UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
REGION 7
11201 Renner Boulevard
Lenexa, Kansas 66219

Mr. Ken Starr
U.S. Department of Energy
Office of Legacy Management
11025 Dover Street, Suite 1000
Westminster, Colorado 80021

Dear Mr. Starr:

The U.S. Environmental Protection Agency is sending this letter as a follow up to the August 14, 2018, correspondence regarding the Femme Osage Slough, or Slough, at the Weldon Spring Quarry/Plant/Pits site. This letter is to inform the Department of Energy, or DOE, that the re-evaluation of potential human health risks at the Slough is complete and to provide a summary of findings. A report fully detailing the EPA's methodology and results is enclosed.

The purpose of this risk assessment re-evaluation was to update estimates of potential health risks posed by the Slough using the EPA's current Superfund risk assessment methodology and guidance, including updated toxicity values and exposure factors. In this re-evaluation, the EPA found no unacceptable human health risks at the Slough. The below table summarizes the estimates of excess lifetime cancer risks and noncancer hazards to both adult and adolescent recreational visitors.

Summary of Recreational Receptor Risks
Human Health Risk Assessment Re-Evaluation
Femme Osage Slough, Quarry Residuals Operable Unit

Media	Excess Lifetime Cancer Risk		Noncancer Hazard Index	
	Adult Receptor	Adolescent Receptor	Adult Receptor	Adolescent Receptor
Surface Water	8E-07	6E-07	0.08	0.2
Sediment	5E-07	6E-07	0.01	0.02
Fish Tissue	2E-05	8E-06	0.2	0.1
Total	**3E-05**	**9E-06**	**0.3***	**0.4****

Notes: All Hazard Indices are rounded to one significant figure.

* This value was rounded up from 0.254. See Table A21 in the enclosed report.
** This value was rounded up from 0.368. See Table A22 in the enclosed report.

Per 40 CFR 300.430(e)(2)(i)(A)(1) of the National Oil and Hazardous Substances Pollution Contingency Plan, "for systemic toxicants [noncancer risk], acceptable exposure levels shall represent concentration levels to which the human population, including sensitive subgroups, may be exposed without adverse effect during a lifetime or part of a lifetime, incorporating an adequate margin of safety." A hazard index greater than one represents the threshold for unacceptable noncancer risk. Per 40 CFR 300.430(e)(2)(i)(A)(2), "for known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6}." Per the April 1991 EPA guidance titled *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions* (OSWER Directive 9355.0-30), "[w]here the cumulative carcinogenic site risk to an individual based on reasonable maximum exposure for both current and future land use is less than 10 (-4) and the non-carcinogenic hazard quotient is less than 1, action generally is not warranted." In this re-evaluation, the estimates of total excess lifetime cancer risks posed by exposure to all media at the Slough fall within the EPA's acceptable cancer risk range, and the total noncancer hazard indices are less than 1, for both adolescent and adult recreational visitors.

During previous correspondence and conversation, concern has been raised regarding the movement, or lack thereof, of surface water (and potentially fish) between the Missouri River and the Slough. The 1998 Quarry Residuals Baseline Risk Assessment states that "[t]he water level in the slough is controlled by a pipe with a valve that normally is left open, allowing fish to move between the river and the slough. As a result, fish species routinely found in big river habitats, such as the Missouri River, are found in the slough." Concern has been raised that site conditions have changed and fish are no longer able to move between the Slough and the Missouri River due to the referenced pipe becoming clogged with sediment. In order to evaluate this concern, the EPA inspected the Slough during the 2018 annual site inspection on December 4, 2018. During the inspection, the EPA observed the referenced pipe and valve between the Missouri River levee and the Slough. The valve was closed at the time of the inspection; however, the inspection team was able to easily open the valve and observed water flow through the pipe towards the Slough. Based on this observation, it appears that surface water can still be exchanged between the Missouri River and the Slough. Regarding fish movement, it appears unlikely, given its location and size, that significant fish movement has ever occurred through the referenced pipe. The EPA found no evidence of a change in site conditions, regarding the referenced pipe and valve, that would impact the assessment of potential risks in this human health risk re-evaluation. The EPA's observations from the 2018 site inspection are documented in the enclosed trip report.

In summary, this re-evaluation, conducted according to current risk assessment methodology, found no unacceptable risks of cancer or noncancer health effects to adult or adolescent recreational visitors at the Slough. In addition, the EPA found no evidence of a change in site conditions based on surface water exchange between the Missouri River and Slough. For these reasons, the EPA is not requiring additional work to be performed by the DOE at the Slough. The EPA considers this issue resolved. If you have any questions, you can contact me at (913) 551-7868 or at oconnor.daniel@epa.gov.

Sincerely,

[redacted]

Danny O'Connor
Remedial Project Manager
Federal Facilities and Post Construction Section
Superfund Division

Enclosure

cc: Taylor Grabner, MDNR (email only)
Tiffany Drake, MDNR (email only)

ENCLOSURE 1

DECEMBER 2018 TRIP REPORT

MEMORANDUM

TO: Weldon Spring Quarry/Plant/Pits File [redacted]

THROUGH: Lynn Juett, Branch Chief SUPR/REMB [redacted]

FROM: Danny O'Connor, RPM SUPR/FFPC [redacted] 12/7/2018

DATE: December 7, 2018

RE: Trip Report – Weldon Spring Quarry/Plant/Pits Annual Site Inspection

Site Name:	Weldon Spring Quarry/Plant/Pits
Address:	Highway 94 St. Charles, Missouri. 25 Miles west of St. Louis, Missouri.
Trip Dates:	12/3-4/2018
EPA Participants:	Danny O'Connor
Other Parties Involved:	MDNR, DOE, and Navarro (DOE contractor).
CERCLIS ID:	MO3210090004
SSID:	073S

Background information/purpose of trip:

This trip included the annual inspection of the Weldon Spring Quarry/Plant/Pits site, or Weldon Spring site. The annual inspection was scheduled to occur on December 4 and 5, 2018; however, EPA only attended on December 4 due to December 5 being declared a national holiday. Activities conducted on December 5, for which EPA was not present, included an inspection of the disposal cell followed by a discussion of issues with the environmental easement and Femme Osage Slough.

Actions taken:

Site Inspection: On December 4, 2018, site team members (MDNR, EPA, DOE, and Navarro) met at the Weldon Spring site job trailer adjacent to the interpretive center. The site team members began the day by discussing health and safety issues and then describing planned activities for the day. The site team broke into two groups, Team 1 and Team 2, for purposes of the site inspection. Team 1 (DOE, Navarro, and MDNR) inspected the monitoring wells on Army property, monitoring wells at the Chemical Plan, historical marker 2, and surface areas near the disposal cell and on Army property to ensure institutional controls were still effective. Team 2 (Navarro, MDNR, and EPA) inspected the southeast drainage, the quarry and associated monitoring wells, and the Highway 94 culvert. No significant issues were identified.

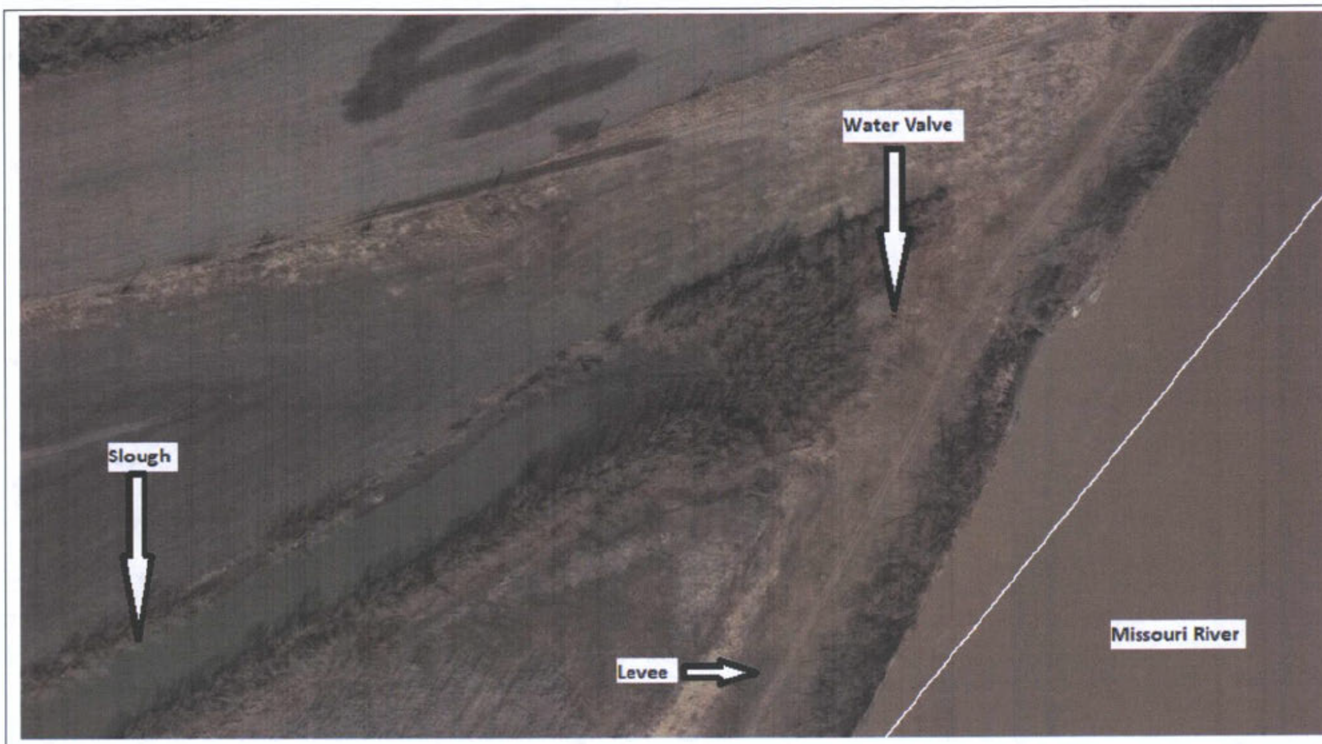
Femme Osage Slough Inspection: In addition to the inspection activities described above, Team 2 inspected the Slough and surrounding areas. The purpose of the inspection was to document current conditions at the Slough. MDNR has previously raised concerns regarding the current status of the Slough as it relates to human health risk. An additional purpose of the inspection was to identify and inspect the condition of a water valve used to allow water flow from the Missouri River to the Slough. MDNR has stated that according to MDC, the value has been plugged and is no longer functional. DOE has stated that according to MDC the valve was unplugged more than a year previous and is currently operational.

During the inspection, EPA observed the following animals either within or very near the Slough: three bald eagles, two blue heron, and one dead fish (approximately 12 inches in length). In addition, there was significant evidence (tree bark removal and teeth marks on trees) of beaver activity near the shoreline of the Slough. The Slough appeared to be approximately 30 feet wide. The water was very turbid and there was little or no movement. For these reasons, a depth could not be estimated.

EPA observed the referenced water valve between the Missouri River levee and the Slough (see Figure 1). The water valve was closed at the time of the inspection; however, the inspection team was able to manually open the valve and water flowed through the valve towards the Slough. The water valve appears to be operational. EPA was unable to locate the inflow pipe on the Missouri River side of the levee due to it be submerged below the water.

Description of Documents/Other Information Obtained and/or Samples Collected

Below is one figure and three photographs pertaining to the Slough. The photographs were taken by Dan Carey with MDNR. Mr. Carey provided the photographs to EPA via email on December 5, 2018. EPA did not collect any photographs during this site visit.



Trip Report Figure 1	Description:	Aerial image showing the Femme Osage Slough, the water valve, the Missouri River, and the levee.
Date: 12/7/2018 Direction: NA	Photographer:	NA, image from Google Earth.

Trip Report Photograph 1	Description:	This photograph shows a water valve between the Femme Osage Slough and the Missouri River Levee.
Date:12/4/2018 Direction: South	Photographer:	Dan Carey, MDNR

Trip Report Photograph 2	Description:	This photograph shows a closer view of the water valve used by MDC to transfer water from the Missouri River to the Femme Osage Slough.
Date: 12/4/2018 Direction: South	Photographer:	Dan Carey, MDNR

Trip Report Photograph 3	Description:	This photograph shows the water Valve looking east towards the Femme Osage Slough. The water valve was approximately 500 feet from the beginning of the Slough.
Date: 12/4/2018 Direction: West	Photographer:	Dan Carey, MDNR

Image Numbers: 1-3
File Name: Weldon Spring 2018 Annual Inspection
Photographer: Dan Carey, MDNR
Type of Camera: Unknown
Digital Recording Media: Delivered via email.
All digital photos were copied by: NA
All digital photos were copied to: NA
Original copy is stored in: NA
No changes were made in the original image files prior to storage on the hard drive.

Report Photo #	Photographer	Date	Approx. Time	File Name (DSCNxxxx.jpg)	Description
NA	NA, Google Earth aerial image	12/7/2018	0851	NA	Aerial image showing the Femme Osage Slough, the water valve, the Missouri River, and the levee.
1	Dan Carey, MDNR	12/4/2018	1622	IMG_4194	This photograph shows a water valve between the Femme Osage Slough and the Missouri River Levee.
2	Dan Carey, MDNR	12/4/2018	1622	IMG_4196	This photograph shows a closer view of the water valve used by MDC to transfer water from the Missouri River to the Femme Osage Slough.
3	Dan Carey, MDNR	12/4/2018	1623	IMG_4197	This photograph shows the water Valve looking east towards the Femme Osage Slough. The water valve was approximately 500 feet from the beginning of the Slough.

ENCLOSURE 2

FINAL HUMAN HEALTH RISK ASSESSMENT RE-EVALUATION REPORT FEMME OSAGE SLOUGH, QUARRY RESIDUALS OPERABLE UNIT

Final Human Health Risk Assessment Re-Evaluation
Femme Osage Slough, Quarry Residuals Operable Unit
Weldon Spring Quarry/Plant/Pits Site
St. Charles, Missouri

March 2019

Prepared for:

US Environmental Protection Agency
Region 7 Superfund Division
Lenexa, Kansas

Prepared by:

Chamberlain Group, Ltd.
400 St. Andrews Circle
Lynchburg, Virginia 24503

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ADAF	Age-dependent adjustment factor
AEC	Atomic Energy Commission
AF	Adherence factor
ABS_d	Absorption fraction, dermal
AT	Averaging time
AT_c	Averaging time, carcinogenic
AT_{nc}	Averaging time, noncarcinogenic
ATSDR	Agency for Toxic Substances and Disease Registry
BRA	Baseline Risk Assessment
BW	Body weight
CA	Chemical concentration in air
CalEPA	California Environmental Protection Agency
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
C_F	Chemical concentration in fish tissue
CF	Conversion factor
CFR	Code of federal regulations
COPC	Chemical of potential concern
CSEM	Conceptual site exposure model
C_{SD}	Chemical concentration in sediment
C_{SW}	Chemical concentration in surface water
D_A	Apparent diffusivity
DA_{event}	Absorbed dose per event
DAD	Dermal absorbed dose
Dia	Diffusivity in air
DI	Daily intake
DOE	Department of Energy
Diw	Diffusivity in water
EC	Exposure concentration
ED	Exposure duration
EF	Exposure frequency
EFH	*Exposure Factors Handbook*
ELCR	Excess lifetime cancer risk
ET	Exposure time
EPA	Environmental Protection Agency
EPC	Exposure point concentration
EV	Event frequency
FA	Fraction of chemical absorbed
f_{OC}	Fraction of organic carbon
GIABS	Gastrointestinal absorption factor
H	Henry's Law Constant
HI	Hazard index

HQ	Hazard quotient
IC	Institutional control
ICRP	International Commission on Radiological Protection
IR	Ingestion rate
IRIS	Integrated Risk Information System
IUR	Inhalation unit risk
Kd	Soil-water partition coefficient
K_{OC}	Soil organic carbon coefficient
Kp	Dermal permeability coefficient in water
MDC	Missouri Department of Conservation
NCEA	National Center for Environmental Exposure
NCP	National Contingency Plan
NHANES	National Health and Nutrition Examination Survey
NPL	National Priority List
ORD	Office of Research and Development
ORNL	Oak Ridge National Laboratory
OU	Operable unit
PEF	Particle emission factor
PPRTV	Provisional Peer-Reviewed Toxicity Value
PRG	Preliminary remediation goal
Q/C	Inverse of mean concentration at center of source
RAGS	Risk Assessment Guidance for Superfund
RfC	Reference concentration
RfD	Reference dose
RI	Remedial Investigation
RME	Reasonable maximum exposure
RSL	Regional Screening Levels
SSA	Skin surface area
SF	Slope factor
T	Total time
TNT	2,4,6-Trinitrotoluene
UCL	Upper Confidence Limit
VF	Volatilization factor

1.0 INTRODUCTION

The Weldon Spring Quarry/Plant/Pits Site is located in St. Charles County, Missouri, approximately 30 miles west of the city of St. Louis. The site encompasses two geographically distinct properties—the Weldon Spring Chemical Plant and Raffinate Pits (Chemical Plant) and the Weldon Spring Quarry (Quarry). In 1940, the U.S. government acquired 17,232 acres of rural land in St. Charles County to construct the Weldon Spring Ordnance Works. In 1941, the U.S. Army (Army) began production of 2,4,6-trinitrotoluene (TNT) and dinitrotoluene to support World War II efforts. The Ordnance Works was decommissioned in 1945 following the end of the war. In 1956, the Army transferred 205 acres of the property to the U.S. Atomic Energy Commission (AEC) for construction of the Weldon Spring Uranium Feed Materials Plant, now referred to as the chemical plant. The chemical plant converted processed uranium ore concentrates to pure uranium trioxide, intermediate compounds, and uranium metal. A small amount of thorium was also processed at the chemical plant. An additional 14.88 acres, including the Quarry, were transferred from the Army to AEC. The Quarry was mined for limestone aggregate used in construction of the Weldon Spring Ordnance Works. The Quarry was also used by the Army for burning wastes from explosives manufacturing and disposal of TNT-contaminated rubble during operation of the Weldon Spring Ordnance Works. In 1960, the Army transferred the Quarry to AEC, which used it from 1963 to 1969 as a disposal area for uranium and thorium residues from the chemical plant.

Historical operations at the site, by both AEC and the Army, resulted in the release of hazardous substances, primarily nitroaromatic and radiological compounds, at the site. The Weldon Spring Quarry/Plant/Pits site, for which the Department of Energy (DOE) is the lead agency, was listed on the National Priority List (NPL) on July 30, 1987. The site was subsequently divided into four Operable Units (OU)—the Chemical Plant OU, the Groundwater OU, the Quarry Bulk Waste OU, and the Quarry Residuals OU. The Weldon Spring Quarry/Plant/Pits site is surrounded by the Weldon Spring Former Army Ordnance Works site, a separate NPL site that is not addressed in this report. The Army is the lead agency for the Weldon Spring Ordnance Works site.

Subsequent to the NPL listing, DOE investigated the site to determine the nature and extent of contamination. This report focuses on potential human health risks at the Femme Osage Slough (Slough), which is part of the Quarry Residuals OU. Results of the investigation for the Quarry Residuals OU can be found in the *Remedial Investigation (RI) Report for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring, Missouri* published in 1998 (USDOE, 1998a). The RI report provides detailed information on the site historical activities and sources of contamination; the physical and ecological settings; and the results of the environmental investigations conducted at the site.

The information and data obtained during the RI was used to develop the *Baseline Risk Assessment (BRA) for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring, Missouri* (USDOE, 1998b) (hereafter referred to as the original risk assessment). The original risk assessment was developed by DOE following standardized US Environmental Protection Agency (EPA) risk assessment methodology, including toxicity values and recommended exposure parameters, available at that time. Since 1998, methodologies for conducting environmental risk assessments have been revised to reflect continuing research, study, and data collection.

