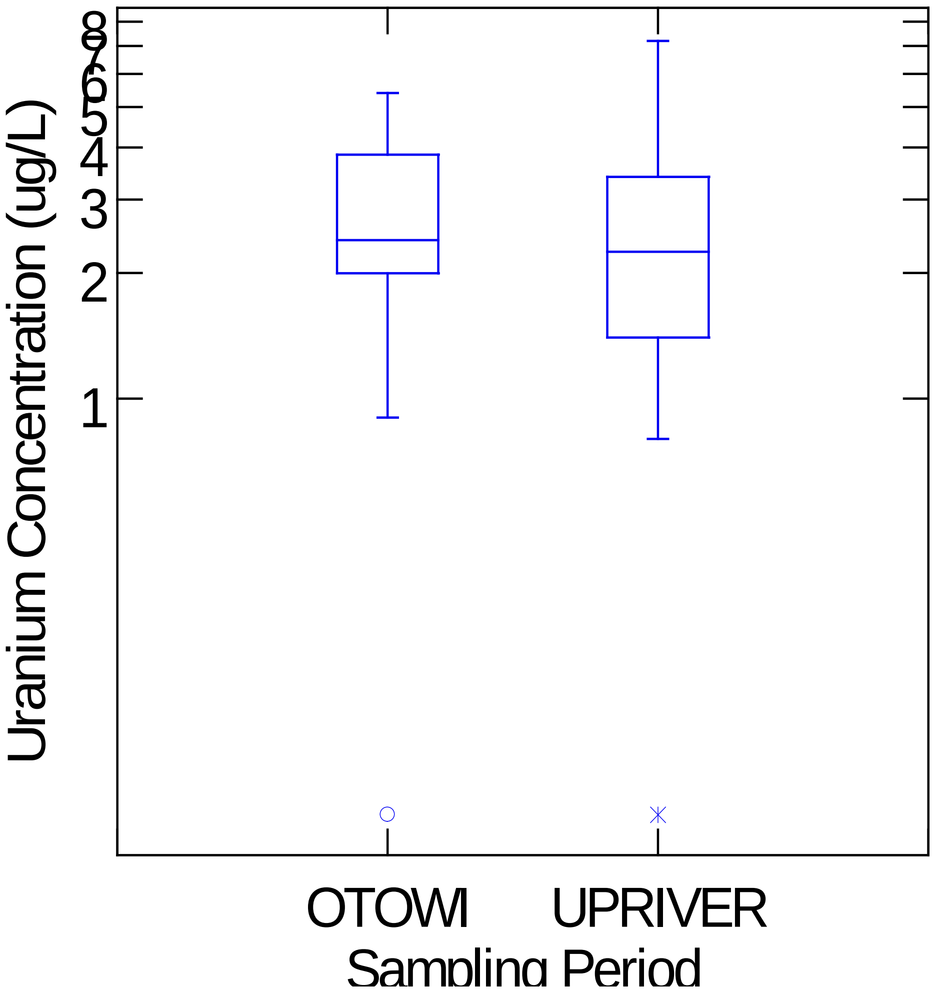
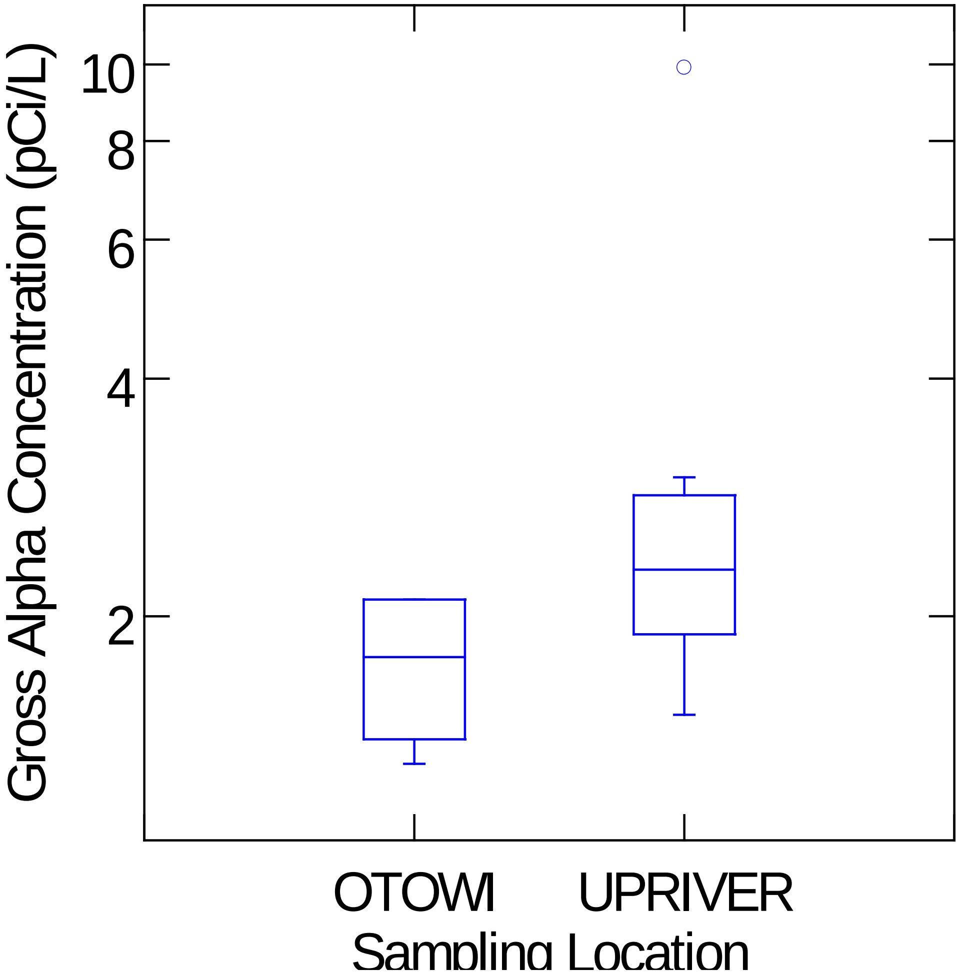
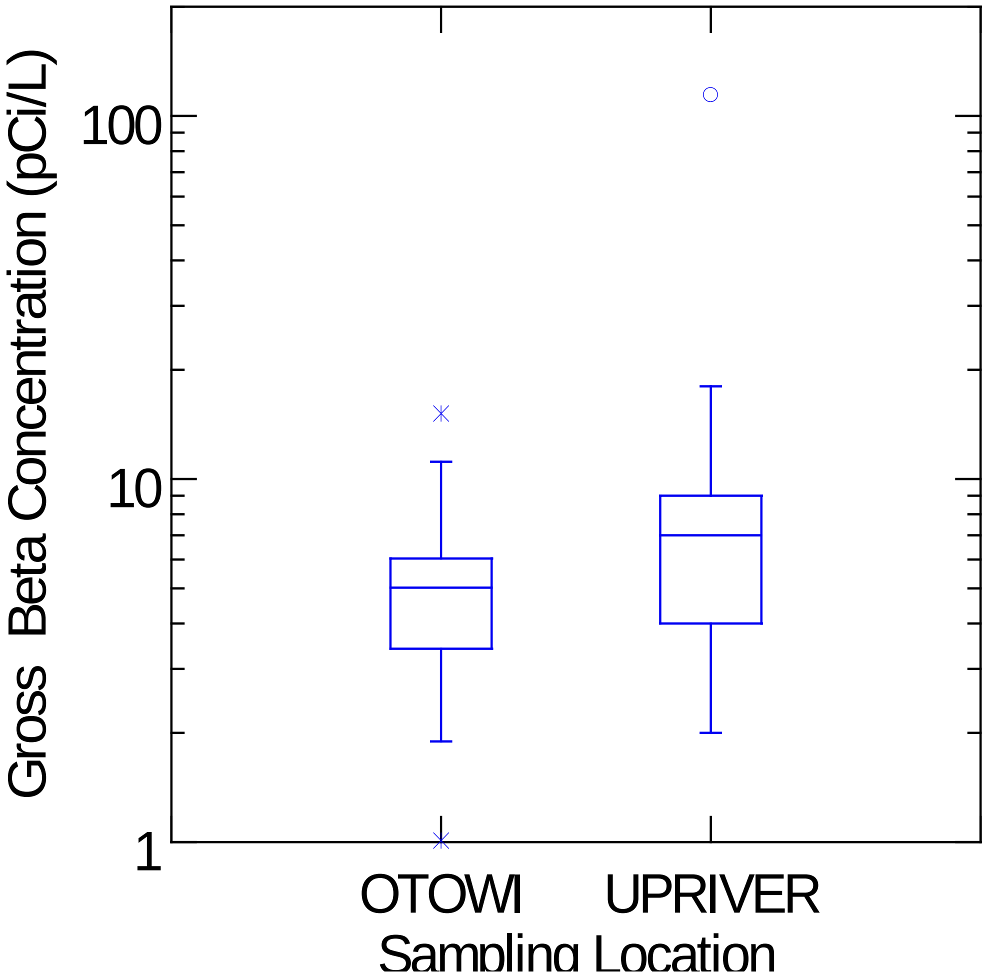
0.100
0.010
0.001
OTOWI
UPRIVER
Sampling Period

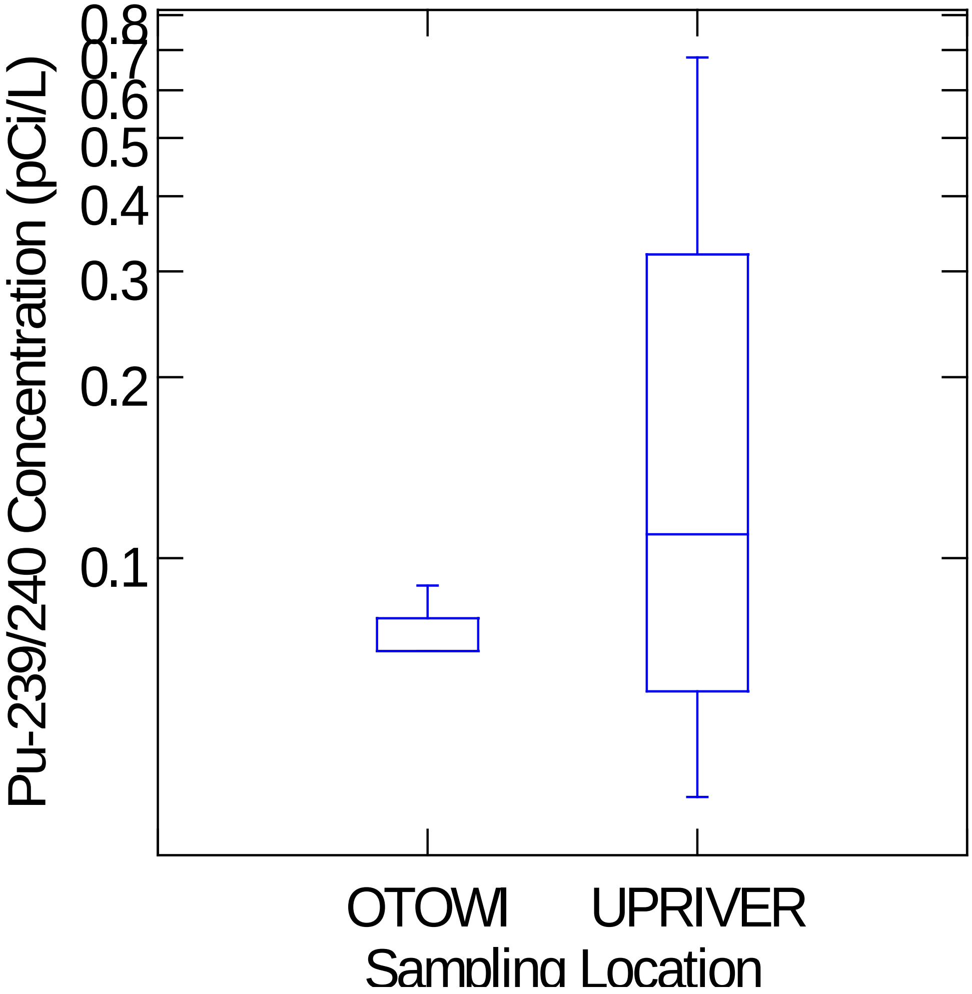

5000
4000
3000
2000
1000
H-3 Concentration (pCi/L)
OTOWI
UPRIVER
Sampling Period


Uranium Concentration (ug/L)
8
7
6
5
4
3
2
1
OTOWI
UPRIVER
Sampling Period

Samples collected before 1970 – Radionuclides and Chemicals




Gross Beta Concentration (pCi/L)
100
10
1
OTOWI
UPRIVER
Sampling Location


0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
Pu-239/240 Concentration (pCi/L)
OTOWI
UPRIVER
Sampling Location

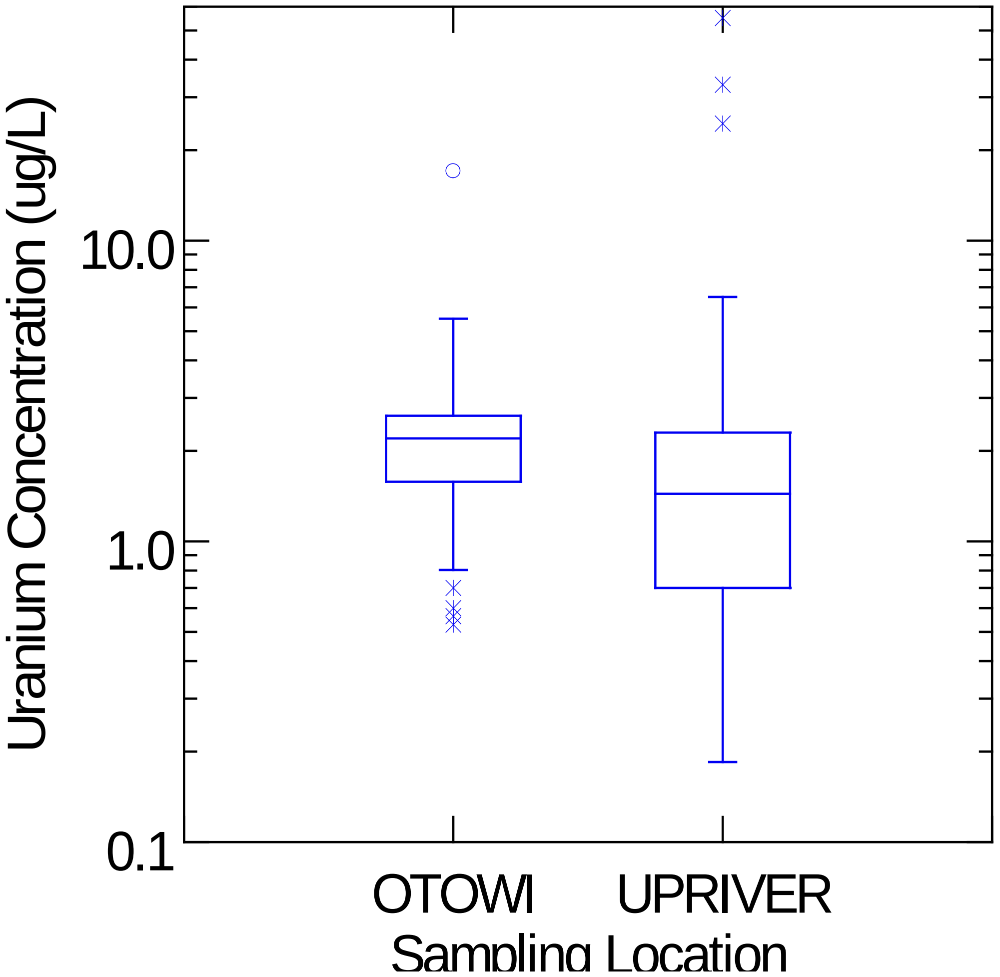

Uranium Concentration (ug/L)
10.0
1.0
0.1
OTOWI
UPRIVER
Sampling Location

Table 5A-1. Chemical Specific Parameters

BDD Analyte	Volatile?	Permeability Coefficient (Kp)[a] (cm/hr)	Generic Volatilzation Factor (VF)[b] (L/m3)	Particulate Slope Factor[c] (ng/m3)/(mg/L)
Acetone	Yes	5.12E-04	0.5	--
Aluminum	--	1.00E-03	--	26.6
Ammonia	--	1.00E-03	--	26.6
Antimony	--	1.00E-03	--	26.6
Arsenic	--	1.00E-03	--	26.6
Barium	--	1.00E-03	--	26.6
Beryllium	--	1.00E-03	--	26.6
Bis(2-ethylhexyl)phthalate	--	1.13*	--	26.6
Boron	--	1.00E-03	--	26.6
Cadmium	--	1.00E-03	--	26.6
Chloromethane	Yes	3.28E-03	0.5	--
Total Chromium	--	1.00E-03	--	26.6
Cobalt	--	4.00E-04	--	26.6
Copper	--	1.00E-03	--	26.6
Cyanide	Yes	1.00E-03	0.5	--
DDE	--	0.545*	--	26.6
Fluoride	--	1.00E-03	--	26.6
Delta HCH	--	2.06E-02	--	26.6
Iron	--	1.00E-03	--	26.6
Lead	--	1.00E-04	--	26.6
Manganese	--	1.00E-03	--	26.6
Mercury	Yes	1.00E-03	0.5	--
Molybdenum	--	1.00E-03	--	26.6
Nickel	--	2.00E-04	--	26.6
Nitrite	--	1.00E-03	--	26.6
OCDD	--	1.16*	--	26.6
Perchlorate	--	1.00E-03	--	26.6
Total PCBs	--	0.545*	--	26.6
Selenium	--	1.00E-03	--	26.6
Silver	--	6.00E-04	--	26.6
Strontium	--	1.00E-03	--	26.6
Thallium	--	1.00E-03	--	26.6
Uranium	--	1.00E-03	--	26.6
Vanadium	--	1.00E-03	--	26.6
Zinc	--	6.00E-03	--	26.6

-- Not applicable.

[a] Values obtained from EPA 2004 and RAIS

[b] VF Source: NMED, RSL; RAGs A, B

[c] PEF source, Finley et al.

Table 5A-2. Toxicity Criteria

			SFo (mg/kg-day)$^{-1}$	SFd[b] (mg/kg-day)$^{-1}$	IUR (ug/m^3)$^{-1}$	Mutagenic Carcinogen[c] ?	EPA Cancer Class[d]	RfDo (mg/kg-day)	RfDd[b] (mg/kg-day)	RfCi (mg/m^3)	Kidney	Circulatory/Cardiovascular System	Skin	Hair Loss	Reproductive Effects	Respiratory	Gastrointestinal	Liver	CNS	Decreased Body/Organ Weights	Immune System/Thyroid	Bone/Tooth	Gout
BDD Analyte	**Notes[a]**	**GI Abs[b]**	**Carcinogenic Toxicity Criteria[e]**					**Noncarcinogenic Toxicity Criteria[e]**			**Non-Carcinogenic Target Organs/Health Endpoints[e]**												
Acetone		100%	--	--	--		D	9.0E-01 I	9.0E-01	3.1E+01 A	x							x	x				
Aluminum		100%	--	--	--	--	D	1.0E+00 P	1.0E+00	5.0E-03 P										x			
Ammonia		100%	--	--	--	--	--	--		1.0E-01 I						x							
Antimony		15%	--	--	--	--	--	4.0E-04 I	6.0E-05	--		x											
Arsenic		100%	1.5E+00 I	1.5E+00	4.3E-03 I	--	A	3.0E-04 I	3.0E-04	1.5E-05 C		x	x		x								
Barium		7%	--	--	--	--	D	2.0E-01 I	1.4E-02	5.0E-04 H	x	x											
Beryllium		1%	--	--	2.4E-03 I	--	B1	2.0E-03 I	1.4E-05	2.0E-05 I						x	x						
Bis(2-ethylhexyl)phthalate		100%	1.4E-02 I	1.4E-02	2.4E-06 C	--	C	2.0E-02 I	2.0E-02	--								x					
Boron		100%	--	--	--	--	--	2.0E-01 I	2.0E-01	2.0E-02 H					x	x							
Cadmium		5%	--	--	1.8E-03 I	--	B1	5.0E-04 I	2.5E-05	1.0E-05 A	x					x							
Chloromethane		100%	--	--	--	--	D	--		9.0E-02 I									x				
Total Chromium	2	3%	--	--	1.2E-02 I	Yes	A	3.0E-03 I	7.5E-05	1.0E-04 I						x							
Cobalt		100%	--	--	9.0E-03 P	--	B1	3.0E-04 P	3.0E-04	6.0E-06 P		x			x				x		x		
Copper		100%	--	--	--	--	D	4.0E-02 H	4.0E-02	--							x						
Cyanide		100%	--	--	--	--	D	2.0E-02 I	2.0E-02	--									x	x	x		
DDE		100%	3.4E-01 I	3.4E-01	9.7E-05 C	--	B2	--		--													
Fluoride		100%	--	--	--	--	--	6.0E-02 I	6.0E-02	1.3E-02												x	
Delta HCH	4	100%	1.8E+00 I	1.8E+00	5.1E-04 I	--	B2	--		--													
Iron		100%	--	--	--	--	--	7.0E-01 P	7.0E-01	--							x						
Lead	5	100%	--	--	--	--	B2	--		--									x				
Manganese		4%	--	--	--	--	D	2.4E-02 I	9.6E-04	5.0E-05 I									x				
Mercury	6	100%	--	--	--	--	D	1.6E-04 C	1.6E-04	3.0E-04 I									x		x		
Molybdenum		100%	--	--	--	--	--	5.0E-03 I	5.0E-03	--													x
Nickel		4%	--	--	--	--	--	2.0E-02 I	8.0E-04	9.0E-05 A						x				x			
Nitrite	7	100%	--	--	--	--	--	1.0E-01 I	1.0E-01	--		x											
OCDD		100%	1.3E+01 C	1.3E+01	3.8E-03 C		B2	--		--													
Perchlorate		100%	--	--	--	--	--	7.0E-04 I	7.0E-04	--											x		

			SFo (mg/kg-day)$^{-1}$	SFd^{b} (mg/kg-day)$^{-1}$	IUR (ug/m^{3})$^{-1}$	Mutagenic Carcinogen^{c} ?	EPA Cancer Class^{d}	RfDo (mg/kg-day)	RfDd^{b} (mg/kg-day)	RfCi (mg/m^{3})	Kidney	Circulatory/Cardiovascular System	Skin	Hair Loss	Reproductive Effects	Respiratory	Gastrointestinal	Liver	CNS	Decreased Body/Organ Weights	Immune System/Thyroid	Bone/Tooth	Gout
Total PCBs		100%	2.0E+00 I	2.0E+00	1.0E-04 I	--	B2	--		--													
Selenium		100%	--	--	--	--	D	5.0E-03 I	5.0E-03	2.0E-02 C			x	x					x				
Silver		4%	--	--	--	--	D	5.0E-03 I	2.0E-04	--			x										
Strontium		100%	--	--	--	--	--	6.0E-01 I	6.0E-01	--												x	
Thallium	8	100%	--	--	--	--	--	6.6E-05 I	6.6E-05	--				x				x					
Uranium		100%	--	--	--	--	--	3.0E-03 I	3.0E-03	3.0E-04 A	x												
Vanadium	9	3%	--	--	--	--	--	5.0E-03 I	1.3E-04	1.0E-03 A				x									
Zinc		100%	--	--	--	--	D	3.0E-01 I	3.0E-01	--		x											

[a] Notes

1. Toxicity criteria are not available for benzo(g,h,i)perylene, therefore toxicity criteria for pyrene were used as surrogate criteria (i.e. toxicity values are assumed to have similar toxicological properties).
2. Toxicity criteria are not available for total chromium, which is considered to consist of both trivalent and hexavalent chromium. Therefore, total chromium was conservatively evaluated as hexavalent chromium.
3. Toxicity criteria are not available for endrin aldehyde, therefore toxicity criteria for endrin were used as surrogate criteria (i.e. toxicity values are assumed to have similar toxicological properties).

properties).

5. Toxicity criteria are not available for lead. Lead is separately, as disuss in the text.
6. Toxicity criteria for elemental mercury were used.
7. Chemical results for nitrate-nitrite as nitrogen were evaluated as nitrite; toxicity criteria for nitrite were used as they are is more conservative than those available for nitrate.
8. The toxicity criteria for thallium are based on information from IRIS prior to the 2009 update; IRIS does not currently provide thallium toxicity criteria.

Guide, 2010).

[b] Dermal Absorption (Abs) values obtained from RAGS Part E (US EPA, 2004); RfDd = RfDo x GI Abs; CSFd = CSFo / GI Abs.

[c] Toxicity criteria for mutagenic carcinogens have not been adjusted by the ADAF in this table.

[d] EPA Cancer Classifications:

A Human carcinogen

B Probable human carcinogen (B1 indicates limited human evidence, B2 indicates sufficient evidence in animals and inadequate or no evidence in humans)

C Possible human carcinogen

D Not classifiable as a carcinogen

[e] Toxicity criteria sources :

A= ATSDR	*P=PPRTV*
C= CalEPA	*E=ECAO*
H= HEAST	*N=NCEA*
I=IRIS	

-- Not applicable.

Table 5A-3, Toxicity criteria adjustments for mutagenic carcinogens

Exposure Age Group	Exposure Duration (years)	Age-Dependent Potency Adjustment Factor (ADAF x SF/URF)
Birth to < 1 year	1	10×
1 to < 3 years	2	10×
3 to < 6 years	3	3×
6 to < 11 years	5	3×
11 to < 16 years	5	3×
16 to < 21 years	5	1× (no adjustment)
21 to < 70 yr	49	1× (no adjustment)

Table 5A-4: Central Tendency Exposure Hazard Indices - Target Health Endpoints for the Infant Age Group

CT Hazard Index: Kidney Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Acetone	0.000	--	--	0.000	0.000	0.000	0.000	*0.000*
Barium	0.030	--	--	0.001	0.000	--	--	*0.031*
Cadmium	0.086	--	--	0.004	0.000	--	--	*0.091*
Uranium	0.055	--	--	0.000	0.000	--	--	*0.055*
TOTAL	*0.171*	--	--	*0.006*	*0.000*	*0.000*	*0.000*	*0.177*

CT Hazard Index: Respiratory Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Ammonia	--	--	--	--	--	--	--	--
Beryllium	0.032	--	--	0.012	0.001	--	--	*0.045*
Boron	0.010	--	--	0.000	0.000	--	--	*0.010*
Cadmium	0.086	--	--	0.004	0.000	--	--	*0.091*
Total Chromium	0.102	--	--	0.010	0.001	--	--	*0.113*
Nickel	0.015	--	--	0.000	0.000	--	--	*0.016*
TOTAL	*0.246*	--	--	*0.026*	*0.002*	*0.000*	--	*0.274*

CT Hazard Index: Decreased Body/Organ Weights

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Aluminum	0.159	--	--	0.000	0.000	--	--	*0.160*
Cyanide	0.006	--	--	0.000	0.000	--	--	*0.006*
Nickel	0.015	--	--	0.000	0.000	--	--	*0.016*
TOTAL	*0.181*	--	--	*0.001*	*0.000*	*0.000*	--	*0.181*

CT Hazard Index: Circulatory/Cardiovascular System Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Antimony	0.061	--	--	0.001	0.000	--	--	*0.062*
Arsenic	0.637	--	--	0.002	0.000	--	--	*0.639*
Barium	0.030	--	--	0.001	0.000	--	--	*0.031*
Cobalt	0.560	--	--	0.001	0.000	--	--	*0.561*
Nitrite	0.002	--	--	--	--	--	--	*0.002*
Zinc	0.003	--	--	0.000	0.000	--	--	*0.003*
TOTAL	*1.292*	--	--	*0.004*	*0.000*	*0.000*	--	*1.296*

CT Hazard Index: Immune System/Thyroid Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Cobalt	0.560	--	--	0.001	0.000	--	--	*0.561*
Cyanide	0.006	--	--	0.000	0.000	--	--	*0.006*
Mercury	0.036	--	--	0.000	0.000	0.002	0.000	*0.039*
Perchlorate	0.006	--	--	0.000	0.000	--	--	*0.006*
TOTAL	*0.608*	--	--	*0.001*	*0.000*	*0.002*	*0.000*	*0.612*

CT Hazard Index: Skin Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Arsenic	0.637	--	--	0.002	0.000	--	--	*0.639*
Selenium	0.020	--	--	0.000	0.000	--	--	*0.020*
Silver	0.001	--	--	0.000	0.000	--	--	*0.001*
TOTAL	*0.658*	--	--	*0.002*	*0.000*	*0.000*	--	0.660

CT Hazard Index: Gastrointestinal Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Beryllium	0.032	--	--	0.012	0.001	--	--	*0.045*
Copper	0.007	--	--	0.000	0.000	--	--	*0.007*
Iron	0.210	--	--	0.001	0.000	--	--	*0.210*
TOTAL	*0.249*	--	--	*0.012*	*0.001*	*0.000*	--	0.262

CT Hazard Index: Bone/Teeth Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Strontium	0.030	--	--	0.000	0.000	--	--	*0.030*
Fluoride	0.380	--	--	0.001	0.000	--	--	*0.381*
TOTAL	*0.410*	--	--	*0.001*	*0.000*	*0.000*	--	0.411

CT Hazard Index: Hair Loss

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Selenium	0.020	--	--	0.000	0.000	--	--	*0.020*
Thallium	0.289	--	--	0.001	0.000	--	--	*0.290*
Vanadium	0.114	--	--	0.011	0.001	--	--	*0.126*
TOTAL	*0.423*	--	--	*0.012*	*0.001*	*0.000*	--	0.436

CT Hazard Index: Liver Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Acetone	0.000	--	--	0.000	0.000	0.000	0.000	*0.000*
Bis(2-ethylhexyl)phthalate	0.008	--	--	--	--	--	--	*0.008*
Thallium	0.289	--	--	0.001	0.000	--	--	*0.290*
TOTAL	*0.297*	--	--	*0.001*	*0.000*	*0.000*	*0.000*	0.298

CT Hazard Index: Gout

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Molybdenum	0.058	--	--	0.000	0.000	--	--	*0.058*
TOTAL	*0.058*	--	--	*0.000*	*0.000*	--	--	0.058

CT Hazard Index: **Reproductive Effects**

	Tapwater: Ingestion	**Homegrown Produce: Ingestion**	**Handwashing: Dermal Uptake**	**Bathing: Dermal Uptake**	**Swimming: Dermal Uptake**	**Bathing: Inhalation**	**Swimming: Inhalation**	***TOTAL***
Arsenic	0.637	--	--	0.002	0.000	--	--	*0.639*
Boron	0.010	--	--	0.000	0.000	--	--	*0.010*
Cobalt	0.560	--	--	0.001	0.000	--	--	*0.561*
TOTAL	*1.207*	--	--	*0.002*	*0.000*	*0.000*	--	*1.209*

CT Hazard Index: **Central Nervous System Effects**

	Tapwater: Ingestion	**Homegrown Produce: Ingestion**	**Handwashing: Dermal Uptake**	**Bathing: Dermal Uptake**	**Swimming: Dermal Uptake**	**Bathing: Inhalation**	**Swimming: Inhalation**	***TOTAL***
Acetone	0.000	--	--	0.000	0.000	0.000	0.000	*0.000*
Chloromethane	--	--	--	--	--	0.000	0.000	*0.000*
Cobalt	0.560	--	--	0.001	0.000	--	--	*0.561*
Cyanide	0.006	--	--	0.000	0.000	--	--	*0.006*
Lead*	--	--	--	--	--	--	--	--
Manganese	0.357	--	--	0.022	0.002	--	--	*0.381*
Mercury	0.036	--	--	0.000	0.000	0.002	0.000	*0.039*
Selenium	0.020	--	--	0.000	0.000	--	--	*0.020*
TOTAL	*0.980*	--	--	*0.023*	*0.002*	*0.002*	*0.000*	*1.007*

Table 5A-5: Reasonable Maximum Exposure Hazard Indices - Target Health Endpoints for the Infant Age Group

RME Hazard Index: Nephrotoxicity Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Acetone	0.001	--	--	0.000	0.000	0.000	0.000	*0.001*
Barium	0.086	--	--	0.001	0.000	0.000	--	*0.087*
Cadmium	0.622	--	--	0.014	0.002	0.000	--	*0.638*
Uranium	0.144	--	--	0.000	0.000	0.000	--	*0.144*
TOTAL	*0.852*	--	--	*0.016*	*0.003*	*0.000*	*0.000*	0.871

RME Hazard Index: Respiratory Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Ammonia	--	--	--	--	--	0.000	--	--
Beryllium	0.071	--	--	0.012	0.002	0.000	--	*0.084*
Boron	0.025	--	--	0.000	0.000	0.000	--	*0.025*
Cadmium	0.622	--	--	0.014	0.002	0.000	--	*0.638*
Total Chromium	0.336	--	--	0.015	0.003	0.000	--	*0.354*
Nickel	0.053	--	--	0.000	0.000	0.000	--	*0.054*
TOTAL	*1.108*	--	--	*0.041*	*0.007*	*0.000*	--	1.156

RME Hazard Index: Decreased Body/Organ Weights

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Aluminum	0.497	--	--	0.001	0.000	0.000	--	*0.498*
Cyanide	0.028	--	--	0.000	0.000	--	--	*0.028*
Nickel	0.053	--	--	0.000	0.000	0.000	--	*0.054*
TOTAL	*0.578*	--	--	*0.001*	*0.000*	*0.000*	--	0.580

RME Hazard Index: Circulatory/Cardiovascular System Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Antimony	0.176	--	--	0.001	0.000	--	--	*0.178*
Arsenic	1.871	--	--	0.002	0.000	0.000	--	*1.874*
Barium	0.086	--	--	0.001	0.000	0.000	--	*0.087*
Cobalt	2.738	--	--	0.001	0.000	0.000	--	*2.740*
Nitrite	0.202	--	--	0.000	0.000	--	--	*0.202*
Zinc	0.009	--	--	0.000	0.000	--	--	*0.009*
TOTAL	*4.905*	--	--	*0.005*	*0.001*	*0.001*	--	5.090

RME Hazard Index: Immune System/Thyroid Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Cobalt	2.738	--	--	0.001	0.000	0.000	--	*2.740*
Cyanide	0.028	--	--	0.000	0.000	--	--	*0.028*
Mercury	0.094	--	--	0.000	0.000	0.003	0.000	*0.097*
Perchlorate	0.016	--	--	0.000	0.000	--	--	*0.016*
TOTAL	*2.876*	--	--	*0.001*	*0.000*	*0.003*	*0.000*	2.881

RME Hazard Index: Skin Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Arsenic	1.871	--	--	0.002	0.000	0.000	--	*1.874*
Selenium	0.076	--	--	0.000	0.000	0.000	--	*0.076*
Silver	0.003	--	--	0.000	0.000	--	--	*0.003*
TOTAL	*1.950*	--	--	*0.002*	*0.000*	*0.000*	--	*1.953*

RME Hazard Index: Gastrointestinal Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Beryllium	0.071	--	--	0.012	0.002	0.000	--	*0.084*
Copper	0.023	--	--	0.000	0.000	--	--	*0.023*
Iron	0.847	--	--	0.001	0.000	--	--	*0.848*
TOTAL	*0.941*	--	--	*0.013*	*0.002*	*0.000*	*0.000*	*0.956*

RME Hazard Index: Bone/Teeth Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Strontium	0.074	--	--	0.000	0.000	--	--	*0.074*
Fluoride	0.944	--	--	0.001	0.000	0.000	--	*0.946*
TOTAL	*1.019*	--	--	*0.001*	*0.000*	*0.000*	--	*1.020*

RME Hazard Index: Hair Loss

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Selenium	0.076	--	--	0.000	0.000	0.000	--	*0.076*
Thallium	1.136	--	--	0.001	0.000	--	--	*1.138*
Vanadium	0.316	--	--	0.014	0.002	0.000	--	*0.332*
TOTAL	*1.528*	--	--	*0.015*	*0.003*	*0.000*	--	*1.546*

RME Hazard Index: Liver Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Acetone	0.001	--	--	0.000	0.000	0.000	0.000	*0.001*
Bis(2-ethylhexyl)p	0.032	--	--	--	--	--	--	*0.032*
Thallium	1.136	--	--	0.001	0.000	--	--	*1.138*
TOTAL	*1.169*	--	--	*0.001*	*0.000*	*0.000*	--	*1.171*

RME Hazard Index: Gout

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Molybdenum	0.150	--	--	0.000	0.000	--	--	*0.150*
TOTAL	*0.150*	--	--	*0.000*	*0.000*	--	--	0.150

RME Hazard Index: Reproductive Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Arsenic	1.871	--	--	0.002	0.000	0.000	--	*1.874*
Boron	0.025	--	--	0.000	0.000	0.000	--	*0.025*
Cobalt	2.738	--	--	0.001	0.000	0.000	--	*2.740*
TOTAL	*4.634*	--	--	*0.003*	*0.001*	*0.000*	--	4.639

RME Hazard Index: Central Nervous System Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Acetone	0.001	--	--	0.000	0.000	0.000	0.000	*0.001*
Chloromethane	--	--	--	--	--	0.000	0.000	*0.000*
Cobalt	2.738	--	--	0.001	0.000	0.000	--	*2.740*
Cyanide	0.028	--	--	0.000	0.000	--	--	*0.028*
Lead*	--	--	--	--	--	--	--	--
Manganese	1.349	--	--	0.038	0.006	0.002	--	*1.395*
Mercury	0.094	--	--	0.000	0.000	0.003	0.000	*0.097*
Selenium	0.076	--	--	0.000	0.000	0.000	--	*0.076*
TOTAL	*1.519*	--	--	*0.040*	*0.007*	*0.005*	*0.000*	4.337

Table 5A-6 Carcinogenic Risk: Central Tendency

Chemical of Interest	**Tapwater: Ingestion**	**Homegrown Produce: Ingestion**	**Handwashing: Dermal Uptake**	**Bathing: Dermal Uptake**	**Swimming: Dermal Uptake**	**Bathing: Inhalation**	**Swimming: Inhalation**	***Total Risk:***
Acetone	--	--	--	--	--	--	--	--
Aluminum	--	--	--	--	--	--	--	--
Ammonia	--	--	--	--	--	--	--	--
Antimony	--	--	--	--	--	--	--	--
Arsenic	7E-05	2E-08	2E-09	4E-07	2E-08	5E-12	--	*7E-05*
Barium	--	--	--	--	--	--	--	--
Beryllium	--	--	--	--	--	9E-13	--	*9E-13*
Bis(2-ethylhexyl)phthalate	6E-07	2E-10	--	--	--	2E-15	--	*6E-07*
Boron	--	--	--	--	--	--	--	--
Cadmium	--	--	--	--	--	4E-13	--	*4E-13*
Chloromethane	--	--	--	--	--	--	--	--
Total Chromium	--	--	--	--	--	3E-11	--	*3E-11*
Cobalt	--	--	--	--	--	8E-12	--	*8E-12*
Copper	--	--	--	--	--	--	--	--
Cyanide	--	--	--	--	--	--	--	--
DDE	4E-08	1E-11	--	--	--	3E-16	--	*4E-08*
Fluoride	--	--	--	--	--	--	--	--
Delta HCH	2E-07	6E-11	1E-10	3E-08	2E-09	2E-15	--	*3E-07*
Iron	--	--	--	--	--	--	--	--
Lead	--	--	--	--	--	--	--	--
Manganese	--	--	--	--	--	--	--	--
Mercury	--	--	--	--	--	--	--	--
Molybdenum	--	--	--	--	--	--	--	--
Nickel	--	--	--	--	--	--	--	--
Nitrite	--	--	--	--	--	--	--	--
OCDD	8E-09	2E-12	--	--	--	6E-17	--	*8E-09*
Perchlorate	--	--	--	--	--	--	--	--
Total PCBs	7E-09	2E-12	--	--	--	8E-18	--	*7E-09*
Selenium	--	--	--	--	--	--	--	--
Silver	--	--	--	--	--	--	--	--
Strontium	--	--	--	--	--	--	--	--
Thallium	--	--	--	--	--	--	--	--
Uranium	--	--	--	--	--	--	--	--
Vanadium	--	--	--	--	--	--	--	--
Zinc	--	--	--	--	--	--	--	--
Total	*7E-05*	*2E-08*	*2E-09*	*4E-07*	*2E-08*	*4E-11*	--	*7E-05*

-- Not Applicable.

