ATSDR
AGENCY FOR TOXIC SUBSTANCES AND DISEASE REGISTRY

# Public Health Assessment for

**Evaluation of Community Exposures Related to Coldwater Creek**

**ST. LOUIS AIRPORT/HAZELWOOD INTERIM STORAGE SITE (HISS)/ FUTURA COATINGS NPL SITE**

**NORTH ST. LOUIS COUNTY, MISSOURI**

**EPA FACILITY ID: MOD980633176**

**APRIL 30, 2019**

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

THE ATSDR PUBLIC HEALTH ASSESSMENT: A NOTE OF EXPLANATION

This Public Health Assessment was prepared by ATSDR pursuant to the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA or Superfund) section 104 (i)(6) (42 U.S.C. 9604 (i)(6)), and in accordance with our implementing regulations (42 C.F.R. Part 90). In preparing this document, ATSDR has collected relevant health data, environmental data, and community health concerns from the Environmental Protection Agency (EPA), state and local health and environmental agencies, the community, and potentially responsible parties, where appropriate.
In addition, this document has previously been provided to EPA and the affected states in an initial release, as required by CERCLA section 104 (i)(6)(H) for their information and review. The revised document was released for a 60 day public comment period. Subsequent to the public comment period, ATSDR addressed all public comments and revised or appended the document as appropriate. The public health assessment has now been reissued. This concludes the public health assessment process for this site, unless additional information is obtained by ATSDR which, in the agency's opinion, indicates a need to revise or append the conclusions previously issued.

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St. Louis Airport/
Hazelwoold Interim Storage Site (HISS)/
Futura Coatings NPL Site

Final Release

# PUBLIC HEALTH ASSESSMENT

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## NORTH ST. LOUIS COUNTY, MISSOURI

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Prepared by the
U.S. Department of Health and Human Services
Agency for Toxic Substances and Disease Registry
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## Summary

## Introduction

The Agency for Toxic Substances and Disease Registry (ATSDR) evaluates community exposures and makes recommendations to prevent harmful exposures to hazardous substances in the environment. This report evaluates potential exposures to people who played or lived near Coldwater Creek in North St. Louis County, Missouri. Historical radiological waste storage sites near the St. Louis Airport released contamination into Coldwater Creek. The Army Corps of Engineers' Formerly Utilized Sites Remedial Action Program (FUSRAP) has been characterizing and cleaning up areas related to these sites since 1998.

Community members asked ATSDR to do this evaluation. They are particularly interested in exposures that occurred in the past, before storage site cleanup began.

This report uses available environmental data and information from the community to evaluate whether people playing or living near Coldwater Creek have or had harmful exposures to radiological or chemical contaminants from the creek. This report also addresses other exposure concerns which could not be fully assessed and makes recommendations for further work.

A draft of this report was provided for public comment from June through August 2018. Changes made in response to public comments are summarized in the report, and detailed responses to comments are provided in an Appendix. Although details of our evaluation changed, ATSDR's overall conclusions remain the same.

## Conclusions of ATSDR's Evaluation

To evaluate possible effects from exposures, ATSDR estimated the exposure and resulting risks for children and adults who directly touched, swallowed, or breathed in sediment and water from Coldwater Creek and soil in its floodplain for many hours a day for many years. We assumed they were always exposed to concentrations of contaminants present in the most highly contaminated areas. Based on different specific assumptions for past (1960s to 1990s) and recent (2000s and on) exposures, detailed in this report, we reached the following four conclusions.

### Conclusion 1

**Radiological contamination in and around Coldwater Creek, prior to remediation activities, could have increased the risk of some types of cancer in people who played or lived there.**

### Basis for Conclusion

- Children and adults who regularly played in or around Coldwater Creek or lived in its floodplain for many years in the past (1960s to 1990s) may have been exposed to radiological contaminants. ATSDR estimated that this exposure could have increased the risk of developing lung cancer, bone cancer, or leukemia.
- More recent exposures (2000s and on) only slightly increased the risk of developing lung cancer from daily residential exposure.
- Estimation of risk, especially for past exposures, involved many uncertainties. The estimated increased risks would not likely result in detectable increased cancer rates in the community as a whole.

### Next Steps

- ATSDR recommends that potentially exposed residents or former residents share their potential exposure related to Coldwater Creek with their physicians as part of their medical history and consult their physicians promptly if new or unusual symptoms develop. Upon request, ATSDR can facilitate a consultation between residents' personal physicians and medical specialists in environmental health.
- ATSDR recommends that the state consider updating analyses on cancer incidence, cancer mortality, and birth defects, as feasible.
- ATSDR will provide technical support, upon request, to update cancer incidence or mortality studies in the area and identify public health actions needed.

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### Conclusion 2

**ATSDR does not recommend additional general disease screening for past or present residents around Coldwater Creek.**

### Basis for Conclusion

- The predicted increases in the number of cancer cases from exposures are small, and no method exists to link a particular cancer with this exposure.
- Not all current or former residents would have experienced exposures as high as assumed by ATSDR in this evaluation.
- Screening people who have no symptoms has risks, including false negative results, false positive results, risks from treating cancers that might never have caused a

problem during a person's lifetime, and additional radiation exposure from diagnostic testing. A personal physician will use a patient's individual history, symptoms, age, and gender to determine appropriate screening and diagnostic testing.

**Next Steps**

- ATSDR recommends that potentially exposed residents or former residents share their potential exposure related to Coldwater Creek with their physicians as part of their medical history and consult their physicians promptly if new or unusual symptoms develop. Upon request, ATSDR can facilitate a consultation between residents' personal physicians and medical specialists in environmental health.

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**Conclusion 3**

**ATSDR supports ongoing efforts to identify and properly remediate radiological waste around Coldwater Creek.**

**Basis for Conclusion**

- Thorium-230 (Th-230) has been found above FUSRAP remedial goals in several areas of the Coldwater Creek floodplain. Reducing Th-230 levels in accessible areas will reduce harmful exposures.
- Waste entered the creek decades ago, and detailed information about how it moved with sediment and into floodplain soil does not exist. Reports of historical use of Coldwater Creek sediment and floodplain soil in other locations indicates a possibility that contamination spread from the floodplain. Identifying and remediating contaminated areas outside the floodplain will reduce potentially harmful exposures.

**Next Steps**

- ATSDR recommends that the FUSRAP program continue investigating and cleaning up Coldwater Creek sediments and floodplain soils to meet regulatory goals. To increase knowledge about contaminant distribution and allay community concerns, we recommend future sampling include
    - areas reported to have received soil or sediment moved from the Coldwater Creek floodplain (such as fill used in construction)
    - areas with possible soil or sediment deposited by flooding of major residential tributaries to Coldwater Creek
    - indoor dust in homes where yards have been cleaned up or require cleanup
    - sediment or soil remaining in basements that were directly flooded by Coldwater Creek in the past
- ATSDR recommends signs to inform residents and visitors of potential exposure risks in areas around Coldwater Creek not yet investigated or cleaned up.

- ATSDR will review new data from Coldwater Creek investigations, upon request, and update conclusions if necessary.

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### Conclusion 4

**Other exposure pathways of concern to the community could have contributed to risk. ATSDR is unable to quantify that risk.**

### Basis for Conclusion

- No sampling data exist that would allow ATSDR to estimate exposures from other pathways, including inhaling dust blown from historical radiological waste storage piles and past consumption of local dairy or agricultural products.

### Next Steps

- ATSDR recommends that public health agencies continue to evaluate, to the extent possible, community concerns about exposure and educate the community about radiological exposures and health.
- ATSDR will remain available to provide, upon request, further technical assistance to the public, partner agencies, or other stakeholders.

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## NOTE

These conclusions may change following availability of new environmental sampling data.

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## Purpose and Health Issues

This report evaluates whether radiological contamination in and around Coldwater Creek in North St. Louis County, Missouri, has affected the health of people playing or living nearby. Historical storage and handling of uranium processing waste at distinct upstream source areas (described in the next section) released contamination into Coldwater Creek, shown in Figure 1. Coldwater Creek and its floodplain areas, the historical upstream source areas, and other nearby properties are all included on the U.S. Environmental Protection Agency's (EPA) National Priorities List (NPL) and are part of the St. Louis Airport NPL Site.

The Agency for Toxic Substances and Disease Registry (ATSDR) conducts public health activities on all sites proposed for the NPL. In 1994, ATSDR released a public health assessment evaluating radiological exposures associated with the historical source areas [1]. The 1994 report recommended dust control during remediation at the historical source areas and further characterization of Coldwater Creek and other offsite areas.

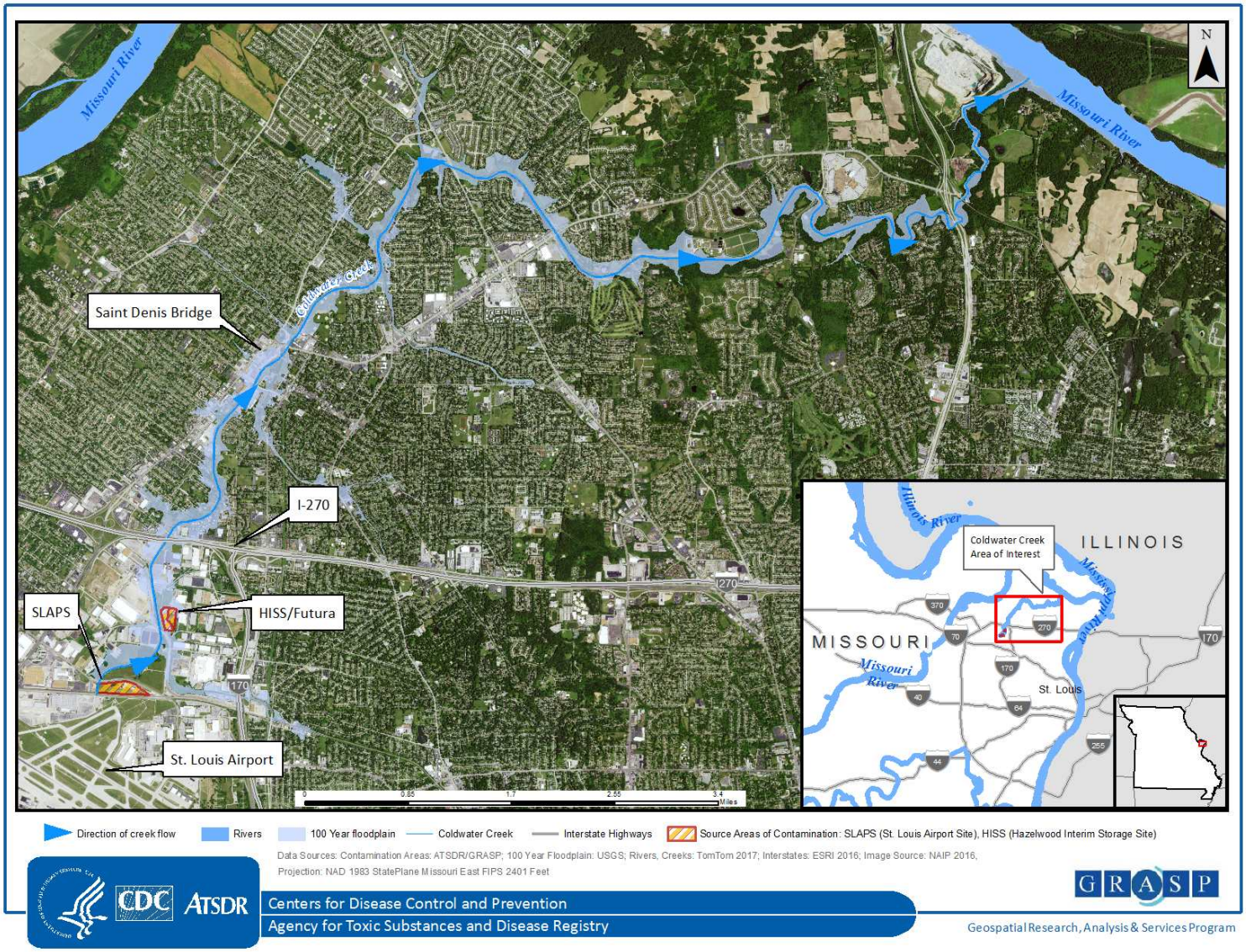
The Army Corps of Engineers' Formerly Utilized Sites Remedial Action Program (FUSRAP) has been characterizing and cleaning up the historical source areas and other properties affected by the site since 1998. They have followed ATSDR's recommendation to perform dust control during remediation. FUSRAP began a detailed investigation of Coldwater Creek and its floodplain areas in October 2012, working downstream from the historical source areas. FUSRAP has identified several areas in parks and residential areas along Coldwater Creek with soil concentrations of radiological contaminants higher than remedial goals. FUSRAP was in the process of cleaning up these areas of contamination as we were preparing this report.

Community members asked ATSDR to evaluate past and present exposures of those who played, lived, or worked near Coldwater Creek. They were particularly interested in exposures that occurred in the past before cleanup began at the sites. In response to community concerns, this public health assessment focuses on Coldwater Creek to help determine potential public health effects of past, present, or future exposures to hazardous substances in or near Coldwater Creek.

In this report, ATSDR uses available environmental sampling data to estimate and evaluate exposure of children and adults to contaminants in Coldwater Creek and floodplain areas for two scenarios:

- Playing in and around the creek, its banks, and floodplain soils and riding bicycles or dirt bikes near the creek
- Playing, gardening, or landscaping in residential yards near the creek

**Figure 1. Coldwater Creek area, North St. Louis County, Missouri**



This report also includes a section listing and addressing other community exposure and health concerns that ATSDR could not evaluate numerically. We provide information about these concerns, indicating any further work that we recommend.

### Changes to the Report Based on Public Comments Received

A draft of this report was available for public review and comment from June 18, 2018 through August 31, 2018. ATSDR received written comments from more than 60 private citizens, three private organizations, the Missouri Department of Natural Resources (MDNR), the Missouri Department of Health and Senior Services (MDHSS), FUSRAP, the Department of Energy (DOE), and EPA. Appendix F contains all public comments received, with ATSDR responses.

ATSDR made several changes to the evaluation in response to public comments. Major changes are summarized below.

- Added language throughout to highlight uncertainties involved with this evaluation. ATSDR used conservative assumptions to account for a lack of historical data describing past contamination levels in residential areas near Coldwater Creek. Actual past exposures will never be known with certainty and could have been lower or higher than estimated in this report.
- Included specific and expanded discussion of diseases of concern to the community, such as autoimmune diseases, for which ATSDR was unable to quantify risk.
- Added further details of ATSDR's method for estimating dose and risk with discussion of its applicability to the public health assessment process.
- Changed calculations to reflect revised uranium external dose coefficients and bone cancer risk coefficients based on comments received. These changes resulted in lower estimated doses and risks for some organ sites, but did not change ATSDR's overall conclusion.

Some commenters raised issues with details of ATSDR's risk estimation and stated that alternative assumptions and/or methods would result in risks "below the level of $10^{-4}$ and … not be of great concern." ATSDR recognizes that other assumptions and other methods could result in lower estimated risks. Because no site-specific data from the time periods of most concern were collected, however, there is no way to validate the contaminant concentrations used in this evaluation. Actual concentrations could have been higher or lower than we estimated. For exposure duration and frequency, ATSDR used its standard procedures as well as information gathered directly from the community. Further, several different ways to estimate risk from a radiation dose have evolved over the years based on different analyses of historical data on exposed populations, such as atomic bomb survivors and radium dial painters. Our approach gives a conservative, yet reasonable estimate of possible doses and risks at this site. Further explanation can be found in Appendix F in responses to public comments.

ATSDR is concerned about exposures at Coldwater Creek based on the following: the alpha radiation-emitting contaminants released from historical source areas have been measured at elevated levels in recreational and residential areas downstream. These contaminants could have been swallowed or breathed in by nearby residents who came in contact with them and remain primarily in target organs (lungs and bones) for years. Because exposures were more frequent and contamination levels are presumed higher in the past, the most concern is for past exposures (pre-2000). Our evaluation confirms that these exposures could contribute to risk, particularly in target organs, and therefore stopping, preventing, or reducing exposures is justified. Regardless of the method used, the estimated risks are low and apply only to people directly exposed, so it is unlikely increased rates of disease would be observable in a typical epidemiological study.

## Background

### Historical Activities and Source of Contamination

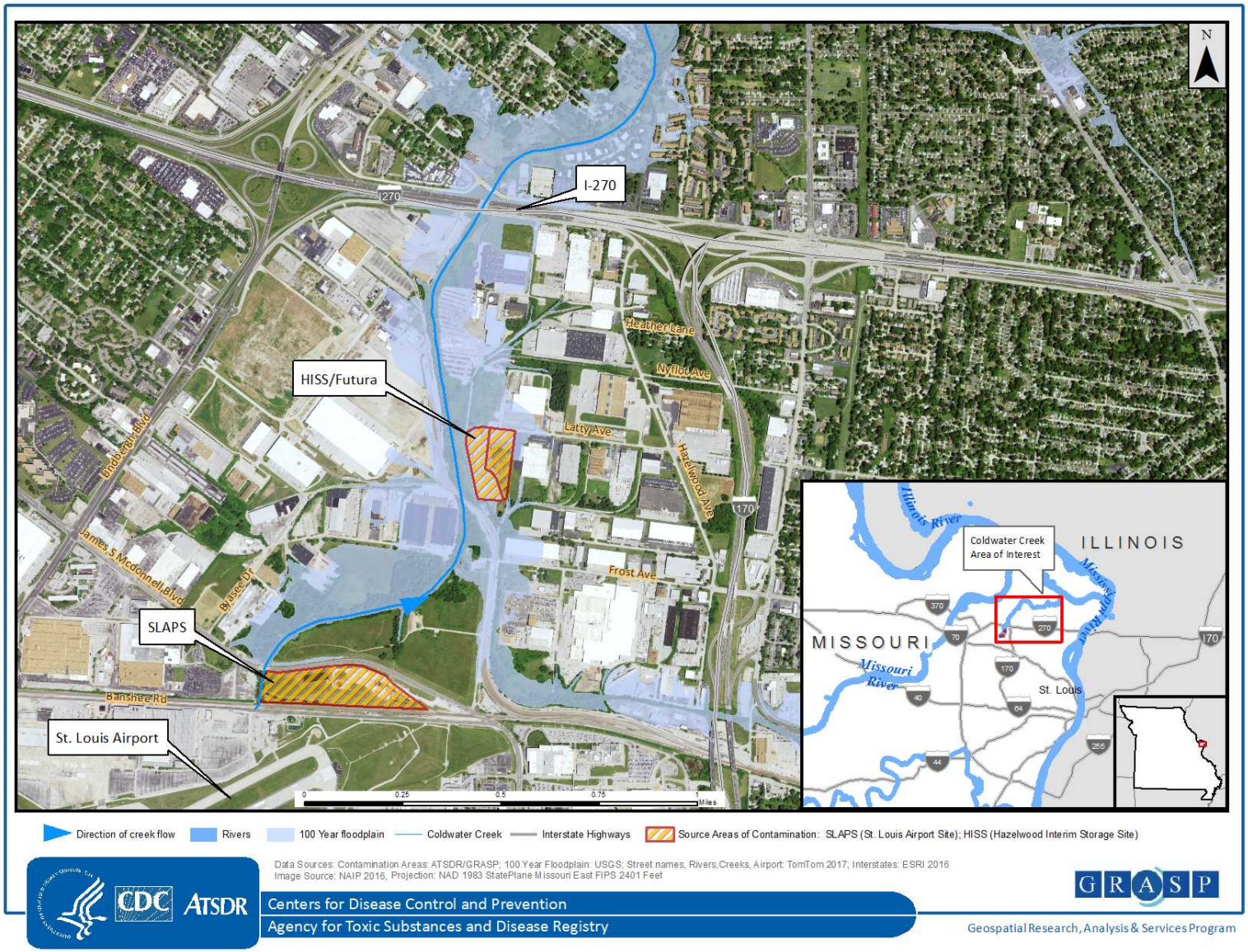
The following is a brief overview of the activities and sources that led to contamination of Coldwater Creek. See site documents for a detailed history [1–9].

During World War II, the Mallinckrodt Chemical Works in downtown St. Louis developed technology for extracting uranium from ore. The extracted uranium was shipped elsewhere to be purified, enriched, and used in the early nuclear weapons program known as the Manhattan Project. After Mallinckrodt extracted the uranium, the remaining wastes contained residual uranium and other radioactive elements.

Beginning in 1946 until the downtown facility stopped operating in 1957, this waste was transported to a storage site in a relatively undeveloped industrial area near the St. Louis Airport. See Figure 2 for a map of the historical source areas and surroundings. This original storage location is the St. Louis Airport Site (SLAPS). The waste at SLAPS included storage drums, scrap metal, and large covered and uncovered piles stored on open ground. In 1966, much of the waste at SLAPS was moved to another location about half a mile to the northeast, where it was processed, dried in open uncovered piles, and shipped offsite, mostly to Colorado companies. This second processing and storage area includes the Hazelwood Interim Storage Site (HISS) and Futura Coatings Site. HISS and Futura are both part of the NPL site along with SLAPS; they are considered historical sources of contamination of Coldwater Creek for the purposes of this report.

While waste piles were uncovered, rain and wind moved particles containing radiological contaminants to surrounding soil and nearby properties. Some of the waste eventually ran off into Coldwater Creek, which flowed past the sites, where it contaminated creek sediments. Contaminated sediments could flow downstream, settle out in certain locations, or end up in soils next to the creek after floods.

**Figure 2. Coldwater Creek historical source areas, North St. Louis County, Missouri**



In October 1989, EPA placed SLAPS and Futura/HISS on the NPL. Associated vicinity properties, including Coldwater Creek, have been considered part of the site for characterization and cleanup. Site cleanup is currently the responsibility of FUSRAP and is directed by the September 2005 Record of Decision (ROD) for the North St. Louis County Sites [2]. Cleanup focused initially on controlling historical source areas and then on cleaning up properties nearest them. As of 2017, the historical source areas at SLAPS and HISS/Futura had been cleaned up, and more than half of the 148 vicinity properties had been released for beneficial use.

FUSRAP began extensive characterization of Coldwater Creek in 2012, working downstream (north) from the historical source areas. Sampling focuses on the ten-year floodplain of the creek; if contaminants found are above remedial goals, sampling may extend past the ten-year floodplain to delineate the edge of contamination. Pre-design investigation sampling has been completed for the stretch of the creek from McDonnell Boulevard (within the industrial area, near SLAPS) to the St. Denis Bridge, about three and a half miles downstream from SLAPS. As FUSRAP works its way down the creek, it is cleaning up soils identified with contaminants above remedial goals.

### Activities by ATSDR and its Public Health Partners

- In 1988 and 1989, the Missouri Department of Health (MDOH, now known as MDHSS) reviewed cancer incidence and mortality data from August 1984 to September 1988 around several sites, including SLAPS and HISS. At that time, MDOH could not calculate the observed and expected cancer rates, because about 15% of hospitals were not yet in compliance with new cancer reporting laws [10]. Graphic plots of cancer cases and deaths around SLAPS and HISS showed no obvious clustering. The review noted one case of leukemia in a child living on Nyflot Avenue, the residential street closest to HISS (See Figure 2).

  Subsequently, MDOH received reports of additional cancer cases on Nyflot Avenue and investigated. They confirmed nine cases of cancer, including lymphoma, thyroid, prostate, colon, breast, melanoma, and three different types of leukemia, in residents of the street from 1963 to 1989. MDOH's review of medical records concluded that radiation induction could not be ruled out for any of the cases except melanoma [10,11].
- In 1994, ATSDR released a preliminary public health assessment of the SLAPS/HISS sites [1].
    - The report concluded that exposure at the site posed an indeterminate public health hazard, but limited data suggested that possible past exposures may have been at levels of health concern.
    - Environmental data from Coldwater Creek-associated residential, recreational, or other floodplain sites were not available at the time of the evaluation.

  - ATSDR recommended additional on-site and off-site sampling, characterization of site contaminants, and implementation of dust control actions during remedial activities at the sites.
  - ATSDR's assessment concluded that follow-up public health actions or studies were appropriate for the site.
- In March 2013, MDHSS reviewed 1996–2004 cancer incidence data from six ZIP codes adjacent to Coldwater Creek [12].
  - Incidence of several types of cancer, including female breast, colon, prostate and kidney, was statistically significantly elevated compared to the Missouri state rates.
- In September 2014, MDHSS released an update to the 2013 report that included more recent incidence data up to 2011. MDHSS added two ZIP codes to the review to account for people who may have moved to nearby areas and refined the analysis to obtain more details about child cancers, leukemia, and rare cancers [13]. The updated analysis found that
  - Incidence of childhood brain and other nervous system cancers was statistically significantly elevated compared to the Missouri state rates.
  - Incidence of leukemia, female breast, colon, prostate, kidney, and bladder cancers was statistically significantly elevated compared to the Missouri state rates.

  Later, empirical Bayesian modeling confirmed these findings.
- In January 2015, ATSDR participated in a meeting with MDHSS and other stakeholders to discuss next steps for Coldwater Creek. The meeting resulted in three key recommendations:
  - Evaluate potential exposures to contaminants along Coldwater Creek.
  - Perform advanced statistical modeling.
  - Engage the community.

This report fulfills the first recommendation from the January 2015 meeting to the extent possible, given the data and science available at this time. In completing this report, ATSDR engaged with the community during multiple ATSDR open houses, community meetings, and FUSRAP public meetings. ATSDR also toured the site with members of a local community group to learn how they currently use areas near the creek and how they used them in the past. We thank the community for sharing this valuable local knowledge. We also thank the FUSRAP program for providing the extensive site-related data used in this assessment and describing that data in both its current and historical context.

## Characteristics of Coldwater Creek and Its Surroundings

### *Land Use and Demographics*

Originally, the area between the St. Louis Airport and current I-270 was used for agricultural purposes; the very few residential dwellings present were several hundred feet away from Coldwater Creek. Industrial development of this area began in the early 1950s. From the early 1970s through the 1980s, an area immediately north of SLAPS and east of Coldwater Creek was used as baseball fields [9]. ATSDR's 1994 public health assessment discussed potential

exposures at these fields and recommended further characterization of contamination there [1]. The ball fields are closed, and the area south of I-270 remains mostly industrial. Two streets, Nyflot Avenue and Heather Lane, are about ¼ mile northeast of the HISS/Futura source area and include residential homes pre-dating the sites. These homes are about ½ mile from Coldwater Creek. Industrial businesses obstruct direct access to the creek from these homes.

The stretch of Coldwater Creek from I-270 and Pershall Road to the St. Denis Bridge (evaluated in this report) was used primarily for agricultural purposes through the 1950s, with a few residential dwellings located several hundred feet from the creek [9]. By 1966, the area was highly developed (residentially and commercially), with recreational parks located within 100 feet of Coldwater Creek [9]. This stretch of the creek remains residential, recreational, and commercial today. Figure 3 illustrates how the demographic profile of the area has changed over the years.

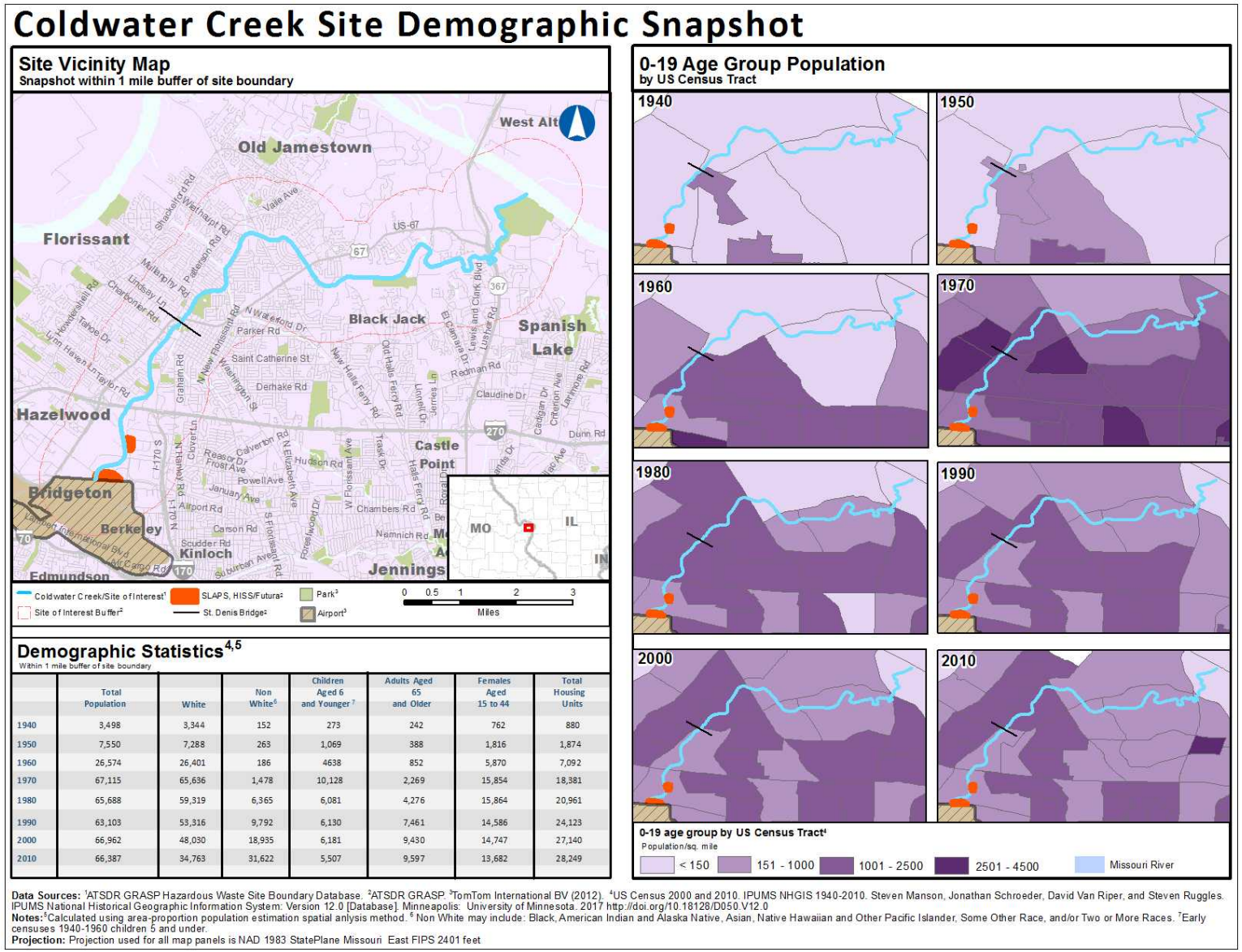
### *Topography, Geology, and Soil*

The historical source areas and Coldwater Creek are located on land slightly elevated above the Missouri River floodplain [2–4]. Bedrock consists of Pennsylvanian shale and Mississippian limestone about 100 feet below the ground surface. The bedrock appears to be almost flat, with no evidence of faulting. Pleistocene soil and recent surficial loess, clay, sands, and gravel overlay the bedrock. Surface soils in the area are mostly silty deposits from former glacial advances, historical Missouri and Mississippi River flooding, and more recent fill activities. The Coldwater Creek floodplain is mostly flat and sloping towards the creek, although depressions lower than the creek exist in various places. A strip of trees, brush, and grass generally borders the creek banks.

### *Surface Water and Groundwater*

Coldwater Creek is the major drainage feature for the historical source areas near SLAPS. The creek originates south of the St. Louis Airport and flows through a channel under the airport. The creek resurfaces at the south edge of the SLAPS site and flows north past SLAPS, HISS/Futura and associated vicinity properties. In the past, ditches around these historical source areas drained stormwater and other surface water runoff to the creek. After passing the historical source areas, Coldwater Creek continues meandering northward through residential, recreational, and commercial areas of North St. Louis County until it empties into the Missouri River. Coldwater Creek floods regularly, mainly due to flash flooding from summer thunderstorms [14]. According to FUSRAP's review of historical aerial photographs and maps described in the work plan for recent Coldwater Creek investigations, the shape of the creek channel has not changed significantly since 1937, before SLAPS existed [9]. Although the shape of the channel has not changed, the channel itself has been altered to reduce the impact of flooding. The banks have been stabilized by the addition of rip-rap or concrete at various locations along the creek [9].

**Figure 3. Demographic information over time, Coldwater Creek area, North St. Louis County, Missouri**




| | Total Population | White | Non White[6] | Children Aged 6 and Younger[7] | Adults Aged 65 and Older | Females Aged 15 to 44 | Total Housing Units |
|---|---|---|---|---|---|---|---|
| 1940 | 3,498 | 3,344 | 152 | 273 | 242 | 762 | 880 |
| 1950 | 7,550 | 7,288 | 263 | 1,069 | 388 | 1,816 | 1,874 |
| 1960 | 26,574 | 26,401 | 186 | 4638 | 852 | 5,870 | 7,092 |
| 1970 | 67,115 | 65,636 | 1,478 | 10,128 | 2,269 | 15,854 | 18,381 |
| 1980 | 65,688 | 59,319 | 6,365 | 6,081 | 4,276 | 15,864 | 20,961 |
| 1990 | 63,103 | 53,316 | 9,792 | 6,130 | 7,461 | 14,586 | 24,123 |
| 2000 | 66,962 | 48,030 | 18,935 | 6,181 | 9,430 | 14,747 | 27,140 |
| 2010 | 66,387 | 34,763 | 31,622 | 5,507 | 9,597 | 13,682 | 28,249 |

**Data Sources:** [1]ATSDR GRASP Hazardous Waste Site Boundary Database. [2]ATSDR GRASP. [3]TomTom International BV (2012). [4]US Census 2000 and 2010. IPUMS NHGIS 1940-2010. Steven Manson, Jonathan Schroeder, David Van Riper, and Steven Ruggles. IPUMS National Historical Geographic Information System: Version 12.0 [Database]. Minneapolis: University of Minnesota. 2017 http://doi.org/10.18128/D050.V12.0
**Notes:** [5]Calculated using area-proportion population estimation spatial anlysis method. [6] Non White may include: Black, American Indian and Alaska Native, Asian, Native Hawaiian and Other Pacific Islander, Some Other Race, and/or Two or More Races. [7]Early censuses 1940-1960 children 5 and under.
**Projection:** Projection used for all map panels is NAD 1983 StatePlane Missouri East FIPS 2401 feet

Surface water serves as a source of drinking water in the metropolitan St. Louis area, but contaminants in Coldwater Creek are unlikely to affect drinking water from surface water sources. A private company supplies drinking water to North St. Louis County using water from the Missouri River; the two intakes are located more than five miles upstream from where Coldwater Creek enters the river [15]. This supplier also uses water from the Meramec River southwest of St. Louis. The City of St. Louis obtains water from two intakes. One is on the Missouri River more than ten miles upstream from where Coldwater Creek enters the river. The other intake is on the Mississippi River, about two miles downstream from the Missouri River and more than five miles downstream of the mouth of Coldwater Creek [16]. All public water is treated and in compliance with Safe Drinking Water Act regulations, including radionuclide limits [17–19].

Groundwater at SLAPS and HISS/Futura is found in two aquifers: an unconfined surface aquifer and a confined deep aquifer. The surface aquifer at the historical source areas has shown elevated levels of radiological contaminants compared to background [6]. Monitoring at the historical source areas and in Coldwater Creek has not shown evidence that groundwater at the historical source areas affects Coldwater Creek. As described earlier, all of the homes in the area are currently served by public drinking water drawn from the Missouri River and treated before distribution. In the past, some homes may have used private wells for domestic purposes. A well survey conducted in 1987–88 identified three domestic wells, all abandoned before 1980 [20]. Two of the wells were about half a mile northeast of the HISS/Futura site, and the other was in a residential area more than a mile downstream from the historical source areas.

### *Climate*

The St. Louis area has a strongly seasonal climate influenced by cold, arctic air masses in the winter and hot, humid air from the Gulf of Mexico in the summer. Spring and fall are transitional seasons where rapid changes in temperature and precipitation can occur due to rapidly moving fronts between air masses. Like all parts of Missouri, St. Louis experiences extreme weather events such as high-intensity rainfall, protracted drought, ice storms, and tornadoes. Heavy thunderstorm events cause flooding in tributaries of the major rivers once or twice a year [14].

## ATSDR's Evaluation Process

The following three steps briefly summarize ATSDR's evaluation process [21].

- First, we identify possible *exposure pathways* at the site. An exposure pathway consists of an uninterrupted path from a contaminant source through the water, air, or soil to a person's body where it can possibly cause harm.

- Next, we use environmental data to identify the *contaminants* of most concern. We compare measured levels with appropriate health-based comparison values[1] and regulatory limits, recommendations, and typical background levels. Concentrations of radiological materials and/or chemicals that are too low to cause harmful effects are not evaluated further. We evaluate contaminants remaining beyond this step in detail, considering how people are exposed, to see if harmful effects are possible.
- Further evaluation estimates how much of the contaminant a person would come near or take into their body and whether it is enough to cause harmful health effects. For radiologic contaminants, we have to consider the amount of energy absorbed by various tissues of the body and target organs, and the type of radiation emitted by the contaminants. To conclude whether exposure to the contaminant is harmful, we compare these estimates with scientific literature reviews of exposures known to cause harmful health effects (non-cancer or cancer).

Appendices of this report present details of ATSDR's evaluation process and specific public comments received on the June 2018 draft of this report.

- Appendix A explains how we used and evaluated community input on exposures at the site and followed standard ATSDR procedures to develop reasonable exposure and intake assumptions used in exposure dose calculations.
- Appendix B describes the screening process for radiological and chemical contaminants. It includes tables showing contaminants detected at the site and selected for further evaluation.
- Appendix C describes how we determined representative yet conservative exposure point concentrations of contaminants evaluated in soil, sediment, and water to use in exposure dose calculations.
- Appendix D describes how we calculated estimates of contaminant intake for the exposures evaluated.
- Appendix E details how we calculated the radiological dose for specific organs and the whole body for the estimated exposures and how we estimated increased cancer risk corresponding to the radiological doses. Appendix E also contains detailed dose and risk results.
- Appendix F contains public comments ATSDR received on the June 2018 draft of this report along with ATSDR responses.

[1] ATSDR calculates comparison values from minimal risk levels published by ATSDR (EMEGs), reference doses published by EPA (RMEGs), or cancer slope factors published by EPA (CREGs). ATSDR currently maintains a tool for viewing comparison values at https://www.atsdr.cdc.gov/sites/brownfields/CVViewer.html.

## Evaluation of Community Exposure While Playing or Living Along Coldwater Creek

### Description of Exposure Pathway

People playing or living downstream of the historical source areas near Coldwater Creek (now or in the past) may have been exposed to contaminants that washed down the creek. Residential areas shown in Figure 1 begin ¾ miles downstream from the site; people who played near the creek would go to parks or the creek close to those areas. As described earlier and shown in Figure 2, people in the homes east of the industrial area are relatively close to former storage areas, though nearby industrial facilities and the airport generally block access to Coldwater Creek for recreational purposes. For this report, we consider any area along the creek north of (downstream from) I-270/ Pershall Road to be available for exposure.

The radiologic and chemical contaminants associated with the historical source areas traveled downstream with creek sediments. People could be exposed by contacting sediment, water (with suspended sediment in it), or floodplain soils (contaminated with sediment during flood events). They could take contaminants into their bodies by accidentally swallowing small amounts of sediment, water, or soil. They could also breathe contaminants if their activities suspend enough dust from dry, contaminated soil. If the contaminants are radioactive, people may receive an external dose of radiation just from being near the contamination.

The direct exposures evaluated in this report are the following:

*Recreational Exposure*

- Accidentally swallowing contaminated soil, sediment, or surface water while playing in and around Coldwater Creek and its floodplain
- Breathing in dust suspended from floodplain soils while playing and riding bicycles or dirt bikes around Coldwater Creek and its floodplain
- Receiving external radiation exposure during recreational activities in and around Coldwater Creek and its floodplain

*Residential Exposure*

- Accidentally swallowing contaminated residential soil and dust while playing in the yard and inside the home, gardening, or landscaping around Coldwater Creek and its floodplain
- Breathing in dust suspended from residential soil while playing in the yard, gardening, or landscaping around Coldwater Creek and its floodplain
- Receiving external radiation exposure during residential activities in the yard around Coldwater Creek and its floodplain

The recreational and residential scenarios evaluated in the report are not intended to be added; rather, each represents a high-end estimate for that particular scenario. A person's specific exposures would depend on their specific recreational and residential activities, frequencies, and durations.

### *Note on Exposures near Tributaries of Coldwater Creek*

Exposures along Coldwater Creek would likely be higher than exposures that may have occurred or may occur along tributaries that feed into Coldwater Creek. Flood events in which Coldwater Creek backed up into tributaries may have deposited sediments. However, the resulting concentrations on tributary banks and floodplains would not likely be higher than the areas of highest contamination measured in the Coldwater Creek floodplain. FUSRAP samples the 10-year floodplain adjacent to Coldwater Creek, including the mouths of tributaries. If contamination is found in this area, additional sampling is performed [9].

## Available Data and Information

ATSDR obtained and reviewed numerous historical and recent reports, correspondence, and articles related to the historical source areas, Coldwater Creek, and the surrounding area in developing this report. Both a local community group and FUSRAP staff provided site-related documents and historical context. ATSDR staff and contractors also reviewed and used additional documents obtained from online databases of scientific literature and governmental reports.

Many reports described investigations of contamination at the historical source areas and vicinity properties near them. While the environmental sampling data in these reports is essential for describing the source of the creek's contamination, ATSDR cannot use the data to estimate potential recreational and residential exposures directly, because they do not describe the locations where exposures occurred.

Quantitative estimation of recreational and residential exposures relied on two main sources of information:

- Information from a local community group on how, how often, and for how long children and adults played near the creek or played or worked in their yards near the creek (described below and in Appendix A) [22]. We used this input to develop exposure assumptions for recreational and residential exposures.
- Environmental sampling data describing the levels of site-related contamination in and around recreational and residential stretches of Coldwater Creek. Because these data were collected to design remediation strategies or for monitoring, they may not fully characterize the nature and extent of contamination. We used these data to identify contaminants of concern and determine exposure point concentrations for each

contaminant in soil, sediment, and surface water (described below and in Appendices B and C). The data relevant to community exposures included:

- Sediment and floodplain soil samples from I-270 north to the St. Denis Bridge collected in 2014-2016 [23]
- Soil and sediment samples along Coldwater Creek from SLAPS to the Missouri River collected between 1986 and 1990 [24]
- Sediment and surface water from a station near I-270 collected from 1998 to 2014 and from two new stations in residential areas in 2014 [25-41]

In this report, we do not cite all of the numerous documents we reviewed, but we have included a list of documents reviewed but not cited immediately following the numbered references at the end of the text.

### Exposure and Intake Assumptions for Recreational and Residential Exposure

To estimate exposures for a given activity, ATSDR needs to use two kinds of assumptions in combination with data on contaminants in the environment. *Exposure assumptions* describe how often people do a certain activity and for how long. *Intake assumptions* are factors to estimate or calculate how much soil, sediment, or water from the environment a person might take into their bodies during the activity. Combining exposure and intake assumptions with concentrations of contaminants allows us to calculate the amount of contaminant taken into the body.

***We used community input and Agency guidelines to estimate how much soil, sediment, or water from the creek people could take into their bodies over time***

To develop exposure assumptions, ATSDR asked a local community group familiar with Coldwater Creek to provide information about how often people living along Coldwater Creek did various activities in the creek and its floodplain. Appendix A summarizes the input received, and explains how we considered the input, along with ATSDR's standard evaluation procedures, to develop the assumptions used in this assessment. ATSDR developed exposure assumptions for past exposures to represent exposures that occurred between the 1960s and 1990s, when children in the area often played in and near Coldwater Creek. ATSDR also determined more recent exposure assumptions that reflect the decreased amount of time currently spent by children and adults playing in the creek. Tables A5 and A6 of Appendix A summarize the exposure assumptions used in ATSDR's evaluation.

For both past and recent exposures, ATSDR assumed a duration of 33 years, beginning at birth. This duration is ATSDR's default high-end residential occupancy period. Data used to estimate recent exposures (described in the next section) are assumed to represent exposures dating back to the early 2000s, but the 33-year duration of exposure assumes recent exposures could

conceivably continue until remedial activities are complete (currently estimated by the FUSRAP program to be in 2033 or 2034).

For intake assumptions, ATSDR used standard defaults and derived factors to describe how much soil, sediment, or surface water a child or adult could breathe in or accidentally swallow while playing or living near Coldwater Creek. We used the same intake assumptions for both past and recent exposures. Tables A7 through A10 of Appendix A summarize the intake assumptions used in this evaluation.

ATSDR used exposure and intake assumptions to estimate:

- Ingestion of soil while playing in and near the creek or playing, gardening, or landscaping in yards of homes near the creek[2]
- Ingestion of sediment and surface water while wading or swimming in the creek
- Inhalation of dust suspended from soil while playing or riding bicycles or dirt bikes near the creek or playing, gardening, or landscaping in yards of homes near the creek

ATSDR also used duration and frequency assumptions to estimate external radiation dose during these activities. The following two sections and the appendices provide more information on these topics.

### Contaminants of Concern

ATSDR reviewed the available data collected from recreational and residential stretches of Coldwater Creek. The data almost exclusively focused on radiological contaminants previously found to be associated with the historical source areas. Appendix B details ATSDR's screening of radiological contaminant data. Of the radiological contaminants detected, thorium-230 (Th-230) was present in soil and sediment at levels consistently above typical background levels (1 to 3 picocuries per gram (pCi/g) for soil and sediment). It was also detected frequently above FUSRAP's remedial goal for Th-230 in soil (14–15 pCi/g). ATSDR included Th-230, radium-226 (Ra-226), and uranium-238 (U-238) in its evaluation of potential community exposures from Coldwater Creek. These contaminants are all long-lasting members of the same radioactive decay chain, depicted in Figure 4. U-238 forms other products as it decays, eventually producing Th-230, which in turn produces Ra-226.

***We looked at all the data and focused on the substances most likely to result in harmful exposure:***

***Thorium-230***
***Radium-226***
***Uranium-238***

[2] ATSDR evaluated only direct exposure to soils during gardening activities, not consumption of home garden products. Please see page 35 for more information.

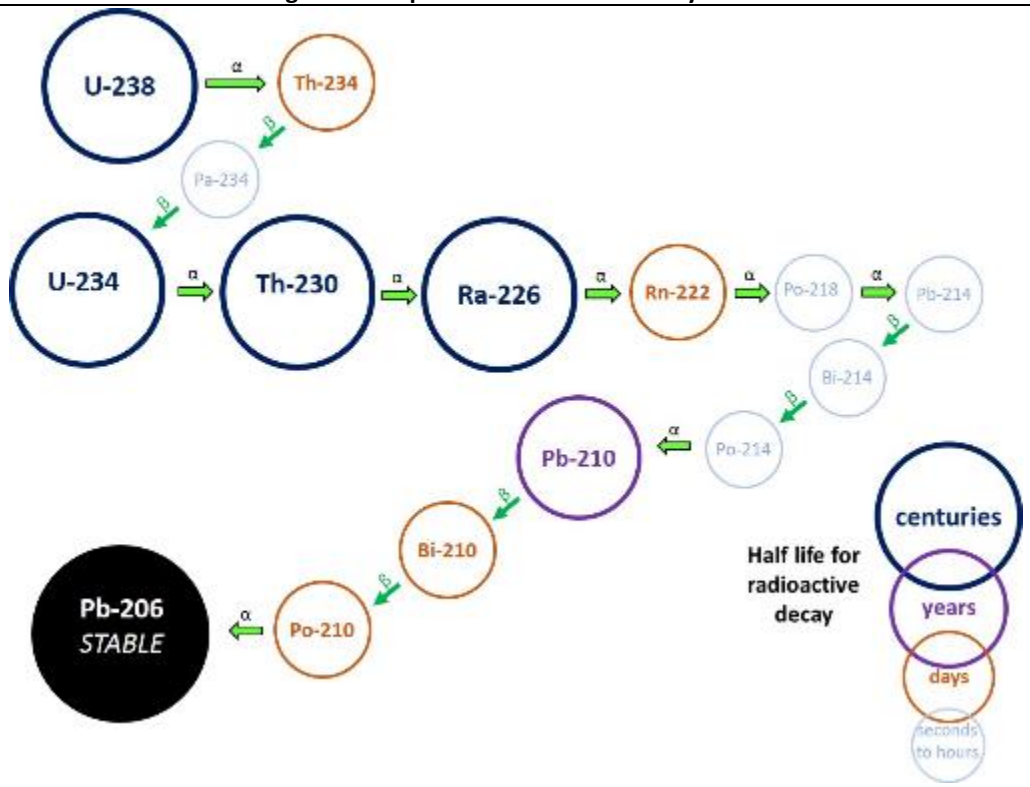
Because processing removed uranium from ore during processing, the process waste contains higher concentrations of Th-230 and Ra-226 than unprocessed ore.

Limited data on metals and other non-radiological chemicals in sediment and surface water were available for the recreational and residential stretches of Coldwater Creek. Appendix B also details ATSDR's screening of non-radiological chemical data. Some chemicals were detected in surface water above drinking water screening values, and some were detected in sediment above screening values for residential soil. ATSDR does not expect any identified non-radiological chemicals to contribute substantially to risk of harmful effects from the exposures evaluated in this report.

***Data are limited, but ATSDR did not identify any non-radiological chemicals that would be expected to contribute substantial risk from recreational or residential exposures***

We recognize that no data on non-radiological chemicals exist for floodplain soils and that very limited data were available for sediment and surface water. However, in the absence of specific data and because the limited data available do not show non-radiological chemicals at concentrations of potential concern, the remainder of this evaluation will focus only on Th-230, Ra-226, and U-238.

**Figure 4. Simplified uranium-238 decay chain**




Simplified uranium-238 decay chain showing primary radioactive emissions—alpha (α) or beta (β)—released as each unstable atom transforms to a new decay product.

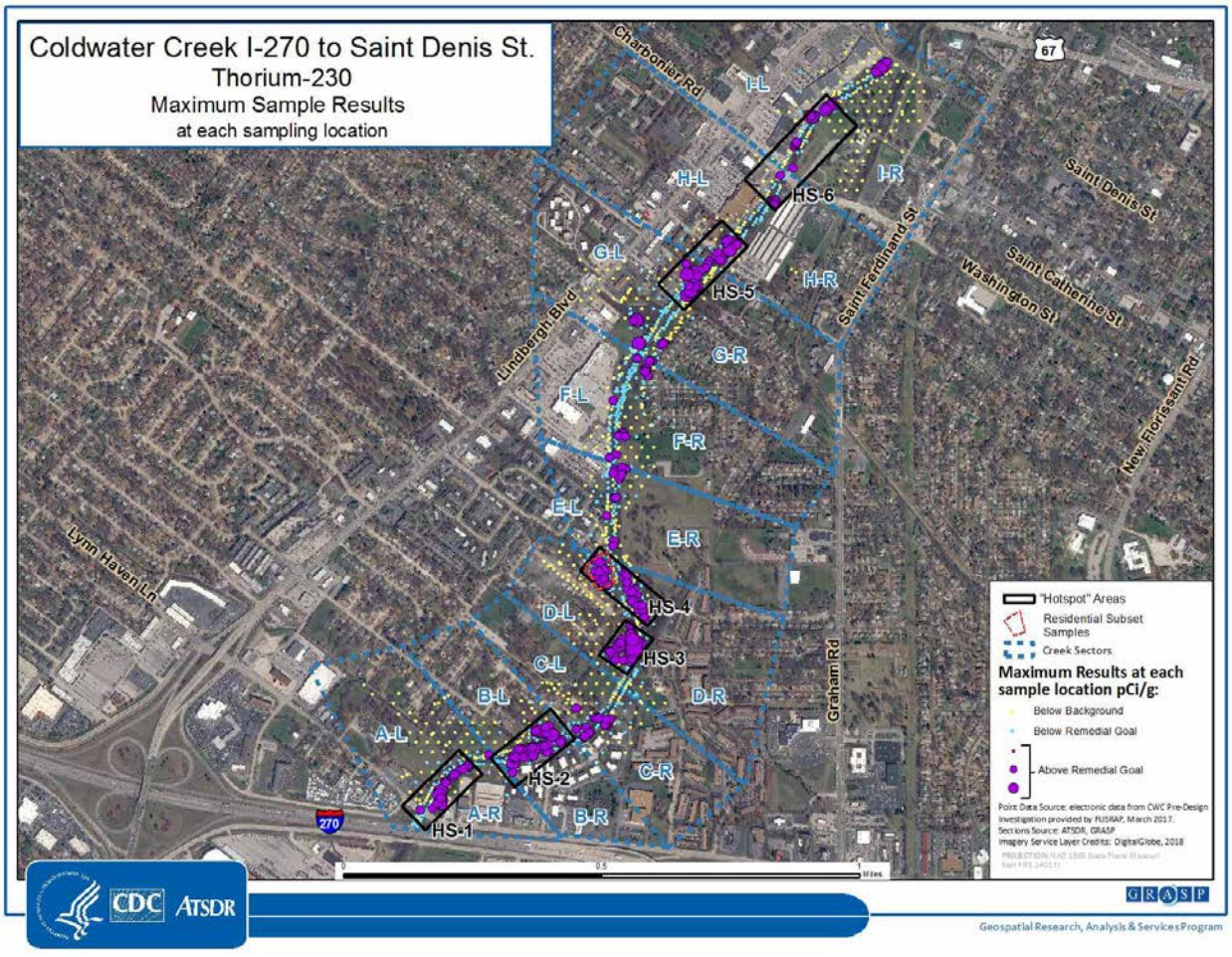
### Exposure Point Concentrations for Soil, Sediment, and Surface Water

Representative exposure point concentrations describing the highest levels of contaminant someone might be exposed to over time are needed to determine how much of each contaminant is taken in by people who accidentally swallow or breathe in soil, sediment, or surface water from Coldwater Creek. ATSDR created maps showing the results from soil and sediment sampling, and used graphical and statistical techniques to get high-end estimates of contaminant exposure point concentrations, as described below.

***We used mapping and statistics to set the level of contaminants in soil, sediment, or water people would contact over time– either in the past or more recently***

- For past exposures to floodplain soil, we used recent soil data from I-270 to the St. Denis Bridge [23]. For each contaminant, we mapped the highest concentration found at any depth for each sample location. We assumed that in the past, these higher concentrations could have been at the ground surface and available for contact. Figure 5 shows an example map of past concentrations of Th-230 in floodplain soil. We split the areas of the creek into several different sectors to see how contaminant levels changed along the creek. In addition, we selected results from several different areas that had higher concentrations of Th-230 and that might be regularly contacted by the same people (labeled "hotspot" areas in the figures and tables). We then used a publicly available program called ProUCL [42] to calculate the 95% upper confidence level on the mean (UCL) of the results falling into the various sectors and sub-areas. Of the various areas for which we obtained recommended UCLs, we used the highest one for the past soil exposure point concentration. We followed the same procedure for Ra-226 and U-238. Appendix C shows the full results.
- For recent exposures to floodplain soil, we used the same data and technique as for past exposures, considering only the top (zero to six-inch) sample of soil. Figure 6 shows the map obtained for evaluating recent exposures to Th-230 in floodplain soil.
- For past exposures to sediment, we followed a similar technique of mapping results for the various sectors of the creek, using soil/sediment data collected in the late 1980s from the water line on each side of the creek [24]. We used ProUCL to determine the highest recommended UCL for the past sediment data.
- For recent exposure to sediment, we used recent sediment data from I-270 to the St. Denis Bridge [23] and mapped the highest concentration of contaminant at any depth. We then used ProUCL to determine the highest recommended UCL for the recent sediment data.

**Figure 5. Map illustrating evaluation of maximum soil concentration of Th-230 at any depth used to estimate past exposures**




- For surface water, we used a different data set that included surface water samples from 1998-2014 collected at I-270 (at the upstream edge of what we consider the recreational and residential stretches of Coldwater Creek) [25-41]. These results showed no concentrations of Th-230, Ra-226, or U-238 higher than background criteria identified in FUSRAP's feasibility study [6]. For surface water, we used the background criteria for each contaminant as the exposure point concentration.

Appendix C includes a complete set of maps and tabulates the recommended UCLs from which we selected exposure point concentrations for soil and sediment.

Table 1 summarizes the selected past and recent exposure point concentrations for soil, sediment, and surface water used in this evaluation.

**Figure 6. Map illustrating evaluation of surface soil Th-230 data used to estimate recent exposures**

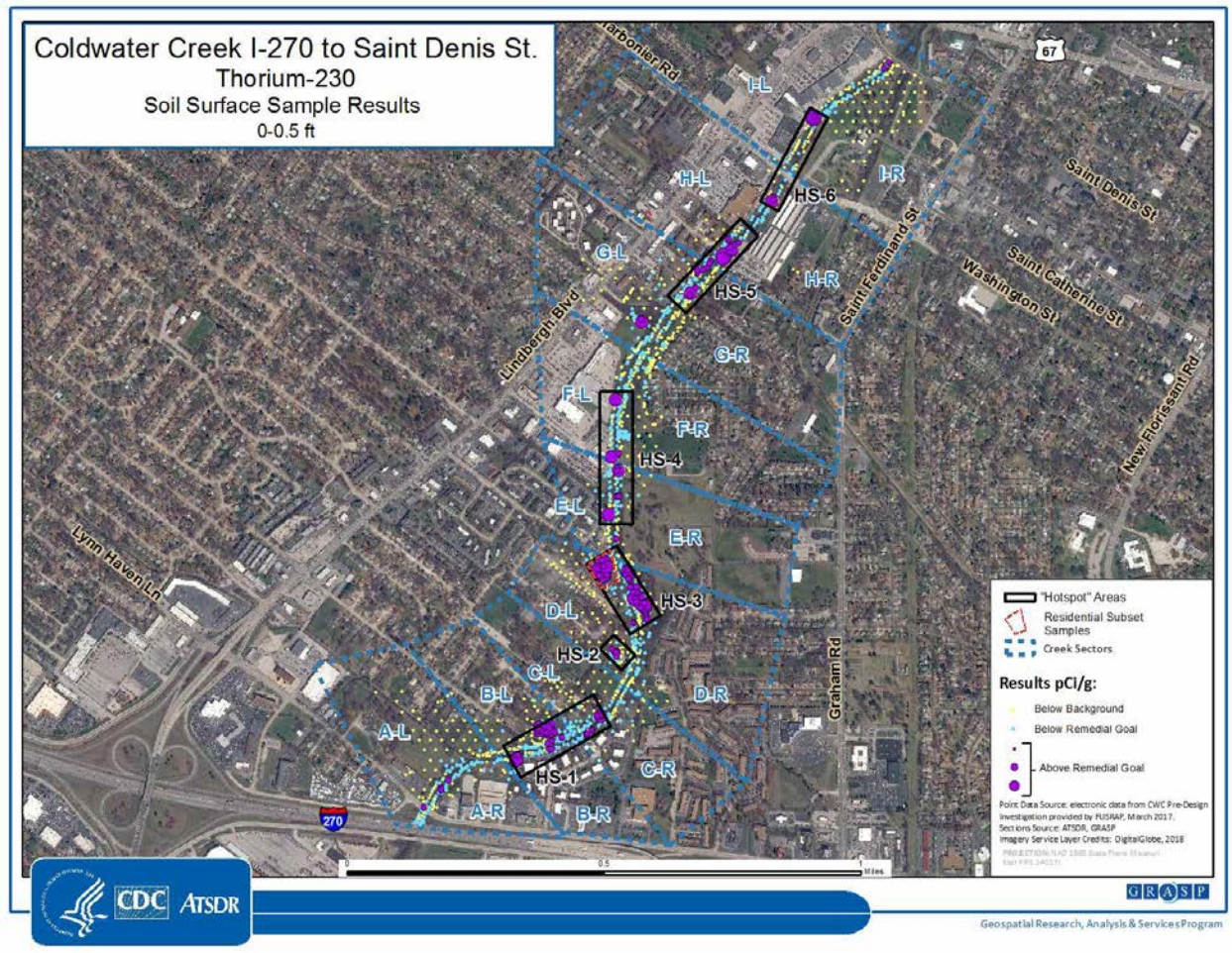



**Table 1. Exposure point concentrations for soil, sediment, and surface water at Coldwater Creek**

| | **Past** Exposure Point Concentration | | | **Recent** Exposure Point Concentration | | |
|---|---|---|---|---|---|---|
| Contaminant | Soil (pCi/g)* | Sediment (pCi/g)* | Surface water (pCi/L)† | Soil (pCi/g)* | Sediment (pCi/g)* | Surface water (pCi/L)† |
| Thorium-230 | 54.5 | 105.4 | 4.65 | 27.3 | 7.9 | 4.65 |
| Radium-226 | 2.5 | 4.8 | 0.88 | 1.9 | 1.8 | 0.88 |
| Uranium-238 | 2.3 | 4.5 | 5.05 | 1.8 | 1.0 | 5.05 |

Used **past** exposure point concentrations to estimate exposures occurring from the 1960s to the 1990s.
Used **recent** exposure point concentrations to estimate potential exposures occurring since the 2000s.

pCi/g = picocuries per gram pCi/L = picocuries per liter

*See Appendix C for explanation of soil and sediment exposure point concentration selection.
†Background criteria for surface water [6]. No positively identified results for surface water in areas at or downstream of I-270 were higher than background criteria.

### Radiological Intake, Dose, and Cancer Risk: Evaluation of Radiological Effects

Intake of contaminants depends on the exposure point concentration combined with exposure and intake assumptions. Appendix D describes the equations used to calculate intake, along with example calculations.

***We estimated a person's intake of contaminant by multiplying the exposure point concentration by the intake of soil, sediment, or water***

We calculated intake by ingestion and by inhalation in picocuries (pCi) for each year of life, assuming exposure begins at birth and continues for 33 years [43].[3] Each year has a different intake since age group, exposure assumptions, and intake assumptions change throughout life.

Intake itself does not completely determine the radiological dose. The radiological dose is a complicated function of what the radiological isotope is, how it enters the body (ingestion or inhalation), how much is taken up by the body, how much is eliminated or metabolized, what organs it is stored in, and how it changes as it radioactively decays. Organs in the body may also receive an external dose from isotopes outside the body. Each radioactive isotope has different characteristics. Appendix E gives more details about how we used coefficients derived by the International Commission on Radiological Protection (ICRP) and by EPA to determine radiological doses from the exposures evaluated in this report [44,45]. ATSDR estimated doses from intakes (ingestion or inhalation) using ICRP dose coefficients, and we estimated doses from external radiation using EPA external dose coefficients. For inhalation exposures, ATSDR estimated dose using two different ICRP Th-230 dose coefficients corresponding to slow versus medium lung solubility. The actual solubility depends on the chemical form of thorium in the environment and affects the dose received to the lungs versus other internal organs [46]. Tables in this report present a range of doses between those assuming slow lung solubility of Th-230 and those assuming medium solubility.

***We calculated dose to specific organs using factors derived by the International Commission on Radiological Protection and by the U.S. Environmental Protection Agency***

#### *Increased Risk – What it Means*

Risk can be defined as "the probability of any negative outcome"—for example, developing cancer after receiving a radiological dose to an organ. Numerically, risk is expressed as a probability between zero (absolute certainty the event will *not* occur) and one (absolute certainty that it will). For example, based on U.S. cancer rates, the lifetime risk of being diagnosed with any form of cancer in the general population is about 0.385, or about 3,850 out of every 10,000 people [47].

[3] 33 years is the ATSDR-recommended residential occupancy period, upper percentile.

Environmental exposures to radiation typically involve doses far below those that caused cancers and other measurable health effects in exposed populations (such as Japanese atomic bomb survivors, radium dial painters, nuclear industry workers, or medical patients treated with radiation). However, most regulatory and advisory agencies assume every dose of radiation, no matter how small, incrementally increases the risk of developing cancer. These agencies have developed methods to predict the increased risk of cancer to help determine cleanup levels and manage risks in a protective manner.

EPA has developed lifetime attributable risk coefficients to estimate increased risk resulting from a given radiological dose to an organ [48]. ATSDR used these lifetime attributable risk coefficients to estimate the increased risk of cancer for various organs from the recreational and residential exposures evaluated in this report. Appendix E presents more discussion and example calculations.

***We estimated increased risk of developing cancer in specific organs from the dose received using EPA-derived coefficients***

Preventing or eliminating all risk is impossible. While ATSDR recognizes that all exposures contribute to the risk of cancer, in this report we focus our discussion and conclusions on those risks estimated to be greater than 1 in 10,000. This is the upper bound of EPA's general "target range" for managing risks as part of a Superfund cleanup: 1 in 10,000 to 1 in 1,000,000 [49].

***In this report, ATSDR focuses its conclusions and recommendations on doses corresponding to risks greater than 1 in 10,000.***

To put this value into context, assume the estimated additional cancer risk resulting from a given organ radiological dose is 1 in 10,000. That means that out of 10,000 people who were exposed to the contaminant for the specified length of time to accumulate that dose, one additional cancer might develop from the exposure, above the normally expected rate. An increased lifetime risk of 1 in 10,000 would raise the lifetime risk of developing cancer in the U.S. from 3,850 to 3,851 out of every 10,000 people.

## Results and Discussion

### Organ-Specific Radiological Dose and Cancers

Children and adults who played and lived near Coldwater Creek in the past (1960s to 1990s) may have had an increased risk of certain types of cancer from their exposure to soil, sediment, and surface water. Table 2 shows the cancer sites for which estimated cancer risks were greater than 1 in 10,000 for the past doses calculated as described in Appendix E and the previous sections. Past recreational exposures resulted in elevated risks to the lungs, bone surface, and red marrow, and past residential exposures resulted in elevated risks to these organs plus the skin.

The past doses and risks in Table 2 represent those resulting from high-end exposures described by community members as occurring in the past, when children played almost daily for several hours a day in and around Coldwater Creek. The concentrations of Th-230, Ra-226, and U-238 used in the calculations assumed the highest concentrations at any depth in recent sampling were at the ground surface, and that exposure occurred regularly to the same high concentrations for 33 years. The results presented in Table 2 may be overestimates for those who were farther from the creek, spent less time there, or may have spent time in areas of the creek with less contamination.

**Table 2. Summary of organs with elevated* cancer risk from 33-year recreational or residential exposures at Coldwater Creek (past years, 1960s-1990s)**

| | Recreational | | Residential | | |
|---|---|---|---|---|---|
| Organ/ cancer site (higher to lower risk) | Dose, mrem** | Risk, out of 10,000† | Dose, mrem** | Risk, out of 10,000† | U.S. lifetime risk of specific cancer in 10,000 people |
| Lungs | 290–640 | **1 to 3** | 1,200–2,700 | **4 to 10** | **650** |
| Bone surface | 5,400–16,000 | 0.4 to **1** | 14,000–63,000 | 0.8 to **3** | **10** |
| Red marrow | 350–860 | 0.5 to **1** | 780–3,100 | **1 to 4** | **150** |
| Skin | 61–78 | below 1 | 140–210 | 0.7 to **1** | **200** |

*As described in the text, ATSDR considered risks above 1 out of 10,000 to be elevated. Elevated risks shown in **bold.**

**Dose = committed radiological dose to age 70 to organ for entire 33-year exposure in millirem (mrem, no more than 2 significant figures; see Appendix E). Range corresponds to different lung solubility dose coefficients for Th-230 inhalation (slow to medium).

†Risk = estimated cancer incidence risk to cancer site based on organ exposure dose for 33-year exposure. See Appendix E.

NOTES:

- Doses vary for different organs based on isotope distribution in the body and differing organ weights. ***Because tissues have different weights and responses to radiation, doses cannot be compared between organs.***
- Dose estimates include external radiation, ingestion, and inhalation.
- The risks shown were estimated without subtracting background levels of Th-230, Ra-226, or U-238. Subtracting background levels did not change the risks substantially.
- See Appendix E for details and results for other organ sites.

Table 3 presents estimated dose and risk for more recent exposures, using surface soil data and less frequent but still reasonably high exposure assumptions. As presented in Table 3, more recent recreational exposures do not result in elevated estimated cancer risks. Recent residential exposures result in elevated risks for the lungs only. Like the results for past exposures, the results in Table 3 assumed 33 years of exposure to the highest areas of contamination (exposure beginning about 10 or 15 years ago and continuing until projected completion of remedial activities in the 2030s). Because contaminated areas are in the process of cleanup, people exposed in the last 10 to 15 years will likely experience less dose and risk than presented in Table 3.

**Table 3. Summary of organs with elevated* cancer risk from 33-year recreational or residential exposures at Coldwater Creek (recent exposures, 2000s and on)**

| | Recreational | | Residential | | |
|---|---|---|---|---|---|
| Organ/ cancer site (higher to lower risk) | Dose, mrem** | Risk, out of 10,000† | Dose, mrem** | Risk, out of 10,000† | U.S. lifetime risk of specific cancer in 10,000 people |
| Lungs | 15–30 | below 1 | 160–340 | 0.6 to **1** | **650** |

*As described in the text, ATSDR considered risks above 1 out of 10,000 to be elevated. Elevated risks shown in **bold**.

**Dose = committed radiological dose to age 70 to organ for entire 33-year exposure in millirem (mrem, no more than 2 significant figures; see Appendix E). Range corresponds to different lung solubility dose coefficients for Th-230 inhalation (slow to medium).

†Risk = estimated cancer incidence risk to cancer site based on organ exposure dose for 33-year exposure. See Appendix E.

NOTES:

- Doses vary for different organs based on isotope distribution in the body and differing organ weights. ***Because tissues have different weights and responses to radiation, doses cannot be compared between organs.***
- Dose estimates include external radiation, ingestion, and inhalation.
- The risks shown were estimated without subtracting background levels of Th-230, Ra-226, or U-238. Subtracting background levels did not change the risks substantially.
- See Appendix E for details and results for other organ sites.

In the next sections, ATSDR presents epidemiological and cancer information related to those organ sites identified as having increased cancer risk.

### *Lungs*

Inhaled thorium, radium, and uranium may stay in the lungs. Inhalation of alpha-emitting radionuclides has been shown to increase lung cancers in both human epidemiological and animal studies [50,51]. Some of the cancers may have been the result of exposure to radon gas, mostly radon-222 (Rn-222) and its decay products formed in the radioactive decay chain, rather than the materials inhaled. All the contaminants evaluated in this report are in a decay chain that will produce Rn-222 and its progeny as they decay. Our dose estimates include the contribution of Rn-222 formed.

Various studies on uranium miners have shown increased rates of lung cancer attributed to high levels of Rn-222 in the underground mines, though other factors may have contributed [50]. Increased rates of lung cancer were also observed in nuclear industry workers who inhaled uranium compounds [51]. Lung tumors were observed in dogs exposed to the alpha emitter plutonium-239, with lung doses as low as 20,000,000 mrem. Other alpha emitters resulted in lung cancers at similar or higher doses in various animal experiments [51].

The human epidemiology studies cited in ATSDR's toxicological profiles did not report radiological dose to the lung. In animal experiments, lung doses that caused lung cancer are

several orders of magnitude higher than those estimated for past recreational or residential exposures at Coldwater Creek (20,000,000 mrem versus up to 2,700 mrem).

The estimated risk of developing lung cancer from the calculated past lung doses are up to 3 in 10,000 for recreational exposures and up to 10 in 10,000 for residential exposures. These risks include contributions from exposure to background levels of Th-230, Ra-226, and U-238, but do not change substantially if background levels are subtracted. Recent exposures were predicted to result in lower increased risks, ranging from below 1 in 10,000 for recreational exposures to just over 1 in 10,000 for residential exposures.

Lung cancer is the second most common form of cancer in the U.S. in both men and women. Based on U.S. cancer rates, the lifetime risk of being diagnosed with cancer of the lung or bronchus is about 6.4%, or 640 out of 10,000 people [47]. The past risks estimated in this report could increase this risk by a small amount, less than 2%. Chest x-rays or tests analyzing cells coughed up in sputum may help diagnose lung cancer, but low-dose computed tomography (LDCT) is the only method with enough sensitivity and specificity to screen for lung cancer in asymptomatic, high-risk groups [52].

The U.S. Preventive Services Task Force recommends annual LDCT screening in adults aged 55-80 years who smoked a pack of cigarettes a day for 30 years and have smoked or quit smoking within the past 15 years. Screening recommendations from other medical groups vary but agree that screening be targeted to those most at risk [52,53]. The benefits of early detection in high-risk groups outweighs possible harms from LDCT screening, including false positive and false negative results, treatment of cancers that would not have otherwise been detected or cause harm during a person's lifetime, and radiation exposure [52]. For people at lower risk, who have no symptoms, screening may cause more harm than good.

According to the American Cancer Society, early symptoms of lung cancer could include a cough that gets worse and doesn't go away, coughing up blood, chest pain, or shortness of breath [54]. Depending on a patient's symptoms, medical history, and results of a physical exam, a physician may decide to perform a number of imaging or diagnostic tests, including those discussed above, to test for lung cancer.

ATSDR does not recommend any special or additional screening for lung cancer in people near Coldwater Creek. A personal physician will use a patient's individual history, symptoms, age, and gender to determine appropriate testing. ATSDR recommends people share their potential exposure related to Coldwater Creek with their physicians as part of their medical history and consult their physicians promptly if new or unusual symptoms develop.