The risk assessment re-evaluation was performed due to continued concerns raised by the Missouri Department of Natural Resources regarding current risk levels at the Slough. This re-evaluation provides updated human health risk estimates for current and potential future receptors at the Slough, utilizing current EPA risk assessment methodology, exposure parameters, and toxicological information, in combination with EPA's knowledge of current site conditions. To the extent possible, standardized methodologies and default input parameters were used. Site-specific assumptions made in the original risk assessment were used in the re-evaluation, if still reflective of current conditions and protective for potential future reasonable maximum exposure scenarios. Other site-specific assumptions were selected to reflect current and potential future use of the Site.

This risk assessment re-evaluation is organized in a manner consistent with the four major steps recommended by EPA *Risk Assessment Guidance for Superfund (RAGS), Part A* (EPA, 1989), as follows:

- Identification of chemicals of potential concern
- Exposure assessment
- Toxicity assessment
- Risk characterization

An uncertainty section is included in the risk characterization section of this report to qualitatively discuss the likelihood of health risks being underestimated or overestimated, given the methodology and input parameters utilized.

2.0 IDENTIFICATION OF CONTAMINANTS OF POTENTIAL CONCERN

According to the original risk assessment, chemicals were eliminated from further consideration if they were:

- not detected,
- found to be present in laboratory blanks per the 10x rule,
- common laboratory contaminants,
- found at concentrations lower than background concentrations, or
- classified as essential nutrients.

Under current EPA risk assessment methodology, chemicals are not excluded as COPCs based on comparison with naturally-occurring background concentrations. Similarly, non-detected chemicals may be retained as COPCs, based on elevated laboratory reporting limits. Therefore, for this risk re-evaluation, EPA evaluated the same COPCs identified by DOE in the original risk assessment.

Using the aforementioned approach, 14 chemicals were retained as COPCs for surface water, 20 chemicals were retained as COPCs for sediment, and four chemicals were retained as COPCs for fish tissue. Table 1 presents a summary of all COPCs retained for the environmental media evaluated.

Uranium was identified as a COPC for both chemical and radiological risk assessment. For the purpose of calculating excess cancer risks from the radiological COPC uranium, this risk assessment re-evaluation assumes that the total uranium concentrations reported for sediment, surface water, and fish tissue include the isotopes uranium-234, uranium-235, and uranium-238. The risk calculations also consider short half-life daughters to be present in secular equilibrium. For natural uranium, uranium-235 is present at 0.7% total mass weight and is five percent of the uranium-238 activity. According to Section 2.2.1 of the original risk assessment, "*The data evaluation process for radionuclides resulted in the identification of radium-226, radium-228, thorium-228, thorium-230, thorium-232, and uranium-238 as COPCs for soils from the quarry proper. For the other media (i.e., Slough surface water and sediment, and groundwater), only uranium was identified as a COPC. Other radionuclides were screened from consideration because they are present at near-background concentrations*." (USDOE 1998b).

3.0 EXPOSURE ASSESSMENT

The objectives of the exposure assessment are to characterize potentially exposed human receptors at the site, to identify actual or potential exposure pathways, and to quantify the potential exposure. Each of these steps are discussed in detail below as to how they pertain to this risk assessment re-evaluation.

3.1 Characterization of the Exposure Setting and Identification of Receptors

As the first step in the exposure assessment, the exposure setting is characterized in terms of its physical characteristics, land use, and potentially exposed populations.

The Slough was described in the RI report as an "*isolated, 1.5 mi long body of water approximately 500 ft south of the quarry. The slough was formed in 1960 when downstream reaches of the Femme Osage Creek and the Little Femme Osage Creek were cut off from their natural channels by a levee constructed…*" (USDOE 1998a). The Slough is within the Weldon Spring Conservation Area which is owned by the Missouri Department of Conservation (MDC). According to MDC's website, the "*department encourages recreational use of the area [referring to the conservation area] by the public, while furnishing fish and wildlife with the resources necessary to be healthy and abundant*." A small parking lot is located north of the Slough along the Katy Trail. The Katy Trail parallels the Slough to the north and is utilized primarily for walking and biking. At its nearest point, the Slough is less than 100 feet from the trail. The banks of the Slough are heavily vegetated and steep, with limited access. Fishing has reportedly occurred at the Slough, although the frequency is likely low due to limited access and likely small fish population. Given current site conditions (limited access, very turbid water, etc.), swimming is considered unlikely; but, was evaluated in this risk assessment re-evaluation due to estimated water depths, the proximity of the Katy Trail and parking lot, and potential for recreational use of the Slough. This risk assessment re-evaluation assumes that a receptor may come into contact with sediment through the act of accessing the Slough for swimming and fishing. There are no known current or future plans for residential, or similar (e.g., schools, daycares, or hospitals), development in the conservation area. The reasonably anticipated future land use is to continue as conservation property under MDC ownership.

The original risk assessment notes that the "*water level in the slough is controlled by a pipe with a valve that normally is left open, allowing fish to move between the [Missouri] river and the slough*" (USDOE, 1998b). More recently, there has been discussion as to whether this connection between the Slough and the Missouri River is still functional. EPA inspected the referenced valve on December 4, 2018, during the annual site inspection. At that time, EPA observed the valve to be operational and when opened, river water flowed through the valve towards the Slough. EPA concluded, based on these observations, that site conditions regarding movement of water between the Missouri River and Slough remain unchanged since the original risk assessment.

As part of the Remedy for the Quarry Residuals OU, a restrictive easement institutional control (IC) was implemented for the area extending from the Quarry south towards the St. Charles County Well Field. This IC encompasses a portion of the Slough directly south of the Quarry. The IC restricts groundwater use within an area extending from the Quarry south towards the St. Charles County Well Field. In addition, the IC prevents drilling, boring, digging, construction, earth moving, and other activities that could result in disturbing the soils within a natural reduction zone along the northern bank of the Slough.

Based on the aforementioned site conditions and property ownership, a recreational visitor is the most likely receptor under both current and future conditions. This receptor evaluation is consistent with the original risk assessment. It is assumed that recreational visitors may come into contact with surface water and sediment of the Slough and may also ingest fish caught from the Slough. The original risk assessment only evaluated an adult recreational visitor; although an age-adjusted sediment ingestion rate was conservatively used to reflect higher ingestion by a child, all of the other exposure parameters were for an adult. Current EPA Region 7 practice is to evaluate children or adolescents under recreational scenarios because their exposures may exceed those to an adult and pose greater health risks. During the December 2018 site inspection, EPA observed the Slough to be heavily vegetated within 10 feet of the bank with steep drop-offs to the water. Although the Slough is near the Katy Trail, direct access to the Slough is limited and unlikely for children 0 to 6 years. Accounting for both current site conditions and EPA Region 7 risk assessment practices, adolescent (age 6 to 16 years) and adult recreational visitors were evaluated in the risk assessment re-evaluation.

3.2 Identification of Exposure Pathways

In the original risk assessment, it was assumed that a recreational visitor to the Slough would come into contact with site media by wading and fishing activities. The reasonable maximum exposure scenario used to evaluate surface water, based on current EPA Region 7 risk assessment practice, is to assume that swimming could occur in water bodies deeper than two to three feet, but that exposures are limited to wading in shallower surface water bodies. Despite the known turbidity of the Slough and steep banks, the more health-protective swimming water scenario was evaluated in the risk assessment re-evaluation because it is supported by the water depths, based on current risk assessment practices.

The following exposure pathways are considered complete and are quantitatively evaluated in this risk assessment re-evaluation for adult and adolescent recreational visitors exposed to chemical contaminants. These same exposure pathways were evaluated in the original risk assessment, for an adult recreational visitor only.

- Surface water ingestion
- Surface water dermal contact
- Sediment ingestion
- Sediment dermal contact
- Inhalation of particles and volatile compounds from sediment
- Fish ingestion

The approach to evaluate exposure to radiological contaminants differs from that of chemical contaminants. In the original risk assessment, the same exposure pathways used to evaluate exposure to chemical contaminants at the Slough were also used to evaluate radiological exposures. However, in the risk assessment re-evaluation, complete exposure pathways were identified in accordance with current risk assessment methodology, as described in the *User's Guide for the EPA's Preliminary Remediation Goals for Radionuclide Contaminants at Superfund Sites* (https://epa-prgs.ornl.gov/radionuclides/users_guide.html). Thus, surface water immersion and sediment external exposure to ionizing radiation were evaluated, in place of dermal contact with surface water and sediment. The following pathways are considered complete and are quantitatively evaluated in this risk assessment re-evaluation for adult and adolescent recreational visitors exposed to radiological contaminants:

- Surface water ingestion
- Surface water immersion
- Sediment ingestion
- Inhalation of sediment particles
- Sediment external exposure
- Fish ingestion

To more easily visualize the pathways considered to be complete for an environmental risk assessment, a Conceptual Site Exposure Model (CSEM) is developed. The CSEM depicts the path a contaminant follows from its release to the environment, to intake by a receptor. Pathways considered to be complete are shown on the CSEM.

Figure 1 presents the CSEM for a receptor's potential exposure to chemical contaminants. As the approach to evaluating exposure to radiological contaminants differs from that of evaluating exposure to chemical contaminants, a separate CSEM has been developed, see Figure 2.

3.3 Quantification of Exposure

In the exposure assessment, intake of COPCs for each receptor resulting from contact with contaminated media are calculated. These values are determined in three steps: 1) exposure point concentrations (EPCs) are calculated for each COPC identified in each medium of concern, 2) exposure assumptions for human contact with contaminated media are selected, and 3) chemical and radiological intakes are calculated using equations that combine the EPCs and exposure assumptions for each receptor.

3.3.1 Chemical and Radiological Exposure Point Concentrations

An exposure point is a location where a receptor is reasonably assumed to move at random, throughout the duration of exposure, and where contact with an environmental medium is equally likely at all sub-locations. The concentration developed to represent that exposure is termed the exposure point concentration (EPC). Because of the randomness assumed for exposure, an EPC is derived as an estimate of the true arithmetic mean concentration of a chemical in a medium at an exposure location. However, because the true arithmetic mean concentration cannot be calculated with certainty from a limited number of measurements, EPA recommends that if enough data are available, the 95^{th} percentile upper confidence limit (UCL) of the arithmetic mean at each exposure point be used when calculating exposure and risk at that location (USEPA, 1992). If the 95% UCL exceeds the highest detected concentration or if insufficient data is available to generate the UCL, the highest detected value is used as the EPC instead (USEPA, 1989).

The statistical software currently used by the EPA to calculate UCLs was not available at the time of the original risk assessment. EPA's model ProUCL version 5.1 (USEPA, 2015) is now used to calculate a number of different statistical UCLs, given the distribution of the data set. This model also takes into account non-detect chemical concentrations using statistical approaches, such as Kaplan-Meier, which differ from the substitution methods used when the original risk assessment was developed. The previous approach to evaluate non-detect chemical concentrations was performed by recognizing a surrogate concentration as one-half the reported detection limit.

In the original risk assessment, EPCs were selected as follows for the environmental media evaluated:

- Surface water – the maximum detected concentration
- Sediment – the 95% UCL
- Fish tissue – the maximum detected concentration

For this risk assessment re-evaluation, the same EPCs are utilized as in the original risk assessment, with the exception of the uranium EPC for surface water. The original risk assessment selected the maximum detected uranium surface water concentration from data collected after 1995 and up to completion of the original risk assessment as the EPC (53 picoCuries per liter [pCi/L]). DOE has continued to collect quarterly surface water samples for uranium analysis from four locations at the Slough since completion of the original risk assessment; therefore, EPA reviewed all surface water uranium data since 1995 to identify the maximum detected concentration for use as the EPC. Uranium surface water data are reported as total uranium in micrograms per liter (µg/L).

For the purpose of converting mass (µg) to activity (pCi), EPA utilized DOE's site-specific mass-to-activity conversion factor of 0.68 pCi/µg. The converted activity value represents the sum of all activity from the isotopes of uranium: uranium-238 (0.33 pCi/µg), uranium-235 (0.02 pCi/µg), and uranium-234 (0.33 pCi/µg).

This risk assessment re-evaluation assumes that the total uranium concentrations for sediment, surface water, and fish include the uranium isotopes uranium-238, -235, and -234. The risk calculation also considers the in-growth of short-lived progeny to be present in secular equilibrium. In the risk assessment re-evaluation, uranium-238 progeny includes thorium-234, protactinium-234, and protactinium-234m (metastable) at equal activities. Uranium-234 is present at an equal activity as uranium-238 for natural uranium. Natural uranium also contains a small mass percentage of uranium-235. Its short-lived progeny, thorium-231, is included in the assessment at the same activity as uranium-235.

Table 2 lists the chemical and radiological EPCs utilized for this risk assessment re-evaluation, for surface water, sediment, and fish tissue.

3.3.2 Human Exposure Assumptions

Human exposure parameters include the frequencies and durations of time a receptor is in contact with contaminated media, as well as parameters reflecting the specific aspects of the receptors, such as body weights, skin surface areas, etc. These exposure parameters are selected to best represent reasonable maximum exposure conditions. When available, the EPA's standard default exposure factors are used (EPA, 2014a). However, default exposure factors are not available for many of the parameters used to evaluate a recreational scenario. Site-specific values from the original risk assessment were used in the re-evaluation, if still reflective of current conditions and representative of reasonable maximum exposure (RME) scenarios. Other values were updated to reflect current EPA Region 7 risk assessment practice and current guidance, include the EPA's *Exposure Factors Handbook* (USEPA, 2011a). The full list of human exposure parameters, including those used in the original risk assessment as compared to those used in this risk assessment re-evaluation, are presented in Table 3. More information is presented below, pertaining to the rationale or approach used to select parameters for this risk assessment re-evaluation.

<u>Exposure Time (ET)</u>
Default exposure times are not available for recreational scenarios. For consistency, the same exposure times are used for this risk assessment re-evaluation as were used in the original risk assessment. The receptors are assumed to be exposed to surface water for 1 hour/event and to sediments for 4 hours/event. These values are consistent with those used to evaluate recreational exposures in other recent Region 7 risk assessments.

<u>Exposure Frequencies (EF)</u>
Default exposure frequencies are not available for recreational scenarios. For surface water and sediment exposure, the same number of events/year are used for this risk assessment re-evaluation as were used in the original risk assessment; that of 20 events/year. Generally, EPA Region 7 evaluates recreational exposures using EFs based on one to two days of exposure per week, during the warmer months of the year. Higher values in this range (e.g., 52 days/year) are more appropriate for locations directly adjacent to residential areas and/or with a child's play area. An EF of 20 events/year continues to represent an RME scenario, based on how receptors are exposed at the Slough.

For the fish ingestion pathway, an EF of 350 days/year is used in this risk assessment re-evaluation. The rationale for this EF is discussed further below, in context with the fish ingestion rate.

<u>Exposure Duration (ED)</u>
Although default exposure durations are not available for recreational scenarios, the default ED for a residential scenario is often used because the most frequent recreational visitors are typically nearby residents. The original risk assessment evaluated only adult receptors, with an ED of 30 years, which was the default residential

ED at the time. This risk assessment re-evaluation uses the updated default residential ED of 26 years, which is published in the EPA's 2011 *Exposure Factors Handbook* (EFH) (USEPA, 2011a).

Unlike the original risk assessment, the adolescent recreational visitor, age 6 to 16 years, is also evaluated in this risk assessment re-evaluation. Hence, the ED for the adolescent is 10 years.

<u>Body Weight (BW)</u>
The original risk assessment utilized the adult BW considered at the time by EPA to be the default exposure parameter, 70 kg. However, with the publication of EPA's 2011 EFH (USEPA, 2011a), the default BW for adults has been revised to 80 kg, which is used in this risk assessment re-evaluation.

Unlike the original risk assessment, the adolescent recreational visitor, age 6 to 16 years, is evaluated in this risk assessment re-evaluation. The BW for the adolescent is 44.3 kg. This BW represents the mean BW of adolescents of ages 6 to 11 years (31.8 kg) and 11 to 16 years (56.8 kg), as reported in Table 8.1 of EPA's current EFH (USEPA, 2011a).

<u>Sediment Ingestion Rate</u>
In the original risk assessment, the sediment ingestion rate used was 120 mg/event. This value represents an age-adjusted soil ingestion rate based on "*6 years for an ingestion rate of 200 mg for a child, and 24 years for ingestion rate of 100 mg per event for an adult*" (USDOE 1998b). In this risk assessment re-evaluation, a sediment ingestion rate of 100 mg/event is used for both the adult and adolescent receptors. This value is the default soil ingestion rate for receptors over the age of 6 years (USEPA, 2011a).

<u>Surface Water Ingestion Rate</u>
For the original risk assessment, it was assumed that a recreator waded for one hour in the Slough. The surface water ingestion rate used for this scenario was 200 mL/event, with no reference of the source provided. Region 7 assumes that swimming can occur when water depths are greater than 2 to 3 feet, which reflects the depths at the Slough. When evaluating surface water ingestion while swimming, current risk assessment methodology is to use the upper percentile values from Table 3-5 of the EPA's 2011 EFH, which are 71 mL/hour for adults and 120 mL/hour for children under the age of 18 years (USEPA, 2011a). For this risk assessment re-evaluation, these standard surface water ingestion rates were used, rather than the original value of 200 mL/event.

Fish Ingestion Rate

Default fish ingestion rates are not available. The original risk assessment used a fish ingestion rate of 55 g/event. For this risk assessment re-evaluation, a fish ingestion rate of 41.8 g/day was selected for adults and 19.2 g/day for adolescents, consistent with current EPA Region 7 risk assessment practice. These values are the 95th percentile for usual fish consumption rates for total finfish in the inland midwest, for adults and youth less than 21 years, respectively, presented in USEPA (2014b). EPA Region 7 selected these values, rather than values in the 2011 Exposure Factors Handbook, because the National Health and Nutrition Examination Survey dataset and the National Cancer Institute methods used to determine these fish ingestion rates reflect the most current data and best available science.

As previously noted, the EF for evaluating fish ingestion also differs from that used in the original risk assessment. Because the currently recommended fish ingestion rates are based on the quantity of fish consumed daily on average, and not based on the number of visits to the Slough, the EF for the fish ingestion pathway used in this risk assessment re-evaluation is 350 days/year. This is the standard default EF for a residential receptor and reflects the days per year fish ingestion is assumed to occur.

Inhalation Rate

The original risk assessment used an inhalation rate of 2.1 m^3/hour, without providing a reference source. Current risk assessment methodology for evaluating exposures to chemicals via the inhalation pathway (EPA, 2009) no longer use an inhalation rate (discussed in further detail below). However, in the revised radiological risk assessment, the 95^{th} percentile short-term inhalation rates for moderate activity were used, as found in Table 6-2 of EPA's 2011 EFH. For adolescent receptors, EPA recommends using 1.89 m^3/hour (3.15E-02 m^3/min), which is the average for receptors ages 6 to < 11 and 11 to < 16 years. For adult receptors, EPA recommends using 2.34 m^3/hour (3.89E-02 m^3/min), which is the average for 6 years at the rate for age 31 to < 41 years (3.7E-02 m^3/min), 10 years at the rate for 41 to < 51 years (3.9E-02 m^3/min), and 10 years at the rate for 51 to < 61 years (4.0E-02 m^3/min). The inhalation rate derived for an adult receptor is protective for adult receptors of all ages because the rates for receptors younger than 31 years or older than 61 years are slightly lower.

Particulate Emission Factor (PEF)

The original risk assessment used a particulate emission factor of 4.63E+09 m^3/kg, without providing a reference source. The PEF used in this risk assessment re-evaluation is the current default value of 1.39E+09 m^3/kg, as provided in EPA's 2002 *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites* (USEPA, 2002).

Skin Surface Area (SSA)
In the original risk assessment, the SSA value of 4,200 cm^2 was used to evaluate surface water exposures to the hands, arms, and lower legs, based on a wading scenario. However, because the depth of the Slough supports swimming rather than wading (as discussed above), the entire surface area of the body is used in this risk assessment re-evaluation to evaluate dermal exposure to chemical COPCs in surface water. For adults, the value of 19,652 cm^2 is used, which is the mean value for adult males and females, as presented in EPA's 2014 publication of standard default exposure factors (USEPA, 2014a). For adolescents, the value of 13,350 cm^2 is used, which is the mean value for males and females ages 6 to 16 years, from Table 7.1 of the EPA's 2011 EFH.