Table 5A-7 Carcinogenic Risk: Reasonable Maximum Exposure

Chemical of Interest	**Tapwater: Ingestion**	**Homegrown Produce: Ingestion**	**Handwashing: Dermal Uptake**	**Bathing: Dermal Uptake**	**Swimming: Dermal Uptake**	**Bathing: Inhalation**	**Swimming: Inhalation**	***Total Risk:***
Acetone	--	--	--	--	--	--	--	--
Aluminum	--	--	--	--	--	--	--	--
Ammonia	--	--	--	--	--	--	--	--
Antimony	--	--	--	--	--	--	--	--
Arsenic	2E-04	7E-08	6E-09	5E-07	7E-08	7E-12	--	*2E-04*
Barium	--	--	--	--	--	--	--	--
Beryllium	--	--	--	--	--	1E-12	--	*1E-12*
Bis(2-ethylhexyl)phthalate	2E-06	7E-10	--	--	--	4E-15	--	*2E-06*
Boron	--	--	--	--	--	--	--	--
Cadmium	--	--	--	--	--	2E-12	--	*2E-12*
Chloromethane	--	--	--	--	--	--	--	--
Total Chromium	--	--	--	--	--	7E-11	--	*7E-11*
Cobalt	--	--	--	--	--	2E-11	--	*2E-11*
Copper	--	--	--	--	--	--	--	--
Cyanide	--	--	--	--	--	--	--	--
DDE	1E-07	3E-11	--	--	--	3E-16	--	*1E-07*
Fluoride	--	--	--	--	--	--	--	--
Delta HCH	6E-07	2E-10	3E-10	3E-08	4E-09	2E-15	--	*6E-07*
Iron	--	--	--	--	--	--	--	--
Lead	--	--	--	--	--	--	--	--
Manganese	--	--	--	--	--	--	--	--
Mercury	--	--	--	--	--	--	--	--
Molybdenum	--	--	--	--	--	--	--	--
Nickel	--	--	--	--	--	--	--	--
Nitrite	--	--	--	--	--	--	--	--
OCDD	7E-08	2E-11	--	--	--	2E-16	--	*7E-08*
Perchlorate	--	--	--	--	--	--	--	--
Total PCBs	4E-08	1E-11	--	--	--	2E-17	--	*4E-08*
Selenium	--	--	--	--	--	--	--	--
Silver	--	--	--	--	--	--	--	--
Strontium	--	--	--	--	--	--	--	--
Thallium	--	--	--	--	--	--	--	--
Uranium	--	--	--	--	--	--	--	--
Vanadium	--	--	--	--	--	--	--	--
Zinc	--	--	--	--	--	--	--	--
Total	*2E-04*	*7E-08*	*6E-09*	*6E-07*	*7E-08*	*1E-10*	--	*2E-04*

5B-1: Central Tendency Exposure Hazard Indices - Target Health Endpoints

CT Hazard Index: Kidney Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Acetone	0.392	--	--	0.001	0.000	0.000	0.000	*0.393*
Barium	0.644	--	--	0.023	0.002	--	--	*0.669*
Cadmium	0.644	--	--	0.032	0.002	--	--	*0.679*
Uranium	0.644	--	--	0.002	0.000	--	--	*0.646*
TOTAL	*2.325*	--	--	*0.057*	*0.004*	*0.000*	*0.000*	2.386

CT Hazard Index: Respiratory Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Ammonia	--	--	--	--	--	--	--	--
Beryllium	0.129	--	--	0.046	0.003	--	--	*0.178*
Boron	1.933	--	--	0.005	0.000	--	--	*1.938*
Cadmium	0.644	--	--	0.032	0.002	--	--	*0.679*
Total Chromium	2.147	--	--	0.215	0.015	--	--	*2.377*
Nickel	2.255	--	--	0.028	0.002	--	--	*2.285*
TOTAL	*7.107*	--	--	*0.326*	*0.023*	*0.000*	--	7.456

CT Hazard Index: Decreased Body/Organ Weights

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Aluminum	2.351	--	--	0.006	0.000	--	--	*2.358*
Cyanide	0.644	--	--	0.002	0.000	--	--	*0.646*
Nickel	2.255	--	--	0.028	0.002	--	--	*2.285*
TOTAL	*5.250*	--	--	*0.036*	*0.002*	*0.000*	--	5.288

CT Hazard Index: Circulatory/Cardiovascular System Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Antimony	0.966	--	--	0.016	0.001	--	--	*0.983*
Arsenic	2.147	--	--	0.005	0.000	--	--	*2.153*
Barium	0.644	--	--	0.023	0.002	--	--	*0.669*
Cobalt	2.362	--	--	0.002	0.000	--	--	*2.364*
Nitrite	0.121	--	--	--	--	--	--	*0.121*
Zinc	0.429	--	--	0.006	0.000	--	--	*0.436*
TOTAL	*6.670*	--	--	*0.053*	*0.004*	*0.000*	--	6.727

CT Hazard Index: Immune System/Thyroid Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Cobalt	2.362	--	--	0.002	0.000	--	--	*2.364*
Cyanide	0.644	--	--	0.002	0.000	--	--	*0.646*
Mercury	0.805	--	--	0.002	0.000	0.001	0.000	*0.808*
Perchlorate	1.380	--	--	0.003	0.000	--	--	*1.384*
TOTAL	*5.192*	--	--	*0.009*	*0.001*	*0.001*	*0.000*	5.202

CT Hazard Index: **Skin Effects**

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Arsenic	2.147	--	--	0.005	0.000	--	--	*2.153*
Selenium	0.644	--	--	0.002	0.000	--	--	*0.646*
Silver	1.288	--	--	0.048	0.003	--	--	*1.340*
TOTAL	*4.080*	--	--	*0.055*	*0.004*	*0.000*	--	4.139

CT Hazard Index: **Gastrointestinal Effects**

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Beryllium	0.129	--	--	0.046	0.003	--	--	*0.178*
Copper	2.094	--	--	0.005	0.000	--	--	*2.099*
Iron	1.012	--	--	0.003	0.000	--	--	*1.015*
TOTAL	*3.235*	--	--	*0.054*	*0.004*	*0.000*	--	3.292

CT Hazard Index: **Bone/Teeth Effects**

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Strontium	0.429	--	--	0.001	0.000	--	--	*0.431*
Fluoride	4.294	--	--	0.011	0.001	--	--	*4.306*
TOTAL	*4.724*	--	--	*0.012*	*0.001*	*0.000*	--	4.737

CT Hazard Index: **Hair Loss**

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Selenium	0.644	--	--	0.002	0.000	--	--	*0.646*
Thallium	1.952	--	--	0.005	0.000	--	--	*1.957*
Vanadium	0.470	--	--	0.045	0.003	--	--	*0.519*
TOTAL	*3.066*	--	--	*0.052*	*0.004*	*0.000*	--	3.122

CT Hazard Index: **Liver Effects**

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Acetone	0.392	--	--	0.001	0.000	0.000	0.000	*0.393*
Bis(2-ethylhexyl)phthalate	0.019	--	--	--	--	--	--	*0.019*
Thallium	1.952	--	--	0.005	0.000	--	--	*1.957*
TOTAL	*2.364*	--	--	*0.005*	*0.000*	*0.000*	*0.000*	2.369

CT Hazard Index: **Gout**

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Molybdenum	0.515	--	--	0.001	0.000	--	--	*0.517*
TOTAL	*0.515*	--	--	*0.001*	*0.000*	--	--	0.517

CT Hazard Index: **Reproductive Effects**

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Arsenic	2.147	--	--	0.005	0.000	--	--	*2.153*
Boron	1.933	--	--	0.005	0.000	--	--	*1.938*
Cobalt	2.362	--	--	0.002	0.000	--	--	*2.364*
TOTAL	*6.442*	--	--	*0.013*	*0.001*	*0.000*	--	6.455

CT Hazard Index:	**Central Nervous System Effects**							
	Tapwater: Ingestion	**Homegrown Produce: Ingestion**	**Handwashing: Dermal Uptake**	**Bathing: Dermal Uptake**	**Swimming: Dermal Uptake**	**Bathing: Inhalation**	**Swimming: Inhalation**	***TOTAL***
Acetone	0.392	--	--	0.001	0.000	0.000	0.000	*0.393*
Chloromethane	--	--	--	--	--	0.000	0.000	*0.000*
Cobalt	2.362	--	--	0.002	0.000	--	--	*2.364*
Cyanide	0.644	--	--	0.002	0.000	--	--	*0.646*
Lead*	--	--	--	--	--	--	--	--
Manganese	0.134	--	--	0.008	0.001	--	--	*0.143*
Mercury	0.805	--	--	0.002	0.000	0.001	0.000	*0.808*
Selenium	0.644	--	--	0.002	0.000	--	--	*0.646*
TOTAL	*4.982*	--	--	*0.017*	*0.001*	*0.001*	*0.000*	5.000

5B-2: Reasonable Maximum Exposure Hazard Indices - Target Health Endpoints

RME Hazard Index: Nephrotoxicity Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Acetone	0.865	--	--	0.001	0.000	0.000	0.000	*0.866*
Barium	1.421	--	--	0.023	0.004	0.002	--	*1.449*
Cadmium	1.421	--	--	0.032	0.005	0.000	--	*1.458*
Uranium	1.421	--	--	0.002	0.000	0.000	--	*1.422*
TOTAL	*5.126*	--	--	*0.057*	*0.010*	*0.002*	*0.000*	*5.195*

RME Hazard Index: Respiratory Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Ammonia	--	--	--	--	--	0.000	--	--
Beryllium	0.284	--	--	0.046	0.008	0.000	--	*0.338*
Boron	4.262	--	--	0.005	0.001	0.000	--	*4.267*
Cadmium	1.421	--	--	0.032	0.005	0.000	--	*1.458*
Total Chromium	4.735	--	--	0.215	0.036	0.000	--	*4.986*
Nickel	4.972	--	--	0.028	0.005	0.003	--	*5.008*
TOTAL	*15.673*	--	--	*0.326*	*0.054*	*0.004*	--	*16.058*

RME Hazard Index: Decreased Body/Organ Weights

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Aluminum	5.185	--	--	0.006	0.001	0.003	--	*5.195*
Cyanide	1.421	--	--	0.002	0.000	--	--	*1.422*
Nickel	4.972	--	--	0.028	0.005	0.003	--	*5.008*
TOTAL	*11.577*	--	--	*0.036*	*0.006*	*0.006*	--	*11.625*

RME Hazard Index: Circulatory/Cardiovascular System Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Antimony	2.131	--	--	0.016	0.003	--	--	*2.150*
Arsenic	4.735	--	--	0.005	0.001	0.000	--	*4.742*
Barium	1.421	--	--	0.023	0.004	0.002	--	*1.449*
Cobalt	5.209	--	--	0.002	0.000	0.001	--	*5.212*
Nitrite	1.421	--	--	0.002	0.002	--	--	*1.424*
Zinc	0.947	--	--	0.006	0.001	--	--	*0.955*
TOTAL	*13.732*	--	--	*0.039*	*0.008*	*0.003*	--	*15.931*

RME Hazard Index: Immune System/Thyroid Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Cobalt	5.209	--	--	0.002	0.000	0.001	--	*5.212*
Cyanide	1.421	--	--	0.002	0.000	--	--	*1.422*
Mercury	1.776	--	--	0.002	0.000	0.001	0.000	*1.779*
Perchlorate	3.044	--	--	0.003	0.001	--	--	*3.048*
TOTAL	*11.449*	--	--	*0.009*	*0.002*	*0.001*	*0.000*	*11.461*

RME Hazard Index: Skin Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Arsenic	4.735	--	--	0.005	0.001	0.000	--	*4.742*
Selenium	1.421	--	--	0.002	0.000	0.000	--	*1.422*
Silver	2.841	--	--	0.048	0.008	--	--	*2.897*
TOTAL	*8.997*	--	--	*0.055*	*0.009*	*0.000*	--	*9.061*

RME Hazard Index: Gastrointestinal Effects

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	*TOTAL*
Beryllium	0.284	--	--	0.046	0.008	0.000	--	*0.338*
Copper	4.617	--	--	0.005	0.001	--	--	*4.623*
Iron	2.232	--	--	0.003	0.000	--	--	*2.235*
TOTAL	*7.133*	--	--	*0.054*	*0.009*	*0.000*	*0.000*	*7.196*

RME Hazard Index: **Bone/Teeth Effects**

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	***TOTAL***
Strontium	0.947	--	--	0.001	0.000	--	--	*0.948*
Fluoride	9.470	--	--	0.011	0.002	0.000	--	*9.483*
TOTAL	*10.417*	--	--	*0.012*	*0.002*	*0.000*	--	*10.431*

RME Hazard Index: **Hair Loss**

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	***TOTAL***
Selenium	1.421	--	--	0.002	0.000	0.000	--	*1.422*
Thallium	4.305	--	--	0.005	0.001	--	--	*4.310*
Vanadium	1.037	--	--	0.045	0.008	0.000	--	*1.090*
TOTAL	*6.762*	--	--	*0.052*	*0.009*	*0.000*	--	*6.822*

RME Hazard Index: **Liver Effects**

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	***TOTAL***
Acetone	0.865	--	--	0.001	0.000	0.000	0.000	*0.866*
Bis(2-ethylhexyl)phthalate	0.043	--	--	--	--	--	--	*0.043*
Thallium	4.305	--	--	0.005	0.001	--	--	*4.310*
TOTAL	*5.212*	--	--	*0.005*	*0.001*	*0.000*	--	*5.218*

RME Hazard Index: **Gout**

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	***TOTAL***
Molybdenum	1.136	--	--	0.001	0.000	--	--	*1.138*
TOTAL	*1.136*	--	--	*0.001*	*0.000*	--	--	*1.138*

RME Hazard Index: **Reproductive Effects**

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	***TOTAL***
Arsenic	4.735	--	--	0.005	0.001	0.000	--	*4.742*
Boron	4.262	--	--	0.005	0.001	0.000	--	*4.267*
Cobalt	5.209	--	--	0.002	0.000	0.001	--	*5.212*
TOTAL	*14.205*	--	--	*0.013*	*0.002*	*0.001*	--	*14.221*

RME Hazard Index: **Central Nervous System Effects**

	Tapwater: Ingestion	Homegrown Produce: Ingestion	Handwashing: Dermal Uptake	Bathing: Dermal Uptake	Swimming: Dermal Uptake	Bathing: Inhalation	Swimming: Inhalation	***TOTAL***
Acetone	0.865	--	--	0.001	0.000	0.000	0.000	*0.866*
Chloromethane	--	--	--	--	--	0.000	0.000	*0.000*
Cobalt	5.209	--	--	0.002	0.000	0.001	--	*5.212*
Cyanide	1.421	--	--	0.002	0.000	--	--	*1.422*
Lead*	--	--	--	--	--	--	--	--
Manganese	0.296	--	--	0.008	0.001	0.000	--	*0.306*
Mercury	1.776	--	--	0.002	0.000	0.001	0.000	*1.779*
Selenium	1.421	--	--	0.002	0.000	0.000	--	*1.422*
TOTAL	*3.492*	--	--	*0.017*	*0.003*	*0.002*	*0.000*	*11.007*

5B-3: Carcinogenic Risk Central Tendency

Chemical of Interest	**Tapwater: Ingestion**	**Homegrown Produce: Ingestion**	**Handwashing: Dermal Uptake**	**Bathing: Dermal Uptake**	**Swimming: Dermal Uptake**	**Bathing: Inhalation**	**Swimming: Inhalation**	***Total Risk:***
Acetone	--	--	--	--	--	--	--	--
Aluminum	--	--	--	--	--	--	--	--
Ammonia	--	--	--	--	--	--	--	--
Antimony	--	--	--	--	--	--	--	--
Arsenic	2E-04	2E-08	7E-09	1E-06	7E-08	2E-11	--	*2E-04*
Barium	--	--	--	--	--	--	--	--
Beryllium	--	--	--	--	--	3E-12	--	*3E-12*
Bis(2-ethylhexyl)phthalate	1E-06	2E-10	--	--	--	5E-15	--	*1E-06*
Boron	--	--	--	--	--	--	--	--
Cadmium	--	--	--	--	--	3E-12	--	*3E-12*
Chloromethane	--	--	--	--	--	--	--	--
Total Chromium	--	--	--	--	--	6E-10	--	*6E-10*
Cobalt	--	--	--	--	--	4E-11	--	*4E-11*
Copper	--	--	--	--	--	--	--	--
Cyanide	--	--	--	--	--	--	--	--
DDE	1E-06	1E-11	--	--	--	7E-15	--	*1E-06*
Fluoride	--	--	--	--	--	--	--	--
Delta HCH	1E-06	6E-11	6E-10	1E-07	7E-09	7E-15	--	*1E-06*
Iron	--	--	--	--	--	--	--	--
Lead	--	--	--	--	--	--	--	--
Manganese	--	--	--	--	--	--	--	--
Mercury	--	--	--	--	--	--	--	--
Molybdenum	--	--	--	--	--	--	--	--
Nickel	--	--	--	--	--	--	--	--
Nitrite	--	--	--	--	--	--	--	--
OCDD	1E-07	2E-12	--	--	--	9E-16	--	*1E-07*
Perchlorate	--	--	--	--	--	--	--	--
Total PCBs	2E-05	2E-12	--	--	--	2E-14	--	*2E-05*
Selenium	--	--	--	--	--	--	--	--
Silver	--	--	--	--	--	--	--	--
Strontium	--	--	--	--	--	--	--	--
Thallium	--	--	--	--	--	--	--	--
Uranium	--	--	--	--	--	--	--	--
Vanadium	--	--	--	--	--	--	--	--
Zinc	--	--	--	--	--	--	--	--
Total	*3E-04*	*2E-08*	*8E-09*	*1E-06*	*8E-08*	*7E-10*	--	*3E-04*

-- Not Applicable.

5B-4: Carcinogenic Risk: Reasonable Maximum Exposure

Chemical of Interest	**Tapwater: Ingestion**	**Homegrown Produce: Ingestion**	**Handwashing: Dermal Uptake**	**Bathing: Dermal Uptake**	**Swimming: Dermal Uptake**	**Bathing: Inhalation**	**Swimming: Inhalation**	***Total Risk:***
Acetone	--	--	--	--	--	--	--	--
Aluminum	--	--	--	--	--	--	--	--
Ammonia	--	--	--	--	--	--	--	--
Antimony	--	--	--	--	--	--	--	--
Arsenic	6E-04	2E-07	1E-08	1E-06	2E-07	2E-11	--	*6E-04*
Barium	--	--	--	--	--	--	--	--
Beryllium	--	--	--	--	--	4E-12	--	*4E-12*
Bis(2-ethylhexyl)phthalate	3E-06	1E-09	--	--	--	6E-15	--	*3E-06*
Boron	--	--	--	--	--	--	--	--
Cadmium	--	--	--	--	--	4E-12	--	*4E-12*
Chloromethane	--	--	--	--	--	--	--	--
Total Chromium	--	--	--	--	--	9E-10	--	*9E-10*
Cobalt	--	--	--	--	--	4E-11	--	*4E-11*
Copper	--	--	--	--	--	--	--	--
Cyanide	--	--	--	--	--	--	--	--
DDE	3E-06	8E-10	--	--	--	8E-15	--	*3E-06*
Fluoride	--	--	--	--	--	--	--	--
Delta HCH	3E-06	8E-10	1E-09	1E-07	2E-08	8E-15	--	*3E-06*
Iron	--	--	--	--	--	--	--	--
Lead	--	--	--	--	--	--	--	--
Manganese	--	--	--	--	--	--	--	--
Mercury	--	--	--	--	--	--	--	--
Molybdenum	--	--	--	--	--	--	--	--
Nickel	--	--	--	--	--	--	--	--
Nitrite	--	--	--	--	--	--	--	--
OCDD	3E-07	1E-10	--	--	--	1E-15	--	*3E-07*
Perchlorate	--	--	--	--	--	--	--	--
Total PCBs	4E-05	1E-08	--	--	--	2E-14	--	*4E-05*
Selenium	--	--	--	--	--	--	--	--
Silver	--	--	--	--	--	--	--	--
Strontium	--	--	--	--	--	--	--	--
Thallium	--	--	--	--	--	--	--	--
Uranium	--	--	--	--	--	--	--	--
Vanadium	--	--	--	--	--	--	--	--
Zinc	--	--	--	--	--	--	--	--
Total	*6E-04*	*2E-07*	*2E-08*	*1E-06*	*2E-07*	*1E-09*	*--*	*6E-04*

5C-1: Exposure Parameters

Age-Specific Exposure Parameters for Male

Age Cohort	Total Years	Chronic Exposure Duration (days)	Tap Water Ingestion Rate (L/day)		Homegrown Produce Ingestion Rate (kg/day)		Bathing Inhalation Rate (m^3/day)	Swimming Inhalation Rate (m^3/day)	Water Immersion Exposure Times Swimming		Bathing
			CT	RME	CT	RME	RME and CT	RME and CT	CT	RME	RME/CT
Birth to < 5 years old	5	1,825	0.40	1.0	0.0050	0.0151	0.28	0.032	1.8E+05	4.3E+05	2.8E+06
5 to < 15 years old	10	3,650	0.54	1.4	0.0095	0.0269	0.37	0.047	4.3E+05	1.0E+06	6.6E+06
15 <25 years old	10	3,650	0.97	2.5	0.0131	0.0393	0.43	0.041	3.1E+05	7.5E+05	7.1E+06
25 < 70 years	45	16,425	1.18	2.8	0.0164	0.0497	0.24	0.019	6.0E+05	1.4E+06	1.7E+07
Birth to < 70 years old	70	25,550	0.99	2.4	0.0140	0.0421	0.29	0.029	1.5E+06	3.7E+06	3.3E+07

Age-Specific Exposure Parameters for Female

Age Cohort	Total Years	Chronic Exposure Duration (days)	Tap Water Ingestion Rate (L/day)		Homegrown Produce Ingestion Rate (kg/day)		Bathing Inhalation Rate (m^3/day)	Swimming Inhalation Rate (m^3/day)	Water Immersion Exposure Times Swimming		Bathing
			CT	RME	CT	RME	RME and CT	RME and CT	CT	RME	RME/CT
Birth to < 5 years old	5	1,825	0.40	1.0	0.0049	0.0148	0.27	0.031	1.8E+05	4.3E+05	2.8E+06
5 to < 15 years old	10	3,650	0.54	1.4	0.0093	0.0263	0.34	0.044	4.3E+05	1.0E+06	6.6E+06
15 <25 years old	10	3,650	0.97	2.5	0.0112	0.0338	0.36	0.033	3.1E+05	7.5E+05	7.1E+06
25 < 70 years	45	16,425	1.18	2.8	0.0141	0.0427	0.19	0.014	6.0E+05	1.4E+06	1.7E+07
Birth to < 70 years old	70	25,550	0.99	2.4	0.0122	0.0366	0.24	0.023	1.5E+06	3.7E+06	3.3E+07

CT Central Tendency exposure parameter (i.e. average, or typical exposure).

RME Reasonable Maximum Exposure parameter (i.e. upperbound exposure).

See Section X for parameter descriptions.

5C-2: Central Tendency Risk Calculations - Males - Concentration Data

Age Cohort	Radionuclide	Tap Water Ingestion[a]		Grown Produce		Inhalation While Bathing		Swimming		Swimming[a]		Bathing[a]		Total Cancer Risk
		Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Dose (Sv)	Lifetime Cancer Risk	Total Dose [Sv]	Lifetime Cancer Risk	Total Dose [Sv]	Lifetime Cancer Risk	
0 < 5 years	Americium-241	2.2E-04	1.7E-07	2.5E-06	1.8E-09	4.0E-09	4.8E-10	--	--	4.4E-12	2.4E-13	5.9E-11	3.2E-12	1.68E-07
	Lead-214	3.3E-03	1.1E-08	5.0E-08	1.7E-13	6.2E-08	1.0E-11	--	--	9.2E-10	5.1E-11	1.2E-08	6.8E-10	1.22E-08
	Plutonium-238	1.6E-06	1.5E-09	1.9E-08	1.7E-11	3.0E-11	4.2E-12	--	--	2.0E-16	1.1E-17	2.6E-15	1.5E-16	1.55E-09
	Plutonium-239	1.8E-06	1.7E-09	2.1E-08	1.9E-11	3.4E-11	4.7E-12	--	--	1.9E-16	1.0E-17	2.5E-15	1.4E-16	1.76E-09
	Potassium-40	5.2E-03	1.3E-06	6.7E-05	1.7E-08	9.7E-08	3.2E-11	--	--	9.7E-10	5.3E-11	1.3E-08	7.2E-10	1.36E-06
	Radium-226	4.4E-04	9.8E-07	5.1E-06	1.1E-08	8.2E-09	5.3E-10	--	--	3.3E-12	1.8E-13	4.4E-11	2.4E-12	9.95E-07
	Radium-228	5.9E-04	4.6E-06	6.9E-06	5.2E-08	1.1E-08	3.4E-10	--	--	--	--	--	--	4.65E-06
	Strontium-90	8.0E-05	2.2E-08	1.0E-06	2.8E-10	1.5E-09	8.8E-13	--	--	1.3E-14	7.0E-16	1.7E-13	9.3E-15	2.21E-08
	Thorium-228	1.1E-04	1.4E-07	1.3E-06	1.5E-09	2.1E-09	1.6E-09	--	--	2.5E-13	1.4E-14	3.4E-12	1.9E-13	1.42E-07
	Thorium-230	9.9E-05	7.2E-08	1.1E-06	8.0E-10	1.8E-09	3.1E-10	--	--	4.2E-14	2.3E-15	5.6E-13	3.1E-14	7.34E-08
	Thorium-232	8.6E-05	7.3E-08	1.0E-06	8.0E-10	1.6E-09	3.9E-10	--	--	1.8E-14	1.0E-15	2.5E-13	1.4E-14	7.42E-08
	Tritium	1.3E-02	3.4E-09	4.0E-04	2.5E-10	4.5E-09	1.2E-15	5.1E-10	1.4E-16	--	--	--	--	3.67E-09
	Uranium-234	9.3E-04	5.6E-07	1.1E-05	6.5E-09	1.7E-08	1.1E-09	--	--	1.8E-13	9.6E-15	2.3E-12	1.3E-13	5.72E-07
	Uranium-235	3.6E-05	2.2E-08	4.2E-07	2.5E-10	6.7E-10	3.9E-11	--	--	6.1E-12	3.4E-13	8.2E-11	4.5E-12	2.22E-08
	Uranium-238	6.2E-04	3.4E-07	7.2E-06	3.9E-09	1.2E-08	6.2E-10	--	--	5.3E-14	2.9E-15	7.1E-13	3.9E-14	3.46E-07
	Total	**2.4E-02**	**8.3E-06**	**5.1E-04**	**9.7E-08**	**2.2E-07**	**5.5E-09**	**5.1E-10**	**1.4E-16**	**1.9E-09**	**1.1E-10**	**2.6E-08**	**1.4E-09**	**8.44E-06**
10 < 15 years	Americium-241	5.9E-04	1.9E-07	9.6E-06	3.1E-09	1.1E-08	7.2E-10	--	--	1.1E-11	5.9E-13	1.4E-10	7.4E-12	1.91E-07
	Lead-214	9.0E-03	1.3E-08	1.9E-07	2.8E-13	1.6E-07	1.7E-11	--	--	2.3E-09	1.2E-10	2.8E-08	1.6E-09	1.49E-08
	Plutonium-238	4.4E-06	1.7E-09	7.1E-08	2.8E-11	7.8E-11	6.3E-12	--	--	4.8E-16	2.7E-17	6.1E-15	3.4E-16	1.73E-09
	Plutonium-239	5.0E-06	2.0E-09	8.1E-08	3.2E-11	8.9E-11	7.0E-12	--	--	4.6E-16	2.5E-17	5.8E-15	3.2E-16	2.00E-09
	Potassium-40	1.4E-02	1.5E-06	2.6E-04	2.7E-08	2.5E-07	4.0E-11	--	--	2.4E-09	1.3E-10	3.0E-08	1.7E-09	1.52E-06
	Radium-226	1.2E-03	1.7E-06	2.0E-05	2.8E-08	2.1E-08	7.4E-10	--	--	8.0E-12	4.4E-13	1.0E-10	5.6E-12	1.72E-06
	Radium-228	1.6E-03	7.3E-06	2.6E-05	1.2E-07	2.9E-08	4.4E-10	--	--	--	--	--	--	7.37E-06
	Strontium-90	2.2E-04	3.0E-08	3.9E-06	5.4E-10	3.9E-09	1.2E-12	--	--	3.1E-14	1.7E-15	3.9E-13	2.1E-14	3.04E-08
	Thorium-228	3.1E-04	1.4E-07	5.0E-06	2.2E-09	5.6E-09	2.3E-09	--	--	6.2E-13	3.4E-14	7.8E-12	4.3E-13	1.40E-07
	Thorium-230	2.7E-04	7.8E-08	4.4E-06	1.3E-09	4.8E-09	4.1E-10	--	--	1.0E-13	5.6E-15	1.3E-12	7.1E-14	7.92E-08
	Thorium-232	2.3E-04	7.7E-08	3.8E-06	1.3E-09	4.2E-09	4.8E-10	--	--	4.5E-14	2.5E-15	5.7E-13	3.1E-14	7.86E-08
	Tritium	3.4E-02	5.2E-09	1.5E-03	5.7E-10	1.2E-08	1.8E-15	1.5E-09	2.3E-16	--	--	--	--	5.80E-09
	Uranium-234	2.5E-03	6.9E-07	4.1E-05	1.1E-08	4.5E-08	1.6E-09	--	--	4.3E-13	2.4E-14	5.4E-12	3.0E-13	7.03E-07
	Uranium-235	9.7E-05	2.7E-08	1.6E-06	4.4E-10	1.7E-09	5.3E-11	--	--	1.5E-11	8.3E-13	1.9E-10	1.0E-11	2.70E-08
	Uranium-238	1.7E-03	4.2E-07	2.8E-05	6.9E-09	3.0E-08	8.6E-10	--	--	1.3E-13	7.2E-15	1.6E-12	9.0E-14	4.25E-07
	Total	**6.6E-02**	**1.2E-05**	**1.9E-03**	**2.0E-07**	**5.8E-07**	**7.6E-09**	**1.5E-09**	**2.3E-16**	**4.7E-09**	**2.6E-10**	**5.9E-08**	**3.2E-09**	**1.23E-05**
15 < 25 years	Americium-241	1.0E-03	1.7E-07	1.3E-05	2.2E-09	1.2E-08	4.9E-10	--	--	7.7E-12	4.3E-13	1.5E-10	8.1E-12	1.74E-07
	Lead-214	1.6E-02	1.0E-08	2.6E-07	1.7E-13	1.9E-07	9.9E-12	--	--	1.6E-09	9.0E-11	3.1E-08	1.7E-09	1.21E-08
	Plutonium-238	7.8E-06	1.6E-09	9.8E-08	2.1E-11	9.2E-11	4.5E-12	--	--	3.5E-16	1.9E-17	6.6E-15	3.6E-16	1.67E-09
	Plutonium-239	8.8E-06	2.0E-09	1.1E-07	2.5E-11	1.0E-10	5.1E-12	--	--	3.3E-16	1.8E-17	6.3E-15	3.5E-16	1.99E-09
	Potassium-40	2.5E-02	9.0E-07	3.5E-04	1.3E-08	3.0E-07	1.7E-11	--	--	1.7E-09	9.4E-11	3.3E-08	1.8E-09	9.15E-07
	Radium-226	2.1E-03	2.2E-06	2.7E-05	2.8E-08	2.5E-08	3.7E-10	--	--	5.8E-12	3.2E-13	1.1E-10	6.0E-12	2.22E-06
	Radium-228	2.8E-03	7.3E-06	3.6E-05	9.4E-08	3.4E-08	2.2E-10	--	--	--	--	--	--	7.38E-06
	Strontium-90	3.9E-04	4.0E-08	5.4E-06	5.7E-10	4.6E-09	6.0E-13	--	--	2.2E-14	1.2E-15	4.2E-13	2.3E-14	4.09E-08
	Thorium-228	5.5E-04	8.2E-08	6.8E-06	1.0E-09	6.5E-09	1.0E-09	--	--	4.4E-13	2.4E-14	8.4E-12	4.6E-13	8.40E-08
	Thorium-230	4.8E-04	7.0E-08	6.0E-06	8.9E-10	5.6E-09	1.7E-10	--	--	7.4E-14	4.1E-15	1.4E-12	7.7E-14	7.15E-08
	Thorium-232	4.2E-04	7.0E-08	5.3E-06	8.9E-10	4.9E-09	2.3E-10	--	--	3.3E-14	1.8E-15	6.2E-13	3.4E-14	7.14E-08
	Tritium	6.1E-02	5.5E-09	2.1E-03	4.2E-10	1.4E-08	1.2E-15	1.3E-09	1.2E-16	--	--	--	--	5.95E-09
	Uranium-234	4.5E-03	5.2E-07	5.7E-05	6.6E-09	5.3E-08	7.7E-10	--	--	3.1E-13	1.7E-14	5.9E-12	3.2E-13	5.27E-07
	Uranium-235	1.7E-04	2.0E-08	2.2E-06	2.5E-10	2.1E-09	2.6E-11	--	--	1.1E-11	6.0E-13	2.1E-10	1.1E-11	1.98E-08
	Uranium-238	3.0E-03	3.1E-07	3.8E-05	4.0E-09	3.6E-08	4.1E-10	--	--	9.4E-14	5.2E-15	1.8E-12	9.8E-14	3.18E-07
	Total	**1.2E-01**	**1.2E-05**	**2.7E-03**	**1.5E-07**	**6.8E-07**	**3.7E-09**	**1.3E-09**	**1.2E-16**	**3.4E-09**	**1.9E-10**	**6.4E-08**	**3.5E-09**	**1.18E-05**
25 < 70 years	Americium-241	5.8E-03	3.9E-07	7.4E-05	5.5E-09	3.1E-08	6.2E-10	--	--	1.5E-11	8.1E-13	1.5E-11	1.9E-11	3.91E-07
	Lead-214	8.8E-02	1.1E-08	1.5E-06	2.1E-13	4.7E-07	1.0E-11	--	--	3.1E-09	1.7E-10	3.1E-09	4.0E-09	1.52E-08
	Plutonium-238	4.3E-05	3.7E-09	5.5E-07	5.3E-11	2.3E-10	5.5E-12	--	--	6.7E-16	3.7E-17	6.7E-16	8.6E-16	3.76E-09
	Plutonium-239	4.9E-05	4.3E-09	6.3E-07	6.2E-11	2.6E-10	6.2E-12	--	--	6.4E-16	3.5E-17	6.4E-16	8.2E-16	4.38E-09
	Potassium-40	1.4E-01	1.4E-06	2.0E-03	2.2E-08	7.4E-07	2.0E-11	--	--	3.3E-09	1.8E-10	3.3E-09	4.2E-09	1.43E-06
	Radium-226	1.2E-02	1.8E-06	1.5E-04	2.6E-08	6.2E-08	4.2E-10	--	--	1.1E-11	6.1E-13	1.1E-11	1.4E-11	1.85E-06
	Radium-228	1.6E-02	5.3E-06	2.0E-04	7.5E-08	8.4E-08	2.6E-10	--	--	--	--	--	--	5.38E-06
	Strontium-90	2.1E-03	8.5E-08	3.1E-05	1.3E-09	1.1E-08	7.5E-13	--	--	4.3E-14	2.3E-15	4.3E-14	5.5E-14	8.68E-08
	Thorium-228	3.0E-03	1.4E-07	3.8E-05	1.9E-09	1.6E-08	1.3E-09	--	--	8.5E-13	4.7E-14	8.5E-13	1.1E-12	1.41E-07
	Thorium-230	2.6E-03	1.4E-07	3.4E-05	2.1E-09	1.4E-08	2.5E-10	--	--	1.4E-13	7.8E-15	1.4E-13	1.8E-13	1.47E-07
	Thorium-232	2.3E-03	1.3E-07	3.0E-05	1.9E-09	1.2E-08	3.8E-10	--	--	6.2E-14	3.4E-15	6.2E-14	8.0E-14	1.36E-07
	Tritium	3.4E-01	1.1E-08	1.2E-02	9.0E-10	3.4E-08	1.1E-15	2.7E-09	8.8E-17	--	--	--	--	1.20E-08
	Uranium-234	2.5E-02	8.7E-07	3.2E-04	1.2E-08	1.3E-07	8.9E-10	--	--	5.9E-13	3.3E-14	5.9E-13	7.6E-13	8.83E-07
	Uranium-235	9.5E-04	3.2E-08	1.2E-05	4.6E-10	5.1E-09	8.0E-11	--	--	2.1E-11	1.1E-12	2.1E-11	2.7E-11	3.27E-08
	Uranium-238	1.6E-02	5.3E-07	2.1E-04	7.6E-09	8.8E-08	4.8E-10	--	--	1.8E-13	9.9E-15	1.8E-13	2.3E-13	5.36E-07
	Total	**6.5E-01**	**1.1E-05**	**1.5E-02**	**1.6E-07**	**1.7E-06**	**4.7E-09**	**2.7E-09**	**8.8E-17**	**6.4E-09**	**3.5E-10**	**6.4E-09**	**8.3E-09**	**1.11E-05**
Lifetime (0 < 70 years)	Americium-241	7.5E-03	7.8E-07	9.9E-05	1.3E-08	5.9E-08	1.6E-09	--	--	3.8E-11	2.1E-12	6.9E-10	3.8E-11	7.94E-07
	Lead-214	1.1E-01	3.9E-08	2.0E-06	9.5E-13	9.0E-07	3.3E-11	--	--	7.9E-09	4.4E-10	1.4E-07	7.9E-09	4.78E-08
	Plutonium-238	5.6E-05	7.3E-09	7.4E-07	1.2E-10	4.4E-10	1.5E-11	--	--	1.7E-15	9.3E-17	3.1E-14	1.7E-15	7.43E-09
	Plutonium-239	6.3E-05	8.5E-09	8.4E-07	1.5E-10	5.0E-10	1.7E-11	--	--	1.6E-15	8.9E-17	3.0E-14	1.6E-15	8.71E-09
	Potassium-40	1.8E-01	4.4E-06	2.6E-03	9.1E-08	1.4E-06	7.0E-11	--	--	8.4E-09	4.6E-10	1.5E-07	8.4E-09	4.54E-06
	Radium-226	1.5E-02	5.8E-06	2.0E-04	1.0E-07	1.2E-07	1.4E-09	--	--	2.8E-11	1.5E-12	5.1E-10	2.8E-11	5.93E-06
	Radium-228	2.0E-02	2.1E-05	2.7E-04	3.9E-07	1.6E-07	8.3E-10	--	--	--	--	--	--	2.16E-05
	Strontium-90	2.8E-03	1.6E-07	4.1E-05	2.8E-09	2.2E-08	2.3E-12	--	--	1.1E-13	6.0E-15	2.0E-12	1.1E-13	1.58E-07
	Thorium-228	3.9E-03	4.2E-07	5.1E-05	7.6E-09	3.1E-08	4.1E-09	--	--	2.2E-12	1.2E-13	3.9E-11	2.2E-12	4.34E-07
	Thorium-230	3.4E-03	3.1E-07	4.5E-05	5.4E-09	2.7E-08	7.6E-10	--	--	3.6E-13	2.0E-14	6.6E-12	3.6E-13	3.17E-07
	Thorium-232	3.0E-03	3.0E-07	4.0E-05	5.3E-09	2.3E-08	1.0E-09	--	--	1.6E-13	8.7E-15	2.9E-12	1.6E-13	3.08E-07
	Tritium	4.4E-01	2.5E-08	1.6E-02	2.3E-09	6.5E-08	3.6E-15	6.4E-09	3.6E-16	--	--	--	--	2.70E-08
	Uranium-234	3.2E-02	2.3E-06	4.3E-04	4.1E-08	2.5E-07	2.9E-09	--	--	1.5E-12	8.3E-14	2.7E-11	1.5E-12	2.32E-06
	Uranium-235	1.2E-03	8.7E-08	1.6E-05	1.6E-09	9.7E-09	9.8E-11	--	--	5.3E-11	2.9E-12	9.6E-10	5.3E-11	8.82E-08
	Uranium-238	2.1E-02	1.4E-06	2.8E-04	2.5E-08	1.7E-07	1.6E-09	--	--	4.6E-13	2.5E-14	8.3E-12	4.6E-13	1.40E-06
	Total	**8.5E-01**	**3.7E-05**	**2.0E-02**	**6.9E-07**	**3.2E-06**	**1.4E-08**	**6.4E-09**	**3.6E-16**	**1.6E-08**	**9.0E-10**	**3.0E-07**	**1.6E-08**	**3.797E-05**