The MDHSS cancer incidence study did not find a statistical elevation in lung cancers from 1996 to 2011 in the combined eight ZIP codes surrounding the creek compared to the rest of Missouri [13]. Radiation-induced solid tumors have a typical latency period of 20 to 40 years, so the study covered years in which some lung cancers resulting from past exposures would have likely developed. However, the people living in the ZIP codes studied by MDHSS may not be the same people who were most highly exposed playing or living near Coldwater Creek in the 1960s to 1990s.

### *Bone Surface*

Thorium, radium, and uranium taken up into the bloodstream are known to build up on bone surface and may be incorporated into the bone matrix. As shown in Table 2, past exposures at Coldwater Creek could result in bone surface doses of up to 63,000 millirem (mrem). Studies showed high rates of bone cancers occurring in people exposed to radium in the early 1900s, including young women who painted watch dials with radium-containing paint and patients treated with radium for medical purposes [55,56]. These workers and patients received very high radiation doses over relatively short periods of time. The lowest bone surface doses associated with bone cancers in these groups were about 18,000,000 mrem, more than 250 times higher than the highest estimated bone surface doses based on 33 years of exposures at Coldwater Creek.

The corresponding lifetime risk of developing bone cancer based on the estimated past bone surface dose is up to 1 in 10,000 for recreational exposures and up to 3 in 10,000 for residential exposures. These risks include contribution from exposure to background levels of Th-230, Ra-226, and U-238, but do not change substantially if background levels are subtracted. Recent exposures were predicted to result in less than 1 in 10,000 increased risk.

Based on U.S. cancer rates, the lifetime risk of being diagnosed with cancer of the bone or joint is about 0.1%, or 10 out of 10,000 people [47]. The past risks estimated in this report could increase this risk by 10 to 30%. There are several distinct types of bone cancer. According to the American Cancer Society, there is no method to screen for bone cancer [57]. Signs and symptoms of bone cancer may include pain at the site, swelling, fractures, numbness or tingling, or other symptoms depending on the location of the tumor [57]. These symptoms are often due to other conditions such as injuries or arthritis.

Several tests may help diagnose bone cancer if it is suspected from the patient's symptoms, physical exam, and personal and family medical history. Blood tests may rule out other possible causes for the symptoms. If bone cells are unusually active, blood tests might show high levels of a bone tissue enzyme, but this level could be the result of normal growth and repair and does not reliably predict cancer [58,59]. X-rays in the area of concern might show abnormalities suggestive of cancer. Further imaging tests, including computed tomography (CT) scans, magnetic resonance imaging (MRI) scans, radionuclide bone scans, or positron emission

tomography (PET) scans, may give additional information about the size and location of a suspected tumor and whether it has spread. Often, however, the only way to confirm bone cancer is with a tissue biopsy, where cells from the bone are removed surgically and examined under a microscope to see if they are cancerous [58,59].

Based on the exposures estimated in this report, ATSDR does not recommend general screening for bone cancer in people near Coldwater Creek. No test has been shown to reliably find bone cancer in people with no symptoms, and the tests themselves all carry some risk, such as additional radiation exposure or complications from physical procedures. A personal physician will use a patient's individual history, symptoms, age, and gender to determine appropriate testing. ATSDR recommends people share their potential exposure related to Coldwater Creek with their physicians as part of their medical history and consult their physicians promptly if new or unusual symptoms develop.

The MDHSS cancer incidence study did not find a statistically significant elevation in bone cancers from 1996 to 2011 in the combined eight ZIP codes surrounding the creek compared to the rest of Missouri [13]. Radiation-induced solid tumors have a typical latency period of 20 to 40 years, so the study covered years in which some bone cancers resulting from past exposures may have developed. However, the people living in the ZIP codes studied by MDHSS may not be the same people who were most highly exposed while playing or living near Coldwater Creek in the 1960s to 1990s.

#### *Red Marrow*

Thorium, radium, and uranium taken up into the bloodstream are known to build up on bone surfaces and may be incorporated into the bone matrix, affecting the red marrow. This may contribute to the risk of leukemia, a cancer of the bone marrow. As shown in Table 2, past exposures at Coldwater Creek could result in red marrow doses of up to 3,100 mrem. Scientific studies have observed excess cases of leukemia in patients who received, on average, red marrow doses of 134,000 mrem—40 times higher than the highest estimated dose in this evaluation [60].

The corresponding risk of developing leukemia from the past estimated red marrow doses is up to 4 in 10,000. The risk includes contribution from exposure to background levels of Th-230, Ra-226, and U-238, but does not change substantially if background levels are subtracted. Recent exposures were predicted to result in less than 1 in 10,000 increased risk.

Based on U.S. cancer rates, the lifetime risk of being diagnosed with leukemia is about 1.51%, or 151 out of 10,000 people [47]. The past risks estimated in this report could increase this risk by about 1 to 3%. There are several distinct types of leukemia, and symptoms may depend on the number of leukemia cells and their location in the body. Some chronic leukemias may not cause any symptoms, but other chronic forms as well as acute leukemias may cause early symptoms

including extreme fatigue, night sweats, fever, anemia, or easy bruising or bleeding [61,62]. These symptoms are associated with many other conditions, as well.

Routine blood tests may identify leukemia before a patient has symptoms, because the disease causes changes in the levels and ratios of red blood cells, white blood cells, and platelets. A physician may order blood tests in patients presenting with symptoms and may conduct a physical exam to look for swollen lymph nodes, spleen, or liver. Other tests used to diagnose leukemias include examining cells from samples of bone marrow or the fluid surrounding a person's spinal cord and looking for swollen lymph nodes or signs of infections on a chest X-ray or chest CT scan [61].

ATSDR does not recommend any special or additional screening for leukemia in people near Coldwater Creek. A personal physician will use a patient's individual history, symptoms, age, and gender to determine appropriate testing. ATSDR recommends people share their potential exposure related to Coldwater Creek with their physicians as part of their medical history and consult their physicians promptly if new or unusual symptoms develop.

The MDHSS cancer incidence study found a statistical elevation in leukemia from 1996 to 2011 in the combined eight ZIP codes surrounding the creek compared to the rest of Missouri [13]. The people living in the ZIP codes studied by MDHSS may not be the same people who were most highly exposed playing or living near Coldwater Creek in the 1960s to 1990s. Leukemia induced by low doses of radiation exposure has a much shorter latency period than solid cancers (5-15 years as opposed to 20-40 years for solid cancers).

#### *Skin*

In contrast to the other organ doses discussed, the skin's dose is mostly from external exposures. The estimated dose to the skin is as high as 210 mrem and corresponds to a risk up to 1 in 10,000 for past residential exposures.[4] This risk includes contribution from exposure to background levels of Th-230, Ra-226, and U-238 that contribute about half of the estimated risk; past risks would not be greater than 1 in 10,000 if background levels were subtracted. Recent exposures were predicted to result in less than 1 in 10,000 increased risk.

Based on U.S. cancer rates, the lifetime risk of being diagnosed with melanoma, the most aggressive type of skin cancer, is about 2.21%, or 221 out of 10,000 people [47]. The risks estimated in this report could increase this risk by less than 1%.

According to the American Cancer Society, melanoma may cause visible changes to skin moles or warts and can be treated successfully if detected early [63]. Information about how to perform

[4] Risk coefficients for skin exclude non-fatal skin cancers [48].

a skin self-exam is available online [64]. People who notice any suspicious marks or changes in their skin should show them to their medical provider. A physician will examine the patient and may take a sample of the suspicious mark for microscopic examination. If the cells are cancerous, the physician may remove the lesion and skin around it and conduct more testing to see if the cancer has spread to other parts of the body [63].

ATSDR does not recommend general screening for skin cancer in people near Coldwater Creek. The U.S. Preventive Services Task Force states that the evidence is insufficient that screening of asymptomatic patients will prevent deaths from skin cancer [65]. A personal physician will use a patient's individual history, symptoms, age, and gender to determine appropriate testing. ATSDR recommends people share their potential exposure related to Coldwater Creek with their physicians as part of their medical history and consult their physicians promptly if new or unusual symptoms develop.

The MDHSS cancer incidence study did not find a statistical elevation in melanoma from 1996 to 2011 in the combined eight ZIP codes surrounding the creek compared to the rest of Missouri [13]. Radiation-induced solid tumors have a typical latency period of 20 to 40 years, so the study covered years in which skin cancers resulting from past exposures would most likely have developed. The people living in the ZIP codes studied by MDHSS may not be the same people who were most highly exposed playing or living near Coldwater Creek in the 1960s to 1990s.

### Effective Whole-Body Radiological Dose and Other Health Effects

In addition to organ-specific doses, ATSDR estimated effective whole-body radiological doses for residential and recreational exposures at Coldwater Creek. As we described earlier, organ-specific doses can't be compared because organs have different weights and sensitivities to radiation. Effective whole-body dose is a way to account for those differences and determine a dose that represents the overall effect. Effective whole-body dose is more comparable between different exposures and is the basis for radiological standards such as worker limits. We calculated the effective whole-body dose for each year of exposure, as shown in Table 4. We can compare this yearly dose to ATSDR's chronic minimal risk level (MRL) for ionizing radiation.

ATSDR's MRL is for a chronic whole-body dose from ionizing radiation of 100 mrem per year above normal background exposures, regardless of source. The MRL does not apply to radiation doses to any individual organ or tissue. ATSDR applies the MRL to whole-body doses resulting from either internal exposure or external exposures [51]. Contributors to a person's normal background radiation dose include cosmic radiation; radon gas present in all air; rocks and soil containing natural radioactive elements; and natural radioactive material normally inside the body. In addition, people are exposed to radiation through medical procedures such as x-rays, nuclear medicine exams such as positron emission tomography (PET) scans, and by consumer products such as granite countertops and some ceramics.

**Table 4. Summary of effective whole-body 70-year committed radiation dose from recreational or residential exposure at Coldwater Creek**

| | Highest annual whole-body effective committed dose, mrem per year | | ATSDR minimal risk level, mrem per year above background | Natural background, mrem per year[5] |
|---|---|---|---|---|
| Time frame | Recreational | Residential | | |
| Past exposures (1960s – 1990s) | 28–30 | 54–71 | 100 | 360 |
| Recent exposures (2000s and on) | 2.1–2.2 | 19–22 | 100 | 360 |

NOTES:

- Range corresponds to different lung solubility dose coefficients for Th-230 inhalation (slow to medium, no more than 2 significant figures).
- Dose estimates include external radiation, ingestion, and inhalation. For internal doses the committed dose to age 70 is applied in the year of intake.

Estimated doses for people who ate soil regularly as children are higher than shown in this table (see full results in Table E10 in Appendix E). Regular soil pica behavior from ages 1 to 6 increases the highest annual committed effective whole-body dose to:

- 76–100 mrem for past residential exposures
- 30–33 mrem for recent residential exposures

The estimated effective whole-body doses for past or recent recreational and residential exposures are all lower than ATSDR's chronic MRL. People who ate soil regularly when children (exhibited soil pica behavior) had higher estimated effective whole-body doses; however, only one annual dose was estimated to equal the MRL.

The chronic MRL is based on studies showing that natural and artificial sources of ionizing radiation ("background") give a person in the U.S, on average, an effective whole-body dose of 360 mrem per year. No harmful effects have been shown to be associated with this dose. [51,66].[5] Several locations around the world have much higher levels of natural background radiation than the United States. People living in these areas with higher background radiation do not have increased rates of cancer or noncancer health effects compared to other locations.

[5] The MRL is based on the average annual effective dose equivalent from the early 1980s, 360 mrem per year. In 2006, this value was revised upwards to 620 mrem per year based largely on increased doses from medical diagnostic procedures [66]. The MRL remains protective because it is a fraction of the annual average U.S. effective dose.

### Uranium Chemical Effects

Uranium poses a risk for non-radiological effects at exposures lower than those that would cause radiological effects. Uranium can cause chemical damage to kidney tubules, the structures in the kidney that maintain balance between waste products and needed compounds in the bloodstream. Uranium exposure leads to microscopic changes in the tubules, which can impair the kidney's function over time or at higher exposures. Inhaling insoluble uranium at very high levels can damage the respiratory tract [67]. We considered oral ingestion of uranium as the most sensitive chemical effect.

As described in Appendix C, ATSDR estimated total uranium chemical exposure point concentrations from radiological U-238 results. We used the same exposure assumptions as for the radiological evaluation to estimate a daily dose of uranium for recreational and residential exposures at Coldwater Creek. These doses are in units of milligrams of uranium per kilogram of body weight per day (mg/kg/day) for chronic exposures. We also evaluated doses to children who exhibited regular pica behavior.

For past exposures, estimated uranium doses ranged from 0.000006 to 0.0001 mg/kg/day for different age groups; the doses for more recent exposures ranged from 0.000003 to 0.00007 mg/kg/day. These doses are lower than ATSDR's minimal risk level for ingestion of soluble forms of uranium of 0.0002 mg/kg/day and would be unlikely to result in any harmful effects.

Children who exhibited regular pica behavior in the residential scenario (intentionally eating tablespoon amounts of soil three times a week) had estimated doses higher than the intermediate MRL, up to 0.001 mg/kg/day for past exposures and up to 0.0007 for more recent exposures. The actual dose is likely to be smaller than estimated, because much of the uranium in soil is likely to be insoluble and not taken up by the body. The intermediate MRL is based on a study in which rats that were fed uranium for three months at doses as low as 0.06 mg/kg/day showed microscopic structural changes in kidney cells. Higher doses caused the kidneys to function improperly [67]. The intermediate MRL was obtained by dividing the 0.06 mg/kg/day minimal effect level by an uncertainty factor of 300 (three for use of a minimal lowest effect level, 10 for extrapolation from animals to humans and 10 for human variability).

### Summary of Findings

As detailed above, ATSDR's evaluation found

- **Recreational** exposures in the **past** (1960s to 1990s) could have resulted in elevated risks for developing lung cancer, bone cancer, or leukemia.
- **Residential** exposures in the **past** (1960s to 1990s) could have resulted in elevated risks for developing lung cancer, bone cancer, leukemia, and (to a lesser extent) skin cancer.
- **Recreational** exposures in **recent** years (2000s and on) did not result in elevated estimated cancer risks.
- **Residential** exposures in **recent** years (2000s and on) could have resulted in elevated risks for developing lung cancer.
- The radiological doses associated with Coldwater Creek exposures were lower than those known to cause specific cancers or other harmful health effects.
- Estimated uranium exposures would not pose any concern for non-radiological kidney effects.

Based on these findings, ATSDR supports efforts to identify and remediate contamination along Coldwater Creek.

People who grew up in the Coldwater Creek area and played often in Coldwater Creek or its floodplain may have had elevated exposures to Th-230 and other radiological contaminants. Based on the properties of these contaminants, the greatest increased lifetime risks would be for developing lung or bone cancers. ATSDR recommends people share their potential exposure related to Coldwater Creek with their physicians as part of their medical history and consult their physicians promptly if new or unusual symptoms develop.

The evaluation described in this report was the only evaluation we identified that could use sampling data from recreational and residential areas to estimate exposure and risk numerically. This evaluation cannot answer the many and varied concerns this community raised about exposure, risk, and health.

## Community Concerns about Exposure and Health

ATSDR considers community health concerns and other information from the community as it estimates and evaluates exposures at sites. The following pages list and address comments and concerns we received related to exposure and health (in addition to those specifically evaluated in this report). Responses provide the information we know about each concern.

ATSDR collected these concerns and questions in various ways to ensure interested community members could give input. We met regularly with representatives of a local community group throughout the evaluation process. In 2015, 2016, 2017, and 2018, ATSDR staff spoke directly with community members at a series of public availability sessions about our work at Coldwater Creek. We also communicated through a dedicated email box for the site and by telephone. We received input from over 500 community members through these interactions. We have updated this section to include several additional concerns provided during the public comment period. Additional summarized and specific comments, with ATSDR responses, are included in Appendix F.

### Exposure Concerns

*Concern: Is dust in my home contaminated?*

ATSDR response: Dirt tracked in from outside can contribute to indoor dust. Depending on the status of soil near your home, dust could contain some radiological contaminants. ATSDR's evaluation of residential exposures included ingestion rates that include soil and indoor dust. We assumed the dust contained the same concentration of contaminants as the soil. To test the validity of this assumption, ATSDR recommends FUSRAP sample indoor dust in a few homes near the floodplain, including those where yards require or required cleanup.

Because the radiological contamination is bound to soil (or dust) particles, normal household cleaning methods, preferably including wet wiping and high efficiency (HEPA) vacuuming, will remove contaminants, if present, from the living space.

*Concern: Basements in the area filled during floods; are the sediments left after floodwaters receded contaminated?*

ATSDR response: If floodwaters inundated a home's basement directly, some of the sediment washed inside could possibly contain Th-230 or other radiological contaminants. If Th-230 was present in sediments remaining on walls or floors of a basement, residents could accidentally swallow it or disturb it enough to inhale it. To allay community concerns about possible contamination on basement walls, ATSDR recommends FUSRAP test Th-230 concentrations in samples of sediment remaining in selected homes directly flooded by Coldwater Creek in the past.

Basements flooded by rising groundwater tables would be very unlikely to contain radiological contaminants from Coldwater Creek. The Th-230 contamination is bound to soil and sediment particles and not much affected by groundwater flowing past. A rising groundwater table would be unlikely to carry the contaminants into a basement.

Radioactive decay of Th-230 eventually forms radon-222, which could contribute to naturally occurring radon levels in some homes. Differentiating between naturally occurring radon and radon that may be present from Coldwater Creek contamination is not possible. Since radon can contribute to lung cancer risk regardless of the source, ATSDR suggests homeowners have their homes tested for radon and take mitigation action if needed. MDHSS offers Missouri residents free radon test kits. Residents can order the kits online (www.health.mo.gov) or by telephone (573-751-6102 or toll free at 1-866-628-9891).

*Concern: Soil from the banks and floodplain of Coldwater Creek was used as backfill when homes in the area were constructed.*

ATSDR response: ATSDR recognizes that in the past, soils may have been moved to other locations. We do not have any written records of where soils went, nor past sampling data indicating levels of contaminants in soils or sediments that may have been moved. Therefore, we cannot evaluate health implications of this potential exposure.

If local authorities identify specific locations that received soil or sediment backfill from Coldwater Creek, we recommend FUSRAP perform targeted sampling for radiological contaminants of concern. If radiological contaminants (particularly Th-230) are present above remedial goals, FUSRAP should clean up the location. If several likely locations are tested and found to contain contaminants below remedial goals, this scenario should cause no further concern. We feel this approach will increase the community's confidence that the remedy is protective, whether tests find elevated contaminant levels or not.

Through public comments, ATSDR received reports of specific and general locations where soil or sediment from near Coldwater Creek was used. We shared this information with the FUSRAP program.

*Concern: Could sediments from Coldwater Creek have contaminated tributaries during flood events?*

ATSDR response: Flood events, particularly from flash floods moving down the creek, could cause some movement of sediment from the creek up a usual tributary. The sediment in the tributary would most likely wash back down into Coldwater Creek after the flood. Any contamination remaining in the tributary's floodplain would likely be at similar or lower concentrations than contamination along the floodplain of Coldwater Creek itself. ATSDR expects that the recreational and residential scenarios evaluated in this report apply to similar exposures in and near tributaries of Coldwater Creek.

According to work plans for investigating Coldwater Creek, FUSRAP is collecting samples in mouths of tributaries to the creek and at some distance upstream from the mouth to confirm that site contaminants are not affecting tributaries [9]. This includes soils and sediments and adjacent properties within the ten-year flood plain of the tributary [68]. ATSDR believes sampling both mouths of tributaries and low-lying areas upstream from the mouth would be most helpful in determining whether past flooding has left contamination in tributaries.

*Concern: The community raised many concerns related to consuming food products affected by contaminants in Coldwater Creek. Community members stated that in the past, area schools used produce as well as milk and other dairy products supplied from farms along Coldwater Creek. The produce may have grown in floodplain soil and been watered with creek water. Dairy cows may have been raised in the floodplain and provided creek water to drink. Community members also told us that in the past, children playing in the creek would eat plants or crawfish from the creek. People frequently grew vegetables in home gardens in the floodplain and ate fruit or nuts from trees growing there. People living near the creek still have home gardens and fruit or nut trees.*

ATSDR response: ATSDR recognizes that contact with products grown in these areas could have indirectly exposed people to contaminants accumulated on the surface or within. Some areas of the floodplain have elevated levels of Th-230. Various food species do take up radiological contaminants from soil, particularly in roots, although not much research is specific to Th-230 [69]. Predicting uptake of radiological contaminants is difficult because it depends on the plant or animal species, the radiological isotope, and specific soil characteristics.

The community raised concerns about consumption of agricultural products and food from the creek itself as past concerns. The area along the creek is no longer used for agriculture. People who may have been exposed in the past through this pathway in addition to the pathways evaluated this report could have had higher exposures and be at a higher risk. People who are

currently concerned about growing plants in floodplain soil can consider gardening practices using clean soil, such as raised beds.

*Concern: Community raised concern about residential exposures to sod purchased from a sod farm once located in the Coldwater Creek floodplain.*

ATSDR response: Sod grown in Coldwater Creek's floodplain may have been contaminated. However, we do not have any written records of the current location of purchased sod, nor past sampling data indicating levels of contaminants in sod moved elsewhere. Therefore, we cannot evaluate the health implications of this potential exposure.

*Concern: Were private wells for drinking and other uses contaminated?*

ATSDR response: All of the homes in the area are currently served by treated public drinking water in compliance with Safe Drinking Water Act regulations [17–19]. In the past, a small number of private wells may have been used for domestic and other purposes.

A well survey conducted in 1987–88 identified eight wells within three miles of the HISS site [20]. Three of the wells were domestic wells: two were about half a mile northeast of the HISS/Futura site, and the other was in a residential area more than a mile downstream from the historical source areas. The domestic wells had been abandoned in 1962, 1968, and 1979 (the report did not indicate which wells were abandoned for each date). In addition to the domestic wells, the survey reported four private wells used for irrigation and one private well used for industrial purposes, all one to three miles west/northwest of the historical source areas and not near Coldwater Creek.

Groundwater in the surface aquifers at both HISS and SLAPS has shown elevated levels of total uranium compared to background [6]. Groundwater contamination did not appear to be migrating offsite in sampling conducted in the late 1990s [70,71]. Monitoring at that time also showed no evidence that Coldwater Creek was affected by groundwater at the historical source areas. However, the private wells may have been in use 30 years or more before these findings. Because no groundwater data exist for the time period the wells were in use, we cannot determine the quality and safety of water from private wells identified in the 1987–88 well survey.

*Concern: Were workers or area residents exposed to harmful levels of windblown dust from uncovered waste storage piles in the past?*

ATSDR response: ATSDR recognizes that from 1946 through about 1974, waste storage piles containing radiological contaminants were present and uncovered at the SLAPS and HISS

historical source areas. During that time, workers or nearby residents could have been exposed by breathing dust blown from the waste piles. We cannot estimate the amount of these potential exposures because very little, if any, air sampling was performed while the storage piles were uncovered. Quantifying this exposure and resulting risk through modeling would involve many uncertainties and would not likely affect our conclusions and recommendations.

This exposure pathway is no longer a concern, because the storage piles were reportedly covered for some years and removed completely by 1974. Although some soil contamination remains at properties that haven't been remediated, the few remaining areas are unlikely to contribute significant levels of contaminants to air through windblown dust.

*Concern: Community members raised concern that workers near uncovered waste piles in the past carried dust home to their families and children on their clothing and in the interiors of cars.*

ATSDR response: ATSDR recognizes that in the past (while the waste storage piles containing radiological contaminants were present and uncovered at the SLAPS and HISS historical source areas), workers or their families could have been exposed to contaminants by breathing or accidentally swallowing contaminated dust brought home on clothing or in cars. We cannot evaluate these potential exposures because we have no information on how much dust was present and how much contamination was in it.

*Concern: Why didn't you evaluate exposures at the ball fields next to SLAPS? Were players exposed to harmful levels of radiological contaminants there?*

ATSDR response: ATSDR's 1994 public health assessment for SLAPS/HISS discussed the ball fields and estimated whole-body doses for players. However, the ball fields had been closed by the city of St. Louis by that time. ATSDR's Coldwater Creek evaluation does not include the ball fields because our focus is on exposures along residential stretches of the creek, downstream from the ball field area. People who were exposed in the past at the ball fields as well as through the pathways evaluated this report could have higher exposures and be at a higher risk.

*Concern: Were workers moving soil for flood control projects exposed to harmful levels of radiological contaminants?*

ATSDR response: ATSDR's evaluation was for many years of regular incidental ingestion, inhalation, and external exposures. Exposures to workers would be less frequent and of shorter duration than the residential and recreational exposures estimated in this report and would be unlikely to result in exposures of health concern.

*Concern: Were workers at Boeing or McDonnell Douglas exposed to harmful levels of contamination from facility flooding?*

ATSDR response: We do not have information on dates, severity, or other circumstances of specific flood events at these facilities located close to the SLAPS and HISS sites. If contaminated sediments were suspended in floodwater and workers came in contact with the floodwater, they may have contacted radiological contaminants in the sediment. If the duration of exposure was relatively short and workers did not swallow large amounts of sediment, the radiological dose would be unlikely to contribute appreciably to their normal radiation dose based on typical background exposure.

### Health Concerns

*Concern: Is there a medical test to see if I've been exposed?*

ATSDR response: High doses of ionizing radiation (much higher than estimated in this report) can cause changes in blood or chromosomes that can be medically tested and used to estimate dose [51]. However, these tests cannot measure the low doses we estimated for people playing or living near Coldwater Creek.

People around Coldwater Creek may have been exposed to specific radioactive materials, especially Th-230. Radioactive materials can be measured indirectly by analyzing blood, feces, saliva, urine, or the whole body for different types of ionizing radiation. Specialized radiochemistry laboratories with bioassay expertise perform such testing, usually for occupational monitoring of workers in regular contact with radiation, such as nuclear power plant employees. Th-230 can be analyzed in urine or fecal samples using radiochemical separation followed by alpha spectroscopy.

Whether a bioassay for Th-230 in urine or feces would give useful information about potential past exposures for people who have lived or played near Coldwater Creek is unknown. The estimated intakes of Th-230 in this assessment were many times smaller than allowable limits for radiological workers. Th-230 accumulates in the bone and is slowly released. The body eliminates Th-230 from bone with a biological half-life of about 22 years. Years after exposure, the amount being released in urine or feces would likely be very small and possibly undetectable over instrument background levels. Assessing the body burden from excreta data requires detailed knowledge of when and how the exposure occurred, and the body may excrete much of the intake in a short timeframe of days or months, rather than years.

*Concern: What are the recommendations for advanced disease screening for people who grew up in this area?*

ATSDR response: Community members concerned about their health should speak to their medical providers and follow recommendations for age- and gender-specific preventive screening. ATSDR does not recommend additional disease screening for residents around Coldwater Creek. Not all current or former residents have experienced exposures as high as assumed by ATSDR in this evaluation. In addition, procedures that could detect the cancers of interest are associated with risk (such as additional radiation from imaging) that may outweigh the potential benefit. A personal physician will use a patient's individual history, symptoms, age, and gender to determine appropriate screening and diagnostic testing.

*Concern: Missouri studies showed that several types of cancers were elevated in the zip codes around Coldwater Creek.*

ATSDR response: The 2014 MDHSS cancer incidence report showed that rates of some types of cancer were elevated in the combined eight ZIP codes around Coldwater creek from 1996-2011, compared to the rest of Missouri [13]. The cancer types included leukemia, female breast, colon, prostate, kidney, and bladder. The radiological doses estimated for past exposures in this report (1960s to 1990s) were associated with elevated risks for lung cancer, bone cancer, leukemia, and skin cancer.

The estimates in this report were for children and adults who spent large amounts of time playing directly in the most highly contaminated areas of the creek and its floodplain. The people living in the ZIP codes studied by MDHSS may not be the same people who were most highly exposed while playing or living near Coldwater Creek in the 1960s to 1990s. In addition, radiation-induced cancers are indistinguishable from cancers caused by other factors (except possibly at very high exposures never approached at this site) [51]. Studying the relationship between Coldwater Creek exposures and area cancer rates is very difficult because of the time that has passed and the uncertainty in past exposure estimates. However, we recommend the state continue to follow cancer incidence in the area.

*Concern: We need a health study for chronic low-level radiation exposures like those we experienced.*

ATSDR response: The estimates of past exposures in this report involved many assumptions and uncertainties, and currently available biomonitoring methods may not be sensitive enough to quantify past exposures. These factors would limit a study's ability to determine the relationship between past exposure and health outcomes in the community. The relatively recent exposures estimated in this report were much lower than past exposures, and we would not expect them to

result in measurable increases in the rate of health effects. In addition, exposures are decreasing or have been eliminated in areas that have been cleaned up. For these reasons, designing and implementing a health study to examine effects of such exposures would be very difficult.

*Concern: Could exposures cause appendix cancer?*

ATSDR response: Please see the added section below.

### *Appendix Cancer*

The community reported a concern about perceived elevated rates of appendix cancers in the area, with some cases occurring in people who played in or near Coldwater Creek while growing up. The appendix lies in the upper large intestine near its junction with the small intestine. Neither ICRP/EPA dose coefficients nor EPA lifetime attributable cancer risk coefficients specifically consider the appendix.

ICRP and EPA dose coefficients are available for both the upper and lower large intestine. EPA lifetime attributable cancer risk coefficients are available for the colon. ATSDR averaged upper and lower large intestine dose coefficients to estimate colon dose and then estimated colon risk using this dose. Although tissues of the colon and the appendix are different in many ways, colon risk appears to be the best estimate available of possible risk for appendix cancer. As tabulated in Tables E8 and E9 in Appendix E, ATSDR found that recreational and residential exposures at Coldwater Creek, both in the past and more recently, resulted in estimated increased colon risks below 1 in 10,000. These results suggest that appendix cancer risk would not be elevated from the exposure.

Based on U.S. cancer rates, the lifetime risk of being diagnosed with cancer of the colon or rectum is about 4.3%, or 430 out of 10,000 people [47]. Appendix cancer is much rarer. McCusker et al. reported an age-adjusted yearly incidence rate of 0.12 out of 1,000,000 from 1973 to 1998, with no temporal trends within that 26-year timeframe [72]. Marmor et al. reported appendix cancer incidence rates to be rising, from 0.67 to 0.97 out of 100,000 per year between 2000 and 2009 [73]. These yearly incidence rates would correspond to fewer than 10 cases per 10,000 people over a 70-year lifetime. Reasons for the apparent increase in incidence of appendix cancer in the U.S. are not known but could include changes in how medical personnel code cancers or increased use of colonoscopy and imaging which can sometimes identify appendix tumors [73].

Neither colonoscopy nor imaging have been shown to be sufficient screening methods for appendix cancer [73,74]. Appendix cancers usually present as appendicitis; a mucous-filled hernia; swelling, discomfort, or a mass in the abdomen; or as an incidental finding as part of another imaging or surgical procedure [75]. There are several types of appendix cancer.

Treatment depends on how far the cancer has spread. Cancers that have spread to the abdominal cavity are currently treated with surgery to remove as many cancer cells as possible, followed by treating the entire abdominal cavity with heated chemotherapy agents [75].

The MDHSS cancer incidence studies found a slight statistical elevation in colon cancer, but no statistical elevation in appendix cancer from 1996 to 2011 in the combined eight ZIP codes surrounding the creek, compared to the rest of Missouri [13]. One ZIP code in the area had statistically higher appendix cancer rates from 1996 to 2011. The type of study performed by MDHSS is limited in its ability to determine cause-effect relationships between exposure and disease since no individual exposure information is available. The people living in the ZIP codes studied by MDHSS may not be the same people who were most highly exposed playing or living near Coldwater Creek in the 1960s to 1990s.

*Concern: Could exposures cause breast cancer?*

ATSDR response: Please see the added section below.

***Breast Cancer***

ATSDR estimated that past residential exposures at Coldwater Creek could have resulted in doses to the breast up to 180 mrem. Estimated increased breast cancer risks associated with these exposures, and the other exposure scenarios evaluated were less than 1 in 10,000.

Breast cancer is the most common form of cancer in women. Based on U.S. cancer rates, the lifetime risk of women being diagnosed with breast cancer is about 12.41%, or 1,241 out of 10,000 people [47]. The risks estimated in this report would increase this risk by less than 0.1%. Mammography (x-ray of the breast) is generally recommended to screen for breast cancer in age groups considered most at risk [76,77].

The U.S. Preventive Services Task Force recommends women aged 50 to 74 years have a screening mammogram for breast cancer every 2 years. It also advises women over age 40 to consider personal factors when deciding whether to begin screening every two years [76]. Recommendations from other medical groups for screening frequency and ages vary [77]. Possible harm from mammography that detracts from the benefits of early detection include distress and risks of additional testing resulting from false positive results, risks from treatment of cancers that would not have otherwise been detected or cause harm during the patient's lifetime, and radiation exposure [76]. Other imaging tests may be used in conjunction with mammography to screen for breast cancer in higher risk groups, including ultrasound or breast magnetic resonance imaging (MRI) scans [77].

According to the American Cancer Society, early symptoms of breast cancer may include a new lump or mass in the breast, swelling of all or part of a breast, skin irritation or dimpling, or pain [77]. A physician evaluating a patient's mammogram or a patient presenting with symptoms may ask for further imaging tests, but the only way to confirm breast cancer is with a tissue biopsy, where cells from the suspect area are removed surgically and examined under a microscope to see if they are cancerous [77].

The MDHSS cancer incidence study found a statistical elevation in female breast cancer from 1996 to 2011 in the combined eight ZIP codes surrounding the creek compared to the rest of Missouri [13]. The people living in the ZIP codes studied by MDHSS may not be the same people who were most highly exposed while playing or living near Coldwater Creek in the 1960s to 1990s. Radiation-induced solid tumors have a typical latency period of 20 to 40 years, so the study covered years in which breast cancers resulting from past exposures would most likely have developed.

*Concern: Could exposures cause other types of cancer?*

ATSDR response: ATSDR's evaluation did not show elevated risks to organs other than those discussed in the Results and Discussion section of the report. Several organ sites did not have corresponding lifetime attributable risk coefficients, so risk could not be estimated.

*Concern: Could exposures cause other diseases besides cancer?*

ATSDR response: Please see the following additional sections for discussion of the possible relationships between exposure and other diseases besides cancer raised as concerns by the community.

### *Immune and Autoimmune Effects*

Many members of the Coldwater Creek community shared their strong belief that their community has an elevated rate of immune disorders and autoimmune disease caused by exposure to radiological contaminants from Coldwater Creek. In this section, ATSDR provides a very brief description of the immune system and its importance in keeping people healthy. We then summarize current research related to immune effects of radiation exposure to relate it to the exposures we estimated for the Coldwater Creek site.

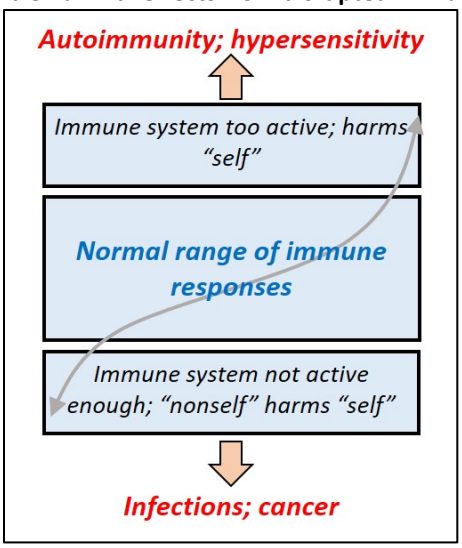
The fields of immunology and immunotoxicology study how exposure to chemicals or radiation affects immune system function. Chapter 12 of *Casarett and Doull's Toxicology: The Science of Poisons* (7th ed.) gives an excellent overview of the immune system and issues related to immunotoxicology; please see this reference for more information about these topics [78].

*Basic function of the immune system*

The human immune system is a complex, delicately balanced system, comprising many distinct types of cells and organs. The essential function of the immune system is to protect the tissues comprising a healthy organism ("self") from "nonself" such as bacteria, viruses, or tumor cells that may ultimately harm it. Correct recognition of and response to potentially harmful "nonself" material is critical for survival, as immune mechanisms are intended to destroy or neutralize "nonself" such as invading pathogens or tumor cells.

Figure 7 (adapted from [78]) illustrates how deviations from normal immune response, in any direction, may lead to harmful effects. The gray arrow represents activity of the immune system compared to an equilibrium balanced state. Raising or lowering this activity controls a wide range of normal immune responses, allowing appropriate protection of body tissues. However, raising or lowering immune activity *too much* can cause harm. If the immune system fails to recognize foreign materials or does not take enough action against them, pathogens or tumors may take over and destroy body tissues. Infections or cancer can result. On the other hand, if the immune system overreacts or mistakenly identifies normal body tissues as foreign, it may erroneously damage the tissues it is meant to protect. Hypersensitivity reactions (allergy) or autoimmune disorders can result.

**Figure 7. Figure illustrating possible harmful effects from disrupted immune function. Adapted from [78].**




Specific immune responses depend on what type of "nonself" the body is responding to and can include many different types of cells and a multitude of cell signaling components interacting together to achieve a response. Any problems with this complex interaction can potentially lead to faulty immune responses. Molecular biology techniques have enabled vast improvements in our knowledge about immune signaling and components; our review does not go into these details but merely covers the most basic framework.

*Possible immune and autoimmune effects from radiation*

ATSDR found several studies on radiation effects on the immune system or immune functions, summarized below. The following paragraphs give a brief background about why these studies often focus on particular organs or immune effects.

Bone marrow is perhaps the most important organ of the immune system; it produces stem cells from which all blood cells, including those important in various immune responses, are derived. The high turnover of cells in bone marrow makes it especially susceptible to damage from high levels of ionizing radiation.

The thyroid gland is part of the endocrine system, not the immune system, but the immune system can have many effects on its function. The thyroid uses iodine from dietary sources to produce hormones that control the body's metabolism. Studies of people exposed to radiation often focus on the thyroid because radioactive iodine was released in nuclear incidents and because iodine is known to concentrate in the thyroid. Thyroid cancer can be induced by radiation exposure, especially if the exposure occurs in childhood [51].

Two autoimmune disorders that can affect the thyroid are Grave's disease and Hashimoto's disease. Grave's disease occurs when the immune system produces antibodies that stimulate the thyroid gland to produce too much thyroid hormone (hyperthyroidism). In Hashimoto's disease, antithyroid antibodies gradually destroy the thyroid, leading to low thyroid levels (hypothyroidism). Levels of different types of thyroid hormones or antibodies against the thyroid can be measured to indicate if people show signs of autoimmune disease.

Many studies have followed exposed populations to determine radiation's effects on the thyroid and the immune system. These include studies on survivors of the Japanese atomic bombs and residents and cleanup workers affected by the Chernobyl accident. Over many years of follow-up, researchers have observed dose- and age-dependent increases in rates of thyroid cancer and thyroid nodules; some of this increase may be due in part to additional, special screening offered only to those exposed [79-81]. Some dose-dependent changes in blood stem cells, immune cell levels, and thyroid function have also been observed, but it is not clear that these changes are great enough to cause clinical symptoms [82–84]. Recent reports have shown no association between dose and several measures of thyroid autoimmune disease in those affected by either the atomic blasts or the Chernobyl accident [85,83].

Several review articles describe effects of radiation on the immune system, mostly in the context of radiation therapy (for cancer treatment, for example). They describe how high doses of radiation suppress the immune system, while low doses may activate it and induce immune responses that may help the body fight cancer [86-89]. Another review suggests that these low doses might cause autoimmune diseases by overstimulating the immune system [90].

*Relationship of studies to Coldwater Creek*

Th-230 and the other site contaminants do not preferentially concentrate in the thyroid. However, they do concentrate in bones and could conceivably affect immune function. We do not know

whether any of the findings discussed above can be applied to the Coldwater Creek situation. Even when described as "low dose," the radiation doses received by studied populations or used in radiation therapy are much larger than the doses ATSDR conservatively estimated for Coldwater Creek residents. The exposures in the epidemiology studies cited were over a very short timeframe and were on the order of 10,000 mrem (whole-body) up to millions of mrem in localized areas of the body. In the cancer therapy literature we reviewed, "low dose" is defined vaguely and inconsistently, but generally refers to short term doses much higher than those we estimated, even over 33 years of exposures.

We consider it unlikely that the lower exposures estimated for Coldwater Creek residents could cause measurable changes in the rates of these diseases because studies of highly exposed populations did not observe changes in measures of autoimmune disorders. However, the exposure characteristics, isotopes involved, and possible duration of continuing exposure are very different, and scientists are still learning about the immune system and its function. ATSDR is open to re-evaluating this conclusion if new science or information become available in the future.

#### *Fertility issues or miscarriages*

The radiological doses estimated from recreational and residential exposures near Coldwater Creek were many times lower than those that have been associated with fertility problems. Studies of radiation exposure to the human reproductive system have shown no permanent effects at doses below 200,000 mrem [91]. Studies on pregnancies of atomic bomb survivors did not include assessment of miscarriages before the fifth month of gestation. The studies showed no statistical differences in the rates of stillborn babies or babies who died within 2 weeks of birth compared to unexposed groups [92].

#### *Birth defects or cancers in the next generations*

Studies following births to atomic bomb survivors have shown no statistical differences compared to unexposed groups in congenital malformations, stillbirth or death soon after birth, other genetic effects, or cancer in the first 20 years of life [92,93]. Mental retardation and reduced IQ were observed in some children who were exposed *in utero* to high levels of radiation (higher than 20,000 to 40,000 mrem) between eight and 15 weeks after conception. [51]. ATSDR did not locate any information on studies of birth defects in children of radium dial painters [55].

The radiological doses estimated from recreational and residential exposures near Coldwater Creek were many times lower than those associated with reduced IQ and experienced by the atomic bomb survivors.

### Other Concerns

*Concern: We need health education for physicians and residents.*

ATSDR response: ATSDR has provided formal and informal health education to local physicians, community leaders, and partner health agencies about exposures and the public health assessment process. ATSDR will continue to work with the community to identify needs and options for educating the public and local medical providers about radiological exposures and health.

*Concern: People who grew up near Coldwater Creek should get downwinder status.*

ATSDR response: The 1990 Radiation Exposure Compensation Act established a compensation program for people who develop specified diseases after working in the uranium industry, participating in atmospheric nuclear weapons tests, or living downwind of the Nevada Test Site during the years of atmospheric testing of nuclear weapons. More information is available at https://www.justice.gov/civil/common/reca.

ATSDR is an advisory public health agency and does not have authority to grant downwinder status.

## Conclusions

To evaluate possible effects from exposures, ATSDR estimated the exposure and resulting risks for children and adults who directly touched, swallowed, or breathed in sediment and water from Coldwater Creek and soil in its floodplain for many hours a day for many years. We assumed they were always exposed to concentrations of contaminants present in the most highly contaminated areas. Based on different specific assumptions for past (1960s to 1990s) and recent (2000s and on) exposures, detailed in this report, we reached the following four conclusions.

*Radiological contamination in and around Coldwater Creek, prior to remediation activities, could have increased the risk of some types of cancer in people who played or lived there.*

- Children and adults who regularly played in and around Coldwater Creek or lived in its floodplain for many years in the past (1960s to 1990s) may have been exposed to radiological contaminants. ATSDR estimated that this exposure could increase the risk of developing lung cancer, bone cancer, or leukemia.
- More recent exposures (2000s and on) only slightly increased the risk of developing lung cancer from daily residential exposure.
- Estimation of risk, especially for past exposures, involved many uncertainties. The estimated increased risks would not likely result in detectable increased cancer rates in the community as a whole.

*ATSDR does not recommend additional general disease screening for past or present residents around Coldwater Creek.*

- The predicted increases in the number of cancer cases from exposures are small, and no method exists to link a particular cancer with this exposure.
- Not all current or former residents would have experienced exposures as high as assumed by ATSDR in this evaluation.
- Screening people who have no symptoms has risks, including false negative results, false positive results, risks from treating cancers that might never have caused a problem during a person's lifetime, and additional radiation exposure from diagnostic tests. A personal physician will use a patient's individual history, symptoms, age, and gender to determine appropriate screening and diagnostic testing.

*ATSDR supports ongoing efforts to identify and properly remediate radiological waste around Coldwater Creek.*

- Th-230 has been found above FUSRAP remedial goals in several areas of the Coldwater Creek floodplain. Reducing Th-230 levels in accessible areas will reduce harmful exposures.
- Waste entered the creek decades ago, and detailed information about how it moved with sediment and into floodplain soil does not exist. Reports of historical use of Coldwater Creek sediment and floodplain soil in other locations indicates a possibility that

contamination spread from the floodplain. Identifying and remediating contaminated areas outside the floodplain will reduce potentially harmful exposures.

*Other exposure pathways of concern to the community could have contributed to risk. ATSDR is unable to quantify that risk.*

- No sampling data exist that would allow ATSDR to estimate exposures from other pathways, such as inhaling dust blown from historical radiological waste storage piles and past consumption of local dairy or agricultural products.

## Recommendations

ATSDR recommends that:

- Potentially exposed residents or former residents share their potential exposure related to Coldwater Creek with their physicians as part of their medical history and consult their physicians promptly if new or unusual symptoms develop. Upon request, ATSDR can facilitate a consultation between residents' personal physicians and medical specialists in environmental health.
- The state consider updating analyses on cancer incidence, cancer mortality, and birth defects, as feasible.
- FUSRAP continue investigating and cleaning up Coldwater Creek sediments and floodplain soils to meet regulatory goals. To increase knowledge about contaminant distribution and allay community concerns, ATSDR recommends future sampling include
    - areas reported to have received soil or sediment moved from the Coldwater Creek floodplain (such as fill used in construction)
    - areas with possible soil or sediment deposited by flooding of major residential tributaries to Coldwater Creek
    - indoor dust in homes where yards have been cleaned up or require cleanup
    - sediment or soil remaining in basements that were directly flooded by Coldwater Creek in the past
- Authorities install signs to inform residents and visitors of potential exposure risks in areas around Coldwater Creek not yet investigated or remediated.
- Public health agencies continue to evaluate, to the extent possible, community concerns about exposure and educate the community about radiological exposures and health.

## Next Steps

Upon request, ATSDR will

- review new data from Coldwater Creek investigations and update conclusions, if necessary
- provide technical support to update cancer incidence or mortality studies in the area and identify needed public health actions
- remain available to provide further technical assistance to the public, partner agencies, or other stakeholders

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# Appendix A. Documentation of Community Exposure Input and ATSDR Selected Parameters

To estimate exposures, we use information on how often and for how long the activities associated with the exposure occurred. We obtained input on Coldwater Creek activities and timing from a local community group: the following section explains how we used this input. Tables summarizing the selected parameters are included at the end of this appendix. Also included in the summary are ATSDR's selected intake parameters for soil, sediment, and surface water used in the evaluation; these values are based on standard ATSDR guidance modified as appropriate for the Coldwater Creek situation.

## Community Input on Exposure Assumptions

We asked a local community group to provide input on how often adults and children of various ages participated in certain activities around Coldwater Creek. The group completed a table of exposure frequencies and times and provided it to ATSDR [22]. Community members indicated that their responses applied mostly to past exposures because children in more recent times have spent far less time in or around the creek. The following describes how ATSDR used the community input to develop exposure assumptions for past and more recent exposures.

### *Community Input – Recreational Exposure*

Suggestions for time spent doing recreational activities near the creek were provided by members of a local group familiar with Coldwater Creek as shown in Table A1.

**Table A 1. Input from community considered in developing recreational exposure assumptions**

Time spent playing in the creek and its banks

| | Summer (out of school) | | School year (warm days) | | School year (cold/rainy days) | |
|---|---|---|---|---|---|---|
| | Days / week | Hours spent | Days / week | Hours spent | Days / week | Hours spent |
| Kids 3 or younger | 2 - 3 | 2 | 3 | 2 | 0 | |
| Pre-school-aged kids | 3 | 2 | 3 | 2 | 0 | |
| Elementary-aged kids | 5 | 8 | 5 | 2 - 4 | 2 - 3 | 1 - 3 |
| Middle school-aged kids | 5 - 7 | 8 | 5 - 7 | 2 - 4 | 2 - 3 | 1 - 3 |
| High school-aged kids | 5 | 2 - 4 | 3 | 1 - 3 | 2 - 3 | 1 - 2 |
| Adults | 2 - 3 | 2 | 3 | 2 | 0 | |

Time spent playing in the parks and woods along the creek (floodplain)

| | Summer (out of school) | | School year (warm days) | | School year (cold/rainy days) | |
|---|---|---|---|---|---|---|
| | Days / week | Hours spent | Days / week | Days / week | Hours spent | Hours spent |
| Kids 3 or younger | 2 - 3 | 2 | 3 | 2 | 0 | |
| Pre-school-aged kids | 3 | 2 | 3 | 2 | 0 | |
| Elementary-aged kids | 5 | 8 | 5 | 2 - 4 | 2 - 3 | 1 - 3 |
| Middle school-aged kids | 5 - 7 | 8 | 5 - 7 | 2 - 4 | 2 - 3 | 1 - 3 |
| High school-aged kids | 5 | 2 - 4 | 3 | 1 - 3 | 2 - 3 | 1 - 2 |
| Adults | 2 - 3 | 2 | 3 | 2 | 0 | |

Time spent riding bikes or dirt bikes on trails along creek

| | Summer (out of school) | | School year (warm days) | | School year (cold/rainy days) | |
|---|---|---|---|---|---|---|
| | Days / week | Hours spent | Days / week | Hours spent | Days / week | Hours spent |
| Kids 3 or younger | N/a | | | | | |
| Pre-school-aged kids | 4 | 2 - 4 | 2 | 2 | 0 | |
| Elementary-aged kids | 7 | 2 - 8 | 5 | 2 - 4 | 2 | 1 - 2 |
| Middle school-aged kids | 7 | 2 - 8 | 5 | 2 - 4 | 4 | 1 - 4 |
| High school-aged kids | 7 | 2 - 5 | 5 | 2 - 4 | 2 | 1 - 3 |
| Adults | 2 | 2 | 2 | 2 - 4 | 0 | |

Given the number of days per week and hours suggested by community input, ATSDR assumed that the times and days reflected a combination of time spent in the creek and its banks, playing in floodplain areas, and riding bikes or dirt bikes along the creek. Therefore, ATSDR used the exposure frequency and time reported for a combination of activities: playing in either the creek and its banks or its floodplain. This activity, regardless of where it occurs, contributes mainly to ingestion exposure from swallowing of soil, sediment, or water. ATSDR considered the assumptions for time spent riding bikes or dirt bikes separately, because this activity contributes to inhalation exposure from breathing in soil stirred up by biking.

Table A2 below summarizes the recreational exposure frequencies and durations selected by ATSDR for the evaluation. We selected past assumptions to reflect the community input as closely as possible while following ATSDR's standard procedures. We reduced recent exposure frequencies and durations, based on community comments that their estimates reflected past exposures and that people today spend far less time recreating along the creek.

**Table A 2. ATSDR selected frequencies for past and recent recreational exposures**

| **Playing in the creek and its banks** - exposure assumptions (**past** / *recent*) | | | | | | |
|---|---|---|---|---|---|---|
| | Summer (out of school)* | | School year (warm days)† | | School year (cold/rainy days)† | |
| | Days per week | Hours spent | Days per week | Hours spent | Days per week | Hours spent |
| Kids less than 3 | **3** / *1* | **2** / *0.5* | **3** / *1* | **2** / *0.5* | **0** / *0* | **0** / *0* |
| Preschool kids | **3** / *1* | **2** / *0.5* | **3** / *1* | **2** / *0.5* | **0** / *0* | **0** / *0* |
| Elementary kids | **5** / *2* | **8** / *1* | **5** / *2* | **3** / *0.5* | **3** / *0* | **3** / *0* |
| Middle school kids | **6** / *4* | **8** / *2* | **6** / *2* | **3** / *0.5* | **3** / *0* | **3** / *0* |
| High school kids | **5** / *4* | **3** / *2* | **3** / *2* | **3** / *0.5* | **3** / *0* | **3** / *0* |
| Adults | **3** / *2* | **2** / *0.5* | **3** / *2* | **2** / *0.5* | **0** / *0* | **0** / *0* |

| **Riding bikes or dirt bikes** on trails along creek - exposure assumptions (**past** / *recent*) | | | | | | |
|---|---|---|---|---|---|---|
| | Summer (out of school)* | | School year (warm days)† | | School year (cold/rainy days)† | |
| | Days per week | Hours spent | Days per week | Hours spent | Days per week | Hours spent |
| Kids less than 3 | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* |
| Preschool kids | **4** / *1* | **3** / *0.5* | **4** / *1* | **2** / *0.5* | **0** / *0* | **0** / *0* |
| Elementary kids | **7** / *4* | **5** / *1* | **7** / *2* | **3** / *0.5* | **2** / *0* | **2** / *0* |
| Middle school kids | **7** / *4* | **5** / *2* | **7** / *2* | **3** / *0.5* | **4** / *0* | **2** / *0* |
| High school kids | **7** / *4* | **4** / *2* | **7** / *2* | **3** / *0.5* | **2** / *0* | **2** / *0* |
| Adults | **2** / *2* | **2** / *0.5* | **2** / *2* | **2** / *0.5* | **0** / *0* | **0** / *0* |

* Summer break assumed to be 12 weeks.

† School year cold/rainy days assumed to be 20 weeks, based on 17 cold weeks (November through March) plus 3 weeks of rainy days—about 1 day a week—for the remaining school year. School year warm days assumed to be remaining 20 weeks.

### *Community Input – Residential Exposure*

Suggestions for time spent and comments about activities in residential yards near the creek were provided by members of a local group familiar with Coldwater Creek as shown in Table A3.

**Table A 3. Input from community considered in developing residential exposure assumptions**

Time spent playing in yard

| | Summer (out of school) | | School year (warm days) | | School year (cold/rainy days) | |
|---|---|---|---|---|---|---|
| | Days / week | Hours spent | Days / week | Hours spent | Days / week | Hours spent |
| Kids 3 or younger | 7 | 8 - 10 | 7 | 4 | 2 | 2 |
| Pre-school-aged kids | 7 | 8 - 12 | 7 | 4 | 2 | 2 |
| Elementary-aged kids | 7 | 8 - 12 | 7 | 4 | 2 | 2 |
| Middle school-aged kids | 7 | 8 - 12 | 7 | 4 | 2 | 2 |
| High school-aged kids | 7 | 6 - 10 | 7 | 4 | 2 | 2 |
| Adults | 7 | 2 - 8 | 7 | 1 - 3 | 2 | 2 |

Time spent doing gardening or yard work

| | Summer (out of school) | | School year (warm days) | | School year (cold/rainy days) | |
|---|---|---|---|---|---|---|
| | Days / week | Hours spent | Days / week | Hours spent | Days / week | Hours spent |
| Kids 3 or younger | This age group would be present when their parents worked in yard. | | | | | |
| Pre-school-aged kids | Same as above. | | | | | |
| Elementary-aged kids | Same as above | | | | | |
| Middle school-aged kids | 1 | 1 - 3 | 1 | 1 - 3 | 0 | |
| High school-aged kids | 1 | 1 - 3 | 1 | 1 - 3 | 0 | |
| Adults | 2 | 2 - 5 | 1 | 2 - 3 | 0 | |

Time spend doing landscaping such as heavy digging

| | Summer (out of school) | | School year (warm days) | | School year (cold/rainy days) | |
|---|---|---|---|---|---|---|
| | Days / week | Hours spent | Days / week | Hours spent | Days / week | Hours spent |
| Kids 3 or younger | 0 | | | | | |
| Pre-school-aged kids | 5 | 2 - 8 | 5 | 3 | 0 | |
| | (This age group played in dirt and used toy shovels to dig.) | | | | | |
| Elementary-aged kids | 5 | 2 - 8 | 5 | 3 | 0 | |
| | (This age group played in dirt and used toy shovels to dig.) | | | | | |
| Middle school-aged kids | 7 | 8 | 5 | 4 | 2 | 2 - 4 |
| | (Dug dirt and built forts instead of landscaping.) | | | | | |
| High school-aged kids | 1 | 3 | 1 | 3 | 0 | |
| Adults | 2 | 2 - 5 | 1 | 3 | 0 | |

ATSDR used the community's suggestions to develop assumptions for past and recent residential exposures. ATSDR's standard protocol assumes 365 days per year of residential exposure. Child default soil ingestion rates account for bystander exposures and include typical play activities such as digging and playing in dirt. No additional ingestion above the default rates were applied for age groups not actually doing gardening or landscaping activities.

Table A4 below summarizes the residential exposure frequencies and durations selected by ATSDR for the evaluation. Recent exposure frequencies and durations were reduced slightly from past values.

**Table A 4. ATSDR selected frequencies for past and recent residential exposures**

| **Playing in yard**- exposure assumptions (**past** / *recent*) | | | | | | |
|---|---|---|---|---|---|---|
| | Summer (out of school)* | | School year (warm days)† | | School year (cold/rainy days)† | |
| | Days per week | Hours spent | Days per week | Hours spent | Days per week | Hours spent |
| Kids less than 3 | **7** / *7* | **8** / *2* | **7** / *7* | **4** / *1* | **7** / *7* | **2** / *0.5* |
| Preschool kids | **7** / *7* | **8** / *2* | **7** / *7* | **4** / *1* | **7** / *7* | **2** / *0.5* |
| Elementary kids | **7** / *7* | **8** / *2* | **7** / *7* | **4** / *1* | **7** / *7* | **2** / *0.5* |
| Middle school kids | **7** / *7* | **8** / *2* | **7** / *7* | **4** / *1* | **7** / *7* | **2** / *0.5* |
| High school kids | **7** / *7* | **8** / *2* | **7** / *7* | **4** / *1* | **7** / *7* | **2** / *0.5* |
| Adults | **7** / *7* | **8** / *1* | **7** / *7* | **2** / *0.5* | **7** / *7* | **2** / *0.5* |

| **Gardening or yard work** - exposure assumptions (**past** / *recent*) | | | | | | |
|---|---|---|---|---|---|---|
| | Summer (out of school)* | | School year (warm days)† | | School year (cold/rainy days)† | |
| | Days per week | Hours spent | Days per week | Days per week | Hours spent | Days per week |
| Kids less than 3 | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* |
| Preschool kids | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* |
| Elementary kids | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* |
| Middle school kids | **1** / *1* | **3** / *1* | **1** / *1* | **3** / *0.5* | **0** / *0* | **0** / *0* |
| High school kids | **1** / *1* | **3** / *1* | **1** / *1* | **3** / *0.5* | **0** / *0* | **0** / *0* |
| Adults | **2** / *2* | **5** / *2* | **1** / *1* | **3** / *2* | **0** / *0* | **0** / *0* |

| **Landscaping** such as heavy digging - exposure assumptions (**past** / *recent*) | | | | | | |
|---|---|---|---|---|---|---|
| | Summer (out of school)* | | School year (warm days)† | | School year (cold/rainy days)† | |
| | Days per week | Hours spent | Days per week | Days per week | Hours spent | Days per week |
| Kids less than 3 | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* |
| Preschool kids | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* |
| Elementary kids | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* |
| Middle school kids | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* |
| High school kids | **1** / *1* | **3** / *1* | **1** / *1* | **3** / *0.5* | **0** / *0* | **0** / *0* |
| Adults | **2** / *2* | **5** / *2* | **1** / *1* | **3** / *2* | **0** / *0* | **0** / *0* |

* Summer break assumed to be 12 weeks.

† School year cold/rainy days assumed to be 20 weeks, based on 17 cold weeks (November through March) plus 3 weeks of rainy days—about 1 day a week—for the remaining school year. School year warm days assumed to be remaining 20 weeks.

*ATSDR Additional Assumptions and Example Calculations:*

To calculate the average hours per day for each activity, we multiplied the days per week and time per day by weeks of the school year.

- Summer break assumed to be 12 weeks
- School year cold/rainy days assumed to be 20 weeks – based on 17 cold weeks (November – March) plus 3 weeks of rainy days—about 1 day a week—for the remaining school year.
- School year warm (non-rainy) days assumed to be remaining 20 weeks

For example, middle school-aged kids are estimated to ride their bikes

$$7\frac{day}{week} \times 12\ weeks + \ 5\frac{day}{week} \times 20\ weeks + \ 4\frac{day}{week} \times 20\ weeks$$

= 264 days a year.

And each day they ride, they spend

$$\frac{\left(7\frac{day}{week} \times 5\frac{hr}{day} \times 12\ weeks + \ 5\frac{day}{week} \times 3\frac{hr}{day} \times 20\ weeks + \ 4\frac{day}{week} \times 2\ \frac{hr}{day} \times 20\ weeks\right)}{264\ days}$$

= 3.3 hours per day riding their bikes.

As another example, adults are estimated to do landscaping

$$2\frac{day}{week} \times 12\ weeks + \ 1\frac{day}{week} \times 20\ weeks + \ 0\frac{day}{week} \times 20\ weeks = 44\ days\ a\ year$$

And each day they landscape they spend

$$\frac{\left(2\frac{day}{week} \times 5\frac{hr}{day} \times 12\ weeks + \ 1\frac{day}{week} \times 3\frac{hr}{day} \times 20\ weeks + \ 0\frac{day}{week} \times 0\ \frac{hr}{day} \times 20\ weeks\right)}{44\ days}$$

= 4.1 hours per day landscaping.

This is how ATSDR determined the days per year and hours per day used in the evaluation (summarized in the tables following).

## Selected Exposure Assumptions for Recreational and Residential Scenarios

**Table A 5. Recreational frequency/duration assumptions (past / *recent*)**

| Age range | Time spent playing in creek, banks, or parks/soil near creek | | Time spent riding bikes along creek | | Duration, years‡‡ |
|---|---|---|---|---|---|
| | Hours per day* | Days per year‡ | Hours per day* | Days per year‡ | |
| Kids less than 3 | **2** / *0.5* | **96** / *32* | **0** / *0* | **0** / *0* | **3** / *3* |
| Preschool kids | **2** / *0.5* | **96** / *32* | **2.5** / *0.5* | **88** / *32* | **3** / *3* |
| Elementary kids | **4.4** / *1.0* | **220** / *64* | **3.6** / *0.5* | **224** / *88* | **5** / *5* |
| Middle school kids | **4.4** / *2.0* | **252** / *88* | **3.3** / *0.5* | **264** / *88* | **3** / *3* |
| High school kids | **2.7** / *2.0* | **180** / *88* | **3.2** / *0.5* | **224** / *88* | **4** / *4* |
| Adults | **2** / *0.5* | **96** / *64* | **2.0** / *0.5* | **64** / *64* | **15** / *15* |

*Average hours per day on days spent at creek – average over school year & summer break as suggested by community. Days per year used to estimate ingestion exposures which are on a per day basis. Hours per day and days per year used to estimate inhalation and external exposures.

‡ Days suggested by community input

**‡‡ Total duration of 33 years represents ATSDR-recommended residential occupancy period, upper percentile**

**Table A 6. Residential frequency/duration assumptions (past / *recent*)**

| Age range | Play in yard/ home | | Gardening | | Landscaping | | Duration, years‡‡ |
|---|---|---|---|---|---|---|---|
| | Hours per day* | Days per year‡ | Hours per day* | Days per year* | Hours per day* | Days per year* | |
| Kids less than 3 | **4.2** / *1.0* | **365** / *365* | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* | **3** / *3* |
| Preschool kids | **4.6** / *1.0* | **365** / *365* | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* | **3** / *3* |
| Elementary kids | **4.6** / *1.0* | **365** / *365* | **0** / *0* | **0** / *0* | **0** / *0* | **0** / *0* | **5** / *5* |
| Middle school kids | **4.6** / *1.0* | **365** / *365* | **3.0** / *0.7* | **32** / *32* | **0** / *0* | **0** / *0* | **3** / *3* |
| High school kids | **4.2** / *1.0* | **365** / *365* | **3.0** / *0.7* | **32** / *32* | **3.0** / *0.7* | **32** / *32* | **4** / *4* |
| Adults | **3.4** / *0.6* | **365** / *365* | **4.1** / *2.0* | **44** / *44* | **4.1** / *2.0* | **44** / *44* | **15** / *15* |

* Default child ingestion rates occur every day and include activities such as playing in dirt. Gardening and landscaping assumed to increase exposure to the person doing the activity, not to child bystanders. Hours per day used to estimate inhalation exposure. Days per year used to estimate ingestion exposures which are on a per day basis. Hours per day and days per year used to estimate inhalation and external exposures.

‡ Default residential assumption of daily exposure

‡‡ Total duration of 33 years represents ATSDR-recommended residential occupancy period, upper percentile

### Intake Parameters for Recreational and Residential Scenarios

ATSDR used Agency guidance and professional judgment to determine how much soil, sediment, or water children and adults would take in while playing or living near Coldwater Creek. The tables below summarize the intake assumptions used in this evaluation. The assumptions for intakes are the same for past and for recent exposures.

**Table A 7. Past and recent recreational ingestion intake assumptions**

| Age range | Soil ingestion, milligrams per day * | Sediment ingestion, milligrams per day ** | Surface water incidental ingestion, milliliters per event† |
|---|---|---|---|
| Kids less than 3 | 100†† | 100 | 30 |
| Preschool kids | 100†† | 100 | 30 |
| Elementary kids | 100 | 100 | 30 |
| Middle school kids | 100 | 100 | 30 |
| High school kids | 100 | 100 | 30 |
| Adults | 50 | 50 | 30 |

*ATSDR-recommended soil only ingestion rates, upper percentile values [94]

**ATSDR-recommended sediment only ingestion rates, upper percentile values [94]

† Assumed one swimming/wading event per day at creek, with about 30 ml (2 tablespoons) of water swallowed each event [professional judgment]

†† Also evaluated soil pica behavior for children between 1 and 6 years old, assuming 5,000 mg of soil ingested once a week during warm, non-rainy days (32 weeks a year) for PAST exposures and twice a year for RECENT exposures [94]. This is based on judgment that in recent years young children are far less likely to access creek areas unsupervised and thus less likely to engage in soil pica activity there.

**Table A 8. Past and recent recreational inhalation intake assumptions**

| Age Range | Particle emission factor, kilogram of soil per cubic meter of air* | Inhalation rate, cubic meter per hour† |
|---|---|---|
| Kids less than 3 ** | $1.18\times10^{-6}$ | 1.32-1.74 |
| Preschool kids | $1.18\times10^{-6}$ | 1.62 |
| Elementary kids | $1.18\times10^{-6}$ | 1.74 |
| Middle school kids | $1.18\times10^{-6}$ | 2.04 |
| High school kids | $1.18\times10^{-6}$ | 2.13 |
| Adults | $1.18\times10^{-6}$ | 2.26 |

* Derived by EPA for all-terrain vehicle riding in Colorado [95]. This value is more conservative than EPA's standard soil suspension assumption for recreational exposures and is consistent with activity-based sampling for dust in other published and unpublished studies [96,97]. See response to public comment PCrac-20 beginning on page F-49 for a detailed explanation of how ATSDR selected the PEF.

† Short-term inhalation rates in cubic meters per hour, males and females combined, moderate intensity, upper percentile values converted from values in Table 6-2 of [98]

- kids less than 1 year old inhale 1.32 cubic meters of air per hour; kids 1 up to 3 years old inhale 1.74 cubic meters of air per hour
- high school kids value is average of rates for ages 14 through 17 (4 year duration); adult value is average of rates for ages 18 through 32 (15 year duration)

**to account for potential inhalation exposures of kids less than 3, we assumed inhalation similar to bike riding for the time they spent playing in and along creek (i.e., 2 hours per day for 96 days a year)

**Table A 9. Past and recent residential ingestion intake assumptions**

| ATSDR age range | Soil and dust ingestion from playing in yard/home, milligrams per day* | Additional soil intake on gardening days, milligrams per day ‡ | Additional soil intake on landscaping days, milligrams per day ‡‡ |
|---|---|---|---|
| Kids less than 3 | 100-200** | - | - |
| Preschool kids | 200** | - | - |
| Elementary kids | 200 | - | - |
| Middle school kids | 200 | 100 | - |
| High school kids | 200 | 100 | 330 |
| Adults | 120 | 100 | 330 |

* ATSDR-recommended soil and indoor dust ingestion rates, upper percentile values [94]. Adults value is weighted for 200 mg/day for 18- to 20-year-olds, 100 mg/day for 21- to 32-year-olds.
**Children 6 weeks up to 1 year old ingest 100 mg/day; all others ingest 200 mg/day. Also evaluated soil pica behavior for children between 1 and 6 years old, assuming 5,000 mg of soil ingested 3 times a week during warm, non-rainy days (32 weeks a year) for both PAST and RECENT exposures [94].
‡ ATSDR-recommended value for gardening [94]. Assumed this is added to daily soil and dust ingestion rate.
‡‡ ATSDR-recommended soil and sediment ingestion rates, worker – outdoor (high intensity soil contact) [94]. Assumed this is added to daily soil and dust ingestion rate.

**Table A 10. Past and recent residential inhalation intake assumptions**

| Age range | Particle emission factor, kilogram of soil per cubic meter of air* | Inhalation rate, cubic meter per hour† |
|---|---|---|
| Kids Less Than 3 | $1.18\times10^{-6}$ | 1.32-1.74 |
| Preschool Kids | $1.18\times10^{-6}$ | 1.62 |
| Elementary Kids | $1.18\times10^{-6}$ | 1.74 |
| Middle School Kids | $1.18\times10^{-6}$ | 2.04 |
| High School Kids | $1.18\times10^{-6}$ | 2.13 |
| Adults | $1.18\times10^{-6}$ | 2.26 |

* Derived by EPA for all-terrain vehicle riding in Colorado [95 This value is more conservative than EPA's standard soil suspension assumption for recreational exposures and is consistent with activity-based sampling for dust in other published and unpublished studies [96,97]. See response to public comment PCrac-20 beginning on page F-49 for a detailed explanation of how ATSDR selected the PEF.
† Short-term inhalation rates in cubic meters per hour, males and females combined, moderate intensity, upper percentile values converted from values in Table 6-2 of [98].
- kids less than 1 year old inhale 1.32 cubic meters of air per hour; kids 1 up to 3 years old inhale 1.74 cubic meters of air per hour
- high school kids value is average of rates for ages 14 through 17 (4 year duration); adult value is average of rates for ages 18 through 32 (15 year duration)

# Appendix B. Pathway Analysis and Selecting Contaminants to Evaluate Further

## Pathway Analysis

ATSDR evaluates whether people may have come into contact with contaminants from a site by examining *exposure pathways*. Exposure pathways consist of five elements: a contamination *source*; *transport* of the contaminant through an environmental medium like air, soil, or water; an *exposure point* where people can come in contact with the contaminant; an *exposure route* whereby the contaminant can be taken into the body; and an *exposed population* of people actually coming in contact with site contaminants [21].

*Completed* exposure pathways are those for which all five pathway elements are evident. If one or more elements is missing or has been stopped, the pathway is *incomplete*. Exposure cannot occur for incomplete exposure pathways. For *potential* exposure pathways, exposure appears possible, but one or more of the elements is not clearly defined.

Radioactive materials may result in exposures outside the body as well as from inside. External exposure depends on what type of radiation the material gives off, how far away it is, whether any materials are in between a person and the contaminant, and how long a person spends near the contaminant. These additional considerations determine whether radiation pathways are complete.

A completed exposure pathway does not necessarily mean that harmful health effects will occur. A contaminant's ability to harm health depends on many factors, including how much is present, how long and how often a person is exposed to it, and the toxicity of the contaminant. Further evaluation of the specific exposure occurring is needed to determine whether the exposure could cause harmful effects.

Below, we discuss the five exposure pathway elements as they describe completed exposure pathways relevant to people living or playing downstream of the source sites near Coldwater Creek (either now or in the past).

- The *source* of contamination was historical storage piles at the SLAPS and HISS/Futura sites upstream from residential areas on Coldwater Creek
- *Transport* of the contaminants occurred as they washed or blew into Coldwater Creek and worked their way downstream with creek sediments, eventually being deposited along the creek bed or (after floods) in floodplain areas
- *Exposure points* are and were present along recreational and residential sections of the creek and its floodplain, where people play and live
- *Exposure routes* include touching (or being in the immediate vicinity for radiological contaminants), accidentally swallowing, or breathing in contaminants

- *Exposed population* includes children and adults who played or lived near Coldwater Creek or its floodplain

As described in the body of this report, recreational and residential exposure scenarios evaluated in this report encompass these completed exposure pathways.

## Selecting Contaminants to be Evaluated Further

### *Radiological Screening*

Results were available for several radiological contaminants in soil and sediment along Coldwater Creek from I-270 to the St. Denis Bridge. Table B-1 summarizes the radiological data for soil and sediment. Because Th-230 was detected more frequently at higher levels than other radiological contaminants, we evaluated it further. We also included Ra-226 and U-238 for further evaluation. U-238 decays into Th-230, and Ra-226 is produced when Th-230 decays. Other radiological contaminants were not detected frequently or were detected at far lower levels than Th-230, and are not likely to contribute significantly to dose. Those contaminants were dropped from further evaluation. The radiological contaminants processed at the historical source areas were particulate and would appear more often in solid matrices like soil and sediment. To be conservative, we retained the same contaminants for evaluating surface water as well.