For sediment, the SSA value of 820 cm^2 was used in the original risk assessment to evaluate exposures to the hands only. The current standard default assumption for residential soil exposures is to evaluate contact with the head, hands, forearms, lower legs, and feet. In this risk assessment re-evaluation, this same assumption is applied to dermal exposures to sediment. Thus, the default mean value of 6,032 cm^2 is used for adults, and 4,683 cm^2 is used for adolescents. The latter value for adolescents is the age-adjusted and body part-specific mean surface area for males and females ages 6 to 16 years, from Table 7-2 of EPA's 2011 EFH. A forearm-to-arm ratio of 0.45 and a lower leg-to-leg ratio of 0.4 were applied, as recommended on page 3-11 of EPA's RAGS Part E, *Supplemental Guidance for Dermal Risk Assessment* (USEPA, 2004).

Adherence Factors (AFs)
AFs are pertinent to dermal pathway for soil and sediment contacting skin. A default AF does not exist for sediment exposures. The original risk assessment utilized a value of 0.2 mg/cm^2-event, but a higher AF is used in this risk assessment re-evaluation for both the adult and adolescent receptors to account for the likely higher adherence of wet sediment to skin. This value has been used to evaluate exposure to wet soil or sediment by adolescent trespassers at other sites in Region 7 and is based on EPA's RAGS Part E.

Permeability Coefficients
The original risk assessment evaluated the chemical dermal absorption pathway for surface water in a manner that has since been updated. The previous method utilized a general permeability coefficient of 1E-03 cm/hour. More current methodology for evaluating the dermal pathway utilizes permeability coefficients that are specific for each chemical in surface water. The dermal pathway and use of intake parameters are discussed in more detail below.

Averaging Time (AT)

Because chemical intakes for the receptors are calculated over an exposure duration, ATs are necessary. In the original risk assessment, the AT values are not provided. For this risk assessment re-evaluation, ATs utilized are as recommended in EPA's Risk Assessment Guidance for Superfund (RAGS), Part A (USEPA, 1989). For chemical carcinogens, the AT is obtained by the following formula:

$$AT_C = 70 \text{ years lifetime exposure x } 365 \text{ days/year}$$

For this risk assessment re-evaluation, the AT_C used for both adults and adolescent receptors is 25,550 days.

For noncarcinogens, the AT is obtained by the following formula:

$$AT_{NC} = \text{exposure duration (ED) years x } 365 \text{ days/year}$$

For this risk assessment re-evaluation, the AT_{NC} used for adults is 9,490 days and for adolescents is 3,650 days.

Absorption Factors from Sediment (ABS_d)

The original risk assessment utilized ABS_d values as appropriate for COPCs at the time of the report development. However, since then, chemical-specific ABS_d values have been updated and can be obtained from EPA's RAGS Part E (USEPA, 2004) or from tables of chemical/physical parameters associated with EPA's RSL tables (USEPA, 2018). The most current ABS_d values available are utilized in this risk assessment re-evaluation.

3.3.3 Estimation of COPC Intake

The methodology used to quantify intake of COPCs in surface water, sediments, and fish, via all complete exposure pathways (Figures 1 and 2) to both adolescent and adult recreational visitors, are described below. For chemical risk assessment, the daily intake values and exposure concentrations described in Sections 3.3.3.1 through 3.3.3.3 represent average daily doses for the evaluation of potential non-carcinogenic hazards and lifetime average daily doses for the evaluation of potential excess cancer risks, due to the use of different AT values as described in Section 3.3.2.

3.3.3.1 Intake of Chemicals from Surface Water

Ingestion

The methodology for chemical intake via the surface water ingestion pathway has not changed since the original risk assessment has been developed. Average daily chemical intake for the ingestion of COPCs in surface water in this risk assessment re-evaluation was calculated for both adolescent and adult recreators by use of the following formula (USEPA, 1989):

$$DI_{SW\text{-}Ing} = \frac{C_{SW} \times IR_{SW} \times EF \times ED}{BW \times AT}$$

where:

- $DI_{SW\text{-}Ing}$ = average daily chemical intake via surface water ingestion (mg/kg-day)
- C_{SW} = chemical concentration in surface water (mg/L)
- IR_{SW} = intake rate (L/event)
- EF = exposure frequency (events/year)
- ED = exposure duration (years)
- BW = body weight (kg)
- AT = averaging time (period over which exposure is averaged, days)

Because of the differences in AT for exposure to carcinogens versus noncarcinogens (as discussed in Section 3.3.2), average daily chemical intake values for surface water ingestion will differ for carcinogenic and noncarcinogenic chemical calculations.

New intake parameters for surface water ingestion, as described in Section 3.3.2 above and presented in Table 3, have been utilized in this risk assessment re-evaluation. Detailed calculation tables showing chemical intake by surface water ingestion are presented in Appendix A. Table A1 presents chemical intake for adults, and Table A2 presents chemical intake for adolescents.

Dermal Absorption

The methodology for calculating average daily chemical intake for dermal absorption pathways have been revised since the original risk assessment was published. Methodology currently recommended by EPA is presented in EPA's RAGS Part E (USEPA, 2004). This more current methodology is used in this risk assessment re-evaluation. Average daily chemical intake for dermal absorption of COPCs in surface water was calculated in this risk assessment re-evaluation for both adolescent and adult recreators by use of the following step-wise formulae (USEPA, 2004):

$$DAD_{SW} = \frac{DA_{event} \times EF \times ED \times EV \times SSA_{SW}}{BW \times AT}$$

where:

for organic COPCs: $DA_{event} = C_{SW} \times CF \times Kp \times 2FA \times SQRT((6 \times tau \times t_{event}) / \pi)$

for inorganics COPCs: $DA_{event} = C_{SW} \times CF \times Kp \times t_{event}$

and

DAD_{SW} = dermal absorbed dose from surface water (mg/kg-day)
DA_{event} = absorbed dose per event (mg/cm^2-event)
EF = exposure frequency (days/year)
ED = exposure duration (years)
EV = event frequency (events/day)
SSA_{SW} = skin surface area available for contact with surface water (cm^2)
BW = body weight (kg)
AT = averaging time (period over which exposure is averaged, days)
C_{SW} = chemical concentration in surface water (mg/L)
CF = conversion factor (L/cm^3)
Kp = chemical specific, dermal permeability coefficient in water (cm/hr) (Source: USEPA, Nov. 2018)
FA = chemical specific, fraction of chemical absorbed (unitless) (Source: USEPA, 2004; Exhibit B-3)
SQRT = square root
tau_{event} = lag time per event (hr/event)
t_{event} = exposure time (hr)
t* = time to reach steady-state (hr), and
$t^* = (tau_{event} \times 2.4)$ *and, if*

$t_{event} \le t^*$, the formula shown is the proper one for that COPC
$t_{event} \ge t^*$, the formula shown is not the proper one for that COPC
Note: that for all COPCs in this risk assessment re-evaluation, the formula shown is the proper formula for the COPCs evaluated.

Table A3 in Appendix A presents the calculations of DA_{event} for organics and Table A4 in Appendix A presents the calculations of DA_{event} for inorganics.

Because of the differences in AT for exposure to carcinogens versus noncarcinogens (as discussed in Section 3.3.2), average dermal absorbed dose values for surface water will differ for carcinogenic and noncarcinogenic chemicals calculations.

New intake parameters for dermal contact with surface water, as described in Section 3.3.2 above and presented in Table 3, have been utilized in this risk assessment re-evaluation. The DAD_{SW} calculations for adults in this risk assessment re-evaluation are presented in Table A5 of Appendix A, and the DAD_{SW} calculations for adolescents in this risk assessment re-evaluation are presented in Table A6 of Appendix A.

3.3.3.2 Intake of Chemicals from Sediment

Ingestion

The methodology for calculating chemical intake via the sediment ingestion pathway has not changed since the original risk assessment has been developed. Average daily chemical intakes of COPCs from ingestion of sediment are calculated for both adolescent and adult recreators by use of the following formula (USEPA, 1989):

$$DI_{SD\text{-}Ing} = \frac{C_{SD} \times IR_{SD} \times CF \times EF \times ED}{BW \times AT}$$

where:

- $DI_{SD\text{-}Ing}$ = average daily chemical intake via sediment ingestion (mg/kg-day)
- C_{SD} = chemical concentration in sediment (mg/kg)
- IR_{SD} = ingestion rate (mg sediment/event)
- CF = conversion factor (10^{-6} kg/mg)
- EF = exposure frequency (days/year)
- ED = exposure duration (years)
- BW = body weight (kg)
- AT = averaging time (period over which exposure is averaged, days)

Because of the differences in AT for exposure to carcinogens versus noncarcinogens (as discussed in Section 3.3.2), average daily chemical intake values for sediment ingestion will differ for carcinogenic and noncarcinogenic chemical calculations.

New intake parameters for sediment ingestion, as described in Section 3.3.2 above and presented in Table 3, have been utilized in this risk assessment re-evaluation. Detailed calculation tables showing chemical intake by sediment ingestion are presented in Appendix A. Table A7 presents chemical intake for adults and Table A8 presents chemical intake for adolescents.

Dermal Absorption

The methodology for calculating average daily chemical intake for dermal absorption pathways have been revised since the original risk assessment was published. Methodology currently recommended by EPA is presented in EPA's RAGS Part E (USEPA, 2004). This more current methodology is used in this risk assessment re-evaluation. Average daily chemical intake for dermal absorption of COPCs in sediment was calculated in this risk assessment re-evaluation for both adolescent and adult recreators by use of the following step-wise formulae (USEPA, 2004):

$$DAD_{SD} = \frac{DA_{event} \times EF \times ED \times EV \times SSA_{SD}}{BW \times AT}$$

where:

DAD_{SW}= dermal absorbed dose (mg/kg-day)
DA_{event}= absorbed dose per event (mg/cm^2-event)
EF = exposure frequency (days/year)
ED = exposure duration (years)
EV = event frequency (events/day)
SSA_{SD}= skin surface area available for contact with sediment (cm^2)
BW = body weight (kg)
AT = averaging time (period over which exposure is averaged, days)

The DA_{event} term was calculated by the following formula (USEPA, 2004):

$$DA_{event} = C_{SD} \times CF \times AF \times ABS_d$$

where:

DA_{event}= absorbed dose per event (mg/cm^2-event)
C_{SD} = chemical concentration in sediment (mg/kg)
CF = conversion factor (10^{-6}kg/mg)
AF = adherence factor of sediment to skin (mg/cm^2-event)
ABS_d = chemical specific dermal absorption fraction (unitless)

For this risk assessment re-evaluation, Table A9 in Appendix A presents the calculations of DA_{event} for dermal absorption of COPCs in sediments.

New intake parameters for dermal contact with sediments, as described in Section 3.3.2 above and presented in Table 3, have been utilized in this risk assessment re-evaluation for dermal exposure to COPCs in sediment. The DAD_{SD} calculations for adults in this risk assessment re-evaluation are presented in Table A10 of Appendix A, and the DAD_{SD} calculations for adolescents in this risk assessment re-evaluation are presented in Table A11 of Appendix A.

Inhalation

The methodology for calculating average daily chemical intake for the inhalation pathway has been revised since the original risk assessment was published. For the purposes of evaluating a receptor's exposure to chemicals in air, as either volatiles or adsorbed to dust particles, the development of the exposure concentration (EC) in air, as recommended by USEPA's *RAGS Part F, Guidance for Inhalation Risk Assessment* (USEPA, 2009), is performed. The EC is calculated by modeling the chemical concentration in air (CA) first, following the methodology presented in USEPA's *Soil*

Screening Guidance (USEPA, 2002). EC has been calculated in this risk assessment re-evaluation by use of the following equation:

$$EC = \frac{CA \times ET \times EF \times ED}{AT}$$

where:

EC	=	exposure concentration (µg/m^3)
CA	=	chemical concentration in air (µg/m^3)
ET	=	exposure time (hours/day)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
AT	=	averaging time (period over which exposure is averaged, days)

Because of the differences in AT for exposure to carcinogens versus noncarcinogens (as discussed in Section 3.3.2), the exposure concentration values for chemicals in air will differ for carcinogenic and noncarcinogenic chemicals calculations.

The chemical concentration in air (CA) term is calculated in this risk assessment re-evaluation as follows:

$$CA = C_{SD} \times CF \times [(1 / PEF) + (1 / VF)]$$

where:

C_{SD}	=	chemical concentration in sediment (mg/kg)
CF	=	conversion factor (1000 µg/mg)
PEF	=	particle emission factor (m^3/kg)
VF	=	volatilization factor (m^3/kg)

The following equation was used to derive VF only for those COPCs considered volatile, as described by USEPA's *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites (*2002). The EPA considers volatile chemicals those with a Henry's law constant greater than or equal to 1 x 10^{-5} atm-m^3/mole or a vapor pressure greater than or equal to 1 mm Hg.

$$VF = [Q/C \times (3.14 \times D_A \times T)^{1/2} \times CF] / (2 \times \rho_b \times D_A)$$

where:

Q/C	=	inverse of mean concentration at center of source (g/m^2-s per kg/m^3)
D_A	=	apparent diffusivity (cm^2/sec)
T	=	exposure interval (sec), receptor dependent

CF	=	conversion factor, 10^{-4} m^2/cm^2
ρ_b	=	dry soil bulk density (g/cm^3) = 1.5 g/cm^3

Additionally, the following equation was used to derive D_A (USEPA, 2002).

$$D_A = [(\theta a^{10/3} \times Dia \times H') + (\theta w^{10/3} \times Diw) / n^2] / [(\rho_b \times Kd) + \theta w + (\theta a \times H')]$$

where:

θa	=	air filled porosity (L_{air}/L_{soil}) = n - θw = 0.284
Dia	=	diffusivity in air (cm^2/sec), chemical specific (USEPA, Nov. 2018)
H'	=	Henry's law constant, unitless, chemical specific (USEPA, Nov. 2018)
θw	=	water-filled porosity (L_{water}/L_{soil}) = 0.15
Diw	=	diffusivity in water (cm^2/sec), chemical specific (USEPA, Nov. 2018)
n	=	total soil porosity (L_{pore}/L_{soil}) = 1 - (ρ_b/ρ_s) = 0.434
Kd	=	soil-water partition coefficient (cm^3/g)

The following equation was used to derive Kd (USEPA, 2002).

$$Kd = K_{OC} \times f_{OC}$$

where:

K_{OC}	=	chemical specific soil organic carbon partition coefficient (cm^3 / g), (USEPA Nov., 2018)
f_{OC}	=	fraction organic carbon in soil (g/g), 0.006

New intake parameters for inhalation of COPCs in sediment, as described in Section 3.3.2 above and presented in Table 3, have been utilized in this risk assessment re-evaluation for inhalation exposure to COPCs in sediment. Appendix A presents all tables necessary for the calculation of the parameters shown above, as follows: AD calculations are presented in Table A12, VF calculations for adults are presented in Table A13, VF calculations for adolescents are presented in Table A14, CA calculations for adults are presented in Table A15, CA calculations for adolescents are presented in Table A16, EC calculations for adults are presented in Table A17, and EC calculations for adolescents are presented in Table A18.

3.3.3.3 Intake of Chemicals from Fish

Ingestion

Average daily chemical intake for the ingestion of fish is calculated in this risk assessment re-evaluation by use of the same formula as in the original risk assessment (USEPA, 1989):

$$DI_{F\text{-}Ing} = \frac{C_F \times IR_F \times CF \times EF \times ED}{BW \times AT}$$

where:

$DI_{F\text{-}Ing}$	=	average daily chemical intake via fish ingestion (mg/kg-day)
C_F	=	chemical concentration in fish (mg/kg)
IR_F	=	ingestion rate (g fish/day)
CF	=	conversion factor (10^{-3} kg/g)
EF	=	exposure frequency (days/year)
ED	=	exposure duration (years)
BW	=	body weight (kg)
AT	=	averaging time (period over which exposure is averaged, days)

Because of the differences in AT for exposure to carcinogens versus noncarcinogens (as discussed in Section 3.3.2), average daily chemical intake values for fish ingestion will differ for carcinogenic and noncarcinogenic chemicals calculations.

New intake parameters for fish ingestion, as described in Section 3.3.2 above and presented in Table 3, have been utilized in this risk assessment re-evaluation. Detailed calculation tables showing chemical intake by fish ingestion are presented in Appendix A. Table A19 presents chemical intake for adults and Table A20 presents chemical intake for adolescents.

3.3.4 Intake of Radioisotopes

Per the June 2014 Distribution of the "Radiation Risk Assessment at CERCLA Sites: Q&A" memorandum (OSWER 9285.6-20) (USEPA, 2014c), the Preliminary Remediation Goals for Radionuclide Contaminants at Superfund Sites (PRG) calculator was utilized to estimate excess cancer risks from exposure to radiological COPCs in sediment, surface water, and fish ingestion by adolescent and adult recreational visitors. The equations used in the PRG calculator are found at: https://epa-prgs.ornl.gov/radionuclides/equations.html and described at: https://epa-prgs.ornl.gov/radionuclides/users_guide.html. Although the tool is a PRG calculator, it back-calculates risk estimates using radiological-specific versions of the PRG equations. In this risk assessment re-evaluation, versions of the Recreator Soil PRG equations for incidental ingestion, inhalation of particulates, and external exposure to ionizing radiation were used to evaluate sediment; the Recreator Surface Water PRG equations for ingestion and immersion were used to evaluate surface water, and the Resident Consumption of Fish PRG equation was used to evaluate fish tissue. The values of the exposure parameters used in these equations are presented in Table 3 and described in Section 3.3.2; otherwise, the default values in the PRG calculator were used.

4.0 TOXICITY ASSESSMENT

Generally, the toxicity assessment consists of two steps: 1) the hazard identification, to determine the types of adverse health effects each COPC can cause in humans and 2) the dose-response assessment, in which toxicity values are derived to quantify the incidence or potential for adverse health effects as a function of exposure. The approach to develop the toxicity values for chemical COPCs relevant to the Slough differs from that for the radiological COPCs. As such, the two assessments are presented separately below.

4.1 Chemical Evaluation

The toxicity assessment identifies the toxicity values (i.e. slope factors and reference doses) for COPCs. These toxicity values are applied to the estimated doses (intakes) calculated in the exposure assessment, in order to estimate potential carcinogenic risks and noncarcinogenic hazards. The Integrated Risk Information System (IRIS) (USEPA, 2019a) is the preferred source of toxicity values, as the Tier 1 option. If a toxicity value was not available through IRIS, EPA's recommended hierarchy of toxicity databases was followed (USEPA, 2003) which suggests that the Tier 2 option should be the Provisional Peer Reviewed Toxicity Values (PPRTVs) developed by The Office of Research and Development (ORD)/National Center for Environmental Assessment (NCEA). Beyond that, if toxicity factors are not available, additional sources include those provided by the Agency for Toxic Substances and Disease Registry (ATSDR), California's Environmental Protection Agency (CalEPA), and others as necessary. The EPA's Regional Screening Level tables, updated on a biannual basis, provide the currently recommended toxicity values, in according with USEPA (2003).

Multiple slope factors and reference doses for COPCs from the Slough have been updated since the original risk assessment has been developed. A detailed discussion of toxicity factors updated is not provided herein this risk assessment re-evaluation report; however, tables presenting the most current toxicity factors utilized in this re-evaluation are provided, as described further below.

4.1.1 Carcinogenicity Evaluation

Carcinogenic oral slope factors (SFs) are presented on Table 4, containing the following information for each COPC: SF, weight of evidence for cancer (USEPA, 2005a), tumor site(s), and reference sources for the toxicity information presented.