5C-3: Reasonable Maximum Exposure Risk Calculations - Males - Concentration Data

Age Cohort	Radionuclide	Tap Water Ingestiona		Grown Produce		Inhalation While Bathing		Inhalation While Swimming		Swimminga		Water Immersion - Bathinga		Total Cancer Risk
		Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Dose (Sv)	Lifetime Cancer Risk	Total Dose [Sv]	Lifetime Cancer Risk	Total Dose [Sv]	Lifetime Cancer Risk	
0 < 5 years	Americium-241	1.4E-03	1.0E-06	1.9E-05	1.4E-08	9.9E-09	1.2E-09	--	--	2.1E-11	1.2E-12	1.4E-10	7.9E-12	1.05E-06
	Lead-214	9.3E-03	3.2E-08	1.7E-07	5.7E-13	6.8E-08	1.1E-11	--	--	2.0E-09	1.1E-10	1.4E-08	7.5E-10	3.30E-08
	Plutonium-238	4.9E-06	4.7E-09	6.8E-08	6.1E-11	3.6E-11	5.1E-12	--	--	4.7E-16	2.6E-17	3.2E-15	1.7E-16	4.76E-09
	Plutonium-239	6.0E-06	5.7E-09	8.3E-08	7.5E-11	4.4E-11	6.0E-12	--	--	4.9E-16	2.7E-17	3.3E-15	1.8E-16	5.82E-09
	Potassium-40	3.5E-02	9.0E-06	5.3E-04	1.4E-07	2.5E-07	8.5E-11	--	--	5.1E-09	2.8E-10	3.4E-08	1.9E-09	9.14E-06
	Radium-226	2.2E-03	5.0E-06	3.1E-05	6.9E-08	1.6E-08	1.1E-09	--	--	1.3E-11	7.2E-13	8.8E-11	4.8E-12	5.11E-06
	Radium-228	1.9E-03	1.4E-05	2.6E-05	1.9E-07	1.4E-08	4.2E-10	--	--	--	--	--	--	1.46E-05
	Strontium-90	5.2E-04	1.4E-07	7.9E-06	2.1E-09	3.8E-09	2.2E-12	--	--	6.4E-14	3.5E-15	4.3E-13	2.3E-14	1.42E-07
	Thorium-228	4.5E-04	5.4E-07	6.0E-06	7.1E-09	3.3E-09	2.5E-09	--	--	7.7E-13	4.2E-14	5.2E-12	2.8E-13	5.54E-07
	Thorium-230	5.5E-04	4.1E-07	7.6E-06	5.3E-09	4.1E-09	6.9E-10	--	--	1.8E-13	1.0E-14	1.2E-12	6.8E-14	4.13E-07
	Thorium-232	3.2E-04	2.7E-07	4.4E-06	3.5E-09	2.3E-09	5.7E-10	--	--	5.4E-14	2.9E-15	3.6E-13	2.0E-14	2.75E-07
	Tritium	3.5E-02	9.5E-09	1.3E-03	8.4E-10	4.9E-09	1.3E-15	5.1E-10	1.4E-16	--	--	--	--	1.04E-08
	Uranium-234	2.9E-03	1.7E-06	4.0E-05	2.4E-08	2.1E-08	1.4E-09	--	--	4.2E-13	2.3E-14	2.8E-12	1.6E-13	1.77E-06
	Uranium-235	1.1E-04	6.7E-08	1.5E-06	9.1E-10	8.0E-10	4.6E-11	--	--	1.5E-11	8.0E-13	9.8E-11	5.4E-12	6.75E-08
	Uranium-238	1.9E-03	1.1E-06	2.7E-05	1.5E-08	1.4E-08	7.6E-10	--	--	1.3E-13	7.1E-15	8.7E-13	4.8E-14	1.08E-06
	Total	**9.2E-02**	**3.4E-05**	**2.0E-03**	**4.7E-07**	**4.2E-07**	**8.7E-09**	**5.1E-10**	**1.4E-16**	**7.2E-09**	**3.9E-10**	**4.8E-08**	**2.6E-09**	**3.43E-05**
10 < 15 years	Americium-241	3.8E-03	1.2E-06	6.6E-05	2.1E-08	2.6E-08	1.8E-09	--	--	5.3E-11	2.9E-12	3.3E-10	1.8E-11	1.23E-06
	Lead-214	2.6E-02	3.8E-08	5.9E-07	8.7E-13	1.8E-07	1.9E-11	--	--	5.0E-09	2.7E-10	3.1E-08	1.7E-09	4.02E-08
	Plutonium-238	1.4E-05	5.4E-09	2.4E-07	9.4E-11	9.4E-11	7.5E-12	--	--	1.2E-15	6.4E-17	7.3E-15	4.0E-16	5.47E-09
	Plutonium-239	1.7E-05	6.7E-09	3.0E-07	1.2E-10	1.1E-10	9.1E-12	--	--	1.2E-15	6.6E-17	7.5E-15	4.1E-16	6.82E-09
	Potassium-40	9.7E-02	1.0E-05	1.9E-03	2.0E-07	6.6E-07	1.0E-10	--	--	1.2E-08	6.9E-10	7.9E-08	4.3E-09	1.05E-05
	Radium-226	6.3E-03	9.0E-06	1.1E-04	1.6E-07	4.3E-08	1.5E-09	--	--	3.2E-11	1.8E-12	2.0E-10	1.1E-11	9.14E-06
	Radium-228	5.2E-03	2.4E-05	9.1E-05	4.1E-07	3.5E-08	5.5E-10	--	--	--	--	--	--	2.40E-05
	Strontium-90	1.4E-03	2.0E-07	2.8E-05	3.8E-09	9.9E-09	2.9E-12	--	--	1.6E-13	8.6E-15	9.8E-13	5.4E-14	2.02E-07
	Thorium-228	1.3E-03	5.5E-07	2.1E-05	9.5E-09	8.5E-09	3.5E-09	--	--	1.9E-12	1.0E-13	1.2E-11	6.6E-13	5.63E-07
	Thorium-230	1.6E-03	4.5E-07	2.7E-05	7.9E-09	1.1E-08	8.9E-10	--	--	4.5E-13	2.5E-14	2.8E-12	1.6E-13	4.59E-07
	Thorium-232	8.9E-04	2.9E-07	1.6E-05	5.2E-09	6.1E-09	7.0E-10	--	--	1.3E-13	7.2E-15	8.3E-13	4.5E-14	3.00E-07
	Tritium	9.9E-02	1.5E-08	4.7E-03	1.7E-09	1.3E-08	1.9E-15	1.5E-09	2.3E-16	--	--	--	--	1.69E-08
	Uranium-234	8.1E-03	2.2E-06	1.4E-04	3.9E-08	5.5E-08	1.9E-09	--	--	1.0E-12	5.7E-14	6.6E-12	3.6E-13	2.25E-06
	Uranium-235	3.0E-04	8.3E-08	5.3E-06	1.5E-09	2.1E-09	6.3E-11	--	--	3.6E-11	2.0E-12	2.3E-10	1.2E-11	8.48E-08
	Uranium-238	5.4E-03	1.3E-06	9.5E-05	2.4E-08	3.7E-08	1.0E-09	--	--	3.2E-13	1.7E-14	2.0E-12	1.1E-13	1.37E-06
	Total	**2.6E-01**	**4.9E-05**	**7.2E-03**	**8.9E-07**	**1.1E-06**	**1.2E-08**	**1.5E-09**	**2.3E-16**	**1.8E-08**	**9.7E-10**	**1.1E-07**	**6.1E-09**	**5.02E-05**
15 < 25 years	Americium-241	6.6E-03	1.1E-06	9.7E-05	1.6E-08	3.0E-08	1.2E-09	--	--	3.8E-11	2.1E-12	3.6E-10	2.0E-11	1.09E-06
	Lead-214	4.5E-02	2.9E-08	8.6E-07	5.6E-13	2.1E-07	1.1E-11	--	--	3.6E-09	2.0E-10	3.4E-08	1.9E-09	3.11E-08
	Plutonium-238	2.4E-05	5.1E-09	3.5E-07	7.5E-11	1.1E-10	5.4E-12	--	--	8.4E-16	4.6E-17	8.0E-15	4.4E-16	5.15E-09
	Plutonium-239	2.9E-05	6.5E-09	4.3E-07	9.7E-11	1.4E-10	6.6E-12	--	--	8.6E-16	4.7E-17	8.2E-15	4.5E-16	6.63E-09
	Potassium-40	1.7E-01	6.1E-06	2.8E-03	1.0E-07	7.8E-07	4.6E-11	--	--	9.0E-09	5.0E-10	8.5E-08	4.7E-09	6.17E-06
	Radium-226	1.1E-02	1.1E-05	1.6E-04	1.7E-07	5.0E-08	7.3E-10	--	--	2.3E-11	1.3E-12	2.2E-10	1.2E-11	1.15E-05
	Radium-228	9.0E-03	2.3E-05	1.3E-04	3.5E-07	4.1E-08	2.7E-10	--	--	--	--	--	--	2.34E-05
	Strontium-90	2.5E-03	2.6E-07	4.1E-05	4.3E-09	1.2E-08	1.5E-12	--	--	1.1E-13	6.2E-15	1.1E-12	5.9E-14	2.65E-07
	Thorium-228	2.2E-03	3.2E-07	3.1E-05	4.7E-09	1.0E-08	1.6E-09	--	--	1.4E-12	7.5E-14	1.3E-11	7.1E-13	3.29E-07
	Thorium-230	2.7E-03	4.0E-07	4.0E-05	5.9E-09	1.2E-08	3.8E-10	--	--	3.3E-13	1.8E-14	3.1E-12	1.7E-13	4.05E-07
	Thorium-232	1.6E-03	2.6E-07	2.3E-05	3.9E-09	7.2E-09	3.3E-10	--	--	9.5E-14	5.2E-15	9.0E-13	4.9E-14	2.66E-07
	Tritium	1.7E-01	1.6E-08	6.9E-03	1.4E-09	1.5E-08	1.3E-15	1.3E-09	1.2E-16	--	--	--	--	1.69E-08
	Uranium-234	1.4E-02	1.6E-06	2.1E-04	2.4E-08	6.4E-08	9.3E-10	--	--	7.5E-13	4.1E-14	7.1E-12	3.9E-13	1.64E-06
	Uranium-235	5.3E-04	6.0E-08	7.8E-06	8.9E-10	2.4E-09	3.1E-11	--	--	2.6E-11	1.4E-12	2.4E-10	1.3E-11	6.07E-08
	Uranium-238	9.4E-03	9.9E-07	1.4E-04	1.5E-08	4.3E-08	5.0E-10	--	--	2.3E-13	1.3E-14	2.2E-12	1.2E-13	1.00E-06
	Total	**4.5E-01**	**4.6E-05**	**1.1E-02**	**6.9E-07**	**1.3E-06**	**6.0E-09**	**1.3E-09**	**1.2E-16**	**1.3E-08**	**7.0E-10**	**1.2E-07**	**6.6E-09**	**4.62E-05**
25 < 70 years	Americium-241	3.4E-02	2.3E-06	1.2E-04	9.0E-09	7.6E-08	1.5E-09	--	--	7.2E-11	4.0E-12	8.4E-10	4.6E-11	2.28E-06
	Lead-214	2.3E-01	2.9E-08	1.1E-06	1.6E-13	5.2E-07	1.1E-11	--	--	6.8E-09	3.8E-10	8.0E-08	4.4E-09	3.38E-08
	Plutonium-238	1.2E-04	1.1E-08	4.5E-07	4.3E-11	2.7E-10	6.6E-12	--	--	1.6E-15	8.8E-17	1.9E-14	1.0E-15	1.07E-08
	Plutonium-239	1.5E-04	1.3E-08	5.5E-07	5.4E-11	3.4E-10	8.0E-12	--	--	1.6E-15	9.1E-17	1.9E-14	1.1E-15	1.35E-08
	Potassium-40	8.7E-01	8.9E-06	3.5E-03	3.9E-08	1.9E-06	5.3E-11	--	--	1.7E-08	9.5E-10	2.0E-07	1.1E-08	8.93E-06
	Radium-226	5.6E-02	8.8E-06	2.1E-04	3.5E-08	1.2E-07	8.4E-10	--	--	4.4E-11	2.4E-12	5.2E-10	2.8E-11	8.85E-06
	Radium-228	4.6E-02	1.6E-05	1.7E-04	6.2E-08	1.0E-07	3.1E-10	--	--	--	--	--	--	1.58E-05
	Strontium-90	1.3E-02	5.2E-07	5.2E-05	2.2E-09	2.9E-08	1.9E-12	--	--	2.1E-13	1.2E-14	2.5E-12	1.4E-13	5.21E-07
	Thorium-228	1.1E-02	5.1E-07	4.0E-05	2.0E-09	2.5E-08	2.0E-09	--	--	2.6E-12	1.4E-13	3.0E-11	1.7E-12	5.13E-07
	Thorium-230	1.4E-02	7.7E-07	5.0E-05	3.1E-09	3.1E-08	5.6E-10	--	--	6.2E-13	3.4E-14	7.3E-12	4.0E-13	7.69E-07
	Thorium-232	8.0E-03	4.6E-07	2.9E-05	1.9E-09	1.8E-08	5.5E-10	--	--	1.8E-13	9.9E-15	2.1E-12	1.2E-13	4.67E-07
	Tritium	8.9E-01	2.9E-08	8.8E-03	6.7E-10	3.7E-08	1.2E-15	2.7E-09	8.8E-17	--	--	--	--	3.00E-08
	Uranium-234	7.2E-02	2.5E-06	2.6E-04	1.0E-08	1.6E-07	1.1E-09	--	--	1.4E-12	7.9E-14	1.7E-11	9.2E-13	2.55E-06
	Uranium-235	2.7E-03	9.2E-08	9.9E-06	3.7E-10	6.1E-09	9.5E-11	--	--	4.9E-11	2.7E-12	5.7E-10	3.2E-11	9.24E-08
	Uranium-238	4.9E-02	1.6E-06	1.8E-04	6.2E-09	1.1E-07	5.9E-10	--	--	4.4E-13	2.4E-14	5.1E-12	2.8E-13	1.56E-06
	Total	**2.3E+00**	**4.2E-05**	**1.3E-02**	**1.7E-07**	**3.2E-06**	**7.6E-09**	**2.7E-09**	**8.8E-17**	**2.4E-08**	**1.3E-09**	**2.8E-07**	**1.6E-08**	**4.24E-05**
Lifetime (0 < 70 years)	Americium-241	4.5E-02	4.7E-06	7.3E-04	9.8E-08	1.4E-07	4.0E-09	--	--	1.8E-10	1.0E-11	1.7E-09	9.2E-11	4.79E-06
	Lead-214	3.1E-01	1.1E-07	6.5E-06	3.1E-12	9.8E-07	3.6E-11	--	--	1.7E-08	9.6E-10	1.6E-07	8.7E-09	1.16E-07
	Plutonium-238	1.6E-04	2.2E-08	2.6E-06	4.5E-10	5.2E-10	1.8E-11	--	--	4.1E-15	2.2E-16	3.7E-14	2.0E-15	2.20E-08
	Plutonium-239	2.0E-04	2.7E-08	3.2E-06	5.6E-10	6.4E-10	2.1E-11	--	--	4.2E-15	2.3E-16	3.8E-14	2.1E-15	2.77E-08
	Potassium-40	1.2E+00	2.9E-05	2.1E-02	7.1E-07	3.7E-06	1.8E-10	--	--	4.4E-08	2.4E-09	4.0E-07	2.2E-08	2.93E-05
	Radium-226	7.5E-02	2.9E-05	1.2E-03	6.3E-07	2.4E-07	2.7E-09	--	--	1.1E-10	6.2E-12	1.0E-09	5.7E-11	2.94E-05
	Radium-228	6.2E-02	6.4E-05	1.0E-03	1.4E-06	2.0E-07	1.0E-09	--	--	--	--	--	--	6.55E-05
	Strontium-90	1.7E-02	9.6E-07	3.1E-04	2.1E-08	5.5E-08	5.8E-12	--	--	5.5E-13	3.0E-14	5.0E-12	2.7E-13	9.84E-07
	Thorium-228	1.5E-02	1.6E-06	2.4E-04	3.5E-08	4.7E-08	6.3E-09	--	--	6.6E-12	3.6E-13	6.0E-11	3.3E-12	1.63E-06
	Thorium-230	1.8E-02	1.7E-06	3.0E-04	3.5E-08	5.9E-08	1.7E-09	--	--	1.6E-12	8.7E-14	1.4E-11	7.9E-13	1.72E-06
	Thorium-232	1.1E-02	1.1E-06	1.7E-04	2.3E-08	3.4E-08	1.5E-09	--	--	4.6E-13	2.5E-14	4.2E-12	2.3E-13	1.10E-06
	Tritium	1.2E+00	6.6E-08	5.2E-02	7.5E-09	7.1E-08	4.0E-15	6.4E-09	3.6E-16	--	--	--	--	7.39E-08
	Uranium-234	9.6E-02	6.8E-06	1.5E-03	1.5E-07	3.1E-07	3.5E-09	--	--	3.6E-12	2.0E-13	3.3E-11	1.8E-12	6.92E-06
	Uranium-235	3.6E-03	2.5E-07	5.9E-05	5.5E-09	1.2E-08	1.2E-10	--	--	1.3E-10	6.9E-12	1.1E-09	6.3E-11	2.58E-07
	Uranium-238	6.4E-02	4.1E-06	1.0E-03	9.0E-08	2.1E-07	1.9E-09	--	--	1.1E-12	6.1E-14	1.0E-11	5.6E-13	4.22E-06
	Total	**3.1E+00**	**1.4E-04**	**7.9E-02**	**3.2E-06**	**6.0E-06**	**2.3E-08**	**6.4E-09**	**3.6E-16**	**6.2E-08**	**3.4E-09**	**5.6E-07**	**3.1E-08**	**1.460E-04**

5C-4: Central Tendency Risk Calculations - Females - Concentration Data

Age Cohort	Radionuclide	Tap Water Ingestiona		Grown Produce		Inhalation While Bathing		Inhalation While Swimming		Swimminga		Water Immersion - Bathinga		Total Cancer Risk
		Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Dose (Sv)	Lifetime Cancer Risk	Total Dose [Sv]	Lifetime Cancer Risk	Total Dose [Sv]	Lifetime Cancer Risk	
0 < 5 years	Americium-241	2.2E-04	1.7E-07	2.5E-06	1.8E-09	3.9E-09	4.6E-10	--	--	4.4E-12	2.4E-13	5.9E-11	3.2E-12	1.68E-07
	Lead-214	3.3E-03	1.1E-08	4.9E-08	1.7E-13	6.0E-08	1.0E-11	--	--	9.2E-10	5.1E-11	1.2E-08	6.8E-10	1.22E-08
	Plutonium-238	1.6E-06	1.5E-09	1.8E-08	1.7E-11	2.9E-11	4.1E-12	--	--	2.0E-16	1.1E-17	2.6E-15	1.5E-16	1.55E-09
	Plutonium-239	1.8E-06	1.7E-09	2.1E-08	1.9E-11	3.3E-11	4.6E-12	--	--	1.9E-16	1.0E-17	2.5E-15	1.4E-16	1.76E-09
	Potassium-40	5.2E-03	1.3E-06	6.5E-05	1.7E-08	9.4E-08	3.2E-11	--	--	9.7E-10	5.3E-11	1.3E-08	7.2E-10	1.36E-06
	Radium-226	4.4E-04	9.8E-07	5.0E-06	1.1E-08	8.0E-09	5.2E-10	--	--	3.3E-12	1.8E-13	4.4E-11	2.4E-12	9.95E-07
	Radium-228	5.9E-04	4.6E-06	6.7E-06	5.1E-08	1.1E-08	3.3E-10	--	--	--	--	--	--	4.64E-06
	Strontium-90	8.0E-05	2.2E-08	1.0E-06	2.7E-10	1.5E-09	8.6E-13	--	--	1.3E-14	7.0E-16	1.7E-13	9.3E-15	2.21E-08
	Thorium-228	1.1E-04	1.4E-07	1.3E-06	1.5E-09	2.1E-09	1.6E-09	--	--	2.5E-13	1.4E-14	3.4E-12	1.9E-13	1.42E-07
	Thorium-230	9.9E-05	7.2E-08	1.1E-06	7.8E-10	1.8E-09	3.1E-10	--	--	4.2E-14	2.3E-15	5.6E-13	3.1E-14	7.34E-08
	Thorium-232	8.6E-05	7.3E-08	9.8E-07	7.8E-10	1.6E-09	3.8E-10	--	--	1.8E-14	1.0E-15	2.5E-13	1.4E-14	7.42E-08
	Tritium	1.3E-02	3.4E-09	3.9E-04	2.5E-10	4.3E-09	1.2E-15	4.9E-10	1.3E-16	--	--	--	--	3.66E-09
	Uranium-234	9.3E-04	5.6E-07	1.1E-05	6.4E-09	1.7E-08	1.1E-09	--	--	1.8E-13	9.6E-15	2.3E-12	1.3E-13	5.72E-07
	Uranium-235	3.6E-05	2.2E-08	4.1E-07	2.5E-10	6.5E-10	3.8E-11	--	--	6.1E-12	3.4E-13	8.2E-11	4.5E-12	2.22E-08
	Uranium-238	6.2E-04	3.4E-07	7.1E-06	3.9E-09	1.1E-08	6.1E-10	--	--	5.3E-14	2.9E-15	7.1E-13	3.9E-14	3.46E-07
	Total	**2.4E-02**	**8.3E-06**	**5.0E-04**	**9.5E-08**	**2.2E-07**	**5.4E-09**	**4.9E-10**	**1.3E-16**	**1.9E-09**	**1.1E-10**	**2.6E-08**	**1.4E-09**	**8.44E-06**
10 < 15 years	Americium-241	5.9E-04	1.9E-07	9.4E-06	3.0E-09	9.9E-09	6.7E-10	--	--	1.1E-11	5.9E-13	1.4E-10	7.4E-12	1.91E-07
	Lead-214	9.0E-03	1.3E-08	1.9E-07	2.7E-13	1.5E-07	1.6E-11	--	--	2.3E-09	1.2E-10	2.8E-08	1.6E-09	1.49E-08
	Plutonium-238	4.4E-06	1.7E-09	7.0E-08	2.7E-11	7.3E-11	5.9E-12	--	--	4.8E-16	2.7E-17	6.1E-15	3.4E-16	1.73E-09
	Plutonium-239	5.0E-06	2.0E-09	7.9E-08	3.2E-11	8.3E-11	6.6E-12	--	--	4.6E-16	2.5E-17	5.8E-15	3.2E-16	2.00E-09
	Potassium-40	1.4E-02	1.5E-06	2.5E-04	2.7E-08	2.4E-07	3.7E-11	--	--	2.4E-09	1.3E-10	3.0E-08	1.7E-09	1.52E-06
	Radium-226	1.2E-03	1.7E-06	1.9E-05	2.8E-08	2.0E-08	6.9E-10	--	--	8.0E-12	4.4E-13	1.0E-10	5.6E-12	1.72E-06
	Radium-228	1.6E-03	7.3E-06	2.6E-05	1.2E-07	2.7E-08	4.2E-10	--	--	--	--	--	--	7.37E-06
	Strontium-90	2.2E-04	3.0E-08	3.9E-06	5.3E-10	3.7E-09	1.1E-12	--	--	3.1E-14	1.7E-15	3.9E-13	2.1E-14	3.04E-08
	Thorium-228	3.1E-04	1.4E-07	4.9E-06	2.2E-09	5.2E-09	2.1E-09	--	--	6.2E-13	3.4E-14	7.8E-12	4.3E-13	1.40E-07
	Thorium-230	2.7E-04	7.8E-08	4.3E-06	1.2E-09	4.5E-09	3.8E-10	--	--	1.0E-13	5.6E-15	1.3E-12	7.1E-14	7.91E-08
	Thorium-232	2.3E-04	7.7E-08	3.7E-06	1.2E-09	3.9E-09	4.5E-10	--	--	4.5E-14	2.5E-15	5.7E-13	3.1E-14	7.86E-08
	Tritium	3.4E-02	5.2E-09	1.5E-03	5.5E-10	1.1E-08	1.7E-15	1.4E-09	2.1E-16	--	--	--	--	5.78E-09
	Uranium-234	2.5E-03	6.9E-07	4.0E-05	1.1E-08	4.2E-08	1.5E-09	--	--	4.3E-13	2.4E-14	5.4E-12	3.0E-13	7.03E-07
	Uranium-235	9.7E-05	2.7E-08	1.6E-06	4.3E-10	1.6E-09	5.0E-11	--	--	1.5E-11	8.3E-13	1.9E-10	1.0E-11	2.70E-08
	Uranium-238	1.7E-03	4.2E-07	2.7E-05	6.7E-09	2.8E-08	8.0E-10	--	--	1.3E-13	7.2E-15	1.6E-12	9.0E-14	4.24E-07
	Total	**6.6E-02**	**1.2E-05**	**1.9E-03**	**2.0E-07**	**5.4E-07**	**7.1E-09**	**1.4E-09**	**2.1E-16**	**4.7E-09**	**2.6E-10**	**5.9E-08**	**3.2E-09**	**1.23E-05**
15 < 25 years	Americium-241	1.0E-03	1.7E-07	1.1E-05	1.9E-09	1.0E-08	4.1E-10	--	--	7.7E-12	4.3E-13	1.5E-10	8.1E-12	1.73E-07
	Lead-214	1.6E-02	1.0E-08	2.2E-07	1.5E-13	1.6E-07	8.3E-12	--	--	1.6E-09	9.0E-11	3.1E-08	1.7E-09	1.21E-08
	Plutonium-238	7.8E-06	1.6E-09	8.4E-08	1.8E-11	7.7E-11	3.7E-12	--	--	3.5E-16	1.9E-17	6.6E-15	3.6E-16	1.66E-09
	Plutonium-239	8.8E-06	2.0E-09	9.6E-08	2.1E-11	8.7E-11	4.3E-12	--	--	3.3E-16	1.8E-17	6.3E-15	3.5E-16	1.99E-09
	Potassium-40	2.5E-02	9.0E-07	3.0E-04	1.1E-08	2.5E-07	1.4E-11	--	--	1.7E-09	9.4E-11	3.3E-08	1.8E-09	9.13E-07
	Radium-226	2.1E-03	2.2E-06	2.3E-05	2.4E-08	2.1E-08	3.0E-10	--	--	5.8E-12	3.2E-13	1.1E-10	6.0E-12	2.22E-06
	Radium-228	2.8E-03	7.3E-06	3.1E-05	8.0E-08	2.8E-08	1.8E-10	--	--	--	--	--	--	7.37E-06
	Strontium-90	3.9E-04	4.0E-08	4.7E-06	4.9E-10	3.8E-09	5.0E-13	--	--	2.2E-14	1.2E-15	4.2E-13	2.3E-14	4.08E-08
	Thorium-228	5.5E-04	8.2E-08	5.9E-06	8.8E-10	5.4E-09	8.6E-10	--	--	4.4E-13	2.4E-14	8.4E-12	4.6E-13	8.36E-08
	Thorium-230	4.8E-04	7.0E-08	5.2E-06	7.6E-10	4.7E-09	1.4E-10	--	--	7.4E-14	4.1E-15	1.4E-12	7.7E-14	7.13E-08
	Thorium-232	4.2E-04	7.0E-08	4.5E-06	7.6E-10	4.1E-09	1.9E-10	--	--	3.3E-14	1.8E-15	6.2E-13	3.4E-14	7.12E-08
	Tritium	6.1E-02	5.5E-09	1.8E-03	3.6E-10	1.1E-08	1.0E-15	1.0E-09	9.5E-17	--	--	--	--	5.89E-09
	Uranium-234	4.5E-03	5.2E-07	4.9E-05	5.6E-09	4.4E-08	6.4E-10	--	--	3.1E-13	1.7E-14	5.9E-12	3.2E-13	5.26E-07
	Uranium-235	1.7E-04	2.0E-08	1.9E-06	2.1E-10	1.7E-09	2.2E-11	--	--	1.1E-11	6.0E-13	2.1E-10	1.1E-11	1.98E-08
	Uranium-238	3.0E-03	3.1E-07	3.2E-05	3.4E-09	3.0E-08	3.4E-10	--	--	9.4E-14	5.2E-15	1.8E-12	9.8E-14	3.18E-07
	Total	**1.2E-01**	**1.2E-05**	**2.3E-03**	**1.3E-07**	**5.7E-07**	**3.1E-09**	**1.0E-09**	**9.5E-17**	**3.4E-09**	**1.9E-10**	**6.4E-08**	**3.5E-09**	**1.18E-05**
25 < 70 years	Americium-241	5.8E-03	3.9E-07	6.4E-05	4.7E-09	2.5E-08	5.0E-10	--	--	1.5E-11	8.1E-13	1.5E-11	1.9E-11	3.91E-07
	Lead-214	8.8E-02	1.1E-08	1.3E-06	1.8E-13	3.8E-07	8.3E-12	--	--	3.1E-09	1.7E-10	3.1E-09	4.0E-09	1.52E-08
	Plutonium-238	4.3E-05	3.7E-09	4.7E-07	4.6E-11	1.8E-10	4.4E-12	--	--	6.7E-16	3.7E-17	6.7E-16	8.6E-16	3.75E-09
	Plutonium-239	4.9E-05	4.3E-09	5.4E-07	5.4E-11	2.1E-10	5.0E-12	--	--	6.4E-16	3.5E-17	6.4E-16	8.2E-16	4.37E-09
	Potassium-40	1.4E-01	1.4E-06	1.7E-03	1.9E-08	6.0E-07	1.6E-11	--	--	3.3E-09	1.8E-10	3.3E-09	4.2E-09	1.43E-06
	Radium-226	1.2E-02	1.8E-06	1.3E-04	2.2E-08	5.0E-08	3.4E-10	--	--	1.1E-11	6.1E-13	1.1E-11	1.4E-11	1.85E-06
	Radium-228	1.6E-02	5.3E-06	1.8E-04	6.4E-08	6.8E-08	2.1E-10	--	--	--	--	--	--	5.37E-06
	Strontium-90	2.1E-03	8.5E-08	2.6E-05	1.1E-09	9.2E-09	6.1E-13	--	--	4.3E-14	2.3E-15	4.3E-14	5.5E-14	8.66E-08
	Thorium-228	3.0E-03	1.4E-07	3.3E-05	1.6E-09	1.3E-08	1.0E-09	--	--	8.5E-13	4.7E-14	8.5E-13	1.1E-12	1.41E-07
	Thorium-230	2.6E-03	1.4E-07	2.9E-05	1.8E-09	1.1E-08	2.0E-10	--	--	1.4E-13	7.8E-15	1.4E-13	1.8E-13	1.47E-07
	Thorium-232	2.3E-03	1.3E-07	2.5E-05	1.7E-09	9.9E-09	3.0E-10	--	--	6.2E-14	3.4E-15	6.2E-14	8.0E-14	1.35E-07
	Tritium	3.4E-01	1.1E-08	1.0E-02	7.8E-10	2.7E-08	9.1E-16	2.0E-09	6.7E-17	--	--	--	--	1.19E-08
	Uranium-234	2.5E-02	8.7E-07	2.7E-04	1.1E-08	1.1E-07	7.2E-10	--	--	5.9E-13	3.3E-14	5.9E-13	7.6E-13	8.81E-07
	Uranium-235	9.5E-04	3.2E-08	1.1E-05	4.0E-10	4.1E-09	6.5E-11	--	--	2.1E-11	1.1E-12	2.1E-11	2.7E-11	3.26E-08
	Uranium-238	1.6E-02	5.3E-07	1.8E-04	6.5E-09	7.1E-08	3.9E-10	--	--	1.8E-13	9.9E-15	1.8E-13	2.3E-13	5.35E-07
	Total	**6.5E-01**	**1.1E-05**	**1.3E-02**	**1.3E-07**	**1.4E-06**	**3.8E-09**	**2.0E-09**	**6.7E-17**	**6.4E-09**	**3.5E-10**	**6.4E-09**	**8.3E-09**	**1.10E-05**
Lifetime (0 < 70 years)	Americium-241	7.5E-03	7.8E-07	8.6E-05	1.2E-08	4.9E-08	1.4E-09	--	--	3.8E-11	2.1E-12	6.9E-10	3.8E-11	7.92E-07
	Lead-214	1.1E-01	3.9E-08	1.7E-06	8.3E-13	7.5E-07	2.7E-11	--	--	7.9E-09	4.4E-10	1.4E-07	7.9E-09	4.78E-08
	Plutonium-238	5.6E-05	7.3E-09	6.4E-07	1.1E-10	3.6E-10	1.2E-11	--	--	1.7E-15	9.3E-17	3.1E-14	1.7E-15	7.42E-09
	Plutonium-239	6.3E-05	8.5E-09	7.3E-07	1.3E-10	4.1E-10	1.4E-11	--	--	1.6E-15	8.9E-17	3.0E-14	1.6E-15	8.68E-09
	Potassium-40	1.8E-01	4.4E-06	2.3E-03	7.9E-08	1.2E-06	5.9E-11	--	--	8.4E-09	4.6E-10	1.5E-07	8.4E-09	4.53E-06
	Radium-226	1.5E-02	5.8E-06	1.8E-04	9.1E-08	9.9E-08	1.1E-09	--	--	2.8E-11	1.5E-12	5.1E-10	2.8E-11	5.92E-06
	Radium-228	2.0E-02	2.1E-05	2.4E-04	3.4E-07	1.3E-07	6.9E-10	--	--	--	--	--	--	2.15E-05
	Strontium-90	2.8E-03	1.6E-07	3.5E-05	2.4E-09	1.8E-08	1.9E-12	--	--	1.1E-13	6.0E-15	2.0E-12	1.1E-13	1.58E-07
	Thorium-228	3.9E-03	4.2E-07	4.5E-05	6.6E-09	2.6E-08	3.4E-09	--	--	2.2E-12	1.2E-13	3.9E-11	2.2E-12	4.33E-07
	Thorium-230	3.4E-03	3.1E-07	3.9E-05	4.7E-09	2.2E-08	6.4E-10	--	--	3.6E-13	2.0E-14	6.6E-12	3.6E-13	3.16E-07
	Thorium-232	3.0E-03	3.0E-07	3.4E-05	4.6E-09	2.0E-08	8.5E-10	--	--	1.6E-13	8.7E-15	2.9E-12	1.6E-13	3.07E-07
	Tritium	4.4E-01	2.5E-08	1.4E-02	2.0E-09	5.4E-08	3.0E-15	5.0E-09	2.8E-16	--	--	--	--	2.67E-08
	Uranium-234	3.2E-02	2.3E-06	3.7E-04	3.5E-08	2.1E-07	2.4E-09	--	--	1.5E-12	8.3E-14	2.7E-11	1.5E-12	2.31E-06
	Uranium-235	1.2E-03	8.7E-08	1.4E-05	1.4E-09	8.1E-09	8.2E-11	--	--	5.3E-11	2.9E-12	9.6E-10	5.3E-11	8.80E-08
	Uranium-238	2.1E-02	1.4E-06	2.5E-04	2.1E-08	1.4E-07	1.3E-09	--	--	4.6E-13	2.5E-14	8.3E-12	4.6E-13	1.40E-06
	Total	**8.5E-01**	**3.7E-05**	**1.7E-02**	**6.0E-07**	**2.7E-06**	**1.2E-08**	**5.0E-09**	**2.8E-16**	**1.6E-08**	**9.0E-10**	**3.0E-07**	**1.6E-08**	**3.788E-05**