**Table B 1. Radiological contaminants measured in Coldwater Creek and its floodplain (data from 2014-2016)**

| | Number of positively identified samples / number of samples | | Highest positively identified result in picocuries per gram | | Reason* |
|---|---|---|---|---|---|
| ***Radioisotope*** | ***Soil*** | ***Sediment*** | ***Soil*** | ***Sediment*** | |
| Radiological Contaminants **Retained** in Evaluation: | | | | | |
| Thorium-230 | 5865 / 5877 | 1161 / 1174 | 465 | 145 | Detected frequently at concentrations significantly above typical background levels (1–3 pCi/g) and remedial goals (RGs) for soil (14-15 pCi/g) or sediment (43 pCi/g). |
| Radium-226 | 5875 / 5877 | 1173 / 1174 | 11.4 | 6.2 | Detected at concentrations above typical background levels (1–5 pCi/g) and RG for soil (5 pCi/g); formed by radioactive decay of Th-230. Not detected above RG for sediment (15 pCi/g). |
| Uranium-238 | 2830 / 5877 | 77 / 1174 | 15.1 | 3.84 | Detected at concentrations above typical background levels (1–5 pCi/g); radioactively decays into Th-230 and Ra-226. Not detected above RG for soil (50 pCi/g) or sediment (150 pCi/g). |
| Radiological Contaminants **Dropped** From Evaluation: | | | | | |
| Thorium-232 | 5652 / 5877 | 1011/ 1174 | 7.13 | 1.86 | Not detected frequently or significantly above typical background levels (0–2 pCi/g). |
| Radium-228 | 5863 / 5877 | 1140 / 1174 | 1.79 | 1.4 | Not detected frequently or significantly above typical background levels (0–1 pCi/g). |
| Thorium-228 | 5644 / 5877 | 1014 / 1174 | 4.98 | 2.24 | Not detected frequently or significantly above typical background levels (0–2 pCi/g). |
| Uranium-235 | 0 / 5877 | 0 / 1174 | N/A | N/A | No positively identified results. |
| Actinium-227 | 268 / 5877 | 13 / 1174 | 5.83 | 3.33 | Not detected frequently or significantly above typical background levels (0.1–0.8 pCi/g). |
| Protactinium-231 | 47 / 5877 | 3 / 1174 | 6.59 | 3.58 | Not detected frequently or significantly above typical background levels (0–1 pCi/g). |
| Americium-241 | 0 / 5877 | 0 / 1174 | N/A | N/A | No positively identified results. |
| Cesium-137 | 1766 / 5877 | 0 / 1174 | 0.63 | N/A | Not detected frequently or significantly above typical background levels (0–0.6 pCi/g). |
| Potassium-40 | 5877 / 5877 | 1174 / 1174 | 27.4 | 21.6 | Not detected frequently or significantly above typical background levels (7–17 pCi/g). |

*Cited typical background levels are ranges of soil and sediment backgrounds listed in Appendix D of the Feasibility Study for the St. Louis North County Site, 2003 [6].

### *Non-radiological Chemical Screening*

Few results were available for chemical contaminants in residential or recreational areas of Coldwater Creek. Annual surface water and sediment monitoring including chemical analyses is available from 1991 to 2014 at a sample location at I-270 upstream of the residential areas. In 2014, two additional monitoring locations were added in residential areas [25-41]. Tables B2 and B3 show a summary of the limited available data for surface water and sediment. Some chemical contaminants were detected in surface water at levels higher than ATSDR comparison values[g] for drinking water, and some contaminants were detected in sediment at levels higher than ATSDR comparison values for residential soil.

The use of drinking water and soil comparison values is for perspective. Drinking water comparison values are concentrations that would not be harmful, even if children and adults used the water as their sole source of drinking water every day. Soil comparison values are concentrations that would not be harmful, even if a small child played in their yard on the soil all day, every day. To ATSDR's knowledge, no one has ever used Coldwater Creek as a drinking water source, and sediment is rarely contacted as frequently or regularly as residential soil. We discuss each non-radiological chemical that exceeded a comparison value below.

*Antimony* – Antimony was detected in surface water, with the highest concentration of 3.3 micrograms per liter (µg/L) slightly above the drinking water comparison value of 2.8 µg/L. The concentration of antimony is not likely to be of concern for surface water exposures, which would involve ingestion of a small fraction of the amount of water assumed for drinking water.

*Arsenic* – Arsenic was detected in surface water at concentrations up to 3.9 µg/L and in sediment at concentrations up to 46 mg/kg. Both are higher than non-cancer and cancer-based comparison values for drinking water and soil. Arsenic is a known carcinogen and exposure contributes to a person's lifetime risk of cancer [99]. The concentrations of arsenic in sediment and surface water at Coldwater Creek may occur naturally from local geologic conditions; they are similar to background arsenic concentrations that have been measured in urban soils. [100,101]. A "worst case" dose using the highest concentrations of arsenic measured in surface water and sediment and exposure and intake assumptions described in Appendix A of this report was below ATSDR's chronic oral minimal risk level for non-cancer effects. The surface water and sediment exposures evaluated in this report would not be expected to contribute significantly to a person's intake of arsenic.

[g] ATSDR calculates comparison values from minimal risk levels published by ATSDR (EMEGs), reference doses published by EPA (RMEGs), or cancer slope factors published by EPA (CREGs). ATSDR currently maintains a tool for viewing comparison values at https://www.atsdr.cdc.gov/sites/brownfields/CVViewer.html.

*Chromium* – Chromium was detected in surface water (up to 15 µg/L) and sediment (up to 80 mg/kg). No comparison value for chromium is available, but a small number of the detected values exceed drinking water and soil comparison values for hexavalent chromium, the most toxic form of chromium. In the absence of a specific source of hexavalent chromium, the less toxic trivalent chromium predominates in surface water and soil/sediment [102]. The concentrations of chromium measured in Coldwater Creek surface water and sediment are within typical ranges measured in the environment [102].

*Lead* – Lead was detected in surface water and sediment; no comparison value for lead exists. Although no safe level of lead has been identified, the highest concentrations measured in surface water (5 µg/L) and sediment (100 mg/kg) are relatively low, within typical urban background ranges [101,103]. The surface water and sediment exposures evaluated in this report would not be expected to contribute substantially to a child's blood lead level.

*Manganese* – Manganese was detected in surface water at concentrations up to 753 µg/L, higher than the drinking water comparison value of 350 µg/L. This concentration of manganese is not likely to be of concern for surface water exposures, which would involve ingestion of a small fraction of the amount of water assumed for drinking water.

*Methylene Chloride* – Methylene chloride was detected in surface water samples at concentrations up to 18 µg/L, higher than the drinking water comparison value of 6.1 µg/L. Methylene chloride is a common laboratory solvent and can easily contaminate environmental samples. The concentration of methylene chloride is not likely to be of concern for surface water exposures, which would involve ingestion of a small fraction of the amount of water assumed for drinking water.

*Molybdenum* – Molybdenum was detected in surface water at concentrations up to 46 µg/L, higher than the drinking water comparison value of 35 µg/L. This concentration of molybdenum is not likely to be of concern for surface water exposures, which would involve ingestion of a small fraction of the amount of water assumed for drinking water.

*Polycyclic Aromatic Hydrocarbons* – Several polycyclic aromatic hydrocarbons (PAHs) were detected in sediment samples at levels above soil comparison values. PAHs are a group of over 100 different chemicals formed during incomplete burning of coal, oil, and gas, garbage, or other organic substances like tobacco or charbroiled meat; PAHs are also found in substances like creosote or roofing tar. Some PAHs are synthesized and used to make products like dyes or plastics [104]. PAHs are a very common contaminant, particularly in urban areas. The concentrations of PAHs detected in sediment in Coldwater Creek, while higher than comparison values, are similar to the ranges detected in urban fill soils [105]. The

surface water and sediment exposures evaluated in this report would not be expected to contribute significantly to a person's intake of PAHs.

*Sodium* – Sodium was detected in surface water at concentrations up to 138,000 µg/L. This exceeds the drinking water advisory of 20,000 µg/L for people on sodium-restricted diets [106]. Surface water exposure would be unlikely to contribute significantly to an individual's overall sodium intake.

*Thallium* – Thallium was detected in surface water samples at concentrations up to 3 µg/L, higher than the drinking water comparison value of 0.2 µg/L. It was detected in sediment at concentrations up to 5 mg/kg, higher than the soil comparison value of 0.78 mg/kg. A "worst case" dose using the highest concentration of thallium measured in surface water and sediment and exposure and intake assumptions described in Appendix A of this report was well below no effect levels in animal studies and only slightly higher than the provisional reference dose developed by EPA for thallium. The surface water and sediment exposures evaluated in this report would not be expected to contribute significantly to a person's intake of thallium [107].

*Uranium* – Uranium was detected in surface water samples at concentrations up to 10 µg/L, lower than the EPA's maximum contaminant level for drinking water but higher than ATSDR's drinking water comparison value of 1.4 µg/L. Uranium was detected in sediment at concentrations up to 79 mg/kg, higher than the soil comparison value of 14 mg/kg. ATSDR previously identified U-238 as a contaminant for further evaluation; possible non-radiological effects of exposure to uranium are included with the evaluation of possible radiological effects from U-238.

With the exception of uranium, ATSDR did not evaluate any of the above non-radiological contaminants further. Chemical contaminants (whether or not they originate from the SLAPS and HISS/Futura sites) could possibly contribute some risk in recreational or residential scenarios. However, no data on chemicals in floodplain soil are available, and not enough surface water and sediment data are available to evaluate potential exposures fully. Further sampling and evaluation would be needed to fully assess contribution of non-radiological contaminants to community exposure.

**Table B 2. Chemical contaminants detected at least once above comparison values in Coldwater Creek surface water near residential areas***

| Chemical | Number of detections / number of samples | Highest concentration detected in µg/L | Drinking water comparison value in µg/L** | CV source |
|---|---|---|---|---|
| Antimony | 6 / 31 | 3 | 2.8 | RMEG |
| Arsenic | 25 / 31 | 4 | 2.1 / 0.016 | EMEG / CREG |
| Chromium | 12 / 31 | 15 | 6.3 | EMEG for hexavalent chromium |
| Lead | 10 / 14 | 5 | none† | N/A |
| Manganese | 14 / 14 | 753 | 350 | RMEG |
| Methylene chloride | 3 / 11 | 18 | 6.1 | CREG |
| Molybdenum | 31 / 31 | 46 | 35 | RMEG |
| Sodium | 14 / 14 | 138,000 | 20,000 | DWA |
| Thallium | 1 / 31 | 3 | 0.2 | RSL |
| Uranium | 10 / 24 | 10 | 30 / 1.4 | MCL / intermediate EMEG for soluble salts |

*Data collected from 1991-2014 at a point near I-270 upstream of residential areas and in 2014 from two points within residential areas [25-41].

**No one has ever used Coldwater Creek as a drinking water source. Comparing the surface water results against drinking water CVs is for perspective only.

†No ATSDR health-based comparison value for lead in drinking water exists because there is no clear threshold for some of the more sensitive health effects from lead exposure. The EPA action level for lead in drinking water is 15 µg/L.

CV – comparison value
µg/L – micrograms per liter
RMEG – remedial media evaluation guide
EMEG – environmental media evaluation guide
CREG – cancer risk evaluation guide
MCL – maximum contaminant level
N/A – not applicable
DWA – drinking water advisory
RSL – regional screening level

**Table B 3. Chemical contaminants detected at least once above comparison values in Coldwater Creek sediment near residential areas***

| Chemical | Number of detections / number of samples | Highest concentration detected in mg/kg | Soil comparison value in mg/kg** | CV source |
|---|---|---|---|---|
| Arsenic | 33 / 34 | 46 | 17 | EMEG |
| Chromium | 34 / 34 | 80 | 51 | EMEG for hexavalent chromium |
| Lead | 16 / 16 | 100 | none† | Not applicable |
| Polycyclic aromatic hydrocarbons: | | | | |
| Benz(a)anthracene | 13 / 14 | 40 | 1.1 | RSL |
| Benzo(a)pyrene* | 13 / 14 | 35 | 0.12 | CREG |
| Benzo(b)fluroanthene | 13 / 14 | 30 | 1.1 | RSL |
| Benzo(g,h,i)perylene | 7 / 14 | 6 | none | Not applicable |
| Benzo(k)fluoranthene | 13 / 14 | 34 | 11 | RSL |
| Carbazole | 2 / 14 | 1 | none | Not applicable |
| Chrysene | 13 / 14 | 47 | 110 | RSL |
| Dibenz(a,h)anthracene* | 3 / 14 | 1 | 0.11 | RSL |
| Indeno(1,2,3-cd)pyrene* | 8 / 14 | 5 | 1.1 | RSL |
| Phenanthrene | 13 / 14 | 93 | none | Not applicable |
| Thallium | 12 / 34 | 5 | 0.78 | RSL |
| Uranium | 15 / 29 | 79 | 11 | Intermediate EMEG for soluble salts |

*Data collected from 1991-2014 at point near I-270 upstream of residential areas and in 2014 from two points within residential areas [25-41].

**Sediment comparison values are not available. Comparing the sediment results against soil CVs is for perspective only.

†No ATSDR health-based comparison value for lead in soil or sediment exists because there is no clear threshold for some of the more sensitive health effects from lead exposure. The EPA RSL for residential soil lead is 400 mg/kg.

CV – comparison value
EMEG – environmental media evaluation guide
N/A – not applicable
mg/kg – milligrams per kilogram
CREG – cancer risk evaluation guide
DWA – drinking water advisory
RMEG – remedial media evaluation guide
MCL – maximum contaminant level
RSL – regional screening level

### *Relevant Toxicological Information for Contaminants Retained for Further Evaluation*

The contaminants selected for further evaluation are Th-230, Ra-226, and U-238. The information presented below may include discussion of effects of other isotopes of thorium, radium, or uranium. How a radiological substance behaves in the human body is primarily determined by its chemical nature, so effects of other isotopes are relevant and likely similar, as long as the half-lives in comparison to the human lifespan are similar.

Th-230, Ra-226, and U-238 are naturally occurring radioisotopes. All give off radiation in the form of alpha particles as they decay, and the energy of the alpha radiation emitted is similar. These three radioisotopes all have very long half-lives (many times the human lifespan) and so they will not decay appreciably during a person's lifetime. For these reasons, ATSDR adds the individual isotopes' doses (to an organ or to the whole body) to assess their potential to cause radiological effects.

For Th-230 and Ra-226, radiological effects are expected to predominate (that is, no health effects from their chemical interactions with the body are known to occur before effects from the radiation are observed). Uranium, on the other hand, may cause chemical damage to the kidneys before any radiation effects would be evident. While we include radiological dose from uranium as contributing to the effects of radium and thorium, we also separately consider non-radiological effects of uranium.

#### *Properties, Uses, Distribution in the Body, and Toxicological Effects*

##### Radium

Radium exhibits chemical properties of the alkaline earth metals: the pure element is shiny, silvery white, and somewhat reactive at standard temperature and pressure. All forms of radium are radioactive. Ra-226 has the longest half-life, about 1,600 years [108]. Ra-226 produces radon gas (Rn-222), which is known to cause lung cancer when inhaled.

Historically, radium was used in paint for luminescent clock and watch dials and in medical treatments and devices. Health effects from the occupational and medical exposures that occurred from these uses were studied for decades and form much of our understanding of radium's harmful effects [55,56].

When inhaled, radium will mostly stay in the lungs. When ingested, only about 20% of radium will be taken into the bloodstream. It goes throughout the body, but it concentrates in the skeletal system due to its chemical similarity to calcium and because soft tissues release the radium relatively quickly compared to bone.

Long-term studies of the radium dial painters showed increases in bone sarcomas (bone cancers) and cancers of the sinuses and jaw (also called head cancers). The Ra-226 isotope appeared to be

the main causative agent for head cancers, as these occurred mainly among those exposed to Ra-226 only. No bone cancers were observed in workers with weighted skeletal doses less than 1,000 rads (for alpha radiation, 1,000 rads is equivalent to 20,000,000 mrem) [55,109]. Patients treated with high doses of Ra-224 (mean bone surface dose of 3,000 rads [60,000,000 mrem]) also showed elevations in bone cancers compared to expected rates, as did patients treated with lower doses [109]. The lowest bone surface dose that resulted in a bone cancer was 900 rads (18,000,000 mrem) [109]. Other cancers suggested or shown to result from these radium exposures include cancers of the lung and breast, leukemia, or multiple myeloma; the evidence for these cancers was not as strong as evidence for bone cancers [109].

### Thorium

Thorium in pure form is a silvery, moderately hard, malleable metal, part of the actinide group of elements. All forms of thorium are radioactive. Most studies and information on thorium relate to Th-232, as it has a half-life of over 14 billion years and comprises more than 99% of the thorium in nature. Th-230, while not as prevalent, has a half-life of over 75,000 years and may have similar biological effects as Th-232.

Thorium is used in magnesium alloys, tungsten filaments for light bulbs, and mantles for incandescent gas lanterns. Several epidemiological studies, summarized below, have followed workers in these industries to determine effects of thorium exposure.

In the early to mid-1900s, Th-232 was used in a colloidal material called Thorotrast injected in patients to increase contrast for x-rays. The very small particle size of Thorotrast and its route via injection make distribution and clearance of Th-232 in the body different from thorium that is ingested or inhaled. Therefore, health data from Thorotrast patients is of limited use in determining possible effects from environmental thorium exposures [45].

When inhaled, thorium may stay in the lungs or dissolve throughout the body, depending on its chemical form. Thorium oxides and hydroxides dissolve slowly in lung fluid and are generally retained in the lungs; thorium nitrate and all other forms exhibit moderate lung fluid solubility and may enter the bloodstream [45]. When ingested, only a small fraction of thorium will be taken into the bloodstream; most is eliminated in feces. Inhaled or ingested thorium taken into the bloodstream will go throughout the body and concentrate in the skeletal system similarly to radium [109,45,110].

Occupational exposure studies of thorium industrial workers who inhaled thorium ore dust have had inconsistent findings. Studies have shown that thorium workers had higher rates of death from respiratory disease, lung cancer, pancreatic cancer, or rectal cancer. But the studies did not show a strong correlation between the number of deaths and exposure, job type, or length of employment. This brings into question whether the excess deaths were a result of thorium

exposure or some other factor (such as silica exposure or higher rates of smoking not accounted for) [110].

Because thorium concentrates on bone surfaces and may remain in the bone matrix for many years, the toxicological issue of greatest concern is effects in the bone caused by radiation from thorium and its decay products over time [110].

### Uranium

Uranium is a silvery heavy metal and is part of the actinide group of elements. All forms of uranium are radioactive. U-238, with a half-life of four and a half billion years, comprises over 99.7% of all the uranium on earth. U-238 forms both Th-230 and Ra-226, among other products, as it radioactively decays.

Uranium is present naturally throughout the world in soil, rock, and water. Since the discovery and development of processes to harness energy from nuclear fission, uranium ores have been mined and extracted for use in weapons or power generation. Studies of uranium miners, nuclear industry workers, and people exposed to high concentrations of uranium in groundwater have contributed to knowledge about uranium exposure.

When inhaled, uranium will mostly stay in the lungs. When ingested, only a small fraction (less than 3%) of uranium will be taken into the bloodstream. Most of the uranium in blood is filtered by the kidneys and leaves the body in urine; the remainder is distributed throughout the body and retained primarily in the bone, kidneys, or other soft tissue.

The International Agency for Research on Cancer (IARC) has determined that there is inadequate evidence in humans and limited evidence in experimental animals for the carcinogenicity of natural uranium [109]. The main toxicological effect of uranium is chemical damage to kidney tubules, the structures in the kidney that maintain balance between waste products and needed compounds in the bloodstream. Uranium exposure leads to microscopic changes in the tubules, which with time or at higher exposures can impair the kidney's function. Inhaling insoluble uranium at high levels can damage the respiratory tract [65].

## Appendix C. Derivation of Exposure Point Concentrations

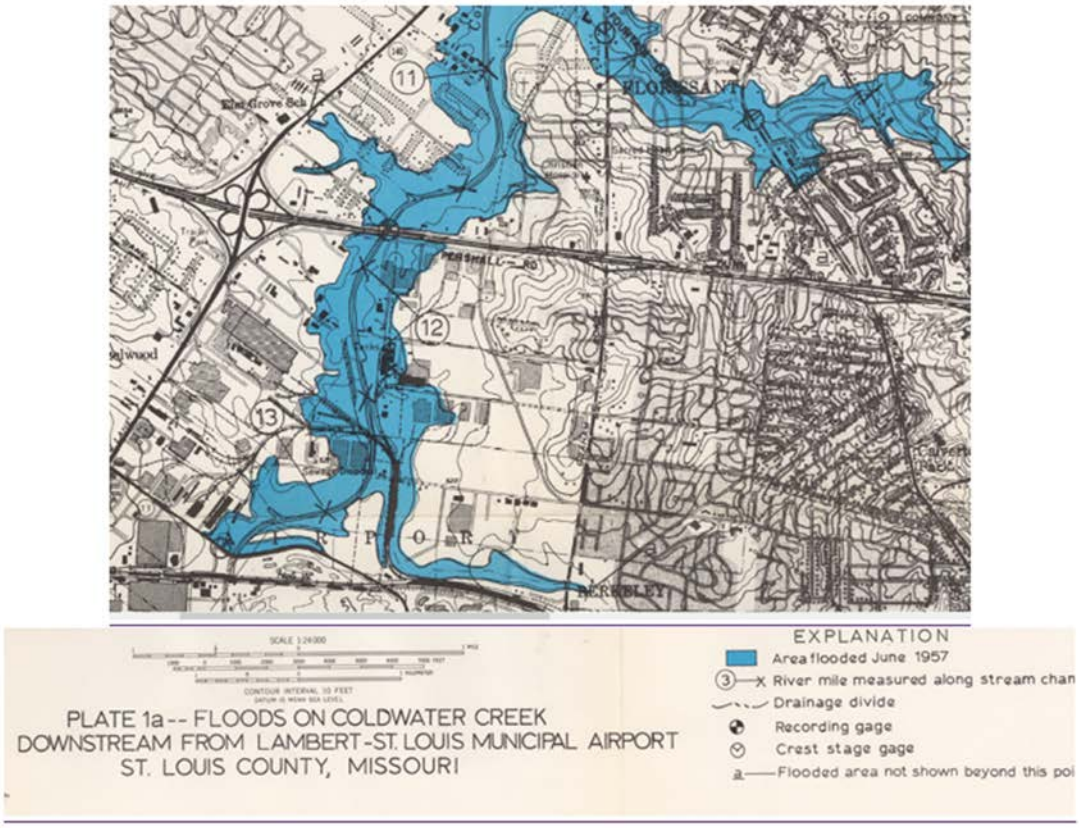
To determine how much of each contaminant is taken in by children and adults who might accidentally swallow or breathe in soil, sediment, or surface water from in or near Coldwater Creek, ATSDR determined representative exposure point concentrations for the contaminants of concern.

### Note on Conservative Assumptions Used

Although much sampling data exists, ATSDR did not use data from south of I-270 to estimate recreational or residential exposures because this is and has been primarily an industrial area with little opportunity for the types of recreational and residential exposure evaluated in our report. However, a review of the historical activities and sampling data from these areas justify the use of conservative assumptions to estimate exposure point concentrations in the residential areas downstream from historical source areas, as described below.

- **The waste could have had a high concentration of Th-230 and entered the creek over many years.** Historical reports indicated that the residues stored at SLAPS and later moved to HISS contained over 75,000 pCi/g of Th-230 [111,112]. In the late 1970s, although Th-230 was not measured, SLAPS showed off-site radiological contamination from surface water erosion of contaminated materials [113]. At HISS, 1977 sampling of surface soil and abandoned waste showed Th-230 concentrations approaching or exceeding those reported in the residues [114]. Even in the 1990s, piles near HISS showed Th-230 concentrations in the hundreds to thousands of pCi/g [6,115]. Because no controls were in place, we presume that contaminants from the original residues could have entered the creek on an ongoing, continual basis from SLAPS between 1946 and 1966, and from HISS between 1966 and 1974. Even after these dates, contaminants may have entered the creek from erosion of contaminated soil remaining at the sites after removal of the main waste piles.
- **The waste flowed downstream.** The contaminants would have associated with creek sediment and moved downstream according to hydrological principles. Contaminants may have accumulated where sediment typically deposits. In addition, contaminants could have been washed out of the creek into the floodplain during floods and remained in the floodplain after waters receded. The residential areas of concern in this evaluation are downstream from SLAPS and HISS, but we do not have enough information to predict exactly where the contamination went and when.
- **Available data may not describe distant past concentrations due to natural and human dispersion of sediment.** For example, much of the area around SLAPS, HISS, and downstream areas was inundated in a 1957 flood (see Figure C 1 below) [116]. Also, developers commonly used floodplain soil from the creek for fill in other locations while downstream areas were being developed in the 1950s and later. These activities and events add significant uncertainty to conclusions about past exposures based on sampling data collected many years later.

**Figure C 1. U.S. Geological Survey map showing areas around and downstream of historical source areas flooded in 1957 (from [116])**




## Floodplain Soil

### *Depth of Soil Used to Estimate Exposure*

ATSDR's standard procedure uses soil concentrations in the top three inches (from 0-3 inches below ground surface) to estimate exposure point concentrations. This is the depth of soil primarily contacted during normal activities on the soil. The data for Coldwater Creek included concentrations in floodplain soil collected from 0-6 inches below ground surface. We assumed these 0-6 inch concentrations to represent what children and adults could be exposed to while playing, biking, gardening, or landscaping near the creek. ATSDR assumes no cover material on top of the soil (grass, leaves, pavement, etc.) to obtain the most conservative estimate of potential exposures.

### *Past vs. Recent Exposure Concentration*

The only environmental sampling data available for recreational or residential stretches of Coldwater Creek include floodplain soil and sediment data from 2014–2016 and limited sediment data from the late 1980s. ATSDR is reasonably confident that surface samples from the

2014–2016 floodplain soil sampling can be used to estimate recent exposures within the past 10 or 15 years.

The 2014–2016 data, however, are inadequate to describe exposures that occurred in the more distant past, such as the 1960s to 1990s. No information on floodplain soil in residential stretches of the creek from this time period is available. Past floodplain soil contaminant concentrations would depend on how much contamination had washed down from the historical source areas at various times, how much flooding occurred as contaminants washed downstream, whether subsequent flood events scoured off surface contamination or buried it, and other physical factors. Historical reports describing contamination at the historical source areas, surrounding properties, drainage ditches, haul roads, and Coldwater Creek did not contain adequate data to describe past contaminant levels in the floodplain in recreational or residential stretches of the creek [20,117–129]. However, as described above beginning on page C-1, data from historical source areas justify the use of conservative assumptions to estimate past exposure.

ATSDR examined the 2014–2016 floodplain soil data and found that soil core samples from below the surface often contained the highest concentrations of Th-230. One explanation for this finding is that contamination initially deposited on the surface was covered up over time. To gain a conservative estimate of the possible past surface concentrations, ATSDR assumed that for each location sampled, the highest result at any depth was once at the ground surface and therefore available for exposure. This assumption is a conservative one based on recent environmental sampling data from the area of concern. However, ATSDR notes that the actual concentrations of contaminants in the distant past will never be known and could have been lower or higher than estimated in this report.

#### *Soil Exposure Point Concentration*

ATSDR uses many conservative assumptions in estimating potential community exposures. When presented with data from a wide area such as the 1.2 miles along Coldwater Creek represented by the floodplain soil data set, we look at the data as a whole but also examine particular areas where a person might have regular exposure. Although a person would not go to the same exact spot every time they do something by the creek, they could potentially go to the same smaller area regularly. We use a statistic called the upper confidence limit on the mean (the 95% UCL) to conservatively estimate the contaminant concentration in the area a person could be expected to go to when they go to the creek. There are a number of ways to estimate the 95% UCL depending on how the data are distributed; ATSDR used a publicly available statistical program called ProUCL to examine the data and suggest the appropriate estimate of the 95% UCL [42].

ATSDR followed the same general mapping procedure (described below) for determining exposure point concentrations for past and recent exposures for Th-230, Ra-226, and U-238. For

past exposures, we mapped the maximum concentration at any depth as an estimate of what may have been present at the surface. These maps are shown in Figures C2, C3, and C4, for Th-230, Ra-226, and U-238, respectively. For recent exposures, we mapped surface soil concentration (corresponding Figures C5, C6, and C7).

For either past or recent exposures, Th-230 was present more often and at higher levels than Ra-226 or U-238. As shown, for example, in Figure C2, ATSDR looked at the Th-230 soil results in various ways to estimate the exposure point concentration. First, we separated the floodplain into nine sectors (labeled A through I) along the creek and looked at data from the right and left sides of the creek in each sector. We also considered data from small "hotspot" areas where exceedances of the FUSRAP remedial goal appeared to be clustered ("hotspot" boxes shown on the figure). We further examined a smaller area which appeared to be in or particularly close to residential yards. Using results from each specific area, we used ProUCL to estimate the appropriate 95% UCL for that area. Table C1 shows the statistics for each unit examined for past Th-230 soil exposure. ATSDR used the highest recommended UCL for all the units examined for the Th-230 soil exposure point concentration. Table C1 also shows the corresponding recommended UCLs for Ra-226 and U-238 for the units evaluated for Th-230.

For estimating soil exposure point concentrations for recent exposures, we followed the same process as for past exposures, using surface soil concentrations instead of the maximum concentration at any depth. The recent exposures were analyzed using different "hotspot" boxes than for past exposures, because the Th-230 surface data was clustered differently. All other units evaluated were the same as for past exposures. Figures C5-C7 and Table C2 present recent data analyzed and results.

**Figure C 2. Map of Th-230 soil maximum data for Coldwater Creek – PAST exposures**

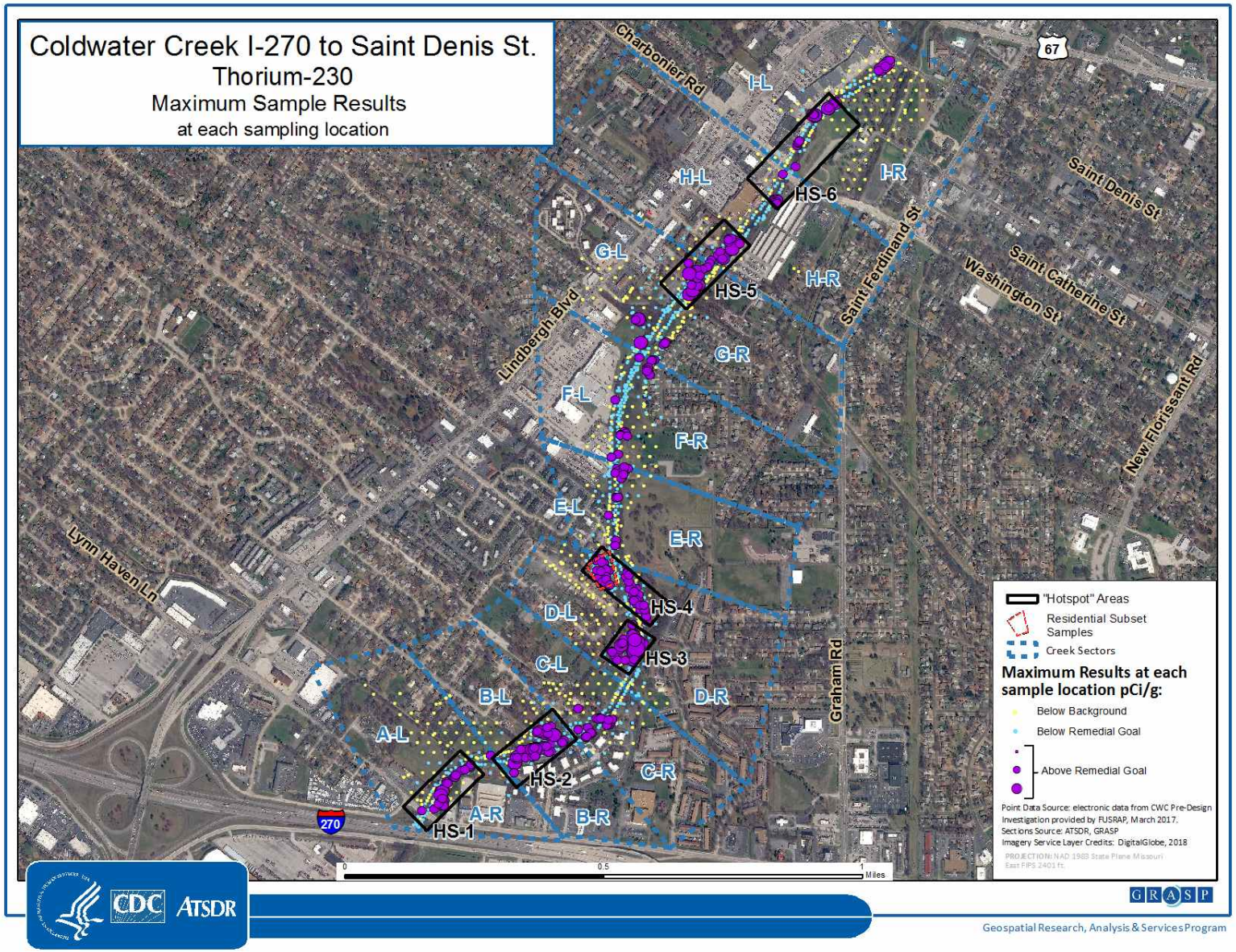


**Figure C 3. Map of Ra-226 soil maximum data for Coldwater Creek – PAST exposures**

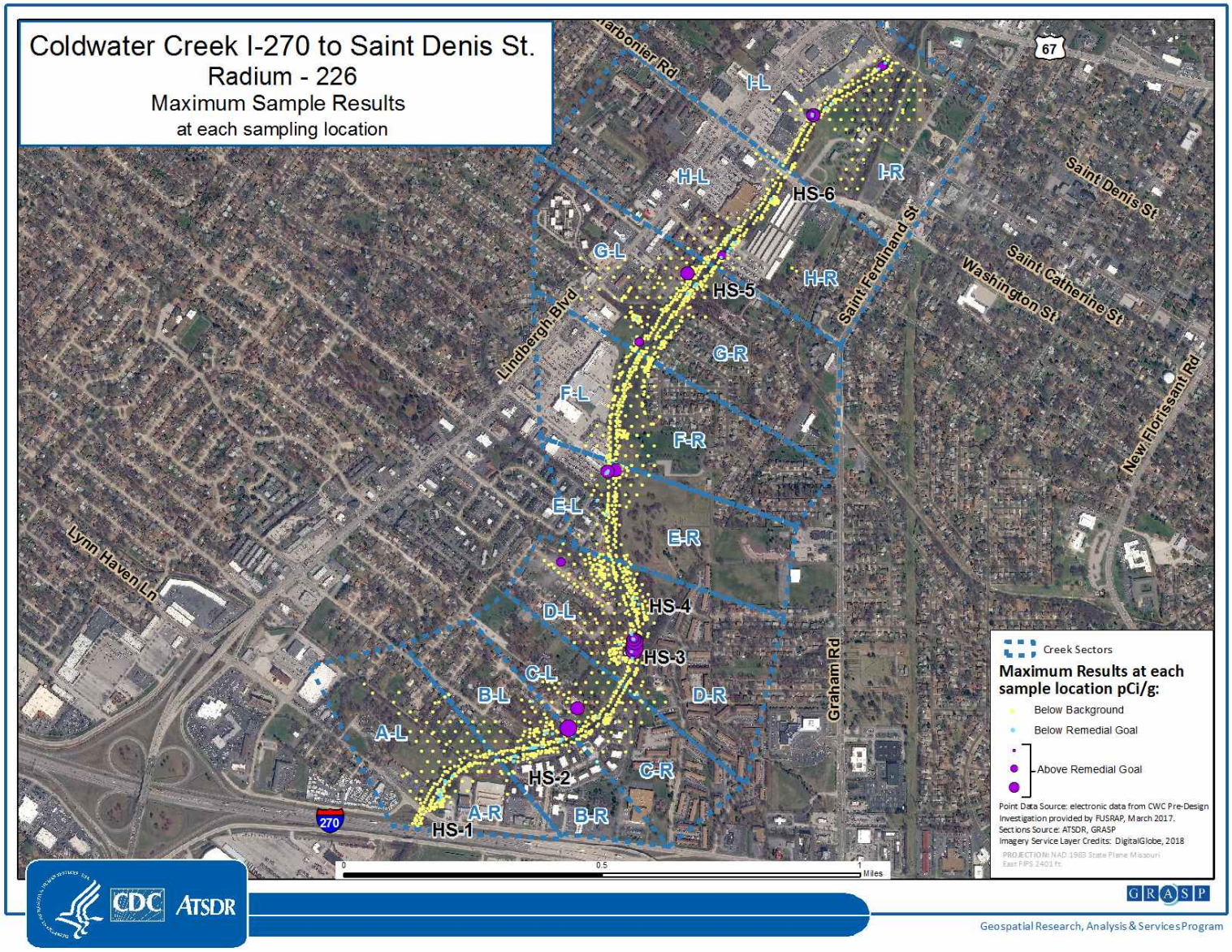


**Figure C 4. Map of U-238 soil maximum data for Coldwater Creek – PAST exposures**

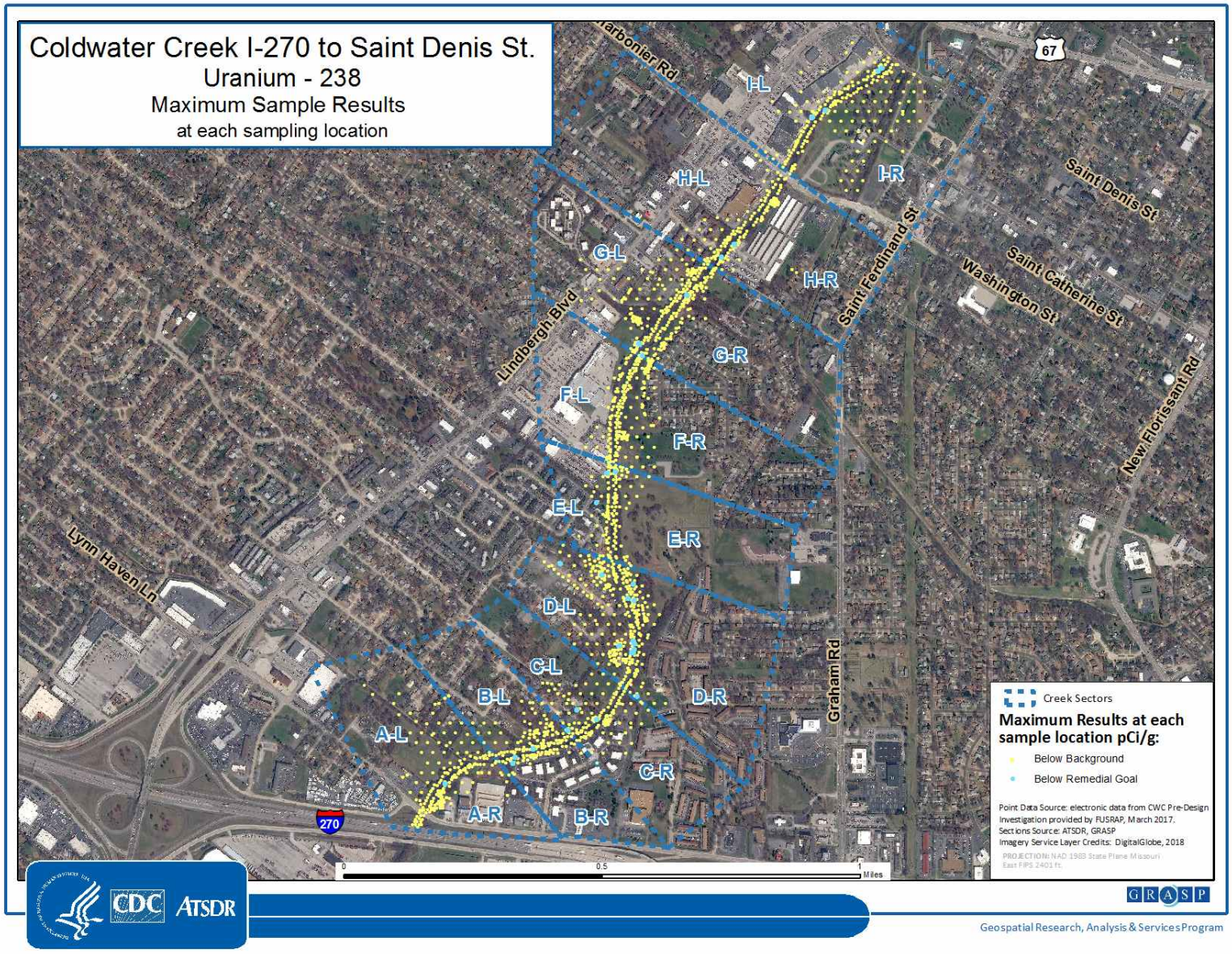


**Table C 1. Recommended 95% UCLs for maximum soil for various units along Coldwater Creek – PAST exposures**

| Maximum at any depth soil data selection | # Positively identified Th-230 results | # of Th-230 results > background † | # of Th-230 results > remedial goal†† | Th-230 mean (pCi/g) | **Recommended Th-230 UCL value* (pCi/g)** | Th-230 data distri-bution** | Ra-226 UCL* (pCi/g) | U-238 UCL* (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| Sector A - left | 96 | 35 | 2 | 3.7 | **5.0** | None | 1.6 | 1.1 |
| Sector A - right | 102 | 85 | 30 | 13.8 | **20.6** | None | 2.0 | 1.4 |
| Sector B - left | 116 | 79 | 33 | 16.5 | **26.7** | None | 2.0 | 1.5 |
| Sector B - right | 54 | 44 | 15 | 15.2 | **20.5** | L | 2.1 | 1.6 |
| Sector C - left | 78 | 42 | 7 | 6.7 | **10.7** | None | 2.0 | 1.7 |
| Sector C - right | 66 | 47 | 16 | 8.7 | **10.4** | L, G | 1.8 | 1.4 |
| Sector D - left | 221 | 144 | 55 | 17.7 | **30.6** | None | 2.0 | 1.7 |
| Sector D - right | 118 | 86 | 29 | 10.9 | **15.8** | None | 1.8 | 1.4 |
| Sector E - left | 84 | 50 | 2 | 5.3 | **8.5** | None | 1.9 | 1.4 |
| Sector E - right | 75 | 47 | 14 | 8.7 | **13.7** | None | 1.9 | 1.5 |
| Sector F - left | 62 | 40 | 3 | 5.7 | **10.0** | L | 1.5 | 1.4 |
| Sector F - right | 145 | 109 | 14 | 6.7 | **8.8** | None | 1.6 | 1.2 |
| Sector G - left | 162 | 108 | 21 | 8.4 | **13.8** | None | 1.6 | 1.2 |
| Sector G - right | 119 | 66 | 16 | 9.4 | **16.4** | None | 1.6 | 1.2 |
| Sector H - left | 71 | 41 | 9 | 7.4 | **12.9** | None | 1.5 | 1.2 |
| Sector H - right | 71 | 58 | 21 | 18.4 | **24.8** | L | 1.9 | 1.8 |
| Sector I - left | 95 | 48 | 16 | 14.0 | **27.6** | None | 1.7 | 1.6 |
| Sector I - right | 122 | 41 | 5 | 5.0 | **9.3** | None | 1.5 | 1.2 |
| "Hot spot"-1 | 123 | 93 | 31 | 12.2 | **18.0** | None | 1.9 | 1.3 |
| " Hot spot "-2 | 149 | 120 | 48 | 18.1 | **26.9** | None | 2.1 | 1.4 |
| " Hot spot "-3 | 98 | 80 | 32 | 26.7 | **54.5** | L | 2.5 | 2.3 |
| " Hot spot "-4 | 141 | 121 | 52 | 16.0 | **22.0** | None | 1.7 | 1.4 |
| " Hot spot "-5 | 158 | 114 | 43 | 15.8 | **24.5** | None | 1.8 | 1.3 |
| " Hot spot "-6 | 118 | 79 | 25 | 13.9 | **24.2** | None | 1.8 | 1.6 |
| Residential subset | 39 | 37 | 23 | 26.3 | **33.7** | G | 1.9 | 2.0 |

†ATSDR considered 3 pCi/g to represent a value statistically different than background

††FUSRAP remedial goal for Th-230 in surface soil is 14 pCi/g

*95% Upper Confidence Limit recommended by ProUCL statistical program based on data distribution [42].

**None: No discernible distribution; G: approximate or adjusted gamma distribution; L: approximate lognormal distribution

**Value used** as exposure point concentration for "past" soil exposures

**Figure C 5. Map of Th-230 surface soil data for Coldwater Creek – RECENT exposures**

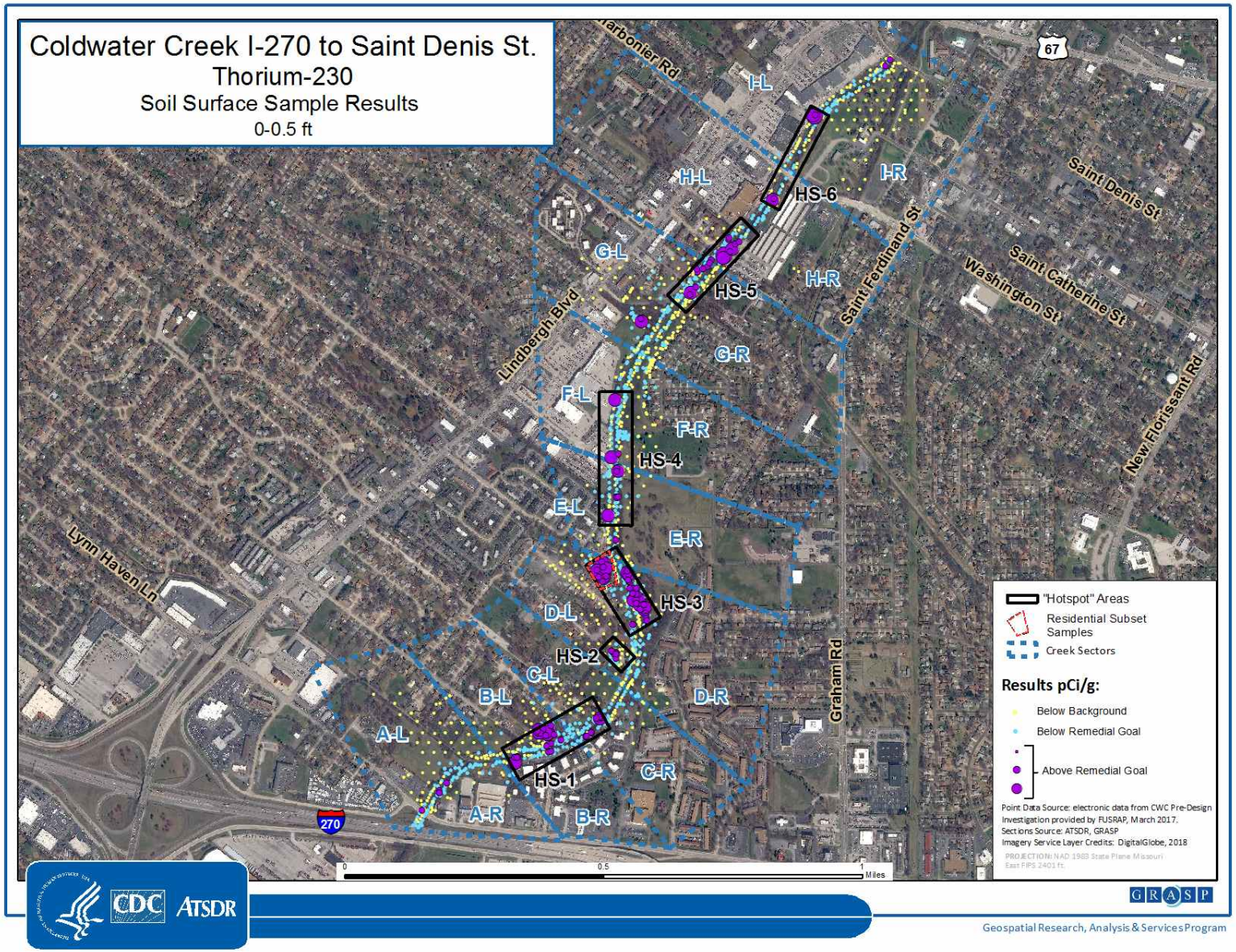


**Figure C 6. Map of Ra-226 surface soil data for Coldwater Creek – RECENT exposures**

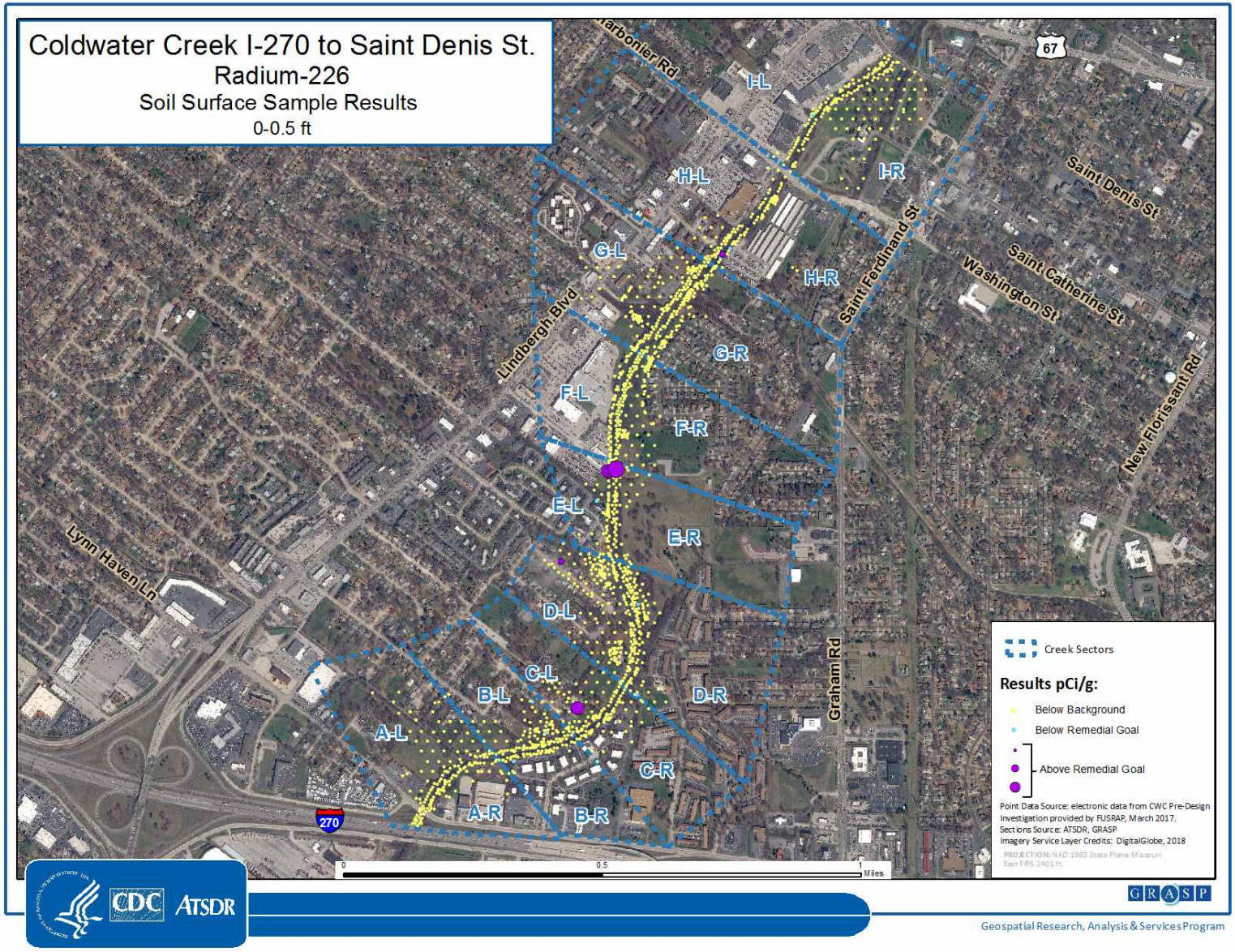


**Figure C 7. Map of U-238 surface soil data for Coldwater Creek – RECENT exposures**

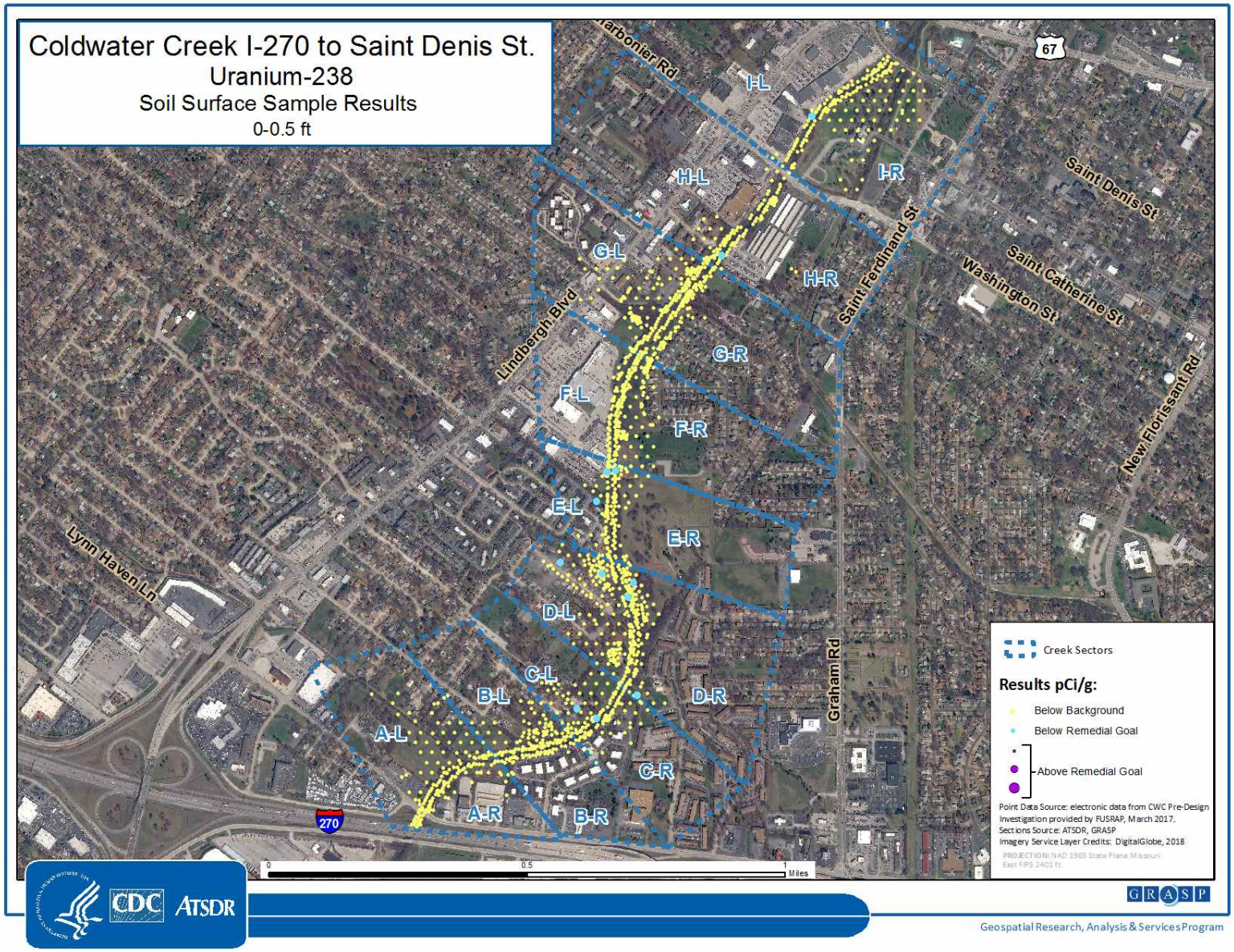


**Table C 2. Recommended 95% UCLs for surface soil for various units along Coldwater Creek – RECENT exposures**

| Surface soil data selection | # Positively identified Th-230 results | # of Th-230 results > background † | # of Th-230 results > remedial goal†† | Th-230 mean (pCi/g) | **Recommended Th-230 UCL value* (pCi/g)** | Th-230 data distri-bution** | Ra-226 UCL* (pCi/g) | U-238 UCL* (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| Sector A - left | 111 | 31 | 1 | 3.0 | **4.1** | None | 1.5 | 0.7 |
| Sector A - right | 92 | 71 | 4 | 5.5 | **7.5** | L | 1.7 | 0.8 |
| Sector B - left | 128 | 76 | 19 | 8.0 | **12.0** | None | 1.6 | 1.0 |
| Sector B - right | 55 | 40 | 10 | 9.5 | **11.8** | L, G | 1.8 | 0.7 |
| Sector C - left | 97 | 49 | 5 | 5.2 | **7.6** | None | 1.6 | 0.9 |
| Sector C - right | 63 | 40 | 5 | 5.7 | **7.1** | L | 1.6 | 0.9 |
| Sector D - left | 245 | 134 | 32 | 7.6 | **10.6** | None | 1.5 | 0.8 |
| Sector D - right | 142 | 97 | 34 | 9.8 | **13.8** | None | 1.7 | 1.0 |
| Sector E - left | 85 | 48 | 1 | 4.4 | **4.8** | L | 1.9 | 1.3 |
| Sector E - right | 94 | 51 | 7 | 5.7 | **8.5** | None | 1.8 | 1.0 |
| Sector F - left | 58 | 38 | 2 | 5.2 | **9.6** | None | 1.4 | 1.1 |
| Sector F - right | 166 | 81 | 1 | 4.0 | **5.1** | None | 1.5 | 0.7 |
| Sector G - left | 180 | 93 | 8 | 4.6 | **6.2** | None | 1.4 | 0.7 |
| Sector G - right | 135 | 47 | 3 | 3.6 | **5.4** | None | 1.4 | 0.7 |
| Sector H - left | 60 | 37 | 4 | 5.1 | **6.0** | L, G | 1.3 | 0.8 |
| Sector H - right | 67 | 47 | 8 | 11.3 | **23.4** | None | 1.6 | 1.3 |
| Sector I - left | 70 | 33 | 5 | 6.6 | **14.4** | None | 1.3 | 0.9 |
| Sector I - right | 141 | 39 | 0 | 2.9 | **3.7** | None | 1.3 | 0.7 |
| "Hot spot"-1’ | 210 | 166 | 39 | 9.7 | **12.8** | None | 1.8 | 0.8 |
| " Hot spot "-2’ | 37 | 23 | 8 | 7.8 | **12.7** | None | 1.6 | 1.4 |
| " Hot spot "-3’ | 185 | 143 | 58 | 12.9 | **17.3** | None | 1.7 | 0.9 |
| " Hot spot "-4’ | 226 | 157 | 10 | 6.0 | **7.9** | None | 1.7 | 1.0 |
| " Hot spot "-5’ | 176 | 116 | 19 | 7.6 | **12.5** | None | 1.4 | 0.9 |
| " Hot spot "-6’ | 77 | 35 | 5 | 6.6 | **14.2** | None | 1.4 | 1.1 |
| Residential subset | 44 | 41 | 22 | 21.5 | **27.3** | L, G | 1.8 | 1.8 |

†ATSDR considered 3 pCi/g to represent a value statistically different than background

††FUSRAP remedial goal for Th-230 in surface soil is 14 pCi/g

*95% Upper Confidence Limit recommended by ProUCL statistical program based on data distribution [42].

**None: No discernible distribution; G: approximate or adjusted gamma distribution; L: approximate lognormal distribution

**Value used** as exposure point concentration for “recent” soil exposures

### Sediment

For past sediment exposures, ATSDR used sediment sampling from the late 1980s. These data may not fully describe potential exposures from as early as the 1960s. To be conservative, we used the maximum concentration of Th-230, Ra-226, and U-238 at any depth to describe concentration at each location. We followed a similar mapping procedure as described for soil, except we did not separate left and right sides of the creek, and we did not include "hotspot" boxes or the residential subsets. For recent exposures, we used the same procedure except using the more recent sediment data collected from 2014–2016. Figures C8–C13 and Tables C3 and C4 present the mapping and ProUCL results for past and recent sediment exposure point concentration. We used the highest recommended UCL for each contaminant as the sediment exposure point concentration.

**Figure C 8. Map of Th-230 sediment maximum data for Coldwater Creek – PAST exposures**

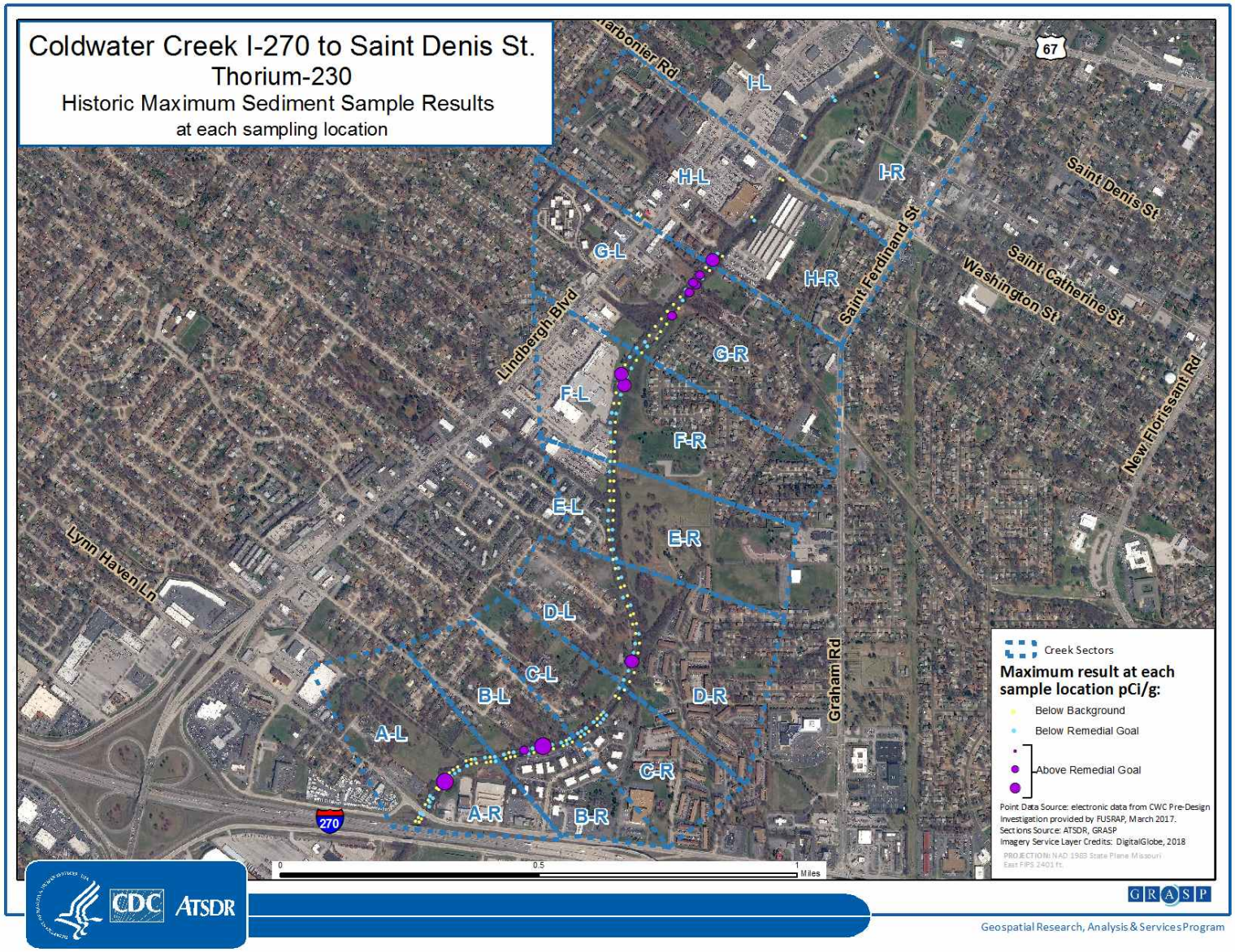


**Figure C 9. Map of Ra-226 sediment maximum data for Coldwater Creek – PAST exposures**

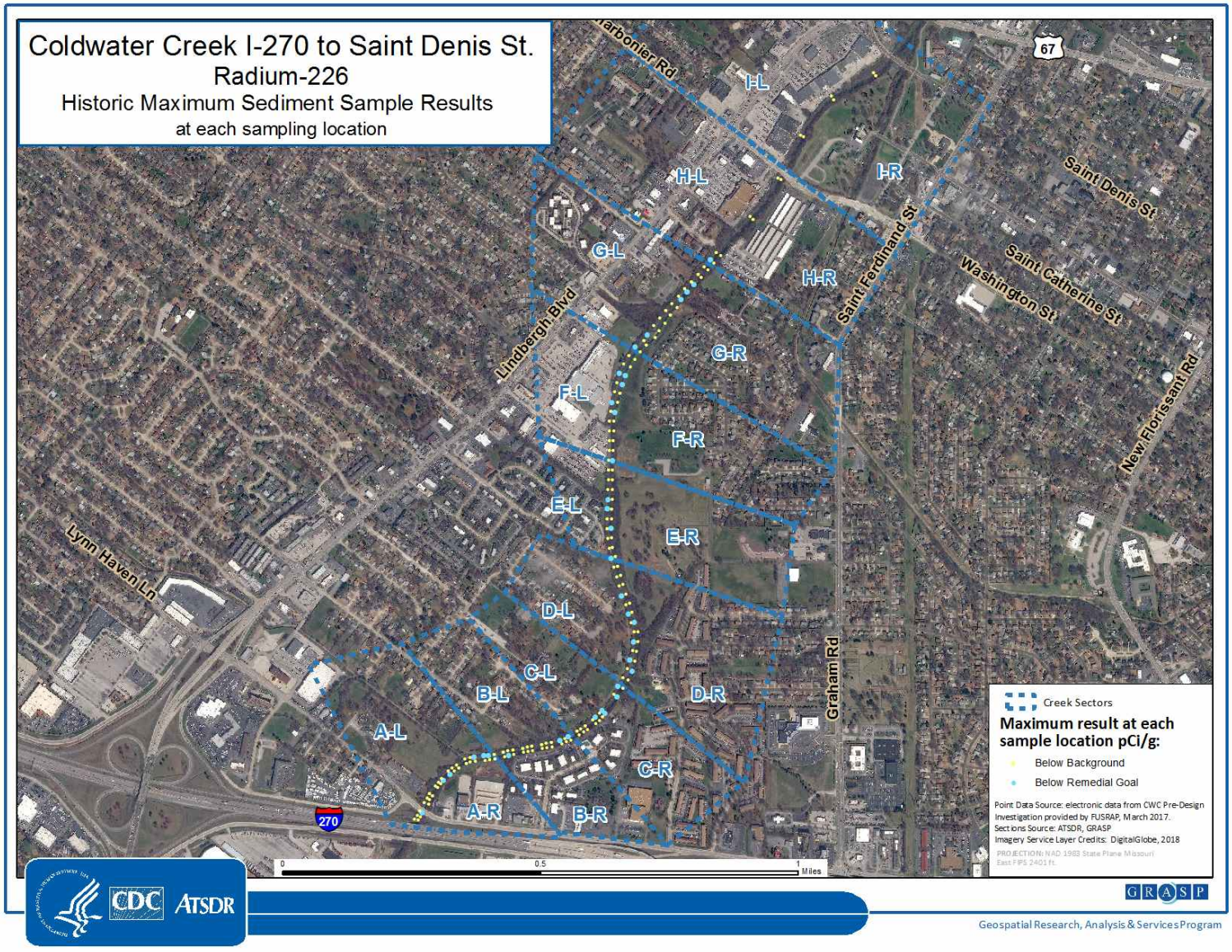


**Figure C 10. Map of U-238 sediment maximum data for Coldwater Creek – PAST exposures**

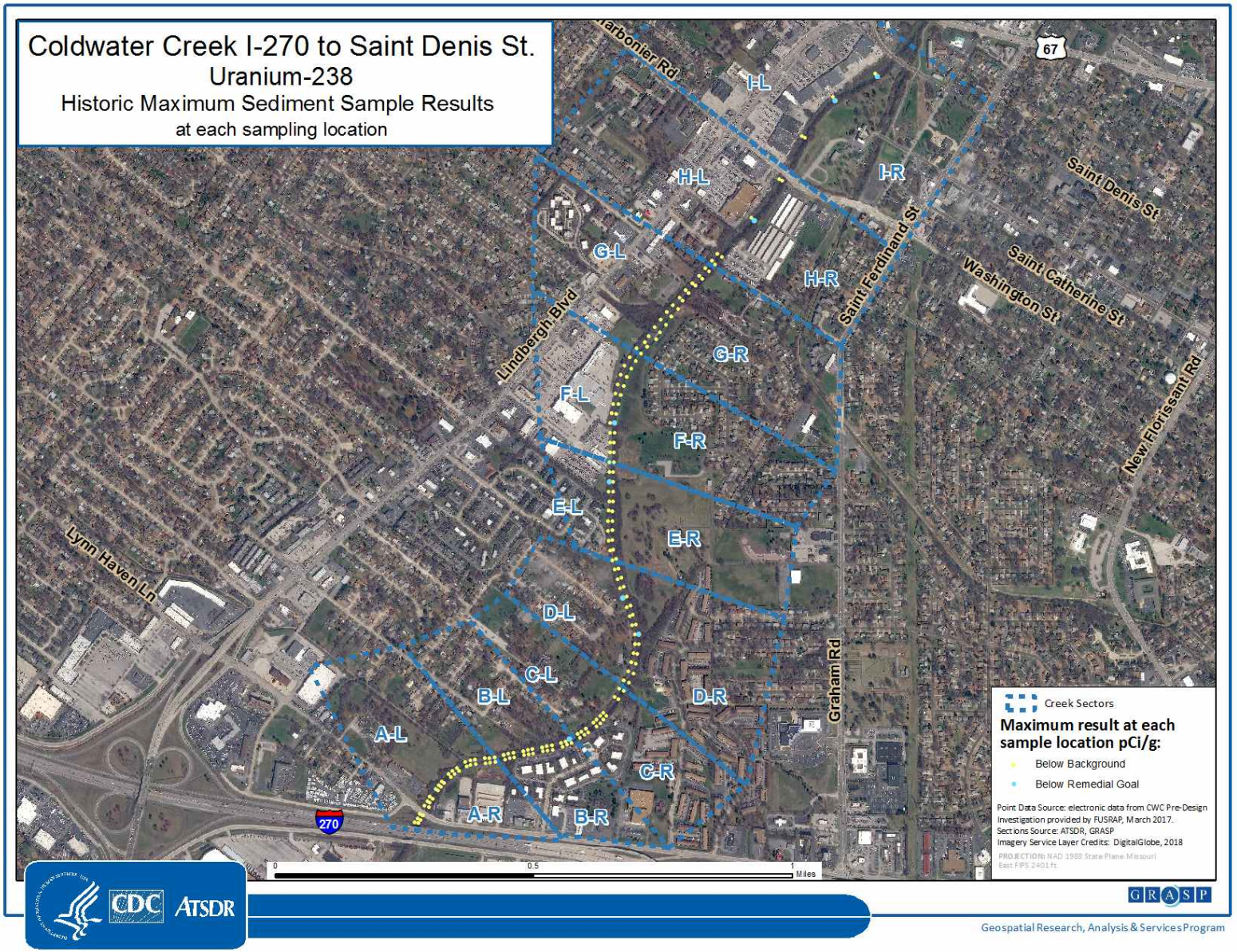


**Table C 3. Recommended 95% UCLs for sediment for various units along Coldwater Creek – PAST exposures**

| Sediment data selection | # Th-230 results | # of Th-230 results > background † | # of Th-230 results > remedial goal†† | Th-230 mean (pCi/g) | **Recommended Th-230 UCL value* (pCi/g)** | Th-230 data distri-bution** | Ra-226 UCL* (pCi/g) | U-238 UCL* (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| Sector A | 36 | 16 | 1 | 11.7 | **33.7** | None | 2.4 | NP |
| Sector B | 24 | 12 | 2 | 15.0 | **50.2** | None | 2.4 | 2.0 |
| Sector C | 24 | 13 | 0 | 5.9 | **10.0** | G,L | 3.5 | NP |
| Sector D | 28 | 11 | 1 | 11.3 | **32.9** | None | 3.3 | 3.9 |
| Sector E | 19 | 6 | 0 | 3.2 | **6.6** | None | 2.8 | 2.0 |
| Sector F | 21 | 10 | 2 | 15.9 | **46.2** | None | 3.1 | 2.1 |
| Sector G | 22 | 10 | 4 | 14.0 | **37.8** | None | 4.8 | NP |
| Sector H | 12 | 6 | 2 | 17.3 | **105.4** | G,L | 3.9 | 2.2 |
| Sector I | 6 | 4 | 0 | 10.6 | **67.1** | G,L | 1.9 | 4.5 |

†ATSDR considered 3 pCi/g to represent a value statistically different than background

††FUSRAP remedial goal for Th-230 in sediment is 43 pCi/g

*Upper confidence limit recommended by ProUCL statistical program based on data distribution [42]. All values represent 95% upper confidence limits.