To evaluate the dermal pathway, USEPA has adopted methodology to obtain dermal SFs by adjusting the oral SFs. The equation for extrapolation of a default dermal SF is as follows:

$$\text{Default Dermal SF} = \text{Oral SF} \div \text{Gastrointestinal Absorption Factor (\%)}$$

Gastrointestinal absorption factors (GIABS) are chemical-specific, as presented in USEPA's RAGS Part E, (USEPA, 2004) and also summarized in EPA's RSLs Chemical and Physical Parameters Table (USEPA, Nov. 2018), both published after the development of the original risk assessment. Dermal SFs utilized in this revised risk assessment are also presented on Table 4.

Inhalation cancer risks are calculated by use of the Inhalation Unit Risk (IUR) Factors, as recommended in USEPA's RAGS Part F (USEPA, 2009), published after the development of the original risk assessment. Table 5 provides a list of IURs utilized in this risk assessment re-evaluation, along with the weight of evidence/cancer description, tumor site(s), and reference sources for the toxicity information presented.

4.1.2 Mutagenic Evaluation

Some receptors are highly sensitive to chemicals that demonstrate a mutagenic mode of action. The most sensitive of such receptors are children and adolescents. Because the adolescent recreational visitor is evaluated in this revised risk assessment, an adjustment is required while calculating the excess lifetime cancer risks to account for the special case of mutagenicity. This approach to chemical toxicity had not been advanced until after the development of the original risk assessment. A mutagenic evaluation is performed in this risk assessment re-evaluation, as discussed below.

Only one COPC evaluated for the Slough has been demonstrated to exert a mutagenic mode of action, hexavalent chromium (USEPA, 2005b). It is standard Region 7 practice to make the health-protective assumption that all total chromium detected is the more toxic hexavalent form. Uncertainty in this assumption is discussed in Section 5.3. For adolescent receptors exposed to this COPC, and by each pathway, an adjustment for mutagenicity is applied. To make this adjustment, an Age-Dependent Adjustment Factor (ADAF) is applied. For receptors between the ages of 2 to < 16, the ADAF is 3 (USEPA, 2005b). Use of the ADAF is shown on the risk characterization tables in Appendix A.

4.1.3 Noncarcinogenic Hazards Evaluation

Oral reference doses (RfDs) are derived from toxicological data and can be obtained from EPA toxicological databases, such as IRIS, and the others described in the hierarchy description above. Multiple RfDs have been revised since the development of the original risk assessment. Oral RfDs utilized in this risk assessment re-evaluation are presented on Table 6, along with the target organ(s) affected, the pertinent uncertainty or modifying factor, and reference sources for the toxicity information presented.

Oral RfDs are adjusted to derive dermal RfDs in an approach somewhat similar to that described above for the derivation of dermal SFs, by using the noted chemical oral absorption factor, as follows:

Dermal RfD = Oral RfD x Gastrointestinal Absorption Factor (%)

Dermal RfDs used in this risk assessment re-evaluation are also presented on Table 6.

Inhalation noncancer hazards are calculated by use of the inhalation reference concentrations (RfCs) as the toxicity factor. Multiple inhalation RfCs have been revised since the development of the risk assessment re-evaluation. Table 7 provides a list of RfCs utilized in this risk assessment re-evaluation, along with target organ(s) affected, the uncertainty or modifying factor, and reference sources for the toxicity information presented.

4.2 Radiological Evaluation

For the radiological evaluation, the appendix radionuclide table, from the Center for Radiation Protection Knowledge, lists ingestion, inhalation and external exposure cancer slope factors (risk coefficients for total cancer morbidity) for radionuclides in conventional units of picocuries (pCi). Ingestion and inhalation slope factors are central estimates in a linear model of the age-averaged, lifetime attributable radiation cancer incidence (fatal and nonfatal cancer) risk per unit of activity inhaled or ingested, expressed as risk/pCi. External exposure slope factors are central estimates of lifetime attributable radiation cancer incidence risk for each year of exposure to external radiation from photon-emitting radionuclides distributed uniformly in a thick layer of soil, and are expressed as risk/yr per pCi/gram soil. External exposure slope factors can also be used which have units of risk/yr per pCi/cm^2 soil. When combined with site-specific media concentration data and appropriate exposure assumptions, slope factors can be used to estimate lifetime cancer risks to members of the general population due to radionuclide exposures. EPA currently provides guidance on inhalation risk assessment in RAGS Part F (USEPA, 2009), which only addresses chemicals. The development of inhalation slope factors for radionuclides differs from the guidance presented in RAGS Part F for development of inhalation unit risk (IUR) values for chemicals.

The SFs from the Center for Radiation Protection Knowledge differ from the values presented in HEAST. The SFs were calculated using ORNL's DCAL software in the manner of Federal Guidance Report 12 and 13. For the calculation of soil ingestion slope factors, a standard soil density of 1.6 g/cm^3 has been used. The radionuclides presented are those provided in the International Commission on Radiological Protection (ICRP) Publication 107 (ICRP, 2008). This document contains a revised database of nuclear decay data (energies and intensities of emitted radiations, physical half-lives and decay modes) for 1,252 naturally occurring and man-made radionuclides. ICRP Publication 107 supersedes the previous database, ICRP Publication 38 published in 1983.

The cancer slope factors for the applicable radionuclides are listed in Table 8 (ORNL, 2014).

5.0 RISK CHARACTERIZATION

The objective of the risk characterization step is to integrate the information developed in the exposure assessment and the toxicity assessment to develop estimates of potential health risks associated with exposure to COPCs at the Slough. Methodology used to characterize risk in this re-evaluation is described below. Following a discussion of methodology, specific risk estimates obtained in this risk assessment re-evaluation are presented.

5.1 Risk Quantification Methods

Separate approaches are used to quantify risk estimates for carcinogens and noncarcinogens. Carcinogenic risk methodology is presented first in Section 5.1.1 below, followed by methodology for noncarcinogens in Section 5.1.2. As discussed in Section 3.3.4, the EPA's PRG calculator for radionuclides was used in this re-assessment to derive estimates of potential risks from exposure to radiological COPCs, without an intermediate step of estimating intakes. Therefore, quantification of radiological risks is presented separately in Section 5.1.3.

5.1.1 Carcinogenic Risk Methods

For carcinogens, risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to that carcinogen. Estimates of cancer risk were calculated in this risk assessment re-evaluation by multiplying the estimated lifetime-averaged daily intake, calculated for a chemical through an exposure route, by the exposure route-specific cancer slope factor. The equation below represents ingestion pathways:

$$ELCR = DI \times SF$$

where:

ELCR = Excess Lifetime Cancer Risk (unitless)
DI = Daily intake of chemical (mg/kg-day), ingestion pathway
SF = Cancer slope factor $(mg/kg\text{-}day)^{-1}$

For the dermal pathway, the DI parameter shown in the above equation is replaced by the dermal absorbed dose (DAD) parameter.

To account for mutagenicity, the following formula is used for receptors below the age of 16, for chemicals denoted as having mutagenic properties:

$$ELCR = DI \times SF \times ADAF$$

where:

ADAF = Age-dependent adjustment factor (unitless)

Similar to what is described just above, in the case of the dermal pathway, the DI parameter is replaced by DAD.

Excess cancer risk for the inhalation pathway was estimated by utilizing the following formula (USEPA, 2009):

$$ELCR = IUR \times EC$$

where:

IUR = inhalation unit risk [$(\mu g/m^3)^{-1}$]

EC = exposure concentration ($\mu g/m^3$)

To account for mutagenicity, the following formula is used for receptors below the age of 16, for chemicals denoted as having mutagenic properties:

$$ELCR = IUR \times EC \times ADAF$$

For this risk assessment re-evaluation, an adjustment for mutagenicity is made only for the adolescent receptor, using an ADAF value of 3 (as discussed above in Section 4.1.2).

Cancer risks are calculated for each COPC with SFs and IURs available, and then summed to show cumulative risk by exposure pathway, cumulative risk by media, and finally, overall site-wide cumulative risk.

5.1.2 Noncarcinogenic Hazard Methods

For noncarcinogens, the reference dose or concentration represents the level of exposure to which it is unlikely for all members of the population, including sensitive subpopulations, to experience adverse health effects. The potential for noncarcinogenic health effects is not calculated as a probability. Rather, hazard quotients (HQs) and hazard indices (HIs, which are HQs summed) are calculated as the ratio of the average daily dose through a given exposure route to the chemical and route-specific reference dose, calculated as presented below for the ingestion pathway.

$$HQ = DI \div RfD$$

where:

HQ	=	Hazard quotient (unitless)
DI	=	Daily chemical intake (mg/kg-day), ingestion pathway
RfD	=	Noncancer oral or dermal reference dose (mg/kg-day)

For the dermal pathway, the DI parameter shown in the above equation is replaced by the dermal absorbed dose (DAD) parameter.

The HQ for the inhalation pathway was calculated in this risk assessment re-evaluation by using the following formula (USEPA, 2009):

$$HQ = EC \div [\, RfC \times 1000\ \mu g/m^3\,]$$

where:

HQ	=	Hazard quotient via the inhalation pathway (unitless)
EC	=	Exposure concentration ($\mu g/m^3$)
RfC	=	Noncancer inhalation reference concentration (mg/m^3)

HQs are calculated for each COPC with RFDs or RfCs available, then summed to obtain an HI for each pathway, summed to obtain an HI for media, and finally, summed to obtain an overall site-wide HI.

5.1.3 Radiological Risk Methods

As previously discussed in Section 3.3.4, the PRG calculator was used in this risk assessment re-evaluation to estimate potential cancer risks associated with exposure to radiological COPCs at the Slough. According to OSWER 9285.6-20, the "*PRG calculators…are recommended by EPA for Superfund remedial radiation risk assessments. These risk and dose assessment models are similar to EPA's methods for chemical risk assessment at CERCLA sites*." As described in the PRG calculator User's Guide (https://epa-prgs.ornl.gov/radionuclides/users_guide.html), risk characterization for radionuclides incorporates the outcomes of the exposure and toxicity assessments in a similar manner as that used to estimate potential chemical risks.

The basic equation for calculating excess lifetime cancer risk from radioisotopes is:

$$ELCR = CDI \times SF$$

where:

ELCR	=	Excess Lifetime Cancer Risk (unitless)
CDI	=	Chronic daily intake or dose (pCi)
SF	=	Cancer slope factor (risk/pCi)

5.2 Risk Results

To interpret environmental risk results, EPA compares the calculated receptor risk levels to the risk thresholds defined in the National Oil and Hazardous Substances Pollution Contingency Plan (NCP) at 40 *Code of Federal Regulations* (CFR) 300.430(e)(2)(i)(A)(1) and (2) (USEPA, 1990). The NCP states that "*for systemic toxicants [noncancer risk], acceptable exposure levels shall represent concentration levels to which the human population, including sensitive subgroups, may be exposed without adverse effect during a lifetime or part of a lifetime, incorporating an adequate margin of safety*." A HI greater than one represents the threshold for unacceptable noncancer risk. Regarding carcinogenic risk, the NCP states that "for known or suspected carcinogens, acceptable exposure levels are generally concentration levels that represent an excess upper bound lifetime cancer risk to an individual of between 10^{-4} and 10^{-6}." Per the 1991 EPA guidance titled *Role of the Baseline Risk Assessment in Superfund Remedy Selection Decisions* (OSWER Directive 9355.0-30) (USEPA, 1991), "*where the cumulative carcinogenic site risk to an individual based on reasonable maximum exposure for both current and future land use is less than* 10^{-4} *and the non-carcinogenic hazard quotient is less than 1, action is generally not warranted unless there are adverse environmental impacts*."

The results of this risk assessment re-evaluation are discussed below, segregated by environmental media, with the discussion of chemical risk estimates first, followed by radiological risk estimates.

5.2.1 Chemical Risk Estimates

<u>Surface Water</u>

Adult and adolescent recreational visitors were evaluated for potential risks of cancer and non-cancer health effects from exposures to COPCs in surface water at the Slough via incidental ingestion and dermal contact. The risk characterization results for each chemical and pathway are presented in detail on Tables A21 and A22 of Appendix A, for adults and adolescents, respectively. Risk results for these receptors are also summarized on Table 9.

For adults, the ELCRs from exposure to COPCs in surface water are 2E-07 by ingestion and 7E-08 by dermal contact. The total ELCR from exposure to COPCs in surface water by all pathways combined, for adults, is 3E-07. For adolescents, the ELCRs from exposure to COPCs in surface water are 3E-07 by ingestion and 3E-08 by dermal contact. The total ELCR from exposure to COPCs in surface water by all pathways combined, for adolescents, is 3E-07.

For both receptors, adults and adolescents, cumulative ELCRs from exposure to COPCs in surface water, by all pathways combined, are lower than EPA's acceptable cancer risk range of 1E-04 to 1E-06.

For adults, the noncancer HIs resulting from exposure to COPCs in surface water are 0.06 by ingestion and 0.02 by dermal contact. The total HI from exposure to COPCs in surface water by all pathways combined, for adults, is 0.08. For adolescents, the noncancer HIs resulting from exposure to COPCs in surface water are 0.2 by ingestion and 0.02 by dermal contact. The total HI from exposure to COPCs in surface water by all pathways combined, for adolescents, is 0.2.

For both receptors, adults and adolescents, the resulting HIs, from exposure to COPCs in surface water by all pathways combined, are less than EPA's level of concern of 1.

Sediment

Adult and adolescent recreational visitors were evaluated for potential risks of cancer and non-cancer health effects from exposures to COPCs in sediment at the Slough via incidental ingestion, dermal contact, and inhalation of particulates and volatiles. The risk characterization results for each chemical and pathway are presented in detail on Tables A21 and A22 of Appendix A, for adults and adolescents, respectively. Risk results for these receptors are also summarized on Table 9.

For adults, the ELCRs from exposure to COPCs in sediment are 3E-07 by ingestion, 2E-08 by dermal contact, and 5E-09 by inhalation. The total ELCR from exposure to COPCs in sediment by all pathways combined, for adults, is 3E-07. For adolescents, the ELCRs from exposure to COPCs in sediment are 5E-07 by ingestion, 9E-09 by dermal contact, and 5E-09 by inhalation. The total ELCR from exposure to COPCs in sediment by all pathways combined, for adolescents, is 5E-07.

For both receptors, adults and adolescents, cumulative ELCRs from exposure to COPCs in sediment, by all pathways combined, are lower than EPA's acceptable cancer risk range of 1E-04 to 1E-06.

For adults, the noncancer HIs resulting from exposure to COPCs in sediment are 0.01 by ingestion, 0.0002 by dermal contact, and 0.0002 by inhalation. The total HI from exposure to COPCs in sediment by all pathways combined, for adults, is 0.01. For adolescents, the noncancer HIs resulting from exposure to COPCs in sediment are 0.02 by ingestion, 0.0003 by dermal contact, and 0.0002 by inhalation. The total HI from exposure to COPCs in sediment by all pathways combined, for adolescents, is 0.02.

For both receptors, adults and adolescents, the resulting HIs, from exposure to COPCs in sediment by all pathways combined, are less than EPA's level of concern of 1.

Fish Ingestion

Adult and adolescent recreational visitors were evaluated for potential risks of cancer and non-cancer health effects from exposures to COPCs in fish from the Slough via ingestion. The risk characterization results for each chemical are presented in detail on Tables A21 and A22 of Appendix A, for adults and adolescents, respectively. Risk results for these receptors are also summarized on Table 9.

For adults, the ELCR from exposure to COPCs by the ingestion of fish is 2E-05. For adolescents, the ELCR from exposure to COPCs by the ingestion fish is 8E-06. Both of the ELCR results for adults and adolescents fall within EPA's acceptable risk range of 1E-04 to 1E-06. The chemical contributing all cancer risk from fish ingestion, for both receptors, is arsenic.

For adults, the noncancer HI resulting from exposure to COPCs by the ingestion of fish was found to be 0.2. The total HI from exposure to COPCs by the ingestion of fish for adolescents is 0.1. For both receptors, adults and adolescents, the resulting HIs, from exposure to COPCs by the ingestion of fish, are less than EPA's level of concern of 1.

Site-Wide Cumulative Chemical Risk Estimates

Risk estimates for each receptor were summed across all environmental media, pathways, and COPCs to derive the cumulative site-wide cancer risks and non-cancer hazards. The cumulative risks for each receptor are presented on Table A21 and A22 in Appendix A, for adults and adolescents, respectively. Site-wide cumulative risk results for these receptors are also presented on Table 9.

The cumulative site-wide ELCR for adult recreators is 2E-05, which is within EPA's acceptable risk range of 1E-04 to 1E-06. The primary contributor to this risk is arsenic via fish ingestion (ELCR of 2E-05).

The cumulative site-wide ELCR for adolescent recreators is 8E-06, which is within EPA's acceptable risk range of 1E-04 to 1E-06. The primary contributor to this risk is arsenic via fish ingestion (ELCR of 8E-06).

The cumulative site-wide noncancer HI for adults is 0.3, which is less than EPA's level of concern of 1.

The cumulative site-wide noncancer HI for adolescents is 0.4, which is less than EPA's level of concern of 1.

5.2.2 Radiological Risk Estimates

Appendix B of this report is dedicated to the presentation of all outputs generated from use of the PRG radionuclide calculator, as described above in Section 3.3.4 and 5.1.3. Tables B1 present surface water outputs, Tables B2 present sediment outputs, and Tables B3 present fish ingestion outputs. Each media output contains three separate tables, designated as 'a', 'b', and 'c' as shown below, respectively:

- input parameters to the PRG calculator,
- PRG results, and
- radionuclide risk results.

Radionuclide risk results are summarized by media, in the following sections.

<u>Surface Water</u>

Adults and adolescents were evaluated for potential risks from exposure to radiological COPCs in surface water by ingestion and immersion. The risk characterization results for each radionuclide and pathway are presented in detail on Printouts B1.c and B2.c of Appendix B, for adults and adolescents, respectively. Risk results for these receptors are also summarized on Table 10.

For adults, the ELCRs from exposure to radionuclides in surface water are 5E-07 by ingestion and 2E-12 by immersion. The total ELCR from exposure to radionuclides in surface water by all pathways combined, for adults, is 5E-07. For adolescents, the ELCRs from exposure to radionuclides in surface water are 3E-07 by ingestion and 7E-13 by immersion. The total ELCR from exposure to radionuclides in surface water by all pathways combined, for adolescents, is 3E-07.

For both receptors, adults and adolescents, cumulative ELCRs from exposure to radionuclides in surface water, by all pathways combined, are below the EPA's acceptable cancer risk range of 1E-04 to 1E-06.

Sediment

Adults and adolescents were evaluated for their exposures to radiological COPCs in sediment via incidental ingestion, inhalation, and external exposure. The risk characterization results for each radionuclide and pathway are presented in detail on Printouts B3.c and B4.c of Appendix B, for adults and adolescents, respectively. Risk results for these receptors are also summarized on Table 10.

For adults, the ELCRs from exposure to radionuclides in sediment are 8E-08 by ingestion, 8E-10 by inhalation, and 2E-07 by external exposure. The total ELCR from exposure to radionuclides in sediment by all pathways combined, for adults, is 2E-07. For adolescents, the ELCRs from exposure to radionuclides in sediment are 3E-08 by ingestion, 3E-10 by inhalation, and 6E-08 by external exposure. The total ELCR from exposure to radionuclides in sediment by all pathways combined, for adolescents, is 9E-08.

For both receptors, adults and adolescents, cumulative ELCRs from exposure to radionuclides in sediment, by all pathways combined, are below the EPA's acceptable cancer risk range of 1E-04 to 1E-06.

Fish Ingestion

Adults and adolescents were evaluated for their exposures to radiological COPCs in fish tissue via ingestion. The risk characterization results for each radionuclide are presented in detail on Printouts B5.c and B6.c of Appendix B, for adults and adolescents, respectively. Risk results for these receptors are also summarized on Table 10.