5C-5: Reasonable Maximum Exposure Risk Calculations - Females - Concentration Data

Age Cohort	Radionuclide	Tap Water Ingestiona		Grown Produce		Inhalation While Bathing		Inhalation While Swimming		Water Immersion - Swimminga		Water Immersion - Bathinga		Total Cancer Risk
		Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Dose (Sv)	Lifetime Cancer Risk	Total Dose [Sv]	Lifetime Cancer Risk	
0 < 5 years	Americium-241	1.4E-03	1.0E-06	1.8E-05	1.3E-08	9.6E-09	1.1E-09	--	--	2.1E-11	1.2E-12	1.4E-10	7.9E-12	1.05E-06
	Lead-214	9.3E-03	3.2E-08	1.6E-07	5.6E-13	6.6E-08	1.1E-11	--	--	2.0E-09	1.1E-10	1.4E-08	7.5E-10	3.30E-08
	Plutonium-238	4.9E-06	4.7E-09	6.7E-08	6.0E-11	3.5E-11	5.0E-12	--	--	4.7E-16	2.6E-17	3.2E-15	1.7E-16	4.75E-09
	Plutonium-239	6.0E-06	5.7E-09	8.1E-08	7.4E-11	4.3E-11	5.9E-12	--	--	4.9E-16	2.7E-17	3.3E-15	1.8E-16	5.82E-09
	Potassium-40	3.5E-02	9.0E-06	5.2E-04	1.3E-07	2.5E-07	8.3E-11	--	--	5.1E-09	2.8E-10	3.4E-08	1.9E-09	9.13E-06
	Radium-226	2.2E-03	5.0E-06	3.1E-05	6.8E-08	1.6E-08	1.0E-09	--	--	1.3E-11	7.2E-13	8.8E-11	4.8E-12	5.11E-06
	Radium-228	1.9E-03	1.4E-05	2.5E-05	1.9E-07	1.3E-08	4.1E-10	--	--	--	--	--	--	1.46E-05
	Strontium-90	5.2E-04	1.4E-07	7.7E-06	2.1E-09	3.7E-09	2.2E-12	--	--	6.4E-14	3.5E-15	4.3E-13	2.3E-14	1.42E-07
	Thorium-228	4.5E-04	5.4E-07	5.9E-06	7.0E-09	3.2E-09	2.4E-09	--	--	7.7E-13	4.2E-14	5.2E-12	2.8E-13	5.54E-07
	Thorium-230	5.5E-04	4.1E-07	7.5E-06	5.2E-09	4.0E-09	6.8E-10	--	--	1.8E-13	1.0E-14	1.2E-12	6.8E-14	4.12E-07
	Thorium-232	3.2E-04	2.7E-07	4.3E-06	3.4E-09	2.3E-09	5.5E-10	--	--	5.4E-14	2.9E-15	3.6E-13	2.0E-14	2.74E-07
	Tritium	3.5E-02	9.5E-09	1.3E-03	8.3E-10	4.8E-09	1.3E-15	4.9E-10	1.3E-16	--	--	--	--	1.04E-08
	Uranium-234	2.9E-03	1.7E-06	3.9E-05	2.4E-08	2.0E-08	1.3E-09	--	--	4.2E-13	2.3E-14	2.8E-12	1.6E-13	1.77E-06
	Uranium-235	1.1E-04	6.7E-08	1.5E-06	8.9E-10	7.8E-10	4.5E-11	--	--	1.5E-11	8.0E-13	9.8E-11	5.4E-12	6.75E-08
	Uranium-238	1.9E-03	1.1E-06	2.6E-05	1.4E-08	1.4E-08	7.4E-10	--	--	1.3E-13	7.1E-15	8.7E-13	4.8E-14	1.08E-06
	Total	**9.2E-02**	**3.4E-05**	**2.0E-03**	**4.6E-07**	**4.1E-07**	**8.5E-09**	**4.9E-10**	**1.3E-16**	**7.2E-09**	**3.9E-10**	**4.8E-08**	**2.6E-09**	**3.43E-05**
10 < 15 years	Americium-241	3.8E-03	1.2E-06	6.5E-05	2.1E-08	2.4E-08	1.6E-09	--	--	5.3E-11	2.9E-12	3.3E-10	1.8E-11	1.23E-06
	Lead-214	2.6E-02	3.8E-08	5.8E-07	8.5E-13	1.7E-07	1.8E-11	--	--	5.0E-09	2.7E-10	3.1E-08	1.7E-09	4.02E-08
	Plutonium-238	1.4E-05	5.4E-09	2.4E-07	9.2E-11	8.8E-11	7.1E-12	--	--	1.2E-15	6.4E-17	7.3E-15	4.0E-16	5.47E-09
	Plutonium-239	1.7E-05	6.7E-09	2.9E-07	1.2E-10	1.1E-10	8.5E-12	--	--	1.2E-15	6.6E-17	7.5E-15	4.1E-16	6.81E-09
	Potassium-40	9.7E-02	1.0E-05	1.9E-03	2.0E-07	6.2E-07	9.7E-11	--	--	1.2E-08	6.9E-10	7.9E-08	4.3E-09	1.05E-05
	Radium-226	6.3E-03	9.0E-06	1.1E-04	1.6E-07	4.0E-08	1.4E-09	--	--	3.2E-11	1.8E-12	2.0E-10	1.1E-11	9.13E-06
	Radium-228	5.2E-03	2.4E-05	9.0E-05	4.0E-07	3.3E-08	5.1E-10	--	--	--	--	--	--	2.40E-05
	Strontium-90	1.4E-03	2.0E-07	2.8E-05	3.8E-09	9.2E-09	2.7E-12	--	--	1.6E-13	8.6E-15	9.8E-13	5.4E-14	2.02E-07
	Thorium-228	1.3E-03	5.5E-07	2.1E-05	9.3E-09	8.0E-09	3.2E-09	--	--	1.9E-12	1.0E-13	1.2E-11	6.6E-13	5.63E-07
	Thorium-230	1.6E-03	4.5E-07	2.7E-05	7.7E-09	9.9E-09	8.4E-10	--	--	4.5E-13	2.5E-14	2.8E-12	1.6E-13	4.59E-07
	Thorium-232	8.9E-04	2.9E-07	1.5E-05	5.1E-09	5.7E-09	6.6E-10	--	--	1.3E-13	7.2E-15	8.3E-13	4.5E-14	3.00E-07
	Tritium	9.9E-02	1.5E-08	4.6E-03	1.7E-09	1.2E-08	1.8E-15	1.4E-09	2.1E-16	--	--	--	--	1.68E-08
	Uranium-234	8.1E-03	2.2E-06	1.4E-04	3.8E-08	5.1E-08	1.8E-09	--	--	1.0E-12	5.7E-14	6.6E-12	3.6E-13	2.25E-06
	Uranium-235	3.0E-04	8.3E-08	5.2E-06	1.4E-09	1.9E-09	5.9E-11	--	--	3.6E-11	2.0E-12	2.3E-10	1.2E-11	8.48E-08
	Uranium-238	5.4E-03	1.3E-06	9.3E-05	2.3E-08	3.5E-08	9.8E-10	--	--	3.2E-13	1.7E-14	2.0E-12	1.1E-13	1.37E-06
	Total	**2.6E-01**	**4.9E-05**	**7.1E-03**	**8.7E-07**	**1.0E-06**	**1.1E-08**	**1.4E-09**	**2.1E-16**	**1.8E-08**	**9.7E-10**	**1.1E-07**	**6.1E-09**	**5.02E-05**
15 < 25 years	Americium-241	6.6E-03	1.1E-06	8.3E-05	1.4E-08	2.5E-08	1.0E-09	--	--	3.8E-11	2.1E-12	3.6E-10	2.0E-11	1.09E-06
	Lead-214	4.5E-02	2.9E-08	7.4E-07	4.8E-13	1.7E-07	9.1E-12	--	--	3.6E-09	2.0E-10	3.4E-08	1.9E-09	3.11E-08
	Plutonium-238	2.4E-05	5.1E-09	3.0E-07	6.4E-11	9.2E-11	4.5E-12	--	--	8.4E-16	4.6E-17	8.0E-15	4.4E-16	5.14E-09
	Plutonium-239	2.9E-05	6.5E-09	3.7E-07	8.3E-11	1.1E-10	5.5E-12	--	--	8.6E-16	4.7E-17	8.2E-15	4.5E-16	6.62E-09
	Potassium-40	1.7E-01	6.1E-06	2.4E-03	8.6E-08	6.5E-07	3.8E-11	--	--	9.0E-09	5.0E-10	8.5E-08	4.7E-09	6.16E-06
	Radium-226	1.1E-02	1.1E-05	1.4E-04	1.5E-07	4.2E-08	6.1E-10	--	--	2.3E-11	1.3E-12	2.2E-10	1.2E-11	1.15E-05
	Radium-228	9.0E-03	2.3E-05	1.1E-04	3.0E-07	3.4E-08	2.2E-10	--	--	--	--	--	--	2.34E-05
	Strontium-90	2.5E-03	2.6E-07	3.5E-05	3.7E-09	9.6E-09	1.3E-12	--	--	1.1E-13	6.2E-15	1.1E-12	5.9E-14	2.65E-07
	Thorium-228	2.2E-03	3.2E-07	2.7E-05	4.0E-09	8.3E-09	1.3E-09	--	--	1.4E-12	7.5E-14	1.3E-11	7.1E-13	3.28E-07
	Thorium-230	2.7E-03	4.0E-07	3.4E-05	5.1E-09	1.0E-08	3.2E-10	--	--	3.3E-13	1.8E-14	3.1E-12	1.7E-13	4.04E-07
	Thorium-232	1.6E-03	2.6E-07	2.0E-05	3.3E-09	5.9E-09	2.8E-10	--	--	9.5E-14	5.2E-15	9.0E-13	4.9E-14	2.66E-07
	Tritium	1.7E-01	1.6E-08	6.0E-03	1.2E-09	1.2E-08	1.1E-15	1.0E-09	9.5E-17	--	--	--	--	1.68E-08
	Uranium-234	1.4E-02	1.6E-06	1.8E-04	2.1E-08	5.4E-08	7.7E-10	--	--	7.5E-13	4.1E-14	7.1E-12	3.9E-13	1.64E-06
	Uranium-235	5.3E-04	6.0E-08	6.7E-06	7.7E-10	2.0E-09	2.6E-11	--	--	2.6E-11	1.4E-12	2.4E-10	1.3E-11	6.05E-08
	Uranium-238	9.4E-03	9.9E-07	1.2E-04	1.3E-08	3.6E-08	4.2E-10	--	--	2.3E-13	1.3E-14	2.2E-12	1.2E-13	1.00E-06
	Total	**4.5E-01**	**4.6E-05**	**9.1E-03**	**6.0E-07**	**1.1E-06**	**5.0E-09**	**1.0E-09**	**9.5E-17**	**1.3E-08**	**7.0E-10**	**1.2E-07**	**6.6E-09**	**4.61E-05**
25 < 70 years	Americium-241	3.4E-02	2.3E-06	4.7E-04	3.5E-08	6.1E-08	1.2E-09	--	--	7.2E-11	4.0E-12	8.4E-10	4.6E-11	2.31E-06
	Lead-214	2.3E-01	2.9E-08	4.2E-06	6.0E-13	4.2E-07	9.1E-12	--	--	6.8E-09	3.8E-10	8.0E-08	4.4E-09	3.38E-08
	Plutonium-238	1.2E-04	1.1E-08	1.7E-06	1.7E-10	2.2E-10	5.3E-12	--	--	1.6E-15	8.8E-17	1.9E-14	1.0E-15	1.09E-08
	Plutonium-239	1.5E-04	1.3E-08	2.1E-06	2.1E-10	2.7E-10	6.4E-12	--	--	1.6E-15	9.1E-17	1.9E-14	1.1E-15	1.36E-08
	Potassium-40	8.7E-01	8.9E-06	1.4E-02	1.5E-07	1.6E-06	4.3E-11	--	--	1.7E-08	9.5E-10	2.0E-07	1.1E-08	9.04E-06
	Radium-226	5.6E-02	8.8E-06	8.0E-04	1.4E-07	1.0E-07	6.8E-10	--	--	4.4E-11	2.4E-12	5.2E-10	2.8E-11	8.95E-06
	Radium-228	4.6E-02	1.6E-05	6.5E-04	2.4E-07	8.3E-08	2.5E-10	--	--	--	--	--	--	1.60E-05
	Strontium-90	1.3E-02	5.2E-07	2.0E-04	8.6E-09	2.3E-08	1.5E-12	--	--	2.1E-13	1.2E-14	2.5E-12	1.4E-13	5.27E-07
	Thorium-228	1.1E-02	5.1E-07	1.5E-04	7.6E-09	2.0E-08	1.6E-09	--	--	2.6E-12	1.4E-13	3.0E-11	1.7E-12	5.18E-07
	Thorium-230	1.4E-02	7.7E-07	1.9E-04	1.2E-08	2.5E-08	4.5E-10	--	--	6.2E-13	3.4E-14	7.3E-12	4.0E-13	7.78E-07
	Thorium-232	8.0E-03	4.6E-07	1.1E-04	7.3E-09	1.4E-08	4.4E-10	--	--	1.8E-13	9.9E-15	2.1E-12	1.2E-13	4.72E-07
	Tritium	8.9E-01	2.9E-08	3.4E-02	2.6E-09	3.0E-08	9.9E-16	2.0E-09	6.7E-17	--	--	--	--	3.19E-08
	Uranium-234	7.2E-02	2.5E-06	1.0E-03	3.9E-08	1.3E-07	8.7E-10	--	--	1.4E-12	7.9E-14	1.7E-11	9.2E-13	2.58E-06
	Uranium-235	2.7E-03	9.2E-08	3.8E-05	1.4E-09	4.9E-09	7.7E-11	--	--	4.9E-11	2.7E-12	5.7E-10	3.2E-11	9.34E-08
	Uranium-238	4.9E-02	1.6E-06	6.8E-04	2.4E-08	8.7E-08	4.8E-10	--	--	4.4E-13	2.4E-14	5.1E-12	2.8E-13	1.58E-06
	Total	**2.3E+00**	**4.2E-05**	**5.2E-02**	**6.6E-07**	**2.6E-06**	**6.1E-09**	**2.0E-09**	**6.7E-17**	**2.4E-08**	**1.3E-09**	**2.8E-07**	**1.6E-08**	**4.29E-05**
Lifetime (0 < 70 years)	Americium-241	4.5E-02	4.7E-06	6.3E-04	8.5E-08	1.2E-07	3.4E-09	--	--	1.8E-10	1.0E-11	1.7E-09	9.2E-11	4.78E-06
	Lead-214	3.1E-01	1.1E-07	5.6E-06	2.7E-12	8.2E-07	3.0E-11	--	--	1.7E-08	9.6E-10	1.6E-07	8.7E-09	1.16E-07
	Plutonium-238	1.6E-04	2.2E-08	2.3E-06	3.9E-10	4.4E-10	1.5E-11	--	--	4.1E-15	2.2E-16	3.7E-14	2.0E-15	2.19E-08
	Plutonium-239	2.0E-04	2.7E-08	2.8E-06	4.9E-10	5.4E-10	1.8E-11	--	--	4.2E-15	2.3E-16	3.8E-14	2.1E-15	2.76E-08
	Potassium-40	1.2E+00	2.9E-05	1.8E-02	6.2E-07	3.1E-06	1.5E-10	--	--	4.4E-08	2.4E-09	4.0E-07	2.2E-08	2.92E-05
	Radium-226	7.5E-02	2.9E-05	1.1E-03	5.5E-07	2.0E-07	2.3E-09	--	--	1.1E-10	6.2E-12	1.0E-09	5.7E-11	2.93E-05
	Radium-228	6.2E-02	6.4E-05	8.7E-04	1.2E-06	1.6E-07	8.5E-10	--	--	--	--	--	--	6.53E-05
	Strontium-90	1.7E-02	9.6E-07	2.7E-04	1.8E-08	4.6E-08	4.8E-12	--	--	5.5E-13	3.0E-14	5.0E-12	2.7E-13	9.81E-07
	Thorium-228	1.5E-02	1.6E-06	2.0E-04	3.0E-08	4.0E-08	5.2E-09	--	--	6.6E-12	3.6E-13	6.0E-11	3.3E-12	1.63E-06
	Thorium-230	1.8E-02	1.7E-06	2.6E-04	3.1E-08	4.9E-08	1.4E-09	--	--	1.6E-12	8.7E-14	1.4E-11	7.9E-13	1.71E-06
	Thorium-232	1.1E-02	1.1E-06	1.5E-04	2.0E-08	2.8E-08	1.2E-09	--	--	4.6E-13	2.5E-14	4.2E-12	2.3E-13	1.10E-06
	Tritium	1.2E+00	6.6E-08	4.5E-02	6.5E-09	5.9E-08	3.3E-15	5.0E-09	2.8E-16	--	--	--	--	7.29E-08
	Uranium-234	9.6E-02	6.8E-06	1.3E-03	1.3E-07	2.6E-07	2.9E-09	--	--	3.6E-12	2.0E-13	3.3E-11	1.8E-12	6.90E-06
	Uranium-235	3.6E-03	2.5E-07	5.1E-05	4.8E-09	9.7E-09	9.8E-11	--	--	1.3E-10	6.9E-12	1.1E-09	6.3E-11	2.57E-07
	Uranium-238	6.4E-02	4.1E-06	9.1E-04	7.8E-08	1.7E-07	1.6E-09	--	--	1.1E-12	6.1E-14	1.0E-11	5.6E-13	4.21E-06
	Total	**3.1E+00**	**1.4E-04**	**6.9E-02**	**2.8E-06**	**5.1E-06**	**1.9E-08**	**5.0E-09**	**2.8E-16**	**6.2E-08**	**3.4E-09**	**5.6E-07**	**3.1E-08**	**1.456E-04**

Table 5D-1: Central Tendency Risk Calculations - Males - MCL Evaluation

Age Cohort	Radionuclide	Tap Water Ingestion[a]		Grown Produce		Inhalation While Bathing		Inhalation While Swimming		Water Immersion - Swimming[a]		Water Immersion - Bathing[a]		Total Cancer Risk
		Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Dose (Sv)	Lifetime Cancer Risk	Total Dose [Sv]	Lifetime Cancer Risk	
0 < 5 years	Americium-241	3.7E-04	2.8E-07	8.0E-05	5.9E-08	6.9E-09	8.2E-10	--	--	6.3E-12	3.5E-13	1.0E-10	5.5E-12	3.45E-07
	Lead-214	1.1E-01	3.9E-07	7.2E-06	2.5E-11	2.1E-06	3.5E-10	--	--	2.6E-08	1.4E-09	4.2E-07	2.3E-08	4.15E-07
	Plutonium-238	3.0E-04	2.8E-07	6.1E-05	5.5E-08	5.5E-09	7.8E-10	--	--	3.0E-14	1.7E-15	4.9E-13	2.7E-14	3.37E-07
	Plutonium-239	2.9E-04	2.7E-07	6.2E-05	5.7E-08	5.3E-09	7.3E-10	--	--	2.5E-14	1.4E-15	4.0E-13	2.2E-14	3.30E-07
	Potassium-40	1.6E-03	4.0E-07	5.5E-04	1.4E-07	2.9E-08	9.8E-12	--	--	2.4E-10	1.3E-11	3.9E-09	2.2E-10	5.47E-07
	Radium-226	6.7E-07	1.5E-09	1.6E-07	3.5E-10	1.2E-11	8.1E-13	--	--	4.2E-15	2.3E-16	6.7E-14	3.7E-15	1.85E-09
	Radium-228	3.7E-05	2.9E-07	5.2E-06	3.9E-08	6.9E-10	2.1E-11	--	--	--	--	--	--	3.30E-07
	Strontium-90	6.9E-04	1.9E-07	2.0E-04	5.3E-08	1.3E-08	7.6E-12	--	--	9.1E-14	5.0E-15	1.5E-12	8.0E-14	2.40E-07
	Thorium-228	3.6E-04	4.4E-07	4.0E-05	4.7E-08	6.7E-09	5.2E-09	--	--	6.6E-13	3.7E-14	1.1E-11	5.9E-13	4.93E-07
	Thorium-230	4.2E-04	3.1E-07	9.2E-05	6.5E-08	7.9E-09	1.4E-09	--	--	1.5E-13	8.3E-15	2.4E-12	1.3E-13	3.77E-07
	Thorium-232	3.8E-04	3.2E-07	8.3E-05	6.7E-08	7.1E-09	1.7E-09	--	--	6.8E-14	3.8E-15	1.1E-12	6.0E-14	3.93E-07
	Tritium	1.1E-01	2.8E-08	1.3E-01	8.2E-08	3.7E-02	9.9E-09	4.2E-03	1.1E-09	--	--	--	--	1.21E-07
	Uranium-234	5.5E-04	3.3E-07	1.2E-04	7.2E-08	1.0E-08	6.6E-10	--	--	8.6E-14	4.7E-15	1.4E-12	7.6E-14	4.05E-07
	Uranium-235	5.6E-04	3.4E-07	1.2E-04	7.4E-08	1.0E-08	6.0E-10	--	--	7.9E-11	4.4E-12	1.3E-09	7.0E-11	4.14E-07
	Uranium-238	6.0E-04	3.3E-07	1.3E-04	7.2E-08	1.1E-08	6.1E-10	--	--	4.3E-14	2.4E-15	6.9E-13	3.8E-14	4.06E-07
	Total	**2.2E-01**	**4.2E-06**	**1.3E-01**	**8.8E-07**	**3.7E-02**	**2.3E-08**	**4.2E-03**	**1.1E-09**	**2.6E-08**	**1.5E-09**	**4.3E-07**	**2.3E-08**	**5.15E-06**
5 < 15 years	Americium-241	1.0E-03	3.2E-07	3.1E-04	9.8E-08	1.8E-08	1.2E-09	--	--	1.5E-11	8.5E-13	2.3E-10	1.3E-11	4.21E-07
	Lead-214	3.0E-01	4.5E-07	2.7E-05	4.0E-11	5.5E-06	5.9E-10	--	--	6.4E-08	3.5E-09	9.7E-07	5.3E-08	5.06E-07
	Plutonium-238	8.0E-04	3.1E-07	2.3E-04	9.0E-08	1.4E-08	1.2E-09	--	--	7.4E-14	4.1E-15	1.1E-12	6.2E-14	4.03E-07
	Plutonium-239	7.8E-04	3.1E-07	2.4E-04	9.6E-08	1.4E-08	1.1E-09	--	--	6.0E-14	3.3E-15	9.1E-13	5.0E-14	4.04E-07
	Potassium-40	4.2E-03	4.5E-07	2.1E-03	2.2E-07	7.6E-08	1.2E-11	--	--	6.0E-10	3.3E-11	9.1E-09	5.0E-10	6.74E-07
	Radium-226	1.8E-06	2.6E-09	6.0E-07	8.6E-10	3.3E-11	1.1E-12	--	--	1.0E-14	5.6E-16	1.5E-13	8.5E-15	3.45E-09
	Radium-228	1.0E-04	4.6E-07	2.0E-05	9.0E-08	1.8E-09	2.8E-11	--	--	--	--	--	--	5.48E-07
	Strontium-90	1.9E-03	2.6E-07	7.5E-04	1.0E-07	3.4E-08	1.0E-11	--	--	2.2E-13	1.2E-14	3.4E-12	1.8E-13	3.59E-07
	Thorium-228	9.8E-04	4.3E-07	1.5E-04	6.8E-08	1.8E-08	7.2E-09	--	--	1.6E-12	9.0E-14	2.5E-11	1.4E-12	5.06E-07
	Thorium-230	1.2E-03	3.3E-07	3.5E-04	1.0E-07	2.1E-08	1.7E-09	--	--	3.7E-13	2.0E-14	5.6E-12	3.1E-13	4.38E-07
	Thorium-232	1.0E-03	3.4E-07	3.2E-04	1.1E-07	1.9E-08	2.1E-09	--	--	1.7E-13	9.2E-15	2.5E-12	1.4E-13	4.49E-07
	Tritium	2.9E-01	4.3E-08	5.0E-01	1.8E-07	9.6E-02	1.5E-08	1.2E-02	1.9E-09	--	--	--	--	2.42E-07
	Uranium-234	1.5E-03	4.1E-07	4.6E-04	1.3E-07	2.7E-08	9.2E-10	--	--	2.1E-13	1.2E-14	3.2E-12	1.8E-13	5.32E-07
	Uranium-235	1.5E-03	4.1E-07	4.6E-04	1.3E-07	2.7E-08	8.3E-10	--	--	1.9E-10	1.1E-11	2.9E-09	1.6E-10	5.39E-07
	Uranium-238	1.6E-03	4.1E-07	5.1E-04	1.3E-07	2.9E-08	8.3E-10	--	--	1.1E-13	5.8E-15	1.6E-12	8.8E-14	5.33E-07
	Total	**6.1E-01**	**4.9E-06**	**5.0E-01**	**1.5E-06**	**9.6E-02**	**3.2E-08**	**1.2E-02**	**1.9E-09**	**6.5E-08**	**3.6E-09**	**9.8E-07**	**5.4E-08**	**6.56E-06**
15< 25 years	Americium-241	1.8E-03	2.9E-07	4.2E-04	6.9E-08	2.1E-08	8.4E-10	--	--	1.1E-11	6.1E-13	2.5E-10	1.4E-11	3.64E-07
	Lead-214	5.4E-01	3.5E-07	3.8E-05	2.4E-11	6.4E-06	3.4E-10	--	--	4.6E-08	2.5E-09	1.1E-06	5.8E-08	4.10E-07
	Plutonium-238	1.4E-03	3.0E-07	3.2E-04	6.8E-08	1.7E-08	8.2E-10	--	--	5.3E-14	2.9E-15	1.2E-12	6.7E-14	3.70E-07
	Plutonium-239	1.4E-03	3.1E-07	3.3E-04	1.3E-07	1.6E-08	8.1E-10	--	--	4.4E-14	2.4E-15	9.9E-13	5.5E-14	4.40E-07
	Potassium-40	7.5E-03	2.7E-07	2.9E-03	1.0E-07	9.0E-08	5.2E-12	--	--	4.3E-10	2.4E-11	9.8E-09	5.4E-10	3.76E-07
	Radium-226	3.2E-06	3.3E-09	8.2E-07	8.6E-10	3.8E-11	5.6E-13	--	--	7.4E-15	4.0E-16	1.7E-13	9.2E-15	4.21E-09
	Radium-228	1.8E-04	4.6E-07	2.7E-05	7.1E-08	2.1E-09	1.4E-11	--	--	--	--	--	--	5.32E-07
	Strontium-90	3.3E-03	3.5E-07	1.0E-03	1.1E-07	4.0E-08	5.2E-12	--	--	1.6E-13	8.8E-15	3.7E-12	2.0E-13	4.55E-07
	Thorium-228	1.7E-03	2.6E-07	2.1E-04	3.2E-08	2.1E-08	3.3E-09	--	--	1.2E-12	6.5E-14	2.7E-11	1.5E-12	2.94E-07
	Thorium-230	2.0E-03	3.0E-07	4.9E-04	7.2E-08	2.4E-08	7.5E-10	--	--	2.7E-13	1.5E-14	6.0E-12	3.3E-13	3.76E-07
	Thorium-232	1.8E-03	3.1E-07	4.4E-04	7.4E-08	2.2E-08	1.0E-09	--	--	1.2E-13	6.6E-15	2.8E-12	1.5E-13	3.87E-07
	Tritium	5.1E-01	4.6E-08	6.8E-01	1.4E-07	1.1E-01	1.0E-08	1.1E-02	9.8E-10	--	--	--	--	1.94E-07
	Uranium-234	2.6E-03	3.1E-07	6.3E-04	7.3E-08	3.1E-08	4.5E-10	--	--	1.5E-13	8.3E-15	3.5E-12	1.9E-13	3.79E-07
	Uranium-235	2.7E-03	3.0E-07	6.4E-04	7.3E-08	3.2E-08	4.0E-10	--	--	1.4E-10	7.7E-12	3.2E-09	1.8E-10	3.76E-07
	Uranium-238	2.9E-03	3.1E-07	6.9E-04	7.3E-08	3.5E-08	4.0E-10	--	--	7.6E-14	4.2E-15	1.7E-12	9.6E-14	3.79E-07
	Total	**1.1E+00**	**4.2E-06**	**6.9E-01**	**1.1E-06**	**1.1E-01**	**1.9E-08**	**1.1E-02**	**9.8E-10**	**4.7E-08**	**2.6E-09**	**1.1E-06**	**5.9E-08**	**5.34E-06**
25 < 70 years	Americium-241	9.9E-03	6.6E-07	2.4E-03	1.7E-07	5.3E-08	1.1E-09	--	--	2.1E-11	1.2E-12	5.1E-11	3.3E-11	8.39E-07
	Lead-214	3.0E+00	3.7E-07	2.1E-04	3.0E-11	1.6E-05	3.5E-10	--	--	8.8E-08	4.9E-09	2.1E-07	1.4E-07	5.15E-07
	Plutonium-238	7.9E-03	6.8E-07	1.8E-03	1.7E-07	4.2E-08	1.0E-09	--	--	1.0E-13	5.6E-15	2.4E-13	1.6E-13	8.54E-07
	Plutonium-239	7.6E-03	6.8E-07	1.9E-03	1.8E-07	4.1E-08	9.7E-10	--	--	8.3E-14	4.6E-15	2.0E-13	1.3E-13	8.61E-07
	Potassium-40	4.2E-02	4.2E-07	1.6E-02	1.8E-07	2.2E-07	6.1E-12	--	--	8.2E-10	4.5E-11	2.0E-09	1.3E-09	6.08E-07
	Radium-226	1.8E-05	2.8E-09	4.6E-06	7.9E-10	9.5E-11	6.4E-13	--	--	1.4E-14	7.7E-16	3.4E-14	2.2E-14	3.58E-09
	Radium-228	9.9E-04	3.4E-07	1.5E-04	5.7E-08	5.3E-09	1.6E-11	--	--	--	--	--	--	3.92E-07
	Strontium-90	1.8E-02	7.4E-07	5.8E-03	2.5E-07	9.9E-08	6.5E-12	--	--	3.1E-13	1.7E-14	7.3E-13	4.7E-13	9.83E-07
	Thorium-228	9.6E-03	4.4E-07	1.2E-03	5.9E-08	5.1E-08	4.0E-09	--	--	2.2E-12	1.2E-13	5.4E-12	3.5E-12	5.00E-07
	Thorium-230	1.1E-02	6.2E-07	2.7E-03	1.7E-07	6.1E-08	1.1E-09	--	--	5.1E-13	2.8E-14	1.2E-12	7.8E-13	7.91E-07
	Thorium-232	1.0E-02	5.9E-07	2.5E-03	1.6E-07	5.5E-08	1.7E-09	--	--	2.3E-13	1.3E-14	5.5E-13	3.6E-13	7.54E-07
	Tritium	2.8E+00	9.2E-08	3.8E+00	2.9E-07	2.8E-01	9.3E-09	2.2E-02	7.3E-10	--	--	--	--	3.94E-07
	Uranium-234	1.5E-02	5.1E-07	3.5E-03	1.4E-07	7.8E-08	5.2E-10	--	--	2.9E-13	1.6E-14	7.0E-13	4.5E-13	6.50E-07
	Uranium-235	1.5E-02	5.0E-07	3.6E-03	1.3E-07	7.9E-08	1.2E-09	--	--	2.7E-10	1.5E-11	6.4E-10	4.1E-10	6.34E-07
	Uranium-238	1.6E-02	5.1E-07	3.9E-03	1.4E-07	8.6E-08	4.7E-10	--	--	1.5E-13	8.0E-15	3.5E-13	2.2E-13	6.53E-07
	Total	**6.0E+00**	**7.2E-06**	**3.9E+00**	**2.1E-06**	**2.8E-01**	**2.2E-08**	**2.2E-02**	**7.3E-10**	**8.9E-08**	**4.9E-09**	**2.1E-07**	**1.4E-07**	**9.43E-06**
Lifetime (0 < 70 years)	Americium-241	1.3E-02	1.3E-06	3.2E-03	4.2E-07	1.0E-07	2.8E-09	--	--	5.4E-11	3.0E-12	1.2E-09	6.5E-11	1.77E-06
	Lead-214	3.9E+00	1.3E-06	2.8E-04	1.4E-10	3.1E-05	1.1E-09	--	--	2.2E-07	1.2E-08	4.9E-06	2.7E-07	1.63E-06
	Plutonium-238	1.0E-02	1.3E-06	2.4E-03	4.1E-07	8.0E-08	2.7E-09	--	--	2.6E-13	1.4E-14	5.7E-12	3.1E-13	1.75E-06
	Plutonium-239	9.9E-03	1.3E-06	2.5E-03	4.3E-07	7.8E-08	2.6E-09	--	--	2.1E-13	1.2E-14	4.6E-12	2.6E-13	1.77E-06
	Potassium-40	5.4E-02	1.3E-06	2.2E-02	7.4E-07	4.2E-07	2.1E-11	--	--	2.1E-09	1.2E-10	4.6E-08	2.5E-09	2.08E-06
	Radium-226	2.3E-05	8.9E-09	6.2E-06	3.2E-09	1.8E-10	2.1E-12	--	--	3.6E-14	2.0E-15	7.8E-13	4.3E-14	1.21E-08
	Radium-228	1.3E-03	1.3E-06	2.1E-04	2.9E-07	1.0E-08	5.2E-11	--	--	--	--	--	--	1.63E-06
	Strontium-90	2.4E-02	1.3E-06	7.7E-03	5.3E-07	1.9E-07	2.0E-11	--	--	7.8E-13	4.3E-14	1.7E-11	9.4E-13	1.87E-06
	Thorium-228	1.3E-02	1.3E-06	1.6E-03	2.4E-07	9.8E-08	1.3E-08	--	--	5.7E-12	3.1E-13	1.2E-10	6.9E-12	1.59E-06
	Thorium-230	1.5E-02	1.3E-06	3.7E-03	4.4E-07	1.2E-07	3.3E-09	--	--	1.3E-12	7.1E-14	2.8E-11	1.6E-12	1.78E-06
	Thorium-232	1.3E-02	1.3E-06	3.3E-03	4.4E-07	1.0E-07	4.5E-09	--	--	5.9E-13	3.2E-14	1.3E-11	7.1E-13	1.78E-06
	Tritium	3.6E+00	2.0E-07	5.1E+00	7.4E-07	5.4E-01	3.0E-08	5.3E-02	3.0E-09	--	--	--	--	9.76E-07
	Uranium-234	1.9E-02	1.3E-06	4.7E-03	4.5E-07	1.5E-07	1.7E-09	--	--	7.4E-13	4.1E-14	1.6E-11	8.9E-13	1.79E-06
	Uranium-235	1.9E-02	1.3E-06	4.8E-03	4.5E-07	1.5E-07	1.5E-09	--	--	6.8E-10	3.7E-11	1.5E-08	8.2E-10	1.79E-06
	Uranium-238	2.1E-02	1.3E-06	5.2E-03	4.5E-07	1.6E-07	1.5E-09	--	--	3.7E-13	2.0E-14	8.1E-12	4.5E-13	1.79E-06
	Total	**7.8E+00**	**1.8E-05**	**5.2E+00**	**6.0E-06**	**5.4E-01**	**6.5E-08**	**5.3E-02**	**3.0E-09**	**2.3E-07**	**1.3E-08**	**5.0E-06**	**2.7E-07**	**2.40E-05**

[a] Risks are non-specific for gender.