**None: No discernible distribution; G: approximate or adjusted gamma distribution; L: approximate lognormal distribution

NP = Not processed; no results greater than background

**Value used** as exposure point concentration for "past" sediment exposures

**Figure C 11. Map of Th-230 sediment maximum data for Coldwater Creek – RECENT exposures**

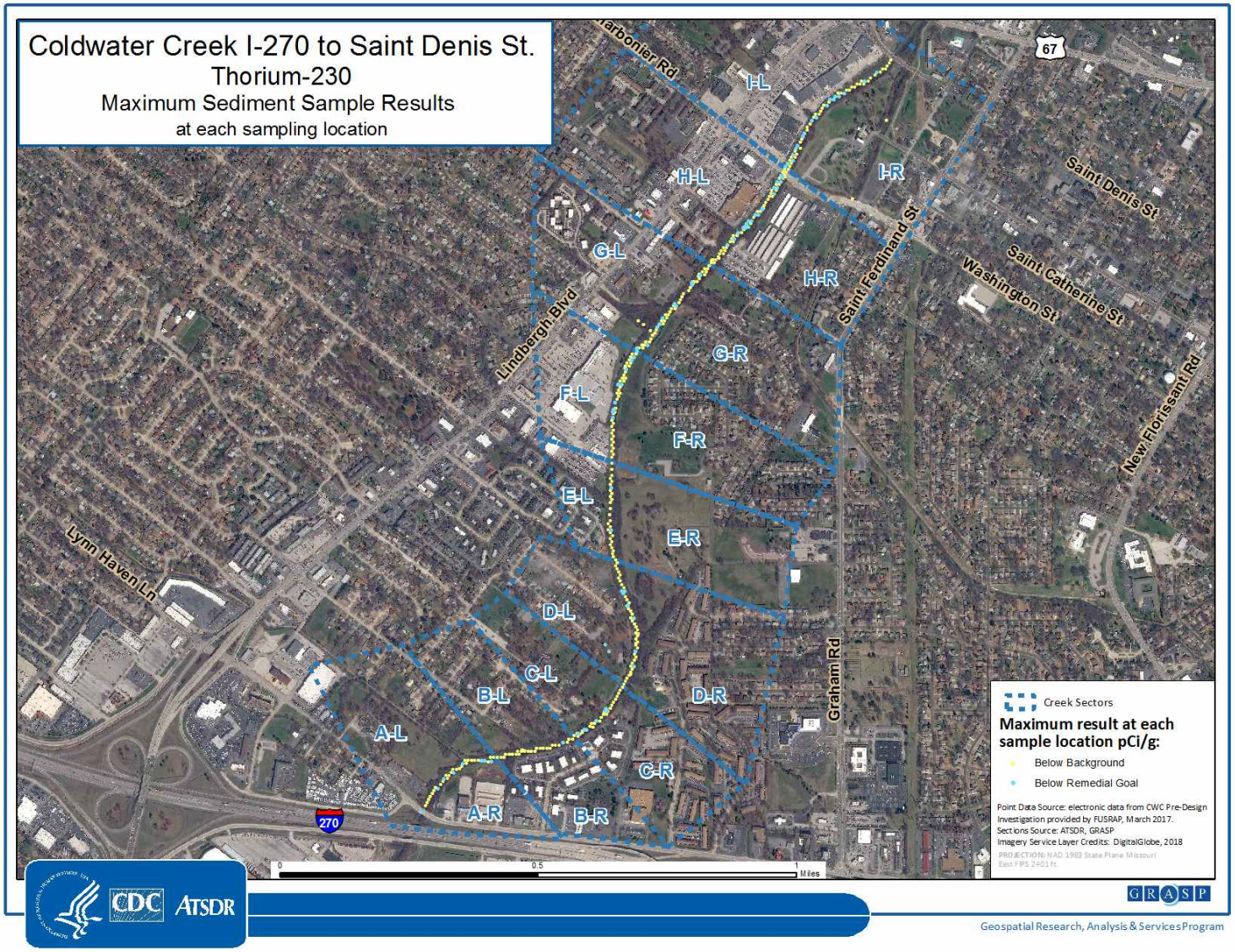


**Figure C 12. Map of Ra-226 sediment maximum data for Coldwater Creek – RECENT exposures**

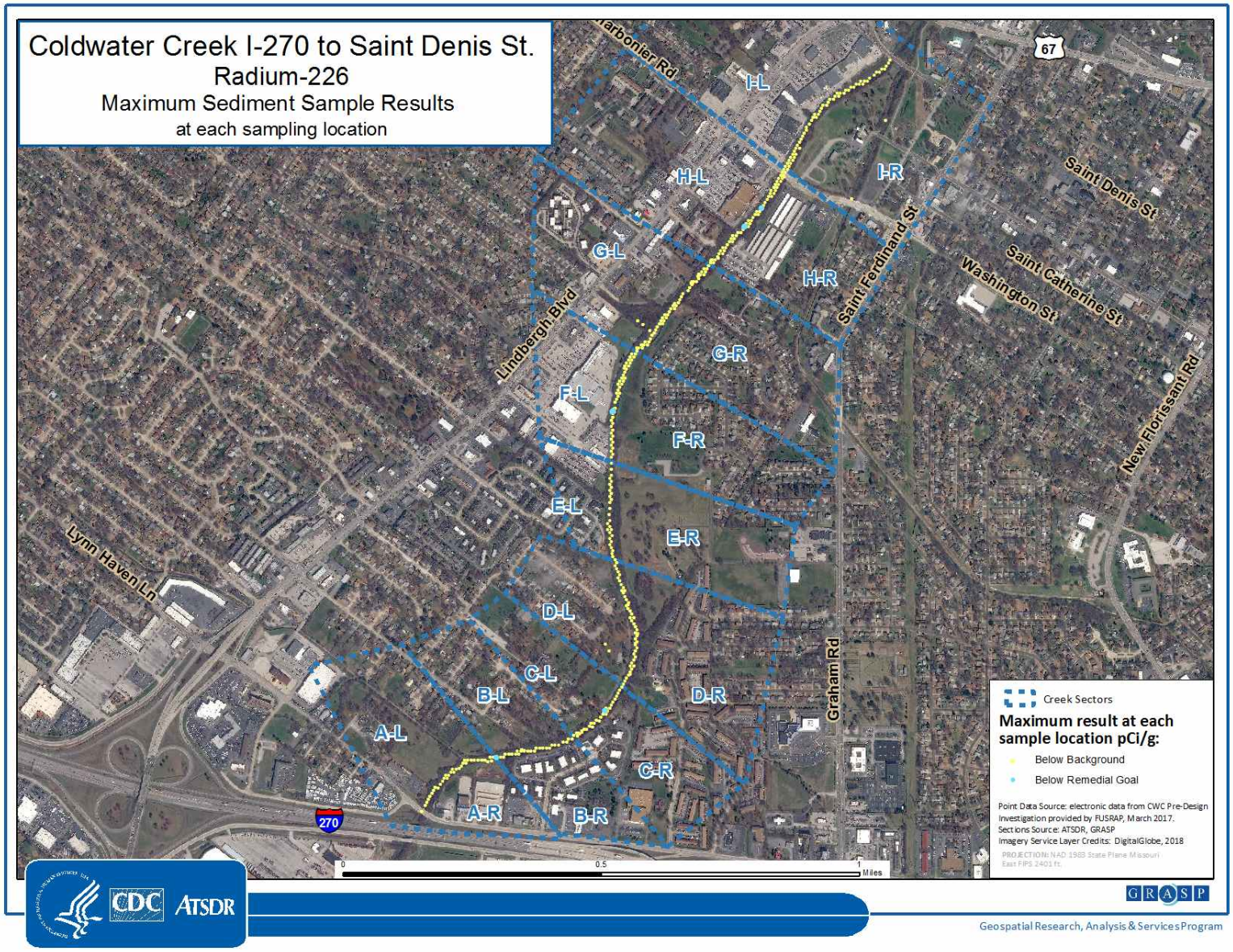


**Figure C 13. Map of U-238 sediment maximum data for Coldwater Creek – RECENT exposures**

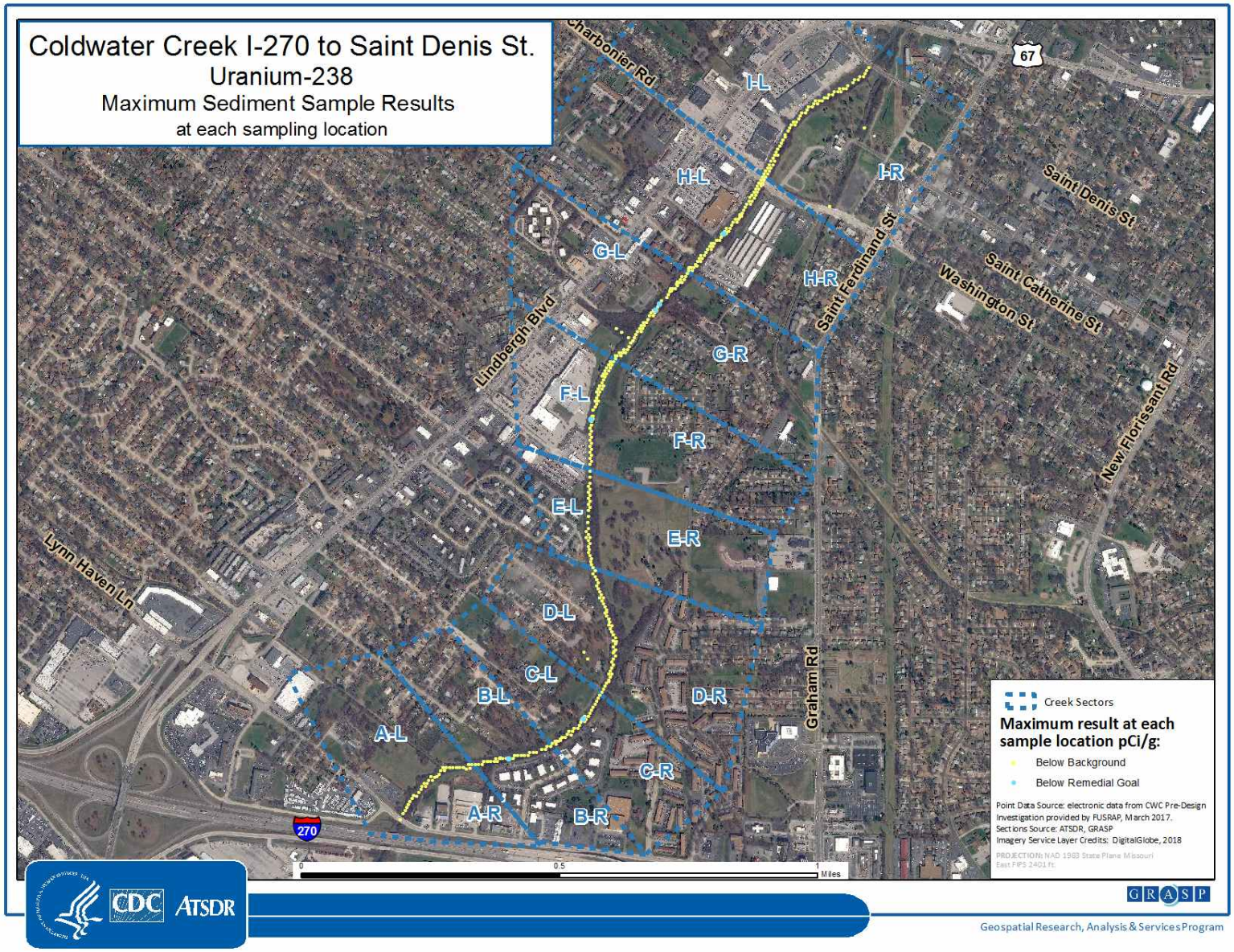


**Table C 4. Recommended 95% UCLs for sediment for various units along Coldwater Creek – RECENT exposures**

| Sediment data selection | # Positively identified Th-230 results | # of Th-230 results > background † | # of Th-230 results > remedial goal†† | Th-230 mean (pCi/g) | **Recommended Th-230 UCL value* (pCi/g)** | Th-230 data distri-bution** | Ra-226 UCL* (pCi/g) | U-238 UCL* (pCi/g) |
|---|---|---|---|---|---|---|---|---|
| Sector A | 34 | 8 | 0 | 2.8 | **4.7** | None | 1.4 | 1.0 |
| Sector B | 28 | 1 | 0 | 2.7 | **7.3** | None | 1.8 | 0.7 |
| Sector C | 35 | 7 | 0 | 35 | **6.9** | None | 1.8 | 0.8 |
| Sector D | 50 | 9 | 0 | 2.1 | **3.0** | L | 1.3 | 0.6 |
| Sector E | 29 | 2 | 0 | 2.0 | **3.7** | None | 1.3 | 0.6 |
| Sector F | 47 | 10 | 0 | 3.8 | **7.1** | None | 1.5 | 0.8 |
| Sector G | 55 | 11 | 0 | 2.7 | **4.7** | None | 1.4 | 0.8 |
| Sector H | 68 | 22 | 0 | 4.5 | **7.9** | None | 1.6 | 0.6 |
| Sector I | 60 | 18 | 0 | 3.6 | **6.0** | None | 1.4 | 0.5 |

†ATSDR considered 3 pCi/g to represent a value statistically different than background
††FUSRAP remedial goal for Th-230 in sediment is 43 pCi/g
*95% Upper confidence limit recommended by ProUCL statistical program based on data distribution [42].
**None: No discernible distribution; L: approximate lognormal distribution
**Value used** as exposure point concentration for "recent" sediment exposures

### Surface Water

No surface water samples were collected in the 2014-2016 pre-design investigation. However, environmental monitoring surface water and sediment data have been collected in Coldwater Creek from 1991-2014 from a station near I-270, at the upstream side of the residential area evaluated in this report. The data show no positively identified results higher than FUSRAP's background criteria [6]. For this reason, ATSDR used the background criteria as the exposure point concentration for Ra-226, Th-230, and U-238.

Table C5 summarizes all the exposure point concentrations used in evaluating radiological dose in this report.

**Table C 5. Exposure point concentrations (EPCs) for soil, sediment, and surface water at Coldwater Creek**

| | **Past exposures (1960s to 1990s)** | | | **Recent exposures (2000s and on)** | | |
|---|---|---|---|---|---|---|
| **Contaminant** | Surface soil EPC, pCi/g | Sediment EPC, pCi/g | Surface water EPC, pCi/L | Surface soil EPC, pCi/g | Sediment EPC, pCi/g | Surface water EPC, pCi/L |
| **Thorium-230** | 54.5 | 105.4 | 4.65 | 27.3 | 7.9 | 4.65 |
| **Radium-226** | 2.5 | 4.8 | 0.88 | 1.9 | 1.8 | 0.88 |
| **Uranium-238** | 2.3 | 4.5 | 5.05 | 1.8 | 1.0 | 5.05 |

pCi/g = picocuries per gram pCi/L = picocuries per liter

**Uranium Concentration for Evaluating Non-radiological effects**

ATSDR also evaluated chemical effects of uranium in this report. All the recent sediment and floodplain soil sampling reported activity of U-238 or other isotopes in soil in pCi/g rather than total uranium in mg/kg. These samples better represent potential residential exposures than the limited data from annual monitoring reported in the chemical screening section of Appendix A. The monitoring data were not collected from recreational or residential stretches of the creek and included no floodplain soil results. Therefore, we used the exposure point concentrations for U-238 in Table C5, along with information about the activity and relative abundance of natural uranium isotopes, to calculate exposure point concentrations for total uranium.

To estimate the concentration of total uranium in soil or sediment in milligrams per kilogram, we divided the U-238 value in picocuries per gram by the specific activity of U-238 and then divided by U-238's natural abundance, 99.27%. (The relative abundance of different uranium isotopes would have remained constant regardless of the processing that occurred in the past.) This is shown using the past exposure point concentration determined for U-238 in the example calculation that follows:

$$2.3\frac{pCi}{g\ soil} \times \frac{g\ \text{U-238}}{3.3\times10^{-7}\ Ci} \times \frac{10^{-12}Ci}{pCi} \times \frac{10^{3}\ g\ soil}{kg\ soil} \times \frac{g\ \text{U}}{0.9927\ g\ \text{U-238}} \times \frac{10^{3}\ mg\ \text{U}}{g\ \text{U}} = 7.02\frac{mg\ \text{U}}{kg\ soil}$$

Table C6 summarizes the uranium concentrations in soil and sediment used to evaluate chemical effects in this report.

**Table C 6. EPCs for evaluating uranium chemical effects at Coldwater Creek**

| | Total uranium surface soil EPC, mg/kg | Total uranium sediment EPC, mg/kg | Total uranium surface water EPC, µg/L |
|---|---|---|---|
| Past exposures (1960s to 1990s) | 7 | 14 | 15 |
| Recent exposures (2000s and on) | 5 | 3 | 15 |

mg/kg = milligrams per kilogram µg/L = microgram per liter

Values calculated using a specific activity of $3.3\times10^{-7}$ Ci/g for U-238 and a natural abundance of 99.27%. Values rounded to nearest whole number.

# Appendix D. Exposure Intake and Example Calculations

## Recreational Contaminant Intake Equations and Example Calculations

We calculated annual exposure intake for ingestion and inhalation for each radioactive contaminant using the exposure point concentration in its respective media, intake rates, and frequencies. The numbers shown in example calculations may not be exactly the same as we used due to rounding.

Intake = Soil Ingestion + Soil Inhalation + Sediment Ingestion + Surface Water Ingestion

### *Soil Ingestion Intake*

$$EPC\ \left(\frac{pCi}{g}\right) \times\ soil\ ingestion\ \left(\frac{mg}{day}\right) \times \left(\frac{1\ g}{1{,}000\ mg}\right) \times$$
$$Days\ per\ year\ playing\ in\ parks\ or\ soil\ near\ creek\ \left(\frac{days}{year}\right)$$

For example, the past recreational soil ingestion Th-230 intake for a middle schooler is:

=54.5*100*(1/1,000)*(252) = 1,373.4 pCi Th-230/year

### *Soil Inhalation Intake*

$$EPC\ \left(\frac{pCi}{g}\right) \times\ PEF\ \left(\frac{kg\ soil}{m^3\ air}\right) \times \left(\frac{1{,}000\ g}{1\ kg}\right) \times breathing\ rate\ \left(\frac{m^3}{hr}\right) \times$$
$$hrs\ per\ day\ riding\ bikes\ \left(\frac{hr}{day}\right) \times Days\ per\ year\ riding\ bikes\ \left(\frac{days}{year}\right)$$

For example, the past recreational soil inhalation Th-230 intake for a middle schooler is:

=54.5*1.18×10$^{-6}$*1,000*2.04*3.3*264 = 114.3 pCi Th-230/year

### *Sediment Ingestion Intake*

$$EPC\ \left(\frac{pCi}{g}\right) \times\ sediment\ ingestion\ \left(\frac{mg}{day}\right) \times \left(\frac{1\ g}{1{,}000\ mg}\right) \times$$
$$Days\ per\ year\ playing\ in\ creek\ or\ banks\ \left(\frac{days}{year}\right)$$

For example, the past recreational sediment ingestion Th-230 intake for a middle schooler is:

=105.4*100*(1/1,000)*(252) = 2,656.1 pCi Th-230/year

### *Surface Water Ingestion Intake*

$$EPC\ \left(\frac{pCi}{L}\right) \times\ surf\ water\ ingestion\ \left(\frac{ml}{day}\right) \times \left(\frac{1\ L}{1{,}000\ ml}\right) \times$$
$$Days\ per\ year\ playing\ in\ creek\ or\ banks\ \left(\frac{days}{year}\right)$$

For example, the past recreational surface water ingestion Th-230 intake for a middle schooler is:

=4.65*30*(1/1,000)*252 = 35.15 pCi Th-230/year

***Pica Intake – for children one to six years old***

$$EPC\ \left(\frac{pCi}{g}\right) \times\ pica\ soil\ ingestion\ \left(\frac{mg}{pica\ event}\right) \times \left(\frac{1\ g}{1{,}000\ mg}\right) \times \frac{pica\ events}{year}$$

For example, the past recreational soil pica ingestion Th-230 intake for a pica child is:

= 54.5*5000*(1/1000)*32 = 8,720 pCi Th-230/year for a child eating large amounts of soil once a week during warm, non-rainy days (32 times a year).

This pica intake adds to normal ingestion and inhalation intakes and external dose for estimating resulting dose.

**Residential Contaminant Intake Equations and Example Calculations**

Intake = Soil Ingestion + Soil Inhalation

***Soil Ingestion Intake***

$$EPC\ \left(\frac{pCi}{g}\right) \times\ soil\ ingestion\ \left(\frac{mg}{day}\right) \times \left(\frac{1\ g}{1{,}000\ mg}\right) \times Days\ per\ year\ in\ yard\ \left(\frac{days}{year}\right) +$$
$$EPC\ \left(\frac{pCi}{g}\right) \times\ gardening\ ingestion\ \left(\frac{mg}{day}\right) \times \left(\frac{1\ g}{1{,}000\ mg}\right) \times$$
$$Days\ per\ year\ gardening\ \left(\frac{days}{year}\right) +$$
$$EPC\ \left(\frac{pCi}{g}\right) \times\ landscaping\ ingestion\ \left(\frac{mg}{day}\right) \times \left(\frac{1\ g}{1{,}000\ mg}\right) \times$$
$$Days\ per\ year\ landscaping\ \left(\frac{days}{year}\right)$$

For example, the past residential soil ingestion Th-230 intake for a high schooler is:

54.5*200*(1/1,000)*(365) + 54.5*100*(1/1,000)*32 + 54.5*330*(1/1,000)*32

= 4,728.4 pCi Th-230/year

***Soil Inhalation Intake***

For this calculation, we assume that activities in the yard could suspend soil into the air and that this can be described with the same particle emission factor developed for dirt bike riding. We included time spent playing the yard, gardening, and landscaping to estimate inhalation intake. The intake is given by:

$$EPC\ \left(\frac{pCi}{g}\right) \times\ PEF\ \left(\frac{kg\ soil}{m^3\ air}\right) \times \left(\frac{1{,}000\ g}{1\ kg}\right) \times breathing\ rate\ \left(\frac{m^3}{hr}\right) \times \left[hrs\ per\ day\ playing\ \left(\frac{hr}{day}\right) \times Days\ per\ year\ playing\ \left(\frac{days}{year}\right) + hrs\ per\ day\ gardening\ \left(\frac{hr}{day}\right) \times Days\ per\ year\ gardening\ \left(\frac{days}{year}\right) + hrs\ per\ day\ landscaping\ \left(\frac{hr}{day}\right) \times Days\ per\ year\ landscaping\ \left(\frac{days}{year}\right)\right]$$

For example, the past residential soil inhalation Th-230 intake for a high schooler is:

54.5*1.18×$10^{-6}$*1,000*2.13* (4.2*365+3.0*32+3.0*32) = 234 pCi Th-230/year

***Pica Intake – for children two to six years old***

Annual intake is given by:

$$Exposure\ Point\ Concentration\ \left(\frac{pCi}{g}\right) \times\ pica\ soil\ ingestion\ \left(\frac{mg}{day}\right) \times \left(\frac{1\ g}{1{,}000\ mg}\right) \times 3\ \frac{pica\ events}{week} \times \left(\frac{warm,non-rainy\ weeks}{year}\right).$$

For example, the past residential soil pica ingestion Th-230 intake for a pica child is:

54.5*5,000*(1/1,000)*3*32 = 26,160 pCi Th-230/year for a child eating large amounts of soil regularly.

This pica intake adds to normal ingestion and inhalation intakes and external dose for estimating resulting dose.

# Appendix E. Radiological Dose and Estimated Increased Cancer Risk

## Radiological Dose

Intake itself does not completely determine the radiological dose. Determining the radiological dose resulting from intake is a complicated function of the identity of the radiological isotope, how it enters the body (ingestion or inhalation), how much is taken in, how much is eliminated or metabolized, what organs it is stored in, and how it changes as it radioactively decays. Each radioactive isotope has different characteristics. The International Commission on Radiological Protection (ICRP) has derived dose coefficients for estimating radiological dose from a given intake at different times after exposure for different isotopes, different age groups, and various organs. [43]. EPA has published external dose coefficients to estimate dose to various organs from external exposures to different isotopes [45].

For this evaluation, ATSDR used dose coefficients for the general public obtained from the program "Radiological Toolbox" v. 3.0.0 (available as a download from the Nuclear Regulatory Commission). This program provides internal dose coefficients based on ICRP Publication 68/72 and external doses based on Federal Guidance Report 12 and includes some dose coefficients for organs not specifically listed in the original publications (but derived following the same techniques). The program was created by the same group who provided dosimetry calculations for those publications [130,44,45]. More details about the dose coefficients selected and example calculations for internal and external dose are provided below.

### *Calculation of Internal Dose*

Radioactive material taken up by the body continues to deliver a radiation dose over a person's lifetime. We determined the *committed radiological dose to age 70* for each year of intake. The committed dose to age 70 is defined as the dose that will accumulate in a person's body from the time of intake to age 70; but this entire dose is considered to occur in the year of the intake. In this report, we will refer to the committed dose to age 70 as "committed dose." Each year of intake estimated in this report has a corresponding committed dose. Subsequent years of intake result in additional annual committed doses. Using coefficients for committed dose results in the highest estimated annual dose for a given intake.

The individual doses from intake of Th-230, Ra-226, and U-238 can be considered additive because they are part of the same radioactive decay chain and all emit primarily alpha radiation.

The annual committed dose to age 70 to a specific organ, resulting from a specific radiological intake, is given by

$$Annual\ Dose_i\left(\frac{millirem}{year}\right) = \sum_{route}\sum_{contaminants} intake\ \left(\frac{pCi}{year}\right) \times DCF_{70-yr,i}\ (\frac{millirem}{pCi})$$

Where the annual dose to a specific organ *i* is the annual intake of each isotope by a particular route (ingestion or inhalation) multiplied by the committed dose coefficient corresponding to the specific organ of interest, isotope, route, and age range of the child or adult during the year of intake; these intake-dose coefficient products are then summed over all the routes and isotopes considered.

For inhalation, different dose coefficients are available depending on how quickly the contaminant dissolves in lung fluid. We used recommended solubility assumptions for inhalation of Ra-226 and U-238. We evaluated Th-230 using both slow-dissolving and moderately-dissolving dose coefficients and present results as a range. Please see the notes in Tables E1-E3 for assumptions used in this evaluation.

Internal dose coefficients for ingestion and inhalation include the contribution of dose from radioactive decay products formed from the material ingested or inhaled for as long as the material is in the body.

### *Calculation of External Dose*

In addition to dose from taking radiological contaminants in the body, a person can get an external dose from radiation outside the body. We calculated external exposures for activities on soil (areas in the floodplain outside of the banks of Coldwater Creek), on sediment (considered to be soil or sediment within the banks of the creek), or in water. Of the recreational time spent in and around the creek as discussed in Appendix A, we assumed 85% of the time is spent on floodplain soil and 15% of the time is spent on sediment within the creek banks. We also assumed, on average, 10 minutes immersed in creek water for each day present around the creek.

To calculate the contribution to total dose from external radiation from soil or sediment, we assumed a person stood on soil or sediment with concentrations of Th-230, Ra-226, and U-238 at the exposure point concentrations derived in Appendix C, uniformly distributed throughout the top 15 centimeters of soil or sediment. Fifteen centimeters roughly corresponds to the 0-6 inch samples for which EPCs were derived. The top 15 cm of soil or sediment is assumed to have an average density of $1.6\times10^6$ grams per cubic meter ($g/m^3$), the standard soil density on which the external dose coefficients are based [45].

We assumed this external exposure would occur during recreational and residential activities with exposure frequencies and durations for each year corresponding to those listed in Appendix A.

For a particular isotope *k*, the annual soil external dose is given by the following equation:

$$EPC_k\left(\frac{pCi}{g}\right) \times \rho_S\left(\frac{g}{m^3}\right) \times DC_{15cmeff,k}\left(\frac{mrem \cdot m^3}{pCi \cdot hr}\right) \times \frac{hr}{year}\ exposed$$

where:

EPC is the exposure point concentration of isotope *k* in picocuries per gram of soil/sediment,
$\rho_S$ is the soil density (assumed for soil and sediment at the standard $1.6\times10^6$ g/m$^3$ used to develop coefficients), and
$DC_{15cm}$ is the 15-cm soil dose coefficient for the public corresponding to the isotope *k* [45]. The units of $DC_{15cm}$ are mrem per (picocurie per cubic meter)-hour.

Sediment doses calculated using the above equation are multiplied by a dose reduction factor of 0.2 for contaminated river shorelines, as recommended by the Federal Guidance Report 12 [45].

For water immersion, the annual surface water external dose is given by the following equation:

$$EPC_k\left(\frac{pCi}{L}\right) \times DC_{WI,k}\left(\frac{mrem \cdot L}{pCi \cdot hr}\right) \times \frac{hr}{year}\ exposed$$

where:

EPC is the exposure point concentration of isotope *k* in picocuries per liter of water,
$DC_{wi}$ is the water immersion dose coefficient for the public corresponding to the isotope *k* [45]. The units of $DC_{wi}$ are mrem per (picocurie per liter)-hour.

The external dose coefficients, unlike internal dose coefficients, do not account for dose from radioactive decay products. To account for external radiation decay products of the U-238, Th-230, and Ra-226 for which we have exposure point concentrations, ATSDR did the following:

- We assumed isotopes not measured between U-238 and Th-230 (Th-234, Pa-234/Pa-234m, and U-234) were in secular equilibrium; that is, they have the same amount of radioactivity. We calculated a summed U-238 external dose coefficient by adding the external dose coefficients of U-238, Th-234, Pa-234/Pa-234m (proportional to their relative formation by Th-234), and U-234. The U-238 exposure point concentration is multiplied by this summed dose coefficient in the dose calculation.

- Because no isotopes fall between Th-230 and Ra-226, the Th-230 exposure point concentration is multiplied by its Th-230 external dose coefficient in the dose calculation.
- Ra-226 forms radon-222 (Rn-222), a gas that may be lost to the atmosphere. We assumed 50% of the Rn-222 would be lost to the atmosphere and that all remaining isotopes were at secular equilibrium. Thus, we calculated a summed Ra-226 external dose coefficient by adding the Ra-226 external dose coefficient to 50% of the sum of external dose coefficients for Rn-222 and lower decay products. Please see Tables E4 and E5 for more information. The Ra-226 exposure point concentration is multiplied by the summed Ra-226 dose coefficient in the calculation.
- We summed all external doses for the year of exposure and added to the annual internal dose.

Tables E4 and E5 summarize the external dose coefficients used in ATSDR's calculations.

**Table E 1. Thorium-230 internal dose coefficients used in Coldwater Creek evaluation**

| | Ingestion | | | | | | Inhalation - Type S (Slow Lung Solubility) | | | | | | Inhalation - Type M (Medium Lung Solubility) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age Range --> | <1 | 1 to <2 | 2 to <7 | 7 to <12 | 12 to <17 | >17 | <1 | 1 to <2 | 2 to <7 | 7 to <12 | 12 to <17 | >17 | <1 | 1 to <2 | 2 to <7 | 7 to <12 | 12 to <17 | >17 |
| Adrenals | 1.70E-03 | 1.52E-04 | 1.04E-04 | 7.41E-05 | 5.56E-05 | 5.19E-05 | 2.70E-03 | 2.26E-03 | 1.70E-03 | 1.26E-03 | 1.15E-03 | 1.11E-03 | 2.63E-02 | 2.52E-02 | 1.70E-02 | 1.19E-02 | 1.00E-02 | 9.63E-03 |
| Bladder | 1.70E-03 | 1.52E-04 | 1.04E-04 | 7.41E-05 | 5.56E-05 | 5.19E-05 | 2.70E-03 | 2.26E-03 | 1.70E-03 | 1.26E-03 | 1.15E-03 | 1.11E-03 | 2.63E-02 | 2.52E-02 | 1.70E-02 | 1.19E-02 | 1.00E-02 | 9.63E-03 |
| Bone Surface | 4.44E-01 | 4.81E-02 | 4.44E-02 | 4.07E-02 | 4.07E-02 | 4.44E-02 | 1.00E+00 | 9.63E-01 | 9.26E-01 | 8.89E-01 | 9.63E-01 | 1.04E+00 | 7.41E+00 | 7.78E+00 | 7.41E+00 | 6.67E+00 | 7.41E+00 | 8.52E+00 |
| Brain | 1.70E-03 | 1.52E-04 | 1.04E-04 | 7.41E-05 | 5.56E-05 | 5.19E-05 | 2.70E-03 | 2.26E-03 | 1.70E-03 | 1.26E-03 | 1.15E-03 | 1.11E-03 | 2.63E-02 | 2.52E-02 | 1.70E-02 | 1.19E-02 | 1.00E-02 | 9.63E-03 |
| Breast | 1.70E-03 | 1.52E-04 | 1.04E-04 | 7.41E-05 | 5.56E-05 | 5.19E-05 | 2.70E-03 | 2.26E-03 | 1.70E-03 | 1.26E-03 | 1.15E-03 | 1.11E-03 | 2.63E-02 | 2.52E-02 | 1.70E-02 | 1.19E-02 | 1.00E-02 | 9.63E-03 |
| Colon | 3.04E-03 | 1.00E-03 | 5.19E-04 | 3.22E-04 | 1.96E-04 | 1.63E-04 | 3.15E-03 | 2.59E-03 | 1.85E-03 | 1.33E-03 | 1.22E-03 | 1.15E-03 | 2.67E-02 | 2.52E-02 | 1.70E-02 | 1.19E-02 | 1.00E-02 | 9.63E-03 |
| Effective (ICRP 60) | 1.52E-02 | 1.52E-03 | 1.15E-03 | 8.89E-04 | 8.15E-04 | 7.78E-04 | 1.48E-01 | 1.30E-01 | 8.89E-02 | 5.93E-02 | 5.56E-02 | 5.19E-02 | 2.85E-01 | 2.74E-01 | 2.04E-01 | 1.59E-01 | 1.56E-01 | 1.59E-01 |
| Esophagus | 1.70E-03 | 1.52E-04 | 1.04E-04 | 7.41E-05 | 5.56E-05 | 5.19E-05 | 2.70E-03 | 2.26E-03 | 1.70E-03 | 1.26E-03 | 1.15E-03 | 1.11E-03 | 2.63E-02 | 2.52E-02 | 1.70E-02 | 1.19E-02 | 1.00E-02 | 9.63E-03 |
| Extratracheal Airways | 1.70E-03 | 1.52E-04 | 1.04E-04 | 7.41E-05 | 5.56E-05 | 5.19E-05 | 7.41E-01 | 6.30E-01 | 3.15E-01 | 2.15E-01 | 1.33E-01 | 1.30E-01 | 2.04E-01 | 1.63E-01 | 7.78E-02 | 5.19E-02 | 3.22E-02 | 3.11E-02 |
| Kidneys | 2.00E-02 | 1.78E-03 | 1.26E-03 | 9.26E-04 | 7.41E-04 | 7.04E-04 | 3.26E-02 | 2.78E-02 | 2.19E-02 | 1.67E-02 | 1.63E-02 | 1.63E-02 | 3.07E-01 | 2.96E-01 | 2.07E-01 | 1.48E-01 | 1.33E-01 | 1.30E-01 |
| Liver | 1.78E-02 | 1.59E-03 | 1.11E-03 | 8.15E-04 | 6.30E-04 | 5.93E-04 | 2.85E-02 | 2.44E-02 | 1.89E-02 | 1.44E-02 | 1.37E-02 | 1.37E-02 | 2.70E-01 | 2.63E-01 | 1.81E-01 | 1.30E-01 | 1.15E-01 | 1.11E-01 |
| Lower Large Intestine | 3.70E-03 | 1.48E-03 | 7.78E-04 | 4.81E-04 | 2.78E-04 | 2.30E-04 | 3.44E-03 | 2.78E-03 | 1.93E-03 | 1.37E-03 | 1.22E-03 | 1.19E-03 | 2.70E-02 | 2.56E-02 | 1.74E-02 | 1.19E-02 | 1.00E-02 | 9.63E-03 |
| Lungs | 1.74E-03 | 1.52E-04 | 1.04E-04 | 7.41E-05 | 5.56E-05 | 5.19E-05 | 1.00E+00 | 8.89E-01 | 5.56E-01 | 3.70E-01 | 3.11E-01 | 2.85E-01 | 4.44E-01 | 3.48E-01 | 2.19E-01 | 1.48E-01 | 1.26E-01 | 1.07E-01 |
| Muscle | 1.70E-03 | 1.52E-04 | 1.04E-04 | 7.41E-05 | 5.56E-05 | 5.19E-05 | 2.70E-03 | 2.26E-03 | 1.70E-03 | 1.26E-03 | 1.15E-03 | 1.11E-03 | 2.63E-02 | 2.52E-02 | 1.70E-02 | 1.19E-02 | 1.00E-02 | 9.63E-03 |
| Ovaries | 7.41E-03 | 7.41E-04 | 7.04E-04 | 5.56E-04 | 4.81E-04 | 3.67E-04 | 1.48E-02 | 1.41E-02 | 1.26E-02 | 1.04E-02 | 9.63E-03 | 8.52E-03 | 1.19E-01 | 1.26E-01 | 1.15E-01 | 9.26E-02 | 8.52E-02 | 7.04E-02 |
| Pancreas | 1.70E-03 | 1.52E-04 | 1.04E-04 | 7.41E-05 | 5.56E-05 | 5.19E-05 | 2.70E-03 | 2.26E-03 | 1.70E-03 | 1.26E-03 | 1.15E-03 | 1.11E-03 | 2.63E-02 | 2.52E-02 | 1.70E-02 | 1.19E-02 | 1.00E-02 | 9.63E-03 |
| Red Marrow | 5.93E-02 | 5.19E-03 | 3.26E-03 | 2.22E-03 | 1.74E-03 | 1.56E-03 | 8.89E-02 | 7.41E-02 | 5.19E-02 | 4.07E-02 | 3.70E-02 | 3.70E-02 | 8.89E-01 | 8.15E-01 | 5.56E-01 | 3.59E-01 | 3.07E-01 | 2.96E-01 |
| Remainder | 1.96E-03 | 1.74E-04 | 1.19E-04 | 8.15E-05 | 6.30E-05 | 5.56E-05 | 3.48E-03 | 2.85E-03 | 2.11E-03 | 1.56E-03 | 1.37E-03 | 1.33E-03 | 3.00E-02 | 2.85E-02 | 1.96E-02 | 1.33E-02 | 1.11E-02 | 1.07E-02 |
| Skin | 1.70E-03 | 1.52E-04 | 1.04E-04 | 7.41E-05 | 5.56E-05 | 5.19E-05 | 2.70E-03 | 2.26E-03 | 1.70E-03 | 1.26E-03 | 1.15E-03 | 1.11E-03 | 2.63E-02 | 2.52E-02 | 1.70E-02 | 1.19E-02 | 1.00E-02 | 9.63E-03 |
| Small Intestine | 1.85E-03 | 2.26E-04 | 1.41E-04 | 9.63E-05 | 7.04E-05 | 5.93E-05 | 2.74E-03 | 2.30E-03 | 1.74E-03 | 1.26E-03 | 1.19E-03 | 1.11E-03 | 2.63E-02 | 2.52E-02 | 1.70E-02 | 1.19E-02 | 1.00E-02 | 9.63E-03 |
| Spleen | 1.70E-03 | 1.52E-04 | 1.04E-04 | 7.41E-05 | 5.56E-05 | 5.19E-05 | 2.70E-03 | 2.26E-03 | 1.70E-03 | 1.26E-03 | 1.19E-03 | 1.11E-03 | 2.63E-02 | 2.52E-02 | 1.70E-02 | 1.19E-02 | 1.00E-02 | 9.63E-03 |
| Stomach | 1.78E-03 | 1.78E-04 | 1.19E-04 | 8.15E-05 | 6.30E-05 | 5.56E-05 | 2.74E-03 | 2.30E-03 | 1.70E-03 | 1.26E-03 | 1.15E-03 | 1.11E-03 | 2.63E-02 | 2.52E-02 | 1.70E-02 | 1.19E-02 | 1.00E-02 | 9.63E-03 |
| Testes | 8.15E-03 | 8.15E-04 | 6.30E-04 | 5.19E-04 | 4.81E-04 | 3.70E-04 | 1.56E-02 | 1.41E-02 | 1.19E-02 | 1.00E-02 | 9.63E-03 | 8.52E-03 | 1.30E-01 | 1.37E-01 | 1.07E-01 | 8.89E-02 | 8.52E-02 | 7.04E-02 |
| Thymus | 1.70E-03 | 1.52E-04 | 1.04E-04 | 7.41E-05 | 5.56E-05 | 5.19E-05 | 2.70E-03 | 2.26E-03 | 1.70E-03 | 1.26E-03 | 1.15E-03 | 1.11E-03 | 2.63E-02 | 2.52E-02 | 1.70E-02 | 1.19E-02 | 1.00E-02 | 9.63E-03 |
| Thyroid | 1.70E-03 | 1.52E-04 | 1.04E-04 | 7.41E-05 | 5.56E-05 | 5.19E-05 | 2.70E-03 | 2.26E-03 | 1.70E-03 | 1.26E-03 | 1.15E-03 | 1.11E-03 | 2.63E-02 | 2.52E-02 | 1.70E-02 | 1.19E-02 | 1.00E-02 | 9.63E-03 |
| Upper Large Intestine | 2.44E-03 | 6.30E-04 | 3.37E-04 | 2.11E-04 | 1.33E-04 | 1.11E-04 | 2.96E-03 | 2.44E-03 | 1.78E-03 | 1.30E-03 | 1.19E-03 | 1.15E-03 | 2.63E-02 | 2.52E-02 | 1.70E-02 | 1.19E-02 | 1.00E-02 | 9.63E-03 |
| Uterus | 1.70E-03 | 1.52E-04 | 1.04E-04 | 7.41E-05 | 5.56E-05 | 5.19E-05 | 2.70E-03 | 2.26E-03 | 1.70E-03 | 1.26E-03 | 1.15E-03 | 1.11E-03 | 2.63E-02 | 2.52E-02 | 1.70E-02 | 1.19E-02 | 1.00E-02 | 9.63E-03 |

**Notes:**

-Committed dose coefficients (to age 70) for the public obtained from program "Radiological Toolbox" v. 3.0.0, based on ICRP 68/72 [130,44]. Units are mrem per pCi.

-Slow lung solubility recommended by ICRP for Th-230 in absence of data on contaminant solubility [44]. Thorium oxide compounds exhibit slow lung solubility [46]. Higher lung dose will result from slow lung solubility.

-Medium lung solubility exhibited by other thorium compounds besides oxides [46]. Higher bone dose will result from medium solubility.

**Table E 2. Radium-226 internal dose coefficients used in Coldwater Creek evaluation**

| | Ingestion | | | | | | Inhalation - Type M (Medium Lung Solubility) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age Range --> | <1 | 1 to <2 | 2 to <7 | 7 to <12 | 12 to <17 | >17 | <1 | 1 to <2 | 2 to <7 | 7 to <12 | 12 to <17 | >17 |
| Adrenals | 1.96E-03 | 7.78E-04 | 4.81E-04 | 3.33E-04 | 3.00E-04 | 1.52E-04 | 4.44E-04 | 2.96E-04 | 1.78E-04 | 1.22E-04 | 1.11E-04 | 8.89E-05 |
| Bladder | 1.96E-03 | 7.78E-04 | 4.81E-04 | 3.26E-04 | 2.70E-04 | 1.48E-04 | 4.44E-04 | 2.96E-04 | 1.78E-04 | 1.19E-04 | 1.00E-04 | 8.89E-05 |
| Bone Surface | 5.93E-01 | 1.07E-01 | 8.52E-02 | 1.44E-01 | 3.48E-01 | 4.44E-02 | 1.22E-01 | 4.07E-02 | 3.15E-02 | 5.56E-02 | 1.30E-01 | 2.74E-02 |
| Brain | 1.96E-03 | 7.78E-04 | 4.81E-04 | 3.33E-04 | 3.00E-04 | 1.52E-04 | 4.44E-04 | 2.96E-04 | 1.78E-04 | 1.19E-04 | 1.11E-04 | 8.89E-05 |
| Breast | 1.96E-03 | 7.78E-04 | 4.81E-04 | 3.22E-04 | 2.70E-04 | 1.48E-04 | 4.44E-04 | 2.96E-04 | 1.78E-04 | 1.15E-04 | 1.00E-04 | 8.89E-05 |
| Colon | 4.44E-03 | 2.41E-03 | 1.30E-03 | 8.15E-04 | 5.56E-04 | 3.67E-04 | 1.33E-03 | 9.26E-04 | 4.44E-04 | 2.85E-04 | 1.93E-04 | 1.63E-04 |
| Effective (ICRP 60) | 1.74E-02 | 3.56E-03 | 2.30E-03 | 2.96E-03 | 5.56E-03 | 1.04E-03 | 5.56E-02 | 4.07E-02 | 2.59E-02 | 1.81E-02 | 1.67E-02 | 1.30E-02 |
| Esophagus | 1.96E-03 | 7.78E-04 | 4.81E-04 | 3.26E-04 | 2.74E-04 | 1.48E-04 | 4.44E-04 | 2.96E-04 | 1.78E-04 | 1.19E-04 | 1.04E-04 | 8.89E-05 |
| Extratracheal Airways | 1.96E-03 | 7.78E-04 | 4.81E-04 | 3.26E-04 | 2.81E-04 | 1.48E-04 | 1.81E-01 | 1.41E-01 | 5.93E-02 | 4.07E-02 | 2.26E-02 | 2.22E-02 |
| Kidneys | 2.56E-03 | 9.26E-04 | 5.93E-04 | 5.93E-04 | 8.89E-04 | 2.19E-04 | 5.56E-04 | 3.41E-04 | 2.19E-04 | 2.15E-04 | 3.30E-04 | 1.30E-04 |
| Liver | 1.41E-02 | 5.56E-03 | 2.89E-03 | 1.96E-03 | 1.48E-03 | 6.67E-04 | 3.11E-03 | 2.07E-03 | 1.04E-03 | 7.04E-04 | 5.56E-04 | 4.07E-04 |
| Lower Large Intestine | 5.93E-03 | 3.63E-03 | 1.93E-03 | 1.19E-03 | 7.78E-04 | 5.56E-04 | 2.04E-03 | 1.41E-03 | 6.67E-04 | 4.07E-04 | 2.59E-04 | 2.19E-04 |
| Lungs | 1.96E-03 | 7.78E-04 | 4.81E-04 | 3.30E-04 | 2.81E-04 | 1.48E-04 | 4.44E-01 | 3.37E-01 | 2.11E-01 | 1.41E-01 | 1.22E-01 | 1.04E-01 |
| Muscle | 1.96E-03 | 7.78E-04 | 4.81E-04 | 3.30E-04 | 2.85E-04 | 1.48E-04 | 4.44E-04 | 2.96E-04 | 1.78E-04 | 1.19E-04 | 1.07E-04 | 8.89E-05 |
| Ovaries | 2.00E-03 | 8.15E-04 | 5.19E-04 | 3.70E-04 | 2.81E-04 | 1.52E-04 | 4.44E-04 | 3.07E-04 | 1.89E-04 | 1.33E-04 | 1.04E-04 | 8.89E-05 |
| Pancreas | 1.96E-03 | 7.78E-04 | 4.81E-04 | 3.26E-04 | 2.81E-04 | 1.48E-04 | 4.44E-04 | 2.96E-04 | 1.78E-04 | 1.19E-04 | 1.04E-04 | 8.89E-05 |
| Red Marrow | 7.41E-02 | 1.11E-02 | 6.67E-03 | 8.89E-03 | 1.52E-02 | 3.22E-03 | 1.44E-02 | 4.07E-03 | 2.48E-03 | 3.37E-03 | 5.56E-03 | 1.93E-03 |
| Remainder | 1.96E-03 | 7.78E-04 | 4.81E-04 | 3.33E-04 | 2.93E-04 | 1.48E-04 | 5.19E-04 | 3.56E-04 | 2.04E-04 | 1.41E-04 | 1.19E-04 | 1.00E-04 |
| Skin | 1.96E-03 | 7.78E-04 | 4.81E-04 | 3.26E-04 | 2.78E-04 | 1.48E-04 | 4.44E-04 | 2.96E-04 | 1.78E-04 | 1.19E-04 | 1.04E-04 | 8.89E-05 |
| Small Intestine | 2.00E-03 | 8.52E-04 | 5.19E-04 | 3.44E-04 | 2.89E-04 | 1.56E-04 | 4.81E-04 | 3.19E-04 | 1.85E-04 | 1.22E-04 | 1.07E-04 | 8.89E-05 |
| Spleen | 2.48E-03 | 8.89E-04 | 5.93E-04 | 5.19E-04 | 7.41E-04 | 1.96E-04 | 5.56E-04 | 3.37E-04 | 2.15E-04 | 1.93E-04 | 2.63E-04 | 1.19E-04 |
| Stomach | 2.00E-03 | 8.15E-04 | 4.81E-04 | 3.33E-04 | 2.78E-04 | 1.52E-04 | 4.44E-04 | 3.04E-04 | 1.81E-04 | 1.19E-04 | 1.04E-04 | 8.89E-05 |
| Testes | 2.04E-03 | 8.15E-04 | 5.56E-04 | 4.81E-04 | 2.81E-04 | 1.48E-04 | 4.44E-04 | 3.11E-04 | 2.04E-04 | 1.78E-04 | 1.04E-04 | 8.89E-05 |
| Thymus | 1.96E-03 | 7.78E-04 | 4.81E-04 | 3.26E-04 | 2.74E-04 | 1.48E-04 | 4.44E-04 | 2.96E-04 | 1.78E-04 | 1.19E-04 | 1.04E-04 | 8.89E-05 |
| Thyroid | 1.96E-03 | 7.78E-04 | 4.81E-04 | 3.26E-04 | 2.81E-04 | 1.48E-04 | 4.44E-04 | 2.96E-04 | 1.78E-04 | 1.19E-04 | 1.04E-04 | 8.89E-05 |
| Upper Large Intestine | 2.93E-03 | 1.44E-03 | 8.15E-04 | 5.19E-04 | 3.70E-04 | 2.37E-04 | 8.15E-04 | 5.56E-04 | 2.93E-04 | 1.85E-04 | 1.37E-04 | 1.19E-04 |
| Uterus | 1.96E-03 | 7.78E-04 | 4.81E-04 | 3.26E-04 | 2.74E-04 | 1.48E-04 | 4.44E-04 | 2.96E-04 | 1.78E-04 | 1.19E-04 | 1.04E-04 | 8.89E-05 |

**Notes:**

-Committed dose coefficients (to age 70) for the public obtained from program “Radiological Toolbox” v. 3.0.0, based on ICRP 68/72 [130,44]. Units are mrem per pCi.

-Medium lung solubility recommended by ICRP for Ra-226 and U-238 in absence of data on contaminant solubility [44].

**Table E 3. Uranium-238 internal dose coefficients used in Coldwater Creek evaluation**

| | Ingestion | | | | | | Inhalation - Type M (Medium Lung Solubility) | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Age Range --> | <1 | 1 to <2 | 2 to <7 | 7 to <12 | 12 to <17 | >17 | <1 | 1 to <2 | 2 to <7 | 7 to <12 | 12 to <17 | >17 |
| Adrenals | 4.44E-04 | 1.96E-04 | 1.48E-04 | 1.15E-04 | 9.63E-05 | 9.26E-05 | 9.63E-04 | 8.89E-04 | 6.67E-04 | 5.19E-04 | 4.44E-04 | 4.44E-04 |
| Bladder | 4.44E-04 | 1.96E-04 | 1.48E-04 | 1.19E-04 | 1.00E-04 | 9.26E-05 | 9.63E-04 | 8.89E-04 | 6.67E-04 | 5.19E-04 | 4.44E-04 | 4.44E-04 |
| Bone Surface | 2.56E-02 | 5.93E-03 | 4.44E-03 | 5.19E-03 | 7.78E-03 | 2.63E-03 | 4.81E-02 | 2.70E-02 | 1.96E-02 | 2.26E-02 | 3.59E-02 | 1.30E-02 |
| Brain | 4.44E-04 | 1.96E-04 | 1.48E-04 | 1.15E-04 | 9.63E-05 | 8.89E-05 | 9.63E-04 | 8.89E-04 | 6.67E-04 | 5.19E-04 | 4.44E-04 | 4.44E-04 |
| Breast | 4.44E-04 | 1.96E-04 | 1.48E-04 | 1.15E-04 | 9.63E-05 | 8.89E-05 | 9.63E-04 | 8.89E-04 | 6.67E-04 | 5.19E-04 | 4.44E-04 | 4.44E-04 |
| Colon | 1.59E-03 | 9.63E-04 | 5.19E-04 | 3.44E-04 | 2.26E-04 | 1.93E-04 | 1.33E-03 | 1.15E-03 | 7.78E-04 | 5.56E-04 | 4.81E-04 | 4.81E-04 |
| Effective (ICRP 60) | 1.26E-03 | 4.44E-04 | 2.96E-04 | 2.52E-04 | 2.48E-04 | 1.67E-04 | 4.44E-02 | 3.48E-02 | 2.19E-02 | 1.48E-02 | 1.26E-02 | 1.07E-02 |
| Esophagus | 4.44E-04 | 1.96E-04 | 1.48E-04 | 1.15E-04 | 9.63E-05 | 8.89E-05 | 9.63E-04 | 8.89E-04 | 6.67E-04 | 5.19E-04 | 4.44E-04 | 4.44E-04 |
| Extratracheal Airways | 4.44E-04 | 1.96E-04 | 1.48E-04 | 1.15E-04 | 9.63E-05 | 8.89E-05 | 1.56E-01 | 1.22E-01 | 5.19E-02 | 3.56E-02 | 1.96E-02 | 1.93E-02 |
| Kidneys | 9.26E-03 | 3.44E-03 | 2.07E-03 | 1.44E-03 | 1.07E-03 | 9.26E-04 | 1.89E-02 | 1.52E-02 | 9.26E-03 | 6.30E-03 | 4.81E-03 | 4.81E-03 |
| Liver | 1.93E-03 | 8.52E-04 | 5.93E-04 | 4.44E-04 | 3.70E-04 | 3.56E-04 | 4.07E-03 | 3.70E-03 | 2.67E-03 | 1.93E-03 | 1.74E-03 | 1.78E-03 |
| Lower Large Intestine | 2.30E-03 | 1.41E-03 | 7.78E-04 | 4.81E-04 | 3.04E-04 | 2.56E-04 | 1.56E-03 | 1.30E-03 | 8.15E-04 | 5.93E-04 | 5.19E-04 | 4.81E-04 |
| Lungs | 4.44E-04 | 1.96E-04 | 1.48E-04 | 1.15E-04 | 9.63E-05 | 9.26E-05 | 3.63E-01 | 2.78E-01 | 1.74E-01 | 1.15E-01 | 9.63E-02 | 8.15E-02 |
| Muscle | 4.44E-04 | 1.96E-04 | 1.48E-04 | 1.15E-04 | 9.63E-05 | 8.89E-05 | 9.63E-04 | 8.89E-04 | 6.67E-04 | 5.19E-04 | 4.44E-04 | 4.44E-04 |
| Ovaries | 4.44E-04 | 2.04E-04 | 1.52E-04 | 1.22E-04 | 9.63E-05 | 9.26E-05 | 9.63E-04 | 8.89E-04 | 6.67E-04 | 5.19E-04 | 4.44E-04 | 4.44E-04 |
| Pancreas | 4.44E-04 | 1.96E-04 | 1.48E-04 | 1.15E-04 | 9.63E-05 | 8.89E-05 | 9.63E-04 | 8.89E-04 | 6.67E-04 | 5.19E-04 | 4.44E-04 | 4.44E-04 |
| Red Marrow | 3.11E-03 | 7.04E-04 | 4.44E-04 | 4.07E-04 | 4.81E-04 | 2.78E-04 | 5.93E-03 | 3.15E-03 | 1.96E-03 | 1.89E-03 | 2.15E-03 | 1.37E-03 |
| Remainder | 5.56E-04 | 2.37E-04 | 1.70E-04 | 1.33E-04 | 1.07E-04 | 1.00E-04 | 1.26E-03 | 1.11E-03 | 7.78E-04 | 5.93E-04 | 5.19E-04 | 5.19E-04 |
| Skin | 4.44E-04 | 1.96E-04 | 1.48E-04 | 1.15E-04 | 9.63E-05 | 8.89E-05 | 9.63E-04 | 8.89E-04 | 6.67E-04 | 5.19E-04 | 4.44E-04 | 4.44E-04 |
| Small Intestine | 5.56E-04 | 2.63E-04 | 1.81E-04 | 1.37E-04 | 1.07E-04 | 1.00E-04 | 1.00E-03 | 8.89E-04 | 6.67E-04 | 5.19E-04 | 4.44E-04 | 4.44E-04 |
| Spleen | 4.44E-04 | 1.96E-04 | 1.48E-04 | 1.15E-04 | 9.63E-05 | 8.89E-05 | 9.63E-04 | 8.89E-04 | 6.67E-04 | 5.19E-04 | 4.44E-04 | 4.44E-04 |
| Stomach | 4.81E-04 | 2.22E-04 | 1.59E-04 | 1.22E-04 | 1.04E-04 | 9.26E-05 | 9.63E-04 | 8.89E-04 | 6.67E-04 | 5.19E-04 | 4.44E-04 | 4.44E-04 |
| Testes | 4.81E-04 | 2.11E-04 | 1.63E-04 | 1.33E-04 | 1.00E-04 | 9.26E-05 | 1.04E-03 | 9.63E-04 | 7.41E-04 | 5.93E-04 | 4.81E-04 | 4.44E-04 |
| Thymus | 4.44E-04 | 1.96E-04 | 1.48E-04 | 1.15E-04 | 9.63E-05 | 8.89E-05 | 9.63E-04 | 8.89E-04 | 6.67E-04 | 5.19E-04 | 4.44E-04 | 4.44E-04 |
| Thyroid | 4.44E-04 | 1.96E-04 | 1.48E-04 | 1.15E-04 | 9.63E-05 | 8.89E-05 | 9.63E-04 | 8.89E-04 | 6.67E-04 | 5.19E-04 | 4.44E-04 | 4.44E-04 |
| Upper Large Intestine | 1.07E-03 | 6.30E-04 | 3.56E-04 | 2.41E-04 | 1.67E-04 | 1.44E-04 | 1.15E-03 | 1.00E-03 | 7.04E-04 | 5.56E-04 | 4.81E-04 | 4.81E-04 |
| Uterus | 4.44E-04 | 1.96E-04 | 1.48E-04 | 1.15E-04 | 9.63E-05 | 8.89E-05 | 9.63E-04 | 8.89E-04 | 6.67E-04 | 5.19E-04 | 4.44E-04 | 4.44E-04 |

**Notes:**

-Committed dose coefficients (to age 70) for the public obtained from program "Radiological Toolbox" v. 3.0.0, based on ICRP 68/72 [130,44]. Units are mrem per pCi.

-Medium lung solubility recommended by ICRP for Ra-226 and U-238 in absence of data on contaminant solubility [46].

**Table E 4. External dose coefficients for soil and sediment used in Coldwater Creek evaluation.‡**

| | External dose coefficient for soil contaminated to a depth of 15 centimeters, in millirem per ((picocurie per cubic meter)-hour) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Organ | U-238 | Th-234 | Pa-234m† | Pa-234† | U-234 | Soil / Sediment Coefficient for U-238* | Soil / Sediment Coefficient for Th-230* | Ra-226 | Rn-222 | Po-218 | Pb-214† | At-218† | Bi-214 | Po-214 | Pb-210 | Bi-210 | Soil / Sediment Coefficient for Ra-226* |
| Adrenals | 2.01E-15 | 1.19E-12 | 4.69E-12 | 6.07E-10 | 1.65E-14 | 6.87E-12 | 5.81E-14 | 1.68E-12 | 1.23E-13 | 2.97E-15 | 7.07E-11 | 2.35E-13 | 5.07E-10 | 2.71E-14 | 8.77E-14 | 1.84E-13 | 2.91E-10 |
| Bladder | 2.53E-15 | 1.32E-12 | 4.84E-12 | 6.23E-10 | 1.85E-14 | 7.17E-12 | 6.43E-14 | 1.83E-12 | 1.27E-13 | 3.05E-15 | 7.44E-11 | 2.79E-13 | 5.13E-10 | 2.77E-14 | 1.07E-13 | 1.99E-13 | 2.96E-10 |
| Bone surface | 1.76E-14 | 5.57E-12 | 8.93E-12 | 1.08E-09 | 7.92E-14 | 1.63E-11 | 2.52E-13 | 5.08E-12 | 2.40E-13 | 5.01E-15 | 1.65E-10 | 1.52E-12 | 7.95E-10 | 4.61E-14 | 6.24E-13 | 6.09E-13 | 4.86E-10 |
| Brain | 2.28E-15 | 1.39E-12 | 5.28E-12 | 6.83E-10 | 1.91E-14 | 7.77E-12 | 6.75E-14 | 1.95E-12 | 1.41E-13 | 3.35E-15 | 8.16E-11 | 2.79E-13 | 5.64E-10 | 3.05E-14 | 1.02E-13 | 2.12E-13 | 3.25E-10 |
| Breast | 1.41E-14 | 1.88E-12 | 5.97E-12 | 7.65E-10 | 3.84E-14 | 9.12E-12 | 9.73E-14 | 2.37E-12 | 1.64E-13 | 3.73E-15 | 9.67E-11 | 5.03E-13 | 6.15E-10 | 3.41E-14 | 2.27E-13 | 2.73E-13 | 3.58E-10 |
| Colon | 1.95E-15 | 1.22E-12 | 4.66E-12 | 6.02E-10 | 1.67E-14 | 6.85E-12 | 5.91E-14 | 1.71E-12 | 1.24E-13 | 2.95E-15 | 7.13E-11 | 2.37E-13 | 5.00E-10 | 2.69E-14 | 8.57E-14 | 1.85E-13 | 2.88E-10 |
| Effective (ICRP 60) | 5.68E-15 | 1.52E-12 | 6.29E-12 | 6.77E-10 | 2.45E-14 | 8.92E-12 | 7.55E-14 | 2.01E-12 | 1.41E-13 | 3.32E-15 | 8.29E-11 | 3.48E-13 | 5.55E-10 | 3.03E-14 | 1.41E-13 | 3.83E-13 | 3.21E-10 |
| Esophagus | 1.40E-15 | 1.07E-12 | 4.43E-12 | 5.75E-10 | 1.45E-14 | 6.42E-12 | 5.20E-14 | 1.59E-12 | 1.18E-13 | 2.81E-15 | 6.73E-11 | 1.80E-13 | 4.83E-10 | 2.56E-14 | 5.99E-14 | 1.69E-13 | 2.77E-10 |
| Extratracheal airways | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Kidneys | 3.09E-15 | 1.40E-12 | 4.95E-12 | 6.36E-10 | 2.00E-14 | 7.38E-12 | 6.81E-14 | 1.88E-12 | 1.35E-13 | 3.11E-15 | 7.80E-11 | 3.16E-13 | 5.27E-10 | 2.84E-14 | 1.27E-13 | 2.09E-13 | 3.04E-10 |
| Liver | 2.63E-15 | 1.40E-12 | 4.92E-12 | 6.35E-10 | 1.95E-14 | 7.35E-12 | 6.76E-14 | 1.88E-12 | 1.32E-13 | 3.11E-15 | 7.71E-11 | 3.00E-13 | 5.21E-10 | 2.83E-14 | 1.15E-13 | 2.07E-13 | 3.01E-10 |
| Lower large intestine | 1.89E-15 | 1.20E-12 | 4.67E-12 | 6.03E-10 | 1.65E-14 | 6.85E-12 | 5.87E-14 | 1.71E-12 | 1.24E-13 | 2.96E-15 | 7.16E-11 | 2.31E-13 | 5.01E-10 | 2.69E-14 | 8.24E-14 | 1.85E-13 | 2.88E-10 |
| Lungs | 3.12E-15 | 1.56E-12 | 5.36E-12 | 6.89E-10 | 2.17E-14 | 8.04E-12 | 7.53E-14 | 2.05E-12 | 1.44E-13 | 3.37E-15 | 8.41E-11 | 3.51E-13 | 5.63E-10 | 3.08E-14 | 1.37E-13 | 2.28E-13 | 3.26E-10 |
| Muscle | 7.55E-15 | 1.56E-12 | 5.43E-12 | 6.99E-10 | 2.72E-14 | 8.13E-12 | 7.88E-14 | 2.07E-12 | 1.47E-13 | 3.43E-15 | 8.53E-11 | 3.75E-13 | 5.68E-10 | 3.12E-14 | 1.59E-13 | 2.32E-13 | 3.29E-10 |
| Ovaries | 1.73E-15 | 1.11E-12 | 4.52E-12 | 5.85E-10 | 1.55E-14 | 6.58E-12 | 5.51E-14 | 1.65E-12 | 1.17E-13 | 2.87E-15 | 6.81E-11 | 2.04E-13 | 4.91E-10 | 2.60E-14 | 6.85E-14 | 1.75E-13 | 2.81E-10 |
| Pancreas | 1.63E-15 | 1.14E-12 | 4.40E-12 | 5.68E-10 | 1.55E-14 | 6.46E-12 | 5.51E-14 | 1.63E-12 | 1.17E-13 | 2.77E-15 | 6.77E-11 | 2.05E-13 | 4.79E-10 | 2.52E-14 | 7.09E-14 | 1.75E-13 | 2.75E-10 |
| Red marrow | 2.91E-15 | 1.35E-12 | 5.28E-12 | 6.84E-10 | 1.95E-14 | 7.73E-12 | 6.63E-14 | 1.95E-12 | 1.41E-13 | 3.36E-15 | 8.19E-11 | 2.63E-13 | 5.64E-10 | 3.05E-14 | 9.97E-14 | 2.11E-13 | 3.25E-10 |
| Remainder | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Skin | 4.73E-14 | 2.00E-12 | 1.09E-10 | 8.29E-10 | 7.97E-14 | 1.12E-10 | 1.29E-13 | 2.51E-12 | 1.75E-13 | 4.04E-15 | 1.04E-10 | 5.93E-13 | 7.28E-10 | 3.69E-14 | 3.01E-13 | 1.60E-11 | 4.27E-10 |
| Small intestine | 1.77E-15 | 1.16E-12 | 4.53E-12 | 5.87E-10 | 1.60E-14 | 6.65E-12 | 5.64E-14 | 1.65E-12 | 1.20E-13 | 2.88E-15 | 6.89E-11 | 2.20E-13 | 4.89E-10 | 2.61E-14 | 7.84E-14 | 1.79E-13 | 2.81E-10 |
| Spleen | 2.56E-15 | 1.40E-12 | 4.96E-12 | 6.39E-10 | 1.93E-14 | 7.40E-12 | 6.80E-14 | 1.89E-12 | 1.33E-13 | 3.12E-15 | 7.76E-11 | 3.01E-13 | 5.27E-10 | 2.85E-14 | 1.15E-13 | 2.08E-13 | 3.04E-10 |
| Stomach | 2.61E-15 | 1.37E-12 | 4.87E-12 | 6.27E-10 | 1.91E-14 | 7.26E-12 | 6.64E-14 | 1.84E-12 | 1.29E-13 | 3.07E-15 | 7.53E-11 | 2.92E-13 | 5.13E-10 | 2.80E-14 | 1.13E-13 | 2.03E-13 | 2.96E-10 |
| Testes | 1.09E-14 | 1.79E-12 | 5.84E-12 | 7.48E-10 | 3.36E-14 | 8.86E-12 | 9.07E-14 | 2.28E-12 | 1.60E-13 | 3.65E-15 | 9.36E-11 | 4.57E-13 | 6.05E-10 | 3.35E-14 | 2.01E-13 | 2.61E-13 | 3.52E-10 |
| Thymus | 3.16E-15 | 1.48E-12 | 5.16E-12 | 6.64E-10 | 2.09E-14 | 7.72E-12 | 7.24E-14 | 1.96E-12 | 1.37E-13 | 3.27E-15 | 8.04E-11 | 3.33E-13 | 5.39E-10 | 2.97E-14 | 1.32E-13 | 2.17E-13 | 3.12E-10 |
| Thyroid | 3.88E-15 | 1.47E-12 | 5.01E-12 | 6.44E-10 | 2.16E-14 | 7.53E-12 | 7.13E-14 | 1.91E-12 | 1.35E-13 | 3.15E-15 | 7.87E-11 | 3.45E-13 | 5.31E-10 | 2.87E-14 | 1.41E-13 | 2.15E-13 | 3.07E-10 |
| Upper large intestine | 2.00E-15 | 1.23E-12 | 4.65E-12 | 6.01E-10 | 1.68E-14 | 6.85E-12 | 5.96E-14 | 1.71E-12 | 1.23E-13 | 2.95E-15 | 7.11E-11 | 2.43E-13 | 4.99E-10 | 2.68E-14 | 8.91E-14 | 1.85E-13 | 2.87E-10 |
| Uterus | 1.68E-15 | 1.14E-12 | 4.49E-12 | 5.83E-10 | 1.55E-14 | 6.57E-12 | 5.51E-14 | 1.61E-12 | 1.18E-13 | 2.87E-15 | 6.80E-11 | 2.11E-13 | 4.83E-10 | 2.60E-14 | 7.39E-14 | 1.75E-13 | 2.77E-10 |

‡ 15-cm soil dose coefficients obtained from program "Radiological Toolbox" v. 3.0.0, based on Federal Guidance Report 12 [130,45]. Po-210 (and other decay products formed at very low frequencies) have a negligible contribution to external dose and are not shown on the table [131]. Sediment doses multiplied by dose reduction factor of 0.2 for contaminated river shorelines, as recommended in Federal Guidance Report 12 [45].

* To account for external dose from daughter products not measured, ATSDR determined dose coefficients for U-238, Th-230, and Ra-226 shown highlighted in blue, assuming secular equilibrium and half of Rn-222 gas lost to atmosphere. The U-238 concentration is multiplied by the sum of dose coefficients U-238 through U-234; the Th-230 concentration is applied to the Th-230 dose coefficient; and the Ra-226 concentration is applied to the Ra-226 dose coefficient plus half of the sum of dose coefficients from Rn-222 through Bi-210.

† Th-234 forms Pa-234m 99.84% of the time and Pa-234 0.16% of the time, and Po-218 forms Pb-214 98.98% of the time and At-218 0.02% of the time; for summing, Pa-234m, Pa-234, Pb-214, and At-218 coefficients were multiplied by these branching ratios.

** Colon dose coefficient not listed; ATSDR estimated dose coefficient for colon by averaging coefficients for upper large intestine and lower large intestine.