For adults, the ELCR from exposure to radionuclides by the ingestion of fish was found to be 2E-07. For adolescents, the ELCR from exposure to radionuclides by the ingestion fish was found to be 4E-08. Both of the ELCR results for adults and adolescents are below the EPA's acceptable risk range of 1E-04 to 1E-06.

Site-Wide Cumulative Radiological Risk Estimates

Risk results for each receptor were summed across all environmental media, pathways, and radionuclides to derive the cumulative site-wide radiological risk. Site-wide cumulative risk results for these receptors are summarized on Table 10.

The cumulative site-wide radiological ELCR for adults is 1E-06, within the EPA's acceptable risk range of 1E-04 to 1E-06.

The cumulative site-wide radiological ELCR for adolescents is 5E-07, below the EPA's acceptable risk range of 1E-04 to 1E-06.

5.2.3 Cumulative Chemical and Radiological Risk

EPA recommends that excess cancer risks from both chemical carcinogens and radionuclides be summed to provide an estimate of the combined risk presented by all carcinogenic contaminants, as specified in EPA's *Establishment of Cleanup Levels at CERCLA Sites with Radioactive Contamination* (USEPA, 1997). Combined cancer risks are provided below.

Media	Excess Lifetime Cancer Risk	
	Adult Receptors	**Adolescent Receptors**
Surface Water	8E-07	6E-07
Sediment	5E-07	6E-07
Fish Tissue	2E-05	8E-06
Cumulative Site-Wide	3E-05	9E-06

As shown above, site-wide cumulative cancer risk results for adults and adolescents from exposure to chemicals and radionuclides are within the EPA's acceptable risk range of 1E-04 to 1E-06.

5.3 Uncertainty Analysis

Uncertainties are inherent in all components of the risk assessment process. The uncertainties presented in this section are qualitative in nature and relevant to the impact of potentially overestimating or underestimating risks of cancer and non-cancer health effects associated with the development of this risk assessment re-evaluation.

<u>Identification of COPCs</u>

In the original risk assessment, chemicals were eliminated from further consideration if they were: not detected, found to be present in laboratory blanks, common laboratory contaminants, found at concentrations below background, or classified as essential nutrients. Under current EPA risk assessment methodology, chemicals are not excluded as COPCs based on comparison with naturally-occurring background concentrations. Similarly, non-detected chemicals may be retained as COPCs, based on elevated laboratory reporting limits. Due to the limited scope and available resources for this risk re-evaluation, EPA evaluated the same COPCs identified by DOE in the original risk assessment.

It is possible that in following current COPC screening protocol, some portion of COPCs identified in the original risk assessment may have been eliminated or additional COPCs may have been identified. However, radioisotopes are the primary compounds of concern for this site, and current risk assessment guidance still directs comparison with background concentrations to limit radiological COPCs.

Data Evaluation

A majority of the analytical data utilized for this risk assessment re-evaluation was collected and analyzed prior to the original risk assessment. Because of this, estimates of potential risks from exposure to COPCs were calculated in this risk assessment re-evaluation assuming that chemical concentrations had not changed in the approximately 20 years since the RI. However, for most inorganic chemicals, it is likely that their concentrations may have attenuated somewhat, with erosion of sediments that may have occurred. For the organic COPCs, specifically the nitroaromatic compounds, it is also likely that they may have biodegraded by some extent. Either of these processes would likely result in lower concentrations than those reported in 1998.

In addition, regarding arsenic, elevated arsenic concentrations in groundwater have been documented along and south of the Slough. DOE previously investigated this area and concluded that "*reducing geochemical conditions in the alluvial aquifer in the vicinity of the Femme Osage slough are favorable for the presence of dissolved arsenic…Thus the arsenic in groundwater is assumed to be naturally occuring and not the result of contaminant migration from the bulk wastes that were present in the quarry*" (USDOE, 2003). The 1998 Quarry Residuals RI states that "*interaction occurs between the Femme Osage Slough and the alluvial aquifer. Typically, the hydraulic head in the slough is higher than in the adjacent alluvium indicating leakage from the slough to groundwater. At some locations the hydraulic head in the adjacent alluvium is higher indicating groundwater discharge into the slough*" (USDOE, 1998a). This reported interaction may impact non-site-specific contaminant concentrations, specifically arsenic, found at the Slough.

Because of this possibility, risk estimates for inorganics and nitroaromatics in surface water, sediment, and fish tissue may be overestimated in this risk assessment re-evaluation.

Calculation of EPCs

For COPCs in surface water and fish tissue, the original risk assessment used the maximum detected concentrations as the EPCs. The maximum concentration is selected as the EPC when not enough data exist to adequately derive the 95% UCL or the calculated 95% UCL is higher than the maximum concentration. Generally, use of maximum concentrations as the EPC overestimates potential risks. For this risk assessment re-evaluation, the uranium EPC for surface water was updated based on data collected since completion of the original risk assessment. No such data is available for sediment, fish tissue, or other surface water COPCs; therefore, EPA utilized identical EPC values for these respective COPCs.

Evaluation of COPCs with a Mutagenic Mode of Action

EPA currently recommends making an adjustment in cancer risk estimates for children and adolescents based on chemicals shown to exert a mutagenic mode of action (as discussed above in Section 4.1.2). This type of evaluation was not common practice during the development of the original risk assessment. For the COPCs evaluated in this risk assessment re-evaluation, the only chemical demonstrating a mutagenic mode of action is chromium, specifically the hexavalent species.

As it is standard Region 7 practice to make the health-protective assumption that all total chromium detected is the more toxic hexavalent form, chromium cancer risks developed for adolescents in this risk assessment re-evaluation have been adjusted for the mutagenic mode of action for chromium. However, for the conditions of the Slough, it is not likely that the chromium detected was in the hexavalent form, as this is the oxidized form of chromium. It is more likely that chromium in the media evaluated, especially sediments, is present in the reduced and less toxic form, trivalent chromium. Hence, the cancer risk estimated for adolescents from exposure to chromium is likely to be overestimated.

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TABLES

Table 1
Human Health Chemicals of Potential Concern (COPCs)
Original and Revised Risk Assessments
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Chemical[a]	Surface Water	Sediment	Fish
Metals			
Aluminum	+	+	n/a
Antimony	-	+	n/a
Arsenic	+	-	+
Beryllium	-	+	n/a
Cadmium	-	+	n/a
Chromium	+	+	n/a
Copper	-	+	n/a
Lead	+	-	+
Manganese	+	+	n/a
Mercury	-	+	+
Molybdenum	-	+	n/a
Nickel	+	+	n/a
Selenium	-	+	n/a
Silver	+	-	n/a
Strontium	+	+	n/a
Uranium[b]	+	+	+
Vanadium	-	+	n/a
Zinc	+	-	n/a
Organic Compounds			
1,3,5-Trinitrobenzene	+	+	n/a
1,3-Dinitrobenzene	-	+	n/a
2,4,6-Trinitrotoluene	+	+	n/a
2,4-Dinitrotoluene	+	+	n/a
2,6-Dinitrotoluene	+	+	n/a
Nitrobenzene	-	+	n/a

(a) All contaminants of concern are those selected in the original baseline risk assessment (DOE, 1998. *Baseline Risk Assessment for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring, MO.*)

(b) For the purpose of calculating excess cancer risks from the radiological COPC uranium, this risk assessment re-evaluation assumes that the total uranium concentrations reported for sediment, surface water, and fish tissue include the isotopes uranium-234, uranium-235, and uranium-238. The risk calculations also considers the in-growth of short-lived progeny to be present in secular equilibrium. Natural uranium also contains a small mass percentage of uranium-235. Its short-lived progeny, thorium-231, is included in the assessment at the same activity as uranium-235.

n/a = not analyzed

Table 2
Exposure Point Concentrations (EPCs)
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

COPC	Surface Water[a]		Sediment[a]		Fish Tissue[b]	
	mg/L	pCi/L	mg/kg	pCi/g	mg/kg	pCi/g
Metals						
Aluminum	7	-	15000	-	-	-
Antimony	-	-	16	-	-	-
Arsenic	0.0087	-	-	-	0.085	-
Beryllium	-	-	1.4	-	-	-
Cadmium	-	-	1.3	-	-	-
Chromium	(c)	-	19	-	-	-
Copper	0.011	-	24	-	-	-
Lead	(c)	-	-	-	0.83	-
Manganese	(c)	-	840	-	-	-
Mercury	-	-	0.10	-	0.14	-
Molybdenum	-	-	2.0	-	-	-
Nickel	0.014	-	23	-	-	-
Selenium	-	-	3.9	-	-	-
Silver	(c)	-	-	-	-	-
Strontium	0.26	-	58	-	-	-
Uranium[d]	0.25	170[e]	13	4.5	0.0079	0.0057
Vanadium	-	-	36	-	-	-
Zinc	0.085	-	77	-	-	-
Organic Compounds						
1,3,5-Trinitrobenzene	0.000040	-	0.025	-	-	-
1,3-Dinitrobenzene	-	-	0.0065	-	-	-
2,4,6-Trinitrotoluene	0.000067	-	0.25	-	-	-
2,4-Dinitrotoluene	0.000037	-	0.0065	-	-	-
2,6-Dinitrotoluene	0.000026	-	0.25	-	-	-
Nitrobenzene	-	-	0.25	-	-	-

COPC = contaminant of potential concern

(a)From Table 3.5 of the original baseline risk assessment (USDOE, 1998).
Surface water EPCs based on maximum detected concentrations.
Sediment EPCs based on the 95% upper confidence level concentrations about the mean.

(b)From Table 3.6 of the original baseline risk assessment (USDOE, 1998). Fish tissue EPCs based on maximum detected concentrations.

(c)Indicates that the chemical is noted as a COPC for the specified media; but, no EPC is presented on Table 3.5 of the original BRA report (USDOE, 1998).

(d)For uranium in surface water, the EPC reported on this table is the maximum concentration detected in the Femme Slough since 1995. The uranium EPC used in the original BHHRA was 0.078 mg/L (53 pCi/L), which was the maximum detected concentration at that time.

(e)The uranium EPC was converted from mass (µg/L) to activity (pCi/L) using DOE's site-specific conversion factor of 0.68 pCi/µg. The converted value represents the sum of all activity from the isotopes uranium-238, -235 and -234.

- dashes indicate that the chemical is not a COPC for that media.

Table 3
Exposure Assumptions and Intake Parameters
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Parameter	Parameter Units	Values		
		Original Risk Assessment[a]	Risk Assessment Re-Evaluation	
			Adolescent	Adult
Exposure time (ET) - for surface water contact	hour/day	1	1	1
Exposure time (ET) - for sediment contact	hour/day	4	4	4
Exposure frequency (EF) for surface water and sediment exposure	events/year	20	20	20
Exposure frequency (EF) for fish ingestion	events/year	20	350	350
Exposure duration (ED), for surface water, sediment, and fish exposure	years	30	10	26
Body weight (BW)[b]	kg	70	44.3	80
Sediment ingestion rate (IR_{SD})[c]	mg/event	120	100	100
Surface water Ingestion rate (IR_{SW})[d]	mL/event	200	120	71
Fish ingestion rate (IR_F)[e]	g/event-original g/day-re-eval.	55	19.2	41.8
Inhalation rate[f]	m^3/hr	2.1	1.89	2.34
Particulate emission factor[g]	m^3/kg	4.63E+09	1.36E+09	1.36E+09
Skin surface area available for contact with surface water (SSA)[h]	cm^2	4200	13,350	19,652
Skin surface area available for contact with sediment (SSA)[i]	cm^2	820	4,683	6,032
Adherence factor of sediment to skin (AF)[j]	mg/cm^2-event	0.2	0.3	0.3
Permeability coefficient[k]	cm/hour	1×10^{-3}	chemical specific	chemical specific
Averaging time - Cancer (AT_C)[l]	days	*not presented*	25550	25550
Averaging time - Noncancer (AT_{NC})[m]	days	*not presented*	3650	9490
Absorption factors from sediment (ABS)[n]:				
Aluminum	unitless	0.01	--	--
Antimony	unitless	0.01	--	--
Beryllium	unitless	0.005	--	--
Cadmium	unitless	0.05	0.001	0.001
Chromium	unitless	0.1	--	--
Copper	unitless	0.5	--	--
Manganese	unitless	0.1	--	--
Mercury	unitless	--	--	--
Molybdenum	unitless	0.05	--	--
Nickel	unitless	0.05	--	--
Selenium	unitless	0.05	--	--
Strontium	unitless	--	--	--
Uranium	unitless	0.002	--	--
Vanadium	unitless	0.01	--	--
1,3,5-Trinitrobenzene	unitless	0.2	0.019	0.019
1,3-Dinitrobenzene	unitless	0.2	0.1	0.1
2,4,6-Trinitrotoluene	unitless	0.2	0.032	0.032
2,4-Dinitrotoluene	unitless	0.2	0.102	0.102
2,6-Dinitrotoluene	unitless	0.2	0.099	0.099
Nitrobenzene	unitless	0.2	--	--

(a)All values in this column are from the original BRA: USDOE. 1998. *Baseline Risk Assessment for the Quarry Residuals Operable Unit of the Weldon Spring Site, Weldon Spring, MO.* DOE/OR/21548.594.

Reference sources are itemized below, with more discussion presented in Section 3.3.3 of the text.

(b)From EPA, 2011a. *Exposure Factors Handbook,* Table 8.1, mean of ages 6-11 and 11-16 years.

(c)From EPA, 2014a. *Standard Default Exposure Parameters* .

(d)From EPA, 2011a. *Exposure Factors Handbook* , Table 3-5 for swimming.

(e)From EPA, 2014b. *Estimated Fish consumption Rates for the US Population and Selected Subpopulations (NHANES 2003-2010) Final Report.* April 2014. EPA-820-R0-14-002. https://www.epa.gov/sites/production/files/2015-01/documents/fish-consumption-rates-2014.pdf.

(f)From EPA, 2011a. *Exposure Factors Handbook* , Table 6-2, for 4 hours exposure.

(g)From EPA, 2002. *Supplemental Guidance for Soil Screening Levels.*

(h)From EPA 2014a. *Standrad Default Exposure Parameters.*

(i)From EPA, 2011a. *Exposure Factors Handbook.*

(j)From EPA, 2004. *RAGS Part E, Supplemental Guidance for Dermal Risk Assessment.*

(k)From EPA, 2004. *RAGS Part E, Supplemental Guidance for Dermal Risk Assessment.*

(l)From EPA, 1989. *RAGS Part A* . Averaging time of exposure for carcinogenic effects are calculated as follows: 70-year lifetime exposure (70 years x 365 days/year = 25,550 days)

(m)From EPA, 1989. *RAGS Part A* . Averaging time for noncarcinogens, calculated as follows: ED years x 365 days/year.

(n)From EPA, 2004. *RAGS Part E, Supplemental Guidance for Dermal Risk Assessment.*

Table 4
Carcinogenic Oral and Dermal Toxicity Values: Chemical Exposure Pathways
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Chemicals of Potential Concern	Oral Slope Factor (mg/kg-day)$^{-1}$	Gastrointestinal Absorption Factor unitless	Dermal Slope Factor[1] (mg/kg-day)	Weight of Evidence/ Cancer Guildeline Description	Oral SF Source
Aluminum	nd	1	nd		
Antimony	nd	0.15	nd		
Arsenic	1.50E+00	1	1.50E+00	A	IRIS
Beryllium	nd	0.007	nd		
Cadmium	nd	0.05	nd		
Chromium	5.00E-01	0.025	2.00E+01	D, mutagenic[2]	CalEPA
Copper	nd	1	nd		
Manganese	nd	0.04	nd		
Mercury	nd	1.00E+00	nd		
Molybdenum	nd	1	nd		
Nickel	nd	0.04	nd		
Selenium	nd	1	nd		
Strontium	nd	1	nd		
Uranium	nd	1	nd		
Vanadium	nd	0.026	nd		
Zinc	nd	1	nd		
1,3,5-Trinitrobenzene	nd	1	nd		
1,3-Dinitrobenzene	nd	1	nd		
2,4,6-Trinitrotoluene	3.00E-02	1	3.0E-02	C, urinary	IRIS
2,4-Dinitrotoluene	3.1E-01	1	3.1E-01	nd	CalEPA
2,6-Dinitrotoluene	1.5E+00	1	1.5E+00	SU, hepatocellular	PPRTV
Nitrobenzene	nd	1.00E+00	nd		

CalEPA = California's Office of Environmental Health and Hazard Assessment (CalEPA, Accessed on-line 2019)
HEAST = Health Effects Assessment Summary Tables (USEPA, 2011b)
IRIS = USEPA's Integrated Risk Information System (USEPA, accessed on-line 2019a)
PPTRV = Provisional Peer-Reviewed Toxicity Values (PPRTV) (USEPA, accessed on-line 2019b)
[1]Dermal slope factor = oral slope factor ÷ gastrointestinal absorption factor (GIABS)
[2]USEPA, 2005a. *Guidelines for Carcinogen Risk Assessment.*
nd = no data

Weight of Evidence Classifications (USEPA, 1986. *Guidelines for Carcinogen Risk Assessment.*)
A = Human carcinogen
B1 = Probable human carcinogen - based on limited evidence in humans and sufficient evidence in animals
B2 = Probable human carcinogen - based on sufficient evidence in animals
C = Possible human carcinogen
D = Not classifiable
SU = suggestive evidence of carcinogenicity in humans (PPRTV)

Table 5
Carcinogenic Inhalation Toxicity Values: Chemical Exposure Pathways
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Chemicals of Potential Concern	Inhalation Unit Risk $(\mu g/m^3)^{-1}$	Weight of Evidence/ Cancer Guildeline, Tumor Site Description	Unit Risk Source
Aluminum	nd		
Antimony	nd		
Arsenic	4.30E-03	A, lung	IRIS
Beryllium	2.40E-03	B1, lung	IRIS
Cadmium	1.80E-03	B1, lung	IRIS
Chromium	8.40E-02	A, lung	USEPA-RSLs UG
Copper	nd		
Manganese	nd		
Mercury	nd		
Molybdenum	nd		
Nickel	2.60E-04	immune system	CalEPA
Selenium	nd		
Strontium	nd		
Uranium	nd		
Vanadium	nd		
Zinc	nd		
1,3,5-Trinitrobenzene	nd		
1,3-Dinitrobenzene	nd		
2,4,6-Trinitrotoluene	nd		
2,4-Dinitrotoluene	8.9E-05	nd	CalEPA
2,6-Dinitrotoluene	nd		
Nitrobenzene	4.00E-05	likely to be carcinogenic; hepatic, urinary, endrocrine	IRIS

IRIS = USEPA's Integrated Risk Information System (USEPA, Accessed on-line 2019a)
USEPA RSLs UG = USEPA's Regional Screening Level Table, Users Guide (USEPA, Accessed on-line 2019)
CalEPA = California's Office of Environmental Health and Hazard Assessment (CalEPA, Accessed on-line 2019)
[1]USEPA, 2005a. *Guidelines for Carcinogen Risk Assessment.*
nd = no data

Weight of Evidence Classifications (USEPA, 1986. *Guidelines for Carcinogen Risk Assessment.*)
A = Human carcinogen
B1 = Probable human carcinogen - based on limited evidence in humans and sufficient evidence in animals
B2 = Probable human carcinogen - based on sufficient evidence in animals
C = Possible human carcinogen
D = Not classifiable