Table 5D-2: Reasonable Maximum Exposure Risk Calculations - Males - MCL Evaluation

Age Cohort	Radionuclide	Tap Water Ingestion[a]		Grown Produce		Inhalation While Bathing		Inhalation While Swimming		Water Immersion - Swimming[a]		Water Immersion - Bathing[a]		Total Cancer Risk
		Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Dose (Sv)	Lifetime Cancer Risk	Total Dose [Sv]	Lifetime Cancer Risk	
0 < 5 years	Americium-241	9.5E-04	7.3E-07	2.4E-04	1.8E-07	6.9E-09	8.2E-10	--	--	1.5E-11	8.3E-13	1.0E-10	5.5E-12	9.08E-07
	Lead-214	2.9E-01	1.0E-06	2.2E-05	7.5E-11	2.1E-06	3.5E-10	--	--	6.3E-08	3.5E-09	4.2E-07	2.3E-08	1.02E-06
	Plutonium-238	7.5E-04	7.2E-07	1.8E-04	1.7E-07	5.5E-09	7.8E-10	--	--	7.3E-14	4.0E-15	4.9E-13	2.7E-14	8.85E-07
	Plutonium-239	7.3E-04	7.0E-07	1.9E-04	1.7E-07	5.3E-09	7.3E-10	--	--	5.9E-14	3.3E-15	4.0E-13	2.2E-14	8.69E-07
	Potassium-40	4.0E-03	1.0E-06	1.7E-03	4.3E-07	2.9E-08	9.8E-12	--	--	5.9E-10	3.2E-11	3.9E-09	2.2E-10	1.47E-06
	Radium-226	1.7E-06	3.8E-09	4.7E-07	1.1E-09	1.2E-11	8.1E-13	--	--	1.0E-14	5.5E-16	6.7E-14	3.7E-15	4.90E-09
	Radium-228	9.5E-05	7.4E-07	1.6E-05	1.2E-07	6.9E-10	2.1E-11	--	--	--	--	--	--	8.61E-07
	Strontium-90	1.8E-03	4.8E-07	5.9E-04	1.6E-07	1.3E-08	7.6E-12	--	--	2.2E-13	1.2E-14	1.5E-12	8.0E-14	6.39E-07
	Thorium-228	9.2E-04	1.1E-06	1.2E-04	1.4E-07	6.7E-09	5.2E-09	--	--	1.6E-12	8.8E-14	1.1E-11	5.9E-13	1.27E-06
	Thorium-230	1.1E-03	8.0E-07	2.8E-04	2.0E-07	7.9E-09	1.4E-09	--	--	3.6E-13	2.0E-14	2.4E-12	1.3E-13	9.93E-07
	Thorium-232	9.8E-04	8.3E-07	2.5E-04	2.0E-07	7.1E-09	1.7E-09	--	--	1.6E-13	9.0E-15	1.1E-12	6.0E-14	1.03E-06
	Tritium	2.7E-01	7.2E-08	3.9E-01	2.5E-07	3.7E-02	9.9E-09	4.2E-03	1.1E-09	--	--	--	--	3.32E-07
	Uranium-234	1.4E-03	8.5E-07	3.6E-04	2.2E-07	1.0E-08	6.6E-10	--	--	2.1E-13	1.1E-14	1.4E-12	7.6E-14	1.07E-06
	Uranium-235	1.4E-03	8.7E-07	3.7E-04	2.2E-07	1.0E-08	6.0E-10	--	--	1.9E-10	1.0E-11	1.3E-09	7.0E-11	1.09E-06
	Uranium-238	1.5E-03	8.5E-07	4.0E-04	2.2E-07	1.1E-08	6.1E-10	--	--	1.0E-13	5.7E-15	6.9E-13	3.8E-14	1.07E-06
	Total	**5.7E-01**	**1.1E-05**	**4.0E-01**	**2.7E-06**	**3.7E-02**	**2.3E-08**	**4.2E-03**	**1.1E-09**	**6.4E-08**	**3.5E-09**	**4.3E-07**	**2.3E-08**	**1.35E-05**
5 < 15 years	Americium-241	2.7E-03	8.5E-07	8.7E-04	2.8E-07	1.8E-08	1.2E-09	--	--	3.7E-11	2.0E-12	2.3E-10	1.3E-11	1.13E-06
	Lead-214	8.1E-01	1.2E-06	7.7E-05	1.1E-10	5.5E-06	5.9E-10	--	--	1.5E-07	8.5E-09	9.7E-07	5.3E-08	1.25E-06
	Plutonium-238	2.1E-03	8.2E-07	6.6E-04	2.6E-07	1.4E-08	1.2E-09	--	--	1.8E-13	9.8E-15	1.1E-12	6.2E-14	1.08E-06
	Plutonium-239	2.1E-03	8.1E-07	6.7E-04	2.7E-07	1.4E-08	1.1E-09	--	--	1.5E-13	8.0E-15	9.1E-13	5.0E-14	1.08E-06
	Potassium-40	1.1E-02	1.2E-06	5.9E-03	6.3E-07	7.6E-08	1.2E-11	--	--	1.4E-09	7.9E-11	9.1E-09	5.0E-10	1.82E-06
	Radium-226	4.8E-06	6.8E-09	1.7E-06	2.4E-09	3.3E-11	1.1E-12	--	--	2.5E-14	1.3E-15	1.5E-13	8.5E-15	9.26E-09
	Radium-228	2.7E-04	1.2E-06	5.6E-05	2.5E-07	1.8E-09	2.8E-11	--	--	--	--	--	--	1.46E-06
	Strontium-90	5.0E-03	6.8E-07	2.1E-03	2.9E-07	3.4E-08	1.0E-11	--	--	5.3E-13	2.9E-14	3.4E-12	1.8E-13	9.68E-07
	Thorium-228	2.6E-03	1.1E-06	4.3E-04	1.9E-07	1.8E-08	7.2E-09	--	--	3.9E-12	2.1E-13	2.5E-11	1.4E-12	1.34E-06
	Thorium-230	3.0E-03	8.8E-07	1.0E-03	2.9E-07	2.1E-08	1.7E-09	--	--	8.8E-13	4.9E-14	5.6E-12	3.1E-13	1.17E-06
	Thorium-232	2.7E-03	9.0E-07	9.0E-04	3.0E-07	1.9E-08	2.1E-09	--	--	4.0E-13	2.2E-14	2.5E-12	1.4E-13	1.20E-06
	Tritium	7.5E-01	1.1E-07	1.4E+00	5.2E-07	9.6E-02	1.5E-08	1.2E-02	1.9E-09	--	--	--	--	6.47E-07
	Uranium-234	3.9E-03	1.1E-06	1.3E-03	3.6E-07	2.7E-08	9.2E-10	--	--	5.0E-13	2.8E-14	3.2E-12	1.8E-13	1.43E-06
	Uranium-235	4.0E-03	1.1E-06	1.3E-03	3.6E-07	2.7E-08	8.3E-10	--	--	4.7E-10	2.6E-11	2.9E-09	1.6E-10	1.45E-06
	Uranium-238	4.3E-03	1.1E-06	1.4E-03	3.6E-07	2.9E-08	8.3E-10	--	--	2.5E-13	1.4E-14	1.6E-12	8.8E-14	1.43E-06
	Total	**1.6E+00**	**1.3E-05**	**1.4E+00**	**4.3E-06**	**9.6E-02**	**3.2E-08**	**1.2E-02**	**1.9E-09**	**1.6E-07**	**8.6E-09**	**9.8E-07**	**5.4E-08**	**1.75E-05**
15 < 25 years	Americium-241	4.6E-03	7.6E-07	1.3E-03	2.1E-07	2.1E-08	8.4E-10	--	--	2.7E-11	1.5E-12	2.5E-10	1.4E-11	9.65E-07
	Lead-214	1.4E+00	9.0E-07	1.1E-04	7.3E-11	6.4E-06	3.4E-10	--	--	1.1E-07	6.1E-09	1.1E-06	5.8E-08	9.63E-07
	Plutonium-238	3.7E-03	7.8E-07	9.6E-04	2.0E-07	1.7E-08	8.2E-10	--	--	1.3E-13	7.0E-15	1.2E-12	6.7E-14	9.81E-07
	Plutonium-239	3.6E-03	7.9E-07	9.9E-04	2.2E-07	1.6E-08	8.1E-10	--	--	1.0E-13	5.8E-15	9.9E-13	5.5E-14	1.01E-06
	Potassium-40	1.9E-02	7.0E-07	8.7E-03	3.1E-07	9.0E-08	5.2E-12	--	--	1.0E-09	5.7E-11	9.8E-09	5.4E-10	1.01E-06
	Radium-226	8.3E-06	8.6E-09	2.5E-06	2.6E-09	3.8E-11	5.6E-13	--	--	1.8E-14	9.7E-16	1.7E-13	9.2E-15	1.12E-08
	Radium-228	4.6E-04	1.2E-06	8.2E-05	2.1E-07	2.1E-09	1.4E-11	--	--	--	--	--	--	1.40E-06
	Strontium-90	8.6E-03	8.9E-07	3.1E-03	3.2E-07	4.0E-08	5.2E-12	--	--	3.8E-13	2.1E-14	3.7E-12	2.0E-13	1.22E-06
	Thorium-228	4.5E-03	6.7E-07	6.4E-04	9.5E-08	2.1E-08	3.3E-09	--	--	2.8E-12	1.5E-13	2.7E-11	1.5E-12	7.66E-07
	Thorium-230	5.3E-03	7.8E-07	1.5E-03	2.2E-07	2.4E-08	7.5E-10	--	--	6.4E-13	3.5E-14	6.0E-12	3.3E-13	9.97E-07
	Thorium-232	4.7E-03	8.0E-07	1.3E-03	2.2E-07	2.2E-08	1.0E-09	--	--	2.9E-13	1.6E-14	2.8E-12	1.5E-13	1.03E-06
	Tritium	1.3E+00	1.2E-07	2.1E+00	4.1E-07	1.1E-01	1.0E-08	1.1E-02	9.8E-10	--	--	--	--	5.41E-07
	Uranium-234	6.8E-03	7.9E-07	1.9E-03	2.2E-07	3.1E-08	4.5E-10	--	--	3.6E-13	2.0E-14	3.5E-12	1.9E-13	1.01E-06
	Uranium-235	6.9E-03	7.8E-07	1.9E-03	2.2E-07	3.2E-08	4.0E-10	--	--	3.4E-10	1.8E-11	3.2E-09	1.8E-10	9.98E-07
	Uranium-238	7.5E-03	7.9E-07	2.1E-03	2.2E-07	3.5E-08	4.0E-10	--	--	1.8E-13	1.0E-14	1.7E-12	9.6E-14	1.01E-06
	Total	**2.8E+00**	**1.1E-05**	**2.1E+00**	**3.1E-06**	**1.1E-01**	**1.9E-08**	**1.1E-02**	**9.8E-10**	**1.1E-07**	**6.2E-09**	**1.1E-06**	**5.9E-08**	**1.39E-05**
25 < 70 years	Americium-241	2.4E-02	1.6E-06	7.2E-03	5.3E-07	5.3E-08	1.1E-09	--	--	5.1E-11	2.8E-12	5.1E-11	3.3E-11	2.13E-06
	Lead-214	7.2E+00	9.0E-07	6.5E-04	9.2E-11	1.6E-05	3.5E-10	--	--	2.1E-07	1.2E-08	2.1E-07	1.4E-07	1.05E-06
	Plutonium-238	1.9E-02	1.6E-06	5.5E-03	5.3E-07	4.2E-08	1.0E-09	--	--	2.4E-13	1.3E-14	2.4E-13	1.6E-13	2.16E-06
	Plutonium-239	1.8E-02	1.6E-06	5.6E-03	5.6E-07	4.1E-08	9.7E-10	--	--	2.0E-13	1.1E-14	2.0E-13	1.3E-13	2.19E-06
	Potassium-40	1.0E-01	1.0E-06	4.9E-02	5.5E-07	2.2E-07	6.1E-12	--	--	2.0E-09	1.1E-10	2.0E-09	1.3E-09	1.58E-06
	Radium-226	4.3E-05	6.7E-09	1.4E-05	2.4E-09	9.5E-11	6.4E-13	--	--	3.4E-14	1.9E-15	3.4E-14	2.2E-14	9.11E-09
	Radium-228	2.4E-03	8.1E-07	4.7E-04	1.7E-07	5.3E-09	1.6E-11	--	--	--	--	--	--	9.79E-07
	Strontium-90	4.4E-02	1.8E-06	1.8E-02	7.5E-07	9.9E-08	6.5E-12	--	--	7.3E-13	4.0E-14	7.3E-13	4.7E-13	2.52E-06
	Thorium-228	2.3E-02	1.1E-06	3.6E-03	1.8E-07	5.1E-08	4.0E-09	--	--	5.4E-12	3.0E-13	5.4E-12	3.5E-12	1.23E-06
	Thorium-230	2.7E-02	1.5E-06	8.3E-03	5.1E-07	6.1E-08	1.1E-09	--	--	1.2E-12	6.7E-14	1.2E-12	7.8E-13	2.01E-06
	Thorium-232	2.5E-02	1.4E-06	7.5E-03	4.9E-07	5.5E-08	1.7E-09	--	--	5.5E-13	3.0E-14	5.5E-13	3.6E-13	1.92E-06
	Tritium	6.7E+00	2.2E-07	1.2E+01	8.9E-07	2.8E-01	9.3E-09	2.2E-02	7.3E-10	--	--	--	--	1.12E-06
	Uranium-234	3.5E-02	1.2E-06	1.1E-02	4.2E-07	7.8E-08	5.2E-10	--	--	7.0E-13	3.8E-14	7.0E-13	4.5E-13	1.65E-06
	Uranium-235	3.6E-02	1.2E-06	1.1E-02	4.1E-07	7.9E-08	1.2E-09	--	--	6.4E-10	3.5E-11	6.4E-10	4.1E-10	1.61E-06
	Uranium-238	3.9E-02	1.2E-06	1.2E-02	4.2E-07	8.6E-08	4.7E-10	--	--	3.5E-13	1.9E-14	3.5E-13	2.2E-13	1.66E-06
	Total	**1.4E+01**	**1.7E-05**	**1.2E+01**	**6.4E-06**	**2.8E-01**	**2.2E-08**	**2.2E-02**	**7.3E-10**	**2.1E-07**	**1.2E-08**	**2.1E-07**	**1.4E-07**	**2.38E-05**
Lifetime (0 < 70 years)	Americium-241	3.2E-02	3.3E-06	9.5E-03	1.3E-06	1.0E-07	2.8E-09	--	--	1.3E-10	7.1E-12	1.2E-09	6.5E-11	4.57E-06
	Lead-214	9.6E+00	3.3E-06	8.5E-04	4.1E-10	3.1E-05	1.1E-09	--	--	5.4E-07	3.0E-08	4.9E-06	2.7E-07	3.60E-06
	Plutonium-238	2.5E-02	3.3E-06	7.2E-03	1.2E-06	8.0E-08	2.7E-09	--	--	6.2E-13	3.4E-14	5.7E-12	3.1E-13	4.51E-06
	Plutonium-239	2.4E-02	3.3E-06	7.4E-03	1.3E-06	7.8E-08	2.6E-09	--	--	5.1E-13	2.8E-14	4.6E-12	2.6E-13	4.58E-06
	Potassium-40	1.3E-01	3.3E-06	6.5E-02	2.2E-06	4.2E-07	2.1E-11	--	--	5.0E-09	2.8E-10	4.6E-08	2.5E-09	5.52E-06
	Radium-226	5.7E-05	2.2E-08	1.9E-05	9.5E-09	1.8E-10	2.1E-12	--	--	8.6E-14	4.7E-15	7.8E-13	4.3E-14	3.14E-08
	Radium-228	3.2E-03	3.3E-06	6.2E-04	8.8E-07	1.0E-08	5.2E-11	--	--	--	--	--	--	4.17E-06
	Strontium-90	5.9E-02	3.3E-06	2.3E-02	1.6E-06	1.9E-07	2.0E-11	--	--	1.9E-12	1.0E-13	1.7E-11	9.4E-13	4.89E-06
	Thorium-228	3.1E-02	3.3E-06	4.8E-03	7.1E-07	9.8E-08	1.3E-08	--	--	1.4E-11	7.5E-13	1.2E-10	6.9E-12	4.01E-06
	Thorium-230	3.6E-02	3.3E-06	1.1E-02	1.3E-06	1.2E-07	3.3E-09	--	--	3.1E-12	1.7E-13	2.8E-11	1.6E-12	4.60E-06
	Thorium-232	3.3E-02	3.3E-06	9.9E-03	1.3E-06	1.0E-07	4.5E-09	--	--	1.4E-12	7.8E-14	1.3E-11	7.1E-13	4.61E-06
	Tritium	9.0E+00	5.0E-07	1.5E+01	2.2E-06	5.4E-01	3.0E-08	5.3E-02	3.0E-09	--	--	--	--	2.75E-06
	Uranium-234	4.7E-02	3.3E-06	1.4E-02	1.4E-06	1.5E-07	1.7E-09	--	--	1.8E-12	9.7E-14	1.6E-11	8.9E-13	4.64E-06
	Uranium-235	4.7E-02	3.3E-06	1.4E-02	1.4E-06	1.5E-07	1.5E-09	--	--	1.6E-09	9.0E-11	1.5E-08	8.2E-10	4.65E-06
	Uranium-238	5.1E-02	3.3E-06	1.6E-02	1.4E-06	1.6E-07	1.5E-09	--	--	8.9E-13	4.9E-14	8.1E-12	4.5E-13	4.65E-06
	Total	**1.9E+01**	**4.3E-05**	**1.6E+01**	**1.8E-05**	**5.4E-01**	**6.5E-08**	**5.3E-02**	**3.0E-09**	**5.5E-07**	**3.0E-08**	**5.0E-06**	**2.7E-07**	**6.18E-05**

[a] These risks are non-specific for gender.

Table 5D-3: Central Tendency Risk Calculations - Females - MCL Evaluation

Age Cohort	Radionuclide	Tap Water Ingestion[a]		Grown Produce		Inhalation While Bathing		Inhalation While Swimming		Water Immersion - Swimming[a]		Water Immersion - Bathing[a]		Total Cancer Risk
		Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Dose (Sv)	Lifetime Cancer Risk	Total Dose [Sv]	Lifetime Cancer Risk	
0 < 5 years	Americium-241	3.7E-04	2.8E-07	7.8E-05	5.8E-08	6.8E-09	8.0E-10	--	--	6.3E-12	3.5E-13	1.0E-10	5.5E-12	3.43E-07
	Lead-214	1.1E-01	3.9E-07	7.0E-06	2.4E-11	2.0E-06	3.4E-10	--	--	2.6E-08	1.4E-09	4.2E-07	2.3E-08	4.15E-07
	Plutonium-238	3.0E-04	2.8E-07	6.0E-05	5.4E-08	5.4E-09	7.6E-10	--	--	3.0E-14	1.7E-15	4.9E-13	2.7E-14	3.35E-07
	Plutonium-239	2.9E-04	2.7E-07	6.1E-05	5.5E-08	5.2E-09	7.1E-10	--	--	2.5E-14	1.4E-15	4.0E-13	2.2E-14	3.29E-07
	Potassium-40	1.6E-03	4.0E-07	5.4E-04	1.4E-07	2.8E-08	9.5E-12	--	--	2.4E-10	1.3E-11	3.9E-09	2.2E-10	5.44E-07
	Radium-226	6.7E-07	1.5E-09	1.5E-07	3.4E-10	1.2E-11	7.9E-13	--	--	4.2E-15	2.3E-16	6.7E-14	3.7E-15	1.84E-09
	Radium-228	3.7E-05	2.9E-07	5.1E-06	3.8E-08	6.8E-10	2.1E-11	--	--	--	--	--	--	3.29E-07
	Strontium-90	6.9E-04	1.9E-07	1.9E-04	5.2E-08	1.3E-08	7.4E-12	--	--	9.1E-14	5.0E-15	1.5E-12	8.0E-14	2.39E-07
	Thorium-228	3.6E-04	4.4E-07	3.9E-05	4.7E-08	6.6E-09	5.0E-09	--	--	6.6E-13	3.7E-14	1.1E-11	5.9E-13	4.92E-07
	Thorium-230	4.2E-04	3.1E-07	9.1E-05	6.3E-08	7.7E-09	1.3E-09	--	--	1.5E-13	8.3E-15	2.4E-12	1.3E-13	3.76E-07
	Thorium-232	3.8E-04	3.2E-07	8.2E-05	6.5E-08	7.0E-09	1.7E-09	--	--	6.8E-14	3.8E-15	1.1E-12	6.0E-14	3.91E-07
	Tritium	1.1E-01	2.8E-08	1.3E-01	8.0E-08	3.6E-02	9.7E-09	4.1E-03	1.1E-09	--	--	--	--	1.19E-07
	Uranium-234	5.5E-04	3.3E-07	1.2E-04	7.1E-08	1.0E-08	6.4E-10	--	--	8.6E-14	4.7E-15	1.4E-12	7.6E-14	4.03E-07
	Uranium-235	5.6E-04	3.4E-07	1.2E-04	7.2E-08	1.0E-08	5.8E-10	--	--	7.9E-11	4.4E-12	1.3E-09	7.0E-11	4.12E-07
	Uranium-238	6.0E-04	3.3E-07	1.3E-04	7.1E-08	1.1E-08	5.9E-10	--	--	4.3E-14	2.4E-15	6.9E-13	3.8E-14	4.04E-07
	Total	**2.2E-01**	**4.2E-06**	**1.3E-01**	**8.7E-07**	**3.6E-02**	**2.2E-08**	**4.1E-03**	**1.1E-09**	**2.6E-08**	**1.5E-09**	**4.3E-07**	**2.3E-08**	**5.14E-06**
5 < 15 years	Americium-241	1.0E-03	3.2E-07	3.0E-04	9.6E-08	1.7E-08	1.2E-09	--	--	1.5E-11	8.5E-13	2.3E-10	1.3E-11	4.19E-07
	Lead-214	3.0E-01	4.5E-07	2.7E-05	3.9E-11	5.1E-06	5.5E-10	--	--	6.4E-08	3.5E-09	9.7E-07	5.3E-08	5.06E-07
	Plutonium-238	8.0E-04	3.1E-07	2.3E-04	8.9E-08	1.3E-08	1.1E-09	--	--	7.4E-14	4.1E-15	1.1E-12	6.2E-14	4.01E-07
	Plutonium-239	7.8E-04	3.1E-07	2.3E-04	9.4E-08	1.3E-08	1.0E-09	--	--	6.0E-14	3.3E-15	9.1E-13	5.0E-14	4.02E-07
	Potassium-40	4.2E-03	4.5E-07	2.1E-03	2.2E-07	7.1E-08	1.1E-11	--	--	6.0E-10	3.3E-11	9.1E-09	5.0E-10	6.70E-07
	Radium-226	1.8E-06	2.6E-09	5.9E-07	8.4E-10	3.0E-11	1.1E-12	--	--	1.0E-14	5.6E-16	1.5E-13	8.5E-15	3.43E-09
	Radium-228	1.0E-04	4.6E-07	1.9E-05	8.8E-08	1.7E-09	2.6E-11	--	--	--	--	--	--	5.46E-07
	Strontium-90	1.9E-03	2.6E-07	7.3E-04	1.0E-07	3.2E-08	9.3E-12	--	--	2.2E-13	1.2E-14	3.4E-12	1.8E-13	3.57E-07
	Thorium-228	9.8E-04	4.3E-07	1.5E-04	6.7E-08	1.6E-08	6.7E-09	--	--	1.6E-12	9.0E-14	2.5E-11	1.4E-12	5.04E-07
	Thorium-230	1.2E-03	3.3E-07	3.5E-04	1.0E-07	1.9E-08	1.6E-09	--	--	3.7E-13	2.0E-14	5.6E-12	3.1E-13	4.36E-07
	Thorium-232	1.0E-03	3.4E-07	3.1E-04	1.0E-07	1.7E-08	2.0E-09	--	--	1.7E-13	9.2E-15	2.5E-12	1.4E-13	4.47E-07
	Tritium	2.9E-01	4.3E-08	4.9E-01	1.8E-07	9.0E-02	1.4E-08	1.1E-02	1.7E-09	--	--	--	--	2.38E-07
	Uranium-234	1.5E-03	4.1E-07	4.5E-04	1.2E-07	2.5E-08	8.6E-10	--	--	2.1E-13	1.2E-14	3.2E-12	1.8E-13	5.30E-07
	Uranium-235	1.5E-03	4.1E-07	4.6E-04	1.2E-07	2.5E-08	7.7E-10	--	--	1.9E-10	1.1E-11	2.9E-09	1.6E-10	5.36E-07
	Uranium-238	1.6E-03	4.1E-07	5.0E-04	1.2E-07	2.8E-08	7.8E-10	--	--	1.1E-13	5.8E-15	1.6E-12	8.8E-14	5.30E-07
	Total	**6.1E-01**	**4.9E-06**	**4.9E-01**	**1.5E-06**	**9.0E-02**	**3.0E-08**	**1.1E-02**	**1.7E-09**	**6.5E-08**	**3.6E-09**	**9.8E-07**	**5.4E-08**	**6.52E-06**
15 < 25 years	Americium-241	1.8E-03	2.9E-07	3.6E-04	5.9E-08	1.8E-08	7.0E-10	--	--	1.1E-11	6.1E-13	2.5E-10	1.4E-11	3.54E-07
	Lead-214	5.4E-01	3.5E-07	3.2E-05	2.1E-11	5.4E-06	2.8E-10	--	--	4.6E-08	2.5E-09	1.1E-06	5.8E-08	4.10E-07
	Plutonium-238	1.4E-03	3.0E-07	2.7E-04	5.8E-08	1.4E-08	6.8E-10	--	--	5.3E-14	2.9E-15	1.2E-12	6.7E-14	3.61E-07
	Plutonium-239	1.4E-03	3.1E-07	2.8E-04	1.1E-07	1.4E-08	6.7E-10	--	--	4.4E-14	2.4E-15	9.9E-13	5.5E-14	4.21E-07
	Potassium-40	7.5E-03	2.7E-07	2.5E-03	8.9E-08	7.4E-08	4.4E-12	--	--	4.3E-10	2.4E-11	9.8E-09	5.4E-10	3.61E-07
	Radium-226	3.2E-06	3.3E-09	7.1E-07	7.4E-10	3.2E-11	4.6E-13	--	--	7.4E-15	4.0E-16	1.7E-13	9.2E-15	4.09E-09
	Radium-228	1.8E-04	4.6E-07	2.3E-05	6.1E-08	1.8E-09	1.1E-11	--	--	--	--	--	--	5.22E-07
	Strontium-90	3.3E-03	3.5E-07	8.8E-04	9.3E-08	3.3E-08	4.3E-12	--	--	1.6E-13	8.8E-15	3.7E-12	2.0E-13	4.40E-07
	Thorium-228	1.7E-03	2.6E-07	1.8E-04	2.7E-08	1.7E-08	2.7E-09	--	--	1.2E-12	6.5E-14	2.7E-11	1.5E-12	2.89E-07
	Thorium-230	2.0E-03	3.0E-07	4.2E-04	6.2E-08	2.0E-08	6.2E-10	--	--	2.7E-13	1.5E-14	6.0E-12	3.3E-13	3.65E-07
	Thorium-232	1.8E-03	3.1E-07	3.8E-04	6.4E-08	1.8E-08	8.4E-10	--	--	1.2E-13	6.6E-15	2.8E-12	1.5E-13	3.77E-07
	Tritium	5.1E-01	4.6E-08	5.9E-01	1.2E-07	9.4E-02	8.5E-09	8.7E-03	7.8E-10	--	--	--	--	1.73E-07
	Uranium-234	2.6E-03	3.1E-07	5.4E-04	6.3E-08	2.6E-08	3.7E-10	--	--	1.5E-13	8.3E-15	3.5E-12	1.9E-13	3.69E-07
	Uranium-235	2.7E-03	3.0E-07	5.5E-04	6.2E-08	2.6E-08	3.3E-10	--	--	1.4E-10	7.7E-12	3.2E-09	1.8E-10	3.66E-07
	Uranium-238	2.9E-03	3.1E-07	6.0E-04	6.3E-08	2.9E-08	3.3E-10	--	--	7.6E-14	4.2E-15	1.7E-12	9.6E-14	3.69E-07
	Total	**1.1E+00**	**4.2E-06**	**5.9E-01**	**9.3E-07**	**9.4E-02**	**1.6E-08**	**8.7E-03**	**7.8E-10**	**4.7E-08**	**2.6E-09**	**1.1E-06**	**5.9E-08**	**5.18E-06**
25 < 70 years	Americium-241	9.9E-03	6.6E-07	2.0E-03	1.5E-07	4.3E-08	8.6E-10	--	--	2.1E-11	1.2E-12	5.1E-11	3.3E-11	8.14E-07
	Lead-214	3.0E+00	3.7E-07	1.8E-04	2.6E-11	1.3E-05	2.8E-10	--	--	8.8E-08	4.9E-09	2.1E-07	1.4E-07	5.15E-07
	Plutonium-238	7.9E-03	6.8E-07	1.5E-03	1.5E-07	3.4E-08	8.1E-10	--	--	1.0E-13	5.6E-15	2.4E-13	1.6E-13	8.30E-07
	Plutonium-239	7.6E-03	6.8E-07	1.6E-03	1.6E-07	3.3E-08	7.8E-10	--	--	8.3E-14	4.6E-15	2.0E-13	1.3E-13	8.35E-07
	Potassium-40	4.2E-02	4.2E-07	1.4E-02	1.6E-07	1.8E-07	4.9E-12	--	--	8.2E-10	4.5E-11	2.0E-09	1.3E-09	5.82E-07
	Radium-226	1.8E-05	2.8E-09	4.0E-06	6.8E-10	7.7E-11	5.1E-13	--	--	1.4E-14	7.7E-16	3.4E-14	2.2E-14	3.47E-09
	Radium-228	9.9E-04	3.4E-07	1.3E-04	4.9E-08	4.3E-09	1.3E-11	--	--	--	--	--	--	3.84E-07
	Strontium-90	1.8E-02	7.4E-07	5.0E-03	2.1E-07	8.0E-08	5.2E-12	--	--	3.1E-13	1.7E-14	7.3E-13	4.7E-13	9.48E-07
	Thorium-228	9.6E-03	4.4E-07	1.0E-03	5.0E-08	4.2E-08	3.3E-09	--	--	2.2E-12	1.2E-13	5.4E-12	3.5E-12	4.90E-07
	Thorium-230	1.1E-02	6.2E-07	2.4E-03	1.4E-07	4.9E-08	8.8E-10	--	--	5.1E-13	2.8E-14	1.2E-12	7.8E-13	7.67E-07
	Thorium-232	1.0E-02	5.9E-07	2.1E-03	1.4E-07	4.4E-08	1.4E-09	--	--	2.3E-13	1.3E-14	5.5E-13	3.6E-13	7.31E-07
	Tritium	2.8E+00	9.2E-08	3.3E+00	2.5E-07	2.3E-01	7.5E-09	1.7E-02	5.5E-10	--	--	--	--	3.51E-07
	Uranium-234	1.5E-02	5.1E-07	3.0E-03	1.2E-07	6.3E-08	4.2E-10	--	--	2.9E-13	1.6E-14	7.0E-13	4.5E-13	6.30E-07
	Uranium-235	1.5E-02	5.0E-07	3.1E-03	1.2E-07	6.4E-08	1.0E-09	--	--	2.7E-10	1.5E-11	6.4E-10	4.1E-10	6.15E-07
	Uranium-238	1.6E-02	5.1E-07	3.4E-03	1.2E-07	7.0E-08	3.8E-10	--	--	1.5E-13	8.0E-15	3.5E-13	2.2E-13	6.34E-07
	Total	**6.0E+00**	**7.2E-06**	**3.3E+00**	**1.8E-06**	**2.3E-01**	**1.8E-08**	**1.7E-02**	**5.5E-10**	**8.9E-08**	**4.9E-09**	**2.1E-07**	**1.4E-07**	**9.13E-06**
Lifetime (0 < 70 years)	Americium-241	1.3E-02	1.3E-06	2.8E-03	3.7E-07	8.4E-08	2.4E-09	--	--	5.4E-11	3.0E-12	1.2E-09	6.5E-11	1.71E-06
	Lead-214	3.9E+00	1.3E-06	2.5E-04	1.2E-10	2.6E-05	9.3E-10	--	--	2.2E-07	1.2E-08	4.9E-06	2.7E-07	1.62E-06
	Plutonium-238	1.0E-02	1.3E-06	2.1E-03	3.5E-07	6.7E-08	2.3E-09	--	--	2.6E-13	1.4E-14	5.7E-12	3.1E-13	1.70E-06
	Plutonium-239	9.9E-03	1.3E-06	2.1E-03	3.7E-07	6.5E-08	2.2E-09	--	--	2.1E-13	1.2E-14	4.6E-12	2.6E-13	1.72E-06
	Potassium-40	5.4E-02	1.3E-06	1.9E-02	6.5E-07	3.6E-07	1.8E-11	--	--	2.1E-09	1.2E-10	4.6E-08	2.5E-09	1.99E-06
	Radium-226	2.3E-05	8.9E-09	5.4E-06	2.8E-09	1.5E-10	1.7E-12	--	--	3.6E-14	2.0E-15	7.8E-13	4.3E-14	1.17E-08
	Radium-228	1.3E-03	1.3E-06	1.8E-04	2.6E-07	8.4E-09	4.4E-11	--	--	--	--	--	--	1.60E-06
	Strontium-90	2.4E-02	1.3E-06	6.7E-03	4.6E-07	1.6E-07	1.6E-11	--	--	7.8E-13	4.3E-14	1.7E-11	9.4E-13	1.80E-06
	Thorium-228	1.3E-02	1.3E-06	1.4E-03	2.0E-07	8.2E-08	1.1E-08	--	--	5.7E-12	3.1E-13	1.2E-10	6.9E-12	1.55E-06
	Thorium-230	1.5E-02	1.3E-06	3.2E-03	3.8E-07	9.6E-08	2.7E-09	--	--	1.3E-12	7.1E-14	2.8E-11	1.6E-12	1.72E-06
	Thorium-232	1.3E-02	1.3E-06	2.9E-03	3.8E-07	8.7E-08	3.8E-09	--	--	5.9E-13	3.2E-14	1.3E-11	7.1E-13	1.73E-06
	Tritium	3.6E+00	2.0E-07	4.5E+00	6.4E-07	4.5E-01	2.5E-08	4.2E-02	2.3E-09	--	--	--	--	8.75E-07
	Uranium-234	1.9E-02	1.3E-06	4.1E-03	3.9E-07	1.2E-07	1.4E-09	--	--	7.4E-13	4.1E-14	1.6E-11	8.9E-13	1.73E-06
	Uranium-235	1.9E-02	1.3E-06	4.2E-03	3.9E-07	1.3E-07	1.3E-09	--	--	6.8E-10	3.7E-11	1.5E-08	8.2E-10	1.74E-06
	Uranium-238	2.1E-02	1.3E-06	4.5E-03	3.9E-07	1.4E-07	1.3E-09	--	--	3.7E-13	2.0E-14	8.1E-12	4.5E-13	1.73E-06
	Total	**7.8E+00**	**1.8E-05**	**4.5E+00**	**5.3E-06**	**4.5E-01**	**5.4E-08**	**4.2E-02**	**2.3E-09**	**2.3E-07**	**1.3E-08**	**5.0E-06**	**2.7E-07**	**2.32E-05**

[a] Risks are non-specific for gender.