ND = Not determined

**Table E 5. External dose coefficients for water used in Coldwater Creek evaluation‡**

| | External dose coefficient for water immersion, in millirem per ((picocurie per liter)-hour) | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Organ | U-238 | Th-234 | Pa-234m† | Pa-234† | U-234 | Water Coefficient for U-238* | Water Coefficient for Th-230* | Ra-226 | Rn-222 | Po-218 | Pb-214† | At-218† | Bi-214 | Po-214 | Pb-210 | Bi-210 | Water Coefficient for Ra-226* |
| Adrenals | 1.80E-11 | 6.51E-09 | 1.61E-08 | 2.19E-06 | 9.16E-11 | 2.62E-08 | 3.09E-10 | 6.83E-09 | 4.49E-10 | 1.05E-11 | 2.68E-07 | 1.92E-09 | 1.83E-06 | 9.59E-11 | 8.13E-10 | 5.68E-10 | 1.06E-06 |
| Bladder | 2.43E-11 | 7.15E-09 | 1.61E-08 | 2.17E-06 | 1.05E-10 | 2.69E-08 | 3.39E-10 | 7.11E-09 | 4.48E-10 | 1.03E-11 | 2.72E-07 | 2.23E-09 | 1.85E-06 | 9.43E-11 | 9.69E-10 | 6.07E-10 | 1.07E-06 |
| Bone surface | 2.29E-10 | 3.37E-08 | 3.48E-08 | 4.39E-06 | 6.05E-10 | 7.63E-08 | 1.60E-09 | 2.36E-08 | 9.67E-10 | 1.99E-11 | 7.17E-07 | 1.29E-08 | 3.17E-06 | 1.83E-10 | 6.00E-09 | 2.32E-09 | 1.97E-06 |
| Brain | 2.43E-11 | 8.65E-09 | 2.08E-08 | 2.81E-06 | 1.22E-10 | 3.41E-08 | 4.11E-10 | 8.83E-09 | 5.72E-10 | 1.36E-11 | 3.44E-07 | 2.68E-09 | 2.32E-06 | 1.24E-10 | 1.15E-09 | 7.44E-10 | 1.34E-06 |
| Breast | 2.67E-10 | 1.22E-08 | 2.28E-08 | 3.01E-06 | 4.47E-10 | 4.05E-08 | 7.24E-10 | 1.05E-08 | 6.21E-10 | 1.44E-11 | 3.88E-07 | 4.95E-09 | 2.44E-06 | 1.31E-10 | 2.55E-09 | 1.02E-09 | 1.43E-06 |
| Colon | 1.61E-11 | 6.35E-09 | 1.61E-08 | 2.18E-06 | 8.80E-11 | 2.61E-08 | 3.01E-10 | 6.71E-09 | 4.37E-10 | 1.05E-11 | 2.62E-07 | 1.81E-09 | 1.84E-06 | 9.55E-11 | 7.43E-10 | 5.51E-10 | 1.06E-06 |
| Effective (ICRP 60) | 7.80E-11 | 8.76E-09 | 2.64E-08 | 2.52E-06 | 1.85E-10 | 3.94E-08 | 4.45E-10 | 8.32E-09 | 5.15E-10 | 1.21E-11 | 3.17E-07 | 2.97E-09 | 2.09E-06 | 1.10E-10 | 1.39E-09 | 3.97E-09 | 1.22E-06 |
| Esophagus | 1.28E-11 | 5.83E-09 | 1.63E-08 | 2.21E-06 | 7.93E-11 | 2.57E-08 | 2.77E-10 | 6.57E-09 | 4.40E-10 | 1.07E-11 | 2.61E-07 | 1.49E-09 | 1.87E-06 | 9.73E-11 | 5.79E-10 | 5.24E-10 | 1.07E-06 |
| Extratracheal airways | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Kidneys | 3.29E-11 | 7.96E-09 | 1.76E-08 | 2.36E-06 | 1.23E-10 | 2.95E-08 | 3.80E-10 | 7.67E-09 | 4.81E-10 | 1.13E-11 | 2.92E-07 | 2.65E-09 | 1.96E-06 | 1.03E-10 | 1.20E-09 | 6.72E-10 | 1.13E-06 |
| Liver | 2.48E-11 | 7.75E-09 | 1.76E-08 | 2.37E-06 | 1.12E-10 | 2.93E-08 | 3.67E-10 | 7.68E-09 | 4.83E-10 | 1.14E-11 | 2.93E-07 | 2.44E-09 | 1.99E-06 | 1.04E-10 | 1.06E-09 | 6.55E-10 | 1.15E-06 |
| Lower large intestine | 1.51E-11 | 6.15E-09 | 1.60E-08 | 2.16E-06 | 8.47E-11 | 2.57E-08 | 2.91E-10 | 6.56E-09 | 4.32E-10 | 1.05E-11 | 2.57E-07 | 1.72E-09 | 1.83E-06 | 9.51E-11 | 6.95E-10 | 5.36E-10 | 1.05E-06 |
| Lungs | 3.05E-11 | 9.01E-09 | 1.96E-08 | 2.63E-06 | 1.32E-10 | 3.29E-08 | 4.27E-10 | 8.67E-09 | 5.37E-10 | 1.26E-11 | 3.29E-07 | 2.95E-09 | 2.17E-06 | 1.15E-10 | 1.30E-09 | 7.52E-10 | 1.26E-06 |
| Muscle | 1.15E-10 | 9.12E-09 | 1.92E-08 | 2.57E-06 | 2.33E-10 | 3.28E-08 | 4.87E-10 | 8.49E-09 | 5.27E-10 | 1.23E-11 | 3.23E-07 | 3.28E-09 | 2.12E-06 | 1.12E-10 | 1.59E-09 | 7.72E-10 | 1.23E-06 |
| Ovaries | 1.32E-11 | 5.67E-09 | 1.59E-08 | 2.16E-06 | 7.83E-11 | 2.51E-08 | 2.69E-10 | 6.32E-09 | 4.01E-10 | 1.05E-11 | 2.43E-07 | 1.55E-09 | 1.83E-06 | 9.45E-11 | 6.05E-10 | 5.01E-10 | 1.04E-06 |
| Pancreas | 1.33E-11 | 5.87E-09 | 1.55E-08 | 2.09E-06 | 8.01E-11 | 2.48E-08 | 2.79E-10 | 6.45E-09 | 4.20E-10 | 1.00E-11 | 2.52E-07 | 1.56E-09 | 1.79E-06 | 9.13E-11 | 6.11E-10 | 5.17E-10 | 1.03E-06 |
| Red marrow | 3.84E-11 | 7.44E-09 | 1.89E-08 | 2.56E-06 | 1.27E-10 | 3.06E-08 | 3.64E-10 | 7.89E-09 | 5.17E-10 | 1.24E-11 | 3.09E-07 | 2.21E-09 | 2.15E-06 | 1.12E-10 | 9.63E-10 | 6.60E-10 | 1.24E-06 |
| Remainder | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND | ND |
| Skin | 9.11E-10 | 1.77E-08 | 7.89E-07 | 3.35E-06 | 1.27E-09 | 8.13E-07 | 1.35E-09 | 1.24E-08 | 6.53E-10 | 1.83E-11 | 5.99E-07 | 6.59E-09 | 3.09E-06 | 1.36E-10 | 4.00E-09 | 3.25E-07 | 2.02E-06 |
| Small intestine | 1.48E-11 | 6.08E-09 | 1.57E-08 | 2.12E-06 | 8.36E-11 | 2.53E-08 | 2.87E-10 | 6.49E-09 | 4.24E-10 | 1.02E-11 | 2.53E-07 | 1.68E-09 | 1.80E-06 | 9.29E-11 | 6.83E-10 | 5.31E-10 | 1.03E-06 |
| Spleen | 2.29E-11 | 7.72E-09 | 1.77E-08 | 2.39E-06 | 1.09E-10 | 2.94E-08 | 3.65E-10 | 7.68E-09 | 4.87E-10 | 1.15E-11 | 2.95E-07 | 2.40E-09 | 1.99E-06 | 1.04E-10 | 1.04E-09 | 6.52E-10 | 1.15E-06 |
| Stomach | 2.53E-11 | 7.59E-09 | 1.73E-08 | 2.35E-06 | 1.11E-10 | 2.88E-08 | 3.60E-10 | 7.51E-09 | 4.79E-10 | 1.12E-11 | 2.89E-07 | 2.40E-09 | 1.96E-06 | 1.02E-10 | 1.05E-09 | 6.43E-10 | 1.13E-06 |
| Testes | 1.37E-10 | 1.02E-08 | 1.99E-08 | 2.65E-06 | 2.71E-10 | 3.47E-08 | 5.45E-10 | 9.09E-09 | 5.43E-10 | 1.27E-11 | 3.39E-07 | 3.89E-09 | 2.15E-06 | 1.16E-10 | 1.92E-09 | 8.55E-10 | 1.25E-06 |
| Thymus | 3.63E-11 | 8.59E-09 | 1.84E-08 | 2.45E-06 | 1.35E-10 | 3.11E-08 | 4.09E-10 | 8.21E-09 | 4.99E-10 | 1.17E-11 | 3.08E-07 | 2.88E-09 | 2.07E-06 | 1.07E-10 | 1.30E-09 | 7.17E-10 | 1.20E-06 |
| Thyroid | 8.45E-11 | 9.79E-09 | 2.03E-08 | 2.71E-06 | 2.04E-10 | 3.46E-08 | 4.91E-10 | 9.08E-09 | 5.52E-10 | 1.30E-11 | 3.41E-07 | 3.52E-09 | 2.21E-06 | 1.18E-10 | 1.68E-09 | 8.25E-10 | 1.29E-06 |
| Upper large intestine | 1.72E-11 | 6.56E-09 | 1.63E-08 | 2.20E-06 | 9.13E-11 | 2.64E-08 | 3.11E-10 | 6.85E-09 | 4.43E-10 | 1.06E-11 | 2.67E-07 | 1.89E-09 | 1.85E-06 | 9.60E-11 | 7.91E-10 | 5.67E-10 | 1.07E-06 |
| Uterus | 1.39E-11 | 5.87E-09 | 1.52E-08 | 2.07E-06 | 8.05E-11 | 2.44E-08 | 2.77E-10 | 6.36E-09 | 4.13E-10 | 9.91E-12 | 2.48E-07 | 1.59E-09 | 1.76E-06 | 9.00E-11 | 6.29E-10 | 5.13E-10 | 1.01E-06 |

‡ Water immersion dose coefficients obtained from program "Radiological Toolbox" v. 3.0.0, based on Federal Guidance Report 12 [130,45]. Po-210 (and other decay products formed at very low frequencies) have a negligible contribution to external dose and are not shown on the table [131]. Assumed surface water immersion for 10 minutes per day spent in or around the creek.

* To account for external dose from daughter products not measured, ATSDR determined dose coefficients for U-238, Th-230, and Ra-226 shown highlighted in blue, assuming secular equilibrium and half of Rn-222 gas lost to atmosphere. The U-238 concentration is multiplied by the sum of dose coefficients U-238 through U-234; the Th-230 concentration is applied to the Th-230 dose coefficient; and the Ra-226 concentration is applied to the Ra-226 dose coefficient plus half of the sum of dose coefficients from Rn-222 through Bi-210.

† Th-234 forms Pa-234m 99.84% of the time and Pa-234 0.16% of the time, and Po-218 forms Pb-214 98.98% of the time and At-218 0.02% of the time; for summing, Pa-234m, Pa-234, Pb-214, and At-218 coefficients were multiplied by these branching ratios.

** Colon dose coefficient not listed; ATSDR estimated dose coefficient for colon by averaging coefficients for upper large intestine and lower large intestine.

ND = Not determined

### Estimating Increased Cancer Risk

To estimate the increased risk of developing cancer from the exposures at Coldwater Creek, ATSDR applied lifetime attributable risk coefficients to the doses estimated using ICRP and EPA dose coefficients. Lifetime attributable risks are estimates of cancer incidence and mortality risks due to low doses of ionizing radiation developed by EPA in 2011 [48].

The EPA lifetime attributable risk coefficients were designed to be used with absorbed dose in a given year and then integrated over the years of exposure and dose. Since the dose to the body from a given intake changes every year due to radioactive decay and biological processes, the integration can become very complicated, especially for multiple years of intake. ATSDR used a different procedure: we estimated the committed dose to age 70 for every year of intake separately and applied risk to that committed dose (plus that year's external dose) in the year the intake occurred. Given the uncertainties involved, this simplified method gives reasonable estimates of lifetime risks from exposure, while greatly improving accessibility of the calculations and results presentation for the general public.

EPA based their risk estimates on risk models developed by the National Academy of Sciences from epidemiological and radio-biological data including studies of Japanese atomic bomb survivors, medically irradiated patients, and occupationally and environmentally exposed groups [132]. Some model details were modified by EPA to increase their applicability to a wider range of exposures [66]. For bone cancers, EPA used data from studies of people exposed to alpha radiation and divided by a factor of 10 to put the risks in terms of low energy transfer radiation such as gamma rays, x-rays, and electrons [66].

EPA lifetime attributable risk coefficients applied to the organs for which dose coefficients are available and used in this evaluation are shown in Table E6 below. We only show coefficients for the cancer sites we estimated doses for, and for ages up to 30, since those were the only ones used for our 33-year exposure. Because risk is higher at younger ages, the risk estimates in this report will overestimate risks to people exposed later in life.

**Table E 6. Selected values from Table 3-12c reported in [48]; sex-averaged lifetime attributable risk coefficients for cancer incidence by age at exposure**

| Cancer site | Age at exposure | | | | | |
|---|---|---|---|---|---|---|
| | 0 | 5 | 10 | 15 | 20 | 30 |
| Bladder | 220 | 188 | 160 | 136 | 116 | 84 |
| Bone | 10.4 | 8.0 | 6.1 | 4.7 | 3.5 | 2.0 |
| Breast | 614 | 480 | 372 | 288 | 222 | 130 |
| Colon | 285 | 244 | 207 | 175 | 149 | 107 |
| Kidney | 117 | 54 | 43 | 36 | 30 | 21 |
| Liver | 81 | 67 | 55 | 46 | 38 | 26 |
| Lung | 547 | 459 | 383 | 320 | 268 | 188 |
| Ovary | 44 | 38 | 31 | 26 | 22 | 15 |
| Leukemia | 183 | 130 | 101 | 86 | 79 | 69 |
| Skin | 1360 | 722 | 381 | 201 | 106 | 30 |
| Stomach | 190 | 157 | 129 | 106 | 87 | 58 |
| Thyroid | 252 | 227 | 126 | 68 | 47 | 21 |
| Uterus | 32 | 27 | 22 | 18 | 15 | 10 |
| Total | 3,970 | 2,850 | 2,230 | 1,780 | 1,460 | 979 |

Note: Values are presented in cases per 10,000 person-Gray.

ATSDR's estimates for internal and external dose were already corrected for the differences between alpha particles and different types of radiation. All the risks were divided by 100 to convert the risk per Gray (equivalent to Sieverts for the radiation EPA based their estimates on) to rem.

Table E7 presents the lifetime attributable risk values corresponding to organs for which doses were estimated and used to estimate increased risk of cancer in this report.

**Table E 7. Lifetime attributable risk for cancer incidence by age at exposure used in Coldwater Creek evaluation**

| Organ (ICRP dose) | Cancer site (EPA) | Age at Exposure | | | | | |
|---|---|---|---|---|---|---|---|
| | | 0 | 5 | 10 | 15 | 20 | 30 |
| Adrenals | N/A | ~ | ~ | ~ | ~ | ~ | ~ |
| Bladder | Bladder | 2.20 | 1.88 | 1.60 | 1.36 | 1.16 | 0.84 |
| Bone surface | Bone | 0.104 | 0.080 | 0.061 | 0.047 | 0.035 | 0.020 |
| Brain | N/A | ~ | ~ | ~ | ~ | ~ | ~ |
| Breast | Breast | 6.14 | 4.80 | 3.72 | 2.88 | 2.22 | 1.30 |
| Colon | Colon | 2.85 | 2.44 | 2.07 | 1.75 | 1.49 | 1.07 |
| Esophagus | N/A | ~ | ~ | ~ | ~ | ~ | ~ |
| Extratracheal airways | N/A | ~ | ~ | ~ | ~ | ~ | ~ |
| Kidneys | Kidney | 1.17 | 0.54 | 0.43 | 0.36 | 0.30 | 0.21 |
| Liver | Liver | 0.81 | 0.67 | 0.55 | 0.46 | 0.38 | 0.26 |
| Lower large intestine | N/A | ~ | ~ | ~ | ~ | ~ | ~ |
| Lungs | Lung | 5.47 | 4.59 | 3.83 | 3.20 | 2.68 | 1.88 |
| Muscle | N/A | ~ | ~ | ~ | ~ | ~ | ~ |
| Ovaries | Ovary | 0.44 | 0.38 | 0.31 | 0.26 | 0.22 | 0.15 |
| Pancreas | N/A | ~ | ~ | ~ | ~ | ~ | ~ |
| Red marrow | Leukemia | 1.83 | 1.30 | 1.01 | 0.86 | 0.79 | 0.69 |
| Remainder | N/A | ~ | ~ | ~ | ~ | ~ | ~ |
| Skin | Skin | 13.60 | 7.22 | 3.81 | 2.01 | 1.06 | 0.30 |
| Small intestine | N/A | ~ | ~ | ~ | ~ | ~ | ~ |
| Spleen | N/A | ~ | ~ | ~ | ~ | ~ | ~ |
| Stomach | Stomach | 1.90 | 1.57 | 1.29 | 1.06 | 0.87 | 0.58 |
| Testes | N/A | ~ | ~ | ~ | ~ | ~ | ~ |
| Thymus | N/A | ~ | ~ | ~ | ~ | ~ | ~ |
| Thyroid | Thyroid | 2.52 | 2.27 | 1.26 | 0.68 | 0.47 | 0.21 |
| Upper large intestine | N/A | ~ | ~ | ~ | ~ | ~ | ~ |

Note: Values are presented per 10,000 persons – rem
N/A, ~ = not estimated for attributable cancer risk

## Calculation of Risk

We calculated the risk by multiplying the lifetime attributable risk (LAR) by the estimated dose in mrem, with appropriate conversions, using the following equation:

$$Risk = \sum_i LAR_i \left(\frac{1}{10{,}000\ person \cdot rem}\right) \times Dose_i(millirem) \times \frac{1\ rem}{1{,}000\ millirem}$$

$$= \sum_i LAR_i \times Dose_i \times 10^{-7}$$

## Complete Organ-Specific Dose and Risk Results

Organ-specific dose and, if available, estimated increased risk of cancer at that site, are presented in Table E8 for past exposures and Table E9 for recent exposures. Estimated increased cancer risks above 1 in 10,000 are highlighted in orange in the tables.

ATSDR recognizes that all exposures may contribute to an increased risk of cancer. As described in the text, in this report we focus our discussion and conclusions on those risks estimated to be greater than 1 in 10,000. This is the upper bound of EPA's general "target range" for managing risks as part of a Superfund cleanup: 1 in 10,000 to 1 in 1,000,000 [49].

### Effective Dose

Effective whole-body doses were estimated for past and recent exposures at Coldwater Creek using appropriate internal and external dose coefficients. Table E10 shows the estimated whole-body doses over the assumed 33-year exposure.

Soil pica behavior may be exhibited by children, typically between the ages of 1 and 6. Regular soil pica behavior increases the estimated effective whole-body doses to the amounts shown in parentheses in Table E10.

**Table E 8. Tabulation of dose and risk results - past exposures and Coldwater Creek**

| | Committed dose for entire exposure, mrem | | | | Lifetime attributable risk from 33-year exposure | | | |
|---|---|---|---|---|---|---|---|---|
| | Recreational | | Residential | | Recreational | | Residential | |
| **Organ** | Slow* | Medium ** | Slow* | Medium ** | Slow* | Medium ** | Slow* | Medium ** |
| Adrenals | 39 | 55 | 88 | 161 | † | † | † | † |
| Bladder | 39 | 56 | 89 | 162 | 6E-06 | 9E-06 | 1E-05 | 3E-05 |
| **Bone surface** | 5,391 | 15,756 | 13,969 | 62,697 | 4E-05 | **1E-04** | 8E-05 | **3E-04** |
| Brain | 42 | 59 | 95 | 168 | † | † | † | † |
| Breast | 45 | 62 | 103 | 176 | 2E-05 | 2E-05 | 4E-05 | 6E-05 |
| Colon | 57 | 73 | 120 | 192 | 1E-05 | 2E-05 | 2E-05 | 4E-05 |
| Esophagus | 37 | 54 | 84 | 157 | † | † | † | † |
| Extratracheal airways | 316 | 87 | 1,364 | 361 | † | † | † | † |
| Kidneys | 151 | 361 | 349 | 1,282 | 1E-05 | 2E-05 | 2E-05 | 7E-05 |
| Liver | 136 | 319 | 312 | 1121 | 8E-06 | 2E-05 | 2E-05 | 6E-05 |
| Lower large intestine | 68 | 85 | 140 | 212 | † | † | † | † |
| **Lungs** | 640 | 289 | 2723 | 1165 | **3E-04** | **1E-04** | **1E-03** | **4E-04** |
| Muscle | 43 | 59 | 96 | 169 | † | † | † | † |
| Ovaries | 88 | 213 | 207 | 729 | 3E-06 | 7E-06 | 6E-06 | 2E-05 |
| Pancreas | 37 | 54 | 84 | 157 | † | † | † | † |
| **Red marrow** | 354 | 865 | 785 | 3052 | 5E-05 | **1E-04** | **1E-04** | **4E-04** |
| **Skin** | 61 | 78 | 138 | 211 | 3E-05 | 4E-05 | 7E-05 | **1E-04** |
| Small intestine | 39 | 56 | 88 | 161 | † | † | † | † |
| Spleen | 41 | 57 | 92 | 165 | † | † | † | † |
| Stomach | 40 | 57 | 90 | 163 | 5E-06 | 8E-06 | 1E-05 | 2E-05 |
| Testes | 95 | 217 | 222 | 738 | † | † | † | † |
| Thymus | 41 | 57 | 92 | 165 | † | † | † | † |
| Thyroid | 40 | 57 | 91 | 164 | 6E-06 | 8E-06 | 1E-05 | 2E-05 |
| Upper large intestine | 48 | 65 | 104 | 177 | † | † | † | † |
| Uterus | 37 | 54 | 85 | 158 | 9E-07 | 1E-06 | 2E-06 | 3E-06 |

*Slow lung solubility Th-230 dose coefficient **Medium lung solubility Th-230 dose coefficient

†No organ-specific attributable risk coefficient available mrem = millirem

Orange highlight means estimated lifetime cancer risk was higher than 1 in 10,000 (1E-4).

Bold values indicate risks still greater than 1E-4 after subtracting contribution of background levels of Th-230, Ra-226, and U-238 in soil, sediment, and surface water.

**Table E 9. Tabulation of dose and risk results - recent exposures at Coldwater Creek**

| | Committed dose for entire exposure, mrem | | | | Lifetime attributable risk from 33-year exposure | | | |
|---|---|---|---|---|---|---|---|---|
| | Recreational | | Residential | | Recreational | | Residential | |
| **Organ** | Slow* | Medium ** | Slow* | Medium ** | Slow* | Medium ** | Slow* | Medium ** |
| Adrenals | 4 | 4 | 21 | 29 | † | † | † | † |
| Bladder | 4 | 4 | 21 | 30 | 5E-07 | 7E-07 | 3E-06 | 5E-06 |
| Bone surface | 488 | 990 | 4517 | 10460 | 3E-06 | 6E-06 | 3E-05 | 6E-05 |
| Brain | 4 | 5 | 22 | 31 | † | † | † | † |
| Breast | 4 | 5 | 23 | 32 | 1E-06 | 2E-06 | 9E-06 | 1E-05 |
| Colon | 5 | 6 | 38 | 46 | 1E-06 | 1E-06 | 8E-06 | 1E-05 |
| Esophagus | 3 | 4 | 20 | 29 | † | † | † | † |
| Extratracheal airways | 14 | 4 | 172 | 51 | † | † | † | † |
| Kidneys | 13 | 22 | 109 | 222 | 8E-07 | 1E-06 | 7E-06 | 1E-05 |
| Liver | 12 | 20 | 98 | 196 | 7E-07 | 1E-06 | 6E-06 | 1E-05 |
| Lower large intestine | 6 | 7 | 48 | 57 | † | † | † | † |
| **Lungs** | 30 | 15 | 345 | 156 | 1E-05 | 5E-06 | **1E-04** | 6E-05 |
| Muscle | 4 | 5 | 22 | 31 | † | † | † | † |
| Ovaries | 7 | 12 | 58 | 121 | 2E-07 | 4E-07 | 2E-06 | 4E-06 |
| Pancreas | 3 | 4 | 20 | 29 | † | † | † | † |
| Red marrow | 31 | 53 | 272 | 546 | 4E-06 | 6E-06 | 4E-05 | 7E-05 |
| Skin | 6 | 6 | 30 | 39 | 2E-06 | 3E-06 | 2E-05 | 2E-05 |
| Small intestine | 4 | 4 | 22 | 30 | † | † | † | † |
| Spleen | 4 | 4 | 22 | 31 | † | † | † | † |
| Stomach | 4 | 4 | 21 | 30 | 4E-07 | 5E-07 | 3E-06 | 4E-06 |
| Testes | 8 | 13 | 61 | 124 | † | † | † | † |
| Thymus | 4 | 4 | 21 | 30 | † | † | † | † |
| Thyroid | 4 | 4 | 21 | 30 | 4E-07 | 5E-07 | 3E-06 | 4E-06 |
| Upper large intestine | 4 | 5 | 30 | 38 | † | † | † | † |
| Uterus | 3 | 4 | 20 | 29 | 7E-08 | 9E-08 | 4E-07 | 6E-07 |

*Slow lung solubility Th-230 dose coefficient **Medium lung solubility Th-230 dose coefficient
†No organ-specific attributable risk coefficient available mrem = millirem
Orange highlight means estimated lifetime cancer risk was higher than 1 in 10,000 (1E-4).
**Bold** values indicate risks still greater than 1E-4 after subtracting contribution of background levels of Th-230, Ra-226, and U-238 in soil, sediment, and surface water.

**Table E 10. Summary of effective doses estimated for past and recent exposures at Coldwater Creek**

| | Past recreational dose in mrem† | | Past residential dose in mrem† | | Recent recreational dose in mrem† | | Recent residential dose in mrem† | |
|---|---|---|---|---|---|---|---|---|
| **Age** | Slow * | Medium** | Slow * | Medium** | Slow * | Medium** | Slow * | Medium** |
| 0 | 28 | 30 | 54 | 71 | 2 | 2 | 19 | 22 |
| 1 | 6 (21) | 9 (24) | 31 (76) | 56 (100) | 0.4 (0.9) | 0.5 (1) | 7 (30) | 10 (33) |
| 2 | 4 (15) | 7 (18) | 22 (56) | 42 (75) | 0.3 (0.6) | 0.4 (0.7) | 5 (22) | 7 (25) |
| 3 | 5 (16) | 7 (18) | 23 (56) | 43 (77) | 0.3 (0.6) | 0.4 (0.7) | 5 (22) | 7 (25) |
| 4 | 5 (16) | 7 (18) | 23 (56) | 43 (77) | 0.3 (0.6) | 0.4 (0.7) | 5 (22) | 7 (25) |
| 5 | 5 (16) | 7 (18) | 23 (56) | 43 (77) | 0.3 (0.6) | 0.4 (0.7) | 5 (22) | 7 (25) |
| 6 | 15 | 25 | 24 | 46 | 0.7 | 1 | 5 | 7 |
| 7 | 11 | 20 | 18 | 37 | 0.5 | 1 | 4 | 6 |
| 8 | 11 | 20 | 18 | 37 | 0.5 | 1 | 4 | 6 |
| 9 | 11 | 20 | 18 | 37 | 0.5 | 1 | 4 | 6 |
| 10 | 11 | 20 | 18 | 37 | 0.5 | 1 | 4 | 6 |
| 11 | 14 | 25 | 21 | 44 | 1 | 1 | 4 | 7 |
| 12 | 13 | 25 | 20 | 43 | 1 | 1 | 4 | 7 |
| 13 | 13 | 25 | 20 | 43 | 1 | 1 | 4 | 7 |
| 14 | 10 | 20 | 21 | 44 | 1 | 1 | 5 | 8 |
| 15 | 10 | 20 | 21 | 44 | 1 | 1 | 5 | 8 |
| 16 | 10 | 20 | 21 | 44 | 1 | 1 | 5 | 8 |
| 17 | 9 | 20 | 19 | 44 | 0.6 | 1.0 | 4 | 7 |
| 18 | 2 | 4 | 19 | 43 | 0.3 | 0.5 | 4 | 7 |
| 19 | 2 | 4 | 19 | 43 | 0.3 | 0.5 | 4 | 7 |
| 20 | 2 | 4 | 17 | 42 | 0.3 | 0.5 | 3 | 6 |
| 21 | 2 | 4 | 17 | 42 | 0.3 | 0.5 | 3 | 6 |
| 22 | 2 | 4 | 17 | 42 | 0.3 | 0.5 | 3 | 6 |
| 23 | 2 | 4 | 17 | 42 | 0.3 | 0.5 | 3 | 6 |
| 24 | 2 | 4 | 17 | 42 | 0.3 | 0.5 | 3 | 6 |
| 25 | 2 | 4 | 17 | 42 | 0.3 | 0.5 | 3 | 6 |
| 26 | 2 | 4 | 17 | 42 | 0.3 | 0.5 | 3 | 6 |
| 27 | 2 | 4 | 17 | 42 | 0.3 | 0.5 | 3 | 6 |
| 28 | 2 | 4 | 17 | 42 | 0.3 | 0.5 | 3 | 6 |
| 29 | 2 | 4 | 17 | 42 | 0.3 | 0.5 | 3 | 6 |
| 30 | 2 | 4 | 17 | 42 | 0.3 | 0.5 | 3 | 6 |
| 31 | 2 | 4 | 17 | 42 | 0.3 | 0.5 | 3 | 6 |
| 32 | 2 | 4 | 17 | 42 | 0.3 | 0.5 | 3 | 6 |

†Dose including regular soil pica behavior between ages 1 and 6 shown in parentheses.

*Slow lung solubility Th-230 dose coefficient **Medium lung solubility Th-230 dose coefficient

**mrem = millirem**

## Appendix F. Public Comments Received and ATSDR Responses

This public health assessment (PHA) was available for public review and comment from June 18, 2018 through August 31, 2018 at the St. Louis County Library, Florissant Valley Branch, in Florissant, Missouri. The document and a fact sheet summary were also available for viewing or downloading from ATSDR's website.

ATSDR distributed the report and information about the public comment period electronically to more than 350 community members and public health partners and announced the release to area media outlets. ATSDR also announced the release and provided a link to the report on social media. ATSDR shared and discussed the findings of the public health assessment with community members at public availability sessions held June 27 and 28, 2018 at St. Mark's United Methodist Church in Florissant. Copies of the draft report and fact sheets summarizing the findings and ATSDR's process were also provided to the community during or after the public availability sessions.

ATSDR received written comments from more than 60 private citizens, three private organizations, the Missouri Department of Natural Resources (MDNR), the Missouri Department of Health and Senior Services (MDHSS), the Army Corps of Engineers' Formerly Utilized Sites Remedial Action Program (FUSRAP), the Department of Energy (DOE), and the U.S. Environmental Protection Agency (EPA). Several of the comments from private citizens contained personally identifiable information (PII) such as individual medical histories or addresses of residence, and many comments were similar; in addition, some comments were not related to the specific Coldwater Creek exposures we evaluated. For providing responses, private citizen comments were reworded and grouped together in the "Compiled comments from private citizens" section below. Other public comments received, with responses, follow. The additional comments are essentially verbatim; if necessary, ATSDR split the comments into numbered items for readability and clarity of inserted responses. ATSDR responses to comments are shown in *blue italicized text*. Following all the comments and responses, ATSDR has included, as far as possible while protecting PII, the verbatim comments received from private citizens.

### PCfusrap – Comments from FUSRAP

PCfusrap-1

1. Title and body of report

USACE recommends that ATSDR clarifies in the title and body of the report that this document is only an assessment of health problems that may occur from exposure to FUSRAP contaminants of concern (COC) in and along Coldwater Creek (CWC). The assessment is based solely on current radiological data from USACE, so the report leaves the reader with the impression that radiological contamination is the only contamination in and along the creek. No mention or assessment was made of the non-radiological hazardous chemical contaminants that may be located in and along the creek, such as jet fuel, trichloroethylene (TCE), benzene, heavy metals, etc. and the biological contamination Escherichia coli (E. coli). These hazardous materials may also possess some of the same cancer risks as the radiological contaminants in the

creek, as well as other health risks. Therefore, the Conclusions that are drawn by ATSDR do not encompass all the risks from hazardous substances that exist in and along CWC.

*ATSDR response: Although we used primarily FUSRAP data for the exposure estimation, the public health assessment was not limited to FUSRAP-related contamination. ATSDR looked for data on other sources of contamination and other contaminants, but only limited data were available. Much of this limited data was in the industrial areas and vicinity properties near the SLAPS and HISS areas and not in the residential or recreational areas. ATSDR evaluated the available non-radiological data and discussed that we do not have complete data but the available data do not indicate levels of potential concern. This is discussed in the Contaminants of Concern section beginning on page 15 and in Appendix B.*

*We recommend that agencies that suspect or are aware of sources contributing to non-radiological contamination or specific areas of concern along the creek provide this information to EPA or MDNR so appropriate follow-up action can be initiated.*

PCfusrap-2

2. Page ii, Conclusion 1

The first Conclusion is misleading. This conclusion, and its Basis for Conclusion, do not address the importance of there being a direct contact pathway and high levels of radioactive material to create the right dose risk exposure scenario for developing certain cancers in certain people. The way the conclusion is written the reader can be misled to think that any level of contamination in any configuration could cause cancer. The areas of contamination found recently in North County along Coldwater Creek and adjacent properties are below ground surface. The contamination in its current configuration below ground surface does not pose a complete exposure pathway to members of the public. In addition, the ongoing long-term monitoring of COCs in CWC shows radiological contamination to be below background levels.

*ATSDR response: To emphasize the conservative nature of our evaluation, ATSDR has added a statement in the summary after "Conclusions": "To evaluate possible effects from exposures, ATSDR estimated the exposure and resulting risks for the general group of children and adults who came in direct contact with sediment and water from Coldwater Creek and soil in its floodplain for many hours a day for many years. We assumed they were always exposed to concentrations of contaminants present in the most highly contaminated areas. Based on different specific assumptions for past (1960s to 1990s) and recent (2000s and on) exposures, detailed in this report, we reached the following four conclusions."*

*We disagree with the commenter's statement that "the contamination in its current configuration below ground surface does not pose a complete exposure pathway". We used surface soil data (0-6 inches below ground surface) to estimate recent exposures. The data files did not indicate any cover materials present above the soil sample. ATSDR does not consider leaves, grass, or other such cover materials protective from exposure at the ground surface. Furthermore, while*

*some of the highest contaminant levels were present deeper within the soil column, many surface soil samples contained Th-230 above remedial goals (sometimes considerably so). Because the floodplain contamination originally came from deposition of creek sediment, at some point in the past all buried contamination was at the ground surface and could be directly contacted. Only a small segment of the creek's floodplain has been assessed to date; we do not know what contaminant levels will be found there. For these reasons, our conservative evaluation is appropriate.*

PCfusrap-3

3. Page iv, Conclusion 3, Basis for Conclusion

The PHA states, "*Reports of historical use of Coldwater Creek sediment and floodplain soil in other locations indicates a possibility that contamination spread from the floodplain. Identifying and remediating contaminated areas outside the floodplain will reduce potentially harmful exposures.*"

Identifying and remediating contaminated soils outside the floodplain is a standard part of USACE procedure. USACE continues to investigate and sample Coldwater Creek sediment, banks, and adjacent properties. When possible contaminated areas are found, sampling investigations continue until the full extent of contamination is determined. This includes going outside the 10-year floodplain, where necessary. The 10-year floodplain is the baseline limit for the sampling investigations of FUSRAP contamination. The USACE recommends that ATSDR revise the statement to state, "*Continuation of identifying and remediating contaminated areas* ..."

*ATSDR response: ATSDR's discussions with community members indicated that most members of the public are unaware of this USACE protocol or how to provide input. ATSDR received some reports of specific locations where floodplain soil was used and has referred these to USACE. To increase public awareness of these actions, ATSDR suggests USACE list on its community website the specific areas it has investigated along with analytical results and any actions taken (redacted to remove personally identifiable information).*

PCfusrap-4

4. Page iv, Conclusion 3, Next Steps: Future Sampling Recommendations

a. The PHA states, "*...include areas reported to have received soil or sediment moved from Coldwater Creek floodplain (such as fill used in construction)."*

This is already a USACE standard practice. When evidence is presented to USACE that potentially contaminated soil has been relocated, investigation will take place.

Request ATSDR revise the report to state, " ... *we recommend future sampling continue to include areas reported to have received soil or sediment moved from Coldwater Creek floodplain.*"

*ATSDR response: ATSDR's discussions with community members indicated that most members of the public are unaware of this USACE protocol or how to provide input. ATSDR received some reports of specific locations where floodplain soil was used and has referred these to USACE. To increase public awareness, ATSDR suggests USACE list on its community website how the public can provide evidence of relocation of sediment or floodplain soil, the specific areas it has investigated to date, and a summary of analytical results and any actions taken (redacted to remove personally identifiable information).*

PCfusrap-5

b. The PHA states, "*...include areas with possible soil or sediment deposited by flooding of major residential tributaries to Coldwater Creek*"

This is already a USACE standard practice. USACE performs sampling at the mouth of tributaries to CWC, and continuing upstream on the tributaries within the 10-year floodplain. Sampling will continue up the tributary and beyond the 10-year floodplain boundary until the farthest point of contamination is determined.

Request ATSDR revise the report to state, " ... *we recommend future sampling continue to include areas with possible soil or sediment deposited by flooding of major residential tributaries to Coldwater Creek.*"

*ATSDR response: ATSDR interprets this comment as stating that sampling occurs at the mouths of tributaries and only continues upstream on the tributaries if contamination is found at the mouth. Contamination at the mouths of tributaries is likely to be washed away fairly quickly, so current sampling at the mouth may not reflect contamination levels further up the tributary. ATSDR recommends that sampling of tributaries occur not only at the mouth, but also in areas upstream of the mouth where sediment deposition may have occurred during flood events.*

*ATSDR's discussions with community members indicated that most members of the public are unaware that tributaries of Coldwater Creek have been sampled. To increase public awareness of these actions, ATSDR suggests USACE list on its community website the specific areas it has investigated along with analytical results and any actions taken (redacted to remove personally identifiable information).*

PCfusrap-6

c. The PHA states, *"...include indoor dust in homes where yards have been cleaned up or require cleanup*"

USACE does not endorse this recommendation. The contamination found in yards is found several inches to several feet below ground surface and, therefore, is not carried by dust into homes. In addition, during remediation the soils are sprayed with water to prevent dust suspension, so dust is not carried into the homes. All remediation sites are equipped with perimeter dust monitoring equipment to determine if any contaminated soil dust is leaving the sites. To date, there is no data to suggest that this is needed.

*ATSDR response: Floodplain contamination originated from deposition of creek sediment; at some point in the past all buried contamination was at the ground surface and could be directly contacted and tracked into homes. Indoor dust could serve as a long-term exposure reservoir for long-lived radioactive contaminants. ATSDR continues to recommend testing of indoor dust in homes whose yards are or were contaminated.*

PCfusrap-7

d. The PHA states, *"...include sediment and soil remaining in basements that were directly flooded by Coldwater Creek in the past*"

The USACE position has always been to sample any basement in which there is a demonstrated direct pathway for flooding that has left behind sediments.

*ATSDR response: ATSDR's discussions with community members indicated that most members of the public are unaware of this USACE protocol or how to request consideration for testing. To increase public awareness, ATSDR suggests USACE list on its community website how to request basement testing and the results of testing to date (redacted to remove personally identifiable information).*

PCfusrap-8

5. Page v, Conclusion 4, and references on pages 24, 29, 33, 36, 37 and 42

As part of its Feasibility Study, USACE performed a wind-dispersion study of contaminated material. The results indicated that the potential for windborne contamination was limited to the area in the immediate vicinity of SLAPS and HISS (former source areas), which have already been investigated and remediated. The model did not predict impacts to areas outside those that have been previously investigated.

*ATSDR response: ATSDR reviewed this report and noted that the wind dispersion study used assumptions selected to model the areas of highest possible deposition around SLAPS and HISS. Different assumptions might give a more conservative estimate of possible windblown exposures to area residents.*

PCfusrap-9

6. Page 11, First Sentence

The PHA states, "*If the contaminants are radioactive, people may receive an external dose of radiation just from being near the contamination.*"

To date, the contamination being found is all below ground surface covered with grass, soil, asphalt or concrete. There is no dose of radiation from below ground surface contamination. Dose risk is tied to contamination levels, location, proximity to the source, and duration. USACE recommends this statement be revised to state, "*People may receive an external dose of radiation from radioactive contaminants if the radioactive levels are sufficiently high, the radiation source is very close to person, and the duration of exposure is sufficiently long.*"

*ATSDR response: ATSDR does not agree with the details in this comment. The quoted statement is a general description of the potential for external radiation exposure. The potential for external exposures to be significant depends on the identity of the radioactive material, what type of radiation it emits, what materials are in between people and the radiation, how close people actually get to the radiation source, and how long they stay there. ATSDR accounted for these factors when it estimated external dose following standard practice. ATSDR used external dose coefficients for contamination in the top 15 centimeters of soil, corresponding closely to the 0-6 inch below ground surface sample results, along with a time component of the exposure extrapolated over a year of possible exposures. Additionally, the data ATSDR used did not indicate or describe any cover material. In general, ATSDR's conservative procedures would not assume cover material provides significant or permanent shielding from external radiation.*

PCfusrap-10

7. Page 12, Available Data and Information, Second Bullet

The PHA states, "*Because these data were collected to design remediation strategies or for monitoring, they may not fully characterize the nature and extent of contamination.*"

Pre-Design Investigation (PDI) sampling is much more detailed investigation than Remedial Investigation (RI) sampling. RI determines the general nature and potential extent; PDI then further defines the location of previously detected contamination. Data collected to design remediation (POI data) is the most detailed step of investigation. ATSDR should revise this statement to accurately describe the data used and not give the impression that PDI may somehow not identify the full nature and extent of the contamination.

*ATSDR response: After staff at FUSRAP reviewed a predecisional draft of this report, they asked ATSDR to acknowledge "its use of USACE PDI data, which was collected for the purposes of designing remediation and includes systematic and biased samples, as opposed to remedial investigation data that is used to characterize and determine the nature and extent of contamination." We added the statement quoted by the commenter; this comment also refers to monitoring and other sampling data that are not as detailed as either PDI or RI sampling. No change made.*

PCfusrap-11

8. Global Reference to "*Source Areas*"

The use of the terminology "*source areas*" should be revised to read *"former source areas*" globally throughout the document. The remedial actions at the former source areas (SLAPS and HISS/Futura) were completed in January 2007 and September 2011, respectively.

*ATSDR response: Where appropriate, ATSDR changed the terminology to "historical source areas."*

PCfusrap-12

9. Global Reference to "*Radon Gas*"

Please note: Radon gas is not a FUSRAP contaminant. USACE shares the St. Louis community's concerns about radon. USACE has tested indoor and outdoor radon concentrations in ongoing air-quality monitoring at the FUSRAP sites for the past 20 years. On the FUSRAP project, USACE knows that MED/ AEC contamination is still present under the Futura Coatings buildings. Knowing this, USACE has tested the inside air quality of these buildings for radon each year from 2000 to the present. The annual results are at or below 3.1 pCi/L, which is nearly equal to results across St. Louis County.

*ATSDR response: Radon gas is referenced in the report as a daughter product of the contaminants we evaluated. No change made.*

**PCepa – Comments from the U.S. Environmental Protection Agency**

PCepa-1

General Comment

EPA recommends that the abbreviations and acronyms be moved to the very front of the document. Additionally, EPA recommends ATSDR take care to define and clarify scientific terms throughout the document as much as possible. This will facilitate the readers' ability to quickly understand the information presented in the report.

*ATSDR Response: Abbreviations and acronyms are defined at their first use in the document. Due to the length and complexity of the report, we decided not to add a separate list of acronyms. The report is written for an educated lay public. We maintained a preference for overall readability and comprehension rather than strict scientific nuances of many technical terms used in the report.*

PCepa-2

EPA recommends that any supplemental information or spreadsheets be included with the report to facility a complete review of all calculations.

*ATSDR response: We have included full example calculations and tables listing all assumptions, coefficients, and other factors used in the calculations. The spreadsheets ATSDR used to calculate intakes, doses, and risks were not developed for public release and cannot be posted because they do not meet accessibility requirements for 508 compliance. ATSDR is willing to demonstrate or share the spreadsheets used for calculations, upon request.*

PCepa-3

Specific Comments

EPA notes that conclusion 1 on page ii states, "Radiological contamination…could have increased the risk of some types of cancer…"

Further, the first bullet related to the basis for the conclusion on the same page states, "…exposure could increase the risk of developing bone or lung cancer, leukemia, or (to a lesser extent) skin or breast cancer."

However, the second bullet related to the basis for conclusion 1 states, "More recent exposures (2000s and on) increased the risk of developing bone or lung cancer from daily residential exposure."

EPA suggests that "could have" be added to the second bullet before the word "increased" for consistency with the rest of conclusion 1. Although there is considerable basis to believe that radiation risk increases with dose, even for "low" doses, there is considerable uncertainty, particularly for individual cancer sites, e.g., bone. See, for example, the recent NCRP Commentary 27 (NCRP 2018) which addresses uncertainties on what can be concluded about risks at low doses and dose rates from epidemiological studies. EPA recommends further explanation be added to provide the reader context that includes this uncertainty.

*ATSDR response: We agree with the comment and have modified language, where appropriate, to include qualifiers such as "could have."*

PCepa-4

Purpose and Health Issues, page1, first paragraph states that a purpose of the health assessment is to evaluate whether radiological contamination associated with Cold Water Creek has "affected" people living nearby. EPA believes additional clarity is needed regarding the meaning of "affected". EPA suggests a more appropriate description of the evaluation would be a determination of whether people living nearby have been exposed to radiological contaminants, and if so, were those exposures at levels that may adversely affect health.

*ATSDR response: The statement referenced does indicate that our focus is on the health implications of exposure ("This report evaluates whether radiological contamination in and around Coldwater Creek in North St. Louis County, Missouri, has affected the health of people playing or living nearby.") ATSDR attempts to follow plain language principles and believes the phrase adequately conveys the general purpose.*

PCepa-5

Purpose and Health Issues, page 1, third paragraph, third sentence: It would seem appropriate to also define/describe what is meant by "remedial goals". EPA recommends a brief explanation about the remedial goals be added to include that they were developed using conservative assumptions to ensure health protectiveness.

*ATSDR response: The remedial goals were determined and approved by FUSRAP and/or EPA in the Record of Decision. We assumed the community around this site generally knows the concept of remedial goals.*

PCepa-6
Activities by ATSDR and its Public Health Partners, pages 5 and 6: EPA recommends that cancers listed in this section be identified if they are associated with exposure to ionizing radiation. EPA notes that without proper context, readers of this report may misinterpret that all the statistically elevated cancers listed in this section are associated with exposure to ionizing radiation coming from Coldwater Creek.

*ATSDR response: The bulleted list is only meant to summarize previous work related to the site. The reader can go to the referenced report for full explanation of the previous findings. ATSDR recognizes that some cancers are not known to be associated with exposure to ionizing radiation. Theoretical risk coefficients have been developed by EPA and other organizations for many of these organs even if cancers of those organs have not been associated with radiation exposure.*

PCepa-7
EPA notes that in Appendix E, page E-1: The term "70-year committed radiological dose" actually refers to a dose committed to age 70.

*ATSDR response: We have reworded this term throughout the report to reflect this comment.*

PCepa-8
EPA recommends that ATSDR review the estimates of risk presented in the health assessment. EPA believes the calculated risks for bone cancer in Tables 2 and 3 may be overestimated by a factor of ten or more due to the misapplication of the relative biological effectiveness defined in the cited EPA's "Blue Book" (EPA 402-R-11-001). More specific details are provided below:

a. In appendix E on page E-10, Table E 6 sites EPA's Sex-averaged Lifetime Attributable Risk for cancer incidence by age at exposure provided in table 3-12c of the "Blue Book" for Low-LET Radiation (EPA 402-R-11-001). Then on page 3-11, the report states, "ATSDR's estimates for internal and external dose were already corrected for the differences between alpha particles and different types of radiation." Further, the committed dose estimates provided in table E 8 are given in the radiation dose unit "mrem". This suggests a quality factor of 20 (for alpha particles) had been applied in the dose calculation.

The report goes on to state, "Therefore, we multiplied the EPA bone cancer risks by 10 before applying them to estimated doses." The "Blue Book" provides a discussion of how EPA determines risks from higher LET Radiation, including alpha particles, in section 5. Stated on page 120 in section 5, "EPA's site-specific α-particle risk estimates will be obtain by applying an RBE of 20 to our γ-ray risk estimates, with two exceptions: 1) an RBE = 2 for leukemia and 2) continued use of models derived from BEIR VI to estimate lung cancer risk from inhaled radon progeny (NAS 1999, EPA 2003). The low-dose, γ- ray risk estimate for bone cancer is obtained

by dividing the risk per Gy for α-particles – estimated from patients injected with 224Ra – by an RBE of 10."

Therefore, applying EPA's organ specific RBE of 10 for bone cancer to account for the greater biological effect of alpha particles is not appropriate if a factor of 20 for alpha particles has already been applied to the dose estimates that are converted to risks using the coefficients in table 3-12c in EPA's "Blue Book".

b. For most cancer sites (including bone cancer), excess risk per unit dose decreases with age at which the dose is received. Thus, an upper bound estimate can be calculated by multiplying the cumulative absorbed dose by the risk per unit dose at age 0. In Table 3, the residential dose to the bone surface is 4,600 – 10,500 mrem or 0.046 – 0.105 Sv. Based on the risk per unit dose value given in Table E 6 (Table 3-12c on p. 55 of EPA's "Blue Book") for age 0 of 10.4 per 10,000 person-Gy, the estimated excess risk would be less than 1 per 10,000 for alpha particles. For doses absorbed later in life, the risk would be even less. In Table 3, the risk range was 3-6 per 10,000.

*ATSDR response: ATSDR agrees that the lifetime attributable risk coefficient for bone surface should not have been multiplied by 10. We have updated risk tables and discussion to reflect the updated risks. This change did not affect our overall conclusions. Please see our additional responses to comments below for discussion about our method for estimating risk.*

PCepa-9

EPA notes that although, in theory, it is acceptable to calculate risks through a two-stage process by first calculating doses and then applying Blue Book values, EPA strongly recommends – whenever possible – to use the resources associated with Federal Guidance Report No. 13 (FGR 13). These would allow one to apply estimates of risks per unit intake. Then any estimate calculated through the two-stage process can be compared to estimates based on the FGR 13 resources. NAS 1999 compared the two-stage process with using risk coefficients that predate FGR 13, and found the risk coefficient approach to be "a methodologically more rigorous approach to assessing risk posed by chronic lifetime exposure to radionuclides, which is particularly important for internal exposures..." A 2002 ISCORS report signed by a number of federal agencies also recommends using the FRG 13 approach when conducting risk assessments that will be used for risk management decisions. For CERCLA sites, EPA recommends the use of risk coefficients (slope factors) for risk assessments of the cancer risk posed by radionuclides (EPA 2014).

*ATSDR response: The EPA slope factor method is a general approach which does not give sufficient ability to examine specific exposure and radionuclide parameters important at this site [133]. The FGR 13 coefficients represent risk per unit intake, which would be a simpler calculation than ATSDR's method [134]. However, the FGR 13 coefficients are dated (based on risks in EPA's previous "blue book" from 1994 [135]), and the organ-specific coefficients are*

*only available on a compact disc-based version of the report. ATSDR used the newer 2011 lifetime attributable risks (new "blue book" values), which are anticipated to update radionuclide risk coefficients in the next revision of FGR 13 [48].*

PCepa-10

EPA recommends that the age-specific risk coefficients from the Blue Book should not be applied to committed doses to age 70. Applying the age-specific risk coefficients in this way adds an additional layer of conservatism into the calculations. EPA suggests a rationale be provided in the report for why age-specific risk coefficients could not have been applied to corresponding age-specific doses and a survival function according to the methodology outlined in FGR 13.

*ATSDR response: The process used by ATSDR is reasonable for the purposes of our public health assessment. ATSDR recognizes that EPA's 2011 lifetime attributable risk coefficients were designed to be used with absorbed dose in a given year and then integrated over the years of exposure and dose. For multiple years of intake this becomes very complicated, typically requiring specialized computer programs that cannot be easily explained to or replicated by members of the public. In contrast, ATSDR estimated the committed dose to age 70 for every year of intake separately, and applied that committed dose in the year the intake occurred. This simplifies the calculations and allows clear presentation of the estimated dose and risk for each year an intake occurred.*

*To test how ATSDR's method compared with integrative methods, we used the AcuteDose code to estimate absorbed organ-specific doses for each year to age 70 and applied the 2011 lifetime attributable risks to determine lifetime cancer risks resulting from 33 years of intake, using the assumptions developed for the Coldwater Creek evaluation [136]. ATSDR's simplified method gives cumulative dose estimates and lifetime cancer risks generally comparable with the more complicated approach. We concluded that our methodology would be a reasonable approximation for estimating lifetime risks. We recognize that this approach would not be used in a detailed dose reconstruction. We believe the improved accessibility of the calculations for the general public outweighs any inaccuracies introduced by our method. Please see response to PCrac-29 on page F-56 for more details.*

PCepa-11

*[The following references were provided by the commenter in support of the above comments.]*

Reference:

EPA, 2014. "Radiation Risk Assessment at CERCLA Sites: Q & A." U.S. Environmental Protection Agency, Washington, DC. 2014

ISCORS, 2002. "A Method for Estimating Radiation Risk from Total Effective Dose Equivalent (TEDE)." Interagency Steering Committee on Radiation Standards, Washington, DC. 2002 http://www.iscors.org/doc/RiskTEDE.pdf

Land, Charles E. "Estimating cancer risks from low doses of ionizing radiation." Science 209, no. 4462 (1980): 1197-1203.

NAS, 1999. “Evaluation of Guidelines for Exposures to Technologically Enhanced Naturally Occurring Radioactive Materials.” National Academy Press, Washington, DC. 1999 https://www.nap.edu/catalog/6360/evaluation-of-guidelines-for-exposures-to-technologically-enhanced-naturally-occurring-radioactive-materials

NCRP, 2018. Implications of recent epidemiologic studies for the linear-nonthreshold model and radiation protection. Bethesda, MD

*ATSDR response: No response necessary.*

**PCdoe – Comments from the Department of Energy**

PCdoe-1

The new Federal Guidance Report No. 15, External Exposure to Radionuclides in Air, Water and Soil was just made available in June 2018. How does the new Guidance change the estimated doses from external radiation in the PHA report?

*ATSDR response: The public comment version of this report was developed and released before Federal Guidance Report (FGR) 15 was available. In the report, ATSDR used external dose coefficients from FGR 12. FGR 15 expanded FGR 12 to obtain external dose coefficients for multiple age groups, using updated tissue weighting factors and more recent ICRP decay and dosimetry data [137]. The dose coefficients in FGR 15 are different than those in FGR 12 and, based on a cursory examination by ATSDR, could change the estimated external doses by a relatively small amount, around 5%. Because external dose was a minor contributor to overall dose in ATSDR’s evaluation, updating the external dose coefficients and calculations would not change our overall conclusions. The final report continues to use FGR 12 as the basis for external dose estimation.*

PCdoe-2

It would be informative to review and discuss the relevant epidemiological studies in nuclear workers occupationally exposed to uranium, in particular those workers at Mallinckrodt Chemical Works, St. Louis, Missouri. Such as:

Canu I G, Ellis E D and Tirmarche M 2008 Cancer risk in nuclear workers occupationally exposed to uranium-emphasis on internal exposure Health Phys.94 1-17.

Dupree-Ellis E, Watkins JP, Ingle JN, Phillips JA (2000). External radiation exposure and mortality in a cohort of uranium processing workers. Am Epidemiol 152:91-95.

*ATSDR response: The articles cited refer to worker studies. The exposures experienced by Mallinckrodt workers are different in many ways from those evaluated in the ATSDR assessment. At the Mallinckrodt site in downtown St. Louis, workers (primarily adult males) processed uranium ore to extract the uranium, and were therefore exposed to high concentrations of uranium aerosols as well as other airborne contaminants such as silica and chemical fumes. The findings of the worker cohort studies do not add to our understanding of exposures of children and adults who incidentally came in contact with the wastes left over from Mallinckrodt processing (containing very little uranium) – waste that sat exposed to the elements for many years and eventually flowed downstream where people lived.*

PCdoe-3

A local Community group provided information on how often and how long the activities associated with the exposure occurred. However, there is no description or discussion on how the community conducted the exposure assessment (contact duration, frequency etc.).

*ATSDR response: The community group provided this information and we understand it was based on their members' recollection of growing up along Coldwater Creek, as well as their communications with many other people who grew up in the area, shared via the group's Facebook page and directly to ATSDR at site-related public meetings.*

PCdoe-4

Table 1: Would it be more consistent and conservative to use the soil maximum sample results for recent exposures? What about using sediment past exposure point concentration also for soil past exposure point concentration?

*ATSDR response: We followed ATSDR standard procedures as well as professional judgment to determine the appropriate exposure point concentrations for recent and past soil and sediment. For soil, ATSDR considers the surface to represent where exposure occurs and recommends using upper confidence limits over exposure units of concern to estimate exposure point concentration. We used the surface soil results collected in the 2014-2016 sampling to represent recent exposure. ATSDR used a different method to determine past exposure point concentration because no past floodplain soil data are available. Assuming deep contamination found in recent sampling may have once been at the surface, we used the highest concentration measured at any depth in the floodplain soil samples to represent past surface concentrations. Using that data, we determined the upper confidence limits for various exposure units. To estimate potential doses and risks for either recent or past exposure, we conservatively used the highest upper confidence limit of all the different exposure units.*

*This procedure for past floodplain soil exposure point concentration, while uncertain, most likely better represents past exposures than using historically measured sediment data. Creek sediment is the source of material that contaminated the floodplain. How much may have entered the floodplain and how widely it dispersed is unknown.*

PCdoe-5
Table 2 title: Delete "increased"?

*ATSDR response: ATSDR deleted "increased" in the title of Table 2 to make it "Summary of organs with elevated cancer risk…"*

PCdoe-6
Appendix D-1, Soil ingestion intake formula: "Sediment ingestion" ~ soil ingestion?

*ATSDR response: ATSDR was unable to identify what this comment referred to. The words "Sediment ingestion" do not appear in the soil ingestion intake formula on page D-1. No change made.*

**PCmdhss – Comments from Missouri Department of Health and Senior Services**
PCmdhss-1
General Comments
1. Estimates of past exposures along the creek are based on multiple assumptions, including conservative assumptions used in calculation of exposure point concentrations (EPCs). MDHSS recommends ATSDR summarize the uncertainties and corresponding assumptions of the evaluation in the Summary section, and consider presenting a range of dose and risk estimates bounded by reasonable maximum exposure (RME) and central tendency exposure (CTE) estimates presented as two separate assessments to reflect those inherent uncertainties.

*ATSDR response: The summary is a required item for ATSDR documents and because it has to be short and written in plain language, cannot contain extensive qualifying language and discussion of uncertainty. To emphasize the specific nature of the evaluation we performed, we added the following statements to the Executive Summary: "To evaluate possible effects from exposures, ATSDR estimated the exposure and resulting risks for the general group of children and adults who came in direct contact with sediment and water from Coldwater Creek and soil in its floodplain for many hours a day for many years. We assumed they were always exposed to concentrations of contaminants present in the most highly contaminated areas. Based on different specific assumptions for past (1960s to 1990s) and recent (2000s and on) exposures, detailed in this report, we reached the following four conclusions."*

*The report and evaluation are already extremely complex; performing additional analysis for different exposure assumptions for all scenarios would complicate the report significantly and be unlikely to affect overall conclusions.*

PCmdhss-2
2. ATSDR used the highest "hotspot" or sector 95% UCLs as EPCs for the entire creek. Those maximum 95% UCLs were from different hotspots or sectors along the creek, but they

were combined in dose and risk estimates. Please discuss how this affects the exposure evaluation and consider evaluating exposure alternatives such as by sector (and presenting a range of potential dose and risk estimates) or by 95% UCL of all data across all sectors. As requested in Comment 1, please consider this in presenting midrange (CTE) estimates for comparison purposes.

*ATSDR response: ATSDR's evaluations are intended to be protective of all exposed community members. Some children and adults could have gone regularly to the same general area of the creek. Therefore, we selected the highest upper confidence limit in any sector as a conservative estimate of possible exposure point concentration. We considered each radionuclide separately for this selection. In most cases, the selected values for U-238 and Ra-226 were from the same exposure unit as Th-230.*

PCmdhss-3

3. ATSDR used the same floodplain soil EPCs to evaluate recreational exposures in and near the creek, and residential exposures along the creek for both past and current exposure scenarios. Based on MDHSS correspondence with the United States Army Corps of Engineers, radiation concentrations identified on residential lots do not approach radiation concentrations in recreational areas. These residential concentrations may be representative of both current and past residential exposures. If EPCs are from hotspot areas adjacent to and not within residential properties, those EPCs may overestimate past residential exposures given the current data and lack of hotspots in residential yards. MDHSS recommends evaluation of residential exposures using data collected on residential properties. In the main text, please describe in greater detail the evaluation of past and recent residential exposure pathways.

*ATSDR response: The "residential hotspot" sector shown on figures contained some of the highest contamination levels along the creek. ATSDR observed no fences and cannot be assured children playing in the yard know where the property line ends. No data on actual past residential contamination exist, and there are many uncertainties in our estimation of past exposures from recent data. We considered a conservative approach appropriate for estimating potential residential exposures. Given the large uncertainties involved with our evaluation and its inherent inability to predict individual exposure and risk, we have added clarifying language in the document to emphasize the conservative nature of our evaluation.*

PCmdhss-4

Specific Comments

1. The risk calculation spreadsheets provided to MDHSS identify an adjustment of lifetime attributable risk (LAR) for cancer incidence for bone surface by a factor of 10 to account for low to high linear energy transfer (LET) for alpha-emitting radionuclides (i.e. thorium-230). Is this adjustment for the relative biological effectiveness (RBE) factor? The 2010 "Blue Book" notes that an adjustment for low to high LET has been provided in the incidence risk projections and

LARs, using alternative data based on radium isotopes studies. If this is an RBE adjustment, what is the final value (i.e. 20)? Please explain.

*ATSDR response: ATSDR agrees that the lifetime attributable risk coefficient for bone surface should not have been multiplied by 10. We have updated risk tables and discussion to reflect the updated risks. This change did not affect our overall conclusions.*

PCmdhss-5

2. The particulate emission factor (PEF) presented in Appendix A (1.18E-06 kg of soil per m3 air) is very conservative as it is based on emissions estimated for all-terrain vehicle (ATV) dust generation. This value can exceed estimated emissions for construction sites, per Environmental Protection Agency (EPA) regional screening level (RSL) methodology. A site-specific estimate of the PEF may be derived from EPA's Soil Screening Guidance, Supplemental, and could be used in a mid-range exposure scenario as discussed above. Notably, ATSDR completed a Health Consultation on the Standard Mine site, which was cited as the source for this ATV PEF, and presented both a CTE and RME scenario in that document, similar to what we are suggesting ATSDR consider here.

*ATSDR response: ATSDR disagrees that the particulate emission factor (PEF) used to estimate inhalation during activities is very conservative. Activities on soil are known to result in suspension of soil or dust particles directly into the breathing zone of the person doing the activity. The concentration of contaminants in the activity-generated "personal dust cloud" can be orders of magnitude greater than that predicted by models of wind-blown dust, such as EPA's standard soil suspension value. Higher soil suspension factors are appropriate for estimating inhalation exposures from activities. Please see response to PCrac-20 on page F-49 for a detailed explanation of how ATSDR selected the PEF used in the assessment and verified it was reasonable for the activities of interest.*

**PCmdnr – Comments from Missouri Department of Natural Resources**

PCmdnr-1

ATSDR is to be commended for taking on the challenge of developing a Public Health Assessment (PHA) that attempts to evaluate increased cancer risk in the community related to past or recent exposure to pre-remediation radiological contamination in and around Coldwater Creek. To do this, ATSDR relied on analytical data collected many years after the time of exposure and on events occurring twenty to sixty years past. Considering these limitations it is understandable that the agency would take a conservative approach to the task. However, stating conclusions in the opening Summary without describing associated assumptions has the potential to unnecessarily alarm some members of the community who may not have experienced the same degree of exposure as that described in later sections of the report.

The following comments identify components of the report that seem confusing or could lead the reader to an initial misunderstanding of the conclusions presented in the opening Summary. In

general the comments apply to selected exposure durations and exposure point concentrations, and the need for a clearer indication of the area considered to be "in and around Coldwater Creek." The comments are not repeated for subsequent sections of the report where they might also be applicable and we ask that ATSDR take note of those occasions where appropriate.

COMMENT 1

Conclusion 1 is stated in the opening Summary as "Radiological contamination in and around Coldwater Creek, prior to remediation activities, could have increased the risk of some types of cancer in children and adults who played or lived there." This statement is confusing. While it does include the reasonable assumption of pre-remediation conditions it does not address other significant qualifying assumptions. The reader is left with an initial impression that living or playing in an undefined general area around the creek for an unspecified length of time could have resulted in increased risk of cancer due to radiological contamination.

In fact, Conclusion 1 represents potential increased risk based, in part, on the assumptions that:

- *A person played or lived near Coldwater Creek for 33 years,*
- *The area they lived or played in was contaminated at the highest levels of contamination determined in limited select areas at the estimated 95% upper confidence limit (UCL), and*
- *The person lived or played in that area of highest contamination for assumed past exposure durations that ATSDR characterizes as high-end".*

RECOMMENDATION: The assumptions should be clearly stated and explained prior to reporting Conclusion 1 in the opening Summary, or immediately after in the section titled "**Basis for Conclusion**". This would give an individual the opportunity to develop a more informed initial understanding of their potential personal exposure.

*ATSDR response: The summary is a required item for ATSDR documents and because it has to be short and written in plain language, cannot contain extensive qualifying language. We recognize that many nuances of our evaluation are lost in translation to such formats. To emphasize the specific nature of the evaluation we performed, we added the following statements to the Executive Summary: "To evaluate possible effects from exposures, ATSDR estimated the exposure and resulting risks for the general group of children and adults who came in direct contact with sediment and water from Coldwater Creek and soil in its floodplain for many hours a day for many years. We assumed they were always exposed to concentrations of contaminants present in the most highly contaminated areas. Based on different specific assumptions for past (1960s to 1990s) and recent (2000s and on) exposures, detailed in this report, we reached the following four conclusions."*

PCmdnr-2

COMMENT 2

Page 20, Paragraph 4: States "*The past dose and risks in Table 2 presents those resulting from high-end exposures described by community members ...* " A TSDR used information provided

by a local community group to arrive at "high end" assumptions for recreational and residential exposures. To ensure that all members of the community have an opportunity to develop a more informed initial understanding of their potential personal exposure it is important for the report to clearly note that estimates of increased risk derived from these "high end" assumptions may not apply to all individuals in the area around Coldwater Creek.

One example of the "high end" values selected by ATSDR for past exposure frequencies can be calculated from information presented in Tables A-2 and A-4. The tables indicate that a middle school student is assumed to have spent 3,724 hours each year playing or bicycling in or near the creek, playing in their yard, or helping with yard work. 3,724 hours is the equivalent of 24 hours a day for 155 days and almost 1,700 hours more than many adults spend at work during the entire year. The report further assumes that this time was spent in areas impacted at the highest estimated 95% UCL levels of contamination.

RECOMMENDATION: The PHA opening Summary or "Basis for Conclusion" should include a table that presents the total annual number of exposure hours assumed for each "ATSDR age range" identified in Appendix A. This table could also list the equivalent number of 24-hour days represented by the total annual hours of assumed exposure. This would allow all members of the community the opportunity to gain a more informed initial understanding of the PHA conclusions relative to the time they actually spent in or around that part of Coldwater Creek covered by the PHA Conclusions.

*ATSDR response: The recreational and residential scenarios evaluated in the report are not intended to be added; rather, each represents a high-end estimate for that particular scenario. ATSDR has added language in the sections on exposure assumptions and how they were developed to clarify this point. A person's specific exposures would depend on their specific recreational and residential activities, frequencies, and durations. Given the large uncertainties involved with our evaluation and its inherent inability to predict individual exposure and risk, we have added clarifying language in the document to emphasize the conservative nature of our evaluation.*

*Exposure parameters were largely provided by members of the community based on their personal recollections or those shared by people they knew. ATSDR uses information from the community regarding their use of sites, when possible. In some cases, ATSDR changed values to make the frequencies consistent with our standard practices (e.g., ATSDR assumes children in a residential scenario are exposed 365 days a year.)*

PCmdnr-3
COMMENT 3
The term "in and around Coldwater Creek" is too ambiguous to be considered helpful for all members of the community and could confuse those area residents who might have resided or played well beyond any locations of detected contamination. The U.S. Army Corps of Engineers

(USACE) has sampled extensively in the section of creek between Interstate 270 and the Saint Denis Bridge. The data indicates that the lateral extent of significant contamination is limited primarily to the creek, its banks, and portions of some properties adjacent to the creek. Most other areas evaluated in that section indicate levels that are below the FUSRAP Remediation Goals (RGs) established to guide cleanup in the area.

RECOMMENDATION: ATSDR should more specifically define the area referred to as "in and around Coldwater Creek." Figure 1 should be suitably qualified to differentiate areas considered to be "in and around Coldwater Creek" from the remainder of the depicted area. The figure could also identify the specific area of the sample sets used to determine exposure point concentrations (later presented in Appendix C). An inset could explain that ATSDR used highest estimated 95% UCL levels of contamination from those specific areas to estimate risk that was then assumed to be representative of the larger area identified as being "in and around Coldwater Creek".

*ATSDR response: ATSDR is required whenever possible to use plain language to assist the audience with readability. ATSDR recognizes that "in and around" does not draw a clear delineation for area residents, but our intent was not to specify particular areas of concern but to determine possible effects of reasonable exposures. Our evaluation estimated direct exposures to contaminated sediments and floodplain soils; this exposure could occur in the creek bed, its banks, areas of the floodplain that were flooded by Coldwater Creek since the mid-1940s, and additional areas where any of the sediment or soils might have been moved in the past.*

**PCpc – Compiled Comments from private citizens**

This section shows ATSDR's responses to private citizen comments, reworded and grouped into similar subjects. Verbatim private citizen comments (with personally identifiable information removed) are presented at the conclusion of the public comment section.

***General comments from private citizens***

PCpc-1

Reports of health conditions, illnesses, and deaths thought to be related to Coldwater Creek exposures. ATSDR received numerous written comments describing personal health information and illnesses and deaths of loved ones.

*ATSDR Response: We recognize the losses so many people in this community have experienced, unfortunately our evaluation cannot prove or disprove that any particular illness was caused by exposure to site contaminants. ATSDR received comments informing us of many specific diseases not discussed in the public comment version of the public health assessment.*
*ATSDR has focused this assessment on target organs known to be associated with the site's contaminants. However, ATSDR has included discussion of additional organs and noncancer diseases, such as autoimmune diseases, that are of particular concern to this community.*

PCpc-2
Reports from many citizens of possible exposure factors. These included descriptions of children who grew up playing in and around the creek, residents who frequently gardened and landscaped near the creek, and basements that flooded frequently.

*ATSDR Response: We thank the community for sharing their experiences to allow a better estimate of possible exposures in this community. ATSDR used conservative assumptions based on such information from the community to perform its evaluation.*

PCpc-3
Concern about what specific locations are contaminated. Questions about how far away the contamination goes. Reports of specific locations where floodplain soil or sediment from Coldwater Creek was used for fill in the past, basements that were regularly flooded, etc.

*ATSDR Response: ATSDR's report evaluated direct contact exposures to Coldwater Creek water, sediment, and soils near the creek that were contaminated. Therefore, our evaluation is primarily concerned with locations in the floodplain of the creek. Because only a section of Coldwater Creek has been characterized by FUSRAP, we cannot reach a conclusion about stretches of the creek downstream from the St. Denis Bridge. We recommend that downstream characterization of the Coldwater Creek floodplain, and remediation if necessary, continue in a timely manner. In addition, our discussions with community members led us to recommend sampling to identify additional locations outside the Coldwater Creek floodplain where contaminated sediments or floodplain soils may have moved or been moved. In private citizen comments, ATSDR received reports of Coldwater Creek floodplain soil being used elsewhere as fill. ATSDR has provided these locations to FUSRAP and EPA for their records. ATSDR recommends that these areas be tested to determine the concentration of radiological contaminants, particularly Th-230. FUSRAP continues to actively sample and remediate areas of concern along Coldwater Creek. ATSDR recommends contacting FUSRAP directly to learn which areas may have been or will be tested at STLFUSRAP@usace.army.mil.*

PCpc-4
Questions about how to join a lawsuit related to the site.

*ATSDR response: As a federal public health agency, we are not associated with any lawsuits and cannot advise on litigation issues.*

PCpc-5
Questions about the health survey we are conducting.

*ATSDR response: ATSDR is not conducting a health survey. The public health assessment does not evaluate individual cases of illness, rather the report uses environmental data and information from the community to evaluate whether people playing or living near Coldwater*

*Creek have or had harmful exposures to radiological or chemical contaminants from the creek and what the potential harmful effects could be. The report cannot say whether or not an individual's illness was caused by exposure to contaminants from Coldwater Creek.*

*ATSDR is aware that the Coldwater Creek Just the Facts Please community group has been collecting individual health information via a survey. You may visit their webpage to learn more at www.coldwatercreekfacts.com.*

***General recommendations from private citizens***

PCpc-6

Continued testing and cleanup of Coldwater Creek and surrounding areas, including backyards and basements through the Army Corps of Engineers FUSRAP Program.

*ATSDR response: We also make this recommendation.*

PCpc-7

Better communication to the public regarding the status of the outcomes of all testing to date, what is going on in what areas to rectify the situation, and communication to those living in areas of potential concern.

*ATSDR response: This recommendation should be directed to the FUSRAP program at STLFUSRAP@usace.army.mil, or call 314-331-8000. ATSDR supports continued communication of cleanup status with the community.*

PCpc-8

Education of current/former residents of North County and healthcare professionals that exposed individuals are an "at risk" population because of exposure.

*ATSDR response: ATSDR has provided formal and informal health education to local physicians, community leaders, and partner health agencies about exposures and the public health assessment process. ATSDR remains available, upon request, to provide assistance to local and state public health agencies to continue to provide education to the community and health care providers about radiological exposures and health.*

PCpc-9

Installation of health warning signs along and around Coldwater Creek explaining the risks of the contaminated creek.

*ATSDR response: ATSDR is an advisory public health agency and cannot install signs. However, we recommend signs be installed to inform the public of the potential exposure. We contacted local agencies to give this recommendation and remain available for further input.*

PCpc-10
We need resources available to those without access to health insurance or who do not have primary care physicians; restitution or educational help for children who have lost a parent to cancer (or other) due to the contamination of the area; and compensation for people who lost their savings due to a loss in home value or excessive health care costs.