Table 6
Noncarcinogenic Oral and Dermal Toxicity Values: Chemical Exposure Pathways
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Chemicals of Potential Concern	Oral Reference Dose (RfD) (mg/kg-day)	Gastrointestinal Absorption Factor (%)	Default Dermal RfD[1] mg/kg-day	Primary Target Organ(s)	Uncertainty/ Modifying Factor	Source
Aluminum	1.0E+00	1	1.0E+00	Neurologic	100	PPRTV
Antimony	4.0E-04	0.15	6.0E-05	Hematologic	1,000	IRIS
Arsenic	3.0E-04	1	3.0E-04	Cardiovascular, Skin	3	IRIS
Beryllium	2.0E-03	0.007	1.4E-05	Gastrointestinal	300	IRIS
Cadmium	1.0E-03	0.025	2.5E-05	Urinary	10	IRIS
Chromium	3.0E-03	0.025	7.5E-05	Respiratory	900	IRIS
Copper	4.0E-02	1	4.0E-02	Gastrointestinal	nd	HEAST
Manganese	2.4E-02	0.04	9.6E-04	Central nervous system	3	USEPA-RSLs UG
Mercury	nd	1	nd			
Molybdenum	5.0E-03	1	5.0E-03	Urinary	30	IRIS
Nickel	2.0E-02	0.04	8.0E-04	Decreased body weight	300	IRIS
Selenium	5.0E-03	1	5.0E-03	Nervous, hematologic,dermal	3	IRIS
Strontium	6.0E-01	1	6.0E-01	Musculoskeletal	300	IRIS
Uranium	2.0E-04	1	2.0E-04	nd	nd	ATSDR
Vanadium	5.0E-03	0.026	1.3E-04	nd	nd	USEPA-RSLs
Zinc	3.0E-01	1	3.0E-01	Immune, hematologic	3	IRIS
1,3,5-Trinitrobenzene	3.0E-02	1	3.0E-02	Hepatic	1000	IRIS
1,3-Dinitrobenzene	1.0E-04	1	1.0E-04	Immune	3000	IRIS
2,4,6-Trinitrotoluene	5.0E-04	1	5.0E-04	Hepatic	1000	IRIS
2,4-Dinitrotoluene	2.0E-03	1	2.0E-03	Nervous, hepatic, hematologic	100	IRIS
2,6-Dinitrotoluene	3.0E-04	1	3.0E-04	Spleen	10000	App PPRTV
Nitrobenzene	2.0E-03	1	2.00E-03	Hematologic	1000	IRIS

ATSDR = Agency for Toxic Substances Disease Registry (ATSDR, Accessed on-line 2019)
HEAST = Health Effects Assessment Summary Tables (USEPA, 2011b)
IRIS = USEPA's Integrated Risk Information System (USEPA, Accessed on-line 2019a)
PPRTV = Provisional Peer-Reviewed Toxicity Values (PPRTV) (USEPA, Accessed on-line 2019b)
App PPRTV = Appendix PPRTV (PPRTV, Accessed on-line 2019)
USEPA RSLs UG = USEPA's Regional Screening Level Table User's Guide (USEPA, Accessed on-line 2019)
USEPA RSLs = USEPA's Regional Screening Level Table (USEPA, November 2018)
nd = no data
[1]Dermal default RfD = Oral reference dose x gastrointestinal absorption factor (GIABS)

Table 7
Noncarcinogenic Inhalation Toxicity Values: Chemical Exposure Pathways
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Chemicals of Potential Concern	Inhalation Reference Concentration RfC (mg/m^3)	Inhalation Reference Concentration RfC ($\mu g/m^3$)	Primary Target Organ(s)	Uncertainty/ Modifying Factor	Source
Aluminum	5.00E-03	5.00E+00	Neurologic	300	PPRTV
Antimony	nd				
Arsenic	1.50E-05	1.50E-02	Cardiovascular	nd	CalEPA
Beryllium	2.00E-05	2.00E-02	Immune, respiratory	10	IRIS
Cadmium	1.00E-05	1.00E-02	Kidney	nd	ATSDR
Chromium	1.00E-04	1.00E-01	Nasal	90	IRIS
Copper	nd				
Manganese	5.00E-05	5.00E-02	Nervous	1000	IRIS
Mercury	3.0E-04	3.00E-01	Nervous	30	IRIS
Molybdenum	nd				
Nickel	9.00E-05	9.00E-02	Respiratory	30	ATSDR
Selenium	2.00E-02	2.00E+01			CalEPA
Strontium	nd				
Uranium	4.00E-05	4.00E-02	Urinary		ATSDR
Vanadium	1.0E-04	1.00E-01	Respiratory, hematalogic		ATSDR
Zinc	nd				
1,3,5-Trinitrobenzene	nd				
1,3-Dinitrobenzene	nd				
2,4,6-Trinitrotoluene	nd				
2,4-Dinitrotoluene	nd				
2,6-Dinitrotoluene	nd				
Nitrobenzene	9.0E-03	9.00E+00	Nervous, respiratory	30	IRIS

ATSDR = Agency for Toxic Substances Disease Registry (ATSDR, Accessed on-line 2019)
CalEPA = California's Office of Environmental Health and Hazard Assessment (CalEPA, Accessed on-line 2019)
IRIS = USEPA's Integrated Risk Information System (USEPA, Accessed on-line 2019a)
PPRTV = Provisional Peer-Reviewed Toxicity Values (PPRTV) (USEPA, Accessed on-line 2019b)
nd = no data

Table 8
Carcinogenic Toxicity Values: Radiological Exposure Pathways
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

	Surface Water		Sediment			Fish
Radionuclide	Ingestion Slope Factor (risk/pCi)	Immersion Slope Factor (risk/yr per pCi/L)	Ingestion Slope Factor (risk/pCi)	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/yr per pCi/g)	Ingestion Slope Factor (risk/pCi)
Thorium-231	2.19E-12	8.89E-14	5.96E-12	1.50E-12	2.49E-08	3.22E-12
Uranium-235	6.96E-11	1.39E-12	1.48E-10	2.50E-08	5.51E-07	9.44E-11
Protactinium-234	2.07E-12	1.35E-11	5.37E-12	1.20E-12	6.62E-06	3.00E-12
Protactinium-234m	--	1.82E-13	--	--	9.06E-08	-
Thorium-234	2.31E-11	6.39E-14	6.25E-11	3.08E-11	1.77E-08	3.39E-11
Uranium-234	7.07E-11	1.17E-15	1.48E-10	2.78E-08	2.53E-10	9.55E-11
Uranium-238	6.40E-11	5.98E-16	1.34E-10	2.36E-08	1.24E-10	8.66E-11

Source for slope factors:
https://epa-prgs.ornl.gov/radionuclides/
https://epa-prgs.ornl.gov/radionuclides/SlopesandDosesMasterTableFinal.pdf

Table 9
Risk Results Summary - Chemical Exposure Pathways
Recreational Visitors, All Pathways
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

	Adults		Adolescents	
COPC / Media	**ELCRs**	**HQs**	**ELCRs**	**HQs**
Surface Water Ingestion				
Aluminum	na	3E-04	na	1E-03
Arsenic	2E-07	1E-03	3E-07	4E-03
Nickel	na	3E-05	na	1E-04
Strontium	na	2E-05	na	6E-05
Uranium	na	6E-02	na	2E-01
Zinc	na	1E-05	na	4E-05
1,3,5-Trinitrobenzene	na	6E-08	na	2E-07
2,4,6-Trinitrotoluene	4E-11	7E-06	4E-11	2E-05
2,4-Dinitrotoluene	2E-10	9E-07	2E-10	3E-06
2,6-Dinitrotoluene	7E-10	4E-06	8E-10	1E-05
Total Surface Water Ingestion	2E-07	6E-02	3E-07	2E-01
Surface Water Dermal				
Aluminum	na	9E-05	na	1E-04
Arsenic	7E-08	4E-04	3E-08	5E-04
Nickel	na	5E-05	na	6E-05
Strontium	na	6E-06	na	7E-06
Uranium	na	2E-02	na	2E-02
Zinc	na	2E-06	na	3E-06
1,3,5-Trinitrobenzene	na	4E-08	na	5E-08
2,4,6-Trinitrotoluene	4E-11	7E-06	2E-11	8E-06
2,4-Dinitrotoluene	5E-10	2E-06	2E-10	3E-06
2,6-Dinitrotoluene	2E-09	1E-05	1E-09	2E-05
Total Surface Water Dermal	7E-08	2E-02	3E-08	2E-02
Total All Surface Water Pathways	3E-07	8E-02	3E-07	2E-01

Table 9
Risk Results Summary - Chemical Exposure Pathways
Recreational Visitors, All Pathways
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

	Adults		Adolescents	
COPC / Media	**ELCRs**	**HQs**	**ELCRs**	**HQs**
Sediment Ingestion				
Aluminum	na	1E-03	na	2E-03
Antimony	na	3E-03	na	5E-03
Beryllium	na	5E-05	na	9E-05
Cadmium	na	9E-05	na	2E-04
Chromium	2E-07	4E-04	5E-07	8E-04
Copper	na	4E-05	na	7E-05
Manganese	na	2E-03	na	4E-03
Mercury	na	na	na	na
Molybdenum	na	3E-05	na	5E-05
Nickel	na	8E-05	na	1E-04
Selenium	na	5E-05	na	1E-04
Strontium	na	7E-06	na	1E-05
Uranium	na	4E-03	na	8E-03
Vanadium	na	5E-04	na	9E-04
1,3,5-Trinitrobenzene	na	6E-08	na	1E-07
1,3-Dinitrobenzene	na	4E-06	na	8E-06
2,4,6-Trinitrotoluene	2E-10	3E-05	1E-10	6E-05
2,4-Dinitrotoluene	5E-11	2E-07	4E-11	4E-07
2,6-Dinitrotoluene	1E-08	6E-05	7E-09	1E-04
Nitrobenzene	na	9E-06	na	2E-05
Total Sediment Ingestion	3E-07	1E-02	5E-07	2E-02
Sediment Dermal				
Aluminum	na	na	na	na
Antimony	na	na	na	na
Beryllium	na	na	na	na
Cadmium	na	6E-05	na	9E-05
Chromium	na	na	na	na
Copper	na	na	na	na
Manganese	na	na	na	na
Mercury	na	na	na	na
Molybdenum	na	na	na	na
Nickel	na	na	na	na
Selenium	na	na	na	na
Strontium	na	na	na	na
Uranium	na	na	na	na
Vanadium	na	na	na	na
1,3,5-Trinitrobenzene	na	2E-08	na	3E-08
1,3-Dinitrobenzene	na	8E-06	na	1E-05
2,4,6-Trinitrotoluene	1E-10	2E-05	6E-11	3E-05
2,4-Dinitrotoluene	9E-11	4E-07	5E-11	6E-07
2,6-Dinitrotoluene	2E-08	1E-04	9E-09	1E-04
Nitrobenzene	na	na	na	na
Total Sediment Dermal	2E-08	2E-04	9E-09	3E-04

Table 9
Risk Results Summary - Chemical Exposure Pathways
Recreational Visitors, All Pathways
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

	Adults		Adolescents	
COPC / Media	**ELCRs**	**HQs**	**ELCRs**	**HQs**
Sediment Inhalation				
Aluminum	na	2E-05	na	2E-05
Antimony	na	na	na	na
Beryllium	8E-12	5E-07	3E-12	5E-07
Cadmium	6E-12	9E-07	2E-12	9E-07
Chromium	4E-09	1E-06	5E-09	1E-06
Copper	na	na	na	na
Manganese	na	1E-04	na	1E-04
Mercury	na	3E-05	na	4E-05
Molybdenum	na	na	na	na
Nickel	2E-11	2E-06	6E-12	2E-06
Selenium	na	1E-09	na	1E-09
Strontium	na	na	na	na
Uranium	na	2E-06	na	2E-06
Vanadium	na	2E-06	na	2E-06
1,3,5-Trinitrobenzene	na	na	na	na
1,3-Dinitrobenzene	na	na	na	na
2,4,6-Trinitrotoluene	na	na	na	na
2,4-Dinitrotoluene	1E-15	na	6E-16	na
2,6-Dinitrotoluene	na	na	na	na
Nitrobenzene	6E-10	4E-06	4E-10	7E-06
Total Sediment Inhalation	5E-09	2E-04	5E-09	2E-04
Total All Sediment Pathways	3E-07	1E-02	5E-07	2E-02
Fish Ingestion				
Arsenic	2E-05	1E-01	8E-06	1E-01
Mercury	na	na	na	na
Uranium	na	2E-02	na	2E-02
Total Fish Ingestion	2E-05	2E-01	8E-06	1E-01

Table 9
Risk Results Summary - Chemical Exposure Pathways
Recreational Visitors, All Pathways
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

	Adults		Adolescents	
COPC / Media	**ELCRs**	**HQs**	**ELCRs**	**HQs**
All Pathways				
Aluminum	na	1E-03	na	3E-03
Antimony	na	3E-03	na	5E-03
Arsenic	2E-05	1E-01	8E-06	1E-01
Beryllium	8E-12	5E-05	3E-12	9E-05
Cadmium	6E-12	9E-05	na	2E-04
Chromium	2E-07	4E-04	5E-07	8E-04
Copper	na	4E-05	na	7E-05
Manganese	na	3E-03	na	4E-03
Mercury	na	3E-05	na	4E-05
Molybdenum	na	3E-05	na	5E-05
Nickel	2E-11	2E-04	6E-12	3E-04
Selenium	na	5E-05	na	1E-04
Strontium	na	3E-05	na	8E-05
Uranium	na	1E-01	na	2E-01
Vanadium	na	5E-04	na	9E-04
Zinc	na	2E-05	na	4E-05
1,3,5-Trinitrobenzene	na	2E-07	na	4E-07
1,3-Dinitrobenzene	na	1E-05	na	2E-05
2,4,6-Trinitrotoluene	4E-10	7E-05	3E-10	1E-04
2,4-Dinitrotoluene	9E-10	4E-06	6E-10	6E-06
2,6-Dinitrotoluene	3E-08	2E-04	2E-08	3E-04
Nitrobenzene	6E-10	1E-05	4E-10	2E-05
Cumulative Site-Wide Totals	2E-05	3E-01	8E-06	4E-01

ELCR = Excess Lifetime Cancer Risk
HQ = Hazard Quotient
na = not applicable; toxicity factors are not available for these chemicals

Note: For radiological ELCRs from exposure to uranium in all media, see Table 10.

Table 10
Risk Results Summary - Radiological Exposure Pathways
Recreational Visitors, All Pathways
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

COPC / Media	Adult ELCRs	Adolescent ELCRs
Surface Water Ingestion		
Thorium-231	3E-10	2E-10
Uranium-235	1E-08	7E-09
Protactinium-234	1E-11	7E-12
Protactinium-234m	0E+00	0E+00
Thorium-234	7E-08	5E-08
Uranium-234	2E-07	1E-07
Uranium-238	2E-07	1E-07
Total Surface Water Ingestion	5E-07	3E-07
Surface Water Immersion		
Thorium-231	2E-14	9E-15
Uranium-235	3E-13	1E-13
Protactinium-234	1E-13	4E-14
Protactinium-234m	9E-13	4E-13
Thorium-234	3E-13	1E-13
Uranium-234	6E-15	2E-15
Uranium-238	3E-15	1E-15
Total Surface Water Immersion	2E-12	7E-13
Total All Surface Water Pathways	5E-07	3E-07
Sediment Ingestion		
Thorium-231	7E-11	3E-11
Uranium-235	2E-09	7E-10
Protactinium-234	2E-12	8E-13
Protactinium-234m	0E+00	0E+00
Thorium-234	1E-08	6E-09
Uranium-234	3E-08	1E-08
Uranium-238	3E-08	1E-08
Total Sediment Ingestion	8E-08	3E-08
Sediment Inhalation		
Thorium-231	1E-15	4E-16
Uranium-235	2E-11	6E-12
Protactinium-234	3E-17	1E-17
Protactinium-234m	0E+00	0E+00
Thorium-234	5E-13	2E-13
Uranium-234	4E-10	1E-10
Uranium-238	4E-10	1E-10
Total Sediment Inhalation	8E-10	3E-10

Table 10
Risk Results Summary - Radiological Exposure Pathways
Recreational Visitors, All Pathways
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

COPC / Media	Adult ELCRs	Adolescent ELCRs
Sediment External Exposure		
Thorium-231	1.33E-09	5E-10
Uranium-235	2.79E-08	1E-08
Protactinium-234	1E-08	4E-09
Protactinium-234m	9E-08	4E-08
Thorium-234	2E-08	7E-09
Uranium-234	3E-10	1E-10
Uranium-238	1E-10	5E-11
Total Sediment External Exposure	2E-07	6E-08
Total All Sediment Pathways	2E-07	9E-08
Fish Ingestion		
Thorium-231	2E-10	3E-11
Uranium-235	5E-09	9E-10
Protactinium-234	5E-12	9E-13
Protactinium-234m	0E+00	0E+00
Thorium-234	4E-08	7E-09
Uranium-234	1E-07	2E-08
Uranium-238	9E-08	2E-08
Total Fish Ingestion	2E-07	4E-08
All Pathways		
Thorium-231	2E-09	8E-10
Uranium-235	5E-08	2E-08
Protactinium-234	1E-08	4E-09
Protactinium-234m	9E-08	4E-08
Thorium-234	1E-07	7E-08
Uranium-234	4E-07	2E-07
Uranium-238	3E-07	2E-07
Cumulative Site-Wide Totals	1E-06	5E-07

COPC = chemical of potential concern
ELCR = excess lifetime cancer risk

FIGURES

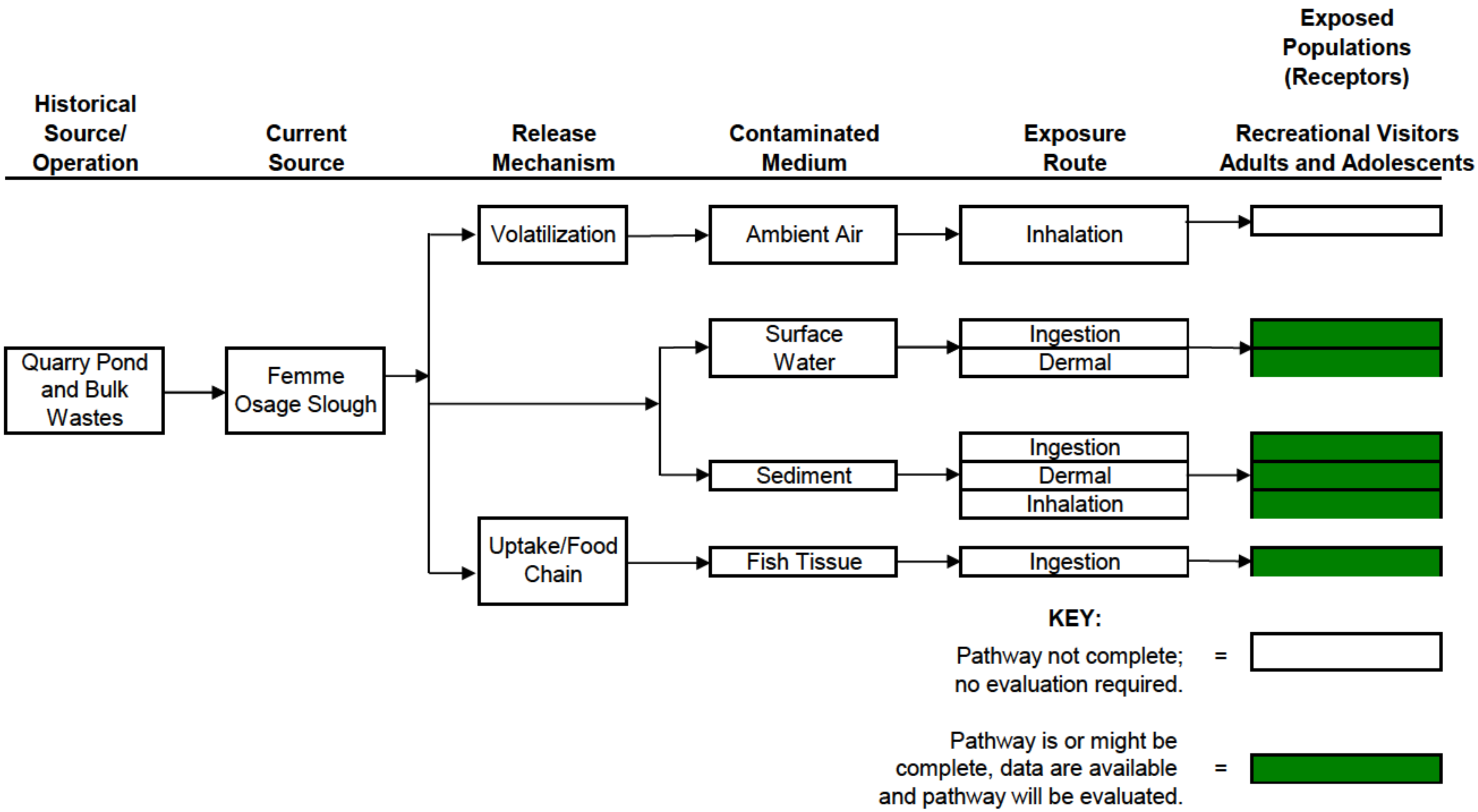

Figure 1. Human Health Conceptual Site Exposure Model (CSEM) for human exposure to chemical contaminants. Femme Osage Slough, Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