Table 5D-4: Reasonable Maximum Exposure Risk Calculations - Females - MCL Evaluation

Age Cohort	Radionuclide	Tap Water Ingestion[a]		Grown Produce		Inhalation While Bathing		Inhalation While Swimming		Water Immersion - Swimming[a]		Water Immersion - Bathing[a]		Total Cancer Risk
		Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Dose (Sv)	Lifetime Cancer Risk	Total Dose [Sv]	Lifetime Cancer Risk	
0 < 5 years	Americium-241	9.5E-04	7.3E-07	2.4E-04	1.8E-07	6.8E-09	8.0E-10	--	--	1.5E-11	8.3E-13	1.0E-10	5.5E-12	9.04E-07
	Lead-214	2.9E-01	1.0E-06	2.1E-05	7.3E-11	2.0E-06	3.4E-10	--	--	6.3E-08	3.5E-09	4.2E-07	2.3E-08	1.02E-06
	Plutonium-238	7.5E-04	7.2E-07	1.8E-04	1.6E-07	5.4E-09	7.6E-10	--	--	7.3E-14	4.0E-15	4.9E-13	2.7E-14	8.82E-07
	Plutonium-239	7.3E-04	7.0E-07	1.9E-04	1.7E-07	5.2E-09	7.1E-10	--	--	5.9E-14	3.3E-15	4.0E-13	2.2E-14	8.65E-07
	Potassium-40	4.0E-03	1.0E-06	1.6E-03	4.2E-07	2.8E-08	9.5E-12	--	--	5.9E-10	3.2E-11	3.9E-09	2.2E-10	1.46E-06
	Radium-226	1.7E-06	3.8E-09	4.7E-07	1.0E-09	1.2E-11	7.9E-13	--	--	1.0E-14	5.5E-16	6.7E-14	3.7E-15	4.88E-09
	Radium-228	9.5E-05	7.4E-07	1.5E-05	1.2E-07	6.8E-10	2.1E-11	--	--	--	--	--	--	8.59E-07
	Strontium-90	1.8E-03	4.8E-07	5.8E-04	1.6E-07	1.3E-08	7.4E-12	--	--	2.2E-13	1.2E-14	1.5E-12	8.0E-14	6.36E-07
	Thorium-228	9.2E-04	1.1E-06	1.2E-04	1.4E-07	6.6E-09	5.0E-09	--	--	1.6E-12	8.8E-14	1.1E-11	5.9E-13	1.27E-06
	Thorium-230	1.1E-03	8.0E-07	2.8E-04	1.9E-07	7.7E-09	1.3E-09	--	--	3.6E-13	2.0E-14	2.4E-12	1.3E-13	9.89E-07
	Thorium-232	9.8E-04	8.3E-07	2.5E-04	2.0E-07	7.0E-09	1.7E-09	--	--	1.6E-13	9.0E-15	1.1E-12	6.0E-14	1.03E-06
	Tritium	2.7E-01	7.2E-08	3.9E-01	2.4E-07	3.6E-02	9.7E-09	4.1E-03	1.1E-09	--	--	--	--	3.27E-07
	Uranium-234	1.4E-03	8.5E-07	3.6E-04	2.2E-07	1.0E-08	6.4E-10	--	--	2.1E-13	1.1E-14	1.4E-12	7.6E-14	1.06E-06
	Uranium-235	1.4E-03	8.7E-07	3.6E-04	2.2E-07	1.0E-08	5.8E-10	--	--	1.9E-10	1.0E-11	1.3E-09	7.0E-11	1.09E-06
	Uranium-238	1.5E-03	8.5E-07	3.9E-04	2.2E-07	1.1E-08	5.9E-10	--	--	1.0E-13	5.7E-15	6.9E-13	3.8E-14	1.07E-06
	Total	**5.7E-01**	**1.1E-05**	**3.9E-01**	**2.6E-06**	**3.6E-02**	**2.2E-08**	**4.1E-03**	**1.1E-09**	**6.4E-08**	**3.5E-09**	**4.3E-07**	**2.3E-08**	**1.35E-05**
5 < 15 years	Americium-241	2.7E-03	8.5E-07	8.5E-04	2.7E-07	1.7E-08	1.2E-09	--	--	3.7E-11	2.0E-12	2.3E-10	1.3E-11	1.12E-06
	Lead-214	8.1E-01	1.2E-06	7.6E-05	1.1E-10	5.1E-06	5.5E-10	--	--	1.5E-07	8.5E-09	9.7E-07	5.3E-08	1.25E-06
	Plutonium-238	2.1E-03	8.2E-07	6.4E-04	2.5E-07	1.3E-08	1.1E-09	--	--	1.8E-13	9.8E-15	1.1E-12	6.2E-14	1.07E-06
	Plutonium-239	2.1E-03	8.1E-07	6.6E-04	2.6E-07	1.3E-08	1.0E-09	--	--	1.5E-13	8.0E-15	9.1E-13	5.0E-14	1.08E-06
	Potassium-40	1.1E-02	1.2E-06	5.8E-03	6.2E-07	7.1E-08	1.1E-11	--	--	1.4E-09	7.9E-11	9.1E-09	5.0E-10	1.81E-06
	Radium-226	4.8E-06	6.8E-09	1.7E-06	2.4E-09	3.0E-11	1.1E-12	--	--	2.5E-14	1.3E-15	1.5E-13	8.5E-15	9.21E-09
	Radium-228	2.7E-04	1.2E-06	5.5E-05	2.5E-07	1.7E-09	2.6E-11	--	--	--	--	--	--	1.46E-06
	Strontium-90	5.0E-03	6.8E-07	2.1E-03	2.8E-07	3.2E-08	9.3E-12	--	--	5.3E-13	2.9E-14	3.4E-12	1.8E-13	9.62E-07
	Thorium-228	2.6E-03	1.1E-06	4.3E-04	1.9E-07	1.6E-08	6.7E-09	--	--	3.9E-12	2.1E-13	2.5E-11	1.4E-12	1.33E-06
	Thorium-230	3.0E-03	8.8E-07	9.8E-04	2.8E-07	1.9E-08	1.6E-09	--	--	8.8E-13	4.9E-14	5.6E-12	3.1E-13	1.17E-06
	Thorium-232	2.7E-03	9.0E-07	8.8E-04	2.9E-07	1.7E-08	2.0E-09	--	--	4.0E-13	2.2E-14	2.5E-12	1.4E-13	1.20E-06
	Tritium	7.5E-01	1.1E-07	1.4E+00	5.1E-07	9.0E-02	1.4E-08	1.1E-02	1.7E-09	--	--	--	--	6.35E-07
	Uranium-234	3.9E-03	1.1E-06	1.3E-03	3.5E-07	2.5E-08	8.6E-10	--	--	5.0E-13	2.8E-14	3.2E-12	1.8E-13	1.42E-06
	Uranium-235	4.0E-03	1.1E-06	1.3E-03	3.5E-07	2.5E-08	7.7E-10	--	--	4.7E-10	2.6E-11	2.9E-09	1.6E-10	1.44E-06
	Uranium-238	4.3E-03	1.1E-06	1.4E-03	3.5E-07	2.8E-08	7.8E-10	--	--	2.5E-13	1.4E-14	1.6E-12	8.8E-14	1.42E-06
	Total	**1.6E+00**	**1.3E-05**	**1.4E+00**	**4.3E-06**	**9.0E-02**	**3.0E-08**	**1.1E-02**	**1.7E-09**	**1.6E-07**	**8.6E-09**	**9.8E-07**	**5.4E-08**	**1.74E-05**
15 < 25 years	Americium-241	4.6E-03	7.6E-07	1.1E-03	1.8E-07	1.8E-08	7.0E-10	--	--	2.7E-11	1.5E-12	2.5E-10	1.4E-11	9.36E-07
	Lead-214	1.4E+00	9.0E-07	9.7E-05	6.3E-11	5.4E-06	2.8E-10	--	--	1.1E-07	6.1E-09	1.1E-06	5.8E-08	9.63E-07
	Plutonium-238	3.7E-03	7.8E-07	8.3E-04	1.7E-07	1.4E-08	6.8E-10	--	--	1.3E-13	7.0E-15	1.2E-12	6.7E-14	9.52E-07
	Plutonium-239	3.6E-03	7.9E-07	8.5E-04	3.4E-07	1.4E-08	6.7E-10	--	--	1.0E-13	5.8E-15	9.9E-13	5.5E-14	1.13E-06
	Potassium-40	1.9E-02	7.0E-07	7.4E-03	2.7E-07	7.4E-08	4.4E-12	--	--	1.0E-09	5.7E-11	9.8E-09	5.4E-10	9.68E-07
	Radium-226	8.3E-06	8.6E-09	2.1E-06	2.2E-09	3.2E-11	4.6E-13	--	--	1.8E-14	9.7E-16	1.7E-13	9.2E-15	1.09E-08
	Radium-228	4.6E-04	1.2E-06	7.1E-05	1.8E-07	1.8E-09	1.1E-11	--	--	--	--	--	--	1.37E-06
	Strontium-90	8.6E-03	8.9E-07	2.7E-03	2.8E-07	3.3E-08	4.3E-12	--	--	3.8E-13	2.1E-14	3.7E-12	2.0E-13	1.17E-06
	Thorium-228	4.5E-03	6.7E-07	5.5E-04	8.2E-08	1.7E-08	2.7E-09	--	--	2.8E-12	1.5E-13	2.7E-11	1.5E-12	7.52E-07
	Thorium-230	5.3E-03	7.8E-07	1.3E-03	1.9E-07	2.0E-08	6.2E-10	--	--	6.4E-13	3.5E-14	6.0E-12	3.3E-13	9.66E-07
	Thorium-232	4.7E-03	8.0E-07	1.1E-03	1.9E-07	1.8E-08	8.4E-10	--	--	2.9E-13	1.6E-14	2.8E-12	1.5E-13	9.95E-07
	Tritium	1.3E+00	1.2E-07	1.8E+00	3.5E-07	9.4E-02	8.5E-09	8.7E-03	7.8E-10	--	--	--	--	4.81E-07
	Uranium-234	6.8E-03	7.9E-07	1.6E-03	1.9E-07	2.6E-08	3.7E-10	--	--	3.6E-13	2.0E-14	3.5E-12	1.9E-13	9.75E-07
	Uranium-235	6.9E-03	7.8E-07	1.6E-03	1.9E-07	2.6E-08	3.3E-10	--	--	3.4E-10	1.8E-11	3.2E-09	1.8E-10	9.67E-07
	Uranium-238	7.5E-03	7.9E-07	1.8E-03	1.9E-07	2.9E-08	3.3E-10	--	--	1.8E-13	1.0E-14	1.7E-12	9.6E-14	9.76E-07
	Total	**2.8E+00**	**1.1E-05**	**1.8E+00**	**2.8E-06**	**9.4E-02**	**1.6E-08**	**8.7E-03**	**7.8E-10**	**1.1E-07**	**6.2E-09**	**1.1E-06**	**5.9E-08**	**1.36E-05**
25 < 70 years	Americium-241	2.4E-02	1.6E-06	6.2E-03	4.6E-07	4.3E-08	8.6E-10	--	--	5.1E-11	2.8E-12	5.1E-11	3.3E-11	2.05E-06
	Lead-214	7.2E+00	9.0E-07	5.5E-04	7.9E-11	1.3E-05	2.8E-10	--	--	2.1E-07	1.2E-08	2.1E-07	1.4E-07	1.05E-06
	Plutonium-238	1.9E-02	1.6E-06	4.7E-03	4.5E-07	3.4E-08	8.1E-10	--	--	2.4E-13	1.3E-14	2.4E-13	1.6E-13	2.09E-06
	Plutonium-239	1.8E-02	1.6E-06	4.8E-03	4.8E-07	3.3E-08	7.8E-10	--	--	2.0E-13	1.1E-14	2.0E-13	1.3E-13	2.11E-06
	Potassium-40	1.0E-01	1.0E-06	4.2E-02	4.7E-07	1.8E-07	4.9E-12	--	--	2.0E-09	1.1E-10	2.0E-09	1.3E-09	1.50E-06
	Radium-226	4.3E-05	6.7E-09	1.2E-05	2.1E-09	7.7E-11	5.1E-13	--	--	3.4E-14	1.9E-15	3.4E-14	2.2E-14	8.77E-09
	Radium-228	2.4E-03	8.1E-07	4.0E-04	1.5E-07	4.3E-09	1.3E-11	--	--	--	--	--	--	9.55E-07
	Strontium-90	4.4E-02	1.8E-06	1.5E-02	6.4E-07	8.0E-08	5.2E-12	--	--	7.3E-13	4.0E-14	7.3E-13	4.7E-13	2.42E-06
	Thorium-228	2.3E-02	1.1E-06	3.1E-03	1.5E-07	4.2E-08	3.3E-09	--	--	5.4E-12	3.0E-13	5.4E-12	3.5E-12	1.21E-06
	Thorium-230	2.7E-02	1.5E-06	7.2E-03	4.4E-07	4.9E-08	8.8E-10	--	--	1.2E-12	6.7E-14	1.2E-12	7.8E-13	1.94E-06
	Thorium-232	2.5E-02	1.4E-06	6.5E-03	4.2E-07	4.4E-08	1.4E-09	--	--	5.5E-13	3.0E-14	5.5E-13	3.6E-13	1.85E-06
	Tritium	6.7E+00	2.2E-07	1.0E+01	7.6E-07	2.3E-01	7.5E-09	1.7E-02	5.5E-10	--	--	--	--	9.91E-07
	Uranium-234	3.5E-02	1.2E-06	9.2E-03	3.6E-07	6.3E-08	4.2E-10	--	--	7.0E-13	3.8E-14	7.0E-13	4.5E-13	1.59E-06
	Uranium-235	3.6E-02	1.2E-06	9.4E-03	3.5E-07	6.4E-08	1.0E-09	--	--	6.4E-10	3.5E-11	6.4E-10	4.1E-10	1.55E-06
	Uranium-238	3.9E-02	1.2E-06	1.0E-02	3.6E-07	7.0E-08	3.8E-10	--	--	3.5E-13	1.9E-14	3.5E-13	2.2E-13	1.60E-06
	Total	**1.4E+01**	**1.7E-05**	**1.0E+01**	**5.5E-06**	**2.3E-01**	**1.8E-08**	**1.7E-02**	**5.5E-10**	**2.1E-07**	**1.2E-08**	**2.1E-07**	**1.4E-07**	**2.29E-05**
Lifetime (0 < 70 years)	Americium-241	3.2E-02	3.3E-06	8.3E-03	1.1E-06	8.4E-08	2.4E-09	--	--	1.3E-10	7.1E-12	1.2E-09	6.5E-11	4.40E-06
	Lead-214	9.6E+00	3.3E-06	7.4E-04	3.6E-10	2.6E-05	9.3E-10	--	--	5.4E-07	3.0E-08	4.9E-06	2.7E-07	3.60E-06
	Plutonium-238	2.5E-02	3.3E-06	6.3E-03	1.1E-06	6.7E-08	2.3E-09	--	--	6.2E-13	3.4E-14	5.7E-12	3.1E-13	4.35E-06
	Plutonium-239	2.4E-02	3.3E-06	6.4E-03	1.1E-06	6.5E-08	2.2E-09	--	--	5.1E-13	2.8E-14	4.6E-12	2.6E-13	4.41E-06
	Potassium-40	1.3E-01	3.3E-06	5.6E-02	1.9E-06	3.6E-07	1.8E-11	--	--	5.0E-09	2.8E-10	4.6E-08	2.5E-09	5.23E-06
	Radium-226	5.7E-05	2.2E-08	1.6E-05	8.3E-09	1.5E-10	1.7E-12	--	--	8.6E-14	4.7E-15	7.8E-13	4.3E-14	3.02E-08
	Radium-228	3.2E-03	3.3E-06	5.4E-04	7.7E-07	8.4E-09	4.4E-11	--	--	--	--	--	--	4.06E-06
	Strontium-90	5.9E-02	3.3E-06	2.0E-02	1.4E-06	1.6E-07	1.6E-11	--	--	1.9E-12	1.0E-13	1.7E-11	9.4E-13	4.68E-06
	Thorium-228	3.1E-02	3.3E-06	4.1E-03	6.1E-07	8.2E-08	1.1E-08	--	--	1.4E-11	7.5E-13	1.2E-10	6.9E-12	3.91E-06
	Thorium-230	3.6E-02	3.3E-06	9.5E-03	1.1E-06	9.6E-08	2.7E-09	--	--	3.1E-12	1.7E-13	2.8E-11	1.6E-12	4.43E-06
	Thorium-232	3.3E-02	3.3E-06	8.6E-03	1.1E-06	8.7E-08	3.8E-09	--	--	1.4E-12	7.8E-14	1.3E-11	7.1E-13	4.44E-06
	Tritium	9.0E+00	5.0E-07	1.3E+01	1.9E-06	4.5E-01	2.5E-08	4.2E-02	2.3E-09	--	--	--	--	2.45E-06
	Uranium-234	4.7E-02	3.3E-06	1.2E-02	1.2E-06	1.2E-07	1.4E-09	--	--	1.8E-12	9.7E-14	1.6E-11	8.9E-13	4.47E-06
	Uranium-235	4.7E-02	3.3E-06	1.3E-02	1.2E-06	1.3E-07	1.3E-09	--	--	1.6E-09	9.0E-11	1.5E-08	8.2E-10	4.47E-06
	Uranium-238	5.1E-02	3.3E-06	1.4E-02	1.2E-06	1.4E-07	1.3E-09	--	--	8.9E-13	4.9E-14	8.1E-12	4.5E-13	4.47E-06
	Total	**1.9E+01**	**4.3E-05**	**1.4E+01**	**1.6E-05**	**4.5E-01**	**5.4E-08**	**4.2E-02**	**2.3E-09**	**5.5E-07**	**3.0E-08**	**5.0E-06**	**2.7E-07**	**5.94E-05**

[a] These risks are non-specific for gender.

Table 5E-1: Central Tendency Risk Calculations - Males - Assuming 95% removal of Plutonium, Americium, Uranium, and Gross Alpha-emitting Radioactivity

Age Cohort	Radionuclide	Tap Water Ingestiona		Grown Produce		Inhalation While Bathing		Inhalation While Swimming		Water Immersion - Swimminga		Water Immersion - Bathinga		Total Cancer Risk
		Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Dose (Sv)	Lifetime Cancer Risk	Total Dose (Sv)	Lifetime Cancer Risk	
0 < 5 years	Americium-241	1.1E-05	8.3E-09	1.3E-07	9.2E-11	2.0E-10	2.4E-11	--	--	2.2E-13	1.2E-14	2.9E-12	1.6E-13	8.40E-09
	Lead-214	3.3E-03	1.1E-08	5.0E-08	1.7E-13	6.2E-08	1.0E-11	--	--	9.2E-10	5.1E-11	1.2E-08	6.8E-10	1.22E-08
	Plutonium-238	8.0E-08	7.6E-11	9.3E-10	8.4E-13	1.5E-12	2.1E-13	--	--	9.9E-18	5.4E-19	1.3E-16	7.3E-18	7.75E-11
	Plutonium-239	9.1E-08	8.7E-11	1.1E-09	9.6E-13	1.7E-12	2.3E-13	--	--	9.4E-18	5.2E-19	1.3E-16	7.0E-18	8.80E-11
	Potassium-40	5.2E-03	1.3E-06	6.7E-05	1.7E-08	9.7E-08	3.2E-11	--	--	9.7E-10	5.3E-11	1.3E-08	7.2E-10	1.36E-06
	Radium-226	4.4E-04	9.8E-07	5.1E-06	1.1E-08	8.2E-09	5.3E-10	--	--	3.3E-12	1.8E-13	4.4E-11	2.4E-12	9.95E-07
	Radium-228	5.9E-04	4.6E-06	6.9E-06	5.2E-08	1.1E-08	3.4E-10	--	--	--	--	--	--	4.65E-06
	Strontium-90	8.0E-05	2.2E-08	1.0E-06	2.8E-10	1.5E-09	8.8E-13	--	--	1.3E-14	7.0E-16	1.7E-13	9.3E-15	2.21E-08
	Thorium-228	1.1E-04	1.4E-07	1.3E-06	1.5E-09	2.1E-09	1.6E-09	--	--	2.5E-13	1.4E-14	3.4E-12	1.9E-13	1.42E-07
	Thorium-230	9.9E-05	7.2E-08	1.1E-06	8.0E-10	1.8E-09	3.1E-10	--	--	4.2E-14	2.3E-15	5.6E-13	3.1E-14	7.34E-08
	Thorium-232	8.6E-05	7.3E-08	1.0E-06	8.0E-10	1.6E-09	3.9E-10	--	--	1.8E-14	1.0E-15	2.5E-13	1.4E-14	7.42E-08
	Tritium	1.3E-02	3.4E-09	4.0E-04	0.0E+00	4.5E-09	1.2E-15	5.1E-10	1.4E-16	--	--	--	--	3.42E-09
	Uranium-234	4.6E-05	2.8E-08	5.4E-07	3.3E-10	8.7E-10	5.6E-11	--	--	8.8E-15	4.8E-16	1.2E-13	6.4E-15	2.86E-08
	Uranium-235	1.8E-06	1.1E-09	2.1E-08	1.3E-11	3.3E-11	1.9E-12	--	--	3.1E-13	1.7E-14	4.1E-12	2.3E-13	1.11E-09
	Uranium-238	3.1E-05	1.7E-08	3.6E-07	2.0E-10	5.8E-10	3.1E-11	--	--	2.7E-15	1.5E-16	3.6E-14	2.0E-15	1.73E-08
	Total	**2.3E-02**	**7.3E-06**	**4.9E-04**	**8.5E-08**	**1.9E-07**	**3.4E-09**	**5.1E-10**	**1.4E-16**	**1.9E-09**	**1.0E-10**	**2.5E-08**	**1.4E-09**	**7.39E-06**
5 < 15 years	Americium-241	2.9E-05	9.3E-09	4.8E-07	1.5E-10	5.3E-10	3.6E-11	--	--	5.4E-13	3.0E-14	6.8E-12	3.7E-13	9.54E-09
	Lead-214	9.0E-03	1.3E-08	1.9E-07	2.8E-13	1.6E-07	1.7E-11	--	--	2.3E-09	1.2E-10	2.8E-08	1.6E-09	1.49E-08
	Plutonium-238	2.2E-07	8.5E-11	3.6E-09	1.4E-12	3.9E-12	3.1E-13	--	--	2.4E-17	1.3E-18	3.0E-16	1.7E-17	8.64E-11
	Plutonium-239	2.5E-07	9.8E-11	4.1E-09	1.6E-12	4.4E-12	3.5E-13	--	--	2.3E-17	1.3E-18	2.9E-16	1.6E-17	1.00E-10
	Potassium-40	1.4E-02	1.5E-06	2.6E-04	2.7E-08	2.5E-07	4.0E-11	--	--	2.4E-09	1.3E-10	3.0E-08	1.7E-09	1.52E-06
	Radium-226	1.2E-03	1.7E-06	2.0E-05	2.8E-08	2.1E-08	7.4E-10	--	--	8.0E-12	4.4E-13	1.0E-10	5.6E-12	1.72E-06
	Radium-228	1.6E-03	7.3E-06	2.6E-05	1.2E-07	2.9E-08	4.4E-10	--	--	--	--	--	--	7.37E-06
	Strontium-90	2.2E-04	3.0E-08	3.9E-06	5.4E-10	3.9E-09	1.2E-12	--	--	3.1E-14	1.7E-15	3.9E-13	2.1E-14	3.04E-08
	Thorium-228	3.1E-04	1.4E-07	5.0E-06	2.2E-09	5.6E-09	2.3E-09	--	--	6.2E-13	3.4E-14	7.8E-12	4.3E-13	1.40E-07
	Thorium-230	2.7E-04	7.8E-08	4.4E-06	1.3E-09	4.8E-09	4.1E-10	--	--	1.0E-13	5.6E-15	1.3E-12	7.1E-14	7.92E-08
	Thorium-232	2.3E-04	7.7E-08	3.8E-06	1.3E-09	4.2E-09	4.8E-10	--	--	4.5E-14	2.5E-15	5.7E-13	3.1E-14	7.86E-08
	Tritium	3.4E-02	5.2E-09	1.5E-03	0.0E+00	1.2E-08	1.8E-15	1.5E-09	2.3E-16	--	--	--	--	5.23E-09
	Uranium-234	1.3E-04	3.5E-08	2.1E-06	5.7E-10	2.3E-09	7.8E-11	--	--	2.1E-14	1.2E-15	2.7E-13	1.5E-14	3.52E-08
	Uranium-235	4.9E-06	1.3E-09	8.0E-08	2.2E-11	8.7E-11	2.7E-12	--	--	7.5E-13	4.1E-14	9.5E-12	5.2E-13	1.35E-09
	Uranium-238	8.4E-05	2.1E-08	1.4E-06	3.4E-10	1.5E-09	4.3E-11	--	--	6.5E-15	3.6E-16	8.2E-14	4.5E-15	2.12E-08
	Total	**6.1E-02**	**1.1E-05**	**1.9E-03**	**1.8E-07**	**5.0E-07**	**4.6E-09**	**1.5E-09**	**2.3E-16**	**4.7E-09**	**2.6E-10**	**5.9E-08**	**3.2E-09**	**1.10E-05**
15 < 25 years	Americium-241	5.2E-05	8.6E-09	6.6E-07	1.1E-10	6.2E-10	2.5E-11	--	--	3.9E-13	2.1E-14	7.3E-12	4.0E-13	8.68E-09
	Lead-214	1.6E-02	1.0E-08	2.6E-07	1.7E-13	1.9E-07	9.9E-12	--	--	1.6E-09	9.0E-11	3.1E-08	1.7E-09	1.21E-08
	Plutonium-238	3.9E-07	8.2E-11	4.9E-09	1.0E-12	4.6E-12	2.2E-13	--	--	1.7E-17	9.6E-19	3.3E-16	1.8E-17	8.34E-11
	Plutonium-239	4.4E-07	9.8E-11	5.6E-09	1.2E-12	5.2E-12	2.6E-13	--	--	1.7E-17	9.2E-19	3.2E-16	1.7E-17	9.97E-11
	Potassium-40	2.5E-02	9.0E-07	3.5E-04	1.3E-08	3.0E-07	1.7E-11	--	--	1.7E-09	9.4E-11	3.3E-08	1.8E-09	9.15E-07
	Radium-226	2.1E-03	2.2E-06	2.7E-05	2.8E-08	2.5E-08	3.7E-10	--	--	5.8E-12	3.2E-13	1.1E-10	6.0E-12	2.22E-06
	Radium-228	2.8E-03	7.3E-06	3.6E-05	9.4E-08	3.4E-08	2.2E-10	--	--	--	--	--	--	7.38E-06
	Strontium-90	3.9E-04	4.0E-08	5.4E-06	5.7E-10	4.6E-09	6.0E-13	--	--	2.2E-14	1.2E-15	4.2E-13	2.3E-14	4.09E-08
	Thorium-228	5.5E-04	8.2E-08	6.8E-06	1.0E-09	6.5E-09	1.0E-09	--	--	4.4E-13	2.4E-14	8.4E-12	4.6E-13	8.40E-08
	Thorium-230	4.8E-04	7.0E-08	6.0E-06	8.9E-10	5.6E-09	1.7E-10	--	--	7.4E-14	4.1E-15	1.4E-12	7.7E-14	7.15E-08
	Thorium-232	4.2E-04	7.0E-08	5.3E-06	8.9E-10	4.9E-09	2.3E-10	--	--	3.3E-14	1.8E-15	6.2E-13	3.4E-14	7.14E-08
	Tritium	6.1E-02	5.5E-09	2.1E-03	0.0E+00	1.4E-08	1.2E-15	1.3E-09	1.2E-16	--	--	--	--	5.53E-09
	Uranium-234	2.2E-04	2.6E-08	2.8E-06	3.3E-10	2.7E-09	3.8E-11	--	--	1.5E-14	8.5E-16	2.9E-13	1.6E-14	2.64E-08
	Uranium-235	8.6E-06	9.8E-10	1.1E-07	1.2E-11	1.0E-10	1.3E-12	--	--	5.4E-13	3.0E-14	1.0E-11	5.7E-13	9.92E-10
	Uranium-238	1.5E-04	1.6E-08	1.9E-06	2.0E-10	1.8E-09	2.1E-11	--	--	4.7E-15	2.6E-16	8.9E-14	4.9E-15	1.59E-08
	Total	**1.1E-01**	**1.1E-05**	**2.6E-03**	**1.4E-07**	**5.9E-07**	**2.1E-09**	**1.3E-09**	**1.2E-16**	**3.4E-09**	**1.8E-10**	**6.4E-08**	**3.5E-09**	**1.09E-05**
25 < 70 years	Americium-241	2.9E-04	1.9E-08	3.7E-06	2.7E-10	1.5E-09	3.1E-11	--	--	7.4E-13	4.1E-14	7.4E-13	9.5E-13	1.96E-08
	Lead-214	8.8E-02	1.1E-08	1.5E-06	2.1E-13	4.7E-07	1.0E-11	--	--	3.1E-09	1.7E-10	3.1E-09	4.0E-09	1.52E-08
	Plutonium-238	2.1E-06	1.9E-10	2.8E-08	2.7E-12	1.1E-11	2.7E-13	--	--	3.3E-17	1.8E-18	3.3E-17	4.3E-17	1.88E-10
	Plutonium-239	2.4E-06	2.2E-10	3.1E-08	3.1E-12	1.3E-11	3.1E-13	--	--	3.2E-17	1.8E-18	3.2E-17	4.1E-17	2.19E-10
	Potassium-40	1.4E-01	1.4E-06	2.0E-03	2.2E-08	7.4E-07	2.0E-11	--	--	3.3E-09	1.8E-10	3.3E-09	4.2E-09	1.43E-06
	Radium-226	1.2E-02	1.8E-06	1.5E-04	2.6E-08	6.2E-08	4.2E-10	--	--	1.1E-11	6.1E-13	1.1E-11	1.4E-11	1.85E-06
	Radium-228	1.6E-02	5.3E-06	2.0E-04	7.5E-08	8.4E-08	2.6E-10	--	--	--	--	--	--	5.38E-06
	Strontium-90	2.1E-03	8.5E-08	3.1E-05	1.3E-09	1.1E-08	7.5E-13	--	--	4.3E-14	2.3E-15	4.3E-14	5.5E-14	8.68E-08
	Thorium-228	3.0E-03	1.4E-07	3.8E-05	0.0E+00	1.6E-08	1.3E-09	--	--	8.5E-13	4.7E-14	8.5E-13	1.1E-12	1.39E-07
	Thorium-230	2.6E-03	1.4E-07	3.4E-05	2.1E-09	1.4E-08	2.5E-10	--	--	1.4E-13	7.8E-15	1.4E-13	1.8E-13	1.47E-07
	Thorium-232	2.3E-03	1.3E-07	3.0E-05	1.9E-09	1.2E-08	3.8E-10	--	--	6.2E-14	3.4E-15	6.2E-14	8.0E-14	1.36E-07
	Tritium	3.4E-01	1.1E-08	1.2E-02	0.0E+00	3.4E-08	1.1E-15	2.7E-09	8.8E-17	--	--	--	--	1.11E-08
	Uranium-234	1.2E-03	4.4E-08	1.6E-05	6.2E-10	6.6E-09	4.4E-11	--	--	3.0E-14	1.6E-15	3.0E-14	3.8E-14	4.42E-08
	Uranium-235	4.8E-05	1.6E-09	6.2E-07	2.3E-11	2.6E-10	4.0E-12	--	--	1.0E-12	5.7E-14	1.0E-12	1.3E-12	1.64E-09
	Uranium-238	8.2E-04	2.6E-08	1.1E-05	3.8E-10	4.4E-09	2.4E-11	--	--	9.0E-15	4.9E-16	9.0E-15	1.2E-14	2.68E-08
	Total	**6.0E-01**	**9.1E-06**	**1.4E-02**	**1.3E-07**	**1.5E-06**	**2.7E-09**	**2.7E-09**	**8.8E-17**	**6.4E-09**	**3.5E-10**	**6.4E-09**	**8.2E-09**	**9.29E-06**
Lifetime (0 < 70 years)	Americium-241	3.7E-04	3.9E-08	5.0E-06	6.6E-10	2.9E-09	8.2E-11	--	--	1.9E-12	1.0E-13	3.4E-11	1.9E-12	3.97E-08
	Lead-214	1.1E-01	3.9E-08	2.0E-06	9.5E-13	9.0E-07	3.3E-11	--	--	7.9E-09	4.4E-10	1.4E-07	7.9E-09	4.78E-08
	Plutonium-238	2.8E-06	3.6E-10	3.7E-08	6.2E-12	2.2E-11	7.3E-13	--	--	8.5E-17	4.7E-18	1.5E-15	8.5E-17	3.72E-10
	Plutonium-239	3.2E-06	4.3E-10	4.2E-08	7.3E-12	2.5E-11	8.3E-13	--	--	8.1E-17	4.5E-18	1.5E-15	8.1E-17	4.35E-10
	Potassium-40	1.8E-01	4.4E-06	2.6E-03	9.1E-08	1.4E-06	7.0E-11	--	--	8.4E-09	4.6E-10	1.5E-07	8.4E-09	4.54E-06
	Radium-226	1.5E-02	5.8E-06	2.0E-04	1.0E-07	1.2E-07	1.4E-09	--	--	2.8E-11	1.5E-12	5.1E-10	2.8E-11	5.93E-06
	Radium-228	2.0E-02	2.1E-05	2.7E-04	3.9E-07	1.6E-07	8.3E-10	--	--	--	--	--	--	2.16E-05
	Strontium-90	2.8E-03	1.6E-07	4.1E-05	2.8E-09	2.2E-08	2.3E-12	--	--	1.1E-13	6.0E-15	2.0E-12	1.1E-13	1.58E-07
	Thorium-228	3.9E-03	4.2E-07	5.1E-05	7.6E-09	3.1E-08	4.1E-09	--	--	2.2E-12	1.2E-13	3.9E-11	2.2E-12	4.34E-07
	Thorium-230	3.4E-03	3.1E-07	4.5E-05	5.4E-09	2.7E-08	7.6E-10	--	--	3.6E-13	2.0E-14	6.6E-12	3.6E-13	3.17E-07
	Thorium-232	3.0E-03	3.0E-07	4.0E-05	5.3E-09	2.3E-08	1.0E-09	--	--	1.6E-13	8.7E-15	2.9E-12	1.6E-13	3.08E-07
	Tritium	4.4E-01	2.5E-08	1.6E-02	0.0E+00	6.5E-08	3.6E-15	6.4E-09	3.6E-16	--	--	--	--	2.47E-08
	Uranium-234	1.6E-03	1.1E-07	2.1E-05	2.0E-09	1.3E-08	1.4E-10	--	--	7.5E-14	4.1E-15	1.4E-12	7.5E-14	1.16E-07
	Uranium-235	6.2E-05	4.3E-09	8.2E-07	7.8E-11	4.9E-10	4.9E-12	--	--	2.6E-12	1.5E-13	4.8E-11	2.6E-12	4.41E-09
	Uranium-238	1.1E-03	6.9E-08	1.4E-05	1.2E-09	8.4E-09	7.8E-11	--	--	2.3E-14	1.3E-15	4.2E-13	2.3E-14	7.01E-08
	Total	**7.9E-01**	**3.3E-05**	**1.9E-02**	**6.1E-07**	**2.8E-06**	**8.5E-09**	**6.4E-09**	**3.6E-16**	**1.6E-08**	**9.0E-10**	**3.0E-07**	**1.6E-08**	**3.36E-05**

Table 5E-2: Reasonable Maximum Exposure Risk Calculations - Males - Assuming 95% removal of Plutonium, Americium, Uranium, and Gross Alpha-emitting Radioactivity