*ATSDR response: ATSDR is an advisory federal public health agency and does not have the authority to provide health care access or compensation for potentially exposed residents or their families.*

PCpc-11
We want our community to be included in the federal Radiation Exposure Compensation Act (RECA or Downwinders). This program brings opportunity for restitution as well as potential federal grants/ funding for the affected communities to set up screening clinics and education programs through HRSA Radiation Exposure Screening and Education Program, or any other available resources/grants/assistance that may benefit the community.

*ATSDR Response: ATSDR is an advisory federal public health agency. We do not have the authority to determine eligibility or grant inclusion in the Radiation Exposure Compensation Act (RECA). More information on this program is available at* https://www.justice.gov/civil/common/reca.

PCpc-12
ATSDR needs to recognize that our exposure caused autoimmune diseases, fertility issues, and health problems in children of the exposed.

*ATSDR response: Our evaluation cannot prove or disprove that any particular illness was caused by exposure to site contaminants. ATSDR has focused this assessment on target organs known to be associated with the site's contaminants. However, ATSDR has included discussion of additional organs and noncancer diseases, such as autoimmune diseases, that are of particular concern to this community.*

PCpc-13
ATSDR needs to study the relationship between our exposure and noncancer diseases including autoimmune diseases.

*ATSDR response: ATSDR is unable to study the relationship between Coldwater Creek exposure and disease because current methods cannot measure a person's past exposure to contaminants specific to Coldwater Creek. Without individual exposure data to link with cases, the correlation between radiation exposure/dose and disease cannot be studied. Many other factors, environmental and otherwise, could contribute to an individual's risk of developing disease.*

PCpc-14
We need an acknowledgment of government wrongdoing and an apology to the innocent victims of friendly fire who didn't know that they were hurt and killed as a result of war profiteering.

*ATSDR response: ATSDR is an advisory federal public health agency and has no authority for assigning responsibility for environmental contamination. ATSDR's mission is to advise other agencies and the public on ways to reduce harmful exposures, improving public health of all communities living with environmental contamination.*

PCpc-15
There needs to be more publicity for those who moved away from the area that may be unaware of the possibility of connections to where they grew up or lived long term and diagnosed cases of cancer.

*ATSDR response: ATSDR presents its findings in print and on the internet and shares our findings during local community outreach sessions. ATSDR relies upon state and local partners, including the community, to reach a wide audience. ATSDR will continue to work with the local community and support outreach to the extent possible.*

PCpc-16
The community would benefit from having access to organized support groups for those who have been negatively impacted from radiation exposure from the creek. The community needs a place where their frustrations can be heard and emotional support can be provided. Also, create a group that would look at the series of events of how this happened and how going forward we can prevent this happening in another community.

*ATSDR response: ATSDR agrees that such groups and aims would be helpful to the community and result in a positive impact for other communities in the future. Although these actions are beyond the scope of ATSDR's mandate and authority, we encourage the local community to initiate these activities.*

***Specific technical comments from private citizens***
*[Note: page numbers referenced in public comments refer to the public comment version of this report released in June 2018.]*

PCpc-17
Page 1 paragraph 4 – "Community members asked ATSDR to evaluate past and present exposures of those who played, lived or worked near Coldwater Creek." As written, this sentence implies that community "workers" (e.g. industrial park area) were included in the report. Workers (nonresidents) were not included. Suggest deletion of reference to "worked."

*ATSDR response: We have deleted "or worked" from this sentence, as suggested.*

PCpc-18

Missouri Cancer Registry should add CC exposure to cancer registry data – The ATSDR report should add a formal recommendation (directed to) The Missouri Cancer Registry and Research Center to include a cancer patient's exposure to the Coldwater Creek area in their tracking and registry of Missouri cancer cases.

The report recognizes there is a 20 to 40 year latency period for radiation induced tumors. As multiple findings have indicated (including page 38 of report), many residents had already moved out of the CC area ("targeted zip codes") when their cancer was/is diagnosed. Simply recording their current zip code may not capture their history of exposure to CC. Furthermore, zip codes do not capture cases of 'workers' that may have had daily CC exposure but reside outside the CC target zip codes. Given the severity, it astonishes that physicians are not asking and registry not recording CC exposure for cancer diagnosis in the St. Louis area.

Understandably it is not within the ATSDR charter to implement such tracking, but the report should formally make this recommendation to the responsible agency. Such recommendation by ATSDR would carry much more weight than a single member of the community might garner.

*ATSDR response: ATSDR cannot make changes to the state of Missouri's cancer tracking systems; however, ATSDR has recommended that the state consider updating analyses on cancer incidence, cancer mortality, and birth defects, as feasible.*

PCpc-19

Prostate Cancer Omission in Appendix E Tables - For Table E-6 (and other tables in Appendix E); Why is there not an assessment for prostate on the list of organ evaluations? Especially since the MDHSS reports showed prostate cancer to be significantly elevated at CC (ref pages 5 & 6).

*ATSDR response: The ICRP dose coefficients do not include the prostate as a specific organ, so ATSDR did not evaluate this organ. If the coefficients for "remainder" are used to estimate dose to the prostate and combined with EPA's lifetime attributable risk for prostate cancer, the risks would all be very low ($1\times10^{-6}$ to $8\times10^{-6}$ for past exposures and $9\times10^{-8}$ to $1.5\times10^{-6}$ for recent exposures).*

PCpc-20

Include "Ball Fields" in the assessment – The health effects at the "ball fields" (located directly across SLAPS/McDonnell Blvd) are not included in the report. These ball fields were at ground zero from the SLAPS radioactive source. Per FUSRAP, radioactive levels at the ball fields were the highest of all offsite samples tested. The ball fields were widely used including the primary fields for McDonnell Douglas (Boeing) company leagues. There was significant airborne dust/dirt blowing from the upwind SLAPS site across the street onto the ball fields. Furthermore, by the nature of its use the ball fields resulted in ingestion of dirt particles. Many users of these ball fields are incurring seemingly high health issues including cancer.

Analysis of health effects by ball field users should be added to the report. If ATSDR chooses to not include such analysis in the current report, recommend at least adding a section that recognizes the ball fields (and their omission) as well as a recommendation that a further study be done to examine health effects for the ball field users.

*ATSDR response: ATSDR's 1994 public health assessment for SLAPS/HISS discussed the ball fields and estimated whole-body doses for players [1]. However, the ball fields had been closed by the city of St. Louis by that time. ATSDR's Coldwater Creek evaluation does not include the ball fields because our focus is on exposures along residential stretches of the creek, downstream from the ball field area. People who were exposed in the past at the ball fields as well as through the pathways evaluated this report could have higher exposures and be at a higher risk.*

PCpc-21

Cannot find the section listing "health concerns not addressed by report". Page 3 paragraph 1 – "This report also includes a section listing and addressing other community exposure and health concerns that ATSDR did not directly evaluate." Where is this section in the report? I couldn't find the referenced section. Perhaps the section exists and should be more clearly titled (e.g. "Exposure That ATSDR Did Not Evaluate") – as it is a very important section.

*ATSDR response: The section "Community Concerns about Health and Exposure" beginning on page 32 discusses concerns that were not quantitatively evaluated in the report.*

PCpc-22

Additionally, add the following to the listing of community health concerns that ATSDR did not directly evaluate:

a. St Ann residents – upstream from SLAPS but contaminated from B&K truck washing into Coldwater Creek

b. Workers – especially the industrial park. This area is immediately downstream from SLAPS and alongside CC. This area is much closer (presumably higher radioactive levels) to SLAPS/HISS than the area included in the report. It was also prone to flooding.

c. Ball Field users – immediately across street from SLAPS site (McDonnell Blvd). Per FUSRAP these fields had the highest concentration of radioactivity of the CC measured areas

*ATSDR response: ATSDR recognizes that there are other exposures of potential concern to the community. ATSDR focused this evaluation on Coldwater Creek and its floodplain and evaluated areas downstream of the historical source areas. St. Ann is upstream of these source areas and natural erosion processes would likely carry contamination away from this area. Industrial workers are beyond the scope of this assessment. Please reference PCpc-20 in regard to ball field users.*

PCpc-23
Airborne Particles – The report states that ingestion of airborne particles was not factored into the health effects analysis (ref page v, page 36, page 41). Airborne pathways can lead to significant negative health effects on internal organs. Furthermore the CC community under analysis is generally downwind from the SLAPS waste. The ball fields (adjacent to SLAPS) in particular were notorious for extensive dirt/dust blowing onto the fields.

Understandably (at this point in time) it is difficult to deduce data for past airborne levels and to factor the ingestion/inhalation of airborne contaminants, but doesn't this omission significantly place the report findings into question? i.e. Significantly underestimate the health effects. Could the lack of factoring airborne inhalation be a major reason between the ATSDR findings compared with the MDHSS report? Specifically, the MDHSS reported a higher incidence of breast, colon, prostate and kidney cancer whereas the ATSDR report did not. If the ATSDR position is that leaving out airborne exposure does not impact the findings then the report should so state

*ATSDR response: ATSDR recognizes that windblown dust from the historical waste piles may contribute to potential residential exposures and risk during the time when the piles were active at the historical source areas. While we did not evaluate windblown dust, we did include inhalation exposure of dust suspended from activities in the floodplain and creek. With no historical data, we cannot state the extent to which windblown dust from the historical waste piles may have contributed to exposure and risk. Because quantifying this exposure and risk through modeling would involve many uncertainties and would not likely affect our conclusions and recommendations, ATSDR does not plan to continue with the modeling effort at this time.*

PCpc-24
Health Effects in addition to Cancer – The report limits its scope to cancer. There are other serious health effects that are of concern (thyroid, lung disease, auto immune, etc). Perhaps the Introduction section should clarify that this report focus is on cancer risks.

*ATSDR response: Cancer is the main effect of concern for the levels of exposure evaluated in this report. Current science does not indicate that noncancer effects would be likely at the doses estimated in this report. However, to address ongoing concerns and this comment, ATSDR added discussion of possible immune and autoimmune effects of radiation exposure to the document beginning on page 41.*

PCpc-25
Exposure Concentration for Surface Water. Reference page C-19 and table C 5. The report states that for surface water contaminants, data environmental monitoring of surface water (collected from 1991 – 2014) was used. And this data showed no results higher than FUSRAP's background data. This is not surprising as the primary source of contaminants (SLAPS & HISS) had been removed a decade prior. The surface water had a decade to flush its contaminants. It

seems fair to use these values for the "Recent exposures (2000s and on) surface water" contaminants in Table C5.

But the same (background) levels are used for the "Past exposures (1960s to 1990s) surface water" values. During the 60s and 70s SLAPS and HISS were actively contaminating the surface water. The surface water was the transport for soil and sediment contaminants. What is the justification for using the same (minimal) values for the "Past" exposure surface water contaminant estimate? I think the values for contaminants should be much higher. Granted it may be difficult to estimate at this point in time.

*ATSDR response: ATSDR has no distant historical sampling data for surface water. However, Th-230 and other radiological contaminants from the former source areas are not very soluble so it is unlikely that past water concentrations were much higher. Most of the exposure and dose comes from sediment and sediment-contaminated soil.*

PCpc-26

Differences in the conclusions between the ATSDR and MDHSS reports. The ATSDR and 2014 MDHSS assessments took different approaches. The two reports had different findings (ref page 38). The MDHSS study showed elevated cancers for leukemia, female breast, colon, prostate, kidney and bladder. The ATSDR report did not arrive at higher incidences for these types of cancers. There should be a better explanation as to why the two reports differ in their findings.

The time frames of the two reports are actually similar. The ATSDR assessment estimated for past exposures 1960s to 1990s. With the 20-40 year latency period that approximately lines up with the MDHSS time frame of 1996 to 2011 and their estimation of actual cancer incidences. Yet the reports have different results.

Page 38 also touches on the possibility that "people living in the zip codes studied by MDHSS may not be the same people … living near Coldwater Creek in the 1960s to 1990s." While it is true that a lot of residents from the 1960s-1990s moved away from the community (targeted zip codes) and were not counted in the MDHSS findings, had they been counted it would have been an even greater difference between reports. I would like to see a more in depth evaluation as to the differences in findings between the ATSDR and MDHSS reports.

*ATSDR response: While the ATSDR and MDHSS reports are both focused on Coldwater Creek, the reports are not comparable. MDHSS examined actual cancer incidence rates in specific zip codes near the site compared to rates of the state and the entire U.S. ATSDR's report estimated how much the specific exposures considered (direct exposure to contaminated soil and sediment from Coldwater Creek) could increase the predicted risk of cancer incidence for the people who had those exposures. The people who had these exposures, if they are still in the area, are likely to make up only a small percentage of the people in the ZIP codes included in the MDHSS study. Some of them may have moved away and not been included. Also, there are many different*

*potential causes of the types of cancer included in either the MDHSS or ATSDR reports.*

PCpc-27
Should prior CC exposure be a factor in the decision of how to medically treat cancer? For example, choosing surgical over radiation treatment or determination of the total allowable (safe) dosage when undergoing radiation treatments.

*ATSDR response: Potentially exposed residents or former residents should share their potential exposure with their physicians as part of their medical history. The physician will determine the appropriate manner of treatment. As described in the text, the radiation doses we estimated in this report are very small in relationship to radiation therapy used for cancer treatment.*

PCpc-28
Should prior CC exposure be a factor when medical staff makes a decision on the extent and frequency a patient can safely receive medical scans (i.e. more radiation) such as CT, PET, bone scans, and nuclear medicine?

*ATSDR response: Potentially exposed residents or former residents should share their potential exposure with their physicians as part of their medical history. The physician will determine appropriate medical scans for their patients. As described in the text, the radiation doses we estimated in this report are very small in relationship to those typically associated with imaging or nuclear medicine applications.*

PCpc-29
The report states, "Upon request, ATSDR can facilitate a consultation between residents' personal physicians and medical specialists in environmental health". What is the process to request this facilitation?

*ATSDR response: Residents who wish to initiate a consultation between their personal physician and medical specialists should contact the Coldwater Creek site team at ColdwaterCreek@cdc.gov or 1800-CDC-INFO.*

PCpc-30
Medical research documents shows that radiation exposure is linked to inflammatory autoimmune illness (Rasoul et al, Radiation-induced inflammation and autoimmune diseases, Military Medical Research (2018) 5:9; Open Access Review https://doi.org/10.1186/s40779-018 0156-7).

Why are these issues not addressed by the CDC in St Louis issue with Cold Water Creek if they have medical research showing what many of us have listed as noncancer illnesses? We would like to have additional acknowledgment that these specific illnesses may be connected.

*ATSDR response: ATSDR has added a section discussing immune and autoimmune effects related to radiation exposure to the document (see page 41). The cited reference is included in this section.*

PCpc-31

There is only a brief note on the land use just north of the SLAPS site that was used as the PRIMARY softball fields for McDonnell Douglas Recreation Department. These fields were used regularly throughout the summer months and many employees were exposed to dust and potential contaminates by direct contact with dirt (base sliding, running and laying on the ground) and indirect contact (through dust inhalation). Because of the location of potential exposure – exposure concentration levels could be significantly higher for this demographic group. Excavation of the old ball fields has recently started and there appears to be testing on-going. This group should be targeted and tracked for special medical conditions – names and address can be obtained from historical McDonnell Douglas personnel files and recreation rosters.

*ATSDR response: This evaluation does not include the ball fields because our focus is on exposures along residential stretches of the creek, downstream from the ball field area. ATSDR's recommendations in this report would apply to people potentially exposed at the ball fields. People who were potentially exposed in the past at the ball fields should share their potential exposure with their physicians as part of their medical history and consult their physicians promptly if new or unusual symptoms develop.*

PCpc-32

What I do not understand is why this has taken so long to become an issue. I knew when I was in high school and probably before that Cold Water Creek was polluted. I don't recall who told me, it seems there were articles in the St. Louis Post Dispatch and on the news about it. I never knew what it was polluted with but someone must have done some research back then. Love Canal happened so many years ago. Why did no one follow up on Cold Water Creek before the 1990s?

*ATSDR response: ATSDR does not know the answer to this question. We do know that increasing knowledge about potential health effects of environmental contaminants has led to greater awareness and a general tightening of regulations over time.*

PCpc-33

Indeed, recent levels of radionuclide contaminants of concern located and measured by FUSRAP only provide a limited piece of the possible exposure to radionuclide contaminants former residents may have absorbed. Extrapolating these pieces of history to possible past human exposure is not an exact science. Further, in estimating the increased cancer risk, ATSDR applied lifetime attributable risk coefficients using ICRP and EPA dose coefficients to the calculated guesstimate potential exposures to residents of the Coldwater Creek area. EPA utilized radio-biological data including studies of Japanese atomic bomb survivors, medically

irradiated patients, and occupationally and environmentally exposed groups. This is where the study deviates strongly from the typical Coldwater Creek resident fact pattern of exposure. Japanese atomic bomb survivors were exposed to the post-fission materials in one big event, but Coldwater Creek residents were exposed to the very raw materials used in producing the Hiroshima bomb over many years in smaller doses. Medically irradiated patients per the BEIR VII Phase 2 report (Item 113) were typically young and had limited exposure to medically applied diagnostic imaging (not whole body/inhalation/ingestion as creek residents had every day), and occupationally and environmentally exposed groups are also not comparable to the Coldwater Creek community exposure fact pattern per the BEIR VII Phase 2 report.

*ATSDR response: ATSDR recognizes the limitations of the evaluation we performed and has added more language about uncertainties in the document. We note that the issue of extrapolation of high exposures in epidemiological and toxicological studies to determine effects from lower exposures is common and applies to many chemicals, not just radionuclides.*

PCpc-34

The Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation (funded by which companies' and other entities' interests?) BEIR VII Phase 2 report interestingly discourages any study of environmentally exposed groups of all ages and both genders to low levels of ionizing radiation due to other possible variables. ATSDR leans heavily on both the BEIR VII Phase 2 report and EPA report, and truthfully shares above this is the only evaluation possible to use residential area sampling data to estimate exposure and cancer risk. Might both the ATSDR and the scientists at the Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation explore looking at the Coldwater Creek community detailed health outcomes we have gathered (with people willing to share more) in the multiples of thousands? Yes, our U.S. federal agencies and international committees would learn the truth of chronic exposure to low-level ionizing radiation from Coldwater Creek residents: a plethora of cancers, autoimmune diseases, birth defects, and infertility may occur in populations exposed to ionizing radiation left to meander haphazardly for over sixty years in our environment. ATSDR and BEIR VII Phase 2 funders...Why are pregnant women discouraged from having x-rays taken? Let us learn from this Coldwater Creek area tragedy, as Coldwater Creek long-time residents are the world's Petri dish of what happens to human life after chronic low-level ionizing radiation exposure.

*ATSDR response: ATSDR is unable to study the relationship between Coldwater Creek exposure and disease because current methods cannot measure a person's past exposure to contaminants specific to Coldwater Creek. Without individual exposure data to link with cases, the correlation between radiation exposure/dose and disease cannot be studied. Many other factors, environmental and otherwise, could contribute to an individual's risk of developing disease.*

PCpc-35

I have several concerns regarding the data analysis. The list of references included quite a few

from groups that would benefit from this going away. Also the 70 year expected lifetime dose evaluation seems contradictory to the referenced 33 year exposure model used. Does that type of thinking alter the data? The water table data seems to reference only the later years' information. I read the hydrogeological surveys for other years including in the 1970's that does not have the same water sources and locations as your current ones do. I understand that the point was to keep the information limited to a small area that you examined, but 6 inches deep in a flood plain may be more than standard but hardly effective. Soil turnover in frequently flooded areas are quite inconsistent. When all of these decisions that you made in forming this report come together, it appears as though the data was cherry picked to create low level exposure look. So many people's lives have been affected. People are sick and dying simply because they had the misfortune to live in an area that did not respect their lives.

*ATSDR response: ATSDR's default exposure assumption for residency is 33 years, so we assumed exposure to Coldwater Creek sediment and soil for that length of time. However, radioactive materials taken in the body remain there and contribute a continuing dose to the body. The committed dose to age 70 (the standard used by radiological protection organizations) is a way to account for the long-term (lifetime) dose resulting from each separate year of exposure. Summing committed doses to age 70 for each year over our assumed 33 years of exposure gave us a conservative estimate of possible lifetime risk of cancer resulting from the exposure. There are limitations in evaluating a site that has been a concern over multiple decades. ATSDR tries to account for these limitations and be protective of public health by using reasonable yet conservative exposure assumptions to determine whether or not exposures could be or could have been potentially harmful.*

PCpc-36

we all lived in Robertson between 1950 until Robertson Community revitalized by the companies that are there now. … The attention is being focused on Bridgeton and Coldwater Creek Families exposure to the Manhattan Project Radioactive Waste. However, the families in our community are being forgotten. I keep hearing the FUSRAP is only focused on the clean-up of Coldwater Creek. It's truly amazing how Robertson land wasn't cleaned up until all of our families where relocated by the Airport buy-out. The problem with this: Damage to our families had already been DONE

*ATSDR response: ATSDR was unable to find records or photographs showing the exact location of this neighborhood. Our evaluation was focused on residential areas along Coldwater Creek downstream from the historical source areas, where direct contact with potentially contaminated soil and sediment was possible. If residents of the former Robertson neighborhood had similar exposures, they could have experienced similar doses and risks.*

PCpc-37

I am also dismayed that there are a multitude of other illnesses/diseases that ATSDR cannot link due to the lack of data, as well as there isn't really a community/population like Coldwater Creek

to be adequately compared to. Although the agency cannot say the vast amount of other illness/disease in our population was caused by our exposure to radiological contaminates from the Manhattan Project, I feel the agency also cannot say the illness/disease weren't caused by it either (since the data does not exist to confirm or deny either claim).

*ATSDR response: Our evaluation cannot prove or disprove that any particular illness was caused by exposure to this site's contaminants.*

PCpc-38

I know that ATSDR is unable to evaluate other exposures, such as inhaling dust blown from historical radiological waste storage piles as no sampling data exists. The reason no sampling data exists is because those in charge of the historical piles at the time did not run monitors and were frequently in violation of the handling of these materials. I am hopeful that if new historical data comes to light it will be reviewed and considered appropriately.

*ATSDR response: ATSDR will, upon request, review new sampling data or newly available historical data and update our conclusions and recommendations regarding the site, if necessary.*

PCpc-39

I do believe there should be some kind of program(s) for those affected by Coldwater Creek (past and present) to utilize in their time of need. I know people who have undergone over 40 surgeries. They still died. I know people who spend $12,000.00+ a month on medication to treat their cancer. They are so sick they can't work. And they are still dying. When those affected pass, they leave their families in a wake of financial devastation and a lifetime of immeasurable grief. There must be some kind of resources allocated to lessen some of the heavy burden those of us that grew up here carry for the rest of our lives.

*ATSDR response: ATSDR is an advisory public health agency and does not have the authority to provide compensation for exposed residents.*

PCpc-40

My comment concerns the use of the language in the following sentence: "Children and adults who regularly played in or around the creek or lived in its floodplain for many years in the past (1960s to 1990s) may have been exposed to radiological contaminants." I do not think the "for many years" is correct as we lived on one of the worst streets (see number of cancers on Palm Drive) for two years, which is probably not considered "for many years,' and my brother still had cancer.

*ATSDR response: ATSDR's evaluation was based on many years of exposure. Many other factors, environmental and otherwise, could contribute to an individual's risk of developing cancer. Our evaluation cannot prove or disprove that any particular illness was caused by*

*exposure to this site's contaminants.*

PCpc-41
My understanding of your process is that any increase of cancer of a certain type in a population of 10,000 is how the PHA derived its conclusions. That methodology doesn't seem to address the actual number of cancer cases among residents immediately adjacent to the creek. Although anecdotal, I personally know so many people now dead from cancer or cancer-related complications, including my father, that I don't trust a government agency measuring another government agency.

*ATSDR response: Many other factors, environmental and otherwise, could contribute to an individual's risk of developing cancer. Our evaluation cannot prove or disprove that any particular illness was caused by exposure to this site's contaminants.*

PCpc-42
RISK MODELS USED TO ASSESS EPIDEMIOLOGICAL AND RADIO-BIOLOGICAL DATA

According to page E-10 the EPA used the National Academy of Sciences report of 2006 Reference 113. This was published in 2006. Was the study of Leurad, et al 2015 "Ionizing Radiation and Risk of death from Leukemia and lymphoma in radiation monitored workers" considered in the EPA report? This report internationally studied over 300,000 workers. This report confirms risks at low dose rates rather than extrapolating them from high levels found at Hiroshima. This report called into question ICRP's use of dose rate effectiveness factors. This report provided strong evidence of a dose response relationship between cumulative, external, chronic low dose exposure to radiation and cancer. This data should be utilized to evaluate lifetime risks, especially where long time exposures to low levels of radiation exist.

*ATSDR response: ATSDR suggests reaching out to EPA directly to receive a response to this question.*

PCpc-43
MODELING OF PAST AIR EXPOSURES

It has been established that Thorium 230 had an affinity to attach to dust particles and can travel long distances. In the SEC Petition Report SEC-00150, April 12, 2010 there is data that could be useful in modeling air exposures. For example it mentioned that Thorium 230 was measured to be 76700 uCI/g in AM-7 residues which were stored 1946-1966. The report also stated that there were 74,000 tons of this inventory. There also was 32,500 tons of AM-10 stored in the open with a high Thorium 230 content. It is strongly recommended that a modeling of past air exposures be completed.

*ATSDR response: ATSDR recognizes that windblown dust from the historical waste piles may contribute to potential residential exposures and risk during the time when the piles were active at the historical source areas. With no historical data, we cannot state the extent to which windblown dust from the historical waste piles may have contributed to exposure and risk. Because quantifying this exposure and risk through modeling would involve many uncertainties and would not likely affect our conclusions and recommendations, ATSDR does not plan to continue with the modeling effort at this time.*

PCpc-44

As a former cartographer, I was disappointed with the size of the maps on the posters in the meeting room. Too much information was presented in the graphics for their size. I was left with the impression that every piece of property along Coldwater Creek from I-270 to St. Denis St. was contaminated with Thorium-230, Radium-226, and/or Uranium-238. I also could not read the legend. After reviewing the graphics in the report, I discovered that not every piece of property along the creek was contaminated. In the future, I would like to suggest:

1. Increasing the size of the poster maps/graphics so that they can be easily read and understood; and
2. Attaching interactive maps/graphics to the reports.

*ATSDR response: ATSDR recognizes that the maps were not presented in high resolution. The posters for our meeting and maps in the report were intended to give a general sense of the extent of sampling and how ATSDR determined exposure units to estimate exposure point concentrations. Due to privacy issues, ATSDR cannot publish materials identifying specific results for individual properties.*

PCpc-45

Also, I would like to encourage ATSDR to conduct a modeling to evaluate possible exposure to windblown dust contaminated with radioactive waste. This might help explain the increased presence of cancer in a region not located near the creek. Were the radioactive waste sites at the airport disturbed between the time they were created and the time they were removed? If they were, the disturbances might have released additional radioactive dust into the environment.

*ATSDR response: ATSDR recognizes that windblown dust from the historical waste piles may contribute to potential residential exposures and risk during the time when the piles were active at the historical source areas. With no historical data, we cannot state the extent to which windblown dust from the historical waste piles may have contributed to exposure and risk. Because quantifying this exposure and risk through modeling would involve many uncertainties and would not likely affect our conclusions and recommendations, ATSDR does not plan to continue with the modeling effort at this time.*

PCpc-46

I also would like to know if there is any recommendation for blood testing that my family can

have done, to see if we have inherited/developed any sort of gene mutations or abnormalities related to cancer.

*ATSDR response: ATSDR does not recommend any additional health screening. Please reference the Health Concerns section of the PHA for more information on medical tests.*

PCpc-47
I would like to however, share and reference that another governmental agency has already researched and acknowledged cause and effect of ionized radiation exposure and lists presumptive diseases that are common to such exposure. The United States Department of Veterans Affairs is the agency and it compensates exposed veterans.

[attached link https://www.publichealth.va.gov/exposures/radiation/diseases.asp]

*ATSDR response: ATSDR has reviewed this information and included the website as a "Reference Reviewed but not Cited." ATSDR's evaluation estimated possible exposures and doses and used EPA's radiogenic risk model coefficients to estimate the risk of several specific types of cancer. Coefficients are available for organ sites that may or may not correspond to the Veteran Affairs' list of presumptive diseases.*

PCpc-48
Why did you choose not to test for fluoride?

*ATSDR response: ATSDR used available data from the residential stretches of Coldwater Creek to screen for non-radiological contaminants; no data on fluoride from these areas were available. In response to this comment, ATSDR examined data from the historical source areas. These fluoride data consisted of only a few samples of soil, sediment, or surface water, but they did not indicate elevated fluoride levels. ATSDR notes that fluoride and fluorine compounds were used in uranium processing, but ore residues such as were stored at the historical source areas near Coldwater Creek would not be expected to contain concentrated fluoride compounds.*

PCpc-49
The rates you stated for appendix cancer are contradictory and don't match the references cited or other online reports.

*ATSDR response: We have added further description of appendix cancer rates and more information on diagnosis and treatment of appendix cancer into the discussion, beginning on page 39 of the final report.*

**PCrac – Comments from Risk Assessment Corporation**
*[ATSDR note: The comments below are provided in their entirety. The cover letter included the following disclosure:* "These comments have been prepared by Risk Assessment Corporation, its

team members, and additional scientists and medical physicians. With the exception of Dr. Keith F. Eckerman, an expert in radiation dosimetry and radiation risk calculations, the authors of this review were part of an investigation of these sites that was funded by Mallinckrodt Pharmaceuticals. This review is part of an independent scientific endeavor. Mallinckrodt funded some but not all authors in this scientific review."*]*

PCrac-1

**SUMMARY AND KEY FINDINGS**

ATSDR is a federal public health agency whose mission is to protect communities from harmful health effects related to exposure to natural and man-made hazardous substances. ATSDR states they do this by responding to environmental health emergencies; investigating emerging environmental health threats; conducting research on the health impacts of hazardous waste sites; and building capabilities of and providing actionable guidance to state and local health partners.

Risk Assessment Corporation (RAC) along with a collaborative team of scientists and medical physicians reviewed the draft report and strongly disagree with ATSDR's conclusions that children and adults who regularly played in or around Coldwater Creek or lived in its floodplain for many years in the past (1960s to 1990s) may have an increased risk of developing bone or lung cancer, leukemia, or (to a lesser extent) skin or breast cancer, or that residents since 2000 may have an increased risk of developing bone or lung cancer from daily residential exposure to radionuclides present in or near Coldwater Creek**.**

Our review considers the individual steps in the dose and risk calculation process starting with the source term which characterizes the radionuclide concentrations in the environment. Because significant soil and sediment sampling data have been collected through numerous investigations since the 1970s and earlier, and continuing to the present day, we have a good understanding of environmental conditions that exist now and in the past.

Our review identified serious errors in the methodology and calculations made by ATSDR which resulted in conclusions that are not scientifically sound and inject an unwarranted level of concern in the community regarding the potential health impacts associated with Coldwater Creek exposures both currently and in the past. A list of key errors and how they impact the ATSDR conclusions follows.

*ATSDR response: ATSDR welcomes comments to improve our evaluation. ATSDR used a simplified methodology, discussed in detail below, to reach its public health conclusions. We recognize that our approach is conservative, but we disagree that our methodology was fundamentally unsound. ATSDR used procedures based on accepted science, information on site use obtained directly from the people who were exposed, and reasonable assumptions based on ATSDR's standard practices for site evaluation to reach its conclusions.*

PCrac-2

1. Media concentrations in soil and sediment used by ATSDR are unrealistic due to numerous assumptions designed to bias the results on the high side and are therefore not representative of long-term or chronic exposure conditions for individuals spending time in this area. Representative $^{230}$Th concentrations to which individuals would have been exposed are likely at least a factor of 2 less than those assumed by ATSDR.

*ATSDR Response: ATSDR disagrees with this comment. We used standard procedures to determine exposure point concentrations for soil and sediment, as described in detail in Appendix C of the report. The Agency uses conservative assumptions to determine exposure point concentrations over an exposure unit. In the case of this evaluation, we used several additional conservative assumptions to estimate past exposure point concentration. This was necessitated because no data were collected in the past in residential areas of the Coldwater Creek floodplain. Floodplain soil Th-230 concentrations in the past (before the 1990s) could have been higher or lower than estimated in our evaluation. Likewise, while we used historical sediment data to estimate past sediment concentrations, those data were from the late 1980s and it is doubtful they represent sediment concentrations over the entire timeframe evaluated. It is very likely that sediment concentrations were significantly higher while the source areas were uncontrolled and still eroding materials into the creek.*

*Furthermore, our methods are intended to obtain a conservative estimate of potential exposures using exposure point concentrations and other assumptions. The estimated exposures do not necessarily apply to individuals or even an average individual. We have added additional qualifying language to the document to emphasize this point.*

PCrac-3

2. ATSDR uses a particulate emission factor developed for an ATV traveling on Colorado trails that is 5,000 times higher than the recreational value recommended by EPA. This assumption would result in a "dust cloud" being present continuously near Coldwater Creek that would exceed the air quality standard for allowable particulate matter by a factor of 50. This particulate emission factor was applied not only to ATV riding near Coldwater Creek, but also to bicycle riding and gardening activities.

*ATSDR response: ATSDR disagrees that the particulate emission factor (PEF) used to estimate inhalation during activities is unrealistic. Activities on soil are known to result in suspension of soil or dust particles directly into the breathing zone of the person doing the activity. The concentration of contaminants in the activity-generated "personal dust cloud" can be orders of magnitude greater than that predicted by models of wind-blown dust, such as EPA's standard soil suspension value. Higher soil suspension factors are appropriate for estimating inhalation exposures from activities.*

*Please see response to PCrac-20 on page F-49 for a detailed explanation of how ATSDR selected the PEF used in the assessment and verified it was reasonable for the activities of interest.*

PCrac-4

3. ATSDR further assumes that the continuously present "dust cloud" is composed of particulates with a median activity aerodynamic diameter (AMAD) of 1 µm. This means that 50% of the activity in air is associated with small particles of less than 1-µm diameter. Smaller particles are inhaled deeper in the lung resulting in higher radiation doses compared to larger particles and consequently have higher dose coefficients. Data from EPA indicate only 9% of inhalable particles suspended from unpaved roads are less than 2.5 µm. Thus, ATSDR should have accounted for the larger respirable particles by using dose coefficients that are appropriate for the larger particles. Correcting this error, coupled with correcting the particulate emission factor, would have the effect of reducing ATSDR's risk estimates from inhalation to significantly below the allowable risk level.

*ATSDR Response: ATSDR disagrees that use of a different AMAD is warranted.*

*Activity median aerodynamic diameter (AMAD) is the aerodynamic diameter in which 50% of the activity is associated with particles smaller than the AMAD, and 50% of the activity is associated with particles larger than the AMAD. The term PM10 refers to inhalable particles, with diameters that are 10 micrometers and smaller. Neither AMAD nor PM10 describe the particle size distribution.*

*In the absence of any data describing either the particle size distribution or the distribution of radiological activity within particles of dust that could be suspended from Coldwater Creek floodplain soil, ATSDR used an AMAD of 1.0 micrometer as a conservative estimate. This is the same assumption made by the Department of Energy in 1988 in its 1988 hazard assessment of the recreational ball field near SLAPS [138].*

PCrac-5

4. Exposure parameters are unreasonably high and do not reflect typical values for children or adults in the Coldwater Creek area. While some intentional overestimation in radiation dose and risk calculations can be prudent to ensure actual doses are not underestimated, the ATSDR assessment has, through both intentional decisions and numerous calculation errors, estimated doses and risks that are in no way representative of those received by any actual individual and are unacceptable even for a screening calculation that is designed to be biased high.

*ATSDR Response: ATSDR disagrees that exposure parameters are unreasonably high. ATSDR uses site-specific information from communities, when available, to more accurately estimate potential exposures. For past exposures, ATSDR engaged with the local community to learn how often and for how long they did various activities while living and playing near Coldwater*

*Creek. Discussions with community members indicated that children in this community who grew up in the 1970s and 1980s spent much of their free time in and around the creek. More recently, children spend far less time in around the creek. ATSDR used this information, along with Agency default values where appropriate, to develop conservative, yet realistic exposure assumptions for past and recent exposures.*

*ATSDR also notes that some commenters appeared to have a misconception that the exposure assumptions for recreational and residential exposures were intended to be added to obtain a total exposure. This is not the case; each scenario reflects assumptions for someone who spent almost all their time in that scenario (e.g., a child who rarely played in his or her yard but instead almost always played along the creek).*

PCrac-6

5. The effective dose is a dose quantity that is used as a benchmark for determining acceptable radiation dose to the public. The allowable limit is 100 millirem per year. ATSDR estimates effective doses that are below the allowable limit of 100 millirem per year, meaning that any risks to the public they reported would be below acceptable levels. The low effective doses should have been a clear signal to ATSDR that there was a serious error in their estimates of cancer risks to the public.

*ATSDR Response: ATSDR disagrees that estimated effective doses indicate that its cancer risk estimates were in error. As discussed in the report, whole-body effective doses from this exposure are small compared to ATSDR's minimal risk level of 100 mrem per year. However, whole-body effective dose does not completely describe potential effects from radiological contaminants taken internally that may distribute preferentially to particular organs. That is why ATSDR estimated organ-specific doses and resulting cancer risks using the methods described in the report. Depending on the specific contaminant, exposure, and organ of concern, it is possible, perhaps even expected, that a 100 mrem whole-body effective dose per year can result in an elevated organ-specific risk.*

PCrac-7

6. ATSDR calculates the wrong dose quantity for its risk calculations. The risk calculation made by ATSDR requires the absorbed dose rate to organ(s) of interest. ATSDR calculates risk incorrectly by using dose coefficients for a commitment period to age 70 for every age of exposure. This error means that for each year of exposure, beginning with a 1-year old infant and going through 33 subsequent years, the individual receives 70 years of dose in each year. The resulting estimates of risk are gross overestimates with no scientific basis that completely misrepresent the possible risk to any actual person.

*ATSDR response: ATSDR disagrees with the assertion that our use of the committed dose to age 70 resulted in gross overestimates of risk. The committed dose to age 70 is a common measure used by multiple organizations for estimating dose. The committed dose is the dose received from*

*an intake of radiological material that reflects organ retention, nuclear transmutation, and biological processes from intake through age 70. For clarity, a one-year-old who had an intake of radiological material will have a committed dose over 69 years. A 30-year-old who had an intake of radiological material will have a committed dose over 40 years.*

*ATSDR recognizes that the lifetime attributable risk coefficients were designed to be used with absorbed dose in a given year and then integrated over the years of exposure and dose. Essentially, to estimate dose and risk, for every year following the intake, the amount of the radioisotope (and its daughter products from radioactive decay) remaining in various organs from previous intakes has to be estimated, and the resulting dose added the absorbed dose for the current year's intake. This process is repeated from birth to age 70. For multiple years of intake this becomes very complicated, typically requiring specialized computer programs that cannot be easily explained to or replicated by members of the public.*

*In contrast, ATSDR estimated the committed dose to age 70 for every year of intake separately, and applied that committed dose in the year the intake occurred. This simplifies the calculations and allows clear presentation of the estimated dose and risk for each year an intake occurred. This method results in a higher dose for the year of intake, but removes the complicated and time-consuming process of carrying over remaining dose to subsequent years. This method results in nearly identical lifetime dose estimates as the more complicated approach. Multiplying the committed dose by the lifetime attributable risk coefficient may overestimate risk for younger ages. However, ATSDR bases its conclusions on lifetime risks from the entire 33 years of exposure, and we concluded that our methodology would be a reasonable approximation for estimating lifetime risks. We recognize that this approach would not be used in a detailed dose reconstruction. We believe the improved accessibility of the calculations for the general public outweighs any inaccuracies introduced by our method.*

*Please also see our response to the detailed comment PCrac-29 on this subject on page F-56.*

PCrac-8

7. ATSDR has failed to indicate to the public that the estimated risks are based on the linear no-threshold (LNT) hypothesis and that there are no scientific data that show a statistically significant increased risk of any of the cancers indicated even at the overestimated values reported by ATSDR.

*ATSDR Response: Most regulatory and advisory agencies assume that every dose of radiation, no matter how small, incrementally increases the risk of developing cancer. We recognize that proving or measuring an increased risk to very low levels of radiation exposure would be very difficult since radiation exposure also occurs from the natural environment, consumer products, and useful medical procedures. Addressing the controversy of this theory is beyond the scope of our public health activities related to communities living near hazardous waste in the environment.*

PCrac-9

8. The ATSDR report should not list estimated lifetime risk of the different cancers from Coldwater Creek exposures without putting these risks into context. A 1/10000 risk of a radiation induced cancer means that it is very unlikely that any cancer identified was caused by radiation from environmental contamination. If 1000 people were exposed to this level of contamination, it would be unlikely that even a single one of the 400 or so expected cancers would be caused by radiation from environmental contamination. ATSDR needs to do a much better job of putting this hypothetical risk into perspective.

*ATSDR Response: The section entitled "Increased Risk – What it Means" includes background and discussion about cancer risk assessment and comparison of what we considered "elevated' risk with U.S. overall lifetime cancer risks. In the text discussing each organ site where cancer risk was elevated, ATSDR included organ-specific U.S. cancer rates and discussed how the estimated increased risk from exposure compares. For this final version of the report, ATSDR has modified the risk summary tables (Tables 2 and 3) to include a column presenting those background rates.*

PCrac-10

The draft ATSDR report is unscientific and misleading, and unless ATSDR corrects its analysis and revises its conclusions and recommendations, ATSDR will fail to meet its mission.

*ATSDR Response: ATSDR disagrees with this statement. ATSDR used procedures based on accepted science, information on site use obtained directly from the people who were exposed, and reasonable assumptions based on ATSDR's standard practices for site evaluation to reach its conclusions.*

*[Beginning of more detailed RAC comments; please note that ATSDR included comments as provided; some text and comments are duplicated]*

PCrac-11

**Review and Comments on ATSDR Public Health Assessment Evaluation of Community Exposures Related to Coldwater Creek St Louis Airport/Hazelwood Interim Storage Site (HISS)/Futura Coatings NPL Site North St Louis County, Missouri EPA Facility ID MOD980633176 JUNE 18, 2018**

The ATSDR report evaluates exposures to people who play or live near Coldwater Creek in North St. Louis County, Missouri. It was prepared in response to requests from community members. The report uses available environmental data and information from the community to evaluate whether people playing or living near Coldwater Creek have or had harmful exposures to radiological contaminants from the creek.

The ATSDR report concludes that children and adults who regularly played in or around Coldwater Creek or lived in its floodplain for many years in the past (1960s to 1990s) may have an increased risk of developing bone or lung cancer, leukemia, or (to a lesser extent) skin or breast cancer. Furthermore, the report concludes that residents since 2000 may have an increased risk of developing bone or lung cancer from daily residential exposure to radionuclides present in or near Coldwater Creek**.** The authors of this review strongly disagree with ATSDR's conclusions because there are serious errors in the methodology and calculations made by ATSDR that lead them to conclusions that are not scientifically sound and inject an unwarranted level of concern among the public.

*ATSDR response: ATSDR used a simplified methodology, discussed in detail below, to reach its public health conclusions. We recognize that our approach is conservative, but we disagree that our methodology was fundamentally unsound. ATSDR used procedures based on accepted science, information on site use obtained directly from the people who were exposed, and reasonable assumptions based on ATSDR's standard practices for site evaluation to reach its conclusions.*

PCrac-12

Risk Assessment Corporation (RAC) along with a collaborative team of additional scientists and medical physicians reviewed the report carefully and submit these comments. We are very familiar with the nature and disposition of the residues stored at the SLAPS and HISS sites which resulted in contamination of some soils and sediment along Coldwater Creek. We are also familiar with the concerns of members of the public and local and state officials regarding the potential risks associated with contamination along the creek and in the floodplain. The implications of the ATSDR report are noteworthy and have been widely reported in the press. Our concerns about misleading and incorrect information in the ATSDR report and our interest in officially documenting these errors resulted in this collaborative response submitted on August 24, 2018 before the end of the official comment period of August 31, 2018, as indicated by ATSDR. We explain our concerns and recommendations in the sections that follow using the basic steps of the risk equation described below.

*ATSDR response: ATSDR's mission is to evaluate the potential for exposure to occur and the potential for harmful health effects to occur from the exposure. Our evaluations use conservative assumptions to ensure that our conclusions and recommendations are protective for all members of the community. One of the main purposes of releasing our evaluations for public comment is to obtain feedback to make our evaluations more helpful to communities, correct inaccuracies, and allow us to clarify our reasoning in the final report. We welcome this feedback.*

PCrac-13

Methodological Approach Used by ATSDR

ATSDR's fundamental methodological approach in its report is consistent with that of standard environmental risk assessment (Till and Grogan 2008):

$Risk = (S \times E \times D \times R)_{uv}$
where
S = source
E = exposure
D = conversion to dose
R = conversion to risk
u = uncertainty
v = validation

The basic steps consist of defining the source (S), estimating the exposure (E), calculating the dose from exposure using established dose coefficients (D), and converting dose to risk (R). Uncertainties for each of these components are typically addressed (u) and validation (v) is undertaken to confirm results of the overall process. In ATSDR's report there is no uncertainty or validation which is acceptable since the process they use is characteristic of a screening exercise where the objective is to obtain a realistic but biased high estimate of dose and risk for initial decision making.

Despite the bias inherent in a screening methodology, input values must be representative of real data and assumptions must fit within the range of confirmed site-specific values. More importantly, the calculations must be based on established scientific methods and they must be performed correctly. It is in these two areas that ATSDR fails to meet the necessary standard of scientific quality. Consequently, ATSDR's findings are seriously flawed and technically unacceptable. In the following sections we explain the calculational errors and the mistakes in assumptions that make the results unacceptable and needing revision.

*ATSDR Response: ATSDR disagrees with this statement. In developing exposure assumptions and inputs, ATSDR used site-specific environmental sampling data, information on site use collected directly from the people who were exposed, and reasonable assumptions based on ATSDR's standard practices for site evaluation. Our procedures are based on accepted scientific methods and suitable for the purposes of our public health assessment. Various public comments allowed us to identify inaccuracies in the calculation inputs and calculations that have been corrected in this final report. These modifications did not change ATSDR's overall conclusion that children and adults who lived and played along Coldwater Creek were potentially exposed to radiological substances that could increase their risk of certain types of cancer.*

PCrac-14
We recognize ATSDR's assessment of doses and risks represents a screening approach and therefore reflect results that deliberately overestimate potential radiation doses and risks. We have compiled an extensive amount of geo-referenced data over the period of operation of the SLAPS and HISS sites to facilitate efficient scientific analysis of the information to support estimates of radiation dose using a variety of scenarios.

Source (S)
The area around Coldwater Creek, including SLAPS and HISS is one of the most well radiologically defined locations in the U.S. with tens of thousands of environmental samples and measurements taken by government and private organizations over many decades. Significant soil and sediment sampling data exist to characterize the areas around SLAPS and HISS and along Coldwater Creek. Figure 1 shows sample locations for data collected through numerous investigations, beginning in the 1970s and continuing to the present day. Additional data have been collected in recent years along Coldwater Creek north of I-270 that are not shown in Figure 1.

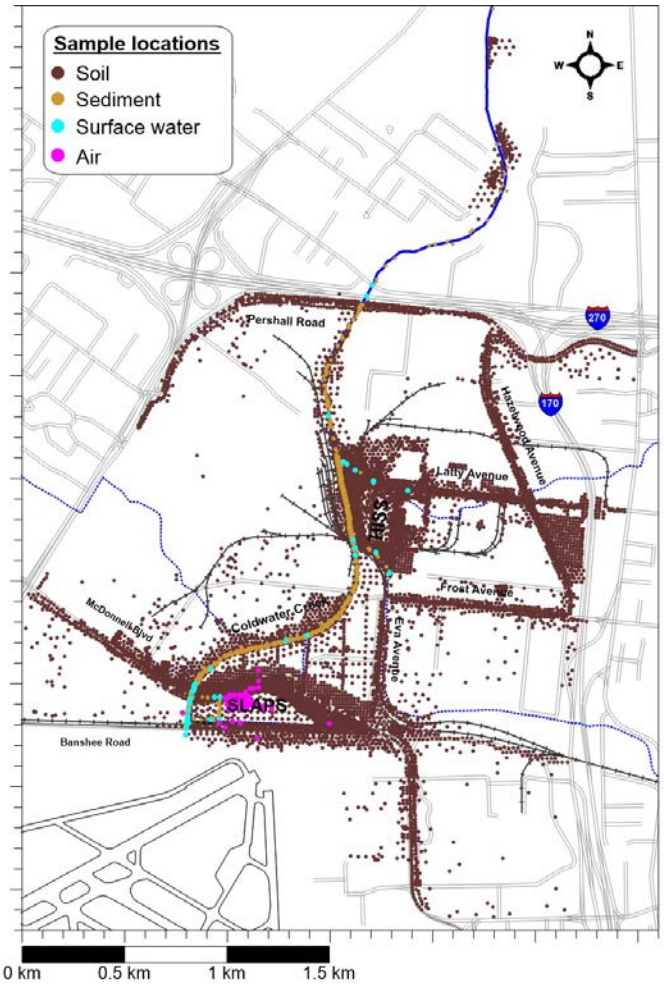


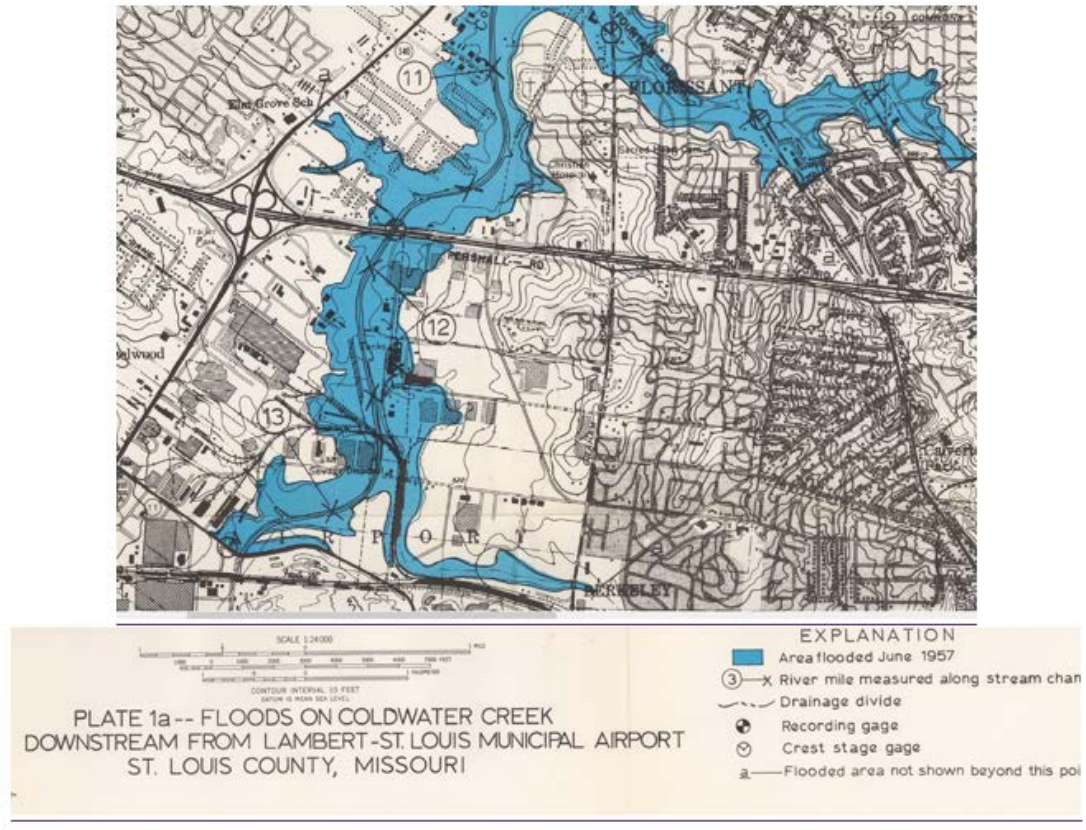

**Figure 1.** Map showing sample locations around SLAPS and HISS and along Coldwater Creek.

*ATSDR response: ATSDR agrees that the areas around SLAPS and HISS are spatially well-characterized, as shown in Figure 1. This is and has been primarily an industrial area with little opportunity for the types of recreational and residential exposure evaluated in our report. ATSDR did not use sampling data from south of I-270 to estimate recreational or residential exposures for this reason. However, a review of the historical activities and sampling data from*

*these areas justify the use of conservative assumptions to estimate exposure point concentrations in the residential areas downstream from SLAPS and HISS.*

- ***The waste could have had a high concentration of Th-230 and entered the creek over many years.*** *Historical reports indicated that the residues stored at SLAPS and later moved to HISS contained over 75,000 pCi/g of Th-230 [111,112] In the late 1970s, although Th-230 was not measured, SLAPS showed off-site radiological contamination from surface water erosion of contaminated materials [113]. At HISS, 1977 sampling of surface soil and abandoned waste showed Th-230 concentrations approaching or exceeding those reported in the residues [114]. Even in the 1990s, piles near HISS showed Th-230 concentrations in the hundreds to thousands of pCi/g [6,115]. Because no controls were in place, we presume that contaminants from the original residues could have entered the creek on an ongoing, continual basis from SLAPS between 1946 and 1966, and from HISS between 1966 and 1974. Even after these dates, contaminants may have entered the creek from erosion of contaminated soil remaining at the sites after removal of the main waste piles.*
- ***The waste flowed downstream.*** *The contaminants would have associated with creek sediment and moved downstream according to hydrological principles. Contaminants may have accumulated where sediment typically deposits. In addition, contaminants could have been washed out of the creek into the floodplain during floods and remained in the floodplain after waters receded. The residential areas of concern in this evaluation are downstream from SLAPS and HISS, but we do not have enough information to predict exactly where the contamination went and when.*
- ***Available data may not describe distant past concentrations due to natural and human dispersion of sediment****. For example, much of the area around SLAPS, HISS, and downstream areas was inundated in a 1957 flood (see Figure F-1 below) [116]. Also, developers commonly used floodplain soil from the creek for fill in other locations when downstream areas were being developed in the 1950s and later. These activities and events add significant uncertainty to conclusions about past exposures based on sampling data collected many years later.*

**Figure F 1. U.S. Geological Survey map showing areas around SLAPS, HISS, and downstream flooded in 1957 (from [116])**




PCrac-15

ATSDR identified several sectors between I-270 and the St. Denis Bridge and then selected the sector with the highest upper confidence limit (UCL) to use as the exposure concentration for both soil and sediment. In addition, the highest UCL concentrations for each radionuclide occur in different sectors but are assumed as the single exposure concentrations. For past soil exposures, the $^{230}$Th UCL concentrations ranged from 5.0 pCi $g^{-1}$ (Sector A – left) to 54.5 pCi $g^{-1}$ (Hot spot – 3) and for past sediment exposures, the concentrations ranged from 6.6 pCi $g^{-1}$ (Sector E) to 105.4 pCi $g^{-1}$ (Sector H) (see Table C 3 in ATSDR report). The actual mean concentrations reported by ATSDR for these areas are between a factor of 2 to 6 lower than the reported UCL values.

*ATSDR response: ATSDR's current standard procedures use the 95% upper confidence limit on the mean, not the mean itself, to estimate exposure point concentration for a particular exposure unit. We are 95% certain that the true mean of an exposure unit is below this value. Our evaluations are intended to be protective of all exposed community members. Some children and adults could have gone regularly to the same general area of the creek. Therefore, we selected the highest upper confidence limit in any sector as a conservative estimate of possible exposure*

*point concentration. We considered each radionuclide separately for this selection. In most cases, the selected values for U-238 and Ra-226 were from the same exposure unit as Th-230.*

PCrac-16

The UCL value reported for Sector I of 67.1 pCi $g^{-1}$ significantly exceeds the maximum value measured in this area. The maximum value is not reported by ATSDR but must be less than 43 pCi $g^{-1}$ since this sector had no values exceeding the FUSRAP remediation goal. This indicates that ATSDR applied little if any professional judgement regarding the ProUCL output to ensure the values were reasonable. The fact that the UCL concentration exceeded any of the maximum measurements in some sectors indicates the distribution is not normal and/or the sample size is insufficient. As an example, the UCL value assumed by ATSDR for sediment of 105.4 pCi $g^{-1}$ exceeds the mean value of 17.3 pCi $g^{-1}$ for the 6 results (out of 12) that were greater than background in Sector H by a factor of 6. This indicates that the two samples with concentrations greater than the remediation goal had a disproportionate impact on the estimated UCL.

*ATSDR response: ProUCL, a publicly available program available from EPA, assesses the underlying distribution of input datasets, calculates upper confidence limits from a variety of distributions, and recommends the most appropriate UCL to use based on the underlying distribution. ATSDR presented the output of ProUCL for transparency. In cases where the recommended UCL is higher than the maximum value, it is standard practice to use the maximum value. However, since ATSDR used the UCL from sector H, not sector I, for estimating past sediment exposure, we did not consider using the UCL from sector I.*

PCrac-17

Exposure concentrations assumed by ATSDR for past exposures (Table C-5 of ATSDR report) were compared to those estimated by RAC for two different exposure areas (CC 5 and CC 6 as shown in Table 1) in the area between I-270 and St. Denis Bridge. The exposure areas developed by RAC are shown in Figure 2. The UCL exposure concentrations assumed by ATSDR are between a factor of approximately 2 to 6 greater than those estimated by RAC.

**Table 1. Exposure concentrations assumed by ATSDR for past exposures compared to RAC- calculated values**

| Media | Nuclide | ATSDR UCL[c] | RAC Arithmetic Mean[a] | |
|---|---|---|---|---|
| | | | CC 5[b] | CC 6 |
| Soil/sediment (pCi $g^{-1}$) | $^{226}$Ra | 2.5 – 4.8 | 1.7 | 1.9 |
| | $^{230}$Th | 54.5 – 105.4 (26.7 – 17.3) | 11.8 | 12.2 |
| | $^{238}$U | 2.3 – 4.5 | 1.5 | 1.4 |
| Surface water[d] (pCi $L^{-1}$) | $^{226}$Ra | 0.9 | NA | |
| | $^{230}$Th | 4.6 | NA | 0.5 |
| | $^{238}$U | 5.1 | 4.8 | 0.1 |

[a] Both soil and sediment sample data are used to estimate concentrations
[b] See Figure 2
[c] Arithmetic mean value in parentheses if available
[d] All ATSDR surface water samples are the FUSRAP background criteria values. These values were also used for recent exposures
NA – no measurements available

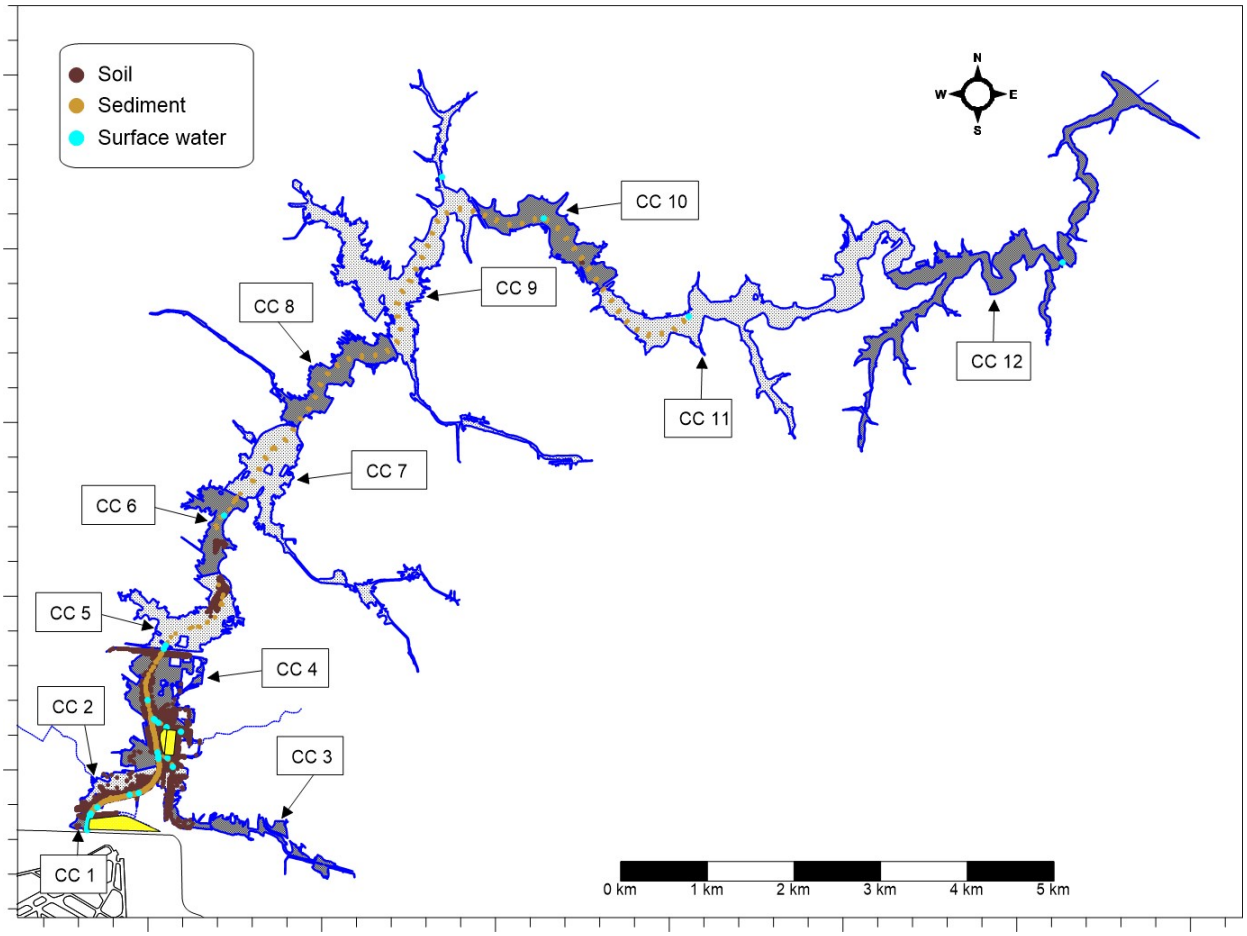



**Figure 2.** This figure shows 12 exposure areas along Coldwater Creek and the associated soil, sediment and surface water sample locations. Exposure area CC 12 ends at the Missouri river, exposure area CC 7 is south of Bruce Drive, and exposure area CC 8 is north of Bruce Drive. SLAPS and HISS are highlighted in yellow.

*ATSDR response: ATSDR cannot determine the source of data analyzed and reported in commenters' Table 1 and Figure 2 and therefore cannot comment on whether the data sets used by ATSDR and by RAC are truly comparable. However, if the underlying data are comparable, Table 1 illustrates why ATSDR uses upper confidence limit (UCL) rather than mean to estimate exposures. The mean of any data set is typically less than the 95% UCL, but we are 95% confident that the 95% UCL will capture the true mean.*

PCrac-18

To characterize exposure concentrations for the exposed population, ATSDR should have used an area weighted-mean UCL concentration. This would provide a more representative exposure concentration compared to simply selecting the sector with the highest UCL concentration. Additionally, the mean concentration provides a conservative (i.e., biased high) estimate of the representative exposure concentration when the data exhibit a lognormal distribution; therefore, using the UCL of the log- transformed data (i.e., the UCL of the geometric mean) may provide a more representative estimate of the actual concentration to which an individual would be exposed during activities in and along Coldwater Creek. Furthermore, based on the footnote in Table C 3 of the ATSDR report, it would appear that only samples with concentrations greater than background were used to estimate the UCL values, which would add additional high bias to the assumed exposure concentrations.

*ATSDR response: ATSDR evaluations are intended to be protective of all exposed community members. Some children and adults could have gone regularly to the same general area of the creek. Using an area-weighted mean could underestimate these exposures.*

*The recent data used to estimate past and recent soil exposure and recent sediment exposure included background concentrations. The older data used to estimate past sediment exposure, in contrast, did not include background. Therefore, in preparing the data reported in Table C3 only, ATSDR added the background values to the reported results. Three of the sectors had no reported results for U-238 above background so it did not make sense to calculate a UCL for these sectors.*

PCrac-19

Although the concentrations assumed by ATSDR may be representative of isolated hot spots along Coldwater Creek, they are not representative of the long-term or chronic concentrations that an individual could be reasonably expected to encounter while spending time in and around the areas along Coldwater Creek that ATSDR evaluated.

*ATSDR response: Because some children and adults could have gone regularly to the same general area of the creek, ATSDR considers its method for determining exposure point concentrations appropriate. It will never be possible to determine the actual long-term concentrations individuals encountered, because no data exist showing how surface soil and sediment concentrations changed over the timeframes evaluated in this report.*

PCrac-20

**Exposure (E)**

**1. ATSDR's use of a particulate emission factor (PEF) for the Coldwater Creek area that was developed for Colorado ATV trails is completely unrealistic and misleading.** ATSDR's use of a particulate emission factor (PEF) developed for all-terrain vehicle (ATV) riding in Colorado is a serious error in their methodology. As stated above, even in screening assessments,

exposure factors must convey some site-specific reality in representing an upper bound value. ATSDR's value of $1.18\times10^{-6}$ kg $m^{-3}$ is over 5,000 times higher than the value recommended by EPA for recreational activities ($2.16\times10^{-10}$ kg $m^{-3}$) and would result in a persistent "dust cloud" over Coldwater Creek (see Table A 8 in ATSDR report). Further, it would result in concentrations that are about 50 times higher than the air quality standard for particulate matter less than 10 µm ($PM_{10}$) of 20 µg $m^{-3}$. ATSDR argues that their value is consistent with published and unpublished dust sampling studies including a study of lead-contaminated tailings in Missouri. Tailings are loose unconsolidated materials that are typically unvegetated. However, the area around Coldwater Creek is clearly vegetated, and creek sediment typically has a high moisture content that would limit soil suspension. In reality, the value used by ATSDR was derived from empirical data collected during ATV riding at the Quincy Smelter site in California as stated in Appendix F of EPA 2008. According to EPA (2008), measured concentrations from a monitor mounted on an ATV trailing behind a second ATV ranged from 18.7 to 23,359 µg $m^{-3}$. The mean value was used in deriving the PEF and was corrected for the fraction of suspended particles that were $PM_{10}$ (0.35). A bicycle does not have the capability to suspend the same amount of dust as an ATV. Yet ATSDR applied the PEF for ATV riding to a 4-year old child riding their bicycle near Coldwater Creek. There may be instances where high dust loading can occur, but this is not a chronic condition expected to persist daily for 33-years. A correct value would represent an average over the exposure period.

The PEF value used by ATSDR is applied not only to riding bikes near Coldwater Creek, but is also applied to gardening activities, which is clearly inappropriate. Using the default RESRAD (Yu et al. 2001) mass loading factor (which is intended to be conservative for chronic conditions) of $1\times10^{-4}$ g $m^{-3}$ ($1\times10^{-7}$ kg $m^{-3}$ or 100 µg $m^{-3}$) would result in reducing inhalation doses and risk by a factor of 11.8.

*ATSDR response: ATSDR disagrees that the PEF used to estimate inhalation during activities is unrealistic. Activities on soil are known to result in suspension of soil or dust particles directly into the breathing zone of the person doing the activity. The concentration of contaminants in the activity-generated "personal dust cloud" can be orders of magnitude greater than that predicted by models of wind-blown dust, such as EPA's standard soil suspension value. Higher soil suspension factors are appropriate for estimating inhalation exposures from activities.*

*Activity-based sampling, roughly analogous to personal air monitoring in occupational settings, is an accepted method to measure exposures resulting from various activities when the inhalation route of exposure is particularly important, such as issues with asbestos contamination. It was important to consider inhalation exposures from activities related to Coldwater Creek because the route of exposure affects the distribution of radiological contaminants within the body. The following details ATSDR's reasoning and selection of the PEF used in the Coldwater Creek evaluation.*

*ATSDR compared results for respirable dust or PM10 from several different activity-based sampling events to determine an appropriate PEF for recreational and residential exposures at Coldwater Creek.*

- *In 2008, EPA developed a PEF for ATV riding to evaluate the dust inhalation exposure pathway at the Standard Mine site in Colorado [95]. The derivation reported that it used dust data collected from two ATVs during EPA testing in 2004 at the Quincy Smelter site in Michigan. The PM10 fraction of the total dust was used to determine a PEF for respirable dust of* $\mathbf{1.18\times10^{-6}\ kg/m^3}$.
- *In 2005, ATSDR collected samples of PM10 and of asbestos during ATV riding on dirt roads in Ambler, Alaska [139]. Only two activity-based samples for PM10 were collected successfully; these corresponded to PEFs of* $\mathbf{4.26\times10^{-6}\ kg/m^3}$ *and* $\mathbf{6.26\times10^{-6}\ kg/m^3}$.
- *In 2004, EPA collected activity-based samples for dust and asbestos at the North Ridge Estates site in Oregon to represent activities of child play, weed trimming, and rototilling (personal communication, J. Wroble, EPA Region 10, April 23, 2018). Preliminary data suggest respirable dust PEFs ranging from* $\mathbf{1\times10^{-6}}$ *to* $\mathbf{6\times10^{-6}\ kg/m^3}$.
- *In 1999, Dames & Moore collected activity-based air samples for metals inhaled by outdoor recreational vehicle (ORV) users on tailings at the Federal Tailings Pile site in Missouri [96]. Dust concentrations were not reported, but the mean time-weighted average of three ORV riders was 0.0042 mg of lead/$m^3$. Considering the representative concentration of lead in tailings at the site (885 mg/kg), the ORV air concentration would be consistent with a PEF of* $\mathbf{4.7\times10^{-6}\ kg/m^3}$.

*All these measured activity-based PEFs for dust are orders of magnitude higher than EPA's default for wind-blown dust ($2.16\times10^{-10}$ kg/$m^3$). The EPA-derived PEF for ATV riding,* $\mathbf{1.18\times10^{-6}}$ *kg/$m^3$, was selected. This is the only published report we found that specifically derives an activity-based PEF for respirable particulates, and it appears to be consistent with incidental findings of other studies. Although the selected PEF was derived for ATV riding, it is consistent with the studies described above for activities including child play and yard work. We applied the PEF to all relevant soil contact activities at Coldwater Creek during the time the activity was occurring, as described in the report.*

*The selected PEF is not inconsistent with standard assumptions used by radiological professionals and experimental data on resuspension of radionuclide particles. A mass loading of soil in air of 5 mg/$m^3$, equivalent to* $\mathbf{5\times10^{-6}\ kg/m^3}$, *was assumed by the Department of Energy in 1988 in its 1988 hazard assessment of the recreational ball field near SLAPS [138]. In 2018, Marshall and coworkers reevaluated existing data to develop a general purpose resuspension rate constant [140]. Their results showed that resuspension of radionuclide particulates was dependent on time following deposition, with factors ranging from* $\mathbf{1.5\times10^{-6}\ kg/m^3}$ *within one day of deposition to* $\mathbf{6.7\times10^{-5}\ kg/m^3}$ *over a period of one year. For periods from 2 to 8 years, resuspension factors were on the order of* $1\times10^{-9}$ kg/$m^3$.

PCrac-21

In addition, the dose coefficients used by ATSDR are based on a lognormal distribution of particle sizes having an activity median aerodynamic diameter (AMAD) of 1 µm, which mean 50% of the activity is associated with particles less than 1-µm. According to EPA's AP-42 (EPA 1995, Section 13.2 as revised in 2006), the fraction of suspended particles from unpaved roads that are PM10 is about 30% and only 3% of the particles are less than 2.5-µm. Based on this, only 9% (0.03/[0.30+0.03]) of the PM10 fraction of particles are less than 2.5-µm and an even lower fraction would represent 1-µm particles. Thus, assuming a 1-µm AMAD is unrealistic. Larger particles have lower inhalation dose coefficients compared to smaller particles. For example, the International Commission on Radiological Protection (ICRP 2001) 50- year committed inhalation lung dose coefficient for 1-µm AMAD particles to an adult is 7.7×10–5 Sv Bq–1 for 230Th type S. The dose coefficients for 5-µm and 10-µm AMAD particles are factors of 1.6 and 3.2 less than the 1-µm AMAD particles respectively. Because less than 9% of the suspended PM10 particles are <2.5-µm, then the dose coefficients for 5-µm or 10 µm particles, or a weighted average of the two, would be more appropriate to use for this analysis.

If all of these factors had been considered using appropriate upper bound but realistic exposure parameters, the air pathway would become a negligible contribution to dose in the ATSDR analysis. This is a serious fault in the ATSDR assessment that must be corrected.