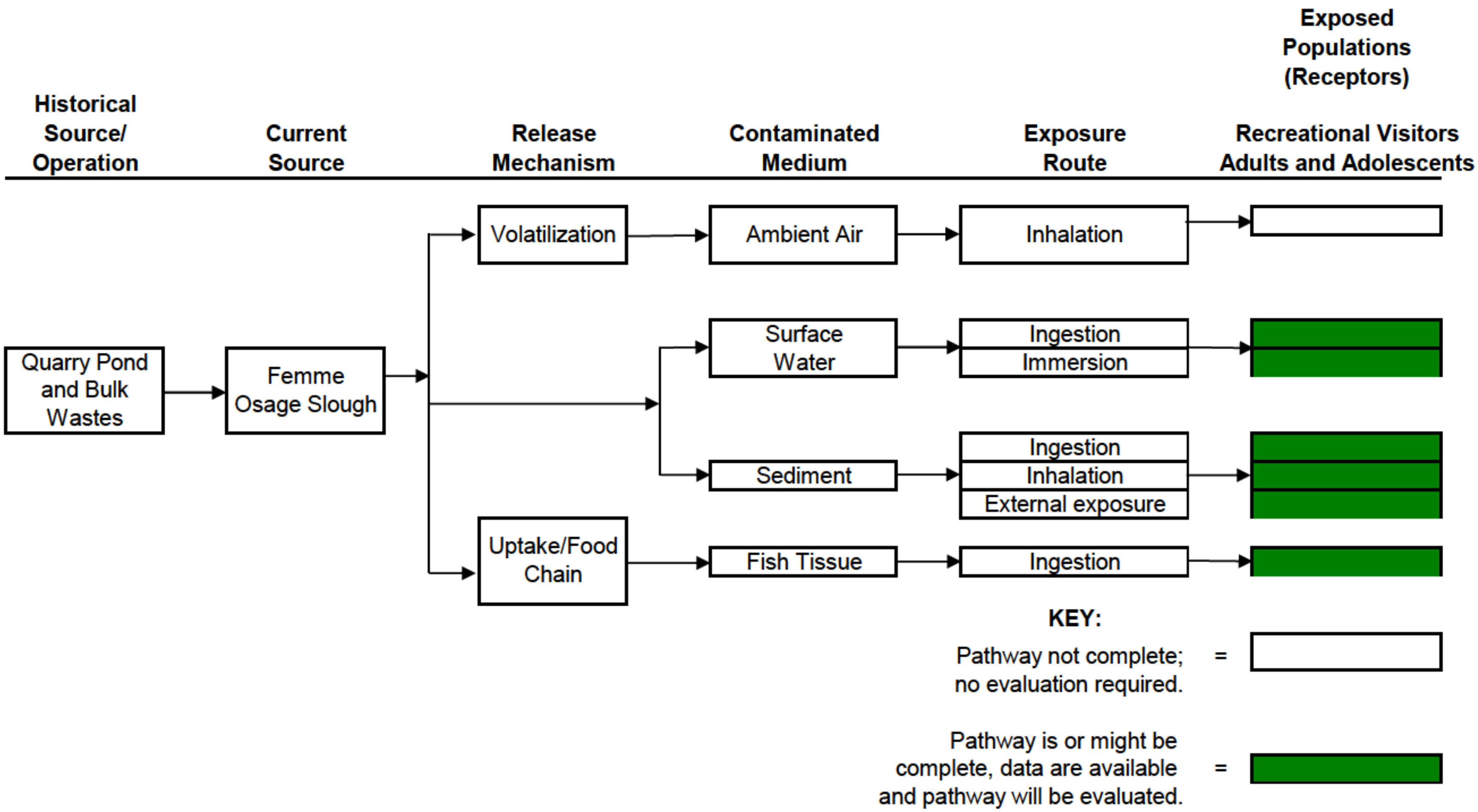

Figure 2. Human Health Conceptual Site Exposure Model (CSEM) for human exposure to radionuclides. Femme Osage Slough, Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

APPENDIX A

DETAILED CALCULATION TABLES
INTAKE AND RISK FOR CHEMICAL EXPOSURE PATHWAYS

Table A1
Daily Intake Calculations: Adult Recreational Visitors
Ingestion of Chemicals in Surface Water
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Equation	**$DI_{SW\text{-}Ing}$**	**= [**	**C_{SW}**	**x**	**IR_{SW}**	**x**	**EF**	**x**	**ED**	**] / [**	**BW**	**x**	**AT**	**]**
Units	**mg/kg-day**		**mg/L**		**L/event**		**events/yr**		**yr**		**kg**		**days**	
CARCINOGENIC EFFECTS														
Aluminum	1.26E-04	= [	7.00E+00	x	0.071	x	20	x	26	] / [	80	x	25,550	]
Arsenic	1.57E-07	= [	8.70E-03	x	0.071	x	20	x	26	] / [	80	x	25,550	]
Nickel	2.53E-07	= [	1.40E-02	x	0.071	x	20	x	26	] / [	80	x	25,550	]
Strontium	4.70E-06	= [	2.60E-01	x	0.071	x	20	x	26	] / [	80	x	25,550	]
Uranium	4.52E-06	= [	2.50E-01	x	0.071	x	20	x	26	] / [	80	x	25,550	]
Zinc	1.54E-06	= [	8.50E-02	x	0.071	x	20	x	26	] / [	80	x	25,550	]
1,3,5-Trinitrobenzene	7.23E-10	= [	4.00E-05	x	0.071	x	20	x	26	] / [	80	x	25,550	]
2,4,6-Trinitrotoluene	1.21E-09	= [	6.70E-05	x	0.071	x	20	x	26	] / [	80	x	25,550	]
2,4-Dinitrotoluene	6.68E-10	= [	3.70E-05	x	0.071	x	20	x	26	] / [	80	x	25,550	]
2,6-Dinitrotoluene	4.70E-10	= [	2.60E-05	x	0.071	x	20	x	26	] / [	80	x	25,550	]
NONCARCINOGENIC EFFECTS														
Aluminum	3.40E-04	= [	7.00E+00	x	0.071	x	20	x	26	] / [	80	x	9,490	]
Arsenic	4.23E-07	= [	8.70E-03	x	0.071	x	20	x	26	] / [	80	x	9,490	]
Nickel	6.81E-07	= [	1.40E-02	x	0.071	x	20	x	26	] / [	80	x	9,490	]
Strontium	1.26E-05	= [	2.60E-01	x	0.071	x	20	x	26	] / [	80	x	9,490	]
Uranium	1.22E-05	= [	2.50E-01	x	0.071	x	20	x	26	] / [	80	x	9,490	]
Zinc	4.13E-06	= [	8.50E-02	x	0.071	x	20	x	26	] / [	80	x	9,490	]
1,3,5-Trinitrobenzene	1.95E-09	= [	4.00E-05	x	0.071	x	20	x	26	] / [	80	x	9,490	]
2,4,6-Trinitrotoluene	3.26E-09	= [	6.70E-05	x	0.071	x	20	x	26	] / [	80	x	9,490	]
2,4-Dinitrotoluene	1.80E-09	= [	3.70E-05	x	0.071	x	20	x	26	] / [	80	x	9,490	]
2,6-Dinitrotoluene	1.26E-09	= [	2.60E-05	x	0.071	x	20	x	26	] / [	80	x	9,490	]

$DI_{SW\text{-}Ing}$ = daily chemical intake via surface water ingestion
C_{SW} = chemical concentration in surface water
IR_{SW} = surface water ingestion rate
EF = exposure frequency
ED = exposure duration
BW = body weight
AT = averaging time

Table A2
Daily Intake Calculations: Adolescent Recreational Visitors
Ingestion of Chemicals in Surface Water
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Equation	DI_{SW-Ing}	= [	C_{SW}	x	IR_{SW}	x	EF	x	ED	] / [	BW	x	AT	]
Units	**mg/kg-day**		**mg/L**		**L/event**		**events/yr**		**yr**		**kg**		**days**	
CARCINOGENIC EFFECTS														
Aluminum	1.48E-04	= [	7.00E+00	x	0.12	x	20	x	10	] / [	44.3	x	25,550	]
Arsenic	1.84E-07	= [	8.70E-03	x	0.12	x	20	x	10	] / [	44.3	x	25,550	]
Nickel	2.97E-07	= [	1.40E-02	x	0.12	x	20	x	10	] / [	44.3	x	25,550	]
Strontium	5.51E-06	= [	2.60E-01	x	0.12	x	20	x	10	] / [	44.3	x	25,550	]
Uranium	5.30E-06	= [	2.50E-01	x	0.12	x	20	x	10	] / [	44.3	x	25,550	]
Zinc	1.80E-06	= [	8.50E-02	x	0.12	x	20	x	10	] / [	44.3	x	25,550	]
1,3,5-Trinitrobenzene	8.48E-10	= [	4.00E-05	x	0.12	x	20	x	10	] / [	44.3	x	25,550	]
2,4,6-Trinitrotoluene	1.42E-09	= [	6.70E-05	x	0.12	x	20	x	10	] / [	44.3	x	25,550	]
2,4-Dinitrotoluene	7.85E-10	= [	3.70E-05	x	0.12	x	20	x	10	] / [	44.3	x	25,550	]
2,6-Dinitrotoluene	5.51E-10	= [	2.60E-05	x	0.12	x	20	x	10	] / [	44.3	x	25,550	]
NONCARCINOGENIC EFFECTS														
Aluminum	1.04E-03	= [	7.00E+00	x	0.12	x	20	x	10	] / [	44.3	x	3,650	]
Arsenic	1.29E-06	= [	8.70E-03	x	0.12	x	20	x	10	] / [	44.3	x	3,650	]
Nickel	2.08E-06	= [	1.40E-02	x	0.12	x	20	x	10	] / [	44.3	x	3,650	]
Strontium	3.86E-05	= [	2.60E-01	x	0.12	x	20	x	10	] / [	44.3	x	3,650	]
Uranium	3.71E-05	= [	2.50E-01	x	0.12	x	20	x	10	] / [	44.3	x	3,650	]
Zinc	1.26E-05	= [	8.50E-02	x	0.12	x	20	x	10	] / [	44.3	x	3,650	]
1,3,5-Trinitrobenzene	5.94E-09	= [	4.00E-05	x	0.12	x	20	x	10	] / [	44.3	x	3,650	]
2,4,6-Trinitrotoluene	9.94E-09	= [	6.70E-05	x	0.12	x	20	x	10	] / [	44.3	x	3,650	]
2,4-Dinitrotoluene	5.49E-09	= [	3.70E-05	x	0.12	x	20	x	10	] / [	44.3	x	3,650	]
2,6-Dinitrotoluene	3.86E-09	= [	2.60E-05	x	0.12	x	20	x	10	] / [	44.3	x	3,650	]

DI_{SW-Ing} = daily chemical intake via surface water ingestion
C_{SW} = chemical concentration in surface water
IR_{SW} = surface water ingestion rate
EF = exposure frequency
ED = exposure duration
BW = body weight
AT = averaging time

Table A3
Absorbed Dose of Chemicals in Surface Water - Organic Chemicals Only
All Recreational Visitors: for $t_{event} \leq t^*$
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Equation	DA_{event}	=	C_{SW}	x	CF	x	Kp	x	2	x	FA	x SQRT ((6 x	tau_{event}	x	t_{event}	) /	π	))	t*	
Units	mg/cm^2-event		mg/L		L/cm^3		cm/hr				unitless		hr/event		hr				hr	$t_{event} \leq t^*$
Aluminum	na	=	7.00E+00	x	1.00E-03	x	1.00E-03	x	2	x	na	x SQRT ((6 x	1.5E-01	x	1	) /	3.14	))		
Arsenic	na	=	8.70E-03	x	1.00E-03	x	1.00E-03	x	2	x	na	x SQRT ((6 x	2.8E-01	x	1	) /	3.14	))		
Nickel	na	=	1.40E-02	x	1.00E-03	x	2.00E-04	x	2	x	na	x SQRT ((6 x	2.2E-01	x	1	) /	3.14	))		
Strontium	na	=	2.60E-01	x	1.00E-03	x	1.00E-03	x	2	x	na	x SQRT ((6 x	3.3E-01	x	1	) /	3.14	))		
Uranium	na	=	2.50E-01	x	1.00E-03	x	1.00E-03	x	2	x	na	x SQRT ((6 x	2.3E+00	x	1	) /	3.14	))		
Zinc	na	=	8.50E-02	x	1.00E-03	x	6.00E-04	x	2	x	na	x SQRT ((6 x	2.4E-01	x	1	) /	3.14	))		
1,3,5-Trinitrobenzene	8.60E-11	=	4.00E-05	x	1.00E-03	x	6.07E-04	x	2	x	1.0	x SQRT ((6 x	1.6E+00	x	1	) /	3.14	))	3.940	**Yes**
2,4,6-Trinitrotoluene	2.50E-10	=	6.70E-05	x	1.00E-03	x	9.63E-04	x	2	x	1.0	x SQRT ((6 x	2.0E+00	x	1	) /	3.14	))	4.720	**Yes**
2,4-Dinitrotoluene	3.31E-10	=	3.70E-05	x	1.00E-03	x	3.08E-03	x	2	x	1.0	x SQRT ((6 x	1.1E+00	x	1	) /	3.14	))	2.643	**Yes**
2,6-Dinitrotoluene	2.79E-10	=	2.60E-05	x	1.00E-03	x	3.70E-03	x	2	x	1.0	x SQRT ((6 x	1.1E+00	x	1	) /	3.14	))	2.643	**Yes**

DA_{event} = absorbed dose per event   nd = no data   na = not applicable

Cw = chemical concentration in water

CF = conversion factor, 1 L/1000 ml, and 1 ml = 1 cm^3

Kp = chemical dermal permeability coefficient in water; source: USEPA RSLs, Parameters Table

FA = fraction of chemical absorbed; source USEPA RAGS Part E, Dermal, Exhibit B-3

B = dimensionless ratio of the permeability coefficient

tau_{event} = lag time per event; source USEPA, 2004, RAGS Part E, Exhibit B-3

t_{event} = exposure time while swimming

π = pi

t* = time to reach steady state, hr

t* =(tau_{event} * 2.4)

is $t_{event} \leq t^*$, Yes - this is the proper formula for DA_{event}

is $t_{event} > t^*$, No - this is not the proper formula for Da_{event}

Table A4
Absorbed Dose of Chemicals in Surface Water - Inorganic Chemical Intake
All Recreational Visitors
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Equation	**DA_{event}**	**=**	**C_{SW}**	**x**	**CF**	**x**	**Kp**	**x**	**t_{event}**
Units	**mg/cm^2-event**		**mg/L**		**L/cm3**		**cm/hr**		**hr**
Aluminum	7.00E-06	=	7.00E+00	x	1.00E-03	x	1.00E-03	x	1
Arsenic	8.70E-09	=	8.70E-03	x	1.00E-03	x	1.00E-03	x	1
Nickel	2.80E-09	=	1.40E-02	x	1.00E-03	x	2.00E-04	x	1
Strontium	2.60E-07	=	2.60E-01	x	1.00E-03	x	1.00E-03	x	1
Uranium	2.50E-07	=	2.50E-01	x	1.00E-03	x	1.00E-03	x	1
Zinc	5.10E-08	=	8.50E-02	x	1.00E-03	x	6.00E-04	x	1
1,3,5-Trinitrobenzene	na	=	4.00E-05	x	1.00E-03	x	6.07E-04	x	1
2,4,6-Trinitrotoluene	na	=	6.70E-05	x	1.00E-03	x	9.63E-04	x	1
2,4-Dinitrotoluene	na	=	3.70E-05	x	1.00E-03	x	3.08E-03	x	1
2,6-Dinitrotoluene	na	=	2.60E-05	x	1.00E-03	x	3.70E-03	x	1

DA_{event} = absorbed dose per event (mg/cm^2-event)

na = not applicable

C_{SW} = chemical concentration in surface water

CF = conversion factor, 1 L/1000 ml, and 1 ml = 1 cm^3

Kp = dermal permeability coefficient in water; source: USEPA Regional Screening Levels, Parameters Table (USEPA, Nov. 2018)

t_{event} = exposure time

na = not applicable

Table A5
Daily Intake Calculations: Adult Recreational Visitors
Dermal Absorbed Dose (DAD) of Chemicals in Surface Water
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Equation	DAD_{SW}	= [	DA_{event}	x	EF	x	ED	x	EV	x	SSA_{SW}	] / [	BW	x	AT	]
Units	mg/kg-day		mg/cm^2-event		days/year		years		events/day		cm^2		kg		days	
CARCINOGENIC EFFECTS																
Aluminum	3.50E-05	= [	7.00E-06	x	20	x	26	x	1	x	19652	] / [	80	x	25,550	]
Arsenic	4.35E-08	= [	8.70E-09	x	20	x	26	x	1	x	19652	] / [	80	x	25,550	]
Nickel	1.40E-08	= [	2.80E-09	x	20	x	26	x	1	x	19652	] / [	80	x	25,550	]
Strontium	1.30E-06	= [	2.60E-07	x	20	x	26	x	1	x	19652	] / [	80	x	25,550	]
Uranium	1.25E-06	= [	2.50E-07	x	20	x	26	x	1	x	19652	] / [	80	x	25,550	]
Zinc	2.55E-07	= [	5.10E-08	x	20	x	26	x	1	x	19652	] / [	80	x	25,550	]
1,3,5-Trinitrobenzene	4.30E-10	= [	8.60E-11	x	20	x	26	x	1	x	19652	] / [	80	x	25,550	]
2,4,6-Trinitrotoluene	1.25E-09	= [	2.50E-10	x	20	x	26	x	1	x	19652	] / [	80	x	25,550	]
2,4-Dinitrotoluene	1.65E-09	= [	3.31E-10	x	20	x	26	x	1	x	19652	] / [	80	x	25,550	]
2,6-Dinitrotoluene	1.40E-09	= [	2.79E-10	x	20	x	26	x	1	x	19652	] / [	80	x	25,550	]
NONCARCINOGENIC EFFECTS																
Aluminum	9.42E-05	= [	7.00E-06	x	20	x	26	x	1	x	19652	] / [	80	x	9,490	]
Arsenic	1.17E-07	= [	8.70E-09	x	20	x	26	x	1	x	19652	] / [	80	x	9,490	]
Nickel	3.77E-08	= [	2.80E-09	x	20	x	26	x	1	x	19652	] / [	80	x	9,490	]
Strontium	3.50E-06	= [	2.60E-07	x	20	x	26	x	1	x	19652	] / [	80	x	9,490	]
Uranium	3.37E-06	= [	2.50E-07	x	20	x	26	x	1	x	19652	] / [	80	x	9,490	]
Zinc	6.86E-07	= [	5.10E-08	x	20	x	26	x	1	x	19652	] / [	80	x	9,490	]
1,3,5-Trinitrobenzene	1.16E-09	= [	8.60E-11	x	20	x	26	x	1	x	19652	] / [	80	x	9,490	]
2,4,6-Trinitrotoluene	3.37E-09	= [	2.50E-10	x	20	x	26	x	1	x	19652	] / [	80	x	9,490	]
2,4-Dinitrotoluene	4.45E-09	= [	3.31E-10	x	20	x	26	x	1	x	19652	] / [	80	x	9,490	]
2,6-Dinitrotoluene	3.76E-09	= [	2.79E-10	x	20	x	26	x	1	x	19652	] / [	80	x	9,490	]