Age Cohort	Radionuclide	Tap Water Ingestion[a]		Grown Produce		Inhalation While Bathing		Inhalation While Swimming		Water Immersion - Swimming[a]		Water Immersion - Bathing[a]		Total Cancer Risk
		Total Intake (uCi)	**Lifetime Cancer Risk**	**Total Intake (uCi)**	**Lifetime Cancer Risk**	**Total Intake (uCi)**	**Lifetime Cancer Risk**	**Total Intake (uCi)**	**Lifetime Cancer Risk**	**Total Dose (Sv)**	**Lifetime Cancer Risk**	**Total Dose (Sv)**	**Lifetime Cancer Risk**	
0 < 5 years	Americium-241	2.0E-05	1.5E-08	2.7E-07	2.0E-10	1.5E-10	1.7E-11	--	--	3.2E-13	1.7E-14	2.1E-12	1.2E-13	1.55E-08
	Lead-214	2.1E-02	7.4E-08	3.8E-07	1.3E-12	1.6E-07	2.6E-11	--	--	4.7E-09	2.6E-10	3.1E-08	1.7E-09	7.62E-08
	Plutonium-238	2.8E-07	2.6E-10	3.8E-09	3.5E-12	2.0E-12	2.9E-13	--	--	2.7E-17	1.5E-18	1.8E-16	9.8E-18	2.68E-10
	Plutonium-239	1.4E-05	1.4E-08	2.0E-07	1.8E-10	1.1E-10	1.4E-11	--	--	1.2E-15	6.4E-17	7.8E-15	4.3E-16	1.40E-08
	Potassium-40	8.8E-02	2.3E-05	1.3E-03	3.5E-07	6.4E-07	2.1E-10	--	--	1.3E-08	7.1E-10	8.6E-08	4.7E-09	2.31E-05
	Radium-226	2.2E-03	5.0E-06	3.1E-05	6.9E-08	1.6E-08	1.1E-09	--	--	1.3E-11	7.2E-13	8.8E-11	4.8E-12	5.11E-06
	Radium-228	1.9E-03	1.4E-05	2.6E-05	1.9E-07	1.4E-08	4.2E-10	--	--	--	--	--	--	1.46E-05
	Strontium-90	5.7E-04	1.5E-07	8.7E-06	2.3E-09	4.2E-09	2.4E-12	--	--	7.0E-14	3.9E-15	4.7E-13	2.6E-14	1.57E-07
	Thorium-228	4.5E-04	5.4E-07	6.0E-06	7.1E-09	3.3E-09	2.5E-09	--	--	7.7E-13	4.2E-14	5.2E-12	2.8E-13	5.54E-07
	Thorium-230	5.5E-04	4.1E-07	7.6E-06	5.3E-09	4.1E-09	6.9E-10	--	--	1.8E-13	1.0E-14	1.2E-12	6.8E-14	4.13E-07
	Thorium-232	3.2E-04	2.7E-07	4.4E-06	3.5E-09	2.3E-09	5.7E-10	--	--	5.4E-14	2.9E-15	3.6E-13	2.0E-14	2.75E-07
	Tritium	3.5E-02	9.5E-09	1.3E-03	0.0E+00	4.9E-09	1.3E-15	5.1E-10	1.4E-16	--	--	--	--	9.52E-09
	Uranium-234	1.4E-04	8.7E-08	2.0E-06	1.2E-09	1.1E-09	6.8E-11	--	--	2.1E-14	1.2E-15	1.4E-13	7.8E-15	8.86E-08
	Uranium-235	5.4E-06	3.3E-09	7.5E-08	4.5E-11	4.0E-11	2.3E-12	--	--	7.3E-13	4.0E-14	4.9E-12	2.7E-13	3.37E-09
	Uranium-238	9.7E-05	5.3E-08	1.3E-06	7.3E-10	7.1E-10	3.8E-11	--	--	6.5E-15	3.6E-16	4.3E-14	2.4E-15	5.41E-08
	Total	**1.5E-01**	**4.4E-05**	**2.8E-03**	**6.3E-07**	**8.5E-07**	**5.6E-09**	**5.1E-10**	**1.4E-16**	**1.8E-08**	**9.7E-10**	**1.2E-07**	**6.5E-09**	**4.45E-05**
5 < 15 years	Americium-241	5.6E-05	1.8E-08	9.8E-07	3.1E-10	3.8E-10	2.6E-11	--	--	7.8E-13	4.3E-14	4.9E-12	2.7E-13	1.82E-08
	Lead-214	6.0E-02	8.8E-08	1.4E-06	2.0E-12	4.1E-07	4.4E-11	--	--	1.1E-08	6.3E-10	7.2E-08	4.0E-09	9.27E-08
	Plutonium-238	7.8E-07	3.0E-10	1.4E-08	5.3E-12	5.3E-12	4.3E-13	--	--	6.6E-17	3.6E-18	4.1E-16	2.3E-17	3.09E-10
	Plutonium-239	4.1E-05	1.6E-08	7.1E-07	2.8E-10	2.8E-10	2.2E-11	--	--	2.9E-15	1.6E-16	1.8E-14	9.9E-16	1.64E-08
	Potassium-40	2.5E-01	2.6E-05	4.8E-03	5.1E-07	1.7E-06	2.6E-10	--	--	3.2E-08	1.7E-09	2.0E-07	1.1E-08	2.66E-05
	Radium-226	6.3E-03	9.0E-06	1.1E-04	1.6E-07	4.3E-08	1.5E-09	--	--	3.2E-11	1.8E-12	2.0E-10	1.1E-11	9.14E-06
	Radium-228	5.2E-03	2.4E-05	9.1E-05	4.1E-07	3.5E-08	5.5E-10	--	--	--	--	--	--	2.40E-05
	Strontium-90	1.6E-03	2.2E-07	3.1E-05	4.2E-09	1.1E-08	3.2E-12	--	--	1.7E-13	9.4E-15	1.1E-12	6.0E-14	2.23E-07
	Thorium-228	1.3E-03	5.5E-07	2.1E-05	9.5E-09	8.5E-09	3.5E-09	--	--	1.9E-12	1.0E-13	1.2E-11	6.6E-13	5.63E-07
	Thorium-230	1.6E-03	4.5E-07	2.7E-05	7.9E-09	1.1E-08	8.9E-10	--	--	4.5E-13	2.5E-14	2.8E-12	1.6E-13	4.59E-07
	Thorium-232	8.9E-04	2.9E-07	1.6E-05	5.2E-09	6.1E-09	7.0E-10	--	--	1.3E-13	7.2E-15	8.3E-13	4.5E-14	3.00E-07
	Tritium	9.9E-02	1.5E-08	4.7E-03	0.0E+00	1.3E-08	1.9E-15	1.5E-09	2.3E-16	--	--	--	--	1.51E-08
	Uranium-234	4.0E-04	1.1E-07	7.1E-06	1.9E-09	2.7E-09	9.4E-11	--	--	5.2E-14	2.9E-15	3.3E-13	1.8E-14	1.12E-07
	Uranium-235	1.5E-05	4.2E-09	2.7E-07	7.3E-11	1.0E-10	3.2E-12	--	--	1.8E-12	9.8E-14	1.1E-11	6.2E-13	4.24E-09
	Uranium-238	2.7E-04	6.7E-08	4.8E-06	1.2E-09	1.8E-09	5.2E-11	--	--	1.6E-14	8.7E-16	1.0E-13	5.5E-15	6.85E-08
	Total	**4.2E-01**	**6.0E-05**	**9.8E-03**	**1.1E-06**	**2.2E-06**	**7.6E-09**	**1.5E-09**	**2.3E-16**	**4.3E-08**	**2.4E-09**	**2.7E-07**	**1.5E-08**	**6.16E-05**
15 < 25 years	Americium-241	9.7E-05	1.6E-08	1.4E-06	2.4E-10	4.5E-10	1.8E-11	--	--	5.6E-13	3.1E-14	5.3E-12	2.9E-13	1.62E-08
	Lead-214	1.0E-01	6.7E-08	2.0E-06	1.3E-12	4.8E-07	2.5E-11	--	--	8.2E-09	4.5E-10	7.8E-08	4.3E-09	7.16E-08
	Plutonium-238	1.4E-06	2.9E-10	2.0E-08	4.2E-12	6.2E-12	3.0E-13	--	--	4.7E-17	2.6E-18	4.5E-16	2.5E-17	2.91E-10
	Plutonium-239	7.0E-05	1.6E-08	1.0E-06	2.3E-10	3.2E-10	1.6E-11	--	--	2.1E-15	1.1E-16	2.0E-14	1.1E-15	1.59E-08
	Potassium-40	4.3E-01	1.5E-05	7.0E-03	2.5E-07	2.0E-06	1.2E-10	--	--	2.3E-08	1.3E-09	2.2E-07	1.2E-08	1.56E-05
	Radium-226	1.1E-02	1.1E-05	1.6E-04	1.7E-07	5.0E-08	7.3E-10	--	--	2.3E-11	1.3E-12	2.2E-10	1.2E-11	1.15E-05
	Radium-228	9.0E-03	2.3E-05	1.3E-04	3.5E-07	4.1E-08	2.7E-10	--	--	--	--	--	--	2.34E-05
	Strontium-90	2.8E-03	2.9E-07	4.5E-05	4.8E-09	1.3E-08	1.7E-12	--	--	1.2E-13	6.8E-15	1.2E-12	6.5E-14	2.92E-07
	Thorium-228	2.2E-03	3.2E-07	3.1E-05	4.7E-09	1.0E-08	1.6E-09	--	--	1.4E-12	7.5E-14	1.3E-11	7.1E-13	3.29E-07
	Thorium-230	2.7E-03	4.0E-07	4.0E-05	5.9E-09	1.2E-08	3.8E-10	--	--	3.3E-13	1.8E-14	3.1E-12	1.7E-13	4.05E-07
	Thorium-232	1.6E-03	2.6E-07	2.3E-05	3.9E-09	7.2E-09	3.3E-10	--	--	9.5E-14	5.2E-15	9.0E-13	4.9E-14	2.66E-07
	Tritium	1.7E-01	1.6E-08	6.9E-03	0.0E+00	1.5E-08	1.3E-15	1.3E-09	1.2E-16	--	--	--	--	1.55E-08
	Uranium-234	7.0E-04	8.1E-08	1.0E-05	1.2E-09	3.2E-09	4.6E-11	--	--	3.7E-14	2.1E-15	3.6E-13	2.0E-14	8.22E-08
	Uranium-235	2.6E-05	3.0E-09	3.9E-07	4.5E-11	1.2E-10	1.5E-12	--	--	1.3E-12	7.1E-14	1.2E-11	6.7E-13	3.03E-09
	Uranium-238	4.7E-04	4.9E-08	7.0E-06	7.3E-10	2.2E-09	2.5E-11	--	--	1.1E-14	6.3E-16	1.1E-13	6.0E-15	5.01E-08
	Total	**7.3E-01**	**5.1E-05**	**1.4E-02**	**7.9E-07**	**2.6E-06**	**3.5E-09**	**1.3E-09**	**1.2E-16**	**3.1E-08**	**1.7E-09**	**2.9E-07**	**1.6E-08**	**5.21E-05**
25 < 70 years	Americium-241	5.0E-04	3.4E-08	1.8E-06	1.3E-10	1.1E-09	2.2E-11	--	--	1.1E-12	5.9E-14	1.2E-11	6.9E-13	3.37E-08
	Lead-214	5.4E-01	6.7E-08	2.5E-06	3.6E-13	1.2E-06	2.6E-11	--	--	1.6E-08	8.7E-10	1.8E-07	1.0E-08	7.80E-08
	Plutonium-238	7.0E-06	6.0E-10	2.5E-08	2.4E-12	1.6E-11	3.7E-13	--	--	9.0E-17	5.0E-18	1.1E-15	5.8E-17	6.06E-10
	Plutonium-239	3.6E-04	3.2E-08	1.3E-06	1.3E-10	8.1E-10	1.9E-11	--	--	4.0E-15	2.2E-16	4.6E-14	2.5E-15	3.23E-08
	Potassium-40	2.2E+00	2.2E-05	8.8E-03	9.9E-08	4.9E-06	1.3E-10	--	--	4.3E-08	2.4E-09	5.1E-07	2.8E-08	2.26E-05
	Radium-226	5.6E-02	8.8E-06	2.1E-04	3.5E-08	1.2E-07	8.4E-10	--	--	4.4E-11	2.4E-12	5.2E-10	2.8E-11	8.85E-06
	Radium-228	4.6E-02	1.6E-05	1.7E-04	6.2E-08	1.0E-07	3.1E-10	--	--	--	--	--	--	1.58E-05
	Strontium-90	1.4E-02	5.7E-07	5.7E-05	2.4E-09	3.2E-08	2.1E-12	--	--	2.4E-13	1.3E-14	2.8E-12	1.5E-13	5.73E-07
	Thorium-228	1.1E-02	5.1E-07	4.0E-05	2.0E-09	2.5E-08	2.0E-09	--	--	2.6E-12	1.4E-13	3.0E-11	1.7E-12	5.13E-07
	Thorium-230	1.4E-02	7.7E-07	5.0E-05	3.1E-09	3.1E-08	5.6E-10	--	--	6.2E-13	3.4E-14	7.3E-12	4.0E-13	7.69E-07
	Thorium-232	8.0E-03	4.6E-07	2.9E-05	1.9E-09	1.8E-08	5.5E-10	--	--	1.8E-13	9.9E-15	2.1E-12	1.2E-13	4.67E-07
	Tritium	8.9E-01	2.9E-08	8.8E-03	0.0E+00	3.7E-08	1.2E-15	2.7E-09	8.8E-17	--	--	--	--	2.93E-08
	Uranium-234	3.6E-03	1.3E-07	1.3E-05	5.1E-10	8.0E-09	5.4E-11	--	--	7.2E-14	3.9E-15	8.4E-13	4.6E-14	1.27E-07
	Uranium-235	1.4E-04	4.6E-09	4.9E-07	1.8E-11	3.0E-10	4.8E-12	--	--	2.5E-12	1.4E-13	2.9E-11	1.6E-12	4.62E-09
	Uranium-238	2.4E-03	7.8E-08	8.8E-06	3.1E-10	5.4E-09	3.0E-11	--	--	2.2E-14	1.2E-15	2.6E-13	1.4E-14	7.80E-08
	Total	**3.8E+00**	**5.0E-05**	**1.8E-02**	**2.1E-07**	**6.5E-06**	**4.5E-09**	**2.7E-09**	**8.8E-17**	**5.9E-08**	**3.3E-09**	**6.9E-07**	**3.8E-08**	**4.99E-05**
Lifetime (0 < 70 years)	Americium-241	6.7E-04	6.9E-08	1.1E-05	1.4E-09	2.1E-09	6.0E-11	--	--	2.7E-12	1.5E-13	2.5E-11	1.4E-12	7.07E-08
	Lead-214	7.1E-01	2.4E-07	1.5E-05	7.2E-12	2.3E-06	8.2E-11	--	--	4.0E-08	2.2E-09	3.7E-07	2.0E-08	2.67E-07
	Plutonium-238	9.3E-06	1.2E-09	1.5E-07	2.5E-11	3.0E-11	9.9E-13	--	--	2.3E-16	1.3E-17	2.1E-15	1.2E-16	1.24E-09
	Plutonium-239	4.8E-04	6.5E-08	7.8E-06	1.4E-09	1.5E-09	5.1E-11	--	--	1.0E-14	5.5E-16	9.2E-14	5.0E-15	6.65E-08
	Potassium-40	2.9E+00	7.2E-05	5.2E-02	1.8E-06	9.3E-06	4.7E-10	--	--	1.1E-07	6.1E-09	1.0E-06	5.5E-08	7.41E-05
	Radium-226	7.5E-02	2.9E-05	1.2E-03	6.3E-07	2.4E-07	2.7E-09	--	--	1.1E-10	6.2E-12	1.0E-09	5.7E-11	2.94E-05
	Radium-228	6.2E-02	6.4E-05	1.0E-03	1.4E-06	2.0E-07	1.0E-09	--	--	--	--	--	--	6.55E-05
	Strontium-90	1.9E-02	1.1E-06	3.4E-04	2.3E-08	6.0E-08	6.4E-12	--	--	6.0E-13	3.3E-14	5.5E-12	3.0E-13	1.08E-06
	Thorium-228	1.5E-02	1.6E-06	2.4E-04	3.5E-08	4.7E-08	6.3E-09	--	--	6.6E-12	3.6E-13	6.0E-11	3.3E-12	1.63E-06
	Thorium-230	1.8E-02	1.7E-06	3.0E-04	3.5E-08	5.9E-08	1.7E-09	--	--	1.6E-12	8.7E-14	1.4E-11	7.9E-13	1.72E-06
	Thorium-232	1.1E-02	1.1E-06	1.7E-04	2.3E-08	3.4E-08	1.5E-09	--	--	4.6E-13	2.5E-14	4.2E-12	2.3E-13	1.10E-06
	Tritium	1.2E+00	6.6E-08	5.2E-02	0.0E+00	7.1E-08	4.0E-15	6.4E-09	3.6E-16	--	--	--	--	6.62E-08
	Uranium-234	4.8E-03	3.4E-07	7.7E-05	7.4E-09	1.5E-08	1.7E-10	--	--	1.8E-13	1.0E-14	1.7E-12	9.1E-14	3.46E-07
	Uranium-235	1.8E-04	1.3E-08	2.9E-06	2.8E-10	5.8E-10	5.8E-12	--	--	6.3E-12	3.4E-13	5.7E-11	3.1E-12	1.29E-08
	Uranium-238	3.2E-03	2.1E-07	5.2E-05	4.5E-09	1.0E-08	9.6E-11	--	--	5.6E-14	3.1E-15	5.1E-13	2.8E-14	2.11E-07
	Total	**5.0E+00**	**1.7E-04**	**1.1E-01**	**4.0E-06**	**1.2E-05**	**1.4E-08**	**6.4E-09**	**3.6E-16**	**1.5E-07**	**8.3E-09**	**1.4E-06**	**7.6E-08**	**1.76E-04**

[a] These risks are non-specific for gender.

Table 5E-3: Central Tendency Risk Calculations - Females - Assuming 95% removal of Plutonium, Americium, Uranium, and Gross Alpha-emitting Radioactivity

Age Cohort	Radionuclide	Tap Water Ingestiona		Grown Produce		Inhalation While Bathing		Inhalation While Swimming		Water Immersion - Swimminga		Water Immersion - Bathinga		Total Cancer Risk
		Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Dose (Sv)	Lifetime Cancer Risk	Total Dose (Sv)	Lifetime Cancer Risk	
0 < 5 years	Americium-241	1.1E-05	8.3E-09	1.2E-07	9.0E-11	2.0E-10	2.3E-11	--	--	2.2E-13	1.2E-14	2.9E-12	1.6E-13	8.40E-09
	Lead-214	3.3E-03	1.1E-08	4.9E-08	1.7E-13	6.0E-08	1.0E-11	--	--	9.2E-10	5.1E-11	1.2E-08	6.8E-10	1.22E-08
	Plutonium-238	8.0E-08	7.6E-11	9.1E-10	8.3E-13	1.5E-12	2.1E-13	--	--	9.9E-18	5.4E-19	1.3E-16	7.3E-18	7.75E-11
	Plutonium-239	9.1E-08	8.7E-11	1.0E-09	9.4E-13	1.7E-12	2.3E-13	--	--	9.4E-18	5.2E-19	1.3E-16	7.0E-18	8.80E-11
	Potassium-40	5.2E-03	1.3E-06	6.5E-05	1.7E-08	9.4E-08	3.2E-11	--	--	9.7E-10	5.3E-11	1.3E-08	7.2E-10	1.36E-06
	Radium-226	4.4E-04	9.8E-07	5.0E-06	1.1E-08	8.0E-09	5.2E-10	--	--	3.3E-12	1.8E-13	4.4E-11	2.4E-12	9.95E-07
	Radium-228	5.9E-04	4.6E-06	6.7E-06	5.1E-08	1.1E-08	3.3E-10	--	--	--	--	--	--	4.64E-06
	Strontium-90	8.0E-05	2.2E-08	1.0E-06	2.7E-10	1.5E-09	8.6E-13	--	--	1.3E-14	7.0E-16	1.7E-13	9.3E-15	2.21E-08
	Thorium-228	1.1E-04	1.4E-07	1.3E-06	1.5E-09	2.1E-09	1.6E-09	--	--	2.5E-13	1.4E-14	3.4E-12	1.9E-13	1.42E-07
	Thorium-230	9.9E-05	7.2E-08	1.1E-06	7.8E-10	1.8E-09	3.1E-10	--	--	4.2E-14	2.3E-15	5.6E-13	3.1E-14	7.34E-08
	Thorium-232	8.6E-05	7.3E-08	9.8E-07	7.8E-10	1.6E-09	3.8E-10	--	--	1.8E-14	1.0E-15	2.5E-13	1.4E-14	7.42E-08
	Tritium	1.3E-02	3.4E-09	3.9E-04	0.0E+00	4.3E-09	1.2E-15	4.9E-10	1.3E-16	--	--	--	--	3.42E-09
	Uranium-234	4.6E-05	2.8E-08	5.3E-07	3.2E-10	8.5E-10	5.5E-11	--	--	8.8E-15	4.8E-16	1.2E-13	6.4E-15	2.86E-08
	Uranium-235	1.8E-06	1.1E-09	2.0E-08	1.2E-11	3.3E-11	1.9E-12	--	--	3.1E-13	1.7E-14	4.1E-12	2.3E-13	1.11E-09
	Uranium-238	3.1E-05	1.7E-08	3.5E-07	1.9E-10	5.6E-10	3.0E-11	--	--	2.7E-15	1.5E-16	3.6E-14	2.0E-15	1.73E-08
	Total	**2.3E-02**	**7.3E-06**	**4.8E-04**	**8.3E-08**	**1.9E-07**	**3.3E-09**	**4.9E-10**	**1.3E-16**	**1.9E-09**	**1.0E-10**	**2.5E-08**	**1.4E-09**	**7.38E-06**
10 < 15 years	Americium-241	2.9E-05	9.3E-09	4.7E-07	1.5E-10	4.9E-10	3.4E-11	--	--	5.4E-13	3.0E-14	6.8E-12	3.7E-13	9.53E-09
	Lead-214	9.0E-03	1.3E-08	1.9E-07	2.7E-13	1.5E-07	1.6E-11	--	--	2.3E-09	1.2E-10	2.8E-08	1.6E-09	1.49E-08
	Plutonium-238	2.2E-07	8.5E-11	3.5E-09	1.4E-12	3.7E-12	2.9E-13	--	--	2.4E-17	1.3E-18	3.0E-16	1.7E-17	8.64E-11
	Plutonium-239	2.5E-07	9.8E-11	4.0E-09	1.6E-12	4.2E-12	3.3E-13	--	--	2.3E-17	1.3E-18	2.9E-16	1.6E-17	9.99E-11
	Potassium-40	1.4E-02	1.5E-06	2.5E-04	2.7E-08	2.4E-07	3.7E-11	--	--	2.4E-09	1.3E-10	3.0E-08	1.7E-09	1.52E-06
	Radium-226	1.2E-03	1.7E-06	1.9E-05	2.8E-08	2.0E-08	6.9E-10	--	--	8.0E-12	4.4E-13	1.0E-10	5.6E-12	1.72E-06
	Radium-228	1.6E-03	7.3E-06	2.6E-05	1.2E-07	2.7E-08	4.2E-10	--	--	--	--	--	--	7.37E-06
	Strontium-90	2.2E-04	3.0E-08	3.9E-06	5.3E-10	3.7E-09	1.1E-12	--	--	3.1E-14	1.7E-15	3.9E-13	2.1E-14	3.04E-08
	Thorium-228	3.1E-04	1.4E-07	4.9E-06	2.2E-09	5.2E-09	2.1E-09	--	--	6.2E-13	3.4E-14	7.8E-12	4.3E-13	1.40E-07
	Thorium-230	2.7E-04	7.8E-08	4.3E-06	1.2E-09	4.5E-09	3.8E-10	--	--	1.0E-13	5.6E-15	1.3E-12	7.1E-14	7.91E-08
	Thorium-232	2.3E-04	7.7E-08	3.7E-06	1.2E-09	3.9E-09	4.5E-10	--	--	4.5E-14	2.5E-15	5.7E-13	3.1E-14	7.86E-08
	Tritium	3.4E-02	5.2E-09	1.5E-03	0.0E+00	1.1E-08	1.7E-15	1.4E-09	2.1E-16	--	--	--	--	5.23E-09
	Uranium-234	1.3E-04	3.5E-08	2.0E-06	5.6E-10	2.1E-09	7.3E-11	--	--	2.1E-14	1.2E-15	2.7E-13	1.5E-14	3.51E-08
	Uranium-235	4.9E-06	1.3E-09	7.8E-08	2.1E-11	8.2E-11	2.5E-12	--	--	7.5E-13	4.1E-14	9.5E-12	5.2E-13	1.35E-09
	Uranium-238	8.4E-05	2.1E-08	1.3E-06	3.4E-10	1.4E-09	4.0E-11	--	--	6.5E-15	3.6E-16	8.2E-14	4.5E-15	2.12E-08
	Total	**6.1E-02**	**1.1E-05**	**1.8E-03**	**1.8E-07**	**4.7E-07**	**4.3E-09**	**1.4E-09**	**2.1E-16**	**4.7E-09**	**2.6E-10**	**5.9E-08**	**3.2E-09**	**1.10E-05**
15 < 25 years	Americium-241	5.2E-05	8.6E-09	5.7E-07	9.3E-11	5.1E-10	2.0E-11	--	--	3.9E-13	2.1E-14	7.3E-12	4.0E-13	8.67E-09
	Lead-214	1.6E-02	1.0E-08	2.2E-07	1.5E-13	1.6E-07	8.3E-12	--	--	1.6E-09	9.0E-11	3.1E-08	1.7E-09	1.21E-08
	Plutonium-238	3.9E-07	8.2E-11	4.2E-09	8.9E-13	3.8E-12	1.9E-13	--	--	1.7E-17	9.6E-19	3.3E-16	1.8E-17	8.32E-11
	Plutonium-239	4.4E-07	9.8E-11	4.8E-09	1.1E-12	4.3E-12	2.1E-13	--	--	1.7E-17	9.2E-19	3.2E-16	1.7E-17	9.95E-11
	Potassium-40	2.5E-02	9.0E-07	3.0E-04	1.1E-08	2.5E-07	1.4E-11	--	--	1.7E-09	9.4E-11	3.3E-08	1.8E-09	9.13E-07
	Radium-226	2.1E-03	2.2E-06	2.3E-05	2.4E-08	2.1E-08	3.0E-10	--	--	5.8E-12	3.2E-13	1.1E-10	6.0E-12	2.22E-06
	Radium-228	2.8E-03	7.3E-06	3.1E-05	8.0E-08	2.8E-08	1.8E-10	--	--	--	--	--	--	7.37E-06
	Strontium-90	3.9E-04	4.0E-08	4.7E-06	4.9E-10	3.8E-09	5.0E-13	--	--	2.2E-14	1.2E-15	4.2E-13	2.3E-14	4.08E-08
	Thorium-228	5.5E-04	8.2E-08	5.9E-06	8.8E-10	5.4E-09	8.6E-10	--	--	4.4E-13	2.4E-14	8.4E-12	4.6E-13	8.36E-08
	Thorium-230	4.8E-04	7.0E-08	5.2E-06	7.6E-10	4.7E-09	1.4E-10	--	--	7.4E-14	4.1E-15	1.4E-12	7.7E-14	7.13E-08
	Thorium-232	4.2E-04	7.0E-08	4.5E-06	7.6E-10	4.1E-09	1.9E-10	--	--	3.3E-14	1.8E-15	6.2E-13	3.4E-14	7.12E-08
	Tritium	6.1E-02	5.5E-09	1.8E-03	0.0E+00	1.1E-08	1.0E-15	1.0E-09	9.5E-17	--	--	--	--	5.53E-09
	Uranium-234	2.2E-04	2.6E-08	2.4E-06	2.8E-10	2.2E-09	3.2E-11	--	--	1.5E-14	8.5E-16	2.9E-13	1.6E-14	2.63E-08
	Uranium-235	8.6E-06	9.8E-10	9.4E-08	1.1E-11	8.5E-11	1.1E-12	--	--	5.4E-13	3.0E-14	1.0E-11	5.7E-13	9.90E-10
	Uranium-238	1.5E-04	1.6E-08	1.6E-06	1.7E-10	1.5E-09	1.7E-11	--	--	4.7E-15	2.6E-16	8.9E-14	4.9E-15	1.59E-08
	Total	**1.1E-01**	**1.1E-05**	**2.2E-03**	**1.2E-07**	**4.9E-07**	**1.8E-09**	**1.0E-09**	**9.5E-17**	**3.4E-09**	**1.8E-10**	**6.4E-08**	**3.5E-09**	**1.08E-05**
25 < 70 years	Americium-241	2.9E-04	1.9E-08	3.2E-06	2.4E-10	1.2E-09	2.5E-11	--	--	7.4E-13	4.1E-14	7.4E-13	9.5E-13	1.95E-08
	Lead-214	8.8E-02	1.1E-08	1.3E-06	1.8E-13	3.8E-07	8.3E-12	--	--	3.1E-09	1.7E-10	3.1E-09	4.0E-09	1.52E-08
	Plutonium-238	2.1E-06	1.9E-10	2.4E-08	2.3E-12	9.2E-12	2.2E-13	--	--	3.3E-17	1.8E-18	3.3E-17	4.3E-17	1.88E-10
	Plutonium-239	2.4E-06	2.2E-10	2.7E-08	2.7E-12	1.1E-11	2.5E-13	--	--	3.2E-17	1.8E-18	3.2E-17	4.1E-17	2.19E-10
	Potassium-40	1.4E-01	1.4E-06	1.7E-03	1.9E-08	6.0E-07	1.6E-11	--	--	3.3E-09	1.8E-10	3.3E-09	4.2E-09	1.43E-06
	Radium-226	1.2E-02	1.8E-06	1.3E-04	2.2E-08	5.0E-08	3.4E-10	--	--	1.1E-11	6.1E-13	1.1E-11	1.4E-11	1.85E-06
	Radium-228	1.6E-02	5.3E-06	1.8E-04	6.4E-08	6.8E-08	2.1E-10	--	--	--	--	--	--	5.37E-06
	Strontium-90	2.1E-03	8.5E-08	2.6E-05	1.1E-09	9.2E-09	6.1E-13	--	--	4.3E-14	2.3E-15	4.3E-14	5.5E-14	8.66E-08
	Thorium-228	3.0E-03	1.4E-07	3.3E-05	1.6E-09	1.3E-08	1.0E-09	--	--	8.5E-13	4.7E-14	8.5E-13	1.1E-12	1.41E-07
	Thorium-230	2.6E-03	1.4E-07	2.9E-05	1.8E-09	1.1E-08	2.0E-10	--	--	1.4E-13	7.8E-15	1.4E-13	1.8E-13	1.47E-07
	Thorium-232	2.3E-03	1.3E-07	2.5E-05	1.7E-09	9.9E-09	3.0E-10	--	--	6.2E-14	3.4E-15	6.2E-14	8.0E-14	1.35E-07
	Tritium	3.4E-01	1.1E-08	1.0E-02	0.0E+00	2.7E-08	9.1E-16	2.0E-09	6.7E-17	--	--	--	--	1.11E-08
	Uranium-234	1.2E-03	4.4E-08	1.4E-05	5.3E-10	5.3E-09	3.6E-11	--	--	3.0E-14	1.6E-15	3.0E-14	3.8E-14	4.41E-08
	Uranium-235	4.8E-05	1.6E-09	5.3E-07	2.0E-11	2.1E-10	3.2E-12	--	--	1.0E-12	5.7E-14	1.0E-12	1.3E-12	1.63E-09
	Uranium-238	8.2E-04	2.6E-08	9.2E-06	3.2E-10	3.6E-09	2.0E-11	--	--	9.0E-15	4.9E-16	9.0E-15	1.2E-14	2.67E-08
	Total	**6.0E-01**	**9.1E-06**	**1.2E-02**	**1.1E-07**	**1.2E-06**	**2.2E-09**	**2.0E-09**	**6.7E-17**	**6.4E-09**	**3.5E-10**	**6.4E-09**	**8.2E-09**	**9.27E-06**
Lifetime (0 <70 years)	Americium-241	3.7E-04	3.9E-08	4.3E-06	5.8E-10	2.5E-09	6.9E-11	--	--	1.9E-12	1.0E-13	3.4E-11	1.9E-12	3.96E-08
	Lead-214	1.1E-01	3.9E-08	1.7E-06	8.3E-13	7.5E-07	2.7E-11	--	--	7.9E-09	4.4E-10	1.4E-07	7.9E-09	4.78E-08
	Plutonium-238	2.8E-06	3.6E-10	3.2E-08	5.4E-12	1.8E-11	6.1E-13	--	--	8.5E-17	4.7E-18	1.5E-15	8.5E-17	3.71E-10
	Plutonium-239	3.2E-06	4.3E-10	3.6E-08	6.3E-12	2.1E-11	6.9E-13	--	--	8.1E-17	4.5E-18	1.5E-15	8.1E-17	4.34E-10
	Potassium-40	1.8E-01	4.4E-06	2.3E-03	7.9E-08	1.2E-06	5.9E-11	--	--	8.4E-09	4.6E-10	1.5E-07	8.4E-09	4.53E-06
	Radium-226	1.5E-02	5.8E-06	1.8E-04	9.1E-08	9.9E-08	1.1E-09	--	--	2.8E-11	1.5E-12	5.1E-10	2.8E-11	5.92E-06
	Radium-228	2.0E-02	2.1E-05	2.4E-04	3.4E-07	1.3E-07	6.9E-10	--	--	--	--	--	--	2.15E-05
	Strontium-90	2.8E-03	1.6E-07	3.5E-05	2.4E-09	1.8E-08	1.9E-12	--	--	1.1E-13	6.0E-15	2.0E-12	1.1E-13	1.58E-07
	Thorium-228	3.9E-03	4.2E-07	4.5E-05	6.6E-09	2.6E-08	3.4E-09	--	--	2.2E-12	1.2E-13	3.9E-11	2.2E-12	4.33E-07
	Thorium-230	3.4E-03	3.1E-07	3.9E-05	4.7E-09	2.2E-08	6.4E-10	--	--	3.6E-13	2.0E-14	6.6E-12	3.6E-13	3.16E-07
	Thorium-232	3.0E-03	3.0E-07	3.4E-05	4.6E-09	2.0E-08	8.5E-10	--	--	1.6E-13	8.7E-15	2.9E-12	1.6E-13	3.07E-07
	Tritium	4.4E-01	2.5E-08	1.4E-02	0.0E+00	5.4E-08	3.0E-15	5.0E-09	2.8E-16	--	--	--	--	2.47E-08
	Uranium-234	1.6E-03	1.1E-07	1.9E-05	1.8E-09	1.1E-08	1.2E-10	--	--	7.5E-14	4.1E-15	1.4E-12	7.5E-14	1.16E-07
	Uranium-235	6.2E-05	4.3E-09	7.2E-07	6.8E-11	4.1E-10	4.1E-12	--	--	2.6E-12	1.5E-13	4.8E-11	2.6E-12	4.40E-09
	Uranium-238	1.1E-03	6.9E-08	1.2E-05	1.1E-09	7.0E-09	6.6E-11	--	--	2.3E-14	1.3E-15	4.2E-13	2.3E-14	6.99E-08
	Total	**7.9E-01**	**3.3E-05**	**1.7E-02**	**5.3E-07**	**2.3E-06**	**7.1E-09**	**5.0E-09**	**2.8E-16**	**1.6E-08**	**9.0E-10**	**3.0E-07**	**1.6E-08**	**3.35E-05**

Table 5E-4: Reasonable Maximum Exposure Risk Calculations - Females - Assuming 95% removal of Plutonium, Americium, Uranium, and Gross Alpha-emitting Radioactivity