*ATSDR response: ATSDR disagrees that use of a different AMAD is warranted.*

*Activity median aerodynamic diameter (AMAD) is the aerodynamic diameter in which 50% of the activity is associated with particles smaller than the AMAD, and 50% of the activity is associated with particles larger than the AMAD. The term PM10 refers to inhalable particles, with diameters that are 10 micrometers and smaller. Neither AMAD nor PM10 describe the particle size distribution.*

*In the absence of any data describing either the particle size distribution or the distribution of radiological activity within particles of dust that could be suspended from Coldwater Creek floodplain soil, ATSDR used an AMAD of 1.0 micrometer as a conservative estimate. This is the same assumption made by the Department of Energy in 1988 in its 1988 hazard assessment of the recreational ball field near SLAPS [138].*

PCrac-22

**2. Exposure parameters are unreasonably high and do not reflect site-specific values.** The exposure scenario intake parameters are based on the upper 95th percentile of inhalation and ingestion rates for short-term exposure yet the analysis is for a long-term situation. ATSDR states the inhalation and ingestion rates were obtained from U.S. Environmental Protection Agency' Exposure Factors Handbook published in 2011. EPA states for the inhalation rates used by ATSDR "It should be noted that there may be a high degree of uncertainty associated with the upper percentiles. These values represent unusually high estimates of caloric intake per day and

are not representative of the average adult or child." The appropriate values of intake which should have been used are about a factor of 3 lower, resulting in dose and risk estimates that are also a factor of 3 lower and more representative of a real individual. While some intentional overestimation in radiation dose and risk calculations can be prudent to ensure actual doses are not underestimated, the ATSDR assessment has, through both intentional decisions and numerous calculation errors, estimated doses and risks that are in no way representative of those received by any actual individual and are unacceptable even for a screening calculation.

*ATSDR response: Use of the 95$^{th}$ percentile values for inhalation rates and other intakes follows ATSDR's standard practice and aligns with our goal to be protective of all potentially exposed community members.*

PCrac-23

**Conversion to Dose (D)**

Once exposure through ingestion, inhalation, and external pathways is established to a hypothetical person, dose can be calculated directly using dose coefficients available in the scientific literature. The following are noted problems with ATDR's dose calculations.

1. **ATSDR calculates an incorrect dose quantity for its risk calculations.** The risk calculation made by ATSDR requires the absorbed dose rate to the organ(s) of interest. ATSDR calculated committed equivalent organ dose. In simple terms, instead of determining the dose to an organ in a given year, ATSDR determined the dose to an organ in a given year and all subsequent years up to age 70 and uses this 70-year committed dose for all 33 years of exposure. This is illustrated in Figure 3, using the dose to an infant in year 1 as an example. As discussed in the risk calculation comments that follow, this is not the correct quantity to use when calculating cancer risk as ATSDR suggests and results in a gross overestimation of cancer risk.

*ATSDR response: ATSDR disagrees with the assertion that our use of the committed dose to age 70 resulted in gross overestimates of risk. Please see our response to a similar comment, PCrac-6, and detailed comments below*

PCrac-24

2. **ATSDR's failure to question calculated risks when effective doses are below the allowable limit raises a serious question about their technical qualifications.** ATSDR reports both effective dose and committed equivalent dose to specific organs for a 33-year period of exposure beginning with a 1- year old infant. The effective dose represents a weighted dose across all organs of the body based on age of exposure. In addition, doses from ingestion and inhalation include the dose not only at the time of intake, but dose from the radionuclides retained in the body over their lifetime (the committed dose). The effective dose is used to compare to recommended allowable limits of exposure to the general public.

In their report, ATSDR calculates effective doses for defined Coldwater Creek scenarios and compares them to ATSDR's minimum risk level (MRL) of an annual effective dose of 100 mrem. The MRL value corresponds to the widely established annual effective dose limit of 100 mrem that is recommended by the International Commission on Radiological Protection (ICRP) and which has been adopted in radiation exposure regulations in the United States [10 CFR 20.1301(a)(1), Radiation Dose Limits for Individual Members the Public]. The ATSDR report states

"*The chronic MRL is based on studies showing that natural and artificial sources of ionizing radiation ("background") give a person in the U.S. on average, and effective whole-body dose of 360 mrem/yr. No harmful effects have been shown to be associated with this dose*".

ATSDR presents their effective dose calculations in Table 4 of their reports. The detailed calculations for each exposure scenario and age are presented in Table E-10.

If ATSDR had examined these results carefully, they would have realized that the effective doses presented are all below the allowable annual limit of 100 mrem, with the exception of one value. This observation should have triggered a question about the accuracy of the risk estimates that exceed the Environmental Protection Agency recommended risk target level of $10^{-4}$ (as shown in Tables E-8 and E- 9). Our discussion of the risk calculation is included in the next section but the point here is that ATSDR staff should have recognized there was something inherently incorrect about their reported risk calculation.

*ATSDR response: ATSDR disagrees with the assertion that estimated effective doses indicate that its cancer risk estimates were in error. As discussed in the report, whole-body effective doses from this exposure are small compared to ATSDR's minimal risk level of 100 mrem per year, based on external exposure and dose only. However, whole-body effective dose and ATSDR's minimal risk level does not completely address potential effects from radiological contaminants taken internally that may distribute preferentially to particular organs. That is why ATSDR estimated organ-specific doses and resulting cancer risks using the methods described in the report. Depending on the specific contaminant, exposure, and organ of concern, it is possible, perhaps even expected, that a 100 mrem whole-body effective dose per year can result in an elevated organ-specific risk.*

PCrac-25

The one exception to the annual effective doses being below the allowable limit of 100 mrem is a value of dose in Table E-10 of 104 mrem (upper bound) to a 1-year old infant. This value is an artifact of the use of extreme exposure factors for the infant discussed above. In their analysis, the 1-year old infant ingests 100 mg of soil per day, 100 mg of sediment per day and consumes 30 mL of water from Coldwater Creek per week. These values apply to all children less than three years of age. We strongly disagree with these extreme assumptions for exposure factors

even in the case of screening assessments. Furthermore, assuming the same values for all children up to age 3 is not appropriate.

*ATSDR response: We used ATSDR's standard ingestion assumptions in this evaluation. The values shown in parentheses in Table E-10 are doses for children exhibiting regular soil pica behavior, i.e., intentionally eating larger amounts of soil. Soil pica behavior is most likely to occur in preschool children as part of their normal exploratory behavior, with between 4% and 20% of preschool children exhibiting soil pica. ATSDR's standard procedure is to consider the soil pica scenario when the target population includes pre-school children [94].*

PCrac-26

**3. Summation of external dose coefficients for environmental concentrations of short-lived progeny from U-238 were performed incorrectly.** ATSDR accounted for the external dose from radioactive progeny in the environment that would be assumed in secular equilibrium with their parent by summing the dose coefficients of parent and progeny. However, they did not include the branching ratios for the U-238 progeny, resulting in the external dose coefficient being overestimated for $^{238}$U. The $^{238}$U external dose coefficient used by ATSDR included contributions from $^{234}$Th, $^{234}$Pa, $^{234m}$Pa, and $^{234}$U. The dose coefficient for $^{234}$Pa is up to five orders of magnitude higher than $^{238}$U and the other progeny, but is formed only 0.16% of the time $^{234}$Th decays. Not accounting for the small fraction of $^{234}$Pa formation results in a gross overestimation of the external dose from uranium.

*ATSDR response: ATSDR agrees that the Th-234 branching ratio should have been accounted for, and we have corrected this in the final document. Failure to account for the branching ratio did not result in a gross overestimation of dose; the overall recreational and residential doses were affected by less than 1%, and the estimated risks were essentially unchanged.*

PCrac-27

**4. Evidence based on historical data indicates $^{230}$Th would be in the insoluble form (viz. the ICRP default solubility class) in the environment, not soluble.** Thorium-230 is the dominant contributor to dose and therefore ATSDR should have more carefully addressed the chemical form of this radionuclide in the environment. There is no evidence that $^{230}$Th is in the moderately soluble form in the soils and sediments around Coldwater Creek, rather it is most likely to be present in its insoluble form, which is the ICRP recommended default. In our work we found no evidence of soluble thorium either in characterization of the original wastes nor in the environment. The presence of thorium primarily in its insoluble form is supported by the fact that the majority of the $^{230}$Th remains in the upper 6 inches of the soil with a rapid decrease in concentration with increasing soil depth. For example, the use of soluble chemical form of $^{230}$Th in the ATSDR analysis increases the estimated doses and risks to bone by a factor of about 2.5. It appears to be an afterthought by ATSDR to include risk values for moderately soluble $^{230}$Th (solubility Type M). Dose coefficients to most organs (notably excluding the lung) are higher for moderately soluble thorium compared to slowly soluble (solubility Type S) thorium.

*ATSDR response: The assumptions for Th-230 solubility refer to lung solubility, not solubility in the environment. ATSDR found no site-specific data describing the chemical form of Th-230 or its solubility in site reports. ATSDR's toxicological profile on thorium states that thorium oxide compounds exhibit slow lung solubility (type S); whereas medium lung solubility (type M) is exhibited by other thorium compounds besides oxides. ICRP Publication 68, Annex F (page 83), recommends the use of moderate lung solubility for unspecified compounds and slow lung solubility for thorium oxide and hydroxide compounds [141]. In contrast, ICRP Publication 72 recommends the use of slow lung solubility for thorium when no specific information is available [142]. ATSDR evaluated Th-230 inhalation using both slow and medium lung solubility coefficients. We present the results as a range. The assumption of slow solubility increases the dose and resulting risk to the lungs; whereas assuming moderate solubility increases the dose and resulting risk to the bones and other internal organs.*

*ATSDR notes that the commenters' statement that Th-230 remains in the top 6 inches of soil and that concentration decreases rapidly with depth appears to contradict both site data and comments from FUSRAP (see, for example, PCfusrap-4c). If both are true, it is further evidence for physical movement of contaminants due to flooding or other human interaction.*

PCrac-28

**Conversion to Risk (R)**

The organ cancer risks presented in the report are calculated incorrectly, significantly overestimate, and completely misrepresent organ cancer risks associated with exposures to Coldwater Creek. These risk values must be corrected. The methodology used by ATSDR is technically flawed giving the impression to the public that risks exceed the maximum risk of $10^{-4}$ recommended by the EPA when they do not. If the doses and risks had been calculated correctly, the screening estimates of risk in the ATSDR report would be below the level of $10^{-4}$ and would justifiably not be of great concern.

*ATSDR response: ATSDR disagrees with this assertion. There are several ways to estimate risk, and much controversy remains about how to interpret risk. The method used by ATSDR, as described earlier in our response to PCrac-7, was adequate for the purposes of our public health assessment. We corrected inaccuracies in the bone cancer risk and U-238 branching ratios identified by multiple commenters. ATSDR also used a different calculation method suggested by the commenters below to compare with our risk estimates. Our evaluation still found risks above 1 in 10,000, and our overall conclusions remain the same. Please also see our response to the following detailed comment on this subject, PCrac-29.*

PCrac-29

**1. The equation for calculating radiation cancer risk is incorrect.** The correct method for calculating cancer risk is specified in Federal Guidance Report 13 (EPA 1999; EPA 2002). The

cancer risk $r_a(x_i)$ from a unit intake of a radionuclide at age $x_i$ is calculated from the continuously varying absorbed dose rate $D(x)$ as (Equation 7.6 in FGR 13, EPA 1999)

$$r_a(x_i) = \frac{\int_{x_i}^{\infty} \dot{D}(x) r(x) S(x) dx}{S(x_i)} \quad (1)$$

where

$r(x)$ = is the cancer risk due to a unit *absorbed* dose at the site at age $x$ ($Gy^{-1}$)

$S(x)$ = the survival function, that is, the fraction of live-born individuals in an unexposed population expected to survive to a given age.

$\dot{D}(x)$ = unit absorbed dose rate ($Gy\ yr^{-1}$).

The unit RBE-weighted absorbed dose rate is the sum of the dose rate from low-LET radiation plus the product of the absorbed dose rate from high-LET radiation and the relative biological effectiveness factor (RBE) for the applicable cancer type. The RBE has a value of 20 for alpha particles for all cancer sites with the exception of 10 for bone cancer and 2 for leukemia (EPA 2011). Thus, the RBE-weighted absorbed dose is the same value as the equivalent dose except in those two instances.

In the report ATSDR calculated risk using the following equation:

$$risk = \sum_i LAR_i \left( \frac{1}{10{,}000\ person \bullet rem} \right) \times Dose_i(millirem) \times \frac{1}{1{,}000\ mrem} \quad (2)$$

where

$LAR_i$ = lifetime attributable risk per 10,000 person-gray for a dose received at age $i$,

$Dose_i(millirem)$ = the 70-year committed equivalent dose.

The dose in the above equation is the committed equivalent dose to age 70 whereas *LAR* (as stated in the EPA 2011) is based on the RBE-weighted absorbed dose *received* at age *i*. Using the committed dose overestimates the risk not only for older adults but children as well because the dose from an intake at age *i* occurs over the lifetime of the individual and is not delivered immediately upon intake. This concept is illustrated in Figure 3 where the cumulative RBE-weighted absorbed dose to the bone is calculated as a function of time after ingestion of 1 Bq of $^{230}$Th by an infant using the AcuteDose[1] code (Eckerman 2012) *[Footnote states: Distributed by EPA at https://www.epa.gov/radiation/tools-calculating-radiation-dose-and-risk]* . The dose rate as a function of time after intake for an infant is shown in Figure 4. The dose in the first year after intake is 3.4% of the total dose received at 70 years. This has the net effect of overestimating dose and risk during infancy by a factor of 30. Except for leukemia and bone cancer, the equivalent dose is equal to the RBE-weighted absorbed dose.

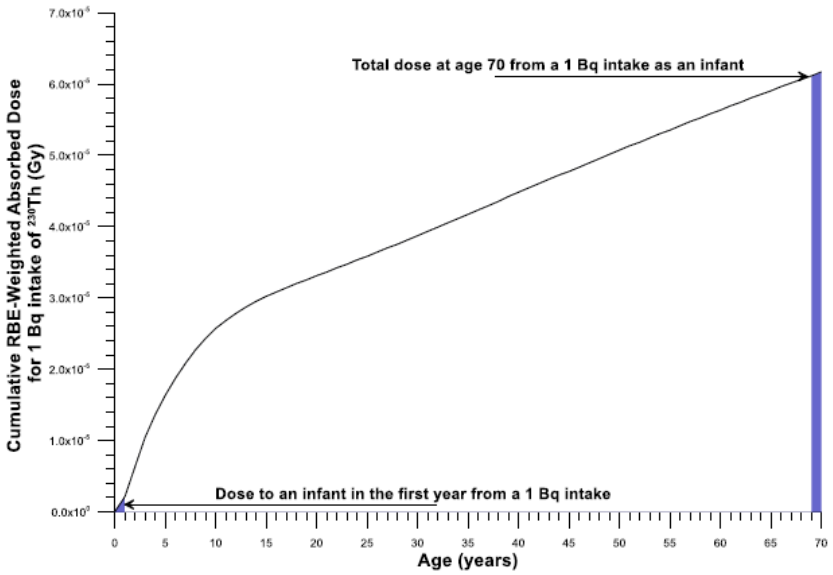



**Figure 3.** This figure shows the cumulative RBE-weighted absorbed dose to the bone as a function of time after ingestion of 1 Bq (27 pCi) of $^{230}$Th by an infant. Using year 1 as an example, it shows the correct dose to use in ATSDR's risk calculation and compares it to the actual dose used by ATSDR which was the cumulative absorbed dose for year 70 following a unit intake. As a consequence, the dose ATSDR uses for an infant is a factor of 30 higher than it should be in the first year.

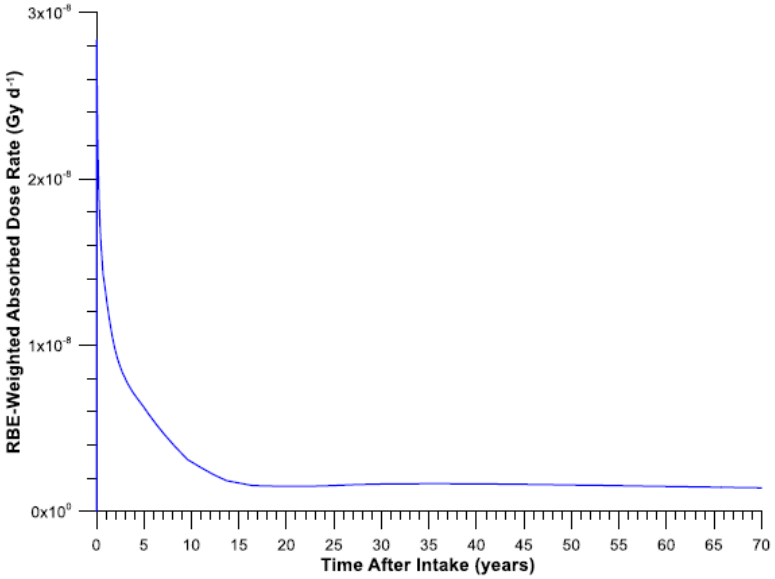



**Figure 4.** This figure shows the RBE-weighted absorbed dose rate to the bone as a function of time after ingestion of 1 Bq (27 pCi) of $^{230}$Th by an infant. These data are used in the risk calculation in Equation 1.

The correct risk calculation can be performed using the dose rate files included in the AcuteDose code distribution, the correct *LAR* values, and the correct external dose coefficients. The necessary files included with AcuteDose are fgr13ing2.drt 9 (ingestion) and fgrinh2.drt (inhalation). A code application would then have to be written to perform the integration in Equation 1 followed by convolution over the lifetime of the person.

*ATSDR response: ATSDR disagrees with the assertion that our use of the committed dose to age 70 resulted in gross overestimates of risk. The committed dose to age 70 is a common measure*

*used by multiple organizations for estimating dose. The committed dose is the dose received from a single intake of radiological material that reflects organ retention, nuclear transmutation, and biological processes from intake through age 70. For clarity, a one-year-old who had an intake of radiological material will have a committed dose over 69 years. A 30-year-old who had an intake of radiological material will have a committed dose over 40 years.*

*ATSDR recognizes that the lifetime attributable risk coefficients were designed to be used with absorbed dose in a given year and then integrated over the years of exposure and dose. Essentially, to estimate dose and risk, for every year following the intake, the amount of the radioisotope (and its daughter products from radioactive decay) remaining in various organs from previous intakes has to be estimated, and the resulting dose added the absorbed dose for the current year's intake. This process is repeated from birth to age 70. For multiple years of intake this becomes very complicated, typically requiring specialized computer programs that cannot be easily explained to or replicated by members of the public.*

*In contrast, ATSDR estimated the committed dose to age 70 for every year of intake separately, and applied that committed dose in the year the intake occurred. This simplifies the calculations and allows clear presentation of the estimated dose and risk for each year an intake occurred. This method results in a higher dose for the year of intake, but removes the complicated and time-consuming process of carrying over remaining dose to subsequent years.*

*To test how ATSDR's method compared with the method suggested by the commenter, we used the AcuteDose code to estimate absorbed organ-specific doses for each year to age 70 and applied the 2011 lifetime attributable risks to determine lifetime cancer risks resulting from 33 years of intake, using the assumptions developed for the Coldwater Creek evaluation [136]. We found that the doses to age 70 from the cumulative exposure were very close (within 10%) to our method. Estimated lifetime cancer risks were also similar to our method (within 17%), with the exception of bone cancer. For bone cancer, lifetime risks estimated using the AcuteDose code and lifetime attributable risks were approximately 50% lower than estimated using ATSDR's method.*

*ATSDR's simplified method gives cumulative dose estimates and lifetime cancer risks generally comparable with the more complicated approach. This finding gives added support for our conclusion that our methodology is a reasonable approximation for estimating lifetime risks at this site.*

PCrac-30

**2. The correction factor for high-LET radiation applied to the lifetime attributable risk (LAR) coefficient for bone cancer is incorrect, resulting in all bone cancer risks being a factor of 10 too high**. The dose coefficients used by ATSDR are committed equivalent doses – not absorbed doses. If absorbed doses were calculated by ATSDR, then the factor of 10 correction (RBE for bone cancer) would be applied to the absorbed dose from high-LET

radiation and not to the lifetime attributable risk values. Equivalent doses calculated by ATSDR already included the correction for high-LET radiation (RBE of 20), and thus the correction factor for bone was applied twice erroneously.

*ATSDR response: ATSDR agrees that the lifetime attributable risk coefficient for bone surface should not have been multiplied by 10. The results mentioned in the previous response to PCrac-30 incorporated this correction. We have updated risk tables and discussion in the report to reflect the updated risks. This change did not affect our overall conclusions.*

PCrac-31

**3. The lifetime attributable risk (LAR) values in Table E 7 are incorrect.** The lifetime attributable risk (LAR) values are presented in Tables E 6 and E 7 in the ATSDR report. The values in Table E 6 are correct and are reported to have come from EPA 2011 (Table 3-12c). The values in Table E 7 are stated to be what was used in the report, but they are incorrect. The values in Table E 6 are in units of cases per 10,000 person-gray. The values in Table E 7 are stated to be in units of cases per 10,000 person-rem. The values in Table E 7 should all be a factor of 100 less than the values in Table E 6 based on the reported units, but they are the same as Table E 6 with the exception of bone. As stated previously, the value for bone in Table E 7 is an additional factor of 10 higher. If these values were actually used in the calculation, then all risk values would be a factor of 100 too high (not accounting for the other methodological errors), and bone risks would be a factor of 1,000 too high.

*ATSDR response: In the public comment version of this report, the footnote in Table E7 stated that values were presented per 10,000 persons – rem. The values were actually per 10,000 persons – Sievert. This was a typographical error in the table and did not affect the accuracy of the calculations. The values in Table E7 have been corrected to be in the units per person – rem, and the bone cancer lifetime attributable risks in Table E7 have also been corrected in response to the previous comment. These changes did not affect our overall conclusions.*

**Additional Comments**

PCrac-32

**1. Lack of caveats about risk estimation and context raises public concern unnecessarily.** The ATSDR report fails to point out a number of issues related to radiogenic cancer risk or to put it in perspective. First, even given the (over) estimated organ doses there is no scientific evidence that has demonstrated an actual increase in these tumors at these organ doses. Rather, the risk that is presented is a hypothetical risk that is based on the LNT hypothesis. This means that it is assumed that risks observed at much higher doses can be extrapolated linearly to low doses, so that no matter how small the dose received it is assumed to be associated with a corresponding risk. That fact should be clearly pointed out and not hidden in the verbiage of using “EPA methodology”.

*ATSDR response: ATSDR used its own standard practices, as well as those of other agencies, in conducting this evaluation. Most regulatory and advisory agencies assume that every dose of radiation, no matter how small, incrementally increases the risk of developing cancer. We recognize that proving or measuring an increased risk to very low levels of radiation exposure would be very difficult since radiation exposure also occurs from the natural environment, consumer products, and useful medical procedures. Addressing the controversy of this theory is beyond the scope of our public health activities related to communities living near hazardous waste in the environment.*

PCrac-33

Second, the scientific evidence clearly shows a practical threshold for bone cancer at about 8 Gy (800 rad). Despite this, the EPA methodology assumes that LNT applies for bone cancers. The lack of scientific evidence to support this assumption deserves to be mentioned.
Third, the term "skin" cancer is incorrect and should be replaced with "non-melanoma" skin cancer. Similarly, the risks estimated for "leukemia" should be classified as "non-CLL" leukemias.
Fourth, the value given on page 19 of 0.385 for the lifetime risk in the general population of being diagnosed with any form of cancer needs to be qualified. This is because most skin cancers are never reported and registered.

*ATSDR response: Determination of a possible threshold for bone cancer is beyond the scope of ATSDR's public health activities related to communities living near hazardous waste in the environment. Please see EPA's 2011 Cancer Risk Projections report, the source of lifetime attributable risks used in this report, for a detailed discussion of bone cancer threshold issues [48]. The skin lifetime attributable risk coefficients published by EPA are noted to exclude nonfatal skin cancers, not non-melanomas, and this is indicated as a footnote in the section on skin cancer beginning on page 27. The lifetime attributable risk coefficients for leukemia published by EPA are not qualified. We have maintained similar language throughout our document. Cancer registry data cited in this document is of high quality, resulting from collaborative efforts of the Centers for Disease Control and Prevention, the National Cancer Institute, the North American Association of Central Cancer Registries (NAACCR), and the American Cancer Society to publish the Annual Report to the Nation on the Status of Cancer. The Missouri Cancer Registry has received a gold level certification from the NAACCR since 2005.*

PCrac-34

The ATSDR report should not list estimated lifetime risk of the different cancers from Coldwater Creek exposures without putting these risks into context. A 1/10000 risk of a radiation induced cancer means that it is very unlikely that any cancer identified was caused by radiation from environmental contamination. The spontaneous lifetime risk of these cancer should also be shown for comparison. If 1000 people were exposed to this level of contamination, it would be unlikely that even a single one of the 400 or so expected cancers would be caused by radiation

from environmental contamination. The ATSDR needs to do a much better job of putting this hypothetical risk into perspective. Similarly, the doses should be compared to lifetime natural background radiation and perhaps organ doses from a CT scan so that people can properly put the risk in perspective. The document should clearly mention that even at the overinflated estimated organ doses, if a person develops cancer, it is much more likely to be due to a cause other than Coldwater Creek radionuclides.

*ATSDR response: The section entitled "Increased Risk – What it Means" includes background and discussion about cancer risk assessment and comparison of what we considered "elevated' risk with U.S. overall lifetime cancer risks. In the text discussing each organ site where cancer risk was elevated, ATSDR included organ-specific U.S. cancer rates and discussed how the estimated increased risk from exposure compares. For this final version of the report, ATSDR has modified the risk summary tables (Tables 2 and 3) to include a column presenting those background rates.*

*ATSDR's evaluation cannot say whether or not any individual's cancer or other disease was due to exposure to contaminants from Coldwater Creek. In fact, determining a single cause of any disease is still very difficult, nearly impossible, even with rapidly increasing knowledge about mechanisms of disease.*

PCrac-35

**2. Medical Issues**

The recommendations in the ATSDR report correctly indicate that medical monitoring is not recommended and may well cause more harm than good. The issue of false positives is mentioned. What is not mentioned, however, is that for most cancers the spontaneous risk of occurrence is higher than that estimated in ATSDR's report and that screening for cancer is not recommended for most cancers because it is not effective. The United States Preventive Services Task Force (USPSTF) recommends cancer screening only for breast, cervical and perhaps colon cancer but not for bone cancer, leukemia, etc.

*ATSDR response: In the text discussing each organ site where cancer risk was elevated, ATSDR included organ-specific U.S. cancer rates and discussed how the estimated increased risk from exposure compares. Each section also includes a discussion of diagnosis, treatment, and screening options specific to that type of cancer. We cite U.S. Preventive Services Task Force recommendations for screening, if any exist.*

PCrac-36

A second issue is the recommendation that potentially exposed residents or former residents inform their physician of the possible exposure. There is no medical, scientific or logical basis for this. Such a recommendation will only serve to increase the unfounded concept that there is a measurable risk and that the risk requires something extra. It also will impart the idea that any cancer that develops was most likely due to this radiation source which is simply not the case.

*ATSDR response: Individual environmental and occupational exposure history is an important component of a person's medical history. A physician can provide patient-specific information to address both real and perceived risks and perhaps alleviate patient concerns about exposure.*

PCrac-37
Recommended Actions to Correct ATSDR's Report
ATSDR should recompute the radiation doses and risks using representative media concentrations, reasonable PEF values that reflect playing by Coldwater Creek, bicycle riding and gardening, and the correct methodology to compute risk from absorbed dose.

*ATSDR response: As detailed in earlier responses, ATSDR considers its exposure assumptions appropriate for this evaluation, and our methodology for estimating dose and resulting risk gave results comparable to that using the method suggested by the commenters. We have made some changes to our calculations based on comments received by multiple commenters and updated tables and discussion in the text correspondingly.*

PCrac-38
The conclusions associated with the corrected results should be updated accordingly.

*ATSDR response: The changes to the calculations did not affect our overall conclusions.*

PCrac-39
Each ATSDR recommendation should be justified on a scientific and economic basis. Currently, some of the recommendations seem politically and emotionally based. As a flagrant example, there is "…that the state consider updating analyses on cancer incidence, cancer mortality, and birth defects." There is absolutely no scientific basis for increased birth defects in humans at fetal doses of less than 100 mGy (10 rad) (see ICRP 2000, 2003; NCRP 1998) or from the radionuclides identified at Coldwater Creek. Such recommendations should be removed. Further, there is no justification for examining cancer incidence based on the calculated doses. The number of persons and the doses will not yield statistical power to reach any valid conclusion (see NRC 2012, 2014).

*ATSDR response: ATSDR makes recommendations to better characterize exposures, reduce harmful exposures, and address community concerns about exposures. As discussed in the report and illustrated in the public comments received from private citizens, the Coldwater Creek community is very concerned about perceived elevated cancer rates, perceived elevated rates of non-cancer diseases such as autoimmune diseases, and possible effects of their exposure on their children. This report established a link between potential past exposures and increased risk of certain types of cancer. Even though the estimated risk increases were small and unlikely to be observed in community-level statistics, we believe the community's concerns deserve investigation to the extent possible within established public health systems. Information from*

*such investigation may confirm current paradigms about biological effects of radiation or open avenues for further research.*

PCrac-40

Finally, ATSDR should provide perspective for the calculated doses and risks. This means including information about background radiation doses in the area, information about other sources of exposure that individuals receive on a regular basis (e.g. from airplane flights or medical procedures), and information about the spontaneous lifetime risk of cancer.

*ATSDR response: Normal background radiation is discussed on page 29 related to ATSDR's minimal risk level for ionizing radiation. The doses calculated in the report include doses contributed by background levels of Th-230, U-238, and Ra-226 in the Coldwater Creek area determined by EPA and FUSRAP. As discussed in table footnotes, ATSDR examined the contribution of these environmental background levels on the estimated risks; they did not contribute significantly to risk except for past exposure for skin cancer.*

*The section entitled "Increased Risk – What it Means" includes background and discussion about cancer risk assessment and comparison of what we considered "elevated' risk with U.S. overall lifetime cancer risks. In the text discussing each organ site where cancer risk was elevated, ATSDR included organ-specific U.S. cancer rates and discussed how the estimated increased risk from exposure compares. For this final version of the report, ATSDR has modified the risk summary tables (Tables 2 and 3) to include a column presenting those background rates.*

PCrac-41

*[The following references were provided by the commenter in support of the above comments.]*

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*ATSDR response: No response necessary.*

**PCscnfc – Comments from the Sierra Club Nuclear Free Campaign**

PCscnfc-1

Comment 1**:** It is essential that the Agency for Toxic Substances & Disease Registry (ATSDR) use consistent, unqualified language throughout the PHA -- especially with respect to its conclusions. For example, Conclusion 1 on page ii states in the last bullet point that "More recent exposures…increased the risk of developing bone or lung cancer from daily residential exposure." This clear, unambiguous statement of fact -- that nuclear waste contaminated the land and water where people lived and, therefore, increased their risk of cancer -- seems contradicted by the conditional language used in previous sentences. If ATSDR considers the Army Corps of Engineers' sampling data to be credible, and if the Formerly Utilized Sites Remedial Action Program (FUSRAP) deemed those residential areas in need of remediation, then ATSDR should be more straightforward with its language.

**Conclusion 1 should therefore state that "Radiological contamination in and around Coldwater Creek … increased the risk of some types of cancer in people who played and lived there." To make the first bullet under "Basis for Conclusion" consistent with the second bullet point, please change "may have been exposed" to "were exposed" and change "could increase" to "increased".**

*ATSDR response: Comment noted. We have added considerable discussion about the uncertainties involved in our evaluation in the final report and provided additional language indicating that the scenarios evaluated may not apply to all people who live or lived nearby.*

PCscnfc-2

Comment 2: As acknowledged later in the PHA, remediation (under FUSRAP) does not result in the removal of all contamination. Nor are people moved, under the program, away from areas that are remediated but still contaminated.

**It is unacceptable for an agency that ostensibly works toward disease control to perpetrate the myth that remediation eliminates contamination. Therefore, in the first sentence of Conclusion 1, please delete the phrase "prior to remediation activities".**

*ATSDR response: It is impossible to remove 100% of contamination and completely eliminate risk. Remediation is intended to reduce risk to acceptable levels, that is, reduce contaminant levels to levels that are unlikely to results in harmful effects given the current knowledge about a contaminant's effects. No change made.*

PCscnfc-3

Comment 3: The Sierra Club is encouraged by ATSDR's statement on page v. that the Agency is "evaluating the feasibility of conducting modeling to evaluate exposure to windblown dust from historical radiological waste storage piles". That program should move forward quickly and models should be developed that can be applied throughout the country where radioactive waste has been dumped on the ground and left uncovered and, therefore, subject to movement by wind and rain onto residential or recreational land, into surface water used for recreation,

irrigation or municipal drinking water, and into groundwater used for drinking water for people, pets & livestock. Active operations also produce radioactive waste that migrates offsite.

**Therefore, the ATSDR should broaden the scope of its modeling investigations to include operating nuclear-waste-producing sites to ensure that it accomplishes its mandate of disease control.**

*ATSDR response: The findings of this assessment cannot be directly applied to other sites. ATSDR does have a means for communities potentially affected by environmental contamination to petition the agency to do an evaluation. The website www.atsdr.cdc.gov/hac/petitionatsdrdchi.html contains information about ATSDR's petition process. ATSDR uses defined criteria when deciding whether to accept a petition request.*

PCscnfc-4

Comment 4: It's a hydrological certainty that sediments will move downstream – faster after heavy rains increase the creek's flow rate, and more slowly during droughts. Sediment is also known to collect in the elbows of the meanders of old rivers and streams.

**Therefore, on page 3, please edit the last sentence of paragraph 5 from "Contaminated sediments could flow downstream, settle…" to "When contaminated sediments flow downstream, they settle…".**

*ATSDR response: This statement is a general description of possible migration of contaminants from the site. We can think of some scenarios, such as when physical barriers are present, when contaminated sediments might not flow downstream to any appreciable extent. No change made.*

PCscnfc-5

Comment 5: City records are likely to contain the dates when municipal drinking water lines were extended to the Coldwater Creek area. Any residences that existed in that area prior to the extension of city water would have had to rely on wells or springs for their drinking water. Page 9 reports that the radioactive waste that Mallinckrodt generated has migrated to the unconfined surface aquifer and contaminated it.

**Therefore, every effort should be made to contact the families who consumed contaminated ground water and alert them of the findings of the Missouri Health Department and of ATSDR.**

*ATSDR response: Site groundwater sampling discussed in several historical reports suggests that groundwater affected by the sites did not migrate offsite. Without past sampling data from wells, there is no way to determine whether people's past drinking water wells contained contaminants or not. Only 3 domestic wells were identified in a three-mile radius around the former source areas, and all of those wells were abandoned prior to 1980.*

PCscnfc-6

Comment 6: Numerous water samples from the Nolichucky River upstream and downstream from Nuclear Fuel Services (NFS) in Erwin, Tennessee, as well as drinking water collected from home faucets in Jonesborough and Greeneville – because both cities have their water intakes on

the Nolichucky downstream from NFS -- have been analyzed for nuclear waste discharged by NFS. Using mass spectrometry, Chemist Dr. Michael Ketterer (whose expertise is in the migration of radioactive materials in the environment) is able to distinguish between naturally-occurring uranium in our surface and ground water from nuclear waste discharged and emitted by Nuclear Fuel Services. One of the ten water samples that were collected in Greenville, Tennessee on random days over the course of a month from a kitchen faucet that was not connected to any water softening or filtering equipment and that was served by the local municipal drinking water system, was found to have contained highly-enriched uranium with NFS's signature on it.

**If nuclear waste is known to contaminate a municipal water system with a water intake that's over 30 river miles downstream from the source, it seems unreasonable to assume that St. Louis' Mississippi River municipal water – the intake for which is only 5 miles downstream from the mouth of Coldwater Creek (p.7) – would not be contaminated with nuclear waste from the Mallinckrodt radioactive waste dumps. The quality of drinking water taken from rivers downstream from Coldwater Creek requires further analysis.**

*ATSDR response: All public water in the St. Louis area is treated, tested regularly, and in compliance with Safe Drinking Water Act regulations, including radionuclide limits.*

PCscnfc-7

Comment 7: Just as remediation under FUSRAP does not remove all of the contaminants from a site, the Safe Drinking Water Act allows a cocktail of radioactive toxins to remain in America's drinking water, even though some of the contaminants of our water supplies may cause synergistic effects. Also, the radionuclide limits do not provide for the elimination, by municipal water systems, of manmade contaminants like nuclear waste. In short, the Safe Drinking Water Act is a government construct that allows contamination to pollute our drinking water.

**It is unacceptable for an agency whose mission is disease control and prevention to perpetrate the myth that Safe Drinking Water Act radionuclide limits are fully protective of the public health. Therefore, please add the following to the sentence that ends at the top of page 9: "which do not eliminate nuclear waste in the public water supply".**

*ATSDR response: Safe Drinking Water Act limits on radionuclides are set at levels that are not expected to cause harm in people drinking or using the water. It is impossible to remove 100% of every potentially harmful substance and completely eliminate risk. All public water in the St. Louis area is treated, tested regularly, and in compliance with Safe Drinking Water Act regulations, including radionuclide limits.*

PCscnfc-8

Comment 8: ATSDR's own construct -- "minimal risk levels" (MRLs) -- give the reader the impression that concentrations of contaminants that are within ATSDR's MRLs are, without doubt, protective of the public's health. Minimal risk is not zero risk. Nor is there any dose greater than zero or any amount of radioactive material that is ingested by a person that does not increase an individual's risk of adverse health effects. Further, the discussion of minimal risk

levels contradicts ATSDR's statement on page 20: "ATSDR recognizes that all exposures contribute to the risk of cancer".

**Therefore, ATSDR should make clear that "minimal risk levels" are risks that Americans are forced to accept because their government will not require corporations (even those that claim to be able to control the atom) to close the loops on their processes. Throughout this PHA, please make it clear that all exposures to nuclear waste – whether internal or external – increase the risk of harmful health effects (including cancer) and the higher the dose and longer the exposure, the greater the risk.**

*ATSDR response: A minimal risk level is defined by ATSDR as "an estimate of the amount of a chemical a person can eat, drink, or breathe each day without a detectable risk to health" [143]. MRLs are based on epidemiological and toxicological studies and can be specified for different exposure durations. MRLs for most chemicals apply only to non-cancer effects; screening for possible cancer effects uses different procedures. The MRL for ionizing radiation, however, is based on background exposures to radiation that are not known to cause any adverse non-cancer or cancer effects. Thus, the MRL for ionizing radiation is considered applicable to both non-cancer and cancer endpoints.*

*While most regulatory and advisory agencies assume that every dose of radiation, no matter how small, incrementally increases the risk of developing cancer, proving or measuring an increased risk to very low levels of radiation exposure has proved very difficult since radiation exposure also occurs from the natural environment, consumer products, and useful medical procedures.*

PCscnfc-9

Comment 9**: Sierra Club supports the ATSDR's use of clear, straightforward language on p.11: "If the contaminants are radioactive, people may receive an external dose of radiation just from being near the contamination."**

*ATSDR response: Thank you for the comment. The potential for external exposures to be significant depends on the identity of the radioactive material, what type of radiation it emits, what materials are in between people and the radiation, how close people actually get to the radiation source, and how long they stay there.*

PCscnfc-10

Comment 10: On page 12, within the discussion of available data, ATSDR states that it "used these data to identify contaminants of concern". This statement implies that there were contaminants that did not rise to a level of concern.

**Please explain in the Public Health Assessment which contaminants were "of concern" and which were not, and why they were not.**

*ATSDR response: The information in Appendix B of the document described the screening process ATSDR used for both radiological and non-radiological contaminants, listing their measured levels in various environmental media at the site and how ATSDR determined which contaminants to retain for further evaluation.*

PCscnfc-11

Comment 11: Footnote 2 on page 13 states: "ATSDR evaluated only direct exposure to soils during gardening activities, not consumption of home garden products."

**After the Chernobyl disaster, governments throughout Europe banned the sale of certain agricultural products and livestock because of the uptake in their tissue of radionuclides that the explosion deposited onto pastures, croplands, and onto woodlands where mushrooms were collected. Those bans dramatically demonstrate that plants do incorporate radioactive contaminants into their tissues, though different species concentrate contaminants at different rates. Bioaccumulation of radionuclides happens.**

**The research of one physician who conducted extensive research in the Rivne region of the Ukraine should especially be explored by ATSDR before it finalizes the Public Health Assessment: Pediatrician Dr. Wladimir Wertelecki did extensive research on radiation exposure and congenital malformations, a disastrous and sometimes fatal health effect that has been ignored in this PHA. On March 12, 2013, Dr. Wertelecki gave a brilliant lecture in which he described the pathways through which radioactive contaminants could be ingested by consuming produce and by breathing smoke from wood-burning fires used for heating or cooking. Dr. Wertelecki's lecture on the teratogenic effects of chronic radiation exposure can be found here: www.youtube.com/watch?v=iMqZj2MnDSE.**

**Before ATSDR disregards the health impacts of consuming garden produce grown on contaminated land, please consider the data that Dr. Wertelecki and his colleagues generated and also his instruction that "prevention is first not epidemiology". So, for the purpose of disease control and prevention, ATSDR should advise women of childbearing age and children – two segments of the population most sensitive to radiation exposure – not to consume vegetables grown on contaminated soils.**

*ATSDR response: ATSDR was not able to evaluate consumption of garden produce due to a lack of data, not only on levels of contamination in garden produce, but also on levels of contamination in floodplain soils where gardens might exist. Although contamination has not been fully characterized, ATSDR provided advice to homeowners on ways they can avoid exposure to Coldwater Creek-related contaminants in our June 2016 fact sheet entitled "Preventing Potential Exposure – Coldwater Creek, North St. Louis County MO" [144]. Recommendations include using raised beds with clean soil for gardens and avoiding using creek water for watering gardens.*

PCscnfc-12

Comment 12: Page 14 states that "FUSRAP's remedial goal for Th-230 in soil" is "14-15 pCi/g", while "typical background levels" of Th-230 are "1 to 3 picocuries per gram (pCi/g) for soil and sediment".

**ATSDR must make it clear to the residents in the Coldwater Creek area that FUSRAP is allowing 5 to 15 times more Th-230 to remain in remediated soils than naturally occurs. Since ATSDR has identified Thorium-230 as one of "the substances most likely to result in harmful exposure", ATSDR needs to advise women and children especially on strategies for minimizing exposure to Th-230.**

*ATSDR response: We identified Th-230 as a contaminant of concern due to its frequent detection in environmental samples above both background and remedial goals. ATSDR provided advice to homeowners on ways they can minimize potential exposure to all Coldwater Creek-related contaminants, including Th-230, in our June 2016 fact sheet entitled "Preventing Potential Exposure – Coldwater Creek, North St. Louis County MO" (see link in previous page footnote). The remedial goal for Th-230, when achieved, is expected to reduce exposures to Th-230 and daughter products like Ra-226, to levels that will not be harmful to public health.*

PCscnfc-13

Comment 13: Figure 4 on page 15 depicts the Uranium-238 decay chain and shows that U-234 is a daughter product just like Th-230 and Ra-226.

**If U-234 is also present in the radioactive waste dumped by Mallinckrodt, why isn't U-234 also considered a "substance most likely to result in harmful exposure"?**

*ATSDR response: The residential soil and sediment data provided by FUSRAP to ATSDR did not include analyses for U-234. Appendix D of the 2003 Feasibility Study for the St. Louis North County Site contains a discussion of how FUSRAP considered long-lived radionuclides for which no data were available [6]. Page D-6 states, "Because the uranium was neither enriched nor depleted, uranium isotopes are assumed to be present in natural abundance (i.e., the ratios for U-238:U-235:U-234 = 1.0:0.046:1.0 by activity or 99.28%:0.711%:0.00555 by mass)." The remedial goal for U-238 was established using U-238 as a surrogate for all of the uranium isotopes (including U-234 and U-235).*

*In its evaluation, ATSDR did not estimate intakes, doses, or risks from U-234. This would cause the estimated doses and risks to be underestimated. The underestimation would be very small, however, about 1% or less. This is because Th-230 was the main contributor to dose and risk.*

PCscnfc-14

Comment 14: Table 1 on page 18 compares "Past Exposure Point Concentration" with "Recent Exposure Point Concentration" for Th-230, Ra-226 and U-238 in soil, sediment and surface water. Th-230 concentration in soil fell by half and by nearly 100% in sediment. On the other hand, past and recent concentrations of Th-230 in surface water remained the same.

**What accounted for the dramatic drop in soil and sediment concentrations of Th-230? Was it because "radiation has legs", as Dr. Wertelecki says in his lecture? If so, where downstream and downwind is this nuclear waste now? Are downstream and downwind communities being monitored? Also, why was there no change in the concentration of Th-230 in surface water?**

*ATSDR response: Sediment concentrations in Coldwater Creek did decrease between sampling events in the late 1980s and 2014-2016. This is expected as sediments are dispersed both through downstream flow and flood events. Between the 1980s and 2014, additional stabilization and removal of the waste piles resulted in less material entering the creek. Portions of the creek*

*have also been remediated. As described in the PHA, the soil data collected more recently was used to estimate past surface soil contaminant concentrations, for which no data exist. Contaminant concentrations in deeper soil were often higher than those measured at the ground surface. We assumed that contamination found below the ground surface was once at the surface and available for contact/exposure. The available data for surface water in residential stretches of the creek never showed Th-230 at levels above background; this is not surprising, since Th-230 is associated with creek sediment and therefore is not expected to be dissolved in water to any appreciable extent. We assumed the same Th-230 surface water concentrations (equal to background) for both past and present timeframes.*

PCscnfc-15

Comment 15: The footnote for Table 1 on p.18, identified by a cross, uses a confusing term: "background criteria". That footnote then references an Army Corps of Engineers Feasibility Study.

**The US Geological Survey measured terrestrial radioactivity and gamma-ray exposure from 1999 to 2005 and makes actual background radiation data publicly available. See mrdata.usgs.gov/metadata/narad.faq.html. Why has ATSDR substituted what seems to be a term of art developed for FUSRAP ("background criteria") for USGS's actual measurements of background radiation? Are FUSRAP's "background criteria" greater than, less than, or equal to actual background radiation in the St. Louis area?**

*ATSDR response: Although useful for informational purposes, the referenced USGS map shows results of aerial surveys of gamma ray emissions from surface rocks or soils and does not give detailed information on the specific contaminants of concern in the exact locations of interest around Coldwater Creek to allow for screening of site contaminants. Collecting site-specific background samples is a standard part of the remedial investigation process. The 2003 feasibility study described the locations of samples and results used to develop site-specific background criteria for various site contaminants possibly associated with the site [6].*

PCscnfc-16

Comment 16: **Sierra Club supports ATSDR's clear statement of fact on page 20: "ATSDR recognizes that all exposures contribute to the risk of cancer".**

*ATSDR response: Comment noted.*

PCscnfc-17

Comment 17: On page 20, ATSDR hints that, like FUSRAP, the EPA has constructed a set of allowable limits for Superfund Site cleanups and permits those hazardous area to still threaten the health of exposed communities with a "'target range' for managing risks" of "1 in 10,000" to 1 in 1,000,000".

**For the sake of public health protection and disease control, ATSDR needs to make it plain to the Coldwater Creek community – as well as other communities like Erwin, TN that have their health attacked daily by the nuclear fuel manufacturer Nuclear Fuel Services (NFS) which routinely pours into the air and water Am-241, Cs-137, Na-22, Pb-**

**212, Pu-238, Pu-239/240, Pu-241, Ra-224, Tc-99Th-238, Th-232, U-233, U-234, U-235, in addition to the radionuclides of most concern to the ATSDR in the Coldwater Creek PHA: Th-230 & U-238 – that they are still being exposed to radioactive waste, that EPA's "target range" is not fully protective of their health, and, therefore, they continue to have a higher cancer risk than people living in areas that are not contaminated with nuclear waste.**

*ATSDR response: This PHA was specific to Coldwater Creek and should not be used to represent potential exposure at other sites. Preventing or eliminating all risk is impossible. Risk assessment methods developed by regulatory and advisory agencies are intended to help determine protective yet achievable and reasonable cleanup goals and exposure limits that will enable appropriate management of risks from operating or contaminated sites in the context of other risks present in our environment.*

PCscnfc-18

Comment 18: ATSDR introduces ambiguity within four sentences on page 20 by, at first, stating that all exposures increase risk of cancer and then qualifying that statement in the first line of the Results and Discussion section of the PHA.

**Consistency is imperative if the goal of ATSDR is to educate the community on their health risks. Therefore, please change "may have had an increased risk of several types of cancer" and insert "have an elevated risk of several types of cancer" and also insert "contaminated" before "soil, sediment, and surface water". These edits will make the first paragraph consistent with the second paragraph, and with Table 2.**

*ATSDR response: ATSDR used a conservative approach due to the uncertainty in many aspects of this evaluation. We have added language emphasizing uncertainty throughout the report. We have also reworded conclusions and recommendations to consistently reflect the uncertain nature of the estimates and evaluation.*

PCscnfc-19

Comment 19: The footnotes to Table 2 on p.21 state that ATSDR included background radiation levels of Th-230, Ra-226 & U-238 in its estimates of "committed radiological dose". But then the footnote states that "Subtracting background levels reduced all breast cancer risks to below 1 in 10,000".

**In order to estimate total radiation exposure, it is appropriate to add to naturally-occurring radiation the extraordinary, unnatural mix of radionuclides which emanate from manmade contaminants. This extra burden of radiation creates a public health hazard because it overwhelms a healthy body's ability to repair damage caused by radiation. Why, then, did ATSDR subtract background radiation from its estimates of total doses instead of subtracting the radiation burden caused by Mallinckrodt? Elimination of this sentence would avoid confusion.**

*ATSDR response: ATSDR examined the contribution of background levels of Th-230, Ra-226, and U-238 in the environment around Coldwater Creek by subtracting them from our dose and risk estimates. In most cases the contribution to risk from these background levels was very small*

*compared to the risk from the contamination. ATSDR did not consider normal background radiation (such as from cosmic rays, consumer products, and medical procedures) in its estimates because we wanted to estimate the risk caused by specific exposures to Coldwater Creek contaminants.*

PCscnfc-20

Comment 20: The last sentence on page 21 assumes dust and runoff control during "the process of cleanup", and that residents are banned from contaminated areas.

**Is the Coldwater Creek community assured that FUSRAP has contained the contamination so that it is no longer spread by wind and rain? Is the community barred from contaminated areas, including the creek? Is there signage, homemade or official?**

*ATSDR response: ATSDR observed signage and barriers for locations in the process of active removals along the creek during its 2015 site visit, and FUSRAP has stated that its cleanup procedures include dust control measures. For stretches of the creek that have not been investigated yet, ATSDR has recommended signage to alert the public to the possibility of exposure.*

PCscnfc-21

Comment 21: The organs that are most susceptible to damage from the radiation emitted by nuclear waste dumped by Mallinckrodt are listed in Table 2 on page 21 as Bone Surface, Lungs, Red Marrow, Skin & Breast. The susceptible organs listed in Table 3, p.22 include Bone Surface and Lungs. In both tables, ATSDR includes only cancers with "elevated risk" -- above 1 out of 10,000 (EPA's criteria). Neither table attempts to distinguish childhood exposures to ionizing radiation from adult exposures, despite the fact that ATSDR had noted on page 5 that the Missouri Department of Health confirmed one case of childhood leukemia on Nyflot Avenue, "the residential street closest to HISS…"

Research performed by biologist Mary Olson, using data from the U.S. National Academy of Science's Biological Effects of Ionizing Radiation, BEIR VII, Phase 2 (2006: http://www.nap.edu/openbook.php?isbn=030909156X), strongly indicates that the impact of radiation exposure on women and girls is 50-100% higher for females than for men and boys. (See https://www.nirs.org/wp-content/uploads/2016/07/movtalkfin1214.pdf ) Further, the research of Wertelecki & of Olson has also found that radiation exposure has a far greater health impact on fetuses and on children than the same exposure does on adults.

**Therefore, for the sake of cancer prevention, ATSDR should acknowledge this research in this Public Health Assessment by clearly stating throughout that the only safe dose from nuclear waste is zero, that none of the risks listed in Table 2 & 3 are zero, and that families need to be especially careful to protect pregnant women and children from radioactive contamination even if their government declares that a nuclear waste dump is clean enough.**

*ATSDR response: ATSDR's dose and risk calculations accounted for age at exposure by using age-specific exposure parameters, internal dose coefficients, and lifetime attributable risk*

*coefficients. We assumed that residents would be exposed for 33 years beginning at birth. The doses and risks listed in the tables reflect the values for this entire period of exposure.*

PCscnfc-22

Comment 22: The Missouri Department of Health & Senior Services (MDHSS) compared bone cancer incidence – a very rare disease affecting 0.1% of the US population -- in the Coldwater Creek area to statewide incidence and ATSDR estimated that past exposures to nuclear waste increased bone cancer risk by 2 to 4 times. (p.23)

**The second sentence on page 23 would make more sense if "past risks" was changed to "past exposures".**

*ATSDR response: The statement is intended to compare the exposure-specific risks estimated in this report with the "background" risk of this type of cancer in the U.S. population, to give perspective on how large an effect this exposure may actually have and to illustrate why it would be difficult to detect the increased risk in actual cases through an epidemiological study. Therefore, no change was made.*

PCscnfc-23

Comment 23: Regarding bone cancer incidence and lung cancer incidence in the Coldwater Creek area, MDHSS found that the rate there was not significantly higher than in the rest of the state. But ATSDR suggests that the people studied may not have been the same residents who were "most highly exposed". (p.23)

**ATSDR is justified in offering this qualification because cancer patients might seek treatment in other cities where they have relatives to care for them or may leave the area on advice of their physicians. Sierra's grassroots activists have reported that they know of at least two instances when a doctor's medical advice was to move. In one case, it was the family of a girl with brain cancer who was told to move away from the Dresden & Braidwood nuclear power plants. The other case involved a woman with thyroid cancer who was advised by her physician to move out of Erwin, TN if she wanted to ever get better.**

*ATSDR response: Comment noted.*

PCscnfc-24

Comment 24: MDHSS did find a statistically-significant elevation in leukemia, female breast cancer, and colon cancer in the Coldwater Creek area compared to the rest of Missouri. ATSDR noted that "routine blood tests may identify leukemia before a patient has symptoms, because the disease causes changes in the levels and ratios of red blood cells, white blood cells, and platelets". ATSDR did not recommend any special or additional screening for leukemia (p.26), for breast cancer (p.28), or for colon cancer (p.29).

**The last sentence on page 25 would make more sense if "past risks" was changed to "past exposures".**

**If the Missouri Health Department found that leukemia incidence in Coldwater Creek was significantly higher than in the rest of the state, and if leukemia can be**

**diagnosed through "routine blood tests", why doesn't ATSDR recommend additional screening? Doesn't early detection of cancer increase cure rates?**

*ATSDR response: ATSDR recommends potentially exposed residents share their potential exposure related to Coldwater Creek with their physicians as part of their medical history and consult their physicians promptly if new or unusual symptoms develop. A personal physician will use a patient's individual history, symptoms, age, and gender to determine appropriate screening and diagnostic testing. Most physicians order routine bloodwork during regular wellness exams.*

PCscnfc-25

Comment 25: Page 28 of the PHA states that the "community reported a concern about perceived elevated rates of appendix cancers in the area, with some cases occurring in people who played in or near Coldwater Creek while growing up."

**When a disease is so rare that it occurs in fewer than 10 in a million people and when a cancer is so odd that no one has ever heard of it, residents of that community are fully justified in their concern. And if some were alarmed it might be because they, like Sierra Club's grassroots activists, are aware of appendix cancer cases in other communities that have been contaminated with nuclear waste: a Pennsylvania woman who lives near NUMEC's former high-enriched uranium & plutonium processing operations and a Tennessee woman who lives between Aerojet Ordnance's depleted uranium weapons plant in Jonesborough and Nuclear Fuel Services' high-enriched reactor fuel manufacturing operations in Erwin.**

**Therefore, not only does ATSDR need to investigate more fully the case or cases of appendix cancer in the Coldwater Creek area, it also needs to map appendix-cancer incidence nationwide and assess whether this extremely rare disease occurs where nuclear operations have caused radioactive contamination of the environment. Studying the relationship between radiation and appendix cancer would be fully justified especially in light of the reported rise in incidence of this "rare and potentially aggressive malignancy". (Reference 68)**

*ATSDR response: ATSDR is unable to study the relationship of appendix cancer, or other diseases, with radiation exposure because current methods cannot measure a person's past exposure to contaminants specific to Coldwater Creek. Without individual exposure data to link with cases, the correlation between radiation exposure/dose and appendix cancer cannot be studied.*

*Cancer registries only record the address at diagnosis. Due to the latency of most cancers and the generally mobile nature of the U.S. population, it would be difficult to draw conclusions about possible exposures from a national map of appendix cancer cases. We support the idea of general research on appendix cancer causes, early detection, and treatment and hope to use findings of such research to improve future assessments.*

PCscnfc-26

Comment 26: Starting on page 29, ATSDR compares its "minimal risk level" (MRL) of 100 mrem per year of chronic exposure to radiation above background with the estimates of whole-body radiological doses for residential and recreational exposures at Coldwater Creek. And, footnote 5 on p.30, ATSDR argues that the "MRL remains protective because it is a fraction of the annual average U.S. effective dose".

**Any dose of radiation greater than natural background increases cancer risk. ATSDR stated as much very clearly on page 20: "ATSDR recognizes that all exposures contribute to the risk of cancer". Therefore, if all exposures above background contribute to the risk of cancer, how can any MRL that is not zero be "protective"? What is the purpose of comparing recreational & residential estimated doses to ATSDR's construct? So long as the public received any dose greater than zero from nuclear waste, that exposure increased their risk of cancer.**

*ATSDR response: The MRL for ionizing radiation is based on background exposures to radiation that are not known to cause any adverse non-cancer or cancer effects. Thus, the MRL for ionizing radiation is considered applicable to both non-cancer and cancer endpoints.*

*While most regulatory and advisory agencies assume that every dose of radiation, no matter how small, incrementally increases the risk of developing cancer, proving or measuring an increased risk to very low levels of radiation exposure has proved very difficult since radiation exposure also occurs from the natural environment, consumer products, and useful medical procedures.*

PCscnfc-27

Comment 27: Footnote 5 on page 30 reports that the public is receiving an estimated average annual effective dose equivalent of 620 mrem due, in large part, to "increased doses from medical diagnostic procedures".

**While some patients understand that the diagnostic procedures prescribed for them involve exposure to radiation (and, therefore, increased cancer risk), too many others do not. If patients don't know because the prescribing doctors fail to inform them of the procedures' risks, then public education is necessary. The ATSDR should undertake such a public education campaign to bring that 72% increase in medical radiation exposure down. If ATSDR believes that its 100 mrem MRL is protective of health, then it should be raising alarms with the medical establishment that is exposing patients to 2.6 times its minimal risk level.**

*ATSDR response: A person's personal physician will use a patient's individual history, symptoms, age, and gender to determine appropriate screening and diagnostic testing. In many cases, risks from diagnostic, screening, or treatment procedures involving radiation exposure are greatly outweighed by the benefits of detecting or treating a condition that would undoubtedly harm a patient's health if left unchecked.*

PCscnfc-28

Comment 28: **On page 31, under the heading "Summary of Findings", the second bullet point regarding Residential Exposures included bone cancer twice. Further, in the interest of straightforward consistency, "could have resulted in" should be deleted so that each of the bullet points state that the exposures "elevated risks".**

*ATSDR response: The summary of findings section has been updated to reflect current findings. ATSDR used a conservative approach due to uncertainty in many aspects of this evaluation. Therefore, ATSDR reworded statements so they all have qualifying language such as "could have."*

PCscnfc-29

Comment 29: On page 31, ATSDR categorically states that recent recreational exposures "did not result in elevated estimated cancer risks".

**It is inexcusable for agency charged with disease control and prevention to lull the public into a false sense of security with respect to recreational exposures along Coldwater Creek. Additionally, ATSDR's categorical statement contradicts its data in Table 1, p.18 which presents estimates of picocurie/liter "exposure point concentrations" which are identical for surface water in the past and in recent years. The language in this bullet seems tortured. Therefore, in the first bullet point on page 32, please substitute "resulted in slightly-elevated cancer risks" for the phrase "did not result in elevated estimated cancer risks".**

*ATSDR response: According to the criteria set forth in the report and the dose and risk estimates detailed within, recreational exposures in recent years did not result in elevated estimated cancer risks.*

PCscnfc-30

Comment 30: **The third bullet point on p. 32 is taken out of context and should, therefore, be deleted. In animal studies where the radiation dose that is administered is (or should be) known, the dose may or may not be higher than in Coldwater Creek because radiation measurements were not taken in the past. Instead, ATSDR is only now making educated guesses about past exposures.**

*ATSDR response: Several epidemiological studies, referenced in the body of the ATSDR report, report the radiological doses associated with specific cancers and other harmful effects. The doses estimated conservatively in this report were orders of magnitude lower than doses that caused these harmful effects. Although historical data were not available from residential stretches of Coldwater Creek, based on limited historical data from the former source areas we consider it very unlikely that past exposure doses approached those reported in epidemiological studies.*

PCscnfc-31

Comment 31: **The last bullet point on p.32 is awkwardly stated. Please change it to state how much uncertainty there really is about ingested uranium: "Non-radiological kidney effects from ingesting uranium contaminants in soil may manifest in the future due to the toxicity of the uranium metal".**

*ATSDR response: ATSDR's evaluation is designed to allow us to determine whether adverse health effects are likely. We found that ingestion of uranium at levels estimated conservatively in this report would not pose any concern for non-radiological kidney effects.*

PCscnfc-32

Comment 32: On page 36, ATSDR states that groundwater "in the surface aquifers at both HISS and SLAPS has shown elevated levels of total uranium compared to background".

**Surely, the flow of groundwater in North St. Louis County has been observed &/or modeled for the purpose of assuring the local water authority that the municipal water that it is distributing is healthful. Therefore, it should be possible to at least estimate whether drinking water wells in the Coldwater Creek area could have exposed well users to contaminants originating in HISS & SLAPS.**

*ATSDR response: The assessment contains a description of public drinking water in the St. Louis area beginning on page 7. Surface water is the source for public water supplies in the metropolitan St. Louis area. Drinking water intakes are miles away from Coldwater Creek. All public water is treated and in compliance with Safe Drinking Water Act regulations, including radionuclide limits.*

PCscnfc-33

Comment 33: **Sierra Club supports ATSDR's admission on p. 38 that there is "uncertainty in past exposure estimates".**

*ATSDR response: Comment noted.*

PCscnfc-34

Comment 34: Page 42 lists ATSDR's recommendations.

**Omitted from the recommendations is a prohibition on the use of sediment, gravel or sand from Coldwater Creek for construction or fill. This should be done to prevent the manmade spread of contamination.**

*ATSDR response: ATSDR is not aware of any use of these materials today; residents told us that in the past, while the area was being developed, materials from the creek were removed and used elsewhere. We recommend known areas where Coldwater Creek materials were used be tested for radiological contamination.*

PCscnfc-35

Comment 35: "Signs to inform…of potential exposure risks in areas around Coldwater Creek not yet investigated or remediated" are included in ATSDR's recommendations.

**Official signage should make it clear that Coldwater Creek is a public health hazard and should not be accessed by people or their pets.**


**This homemade sign in a plastic sheet protector was found in 2010 stapled to a wooden fence along the Linear Trail which is downstream and downhill from Nuclear Fuel Services in Erwin, TN. No official signage warns trail users that the water is contaminated with nuclear waste from NFS. Missouri officials must do a better job of protecting the Coldwater Creek community from surface water that is a public health hazard.**

*ATSDR response: ATSDR recommended signs warning of the potential for exposure be placed in areas along Coldwater Creek that have not yet been investigated or cleaned up. Until those areas are characterized there is no way to make a determination whether exposures there may be harmful or not.*

**PCecan – Comments from the Erwin Citizens Awareness Network, Inc.**

PCecan-1

On August 7, 2018, the CBS Morning News headline "For the first time, federal health officials agree radioactive waste may be linked to cancer." Never in our lifetime did we ever expect to hear those words – and even more surprising to know they came from federal officials at the Agency for Toxic Substances and Disease Registry (ATSDR). Congratulations to the community of Coldwater Creek for making this second public health assessment happen.

To the best of our knowledge, it is the first time that ATSDR, or any other federal agency, has agreed that radioactive waste and cancer may be linked. Finally!

Although the Coldwater Creek Public Health Assessment (PHA) contains maybe's, could have's and may have's, it is still good compared to many other ATSDR PHAs, and likely validates what the community has already known, or at least suspected, for years. Similar PHAs could certainly apply to many communities near nuclear facilities, nuclear waste processing facilities, and nuclear waste storage sites.

*ATSDR response: Public health assessments are site-specific documents. Conclusions of the Coldwater Creek PHA reflect estimated site-specific past and present recreational and residential exposures to contaminants specific to Coldwater Creek and its floodplain and cannot be extrapolated to other sites.*

PCecan-2

ATSDR must have changed significantly since the March 2009 Congressional Hearings when then Tennessee Congressman Bart Gordon said "Unfortunately, ATSDR seems to be the gang that can't shoot straight. They come into local communities, often ignore the health complaints of local citizens, seem to ignore obvious ways to determine what might be happening, and more often than not go away saying there is nothing to worry about because they couldn't find anything." (Perhaps much like the previous Indeterminant Public Health Hazard in the 1994 Public Health Assessment of SLAPS/HISS).

*ATSDR response: Conclusions of the 1994 PHA for the St. Louis Airport Site / Hazelwood Interim Storage Site were based on environmental data available at the time. In the early 1990s, insufficient data existed to estimate past exposures on the sites or to estimate past or current exposures at off-site areas.*

PCecan-3

In May 2007, ATSDR conducted a Public Health Assessment of Nuclear Fuel Services, Inc. (NFS) for the community of Erwin, Tennessee. The result was also an Indeterminant Public Health Hazard in the past and No Apparent Public Health Hazard for the present and future. Dr. Paul Charp, obviously a predictor of the future and one of the same authors of the Coldwater Creek PHA, told the Erwin community that the attorneys would not allow him to include radionuclides, so the PHA considered only Volatile Organic Compounds. That's pretty interesting considering working with radionuclides and chemicals is the only thing NFS has done for 66 years making fuel for the Navy and nuclear reactors – radionuclides such as: Th-228, Th-230, Th-232, U-234, U-235/236, U-238, Pu-238, Pu-239/240, Pu-241, Tc-99, Am-241 -- to name a few. The PHA we received in no way accurately reflected the public's exposure in our community.

*ATSDR response: This comment is mostly unrelated to the Coldwater Creek evaluation. The St. Louis Airport Site and Hazelwood Interim Storage Site (sites that contributed to contamination of Coldwater Creek) were added to the National Priorities List (Superfund) in 1989; therefore, ATSDR is mandated to evaluate exposures there.*

PCecan-4

In the Coldwater Creek Public Health Assessment, we were particularly struck by the statement: "If the contaminants are radioactive, people may receive an external dose of radiation just from being near the contamination." (Page 11). This is a stunning statement, and one that could likely apply to many communities near nuclear facilities and nuclear waste sites. We hope they are reading this PHA.

*ATSDR response: The quoted statement is a general description of the potential for external radiation exposure. The potential for external exposures to be significant depends on the identity of the radioactive material, what type of radiation it emits, what materials are in between people and the radiation, how close people actually get to the radiation source, and how long they stay there.*

PCecan-5

The National Academies of Science likely already knew that nuclear facilities/activities and nuclear waste were linked to cancer when they selected these six active nuclear facility sites for the proposed Cancer Risk Pilot Study: (Nuclear Fuel Services (BWXT), Erwin, TN; Oyster Creek, NJ; Big Rock Point, MI; Dresden, IL; Millstone, Haddam Neck, CT; San Onofre, CA). The study was finally quashed by the Nuclear Regulatory Commission (NRC). Not surprising given all of their cover-ups over the years.

*ATSDR response: This comment is not related to the Coldwater Creek evaluation. No response required.*

PCecan-6

From what we read in the Coldwater Creek PHA, we wholeheartedly agree with the following statements because many of them actually make sense:

''Both recreational and residential exposures could have resulted in developing certain kinds of cancer, or in elevated risks for developing certain cancers." (page 11). (This is probably true for many communities near nuclear/nuclear waste facilities).

"People playing or living downstream of the source areas near Coldwater Creek (now or in the past) may have been exposed to contaminants that washed down the creek. They could take contaminants into their bodies by accidently swallowing small amounts of sediment, water, or soil. They could also breathe in contaminants if their activities suspend enough dust from dry, contaminated soil." (Page 10). (This would be particularly applicable to children).

"Organs in the body may also receive an external dose from isotopes outside the body." (Page 18)

"That every dose of radiation, no matter how small, incrementally increases the risk of developing cancer." (page 19)

*ATSDR response: Conclusions in the PHA reflect the site-specific exposures estimated and evaluated in the report and only pertain to Coldwater Creek areas. ATSDR notes that some of the above statements are taken out of context or reworded from the report. They should not be taken as ATSDR's general, official position. For example, the description of how people could take in contaminants that washed down the creek is only a general description. ATSDR's estimation and evaluation of recreational and residential exposures at Coldwater Creek leads to our conclusions about the potential effect of those exposures on the community's public health. The final quote omits the introductory language indicating that this statement is not a universally accepted fact, i.e., "However, most regulatory and advisory agencies assume every dose of radiation, no matter how small, incrementally increases the risk of developing cancer."*

PCecan-7

We agree with the community concern about elevated rates of Appendix Cancer, which is very rare, and believe further study should be done to see if this type of rare cancer is related to radiation exposure. (Page 28)

*ATSDR response: ATSDR is unable to study the relationship of appendix cancer, or other diseases, with radiation exposure because current methods cannot measure a person's past exposure to contaminants specific to Coldwater Creek. Without individual exposure data to link with cases, the correlation between radiation exposure/dose and appendix cancer cannot be studied. We support the idea of general research on appendix cancer causes, early detection, and treatment and hope to use findings of such research to improve future assessments.*

PCecan-8

We believe the concerns of the community are valid regarding vegetables, gardens, and sod grown on the floodplain and watered by the creek. The PHA states that ATSDR recognizes that contact with products grown in these areas could have indirectly exposed people to contaminants accumulated on the surface or within. Some areas of the floodplain have elevated levels of Th-230. Various food species do take up radiological contaminants from soil, particular in the roots, although not much research is specific to Th-230. Predicting uptake of radiological contaminants is difficult because it depends on the plant or animal species, the radiological isotope, and specific soil characteristics (Page 35).

Regarding plants and radiation, we were told by a physics professor that the Spiderwort (Tradescantia) plant is a good measure of ionizing radiation. The cells of the stamen hairs of Spiderwort plants are colored blue, but when exposed to sources of ionizing radiation, such as gamma rays, the cells mutate and change color to pink. They are one of the few tissues known to serve as an effective bioassay for ambient radiation levels. (He cited a news article from the Augusta Georgia Sentinel, May 4, 2012, which further referenced a 1949 article in the Bulletin of Atomic Scientists and more recently four papers authored at the prestigious Brookhaven National Laboratory in Long Island, N.Y.)

We also believe the community concerns are valid regarding dairy cows that have been raised in the floodplain and provided creek water to drink. (Pages 13,34,35). Would certainly suggest the milk from those cows be tested. It is our understanding that in the 1970's milk studies regarding

radiation were conducted in some states; perhaps Missouri was one of them. The community could check with their State Dept. of Health. Additionally, if fish from the creek are consumed, they should also be tested, although, we understand from experts who have done testing for our community that radiation is generally found to be concentrated in the fish bones.

*ATSDR response: Crops and dairy agriculture were raised as concerns based on past practices. To our knowledge, these activities no longer occur in the Coldwater Creek floodplain or nearby. A lack of data and detailed, specific information on past agricultural practices prevents ATSDR from performing further evaluation of possible past exposures from these exposure routes.*

PCecan-9

We believe more information and testing could have been done on the use of private wells in the area, or any wells used in the area, especially since the assessment states that "private wells may have been used for 30 years before these finding." (Pages 9,35,36).

*ATSDR response: Only three private domestic wells were identified in a 1987-88 well survey of the area, and all of those wells had been taken out of operation before 1980. No data exist on the use or water quality of these wells. Even if any of these wells could still be sampled, taking a sample of water from the well today would not provide information representative of contaminants users may have been exposed to when the wells were in use.*

PCecan-10

This PHA should now set a precedent and empower many other communities who have the same or similar exposures to radioactive materials and radioactive waste, such as the three major Contaminants of Concern in this PHA found to be above background levels at Coldwater Creek: Thorium-230, Radium-226 and Uranium-238. (These three radionuclides taken up into the bloodstream are known to build up on bone surface and may be incorporated into the bone matrix, affecting the red marrow. This may contribute to the risk of leukemia (Pages 22&25). Inhaled thorium, radium and uranium may stay in the lungs (Page 24).

*ATSDR response: The findings of this assessment cannot be directly applied to other sites. ATSDR does have a means for communities potentially affected by environmental contamination to petition the agency to do an evaluation. Please see www.atsdr.cdc.gov/hac/petitionatsdrdchi.html for more information on ATSDR's petition process.*

PCecan-11

We were especially touched by a comment from a member of the community in the news interviews, who said "If I would've known I could've done something and left," and "We didn't know or we wouldn't have bought this house."

Perhaps the ATSDR assessment of 1994 should have reflected what this assessment did. The public always has a right to know about this or any contamination and their exposure to it – and

they should know immediately – not 25 years later. If they have information, they can make choices, and these choices may affect their lives, and the lives of their families forever.

*ATSDR response: Data were not available in 1994 to perform the type of evaluation this report described. This assessment relied on data collected by the Army Corps of Engineers' FUSRAP program in Coldwater Creek and its floodplain downstream of the former source areas of SLAPS and HISS. FUSRAP began collecting these data in October 2012.*

**Comments from private citizens – personally identifiable information (PII) removed**

The following comments from private citizens are shown below, in the order they were received. *No ATSDR responses are included in this section.* Because many comments contained similar concerns, suggestions, and information, we combined and summarized concerns for inclusion in the response section above. Individual comments are included here for transparency. Many comments contained personally identifiable information which has been removed by ATSDR Coldwater Creek Site Team staff; deletions and insertions by ATSDR are indicated in a different font in brackets. Some obvious typographical errors were also corrected and are not marked. Handwritten and other hard copy comments that could not be transcribed into this format are summarized herein.

Sent 6/18/18
We moved from [PII removed] in 2006 and did not receive a survey. Our household had appendix carcinoid tumor 2006 in a child, and a brain tumor resulting in death in 1995 in a 61 year old. I responded to the survey today. But the news also said to email to have additions to the report.

We also had a few other odd illnesses in the house that are likely unrelated: rapid bone aging, oral allergy syndrome, severe asthma (till 3 months after moving) and unusual learning disability in one child born there in 1995. I had thyroid nodules causing rapid fluctuation in hormones, severe osteopenia in mid 40s, and am seeing an immunologist for IGg levels a hair above limit for insurance to give infusions unless I continue getting sick too frequently after prevnar 23 and 13 showed only minimal improvement.

Sent 6/19/18
What is considered living along the creek? I have lived in the area my whole life and I live near the creek now it is not in my back yard as a matter of fact there are some condos between me and the creek. Is this too close now or is the creek safe now?

Sent 6/20/18
First thank you very much for the report and making it available on-line. I've read through most of it. I need to go back and read it again more carefully. I intent to be at the Q&A session. I am sure there will be a lot of questions with some emotion. I therefore want to be sure to bring forth one concern about where fill ended up in a focused manner.
My concern is with the newer neighborhood at the end of Jana Dr, in front of Jana Elementary. It is my understanding those newer houses were built on fill at about 1990. The fill came from the field directly behind the houses on the Cold Water Creek side. That area of the field is/was in the Cold Water Creek flood plain. Currently your map with highlighted area of concern does not include that neighborhood, at the end of Jana. As a point of reference the

neighborhood was bordered by a tributary of Cold Water Creek and Cold Water Creek as shown in the red circle below.

My reference for this is in the fact my wife and I built, as new construction, the house at [PII removed] in 1992. We followed the neighborhood as it was being built from the beginning and saw what was done (removing the fill and placing it to make the neighborhood. This explains why the field dips and is below the grade along the creek). My hopes are for this to be recognized and brought to the appropriate authorities so that testing can be conducted. How can this be confirmed and who would address this?
And if the information is being collected; [PII removed concerning melanoma incidence].

Thank you very much for your time!

Delivered to ATSDR 6/26/18
Three pages of handwritten comments and 56 pages of printouts from various websites and research articles related to appendix cancer. Notes that on page 41, rate is listed as 0.97 per 100,000 and from 2000 to 2009 thee was 54% increase. Notes that the NORD report listed 1 or 2 per million; same report contradicts itself (0.15/0.09 per 100,000) due to a different cancer cell. States that ATSDR reviewed the wrong reports (ATSDR reviewed before 2009; CWC is 2011 to now).

Sent 7/1/18
My name is [PII removed], and I am a former resident of Florissant from the 1980's to the early 2000's.
I grew up in the Wedgewood neighborhood just a couple of houses up from Coldwater Creek. My basement flooded frequently during childhood, and I played in the creek frequently.
My [PII removed] was diagnosed and eventually succumbed to non-small cell lung cancer with a rare mutation that was linked to radiation exposure a few years back. My husband grew up in Spanish Lake and eventually moved to Florissant in his teens. He had testicular cancer in 2012, he had it removed and is in remission. His father [PII removed] who grew up in Florissant and played in the creek was diagnosed with bladder cancer in 2017, since removed and has a neo-bladder now. His uncle [PII removed] had tonsil cancer back around 2015. His uncle [PII removed] is a resident of Spanish Lake, and has Leukemia. I am also aware of several neighbors from Wedgewood whom have also suffered from various cancers over the years. The contamination of this creek has deeply and terribly effected my life and so many other lives around us.

Here are my suggestions on what this community desperately needs:

1. Continued testing and cleanup of Coldwater Creek and surrounding areas, including backyards and basements through the Army Corps of Engineers FUSRAP Program. In their 20 year

cleanup, I am only aware of a few yards that they have tested. I would like this to be a priority.

2. Education of current/ former residents of North County and healthcare professionals that we are an "at risk" population because of our exposure. We also need resources available to those without access to health insurance. Awareness is the key to early intervention for potential health concerns from chronic exposure to ionizing radiation.

3. Inclusion for our community in the federal Radiation Exposure Compensation Act (RECA or Downwinders). This program brings opportunity for restitution as well as potential federal grants/ funding for the effected communities to set up screening clinics and education programs through HRSA Radiation Exposure Screening and Education Program, or any other available resource that may benefit the community.

4. Installation of health warning signs along and around Coldwater Creek explaining the risks of the contaminated creek.

5. The community would also benefit from having access to organized support groups for those who have been negatively impacted from radiation exposure from the creek.

Sent 6/30/18
[PII removed]
I played in Cold Water Creek, Florissant, MO in the 1970's. I also spent significant time playing in the wooded areas (in the 1970's) directly next to the creek. I have read the ATSDR Public Health Assessment For Exposures Related to Coldwater Creek, June 18, 2018 and have the following comments.

This report focuses only on parts of the Cold Water Creek between highway I-270 and St. Denis Street. The report needs to provide significant information for the creek areas downstream of St. Denis Street. Areas of concern for me would extend to Old Halls Ferry Road that crosses the creek. I would also expect that others need to be informed further downstream of Old Halls Ferry road and the report should clearly cover all the way to the intersection with the Missouri River. Along with that, any contributions to the Missouri River.

Sent 7/3/18
As an outcome to the latest ColdWater Creek meeting, I would like to suggest some of the following. I recently lost a son [PII removed] to this atrocity. After being diagnosed with cancer at 3 and going into remission he continued to do rock hunting in the creek due to lack of knowledge about the creek area. There were no postings. He died at age 30 with a 2-year-old left behind. There is nothing that can give back the love my son would have given his son. We carry on the best way that we can.

Please consider the following:

1. Better communication to the public regarding the status of the outcomes of all testing to date. Continued public communications sharing what is going on in what areas to rectify the situation. Communication to those even in some type of potential concern area. Continue clean up efforts

of Coldwater Creek and surrounding areas, including backyards and basements through the Army Corps of Engineers FUSRAP Program.
2. Education of current/former residents of North County and healthcare professionals that we are an "at risk" population because of our exposure. We also need resources available to those without access to health insurance and those who do not have primary care physicians. Awareness is the key to early intervention for potential health concerns from chronic exposure to ionizing radiation.
3. Restitution or educational help for children who have lost a parent to cancer (or other) due to the contamination of the area.
4. Inclusion for our community in the federal
Radiation Exposure Compensation Act (RECA or Downwinders). This program brings opportunity for restitution as well as potential federal grants/ funding for the affected communities to set up screening clinics and education programs through HRSA Radiation Exposure Screening and Education Program, or any other available resources/grants/assistance that may benefit the community.
4. Installation of health warning signs along and around Coldwater Creek explaining the risks of the contaminated creek.
5. The community would also benefit from having access to organized support groups for those who have been negatively impacted from radiation exposure from the creek. The community needs a place where their frustrations can be heard and emotional support can be provided.
6. Lessons learned - Define a group that would look at the series of events of how this happened and how going forward we can prevent this happening in another community.
7. Federal government and state help for those having lost love ones and address the market loss to property and homes in the affected areas. Not as important but many people have lost their savings due to homes not appreciating and spending their money on healthcare instead of saving for their retirement age. Some type of help should be assigned to this area that took on the "Manhattan Project" for the good of all of the United States to protect ourselves.
8. Never allow a program like this to take place in a growing community area without specific education to the population living there what the consequences truly area.

Sent 7/24/18
As a member of the Coldwater Creek community I would like to thank ATSDR for producing this health assessment and report. I have included my comments against the report followed by several questions for the ATSDR staff.

**Comments:**

1. **Delete the reference that the report covers area workers.** Page 1 paragraph 4 – "Community members asked ATSDR to evaluate past and present exposures of those who played, lived or *worked* near Coldwater Creek." As written, this sentence implies that community "workers" (e.g. industrial park area) were included in the report. Workers (nonresidents) were not included. Suggest deletion of reference to "worked." If ATSDR chooses to keep this sentence as is, suggest the report follows with a clarification that despite the community request, the report does not attempt to include workers in the health assessment.

2. **Missouri Cancer Registry should add CC exposure to cancer registry data – The** ATSDR report should add a formal recommendation (directed to) The Missouri Cancer

Registry and Research Center to include a cancer patient's exposure to the Coldwater Creek area in their tracking and registry of Missouri cancer cases.

The report recognizes there is a 20 to 40 year latency period for radiation induced tumors. As multiple findings have indicated (including page 38 of report), many residents had already moved out of the CC area ("targeted zip codes") when their cancer was/is diagnosed. Simply recording their current zip code may not capture their history of exposure to CC. Furthermore, zip codes do not capture cases of 'workers' that may have had daily CC exposure but reside outside the CC target zip codes. Given the severity, it astonishes that physicians are not asking and registry not recording CC exposure for cancer diagnosis in the St. Louis area.

Understandably it is not within the ATSDR charter to implement such tracking, but the report should formally make this recommendation to the responsible agency. Such recommendation by ATSDR would carry much more weight than a single member of the community might garner.

3. **Prostate Cancer Omission in Appendix E Tables -** For Table E-6 (and other tables in Appendix E); Why is there not an assessment for prostate on the list of organ evaluations? Especially since the MDHSS reports showed prostate cancer to be significantly elevated at CC (ref pages 5 & 6).

4. **Include "Ball Fields" in the assessment** – The health effects at the "ball fields" (located directly across SLAPS/McDonnell Blvd) are not included in the report. These ball fields were at ground zero from the SLAPS radioactive source. Per FUSRAP, radioactive levels at the ball fields were the highest of all offsite samples tested. The ball fields were widely used including the primary fields for McDonnell Douglas (Boeing) company leagues. There was significant airborne dust/dirt blowing from the upwind SLAPS site across the street onto the ball fields. Furthermore, by the nature of its use the ball fields resulted in ingestion of dirt particles. Many users of these ball fields are incurring seemingly high health issues including cancer.

Analysis of health effects by ball field users should be added to the report. If ATSDR chooses to not include such analysis in the current report, recommend at least adding a section that recognizes the ball fields (and their omission) as well as a recommendation that a further study be done to examine health effects for the ball field users.

5. **Cannot find the section listing "health concerns not addressed by report".** Page 3 paragraph 1 – "This report also includes a section listing and addressing other community exposure and health concerns that ATSDR did not directly evaluate." Where is this section in the report? I couldn't find the referenced section. Perhaps the section exists and should be more clearly titled (e.g. "Exposure That ATSDR Did Not Evaluate") – as it is a very important section.

Additionally, add the following to the listing of community health concerns that ATSDR did not directly evaluate:

   a. St Ann residents – upstream from SLAPS but contaminated from B&K truck washing into Coldwater Creek

b. Workers – especially the industrial park. This area is immediately downstream from SLAPS and alongside CC. This area is much closer (presumably higher radioactive levels) to SLAPS/HISS than the area included in the report. It was also prone to flooding.
c. Ball Field users – immediately across street from SLAPS site (McDonnell Blvd). Per FUSRAP these fields had the highest concentration of radioactivity of the CC measured areas.

6. **Airborne Particles –** The report states that ingestion of airborne particles was not factored into the health effects analysis (ref page v, page 36, page 41). Airborne pathways can lead to significant negative health effects on internal organs. Furthermore the CC community under analysis is generally downwind from the SLAPS waste. The ball fields (adjacent to SLAPS) in particular were notorious for extensive dirt/dust blowing onto the fields.

Understandably (at this point in time) it is difficult to deduce data for past airborne levels and to factor the ingestion/inhalation of airborne contaminants, but doesn't this omission significantly place the report findings into question? i.e. Significantly underestimate the health effects. Could the lack of factoring airborne inhalation be a major reason between the ATSDR findings compared with the MDHSS report? Specifically, the MDHSS reported a higher incidence of breast, colon, prostate and kidney cancer whereas the ATSDR report did not. If the ATSDR position is that leaving out airborne exposure does not impact the findings then the report should so state.

7. **Health Effects in addition to Cancer –** The report limits its scope to cancer. There are other serious health effects that are of concern (thyroid, lung disease, auto immune, etc). Perhaps the Introduction section should clarify that this report focus is on cancer risks.

8. **Exposure Concentration for Surface Water**. Reference page C-19 and table C 5. The report states that for surface water contaminants, data environmental monitoring of surface water (collected from 1991 – 2014) was used. And this data showed no results higher than FUSRAP's background data. This is not surprising as the primary source of contaminants (SLAPS & HISS) had been removed a decade prior. The surface water had a decade to flush its contaminants. It seems fair to use these values for the "Recent exposures (2000s and on) surface water" contaminants in Table C5.

But the same (background) levels are used for the "Past exposures (1960s to 1990s) surface water" values. During the 60s and 70s SLAPS and HISS were actively contaminating the surface water. The surface water was the transport for soil and sediment contaminants. What is the justification for using the same (minimal) values for the "Past" exposure surface water contaminant estimate? I think the values for contaminants should be much higher. Granted it may be difficult to estimate at this point in time.

9. **Differences in the conclusions between the ATSDR and MDHSS reports.** The ATSDR and 2014 MDHSS assessments took different approaches. The two reports had different findings (ref page 38). The MDHSS study showed elevated cancers for leukemia, female breast, colon, prostate, kidney and bladder. The ATSDR report did not arrive at higher

incidences for these types of cancers. There should be a better explanation as to why the two reports differ in their findings.

The time frames of the two reports are actually similar. The ATSDR assessment estimated for past exposures 1960s to 1990s. With the 20-40 year latency period that approximately lines up with the MDHSS time frame of 1996 to 2011 and their estimation of actual cancer incidences. Yet the reports have different results.

Page 38 also touches on the possibility that "people living in the zip codes studied by MDHSS may not be the same people … living near Coldwater Creek in the 1960s to 1990s." While it is true that a lot of residents from the 1960s-1990s moved away from the community (targeted zip codes) and were not counted in the MDHSS findings, had they been counted it would have been an even greater difference between reports. I would like to see a more in depth evaluation as to the differences in findings between the ATSDR and MDHSS reports.

**Questions:**

As the report indicates

- Every dose of radiation incrementally increases the risk of developing cancer (page 19)
- CC exposure raised the (per year) MRL above the normal background dosage (table 4)

**Question 1** – Should prior CC exposure be a factor in the decision of how to medically treat cancer? For example:

- Choosing surgical over radiation treatment
- Determination of the total allowable (safe) dosage when undergoing radiation treatments.

**Question 2** - Should prior CC exposure be a factor when medical staff makes a decision on the extent and frequency a patient can safely receive medical scans (i.e. more radiation) such as CT, PET, bone scans, and nuclear medicine?

**Question 3 - Consultation Facilitation –** page iii paragraph 1 – "Upon request, ATSDR can facilitate a consultation between residents' personal physicians and medical specialists in environmental health". What is the process to request this facilitation? I would like to make this request.

Sent 7/28/18

I would like to disagree with your statement of Long Term Exposure not known to have possible Non Cancer Illness-effects.

I was born, grew up , worked, raised my family 44 of my 48 years in North County . (zip codes :63138,63033 and 63042; zip codes 63031,63033,63042 and 63044) I worked my teen years at places right next to the creek and my career as a physical therapist assistant was in several areas along business within the flood plain of the creek. I lived through MULTIPLE tornadoes that touched down in our neighborhoods. I remember the huge amounts of dust that occurred when I worked next to highway 270 and Graham as they expanded to add extra lanes and a new off

ramp to 170 back in the 1990's and when Christian Hospital NW located at Graham and 270 was torn down 2003 . At that time I drove a Jeep and could remember how dirty I would get driving past all of the dust every day.

I was diagnosed with hypothyroid disease in 1996 when I was pregnant with my first child. From age of 26-36 I had multiple issues and surgeries with infertility, PCOS, Endometriosis, Fibroids and Pelvic Inflammation NOT related to any sexually transmitted disease. I had my left ovary removed that was loaded with cyst. At age 33 I gave birth to my second child and at age 35, a miscarriage in my 4th month of pregnancy with a cyst on my one remaining ovary. Several months later at age 36 underwent a complete abdominal hysterectomy with abdominal cyst attached to my abdomen along my c-section scar.

At age 40 I was diagnosed with a 5 MM pituitary tumor, a left breast cyst and a left saliva gland cyst that was surgically removed with the gland.

At age 43 diagnosed with Rheumatoid Arthritis, Hashimoto's thyroid Disease, Chronic inflammation , multiple lung infections ,Obesity, Fuchs Dystrophy-that will require Corneal transplants (most patients with Fuchs dystrophy , my finger and toe nails do not grow , I was diagnosed with spinal stenosis and degenerative disc disease in several areas of low back and knee. I have worked in orthopedic physical therapy for most of my career 20 plus years and many of the illnesses I have are common but not all in the same person. Also many of these illnesses do not present in a patient so young in their 40s -many are diagnosed much older in late 60 and 70s)

Along with all of this I have a compromised immune system that has caused multiple episodes of infections leading to bronchitis/ pneumonia due to the medications for RA. 5 years ago after a year on heavy antibiotic/Leviquin for Chronic illness I was forced to leave my health care career and place my PTA license on hold with the state of Missouri. I am unable to work because of these conditions as stated.
Both of my children also have issues:

My first born daughter has Celiacs Disease, allergies and anxiety

My second child has asthma, allergies,IBS, Chronic lung infections , had chronic illness through his first 8 years requiring antibiotics , he had adenoids removed that were grey and deformed age 6 ,a vein that abnormally developed over his trachea where normal anatomy there isn't one and causes issues with breathing, a deformed extra vertebra between L5-S1 / Spina Bifida Occulita - scoliosis, and deep cystic acne

No family history of ANY of the illnesses I've mentioned.

My father was a grain farmer in Spanish Lake, we lived in an area where the creek had streams and storm runoff, I always was playing in the dirt and a huge gardener. At our Hazelwood home continually I was Digging and replanting up flowerbeds, renovating our yard and even dug a 3' deep 3'x 6' fish pond and tilling a garden. We ate seasonal vegetables I grew or grown from local places along the creek in Florissant prior to my illnesses and knowing of the possible toxic

exposure. Most of my life I lived, worked and played right in north county 1979-2014 .We lived from 1996-2014 at [PII removed]. Our home was 4 blocks from Palm Dr homes and the first park closed for remediation by the ASTDR.

Many of my husband's classmates from McClure North 1989 class have become ill or died at a young age from Cancer, Auto Immune illness. Many of my class mates from Hazelwood East 1988 have also become ill or died at a young age. 2 if my coworkers from my job I had in high school died from appendix cancer , 10 percent of Our daughters graduation class for Incarnate Word Academy 2016 had a parent that has died and 20 percent had a parent that was ill from Cancer or an autoimmune illness.

I understand that not all these issues are caused by low levels of radioactivity but I have had more than one illness unrelated to family history that has come up , I have gone to so many funerals for friends under age 50 that I feel strongly relates to exposure from north county. I am asking that further studies look at the auto immune illness and the statement in your physician alert is changed to add possible auto immune illnesses may be linked to low levels of radiation exposure.

I have filed for disability but at this time I have not received any benefits/ decision. I was told at my hearing with the judge that Fuchs dystrophy has not been seen in any disability cases the judge or medical advisor has reviewed. (This usually doesn't even show up in a patient until they are in their late 60s early 70s. )This eye disease is very difficult it slowly progresses with fluid filled cysts that fill and empty inside the corneas that cause severe glare sensitivity, double vision, poor night vision and when the disease progresses to point cyst stay full only treatment is Corneal Transplants. I am currently the youngest patient my optometrist and ophthalmologist that specializes with Fuchs Dystrophy have seen.

The known Effects of low level radiation exposure is NOT well understood in our medical community OR in the judicial system for disability. Having the government acknowledge that low level radiation exposure from cold water creek is possible to cause auto immune illness could have a positive impact to improve our medical care and improve the process to get disability benefits for those of us who are suffering.

(From same resident as above) Sent 8/4/18
I found documents on military medical research linked to the cdc downwinders search page. It links inflammatory auto immune illness to exposure.
et al. Military Medical Research (2018) 5:9 https://doi.org/10.1186/s40779-018-0156-7
REVIEW Open Access
Radiation-induced inflammation and autoimmune diseases Rasoul Yahyapour1, Peyman Amini2, Saeed Rezapour2, Mohsen Cheki3, Abolhasan Rezaeyan4, Bagher Farhood5, Dheyauldeen Shabeeb6,7, Ahmed Eleojo Musa8, Hengameh Fallah9 and Masoud Najafi10*

Abstract
Currently, ionizing radiation (IR) plays a key role in the agricultural and medical industry, while accidental exposure resulting from leakage of radioactive sources or radiological terrorism is a serious concern. Exposure to IR has various detrimental effects on normal tissues. Although an

increased risk of carcinogenesis is the best-known long-term consequence of IR, evidence has shown that other diseases, particularly diseases related to inflammation, are common disorders among irradiated people. Autoimmune disorders are among the various types of immune diseases that have been investigated among exposed people. Thyroid diseases and diabetes are two autoimmune diseases potentially induced by IR. However, the precise mechanisms of IR-induced thyroid diseases and diabetes remain to be elucidated, and several studies have shown that chronic increased levels of inflammatory cytokines after exposure play a pivotal role. Thus, cytokines, including interleukin-1 (IL-1), tumor necrosis factor (TNF-α) and interferon gamma (IFN-γ), play a key role in chronic oxidative damage following exposure to IR. Additionally, these cytokines change the secretion of insulin and thyroid-stimulating hormone (TSH). It is likely that the management of inflammation and oxidative damage is one of the best strategies for the amelioration of these diseases after a radiological or nuclear disaster. In the present study, we reviewed the evidence of radiation-induced diabetes and thyroid diseases, as well as the potential roles of inflammatory responses. In addition, we proposed that the mitigation of inflammatory and oxidative damage markers after exposure to IR may reduce the incidence of these diseases among individuals exposed to radiation.
Keywords: Radiation, Inflammation, Autoimmune diseases, Thyroid, Diabetes

Why are these issues not addressed by the CDC in St Louis issue with Cold Water Creek if they have medical research showing what many of us have listed as noncancer illnesses? We would like to have additional acknowledgment that these specific illnesses may be connected.

Sent 8/1/18
My name is [PII removed]
My family lived at [PII removed] Florissant, Mo. 63303
Original owners of home built in the mid-sixties.
4 kids in our family and we played frequently in the creek as our house backed up to a tributary 2 houses from the creek.
Our basement would flood (sewer backup) frequently every time the creek flooded which was often.
Mother, [PII removed] died of rare stomach cancer at age 60 in 1998 and she was still a resident at the time of her death.
Last year at age 60 I was diagnosed was diagnosed with a rare auto immune disease that effected my spinal cord resulting in transverse myelitis. Drs say this is non curable.
If any additional health information is needed I can be contacted at [PII removed]
Thank you

Handwritten request for report copy received 8/2/18
“I lived yards away from Coldwater Creek from 1978-1992. My three daughters played in the creek.”

Sent 8/4/18
My name is [PII removed]. I am 31 years old and I have lived in the same house my entire life and I just had a baby girl who is two months old. I live in a neighborhood called Sunland Hills which is located in Florissant Missouri I live less than a mile from cold water creek. My mother moved in this house in 1976 and has always enjoyed gardening and Landscaping. In October 2014 she

developed triple negative breast cancer which is a rare type of breast cancer. She had to go through chemotherapy and radiation for over a year, but her cancer has been in remission for 4 years. It's not until later that we wonder could her cancer have been brought on because of living so close to Coldwater Creek. I am contacting you to ask is there an increased risk of my daughter and I developing some type of cancer by living in the cold Water Creek area?

Sent 8/4/18
Not sure what info you are seeking but my name is [PII removed] and I lived from 1967 to 1983 at [PII removed], Florissant Mo 63031. We were 1 street over from Coldwater creek. I played in it throughout my childhood and early adolescence. I was diagnosed with papillary thyroid cancer in 2001 and had my first surgery to remove my thyroid. There were numerous tumors that had spread into my neck. I had a radical partial neck dissection in 2004 to remove more cancerous tumors and another surgery in 2010 to remove 2 more tumors. The only known cause of thyroid cancer is exposure to radiation. Please do all you can to rectify this travesty perpetrated by our government and protect those of us who have suffered the consequences of their actions.

Thank you for your help.

Sent 8/3/18
My son is the illest child.

Sent 8/3/18
I lived on Cold Water Creek. [PII removed]. Two of my kids had Trisomy 3, one died. The one who survived had a brain tumor. I lost my uterus to precancer. I am disabled for a lot of reasons. I also had a melanoma on my foot. My Dad [PII removed] has stage four Squamous Cell Carcinoma of the head, neck, face, brain and lymph nodes. He is dying. He's only 60. I hope this helps your statistics.

Sent 8/3/18
My name is [PII removed]. I lived at [PII removed] from birth until I was 15, then [PII removed] until I was 22 years old. Both are residences in Florissant. My brother and I played in Coldwater Creek and cut through the creek throughout our childhood. I was recently diagnosed with a pituitary Tumor a year ago. I have spent thousands of dollars to determine the problem and how to treat it, in addition to the long term suffering (years).

My mom has a brain tumor. My brother’s daughter has an inoperable brain tumor.

Please contact me.

Sent 8/4/18
I want to fill out whatever forms I need to. I saw there was a deadline of August 31st and I'm unclear of what the deadline is in reference to exactly. But I think myself and family have been effected.

Sent 8/4/18
We are [PII removed]. We raised our family at [PII removed], Florissant, Mo., from 1965 to 1998.

Our daughter [PII removed] was diagnosed with a very rare disease named Pseudo Myxoma Peritonei. There was a one in a million chance of contacting the disease at that time. There are presently several cases of PMP (some in appendix) in the cluster of Coldwater Creek Area. She fought this total life and body destruction for 8 years, knowing that there was no cure. Fifteen trips to [PII removed] in San Diego, California for surgeries to alleviate ungodly pain and to save her life. Also had several procedures done here in St. Louis. Two of our daughter's friends from High school died from PMP within 2 years of her death. [PII removed], our daughter passed away [PII removed] 23, 2016. It is so obvious that the Mallinckrodt uranium waste dump has caused this dreadful, unimaginable blight of this area so full of families suffering.

Sent 8/6/18
I was born in florissant in 1967 I still live in the community. I have a brother that has Pompe disease and I neuropathy that is increasingly getting worse, along with hip and lower back pain that the neurologist can't come up with and answer as to why I have what I have. Is it due to living and playing as a child in cold water creek? My oldest son as a child had osteomyelitis he also played in the creeks. My nephew has outrageous Ck levels that the doctors can't explain he too is being raised in Florissant.

Sent 8/6/18
I've already registered that I have skin cancer and I have lung cancer that radiation and chemo won't work. I have paid a lot of money out for. Surgery and Dr bills and still have cancer

Sent 8/7/18
Hi my name is [PII removed]. I grew up in St. Ann, MO, right across the street from Coldwater Creek. As a child I grew up playing in the creek with the kids next door. In 2015 at the age of 27 I was diagnosed with stage 2 ER/PR positive breast cancer. No history of it in my family and both BRCA 1 and 2 came back negative. In 2016 my sister was diagnosed stage 1 triple negative breast cancer. She was 42 when she got diagnosed. She's the healthiest person that I know and yet she was diagnosed. The only thing that makes sense is we both grew up playing in Coldwater Creek. I want the entire creek from start to end be tested for radioactive contamination.
Thank you for taking the time to read my email.

Sent 8/9/18
Hi, my name is [PII removed]. I'm 37 years old and lived in Florissant and played in the creek for many many years. I lived there 26 years in fact. From 1981-2007 and then moved to Maryland Heights for a year. Now I am in Lake St. Louis. I cannot get far enough from the Creek. I was diagnosed with Stage 2B invasive ductile carcinoma Breast cancer at 32. I did the evasive genetic test to check my genes for any family related cancer genes. I was negative for all. I had TWO MUTATIONS in my genes. That's where cancer came from. Mutations. I am certain Coldwater Creek caused my cancer. I really would like a response to this. I've been waiting for 5 years to finally get people to believe us. I literally rode my bike through radioactive waste and played in the dirt barefoot and made mud pies with it. Please respond with anything I need to do to be involved with this. I am already a member of Coldwater Creek just the facts please.

Sent 8/10/18
Hello, My name is [PII removed], and I grew up living on, and in Coldwater Creek as a child. 76-

93. And as an adult, 2014-17. I'm currently 43 and am interested in possible screenings. I lost both my parents in June 2010. MS/Liver failure (non-drinker), and Pancreatic cancer. 61 and 63 years of age. I also have 2 siblings diagnosed and under treatment for autoimmune diseases. Please let me know if screenings are available, or I can provide any additional assistance. Thank you

Sent 8/11/18
In the late 70' my parents bought their first home in Florissant, where they still live today. This home is where they started their lives, brought their 3 children home from the hospital, raised them, and now are creating memories with their 5 grandchildren. Unfortunately, not all memories in this home are turning out to be good.

On Monday August 6th, 2018, I stood in their living room as I watched an ambulance pull into their driveway and take my father out if the ambulance. This ambulance was bringing my father back home, home to die. He was officially placed on hospice as a result of a very aggressively blood and bone cancer, Myelfibrosis, caused from exposure to chemicals and radiation. The progression of this cancer has been fast, nasty, and now has developed into leukemia. There is no family history of anything like this, the only history linked to this is Cold Water Creek, and living a quarter mile from it for 40 years.

To most, he is just a number or a statistic, but to our family he is so much more. He is a husband, a father, a grandfather, a provider, a friend, a golf enthusiast, a camping lover, and a man taken from this earth too soon. God should have been the one to choose his time to go, not the careless mistakes of Malinkrodt and the Federal Governments lack of concern to take action.

Please, please continue to not just listen, but research and most importantly TAKE ACTION.

Sent 8/11/18
I am requesting more information.
My grand parents ([PII removed]) lived at [PII removed] in Florissant 63031. Currently my Uncle lives at the homestead since my grandparents death in 1977. I spent much of my years there from 1955 to 1977. I drank from their well and I played at the creek. It runs through the acreage at that address. We ate the livestock and the vegetables grown there fed from the water from the creek.
My name is [PII removed] and I now reside in [PII removed]. My phone is [PII removed] and my email is listed above.
I am very much interested in this situation.
Thank you

Sent 8/12/18
My late husband, [PII removed] passed away in July 2011 from Kidney Cancer at the age of 52.

[PII removed] lived off Berkeley Rd until his family moved to Carrollton in Bridgeton. [PII removed] lived, and played growing up in the area until 1989 when we were married.

Well over 25 years he worked at Lambert Internal Airport. He worked for United Airlines until

the day he had his Kidney removed. He was already stage 4 Kidney cancer when he was diagnosed.

We asked one of his physicians if he had an idea what caused his cancer. His Dr responded and said "it is environmental". ([PII removed] worked in the ramp at Lambert for many years). He asked the Dr if it was related to jet fuel and his physician said "no". Mark replied and said "it was from all of that sh*t at the airport". His physician was not aware of the issue at the time. But [PII removed] knew. I know. Yes, his Kidney Cancer came from the Radioactive Waste at St Louis Airport and Cold Water creek.

[PII removed] knew about the radioactive waste at the Airport. He would come home from work, take his shoes off in the garage, so he didn't track anything into the house.

We were devastated by his diagnosis. He was given 2 years to live. We sought different opinions and treatment plans from multiple Oncologist, including making a trip to MD Anderson in Texas. There was no hope. He lost his life because he lived in Bridgeton, grew up around Cold Water Creek, went to the old Khoury League park, Champ park in Berkeley, the Bridgeton Athletic Complex and worked at the Airport.

I still struggle with losing him and miss him tremendously. Our kids do too. My son had turned 14 a few days before [PII removed] passed away. He is in college now. He didn't have his Dad here to teach him how tie a tie. Or how to drive, take care of cars, or use tools, fix things. Let alone see him play in the Band at school, graduate and go off to college. Our daughter was 19 and in college when [PII removed] passed away. She struggled after that and ended up giving up and not graduating. She is engaged now. [PII removed] won't be here to walk her down the aisle for her wedding. I am crushed over that. He won't be here to meet his son-in law, and eventually his grandchildren. Our plans for empty nesters is gone. It's just me.

I believe you are on the right track now by admitting the contamination is real, it is there and making people sick. The cleanup has been underway. But it was too late for my husband. I beg you to continue to make North County safe again. Continue with the testing and remediation of the area. Please don't let anyone else suffer the way our family has. You cannot imagine what we have lost and the lifelong impact it has had on myself, our kids, my family and friends. We are counting on you to do what is right!

Sent 8/12/18
To whom it may concern.
We moved to St. Ann in 1968 and my parents bought a house at [PII removed].
I also played and ice skated in the creek, in the summer months I would catch crayfish with my friends it was a wonderful life but never did I hear anything about the poison in the creek I guess it was all a big secret to those that made all the money and should have been held accountable for this tragedy.
I lost my brother to pancreatic cancer when he was only 47.
When I was in high school I developed epilepsy but have been lucky to have them controlled by medication for over 43 years.
I'm now 61 and hope to live long enough to enjoy my grandchildren, it's just too bad that my

brother wasn't as lucky as me.
I hope the people responsible for this devastation of St. Ann and all the other towns that were contaminated will see it all cleaned up and encapsulated in something that will prevent the spread of toxins.

Sent 8/12/18
I lived on [PII removed] from around 1959 to 1970. Played in that creek all the time as a kid. Moved back to the same house around 1977 to 2000. I too have cancer.

Sent 8/12/18
My family lived on [PII removed] in Hazelwood in the 1960's. I was born there in 1964 and we moved in late 1969. My siblings and I played in Coldwater Creek and the parks frequently. My mother died young. Her autopsy stated she died of unknown causes and it stated that her body was filled with gray matter. Two of her six children have had Hodgkins. One having the cancer and issues with the thyroid and liver, gallbladder. I thought this information may help you with any research.

Sent 8/10/18
How do I file a claim for Coldwater creek lawsuit

Sent 8/10/18
Hello,
I am responding to the article in St. Louis Magazine about the pollution that is in Coldwater Creek, this article appeared in Facebook today and I have something to say. My family and I lived there from September 1st 1988 until my husband's death in April [PII removed] 2009. Our address was [PII removed] in the Wedgewood subdivision. We rented our house. Coldwater Creek was just behind our neighborhood. On some days if you were outside you could actually smell the bad odors coming from Coldwater Creek.

My husband died of cancer of the esophagus. He was a cigarette smoker so it would not be fair to blame his death on Coldwater Creek but perhaps the pollution in Coldwater Creek added to his illness. After my husband's death I moved to New England which is my birthplace and I now reside in [PII removed]. In 2013 I was diagnosed with stage 1 breast cancer. I am fine now but I often wonder if my cancer could be linked with living at [PII removed]. I worry about the health of our daughters. Our youngest daughter walked to Wedgewood Elementary School. They are married ladies now with their own families but now I question if their own children could have a health risk resulting from that dirty filthy cesspool that was in our back yard!

It pleases me to read that the Federal Government publicly conceded that exposure to radiological contaminants polluting the creek could increase the risk of cancer. But there is still a long way to go. I truly believe polluting Coldwater Creek behind our backs is totally unfair and all of us affected should be financially compensated.

If you would like to follow up with me I would be happy to talk with you more about this. [PII removed].

Received by ATSDR on 8/13/18
Forty-eight printed pages in plastic sleeves with comments related to fluoride, stated as used extensively in uranium processing, as a potential contaminant. *[ATSDR notes that most of the information provided was not related to the Coldwater Creek evaluation per se.]*

Received by MDNR on 8/15/18 and provided to ATSDR
Nineteen handwritten pages of comments containing PII related to locations of residence in the Coldwater Creek area, health condition experienced by the commenter and family members, and information on how the commenter was potentially exposed. Issues in comments similar to others received, including need for more testing and remediation, apology from responsible parties, compensation for affected people, and more follow-up of people whose health was affected by contamination.

Sent 8/17/18
I'm just writing to let you know my exposure to Cold Water Creek. I was born and raised in Florissant Missouri at Waterford and Paddock and Parker Road. As kids we used to always play in the creek behind our house and beyond. My mom passed away due to certain kinds of cancers and my dad also passed away due to cancer. I was diagnosed with a false positive of lupus and also a histoplasmosis in my left lung.
Just passing this along.

Sent 8/19/18
My husband died of Islet cell pancreatic cancer Nov [PII removed] 2009. During his childhood he played in one of the creeks located by his house on [PII removed] in Ferguson. Is this one of the related cancers?

Sent 8/18/18
Dear Sirs,

I have been employed by Boeing / McDonnell Douglas since 1980, passing by the SLAPS storage site every workday for the past 38 years. When reading the report, there is only a brief note on the land use just north of the SLAPS site that was used as the PRIMARY softball fields for McDonnell Douglas Recreation Department. These fields were used regularly throughout the summer months and many employees were exposed to dust and potential contaminates by direct contact with dirt (base sliding, running and laying on the ground) and indirect contact (through dust inhalation). Because of the location of potential exposure – exposure concentration levels could be significantly higher for this demographic group. Excavation of the old ball fields has recently started and there appears to be testing on-going. This group should be targeted and tracked for special medical conditions – names and address can be obtained from historical McDonnell Douglas personnel files and recreation rosters.

In addition, I lived at the Chez Paree apartment complex located off Lindbergh from Feb 1980 to Jun 1985. This apartment complex shares a geographical boundary with Cold Water Creek.

While I have not experienced any noticeable effect from the carcinogen exposure – I am concerned about it.

Sent 8/22/18
Dear Keeper of Records for Coldwater Creek,

My name is [PII removed]. I am the daughter of [PII removed]. My mother grew up in North St. Louis County. St. Ann to be specific.

I lost my mom to triple negative breast cancer on October [PII removed], 2016.

My mom was born and raised in North St. Louis County. Her date of birth is [PII removed].

She lived in north county from her birth until the early 1970's.

Her battle with cancer began in 2002, right around the time she turned 50. She had an "atypical cell read" from a biopsy, was advised by her doctor to take tamoxifen for 5 years. She took the entire prescription.

In 2014, after a breast self exam, she found a lump. She had annual mammograms, and was literally to-the-day precision on her annual screening. However, a lump was missed in her 2013 screening. Apparently she had dense breast tissue. It was discovered she had stage 3, triple negative breast cancer. She had a double mastectomy, chemo (Adriamycin) and radiation.

In 2016, the cancer returned with vengeance. It ripped through her body, spreading to lungs, liver, bone...everywhere.

That sweet, beautiful woman lived a healthy life. She was always a healthy weight, drank in extreme moderation (less than 2 drinks/week) and exercised daily.

I know, without a doubt, that the cancerous flow from Coldwater Creek led to her cancer.

Throughout her diagnosis, she stumped every doctor ("you're so healthy, we don't know why, it's not genetic".....) The only logical connection is that poisonous river flowing by her and her water supply her entire childhood and young adult life.

PLEASE FIX THIS!! I miss my mom Every. Single. Day.

If you need more from me, here's my information: [PII removed]

Sent 8/24/18
Hello,
My name is [PII removed]. I grew up in Hazelwood MO. I am writing to say that i also have been exposed to the "poison" that was dumped in the coldwater creek. I have several medical issues that indicate they may have been caused and are causing the problems i have today.

Sent 8/29/18
I just found out about all this from a friend who also grew up in Florissant. My family moved to

Paddock Hills in 1956, I graduated from McCluer in 1968, and I moved away from Missouri when I got married in 1970 So please excuse me if I seem confused. My sister and I never played in or near the creek, but my 3 younger brothers did. One lost a kidney to cancer almost 20 years ago and another died of a plethora of strange ills including cancer just 3 years ago.

What I do not understand is why this has taken so long to become an issue. I knew when I was in high school and probably before that Cold Water Creek was polluted. I don't recall who told me, it seems there were articles in the St. Louis Post Dispatch and on the news about it. I never knew what it was polluted with but someone must have done some research back then. Love Canal happened so many years ago. Why did no one follow up on Cold Water Creek before the 1990s?

Sent 8/29/18
To whom it may concern-
My husband and his father both had cancer. Every house on his street had cancer in it. Many have suffered and died due to exposure from cold water creek. Please- please do something about this.

Sent 8/29/18
Lost my dad in 08 [PII removed] died of bone cancer we were in the lawsuit but disqualified because he died to long ago?? How long does nuclear waste last? millions of years!! Well mom just passed in December of 17 of lung cancer after being in remission from lung cancer in 98 so what's the excuse gonna be this time? dad worked at lambert field from 69-79 and we lived in the heart of Florissant from 69-02 and the creek flooded our home numerous times, so what's the answer or excuse gonna be my sister has health problems I have health problems when is it gonna end?? oh I know you're just waiting for us all to die miserably so you can keep the billions you put away for what a bunch of greedy inconsiderate pigs!

Sent 8/29/18
In the late 80's & early 90's, I was working for a local North County tree service. We were contracted by MSD to clear Cold water creek as well as other water ways in N. County.
Most of the times, tree debris could be cleared via the bank. But then there were cases where someone had to enter the water to accomplish these tasks (yours truly).
If I had known then what I know now (thanks to [PII removed]), I would have quit immediately!!! I found myself (unaware) fully submerged while performing needed tasks.
I was also continually exposed as an elementary student while participating in soccer activities on McDonald blvd. We all (unknowingly) played in the creek when it was hot.

Over the years since, I have had numerous health issues starting with severe ear infections, continual sinusitis, then I was diagnosed with Blastomycosis in 2011 which I was informed can lay dormant in the body for decades !!! I also had an Arachnoid cyst removed from T-1,T-2 in 2016 which is another one in a million that I was informed they don't know what caused it !!! Not to mention the spinal cord does NOT repair itself & will only get worse eventually causing paralysis. Degenerative disc, rheumatoid arthritis, severe headaches etc.

Compared to some other Families in NoCo, I feel LUCKY!!! Agonizing death by Cancer is far to common amongst Friends and acquaintances. Until I relocated my Family to W. Tennessee in

1996, I thought these occurrences were normal. They are not, they are of much higher frequency in NoCo St.Louis.

I don't know if any of this even matters at this point. The deception and damage is done & NoCo's Families have paid the ultimate price for the War Machine. Every one of the deceased and suffering are no more than casualties of war to the people who made this fateful decisions. But to me they are the unsung Heroes who paid the ultimate price, LIFE.

Sent 8/29/18
To Whom It May Concern:

The St. Louis Coldwater Creek contamination situation was just brought to my attention by a relative, and I got this contact information from the Facebook page. I am emailing to report about my father, [PII removed], who was born in 1953, and died in 2013. He lived on [PII removed], Florissant, MO 63033 from approximately 1956-1979, and off and on throughout the 1980s and even early 1990s. This was my grandparent's residence. According my father's oldest sister, my dad and his brothers frequently played in Coldwater Creek as children during the time of the contamination. He also lived and stayed at this residence off and on for many years, always staying in a room in the basement.

My father struggled with Crohn's disease, and was misdiagnosed with Ulcerative Colitis back in the 1980's, when he had his entire large intestine removed. He was always sick and in and out of hospitals, as long as I could remember. In 2009, he had a mental break and lost his job, having early onset dementia in his 50s. No one could figure out what was wrong with him for years because of his age and all of his strange symptoms (digestive, skin irritations, memory loss, random infections, etc. - it was all over the place really.) He was a skilled and respected [PII removed] in Columbia, MO, and couldn't even remember his job or his granddaughter's name, just a year or so later. It was beyond heartbreaking, and he needed full time care.

Then, in 2013, a specialist in Charlottesville, VA found liver cancer and cirrhosis, giving him 3-6 months at best. (He NEVER drank alcohol either, so this wasn't lifestyle related.) And because of his poor condition with the Crohn's and all of the other strange ongoing symptoms, he wasn't a good candidate for surgery. He died in August of 2013. His story haunts me to this day, not even knowing about the Coldwater Creek situation. Doctors couldn't ever believe all of the multiple symptoms, and rare illness that he had so young. Maybe now I have some answers, but I just want my dad back.

My uncle, one of the brothers that played in the creek with my dad, also developed kidney cancer at a young age. He is still alive. My grandmother also lived on an oxygen tank for many years at the same [PII removed] residence, and I believe had cancer as well, but I was young and have limited information there. She passed away in 1998 though. And my grandfather died just a couple of years later.

I don't know what will come of me reporting any of this, but I hope and pray that this situation is dealt with, and for all of the other family members affected. I am an only child, and I lost my dad and my grandparents way too soon. When I see people that were born the same year or close to

them, I am saddened by the fact that maybe they could still be alive.

Thank you for taking the time to read my dad's story. Please feel free to contact me if you have any further questions, and I will try and help if I can.

Sent 8/29/18
Coldwater Creek public health survey public comments. Please know being born in 1961 and living there for decades I have seen decades of the toll the Waste has taken on my community and metro area. The sickness and financial and mental toll cannot be given proper justice in a survey. Every imaginable cancer and auto immune disease imaginable. The sickness of my grade school in late sixties and seventies continues. The DNA consequences strongly exists today. The damage to my family I cannot briefly do justice too. Please consider every possible assistance possible. The incredible harm cannot be taken back but this community desperately needs Reca Downwinders Status as fast as possible. The Coldwater Creek residents of the past 60+ yrs need support recognition knowledge and ATSDR plays a vital role. Please don't let us down. Thank You

Sent 8/30/18
My name is [PII removed], I grew up at [PII removed] in Wedgewood. My parents bought their house new in 1965. They put in all their own landscaping and grew their lawn. Our neighborhood was an ideal place to raise a family. I and my friend [PII removed] used to play in the creek almost every day. We caught crawdads out of the creek and her mom would cook them like crawfish and we would eat their tails. We built a fort in the woods by the creek and in the summer we would explore and swim and walk the creek barefoot sometimes cutting feet on rocks. We were in that creek almost every day, even skating on the creek in the winter beginning by age 5 or 6. As teenagers we hung out in our fort or under the new halls ferry bridge. We played ball in wedgewood park and ran the hills and crawled thru the tunnel and explored the creek there also. Sometimes the park would flood and we would play in the water.

My friend's mom [PII removed] died of breast cancer after many recurrences and my best friend [PII removed] died of a very rare breast cancer at 42 years old in 2006 Her sister had breast cancer and her brother had cancer.

My father died of lung cancer 2007. My sister had breast cancer at the age of 32 and I was diagnosed with breast cancer in 2017.
Please put us in your records [PII removed] died 2007 lung cancer. [PII removed] breast cancer 1993. Myself [PII removed]. Breast cancer 2017.

Sent 8/31/18
Thank you, ATSDR, for your evaluation of community exposure to our country's first nuclear weapons waste allowed to migrate into Coldwater Creek and its floodwaters. Thank you for your recommendations, particularly relating to additional FUSRAP investigation and testing in order to properly contain and remediate all affected areas from contaminated prior floodwaters in addition to movement of Coldwater Creek sediment from re-routing activities, developing neighborhoods, and building the beautiful North County community. Thank you for listening, working diligently, and doing your best to serve the Coldwater Creek community.

In the Summary of Findings on page 32 of the ATSDR PHA draft, the following paragraph was included: "The evaluation described in this report was the only evaluation we identified that could use sampling data from residential areas to estimate exposure and risk numerically. This evaluation cannot answer the many and varied concerns this community raised about exposure, risk, and health."

Indeed, recent levels of radionuclide contaminants of concern located and measured by FUSRAP only provide a limited piece of the possible exposure to radionuclide contaminants former residents may have absorbed. Extrapolating these pieces of history to possible past human exposure is not an exact science. Further, in estimating the increased cancer risk, ATSDR applied lifetime attributable risk coefficients using ICRP and EPA dose coefficients to the calculated guesstimate potential exposures to residents of the Coldwater Creek area. EPA utilized radio-biological data including studies of Japanese atomic bomb survivors, medically irradiated patients, and occupationally and environmentally exposed groups. This is where the study deviates strongly from the typical Coldwater Creek resident fact pattern of exposure. Japanese atomic bomb survivors were exposed to the post-fission materials in one big event, but Coldwater Creek residents were exposed to the very raw materials used in producing the Hiroshima bomb over many years in smaller doses. Medically irradiated patients per the BEIR VII Phase 2 report (Item 113) were typically young and had limited exposure to medically applied diagnostic imaging (not whole body/inhalation/ingestion as creek residents had every day), and occupationally and environmentally exposed groups are also not comparable to the Coldwater Creek community exposure fact pattern per the BEIR VII Phase 2 report.

The Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation (funded by which companies' and other entities' interests?) BEIR VII Phase 2 report interestingly discourages any study of environmentally exposed groups of all ages and both genders to low levels of ionizing radiation due to other possible variables. ATSDR leans heavily on both the BEIR VII Phase 2 report and EPA report, and truthfully shares above this is the only evaluation possible to use residential area sampling data to estimate exposure and cancer risk. Might both the ATSDR and the scientists at the Committee to Assess Health Risks from Exposure to Low Levels of Ionizing Radiation explore looking at the Coldwater Creek community detailed health outcomes we have gathered (with people willing to share more) in the multiples of thousands? Yes, our U.S. federal agencies and international committees would learn the truth of chronic exposure to low-level ionizing radiation from Coldwater Creek residents: a plethora of cancers, autoimmune diseases, birth defects, and infertility may occur in populations exposed to ionizing radiation left to meander haphazardly for over sixty years in our environment. ATSDR and BEIR VII Phase 2 funders...Why are pregnant women discouraged from having x-rays taken? Let us learn from this Coldwater Creek area tragedy, as Coldwater Creek long-time residents are the world's Petri dish of what happens to human life after chronic low-level ionizing radiation exposure.

Sent 8/31/18
To Whom it May Concern,

I grew up in Black Jack Missouri. I lived there from 1976 to 1988. I also lived in several other north county locations and St Charles locations prior to that. I am now a nurse in Illinois.

I recently found out that I have thyroid cancer. It is a rare type frequently found in patients who have been exposed to radiation. I have spoken with many experts. I also had to have a quintuple bypass at 41 and have had 30+ kidney stones.

I read the report regarding the cold water creek area radiation exposure. Although there was a lot of work having gone into it and it did make certain strides to addressing the community concerns, I have several concerns regarding the data analysis. The list of references included quite a few from groups that would benefit from this going away. Also the 70 year expected lifetime dose evaluation seems contradictory to the referenced 33 year exposure model used. Does that type of thinking alter the data? The water table data seems to reference only the later years' information. I read the hydrogeological surveys for other years including in the 1970's that does not have the same water sources and locations as your current ones do. I understand that the point was to keep the information limited to a small area that you examined, but 6 inches deep in a flood plain may be more than standard but hardly effective. Soil turnover in frequently flooded areas are quite inconsistent. When all of these decisions that you made in forming this report come together, it appears as though the data was cherry picked to create low level exposure look. So many people's lives have been affected. People are sick and dying simply because they had the misfortune to live in an area that did not respect their lives.

Sent 8/30/18
To whom it may concern:
Regarding, the recent report and findings of the report by ATSDR reviewed in St Louis County, Mo:
During the time period of 1964 - 1987, I lived and grew up in Florissant, Mo. area. The first address was in the subdivision of Wedgewood and second address was subdivision of Paddock Estates. During the time of living in these areas, I spent time outside playing in and around Cold Water Creek. In addition, we played in the dirt of this area as new homes were being constructed. In both homes the basements would flood and back up with water from the creek. In addition being a part of Girl Scouts, meant spending time in many of the local parks.
I recently became aware of the issues surrounding the Cold Water Creek Area; I, moved from the St. Louis area in 1987 to [PII removed], North Carolina where I currently reside. I was shocked saddened and in general, had a feeling of disbelief. The area I had grown up in was a contaminated!!
Listed below are health concerns I have experienced as well as family members no longer living:
1.) I was diagnosed with ovarian cysts of large size which had to be removed and repair what was left of the ovary. In addition I was diagnosed with Endometriosis.
2.) Approximately, 4 years later I was diagnosed with hypothyroidism.
My Father died at age 60 with lung cancer. He owned a business which backed up to the Creek; not to mention the many times our basements flooded from the creek.
My Step-Mother who worked daily at the business, my father owned, died of a grade 4 melanoma brain tumor.

Several suggestions have been proposed on the handling of the issues of the Cold Water Creek area. One of my main concerns is notifying all of the population who lived In this affected area Nationwide!!!!. I still have family and friends who are completely unaware of the problems of the Cold Water Creek area who live in the St. Louis area!!! I believe it is very important to have some type of notification on a national scale to alert and advise on the Cold Water Creek

situation.

I look forward to future recommendations and actions.

Sent 8/30/18
To whom it may concern,
I grew up in St. Louis right next to the airport. In January of 2000 I had a seizure. I found out that I had a tumor 1/4 of my right Frontal Lobe. I was told it was a very rare and slow growing tumor. Because I didn't still reside there, I had no way of knowing about the Cold Water Creek exposure. There is no doubt in my mind that the tumor I had was caused by the Radiological contamination! Once it hits water, there is no way of knowing how far it contaminated. Everything I've read from the improper methods of transporting to it seeping into waterways is all incorrect. I'm a 40 Hr. Haz-WOPER trained individual in California. Hazardous waste is the same everywhere. Only difference is the laws in different States. I'm lucky to be Alive! I'm sending this information to meet your August 31, 2018 deadline.

Thank you very much for your time and attention to this disaster that has been created.

Sent 8/31/18
This is part of my family history connection to this issue, and it's still being wrote.

[PII removed] Families. There has been more deaths in our family associated with some form of cancer, and we all lived in Robertson between 1950 until Robertson Community revitalized by the companies that are there now. The only BUILDING left from Robertson is our Church:

1st Baptist Church of Robertson

Attached comments:
My Robertson Families
It's Time OUR Voices Are Heard

The attention is being focused on Bridgeton and Coldwater Creek Families exposure to the Manhattan Project Radioactive Waste. However, the families in our community are being forgotten. I keep hearing the FUSRAP is only focused on the clean-up of Coldwater Creek. It's truly amazing how Robertson land wasn't cleaned up until all of our families where relocated by the Airport buy-out. The problem with this:

Damage to our families had already been DONE

I've asked this question at each meeting. Where are the maps of Robertson, since you have them of Lindbergh, Coldwater Creek and 270? They even have a map with Berry Hill golf course. If I'm not mistaking Robertson was in the middle of Berry Hill and Lindbergh, so why wouldn't our community appear on the map. They don't want to admit our community was impacted by the Manhattan Project Radioactive Waste. If you don't know my sister [PII removed] is fighting breast cancer, and based on our research this and other illness come from being exposed to this STUFF. Also, my aunt [PII removed] is fighting several health issues and she also had breast

cancer. Our mother, aunt and uncle passed from cancer. Leukemia is another form of cancer being associated with this STUFF. Years after my cousin [PII removed] on passed we couldn't find any connection that could be associated with this rare cancer Studies are now linking Leukemia to this STUFF. [PII removed] was 14yrs old when she started going to the doctor and they didn't find the Leukemia for 2 years. What I remember the doctor telling her parents was it hides from the light that could detect it. When it was finally discovered it was too late. She lived to make it to her 16th birthday ([PII removed]/86). She pasted away in November of the same year.

I've been told that the Statue of Limitation has expired for my Mother, Aunt, Uncle and Cousin. Please explain how this could be; if we never had knowledge that our family was EXPOSED to this STUFF.

My aunt [PII removed] just pasted (07/2018) and my sister is trying to set up a 5 year survival trip in 2 years. We don't even know; if she will make it. She's a fighter like our mother, and I pray she makes it.

We are trying to gather as much health data as possible to present to whoever is listening and reacting to the Bridgeton and Coldwater Creek families. If you have pictures of Robertson that shows this community was here before the Hazelwood Logistic and the other companies where built. Please provide or post on the Robertson Website.

Sent 8/31/18
To whom it may concern,
The following is my response to the Coldwater Creek Public Health Assessment.

I fully understand that this public health assessment is entirely data driven. While I am satisfied that ATSDR was able to determine that exposures at Coldwater Creek could lead to increased risk for certain types of cancer; I am also dismayed that there are a multitude of other illnesses/diseases that ATSDR cannot link due to the lack of data, as well as there isn't really a community/population like Coldwater Creek to be adequately compared to. Although the agency cannot say the vast amount of other illness/disease in our population was caused by our exposure to radiological contaminates from the Manhattan Project, I feel the agency also cannot say the illness/disease weren't caused by it either (since the data does not exist to confirm or deny either claim).

I am for the most part pleased with ATSDR's recommendations and willingness to facilitate consultations between current and former residents' personal physicians and medical specialists in environmental health. I am also pleased with the agency's support for efforts to identify and properly remediate radiological waste around Coldwater Creek, specifically in regards to tributaries and sediment moved from the floodplain and used as fill in construction.

I know that ATSDR is unable to evaluate other exposures, such as inhaling dust blown from historical radiological waste storage piles as no sampling data exists. The reason no sampling data exists is because those in charge of the historical piles at the time did not run monitors and were frequently in violation of the handling of these materials. I am hopeful that if new

historical data comes to light it will be reviewed and considered appropriately.

As far as the ATSDR recommending "public health agencies continue to evaluate community concerns about exposures to the extent possible and educate the community about radiological exposures and health" - I think that's great. However, I also think we are way beyond "concerns" at this point. We are in a full blown health crisis and have been for a number of years. Decades. I am thankful that these issues are getting the attention they deserve now, although it is too little/too late for the thousands of people that have already died and also those whose lives have been irrevocably changed due to the gross negligence of the handling of these radiological contaminates from the Manhattan Project.

I understand why ATSDR does not recommend additional general disease screening for past or present residents around Coldwater Creek. I agree that people who are not displaying any medical symptoms/issues should not just go out and start getting diagnostic imaging/tests done as it will only increase the amount of radiation their bodies have been exposed to. Makes sense. With that said, I do believe there should be some kind of program(s) for those affected by Coldwater Creek (past and present) to utilize in their time of need. I know people who have undergone over 40 surgeries. They still died. I know people who spend $12,000.00+ a month on medication to treat their cancer. They are so sick they can't work. And they are still dying. When those affected pass, they leave their families in a wake of financial devastation and a lifetime of immeasurable grief. There must be some kind of resources allocated to lessen some of the heavy burden those of us that grew up here carry for the rest of our lives.

ATSDR touts itself on being protective of human health and the environment. I feel that many recommendations of the PHA adequately support these protections; however, there is still much more work that needs to be done. Unfortunately, we cannot undo decades of the negligent mishandling of these radioactive materials that poisoned entire generations of North St. Louis County. We can only move forward. In closing, I would like to see a recommendation for Coldwater Creek's inclusion into the Radiation Exposure Compensation Act (RECA).

Sent 8/31/18
To Whom it may concern,

Thank you for the Public health Assessment. The communities that have been affected from this radiation appreciate any data we can receive to show our doctors. I am requesting today that there can be a focus on the other disorder that have plagued the community. I by no means want to take cancer lightly but, I know for a fact living in Hazelwood next to Coldwater Creek from 1979- 2005 that my family and friends have other health issues that need to be mentioned and not ignored. A lot of us either have some type of auto Immune disorder such as Hashimoto’s, Hypothyroidism. My sister was just diagnose with ALS and if you study that disease you will see that being expose to radiation is one of the factors. Not only are we that lived in the neighborhood during the time of the expose being affected by these disorders but our children and grand- children are being affected as well with these disorders.
To summarize what I am requesting is to please keep not ignore that the radiation not only gave us cancer but it has also affected 10000 of people with other diseases as well.

Thank you for your time,

Sent 8/31/18
Thank you so much for all of the time and effort involved in your study. My family lived on Palm Drive in Hazelwood from 1968-1970. My brother, [PII removed], passed away in January 2018 from Synovial Sarcoma, a rare cancer. My comment concerns the use of the language in the following sentence: "Children and adults who regularly played in or around the creek or lived in its floodplain for many years in the past (1960s to 1990s) may have been exposed to radiological contaminants." I do not think the "for many years" is correct as we lived on one of the worst streets (see number of cancers on Palm Drive) for two years, which is probably not considered "for many years,' and my brother still had cancer. He was 3-5 years old when we lived in Hazelwood and constantly outside. The creek was just down the street and flooded our backyard and our vegetable garden every time it rained.

Thank you for paying attention to all of the victims of the Coldwater Creek Exposure.

Sent 8/31/18
To Whom it May Concern:

As a Florissant resident until age 25, spanning from 1971 - 1997, this serves as my testimony and statement to the CDC/ATSDR regarding my experience with Coldwater Creek. I strongly believe that exposure to creek pollutants is the only possible explanation for my many health concerns.

I am currently 47, and deaf in my right ear from a congenital birth defect. At age 31, I was diagnosed with Grave's Disease, as well as a tumor in my parotid gland, a pleomorphic adenoma. From 2006-2009, I went through many fertility procedures including multiple rounds of ART (assisted reproductive technology), to no avail. In December 2017, after months of misdiagnosis and multiple physicians across many specialties, I was diagnosed and had 3 surgeries for osteomyelitis of the mandible. No one in my immediate or extended family has any of these health issues.

At my primary school, Salem Lutheran - Blackjack on Parker Road, I know many of my classmates, schoolmates, teachers, and parents that have had a wide range of maladies to include autoimmune diseases, tumors, bone diseases, GBM's, childhood testicular cancer, among others, and other unusual illnesses.

Our home was [PII removed] to Paddock golf course, where a creek separated backyards from fairways. Kids from around the neighborhood would often get in the creek. We would look for golf balls, wade in shallow water when it was hot, and spent nice days enjoying the shade of the trees. In the 1970's-early 80's, kids played outside much more. There was no cable TV or video games, so all of the kids would play outside, when they got home from school, on weekends and all summer. I never imagined that one day, due to mankind's negligence and greed, there would be evidence that ionizing radiation particles had dangerously polluted my hometown.

My understanding of your process is that any increase of cancer of a certain type in a population of 10,000 is how the PHA derived its conclusions. That methodology doesn't seem to address the

actual number of cancer cases among residents immediately adjacent to the creek. Although anecdotal, I personally know so many people now dead from cancer or cancer-related complications, including my father, that I don't trust a government agency measuring another government agency. Cost/benefit analysis does not take into consideration that the people most sickened by this war weapons waste were vulnerable children. The way that the current administration policies support expanding war and minimizing government responsibility gives me little confidence that the government can fix the government. It's like asking cancer to cure cancer. There is no incentive.

The daily horrors of knowing that I and people close to me have suffered terribly and continue to suffer, there is no excuse for the government to delay action. Please pursue resolution as quickly and robustly as possible. This includes acknowledgment of government wrongdoing, inclusion into RECA, and an apology to the innocent victims of friendly fire who didn't know that they were hurt and killed as a result of war profiteering.

Sent 8/31/18
This is in response to an article in the St. Louis American titled Settlement at Bridgeton Landfill Resident comment on CDC report on higher cancer incidence from Coldwater Creek by Sandra Jordan July 5, 2018.
My father [PII removed] worked at the Coldwater Treatment Plant for many years and lived in the Hazelwood, North County area for many years and contracted cancer which may have been caused as a result of the Coldwater Creek. What recourse does he have?

Sent 9/1/18
Hello, my name is [PII removed] I use to live in Florissant in 2011. I was diagnosed with cancer triple negative breast cancer back in 2013. I was only 30 years old with 3 children, when this occurred. The doctor's did genetic testing on me. The cancer trace was not in my genes. I asked my oncologist how did the cancer come about if it wasn't genetic she replied, "I don't know". I had a double mastectomy and tradition the cancer came back behind my sternum while getting treatments. So I had to do more radiation and more chemotherapy. Know today I suffer from lymphedema in my right arm due to radiation treatments. All I have is scars left from this unknown cancer.
I would like to be considered as a candidate for this cold water creek lawsuit.

8/31/18
Good evening

I have read the findings that were released regarding Cold Water creek in North St. Louis County, Missouri.

I find it encouraging that part of the conclusions were that there was an increase of some risks of some cancers.

I would propose that a wider study be done, especially in relation to nonhereditary rare cancers but that there needs to be more publicity for those who moved away from the area that may be unaware of the possibility of connections to where they grew up or lived long term and

diagnosed cases of cancer. It would also be interesting to research auto-immune conditions as well.

I was diagnosed with a rare ovarian cancer called granulosa germ cell. it is caused by a gene mutation in The FoxL2 gene. The only cancer that runs in my family is lung cancer in my father's side, but both individuals who had it were previous smokers who lived in downtown during the 1940-1950 and then my dad moved to Berkeley and Florissant as an adult. He also randomly acquired type one insulin dependent diabetes at age 55.

I had no idea of the situation in North St Louis County until earlier this year. I grew up in Berkeley for seven years and then lived in Florissant off of New Halls Ferry, went to school in downtown Florissant, played softball on a field that would flood with creek water, had a basement that flooded with water often that I played in for hours at a time when it was dry, and played in St. Ferdinand park often. I imagine there are others that have battled cancer that are unaware that there may be a connection or who should report their health history to an additional study.

I am thankful I no longer live there, but if I did, I would want my house and heard tested.

Thanks for how you are currently researching this matter.

Sent 8/31/18

Please continue testing and cleanup of Coldwater Creek and it's areas through the Army Corps of Engineers program. Please continue to educate the at risk population please include our community and the federal radiation exposure compensation act/downwinders program & please please include Autoimmune diseases and other issues such as fertility and children of the exposed medical concerns.

Sent 8/31/18
Coldwater Creek PHA Comment- ASTDR Report June 18, 2018

Thank you for your evaluation of community exposure to the World War II nuclear weapons waste which was allowed to migrate into Coldwater Creek and its floodwaters. Thank you also for your recommendations relating to additional FUSRAP investigation and testing to properly contain and remediate all affected areas. The following comments are directed toward assisting in the efforts to protect the community and provide assistance to those impacted by the nuclear waste products.

RISK MODELS USED TO ASSESS EPIDEMIOLOGICAL AND RADIO-BIOLOGICAL DATA

- According to page E-10 the EPA used the National Academy of Sciences report of 2006 Reference 113. This was published in 2006. Was the study of Leurad, et al 2015 "Ionizing Radiation and Risk of death from Leukemia and lymphoma in radiation monitored workers" considered in the EPA report? This report internationally studied over 300,000 workers. This report confirms risks at low dose rates rather than extrapolating them from high levels found at

Hiroshima. This report called into question ICRP's use of dose rate effectiveness factors. This report provided strong evidence of a dose response relationship between cumulative, external, chronic low dose exposure to radiation and cancer. This data should be utilized to evaluate lifetime risks, especially where long time exposures to low levels of radiation exist.

MODELING OF PAST AIR EXPOSURES

• It has been established that Thorium 230 had an affinity to attach to dust particles and can travel long distances. In the SEC Petition Report SEC-00150, April 12, 2010 there is data that could be useful in modeling air exposures. For example it mentioned that Thorium 230 was measured to be 76700 uCI/g in AM-7 residues which were stored 1946-1966. The report also stated that there were 74,000 tons of this inventory. There also was 32,500 tons of AM-10 stored in the open with a high Thorium 230 content. It is strongly recommended that a modeling of past air exposures be completed.

Thank you again for all your efforts
[PII removed]
former Florissant resident of 29 years.

Sent 8/31/18
Hello,
I am writing to beg for help as a florissant & Coldwater creek resident. I have lived here in the community for 50 years. Between four residences I have always lived along the creek. For the last several years I have been fighting multiple immune disorders and been a medical puzzle so to say. No family history. Another one of my children has strange anomalies in his brain etc. I have three children. I have lost many friends to brain and other cancers. Please include us in the radiation exposure compensation act. Please include us and testing of tributaries and personal properties. I am just learning of many things including today's the deadline to ask for more help with this issue? So many of us need information. My parents bought their first home here when I was One year old. I could go on and on with examples. My health holds me back from so many things. I would love more information and to talk with someone. My phone number is [PII removed]. Thank you for everything and anything you can do to help us.

Sent 8/31/18
Subject Coldwater Creek
Please continue testing and cleanup of Coldwater Creek and it's areas through the Army Corps of Engineers program. Please continue to educate the at risk population please include our community and the federal radiation exposure compensation act/downwinders program & please please include Autoimmune diseases and other issues such as fertility and children of the exposed medical concerns.

Thanks

Sent 8/31/18
Dear Madam or Sir:

My compliments for the courage to give a presentation at St. Mark's United Methodist Church on June 27th and 28th, 2018, in front of an audience that, at times, was hostile.

As a former cartographer, I was disappointed with the size of the maps on the posters in the meeting room. Too much information was presented in the graphics for their size. I was left with the impression that every piece of property along Coldwater Creek from I-270 to St. Denis St. was contaminated with Thorium-230, Radium-226, and/or Uranium-238. I also could not read the legend. After reviewing the graphics in the report, I discovered that not every piece of property along the creek was contaminated. In the future, I would like to suggest:

1. Increasing the size of the poster maps/graphics so that they can be easily read and understood; and
2. Attaching interactive maps/graphics to the reports.

Also, I would like to encourage ATSDR to conduct a modeling to evaluate possible exposure to windblown dust contaminated with radioactive waste. This might help explain the increased presence of cancer in a region not located near the creek.

I have a question. Were the radioactive waste sites at the airport disturbed between the time they were created and the time they were removed? If they were, the disturbances might have released additional radioactive dust into the environment.

Thank you for the opportunity to comment.

Sent 9/1/18
My name is [PII removed] and I am 36 years old. The creek runs behind my house and a tributary runs alongside. I have lost both of my parents in the last 5 years, both from cancer. My mom in 2014 passed away at 68 from Glioblastoma Multiforme, (brain tumor) and my dad passed away this April from complications related to lung cancer, although he has never smoked a cigarette in his life. My parents lived near the airport in 1969, and bought their first house in the 70s, right by Coldwater Creek. Although we have lived in multiple locations since then, my Mom bought our current house in 2011. We didn't know the creek by our house was Coldwater Creek. I also can see Jana Elementary from my backyard. I see kids out there year after year, in the field, within a stone's throw of the creek. My 13 year old son was one of those kids for 5 years. I know of 5 people in my neighborhood of 105 homes that have died from cancer in last 5 years. According to Coldwater Creek Facebook page, many more over the years, several from brain tumors, many lived on my street ([PII removed]). Our area hasn't been tested yet, and I was told it may never be tested. There is also easy access to the creek and tributary right behind our house. This is the "hangout" for so many kids, who probably have no idea what they are playing in. There are NO SIGNS of any kind to warn of anything, and I have been told it's because it doesn't pose a significant threat. How does anyone really know this if it hasn't been tested yet? Judging from the number of cancers in my neighborhood alone, I strongly disagree. I like many of my neighbors, feel stuck and don't want to pass this problem on to somebody else, like so many others have. I also would like to know if there is any recommendation for blood testing that my son and I can have done, to see if we have inherited/developed any sort of gene mutations or abnormalities related to cancer, I plan on bringing it up at next dr. appointment, but would like

any information to guide them to the right test. I have a lot more to say, but want to be sure I get this in before deadline. Thank you for what you are doing.

Sent 9/1/18
It seems positive and encouraging that this government report indicates and acknowledges that there "may" be correlation from exposure from Coldwater Creek ionized radiation pollution and certain cancers. It is a good start.

I would like to however, share and reference that another governmental agency gas already researched and acknowledged cause and effect of ionized radiation exposure and lists presumptive diseases that are common to such exposure. The United States Department if Veterans Affairs is the agency and it compensates exposed veterans. The VA's list was of particular interest to me, as my father, who had been otherwise active and healthy for a man his age, developed and dues from bile duct cancer. He moved to Florissant in 1979 and lived there until his death in 2013.

Please review the attached list for reference.

I hope that there will be continued cleanup efforts and that this concerning exposure will no longer remain the elephant in the room of North County, that no one wants to notice or claim to be real.

[attached link www.publichealth.va.gov/exposures/radiation/diseases.asp]

Sent 9/1/18
My name is [PII removed] and I lived in Florissant MO from birth 1975 to 2006. I lived at [PII removed] from 1975-1991; then [PII removed] from 1991-1997; [PII removed] from 1997-2000; [PII removed] from 2000-2003; [PII removed] from 2003-2009.

I have a pituitary Tumor that is wrapped around my carotid artery that was discovered b/c of headaches caused by pressure on my optic nerve by this Tumor. This was found in July of 2017. I have been on medicine since then and it has had a negative impact on my life in many ways: physically, financially and emotionally.