Age Cohort	Radionuclide	Tap Water Ingestion[a]		Grown Produce		Inhalation While Bathing		Inhalation While Swimming		Water Immersion - Swimming[a]		Water Immersion - Bathing[a]		Total Cancer Risk
		Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Dose (Sv)	Lifetime Cancer Risk	Total Dose (Sv)	Lifetime Cancer Risk	
0 < 5 years	Americium-241	2.0E-05	1.5E-08	2.7E-07	2.0E-10	1.4E-10	1.7E-11	--	--	3.2E-13	1.7E-14	2.1E-12	1.2E-13	1.55E-08
	Lead-214	2.1E-02	7.4E-08	3.7E-07	1.3E-12	1.5E-07	2.5E-11	--	--	4.7E-09	2.6E-10	3.1E-08	1.7E-09	7.62E-08
	Plutonium-238	2.8E-07	2.6E-10	3.8E-09	3.4E-12	2.0E-12	2.8E-13	--	--	2.7E-17	1.5E-18	1.8E-16	9.8E-18	2.68E-10
	Plutonium-239	1.4E-05	1.4E-08	2.0E-07	1.8E-10	1.0E-10	1.4E-11	--	--	1.2E-15	6.4E-17	7.8E-15	4.3E-16	1.40E-08
	Potassium-40	8.8E-02	2.3E-05	1.3E-03	3.4E-07	6.3E-07	2.1E-10	--	--	1.3E-08	7.1E-10	8.6E-08	4.7E-09	2.31E-05
	Radium-226	2.2E-03	5.0E-06	3.1E-05	6.8E-08	1.6E-08	1.0E-09	--	--	1.3E-11	7.2E-13	8.8E-11	4.8E-12	5.11E-06
	Radium-228	1.9E-03	1.4E-05	2.5E-05	1.9E-07	1.3E-08	4.1E-10	--	--	--	--	--	--	1.46E-05
	Strontium-90	5.7E-04	1.5E-07	8.5E-06	2.3E-09	4.1E-09	2.4E-12	--	--	7.0E-14	3.9E-15	4.7E-13	2.6E-14	1.57E-07
	Thorium-228	4.5E-04	5.4E-07	5.9E-06	7.0E-09	3.2E-09	2.4E-09	--	--	7.7E-13	4.2E-14	5.2E-12	2.8E-13	5.54E-07
	Thorium-230	5.5E-04	4.1E-07	7.5E-06	5.2E-09	4.0E-09	6.8E-10	--	--	1.8E-13	1.0E-14	1.2E-12	6.8E-14	4.12E-07
	Thorium-232	3.2E-04	2.7E-07	4.3E-06	3.4E-09	2.3E-09	5.5E-10	--	--	5.4E-14	2.9E-15	3.6E-13	2.0E-14	2.74E-07
	Tritium	3.5E-02	9.5E-09	1.3E-03	0.0E+00	4.7E-09	1.3E-15	4.9E-10	1.3E-16	--	--	--	--	9.52E-09
	Uranium-234	1.4E-04	8.7E-08	1.9E-06	1.2E-09	1.0E-09	6.6E-11	--	--	2.1E-14	1.2E-15	1.4E-13	7.8E-15	8.85E-08
	Uranium-235	5.4E-06	3.3E-09	7.4E-08	4.5E-11	3.9E-11	2.2E-12	--	--	7.3E-13	4.0E-14	4.9E-12	2.7E-13	3.37E-09
	Uranium-238	9.7E-05	5.3E-08	1.3E-06	7.2E-10	6.9E-10	3.7E-11	--	--	6.5E-15	3.6E-16	4.3E-14	2.4E-15	5.41E-08
	Total	**1.5E-01**	**4.4E-05**	**2.7E-03**	**6.2E-07**	**8.3E-07**	**5.5E-09**	**4.9E-10**	**1.3E-16**	**1.8E-08**	**9.7E-10**	**1.2E-07**	**6.5E-09**	**4.45E-05**
5 < 15 years	Americium-241	5.6E-05	1.8E-08	9.6E-07	3.1E-10	3.6E-10	2.4E-11	--	--	7.8E-13	4.3E-14	4.9E-12	2.7E-13	1.82E-08
	Lead-214	6.0E-02	8.8E-08	1.3E-06	2.0E-12	3.8E-07	4.1E-11	--	--	1.1E-08	6.3E-10	7.2E-08	4.0E-09	9.27E-08
	Plutonium-238	7.8E-07	3.0E-10	1.3E-08	5.2E-12	5.0E-12	4.0E-13	--	--	6.6E-17	3.6E-18	4.1E-16	2.3E-17	3.09E-10
	Plutonium-239	4.1E-05	1.6E-08	7.0E-07	2.8E-10	2.6E-10	2.0E-11	--	--	2.9E-15	1.6E-16	1.8E-14	9.9E-16	1.64E-08
	Radium-226	6.3E-03	9.0E-06	1.1E-04	1.6E-07	4.0E-08	1.4E-09	--	--	3.2E-11	1.8E-12	2.0E-10	1.1E-11	9.13E-06
	Radium-228	5.2E-03	2.4E-05	9.0E-05	4.0E-07	3.3E-08	5.1E-10	--	--	--	--	--	--	2.40E-05
	Strontium-90	1.6E-03	2.2E-07	3.0E-05	4.2E-09	1.0E-08	3.0E-12	--	--	1.7E-13	9.4E-15	1.1E-12	6.0E-14	2.23E-07
	Thorium-228	1.3E-03	5.5E-07	2.1E-05	9.3E-09	8.0E-09	3.2E-09	--	--	1.9E-12	1.0E-13	1.2E-11	6.6E-13	5.63E-07
	Thorium-230	1.6E-03	4.5E-07	2.7E-05	7.7E-09	9.9E-09	8.4E-10	--	--	4.5E-13	2.5E-14	2.8E-12	1.6E-13	4.59E-07
	Thorium-232	8.9E-04	2.9E-07	1.5E-05	5.1E-09	5.7E-09	6.6E-10	--	--	1.3E-13	7.2E-15	8.3E-13	4.5E-14	3.00E-07
	Tritium	9.9E-02	1.5E-08	4.6E-03	0.0E+00	1.2E-08	1.8E-15	1.4E-09	2.1E-16	--	--	--	--	1.51E-08
	Uranium-234	4.0E-04	1.1E-07	6.9E-06	1.9E-09	2.6E-09	8.8E-11	--	--	5.2E-14	2.9E-15	3.3E-13	1.8E-14	1.12E-07
	Uranium-235	1.5E-05	4.2E-09	2.6E-07	7.2E-11	9.7E-11	3.0E-12	--	--	1.8E-12	9.8E-14	1.1E-11	6.2E-13	4.24E-09
	Uranium-238	2.7E-04	6.7E-08	4.7E-06	1.2E-09	1.7E-09	4.9E-11	--	--	1.6E-14	8.7E-16	1.0E-13	5.5E-15	6.85E-08
	Total	**1.8E-01**	**3.4E-05**	**4.9E-03**	**5.9E-07**	**5.1E-07**	**6.9E-09**	**1.4E-09**	**2.1E-16**	**1.1E-08**	**6.3E-10**	**7.2E-08**	**4.0E-09**	**3.50E-05**
15 < 25 years	Americium-241	9.7E-05	1.6E-08	1.2E-06	2.0E-10	3.7E-10	1.5E-11	--	--	5.6E-13	3.1E-14	5.3E-12	2.9E-13	1.61E-08
	Lead-214	1.0E-01	6.7E-08	1.7E-06	1.1E-12	4.0E-07	2.1E-11	--	--	8.2E-09	4.5E-10	7.8E-08	4.3E-09	7.16E-08
	Plutonium-238	1.4E-06	2.9E-10	1.7E-08	3.6E-12	5.2E-12	2.5E-13	--	--	4.7E-17	2.6E-18	4.5E-16	2.5E-17	2.90E-10
	Plutonium-239	7.0E-05	1.6E-08	8.9E-07	2.0E-10	2.7E-10	1.3E-11	--	--	2.1E-15	1.1E-16	2.0E-14	1.1E-15	1.59E-08
	Potassium-40	4.3E-01	1.5E-05	6.0E-03	2.2E-07	1.6E-06	9.6E-11	--	--	2.3E-08	1.3E-09	2.2E-07	1.2E-08	1.56E-05
	Radium-226	1.1E-02	1.1E-05	1.4E-04	1.5E-07	4.2E-08	6.1E-10	--	--	2.3E-11	1.3E-12	2.2E-10	1.2E-11	1.15E-05
	Radium-228	9.0E-03	2.3E-05	1.1E-04	3.0E-07	3.4E-08	2.2E-10	--	--	--	--	--	--	2.34E-05
	Strontium-90	2.8E-03	2.9E-07	3.9E-05	4.1E-09	1.1E-08	1.4E-12	--	--	1.2E-13	6.8E-15	1.2E-12	6.5E-14	2.92E-07
	Thorium-228	2.2E-03	3.2E-07	2.7E-05	4.0E-09	8.3E-09	1.3E-09	--	--	1.4E-12	7.5E-14	1.3E-11	7.1E-13	3.28E-07
	Thorium-230	2.7E-03	4.0E-07	3.4E-05	5.1E-09	1.0E-08	3.2E-10	--	--	3.3E-13	1.8E-14	3.1E-12	1.7E-13	4.04E-07
	Thorium-232	1.6E-03	2.6E-07	2.0E-05	3.3E-09	5.9E-09	2.8E-10	--	--	9.5E-14	5.2E-15	9.0E-13	4.9E-14	2.66E-07
	Tritium	1.7E-01	1.6E-08	5.9E-03	0.0E+00	1.2E-08	1.1E-15	1.0E-09	9.5E-17	--	--	--	--	1.55E-08
	Uranium-234	7.0E-04	8.1E-08	8.9E-06	1.0E-09	2.7E-09	3.9E-11	--	--	3.7E-14	2.1E-15	3.6E-13	2.0E-14	8.20E-08
	Uranium-235	2.6E-05	3.0E-09	3.4E-07	3.8E-11	1.0E-10	1.3E-12	--	--	1.3E-12	7.1E-14	1.2E-11	6.7E-13	3.03E-09
	Uranium-238	4.7E-04	4.9E-08	6.0E-06	6.3E-10	1.8E-09	2.1E-11	--	--	1.1E-14	6.3E-16	1.1E-13	6.0E-15	5.00E-08
	Total	**7.3E-01**	**5.1E-05**	**1.2E-02**	**6.8E-07**	**2.2E-06**	**2.9E-09**	**1.0E-09**	**9.5E-17**	**3.1E-08**	**1.7E-09**	**2.9E-07**	**1.6E-08**	**5.20E-05**
25 < 70 years	Americium-241	5.0E-04	3.4E-08	7.0E-06	5.2E-10	9.0E-10	1.8E-11	--	--	1.1E-12	5.9E-14	1.2E-11	6.9E-13	3.41E-08
	Lead-214	5.4E-01	6.7E-08	9.7E-06	1.4E-12	9.6E-07	2.1E-11	--	--	1.6E-08	8.7E-10	1.8E-07	1.0E-08	7.80E-08
	Plutonium-238	7.0E-06	6.0E-10	9.8E-08	9.4E-12	1.3E-11	3.0E-13	--	--	9.0E-17	5.0E-18	1.1E-15	5.8E-17	6.13E-10
	Plutonium-239	3.6E-04	3.2E-08	5.1E-06	5.0E-10	6.5E-10	1.5E-11	--	--	4.0E-15	2.2E-16	4.6E-14	2.5E-15	3.27E-08
	Potassium-40	2.2E+00	2.2E-05	3.4E-02	3.8E-07	4.0E-06	1.1E-10	--	--	4.3E-08	2.4E-09	5.1E-07	2.8E-08	2.29E-05
	Radium-226	5.6E-02	8.8E-06	8.0E-04	1.4E-07	1.0E-07	6.8E-10	--	--	4.4E-11	2.4E-12	5.2E-10	2.8E-11	8.95E-06
	Radium-228	4.6E-02	1.6E-05	6.5E-04	2.4E-07	8.3E-08	2.5E-10	--	--	--	--	--	--	1.60E-05
	Strontium-90	1.4E-02	5.7E-07	2.2E-04	9.4E-09	2.6E-08	1.7E-12	--	--	2.4E-13	1.3E-14	2.8E-12	1.5E-13	5.80E-07
	Thorium-228	1.1E-02	5.1E-07	1.5E-04	7.6E-09	2.0E-08	1.6E-09	--	--	2.6E-12	1.4E-13	3.0E-11	1.7E-12	5.18E-07
	Thorium-230	1.4E-02	7.7E-07	1.9E-04	1.2E-08	2.5E-08	4.5E-10	--	--	6.2E-13	3.4E-14	7.3E-12	4.0E-13	7.78E-07
	Thorium-232	8.0E-03	4.6E-07	1.1E-04	7.3E-09	1.4E-08	4.4E-10	--	--	1.8E-13	9.9E-15	2.1E-12	1.2E-13	4.72E-07
	Tritium	8.9E-01	2.9E-08	3.4E-02	0.0E+00	3.0E-08	9.9E-16	2.0E-09	6.7E-17	--	--	--	--	2.93E-08
	Uranium-234	3.6E-03	1.3E-07	5.0E-05	2.0E-09	6.5E-09	4.3E-11	--	--	7.2E-14	3.9E-15	8.4E-13	4.6E-14	1.29E-07
	Uranium-235	1.4E-04	4.6E-09	1.9E-06	7.1E-11	2.5E-10	3.8E-12	--	--	2.5E-12	1.4E-13	2.9E-11	1.6E-12	4.67E-09
	Uranium-238	2.4E-03	7.8E-08	3.4E-05	1.2E-09	4.4E-09	2.4E-11	--	--	2.2E-14	1.2E-15	2.6E-13	1.4E-14	7.88E-08
	Total	**3.8E+00**	**5.0E-05**	**7.0E-02**	**8.0E-07**	**5.2E-06**	**3.6E-09**	**2.0E-09**	**6.7E-17**	**5.9E-08**	**3.3E-09**	**6.9E-07**	**3.8E-08**	**5.05E-05**
Lifetime (0 < 70 years)	Americium-241	6.7E-04	6.9E-08	9.3E-06	1.3E-09	1.8E-09	5.0E-11	--	--	2.7E-12	1.5E-13	2.5E-11	1.4E-12	7.05E-08
	Lead-214	7.1E-01	2.4E-07	1.3E-05	6.3E-12	1.9E-06	6.9E-11	--	--	4.0E-08	2.2E-09	3.7E-07	2.0E-08	2.67E-07
	Plutonium-238	9.3E-06	1.2E-09	1.3E-07	2.2E-11	2.5E-11	8.3E-13	--	--	2.3E-16	1.3E-17	2.1E-15	1.2E-16	1.24E-09
	Plutonium-239	4.8E-04	6.5E-08	6.8E-06	1.2E-09	1.3E-09	4.3E-11	--	--	1.0E-14	5.5E-16	9.2E-14	5.0E-15	6.63E-08
	Potassium-40	2.9E+00	7.2E-05	4.6E-02	1.6E-06	7.8E-06	3.9E-10	--	--	1.1E-07	6.1E-09	1.0E-06	5.5E-08	7.39E-05
	Radium-226	7.5E-02	2.9E-05	1.1E-03	5.5E-07	2.0E-07	2.3E-09	--	--	1.1E-10	6.2E-12	1.0E-09	5.7E-11	2.93E-05
	Radium-228	6.2E-02	6.4E-05	8.7E-04	1.2E-06	1.6E-07	8.5E-10	--	--	--	--	--	--	6.53E-05
	Strontium-90	1.9E-02	1.1E-06	2.9E-04	2.0E-08	5.1E-08	5.3E-12	--	--	6.0E-13	3.3E-14	5.5E-12	3.0E-13	1.08E-06
	Thorium-228	1.5E-02	1.6E-06	2.0E-04	3.0E-08	4.0E-08	5.2E-09	--	--	6.6E-12	3.6E-13	6.0E-11	3.3E-12	1.63E-06
	Thorium-230	1.8E-02	1.7E-06	2.6E-04	3.1E-08	4.9E-08	1.4E-09	--	--	1.6E-12	8.7E-14	1.4E-11	7.9E-13	1.71E-06
	Thorium-232	1.1E-02	1.1E-06	1.5E-04	2.0E-08	2.8E-08	1.2E-09	--	--	4.6E-13	2.5E-14	4.2E-12	2.3E-13	1.10E-06
	Tritium	1.2E+00	6.6E-08	4.5E-02	0.0E+00	5.9E-08	3.3E-15	5.0E-09	2.8E-16	--	--	--	--	6.62E-08
	Uranium-234	4.8E-03	3.4E-07	6.7E-05	6.4E-09	1.3E-08	1.5E-10	--	--	1.8E-13	1.0E-14	1.7E-12	9.1E-14	3.45E-07
	Uranium-235	1.8E-04	1.3E-08	2.5E-06	2.4E-10	4.8E-10	4.9E-12	--	--	6.3E-12	3.4E-13	5.7E-11	3.1E-12	1.29E-08
	Uranium-238	3.2E-03	2.1E-07	4.5E-05	3.9E-09	8.6E-09	8.0E-11	--	--	5.6E-14	3.1E-15	5.1E-13	2.8E-14	2.10E-07
	Total	**5.0E+00**	**1.7E-04**	**9.4E-02**	**3.5E-06**	**1.0E-05**	**1.2E-08**	**5.0E-09**	**2.8E-16**	**1.5E-07**	**8.3E-09**	**1.4E-06**	**7.6E-08**	**1.75E-04**

[a] These risks are non-specific for gender.

5F-1: Central Tendency Risk Calculations - Males - Buckman

Age Cohort	Radionuclide	Tap Water Ingestion[a]		Grown Produce		Inhalation While Bathing		Inhalation While Swimming		Water Immersion - Swimming[a]		Water Immersion - Bathing[a]		Total Cancer Risk
		Total Intake (uCi)	**Lifetime Cancer Risk**	**Total Intake (uCi)**	**Lifetime Cancer Risk**	**Total Intake (uCi)**	**Lifetime Cancer Risk**	**Total Intake (uCi)**	**Lifetime Cancer Risk**	**Total Dose (Sv)**	**Lifetime Cancer Risk**	**Total Dose [Sv]**	**Lifetime Cancer Risk**	
0 < 5 years	Radium-226	6.9E-04	1.6E-06	5.1E-06	1.1E-08	1.3E-08	8.3E-10	--	--	5.2E-12	2.8E-13	6.9E-11	3.8E-12	2.E-06
	Radium-228	1.2E-03	9.2E-06	3.7E-06	2.8E-08	2.2E-08	6.7E-10	--	--	--	--	--	--	9.E-06
	Uranium-234	9.2E-03	5.6E-06	5.4E-07	3.3E-10	1.7E-07	1.1E-08	--	--	1.7E-12	9.6E-14	2.3E-11	1.3E-12	6.E-06
	Uranium-235	4.5E-04	2.8E-07	2.1E-08	1.3E-11	8.5E-09	4.9E-10	--	--	7.8E-11	4.3E-12	1.0E-09	5.7E-11	3.E-07
	Uranium-238	5.5E-03	3.0E-06	3.6E-07	2.0E-10	1.0E-07	5.5E-09	--	--	4.7E-13	2.6E-14	6.3E-12	3.4E-13	3.E-06
	Total	**1.7E-02**	**2.0E-05**	**9.8E-06**	**4.0E-08**	**3.2E-07**	**1.9E-08**	**0.0E+00**	**0.0E+00**	**8.5E-11**	**4.7E-12**	**1.1E-09**	**6.3E-11**	**2.E-05**
5 < 15 years	Radium-226	1.9E-03	2.7E-06	2.0E-05	2.8E-08	3.4E-08	1.2E-09	--	--	1.3E-11	7.0E-13	1.6E-10	8.8E-12	3.E-06
	Radium-228	3.2E-03	1.4E-05	1.4E-05	6.4E-08	5.7E-08	8.9E-10	--	--	--	--	--	--	1.E-05
	Uranium-234	2.5E-02	6.9E-06	2.1E-06	5.7E-10	4.5E-07	1.5E-08	--	--	4.3E-12	2.3E-13	5.4E-11	3.0E-12	7.E-06
	Uranium-235	1.2E-03	3.4E-07	7.9E-08	2.2E-11	2.2E-08	6.8E-10	--	--	1.9E-10	1.0E-11	2.4E-09	1.3E-10	3.E-07
	Uranium-238	1.5E-02	3.7E-06	1.4E-06	3.4E-10	2.7E-07	7.5E-09	--	--	1.1E-12	6.3E-14	1.4E-11	7.9E-13	4.E-06
	Total	**4.6E-02**	**2.8E-05**	**3.7E-05**	**9.3E-08**	**8.3E-07**	**2.6E-08**	**0.0E+00**	**0.0E+00**	**2.1E-10**	**1.1E-11**	**2.6E-09**	**1.4E-10**	**3.E-05**
15 < 25 years	Radium-226	3.3E-03	3.5E-06	2.7E-05	2.8E-08	3.9E-08	5.8E-10	--	--	9.1E-12	5.0E-13	1.7E-10	9.5E-12	3.E-06
	Radium-228	5.7E-03	1.5E-05	2.0E-05	5.1E-08	6.7E-08	4.3E-10	--	--	--	--	--	--	1.E-05
	Uranium-234	4.5E-02	5.2E-06	2.8E-06	3.3E-10	5.3E-07	7.6E-09	--	--	3.1E-12	1.7E-13	5.8E-11	3.2E-12	5.E-06
	Uranium-235	2.2E-03	2.5E-07	1.1E-07	1.2E-11	2.6E-08	3.3E-10	--	--	1.4E-10	7.6E-12	2.6E-09	1.4E-10	2.E-07
	Uranium-238	2.6E-02	2.8E-06	1.9E-06	2.0E-10	3.1E-07	3.6E-09	--	--	8.3E-13	4.5E-14	1.6E-11	8.6E-13	3.E-06
	Total	**8.2E-02**	**2.6E-05**	**5.1E-05**	**8.0E-08**	**9.7E-07**	**1.3E-08**	**0.0E+00**	**0.0E+00**	**1.5E-10**	**8.3E-12**	**2.9E-09**	**1.6E-10**	**3.E-05**
25 < 70 years	Radium-226	1.8E-02	2.9E-06	1.5E-04	2.6E-08	9.8E-08	6.6E-10	--	--	1.7E-11	9.6E-13	1.7E-11	2.2E-11	3.E-06
	Radium-228	3.1E-02	1.1E-05	1.1E-04	4.1E-08	1.7E-07	5.1E-10	--	--	--	--	--	--	1.E-05
	Uranium-234	2.5E-01	8.7E-06	1.6E-05	6.2E-10	1.3E-06	8.8E-09	--	--	5.9E-12	3.2E-13	5.9E-12	7.5E-12	9.E-06
	Uranium-235	1.2E-02	4.1E-07	6.1E-07	2.3E-11	6.5E-08	1.0E-09	--	--	2.6E-10	1.4E-11	2.6E-10	3.4E-10	4.E-07
	Uranium-238	1.5E-01	4.6E-06	1.1E-05	3.8E-10	7.8E-07	4.3E-09	--	--	1.6E-12	8.7E-14	1.6E-12	2.0E-12	5.E-06
	Total	**4.5E-01**	**2.7E-05**	**2.9E-04**	**6.8E-08**	**2.4E-06**	**1.5E-08**	**0.0E+00**	**0.0E+00**	**2.9E-10**	**1.6E-11**	**2.9E-10**	**3.7E-10**	**3.E-05**
Lifetime (0 < 70 years)	Radium-226	2.4E-02	9.2E-06	2.0E-04	1.0E-07	1.9E-07	2.2E-09	--	--	4.4E-11	2.4E-12	8.1E-10	4.4E-11	9.E-06
	Radium-228	4.1E-02	4.2E-05	1.5E-04	2.1E-07	3.2E-07	1.6E-09	--	--	--	--	--	--	4.E-05
	Uranium-234	3.2E-01	2.3E-05	2.1E-05	2.0E-09	2.5E-06	2.9E-08	--	--	1.5E-11	8.2E-13	2.7E-10	1.5E-11	2.E-05
	Uranium-235	1.6E-02	1.1E-06	8.2E-07	7.7E-11	1.2E-07	1.2E-09	--	--	6.7E-10	3.7E-11	1.2E-08	6.7E-10	1.E-06
	Uranium-238	1.9E-01	1.2E-05	1.4E-05	1.2E-09	1.5E-06	1.4E-08	--	--	4.0E-12	2.2E-13	7.3E-11	4.0E-12	1.E-05
	Total	**5.9E-01**	**8.7E-05**	**3.9E-04**	**3.2E-07**	**4.6E-06**	**4.7E-08**	**0.0E+00**	**0.0E+00**	**7.3E-10**	**4.0E-11**	**1.3E-08**	**7.3E-10**	**9.E-05**

[a] Risks are non-specific for gender.

5F-2: Reasonable Maximum Exposure Risk Calculations - Males - Buckman

Age Cohort	Radionuclide	Tap Water Ingestion[a]		Grown Produce		Inhalation While Bathing		Inhalation While Swimming		Water Immersion - Swimming[a]		Water Immersion - Bathing[a]		Total Cancer Risk
		Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Dose (Sv)	Lifetime Cancer Risk	Total Dose [Sv]	Lifetime Cancer Risk	
0 < 5 years	Radium-226	2.6E-03	5.8E-06	3.1E-05	6.9E-08	1.9E-08	1.2E-09	--	--	1.5E-11	8.3E-13	1.0E-10	5.6E-12	6.E-06
	Radium-228	4.4E-03	3.4E-05	2.6E-05	1.9E-07	3.2E-08	9.9E-10	--	--	--	--	--	--	3.E-05
	Uranium-234	6.2E-02	3.7E-05	2.0E-06	1.2E-09	4.5E-07	2.9E-08	--	--	9.1E-12	5.0E-13	6.1E-11	3.3E-12	4.E-05
	Uranium-235	3.0E-03	1.8E-06	7.5E-08	4.5E-11	2.2E-08	1.3E-09	--	--	4.1E-10	2.2E-11	2.7E-09	1.5E-10	2.E-06
	Uranium-238	3.6E-02	2.0E-05	1.3E-06	7.3E-10	2.7E-07	1.4E-08	--	--	2.4E-12	1.3E-13	1.6E-11	9.0E-13	2.E-05
	Total	**1.1E-01**	**9.9E-05**	**6.0E-05**	**2.7E-07**	**7.9E-07**	**4.7E-08**	**0.0E+00**	**0.0E+00**	**4.3E-10**	**2.4E-11**	**2.9E-09**	**1.6E-10**	**1.E-04**
5 < 15 years	Radium-226	7.2E-03	1.0E-05	1.1E-04	1.6E-07	4.9E-08	1.7E-09	--	--	3.7E-11	2.0E-12	2.3E-10	1.3E-11	1.E-05
	Radium-228	1.2E-02	5.6E-05	9.1E-05	4.1E-07	8.4E-08	1.3E-09	--	--	--	--	--	--	6.E-05
	Uranium-234	1.7E-01	4.7E-05	7.1E-06	1.9E-09	1.2E-06	4.0E-08	--	--	2.2E-11	1.2E-12	1.4E-10	7.7E-12	5.E-05
	Uranium-235	8.5E-03	2.3E-06	2.7E-07	7.3E-11	5.8E-08	1.8E-09	--	--	9.9E-10	5.5E-11	6.3E-09	3.4E-10	2.E-06
	Uranium-238	1.0E-01	2.5E-05	4.8E-06	1.2E-09	6.9E-07	2.0E-08	--	--	6.0E-12	3.3E-13	3.8E-11	2.1E-12	3.E-05
	Total	**3.0E-01**	**1.4E-04**	**2.2E-04**	**5.8E-07**	**2.1E-06**	**6.5E-08**	**0.0E+00**	**0.0E+00**	**1.1E-09**	**5.8E-11**	**6.7E-09**	**3.7E-10**	**1.E-04**
15 < 25 years	Radium-226	1.3E-02	1.3E-05	1.6E-04	1.7E-07	5.8E-08	8.4E-10	--	--	2.7E-11	1.5E-12	2.5E-10	1.4E-11	1.E-05
	Radium-228	2.1E-02	5.5E-05	1.3E-04	3.5E-07	9.8E-08	6.3E-10	--	--	--	--	--	--	6.E-05
	Uranium-234	3.0E-01	3.5E-05	1.0E-05	1.2E-09	1.4E-06	2.0E-08	--	--	1.6E-11	8.8E-13	1.5E-10	8.4E-12	3.E-05
	Uranium-235	1.5E-02	1.7E-06	3.9E-07	4.5E-11	6.8E-08	8.5E-10	--	--	7.2E-10	3.9E-11	6.8E-09	3.7E-10	2.E-06
	Uranium-238	1.8E-01	1.9E-05	7.0E-06	7.3E-10	8.1E-07	9.4E-09	--	--	4.3E-12	2.4E-13	4.1E-11	2.2E-12	2.E-05
	Total	**5.2E-01**	**1.2E-04**	**3.1E-04**	**5.2E-07**	**2.4E-06**	**3.2E-08**	**0.0E+00**	**0.0E+00**	**7.6E-10**	**4.2E-11**	**7.3E-09**	**4.0E-10**	**1.E-04**
25 < 70 years	Radium-226	6.5E-02	1.0E-05	2.1E-04	3.5E-08	1.4E-07	9.6E-10	--	--	5.1E-11	2.8E-12	5.9E-10	3.3E-11	1.E-05
	Radium-228	1.1E-01	3.7E-05	1.7E-04	6.2E-08	2.4E-07	7.5E-10	--	--	--	--	--	--	4.E-05
	Uranium-234	1.5E+00	5.4E-05	1.3E-05	5.1E-10	3.4E-06	2.3E-08	--	--	3.1E-11	1.7E-12	3.6E-10	2.0E-11	5.E-05
	Uranium-235	7.6E-02	2.6E-06	4.9E-07	1.8E-11	1.7E-07	2.6E-09	--	--	1.4E-09	7.5E-11	1.6E-08	8.8E-10	3.E-06
	Uranium-238	9.1E-01	2.9E-05	8.8E-06	3.1E-10	2.0E-06	1.1E-08	--	--	8.2E-12	4.5E-13	9.6E-11	5.3E-12	3.E-05
	Total	**2.7E+00**	**1.3E-04**	**4.0E-04**	**9.8E-08**	**6.0E-06**	**3.8E-08**	**0.0E+00**	**0.0E+00**	**1.5E-09**	**8.0E-11**	**1.7E-08**	**9.4E-10**	**1.E-04**
Lifetime (0 < 70 years)	Radium-226	8.6E-02	3.3E-05	1.2E-03	6.3E-07	2.7E-07	3.1E-09	--	--	1.3E-10	7.1E-12	1.2E-09	6.5E-11	3.E-05
	Radium-228	1.5E-01	1.5E-04	1.0E-03	1.4E-06	4.7E-07	2.4E-09	--	--	--	--	--	--	2.E-04
	Uranium-234	2.0E+00	1.4E-04	7.7E-05	7.4E-09	6.5E-06	7.4E-08	--	--	7.8E-11	4.3E-12	7.1E-10	3.9E-11	1.E-04
	Uranium-235	1.0E-01	7.0E-06	2.9E-06	2.8E-10	3.2E-07	3.2E-09	--	--	3.5E-09	1.9E-10	3.2E-08	1.7E-09	7.E-06
	Uranium-238	1.2E+00	7.7E-05	5.2E-05	4.5E-09	3.9E-06	3.6E-08	--	--	2.1E-11	1.1E-12	1.9E-10	1.0E-11	8.E-05
	Total	**3.6E+00**	**4.1E-04**	**2.4E-03**	**2.1E-06**	**1.1E-05**	**1.2E-07**	**0.0E+00**	**0.0E+00**	**3.7E-09**	**2.0E-10**	**3.4E-08**	**1.9E-09**	**4.E-04**

[a] These risks are non-specific for gender.

5F-3: Central Tendency Risk Calculations - Females - Buckman

Age Cohort	Radionuclide	Tap Water Ingestion[a]		Grown Produce		Inhalation While Bathing		Inhalation While Swimming		Water Immersion - Swimming[a]		Water Immersion - Bathing[a]		Total Cancer Risk
		Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Dose (Sv)	Lifetime Cancer Risk	Total Dose [Sv]	Lifetime Cancer Risk	
0 < 5 years	Radium-226	6.9E-04	1.6E-06	5.0E-06	1.1E-08	1.3E-08	8.1E-10	--	--	5.2E-12	2.8E-13	6.9E-11	3.8E-12	2.E-06
	Radium-228	1.2E-03	9.2E-06	3.7E-06	2.8E-08	2.1E-08	6.6E-10	--	--	--	--	--	--	9.E-06
	Uranium-234	9.2E-03	5.6E-06	5.3E-07	3.2E-10	1.7E-07	1.1E-08	--	--	1.7E-12	9.6E-14	2.3E-11	1.3E-12	6.E-06
	Uranium-235	4.5E-04	2.8E-07	2.0E-08	1.2E-11	8.3E-09	4.8E-10	--	--	7.8E-11	4.3E-12	1.0E-09	5.7E-11	3.E-07
	Uranium-238	5.5E-03	3.0E-06	3.5E-07	1.9E-10	9.9E-08	5.3E-09	--	--	4.7E-13	2.6E-14	6.3E-12	3.4E-13	3.E-06
	Total	**1.7E-02**	**2.0E-05**	**9.6E-06**	**3.9E-08**	**3.1E-07**	**1.8E-08**	**0.0E+00**	**0.0E+00**	**8.5E-11**	**4.7E-12**	**1.1E-09**	**6.3E-11**	**2.E-05**
5 < 15 years	Radium-226	1.9E-03	2.7E-06	1.9E-05	2.8E-08	3.1E-08	1.1E-09	--	--	1.3E-11	7.0E-13	1.6E-10	8.8E-12	3.E-06
	Radium-228	3.2E-03	1.4E-05	1.4E-05	6.3E-08	5.3E-08	8.3E-10	--	--	--	--	--	--	1.E-05
	Uranium-234	2.5E-02	6.9E-06	2.0E-06	5.6E-10	4.2E-07	1.5E-08	--	--	4.3E-12	2.3E-13	5.4E-11	3.0E-12	7.E-06
	Uranium-235	1.2E-03	3.4E-07	7.8E-08	2.1E-11	2.1E-08	6.3E-10	--	--	1.9E-10	1.0E-11	2.4E-09	1.3E-10	3.E-07
	Uranium-238	1.5E-02	3.7E-06	1.3E-06	3.4E-10	2.5E-07	7.0E-09	--	--	1.1E-12	6.3E-14	1.4E-11	7.9E-13	4.E-06
	Total	**4.6E-02**	**2.8E-05**	**3.7E-05**	**9.2E-08**	**7.8E-07**	**2.4E-08**	**0.0E+00**	**0.0E+00**	**2.1E-10**	**1.1E-11**	**2.6E-09**	**1.4E-10**	**3.E-05**
15 < 25 years	Radium-226	3.3E-03	3.5E-06	2.3E-05	2.4E-08	3.3E-08	4.8E-10	--	--	9.1E-12	5.0E-13	1.7E-10	9.5E-12	3.E-06
	Radium-228	5.7E-03	1.5E-05	1.7E-05	4.4E-08	5.6E-08	3.6E-10	--	--	--	--	--	--	1.E-05
	Uranium-234	4.5E-02	5.2E-06	2.4E-06	2.8E-10	4.4E-07	6.3E-09	--	--	3.1E-12	1.7E-13	5.8E-11	3.2E-12	5.E-06
	Uranium-235	2.2E-03	2.5E-07	9.3E-08	1.1E-11	2.2E-08	2.7E-10	--	--	1.4E-10	7.6E-12	2.6E-09	1.4E-10	2.E-07
	Uranium-238	2.6E-02	2.8E-06	1.6E-06	1.7E-10	2.6E-07	3.0E-09	--	--	8.3E-13	4.5E-14	1.6E-11	8.6E-13	3.E-06
	Total	**8.2E-02**	**2.6E-05**	**4.4E-05**	**6.8E-08**	**8.1E-07**	**1.0E-08**	**0.0E+00**	**0.0E+00**	**1.5E-10**	**8.3E-12**	**2.9E-09**	**1.6E-10**	**3.E-05**
25 < 70 years	Radium-226	1.8E-02	2.9E-06	1.3E-04	2.2E-08	7.9E-08	5.3E-10	--	--	1.7E-11	9.6E-13	1.7E-11	2.2E-11	3.E-06
	Radium-228	3.1E-02	1.1E-05	9.5E-05	3.5E-08	1.3E-07	4.1E-10	--	--	--	--	--	--	1.E-05
	Uranium-234	2.5E-01	8.7E-06	1.4E-05	5.3E-10	1.1E-06	7.1E-09	--	--	5.9E-12	3.2E-13	5.9E-12	7.5E-12	9.E-06
	Uranium-235	1.2E-02	4.1E-07	5.3E-07	2.0E-11	5.2E-08	8.2E-10	--	--	2.6E-10	1.4E-11	2.6E-10	3.4E-10	4.E-07
	Uranium-238	1.5E-01	4.6E-06	9.2E-06	3.2E-10	6.3E-07	3.4E-09	--	--	1.6E-12	8.7E-14	1.6E-12	2.0E-12	5.E-06
	Total	**4.5E-01**	**2.7E-05**	**2.5E-04**	**5.8E-08**	**2.0E-06**	**1.2E-08**	**0.0E+00**	**0.0E+00**	**2.9E-10**	**1.6E-11**	**2.9E-10**	**3.7E-10**	**3.E-05**
Lifetime (0 < 70 years)	Radium-226	2.4E-02	9.2E-06	1.8E-04	9.1E-08	1.6E-07	1.8E-09	--	--	4.4E-11	2.4E-12	8.1E-10	4.4E-11	9.E-06
	Radium-228	4.1E-02	4.2E-05	1.3E-04	1.8E-07	2.7E-07	1.4E-09	--	--	--	--	--	--	4.E-05
	Uranium-234	3.2E-01	2.3E-05	1.9E-05	1.8E-09	2.1E-06	2.4E-08	--	--	1.5E-11	8.2E-13	2.7E-10	1.5E-11	2.E-05
	Uranium-235	1.6E-02	1.1E-06	7.1E-07	6.7E-11	1.0E-07	1.0E-09	--	--	6.7E-10	3.7E-11	1.2E-08	6.7E-10	1.E-06
	Uranium-238	1.9E-01	1.2E-05	3.7E-05	3.2E-09	1.2E-06	1.2E-08	--	--	4.0E-12	2.2E-13	7.3E-11	4.0E-12	1.E-05
	Total	**5.9E-01**	**8.7E-05**	**3.6E-04**	**2.8E-07**	**3.9E-06**	**4.0E-08**	**0.0E+00**	**0.0E+00**	**7.3E-10**	**4.0E-11**	**1.3E-08**	**7.3E-10**	**9.E-05**

[a] Risks are non-specific for gender.

5F-4: Reasonable Maximum Exposure Risk Calculations - Females - Buckman

Age Cohort	Radionuclide	Tap Water Ingestion[a]		Grown Produce		Inhalation While Bathing		Inhalation While Swimming		Water Immersion - Swimming[a]		Water Immersion - Bathing[a]		Total Cancer Risk
		Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Intake (uCi)	Lifetime Cancer Risk	Total Dose (Sv)	Lifetime Cancer Risk	Total Dose [Sv]	Lifetime Cancer Risk	
0 < 5 years	Radium-226	2.6E-03	5.8E-06	3.1E-05	6.8E-08	1.8E-08	1.2E-09	--	--	1.5E-11	8.3E-13	1.0E-10	5.6E-12	6.E-06
	Radium-228	4.4E-03	3.4E-05	2.5E-05	1.9E-07	3.1E-08	9.6E-10	--	--	--	--	--	--	3.E-05
	Uranium-234	6.2E-02	3.7E-05	1.9E-06	1.2E-09	4.4E-07	2.8E-08	--	--	9.1E-12	5.0E-13	6.1E-11	3.3E-12	4.E-05
	Uranium-235	3.0E-03	1.8E-06	7.4E-08	4.5E-11	2.2E-08	1.2E-09	--	--	4.1E-10	2.2E-11	2.7E-09	1.5E-10	2.E-06
	Uranium-238	3.6E-02	2.0E-05	1.3E-06	7.2E-10	2.6E-07	1.4E-08	--	--	2.4E-12	1.3E-13	1.6E-11	9.0E-13	2.E-05
	Total	**1.1E-01**	**9.9E-05**	**5.9E-05**	**2.6E-07**	**7.7E-07**	**4.6E-08**	**0.0E+00**	**0.0E+00**	**4.3E-10**	**2.4E-11**	**2.9E-09**	**1.6E-10**	**1.E-04**
5 < 15 years	Radium-226	7.2E-03	1.0E-05	1.1E-04	1.6E-07	4.6E-08	1.6E-09	--	--	3.7E-11	2.0E-12	2.3E-10	1.3E-11	1.E-05
	Radium-228	1.2E-02	5.6E-05	9.0E-05	4.0E-07	7.8E-08	1.2E-09	--	--	--	--	--	--	6.E-05
	Uranium-234	1.7E-01	4.7E-05	6.9E-06	1.9E-09	1.1E-06	3.8E-08	--	--	2.2E-11	1.2E-12	1.4E-10	7.7E-12	5.E-05
	Uranium-235	8.5E-03	2.3E-06	2.6E-07	7.2E-11	5.4E-08	1.7E-09	--	--	9.9E-10	5.5E-11	6.3E-09	3.4E-10	2.E-06
	Uranium-238	1.0E-01	2.5E-05	4.7E-06	1.2E-09	6.5E-07	1.8E-08	--	--	6.0E-12	3.3E-13	3.8E-11	2.1E-12	3.E-05
	Total	**3.0E-01**	**1.4E-04**	**2.1E-04**	**5.6E-07**	**1.9E-06**	**6.1E-08**	**0.0E+00**	**0.0E+00**	**1.1E-09**	**5.8E-11**	**6.7E-09**	**3.7E-10**	**1.E-04**
15 < 25 years	Radium-226	1.3E-02	1.3E-05	1.4E-04	1.5E-07	4.8E-08	7.0E-10	--	--	2.7E-11	1.5E-12	2.5E-10	1.4E-11	1.E-05
	Radium-228	2.1E-02	5.5E-05	1.1E-04	3.0E-07	8.2E-08	5.3E-10	--	--	--	--	--	--	6.E-05
	Uranium-234	3.0E-01	3.5E-05	8.9E-06	1.0E-09	1.1E-06	1.6E-08	--	--	1.6E-11	8.8E-13	1.5E-10	8.4E-12	3.E-05
	Uranium-235	1.5E-02	1.7E-06	3.4E-07	3.8E-11	5.6E-08	7.1E-10	--	--	7.2E-10	3.9E-11	6.8E-09	3.7E-10	2.E-06
	Uranium-238	1.8E-01	1.9E-05	6.0E-06	6.3E-10	6.8E-07	7.8E-09	--	--	4.3E-12	2.4E-13	4.1E-11	2.2E-12	2.E-05
	Total	**5.2E-01**	**1.2E-04**	**2.7E-04**	**4.5E-07**	**2.0E-06**	**2.6E-08**	**0.0E+00**	**0.0E+00**	**7.6E-10**	**4.2E-11**	**7.3E-09**	**4.0E-10**	**1.E-04**
25 < 70 years	Radium-226	6.5E-02	1.0E-05	8.0E-04	1.4E-07	1.2E-07	7.8E-10	--	--	5.1E-11	2.8E-12	5.9E-10	3.3E-11	1.E-05
	Radium-228	1.1E-01	3.7E-05	6.5E-04	2.4E-07	2.0E-07	6.0E-10	--	--	--	--	--	--	4.E-05
	Uranium-234	1.5E+00	5.4E-05	5.0E-05	2.0E-09	2.8E-06	1.9E-08	--	--	3.1E-11	1.7E-12	3.6E-10	2.0E-11	5.E-05
	Uranium-235	7.6E-02	2.6E-06	1.9E-06	7.1E-11	1.4E-07	2.1E-09	--	--	1.4E-09	7.5E-11	1.6E-08	8.8E-10	3.E-06
	Uranium-238	9.1E-01	2.9E-05	3.4E-05	1.2E-09	1.6E-06	9.0E-09	--	--	8.2E-12	4.5E-13	9.6E-11	5.3E-12	3.E-05
	Total	**2.7E+00**	**1.3E-04**	**1.5E-03**	**3.8E-07**	**4.9E-06**	**3.1E-08**	**0.0E+00**	**0.0E+00**	**1.5E-09**	**8.0E-11**	**1.7E-08**	**9.4E-10**	**1.E-04**
Lifetime (0 < 70 years)	Radium-226	8.6E-02	3.3E-05	1.1E-03	5.5E-07	2.3E-07	2.6E-09	--	--	1.3E-10	7.1E-12	1.2E-09	6.5E-11	3.E-05
	Radium-228	1.5E-01	1.5E-04	8.7E-04	1.2E-06	3.9E-07	2.0E-09	--	--	--	--	--	--	2.E-04
	Uranium-234	2.0E+00	1.4E-04	6.7E-05	6.4E-09	5.5E-06	6.2E-08	--	--	7.8E-11	4.3E-12	7.1E-10	3.9E-11	1.E-04
	Uranium-235	1.0E-01	7.0E-06	2.5E-06	2.4E-10	2.7E-07	2.7E-09	--	--	3.5E-09	1.9E-10	3.2E-08	1.7E-09	7.E-06
	Uranium-238	1.2E+00	7.7E-05	4.5E-05	3.9E-09	3.2E-06	3.0E-08	--	--	2.1E-11	1.1E-12	1.9E-10	1.0E-11	8.E-05
	Total	**3.6E+00**	**4.1E-04**	**2.0E-03**	**1.8E-06**	**9.6E-06**	**1.0E-07**	**0.0E+00**	**0.0E+00**	**3.7E-09**	**2.0E-10**	**3.4E-08**	**1.9E-09**	**4.E-04**

[a] These risks are non-specific for gender.