DAD_{SW} = dermal absorbed dose (mg/kg-day)
DA_{event} = absorbed dose per event (mg/cm^2-event)
EF = exposure frequency (days/year)
ED = exposure duration (years)
EV = event frequency (events/day)
SSA_{SW} = skin surface area available for contact (cm^2)
BW = body weight
AT = averaging time

Table A6
Daily Intake Calculations: Adolescent Recreational Visitors
Dermal Absorbed Dose (DAD) of Chemicals in Surface Water
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Equation	**DAD_{SW}**	**= [**	**DA_{event}**	**x**	**EF**	**x**	**ED**	**x**	**EV**	**x**	**SSA_{SW}**	**] / [**	**BW**	**x**	**AT**	**]**
Units	**mg/kg-day**		**mg/cm^2-event**		**days/year**		**years**		**events/day**		**cm^2**		**kg**		**days**	
CARCINOGENIC EFFECTS																
Aluminum	1.65E-05	= [	7.00E-06	x	20	x	10	x	1	x	13350	] / [	44.3	x	25,550	]
Arsenic	2.05E-08	= [	8.70E-09	x	20	x	10	x	1	x	13350	] / [	44.3	x	25,550	]
Nickel	6.61E-09	= [	2.80E-09	x	20	x	10	x	1	x	13350	] / [	44.3	x	25,550	]
Strontium	6.13E-07	= [	2.60E-07	x	20	x	10	x	1	x	13350	] / [	44.3	x	25,550	]
Uranium	5.90E-07	= [	2.50E-07	x	20	x	10	x	1	x	13350	] / [	44.3	x	25,550	]
Zinc	1.20E-07	= [	5.10E-08	x	20	x	10	x	1	x	13350	] / [	44.3	x	25,550	]
1,3,5-Trinitrobenzene	2.03E-10	= [	8.60E-11	x	20	x	10	x	1	x	13350	] / [	44.3	x	25,550	]
2,4,6-Trinitrotoluene	5.90E-10	= [	2.50E-10	x	20	x	10	x	1	x	13350	] / [	44.3	x	25,550	]
2,4-Dinitrotoluene	7.80E-10	= [	3.31E-10	x	20	x	10	x	1	x	13350	] / [	44.3	x	25,550	]
2,6-Dinitrotoluene	6.58E-10	= [	2.79E-10	x	20	x	10	x	1	x	13350	] / [	44.3	x	25,550	]
NONCARCINOGENIC EFFECTS																
Aluminum	1.16E-04	= [	7.00E-06	x	20	x	10	x	1	x	13350	] / [	44.3	x	3,650	]
Arsenic	1.44E-07	= [	8.70E-09	x	20	x	10	x	1	x	13350	] / [	44.3	x	3,650	]
Nickel	4.62E-08	= [	2.80E-09	x	20	x	10	x	1	x	13350	] / [	44.3	x	3,650	]
Strontium	4.29E-06	= [	2.60E-07	x	20	x	10	x	1	x	13350	] / [	44.3	x	3,650	]
Uranium	4.13E-06	= [	2.50E-07	x	20	x	10	x	1	x	13350	] / [	44.3	x	3,650	]
Zinc	8.42E-07	= [	5.10E-08	x	20	x	10	x	1	x	13350	] / [	44.3	x	3,650	]
1,3,5-Trinitrobenzene	1.42E-09	= [	8.60E-11	x	20	x	10	x	1	x	13350	] / [	44.3	x	3,650	]
2,4,6-Trinitrotoluene	4.13E-09	= [	2.50E-10	x	20	x	10	x	1	x	13350	] / [	44.3	x	3,650	]
2,4-Dinitrotoluene	5.46E-09	= [	3.31E-10	x	20	x	10	x	1	x	13350	] / [	44.3	x	3,650	]
2,6-Dinitrotoluene	4.61E-09	= [	2.79E-10	x	20	x	10	x	1	x	13350	] / [	44.3	x	3,650	]

DAD_{SW} = dermal absorbed dose (mg/kg-day)
DA_{event} = absorbed dose per event (mg/cm^2-event)
EF = exposure frequency (days/year)
ED = exposure duration (years)
EV = event frequency (events/day)
SSA_{SW} = skin surface area available for contact (cm^2)
BW = body weight
AT = averaging time

Table A7
Daily Intake Calculations: Adult Recreational Visitors
Ingestion of Chemicals in Sediment
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Equation	DI_{SD-Ing}	= [	C_{SD}	x	IR	x	CF	x	EF	x	ED	] / [	BW	x	AT	]
Units	**mg/kg-day**		**mg/kg**		**mg/event**		**kg/mg**		**events/yr**		**yr**		**kg**		**days**	
CARCINOGENIC EFFECTS																
Aluminum	3.82E-04	= [	1.50E+04	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	25,550	]
Antimony	4.07E-07	= [	1.60E+01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	25,550	]
Beryllium	3.56E-08	= [	1.40E+00	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	25,550	]
Cadmium	3.31E-08	= [	1.30E+00	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	25,550	]
Chromium	4.83E-07	= [	1.90E+01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	25,550	]
Copper	6.11E-07	= [	2.40E+01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	25,550	]
Manganese	2.14E-05	= [	8.40E+02	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	25,550	]
Mercury	2.54E-09	= [	1.00E-01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	25,550	]
Molybdenum	5.09E-08	= [	2.00E+00	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	25,550	]
Nickel	5.85E-07	= [	2.30E+01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	25,550	]
Selenium	9.92E-08	= [	3.90E+00	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	25,550	]
Strontium	1.48E-06	= [	5.80E+01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	25,550	]
Uranium	3.31E-07	= [	1.30E+01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	25,550	]
Vanadium	9.16E-07	= [	3.60E+01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	25,550	]
1,3,5-Trinitrobenzene	6.36E-10	= [	2.50E-02	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	25,550	]
1,3-Dinitrobenzene	1.65E-10	= [	6.50E-03	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	25,550	]
2,4,6-Trinitrotoluene	6.36E-09	= [	2.50E-01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	25,550	]
2,4-Dinitrotoluene	1.65E-10	= [	6.50E-03	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	25,550	]
2,6-Dinitrotoluene	6.36E-09	= [	2.50E-01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	25,550	]
Nitrobenzene	6.36E-09	= [	2.50E-01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	25,550	]
NONCARCINOGENIC EFFECTS																
Aluminum	1.03E-03	= [	1.50E+04	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	9,490	]
Antimony	1.10E-06	= [	1.60E+01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	9,490	]
Beryllium	9.59E-08	= [	1.40E+00	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	9,490	]
Cadmium	8.90E-08	= [	1.30E+00	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	9,490	]
Chromium	1.30E-06	= [	1.90E+01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	9,490	]
Copper	1.64E-06	= [	2.40E+01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	9,490	]
Manganese	5.75E-05	= [	8.40E+02	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	9,490	]
Mercury	6.85E-09	= [	1.00E-01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	9,490	]
Molybdenum	1.37E-07	= [	2.00E+00	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	9,490	]
Nickel	1.58E-06	= [	2.30E+01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	9,490	]
Selenium	2.67E-07	= [	3.90E+00	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	9,490	]
Strontium	3.97E-06	= [	5.80E+01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	9,490	]
Uranium	8.90E-07	= [	1.30E+01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	9,490	]
Vanadium	2.47E-06	= [	3.60E+01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	9,490	]
1,3,5-Trinitrobenzene	1.71E-09	= [	2.50E-02	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	9,490	]
1,3-Dinitrobenzene	4.45E-10	= [	6.50E-03	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	9,490	]
2,4,6-Trinitrotoluene	1.71E-08	= [	2.50E-01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	9,490	]
2,4-Dinitrotoluene	4.45E-10	= [	6.50E-03	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	9,490	]
2,6-Dinitrotoluene	1.71E-08	= [	2.50E-01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	9,490	]
Nitrobenzene	1.71E-08	= [	2.50E-01	x	100	x	1.00E-06	x	20	x	26	] / [	80	x	9,490	]

DI_{SD-Ing} = daily chemical intake via soil ingestion
CW = chemical concentration in surface water
IRW = water ingestion rate
CF = conversion factor, 1 kg/10^6 mg
EF = exposure frequency
ED = exposure duration
BW = body weight
AT = averaging time

Table A8
Daily Intake Calculations: Adolescent Recreational Visitors
Ingestion of Chemicals in Sediment
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Equation	DI_{SD-Ing}	= [	C_{SD}	x	IR	x	CF	x	EF	x	ED	] / [	BW	x	AT	]
Units	mg/kg-day		mg/kg		mg/event		kg/mg		events/yr		yr		kg		days	
CARCINOGENIC EFFECTS																
Aluminum	2.65E-04	= [	1.50E+04	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	25,550	]
Antimony	2.83E-07	= [	1.60E+01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	25,550	]
Beryllium	2.47E-08	= [	1.40E+00	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	25,550	]
Cadmium	2.30E-08	= [	1.30E+00	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	25,550	]
Chromium	3.36E-07	= [	1.90E+01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	25,550	]
Copper	4.24E-07	= [	2.40E+01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	25,550	]
Manganese	1.48E-05	= [	8.40E+02	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	25,550	]
Mercury	1.77E-09	= [	1.00E-01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	25,550	]
Molybdenum	3.53E-08	= [	2.00E+00	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	25,550	]
Nickel	4.06E-07	= [	2.30E+01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	25,550	]
Selenium	6.89E-08	= [	3.90E+00	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	25,550	]
Strontium	1.02E-06	= [	5.80E+01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	25,550	]
Uranium	2.30E-07	= [	1.30E+01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	25,550	]
Vanadium	6.36E-07	= [	3.60E+01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	25,550	]
1,3,5-Trinitrobenzene	4.42E-10	= [	2.50E-02	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	25,550	]
1,3-Dinitrobenzene	1.15E-10	= [	6.50E-03	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	25,550	]
2,4,6-Trinitrotoluene	4.42E-09	= [	2.50E-01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	25,550	]
2,4-Dinitrotoluene	1.15E-10	= [	6.50E-03	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	25,550	]
2,6-Dinitrotoluene	4.42E-09	= [	2.50E-01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	25,550	]
Nitrobenzene	4.42E-09	= [	2.50E-01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	25,550	]
NONCARCINOGENIC EFFECTS																
Aluminum	1.86E-03	= [	1.50E+04	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	3,650	]
Antimony	1.98E-06	= [	1.60E+01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	3,650	]
Beryllium	1.73E-07	= [	1.40E+00	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	3,650	]
Cadmium	1.61E-07	= [	1.30E+00	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	3,650	]
Chromium	2.35E-06	= [	1.90E+01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	3,650	]
Copper	2.97E-06	= [	2.40E+01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	3,650	]
Manganese	1.04E-04	= [	8.40E+02	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	3,650	]
Mercury	1.24E-08	= [	1.00E-01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	3,650	]
Molybdenum	2.47E-07	= [	2.00E+00	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	3,650	]
Nickel	2.84E-06	= [	2.30E+01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	3,650	]
Selenium	4.82E-07	= [	3.90E+00	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	3,650	]
Strontium	7.17E-06	= [	5.80E+01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	3,650	]
Uranium	1.61E-06	= [	1.30E+01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	3,650	]
Vanadium	4.45E-06	= [	3.60E+01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	3,650	]
1,3,5-Trinitrobenzene	3.09E-09	= [	2.50E-02	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	3,650	]
1,3-Dinitrobenzene	8.04E-10	= [	6.50E-03	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	3,650	]
2,4,6-Trinitrotoluene	3.09E-08	= [	2.50E-01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	3,650	]
2,4-Dinitrotoluene	8.04E-10	= [	6.50E-03	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	3,650	]
2,6-Dinitrotoluene	3.09E-08	= [	2.50E-01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	3,650	]
Nitrobenzene	3.09E-08	= [	2.50E-01	x	100	x	1.00E-06	x	20	x	10	] / [	44.3	x	3,650	]

DI_{SD-Ing} = daily chemical intake via soil ingestion
CW = chemical concentration in surface water
CF = conversion factor, 1 kg/10^6 mg
IRW = water ingestion rate
EF = exposure frequency
ED = exposure duration
BW = body weight
AT = averaging time

Table A9
Daily Intake Calculations: All Recreational Visitors
Dermal Contact with Chemicals in Sediment - Absorbed dose per event (DA_{event})
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Equation	DA_{event}	=	C_{SD}	x	CF	x	AF	x	ABS_d
Units	mg/cm^2-event		mg/kg		kg/mg		mg/cm^2-event		unitless
Aluminum	na	=	1.50E+04	x	1.00E-06	x	0.3	x	--
Antimony	na	=	1.60E+01	x	1.00E-06	x	0.3	x	--
Beryllium	na	=	1.40E+00	x	1.00E-06	x	0.3	x	--
Cadmium	3.90E-10	=	1.30E+00	x	1.00E-06	x	0.3	x	0.001
Chromium	na	=	1.90E+01	x	1.00E-06	x	0.3	x	--
Copper	na	=	2.40E+01	x	1.00E-06	x	0.3	x	--
Manganese	na	=	8.40E+02	x	1.00E-06	x	0.3	x	--
Mercury	na	=	1.00E-01	x	1.00E-06	x	0.3	x	--
Molybdenum	na	=	2.00E+00	x	1.00E-06	x	0.3	x	--
Nickel	na	=	2.30E+01	x	1.00E-06	x	0.3	x	--
Selenium	na	=	3.90E+00	x	1.00E-06	x	0.3	x	--
Strontium	na	=	5.80E+01	x	1.00E-06	x	0.3	x	--
Uranium	na	=	1.30E+01	x	1.00E-06	x	0.3	x	--
Vanadium	na	=	3.60E+01	x	1.00E-06	x	0.3	x	--
1,3,5-Trinitrobenzene	1.43E-10	=	2.50E-02	x	1.00E-06	x	0.3	x	0.019
1,3-Dinitrobenzene	1.95E-10	=	6.50E-03	x	1.00E-06	x	0.3	x	0.1
2,4,6-Trinitrotoluene	2.40E-09	=	2.50E-01	x	1.00E-06	x	0.3	x	0.032
2,4-Dinitrotoluene	1.99E-10	=	6.50E-03	x	1.00E-06	x	0.3	x	0.102
2,6-Dinitrotoluene	7.43E-09	=	2.50E-01	x	1.00E-06	x	0.3	x	0.099
Nitrobenzene	na	=	2.50E-01	x	1.00E-06	x	0.3	x	--

DA_{event} = absorbed dose per event (mg/cm^2-event)
C_{SD} = chemical concentration in sediment
CF = conversion factor, 1 kg/10^6 mg
AF =sediment to skin adherence factor
ABS_d = dermal absorption fraction, per exhibit 3-4 in RAGS Part E, Dermal Risk Assessment (USEPA, 2004)
na = not applicable
-- dashes indicate that no data are available for this chemical

Table A10
Daily Intake Calculations: Adult Recreational Visitors
Dermal Absorbed Dose (DAD) of Chemicals in Sediment
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Equation	DAD_{SD}	= [	DA_{event}	x	EF	x	ED	x	SSA_{SD}	] / [	BW	x	AT	]
Units	mg/kg-day		mg/cm²-event		events/yr		years		cm²		kg		days	
CARCINOGENIC EFFECTS														
Aluminum	na	= [	na	x	20	x	26	x	6032	] / [	80	x	25,550	]
Antimony	na	= [	na	x	20	x	26	x	6032	] / [	80	x	25,550	]
Beryllium	na	= [	na	x	20	x	26	x	6032	] / [	80	x	25,550	]
Cadmium	5.98E-10	= [	3.90E-10	x	20	x	26	x	6032	] / [	80	x	25,550	]
Chromium	na	= [	na	x	20	x	26	x	6032	] / [	80	x	25,550	]
Copper	na	= [	na	x	20	x	26	x	6032	] / [	80	x	25,550	]
Manganese	na	= [	na	x	20	x	26	x	6032	] / [	80	x	25,550	]
Mercury	na	= [	na	x	20	x	26	x	6032	] / [	80	x	25,550	]
Molybdenum	na	= [	na	x	20	x	26	x	6032	] / [	80	x	25,550	]
Nickel	na	= [	na	x	20	x	26	x	6032	] / [	80	x	25,550	]
Selenium	na	= [	na	x	20	x	26	x	6032	] / [	80	x	25,550	]
Strontium	na	= [	na	x	20	x	26	x	6032	] / [	80	x	25,550	]
Uranium	na	= [	na	x	20	x	26	x	6032	] / [	80	x	25,550	]
Vanadium	na	= [	na	x	20	x	26	x	6032	] / [	80	x	25,550	]
1,3,5-Trinitrobenzene	2.19E-10	= [	1.43E-10	x	20	x	26	x	6032	] / [	80	x	25,550	]
1,3-Dinitrobenzene	2.99E-10	= [	1.95E-10	x	20	x	26	x	6032	] / [	80	x	25,550	]
2,4,6-Trinitrotoluene	3.68E-09	= [	2.40E-09	x	20	x	26	x	6032	] / [	80	x	25,550	]
2,4-Dinitrotoluene	3.05E-10	= [	1.99E-10	x	20	x	26	x	6032	] / [	80	x	25,550	]
2,6-Dinitrotoluene	1.14E-08	= [	7.43E-09	x	20	x	26	x	6032	] / [	80	x	25,550	]
Nitrobenzene	na	= [	na	x	20	x	26	x	6032	] / [	80	x	25,550	]
NONCARCINOGENIC EFFECTS														
Aluminum	na	= [	na	x	20	x	26	x	6032	] / [	80	x	9,490	]
Antimony	na	= [	na	x	20	x	26	x	6032	] / [	80	x	9,490	]
Beryllium	na	= [	na	x	20	x	26	x	6032	] / [	80	x	9,490	]
Cadmium	1.61E-09	= [	3.90E-10	x	20	x	26	x	6032	] / [	80	x	9,490	]
Chromium	na	= [	na	x	20	x	26	x	6032	] / [	80	x	9,490	]
Copper	na	= [	na	x	20	x	26	x	6032	] / [	80	x	9,490	]
Manganese	na	= [	na	x	20	x	26	x	6032	] / [	80	x	9,490	]
Mercury	na	= [	na	x	20	x	26	x	6032	] / [	80	x	9,490	]
Molybdenum	na	= [	na	x	20	x	26	x	6032	] / [	80	x	9,490	]
Nickel	na	= [	na	x	20	x	26	x	6032	] / [	80	x	9,490	]
Selenium	na	= [	na	x	20	x	26	x	6032	] / [	80	x	9,490	]
Strontium	na	= [	na	x	20	x	26	x	6032	] / [	80	x	9,490	]
Uranium	na	= [	na	x	20	x	26	x	6032	] / [	80	x	9,490	]
Vanadium	na	= [	na	x	20	x	26	x	6032	] / [	80	x	9,490	]
1,3,5-Trinitrobenzene	5.89E-10	= [	1.43E-10	x	20	x	26	x	6032	] / [	80	x	9,490	]
1,3-Dinitrobenzene	8.06E-10	= [	1.95E-10	x	20	x	26	x	6032	] / [	80	x	9,490	]
2,4,6-Trinitrotoluene	9.92E-09	= [	2.40E-09	x	20	x	26	x	6032	] / [	80	x	9,490	]
2,4-Dinitrotoluene	8.22E-10	= [	1.99E-10	x	20	x	26	x	6032	] / [	80	x	9,490	]
2,6-Dinitrotoluene	3.07E-08	= [	7.43E-09	x	20	x	26	x	6032	] / [	80	x	9,490	]
Nitrobenzene	na	= [	na	x	20	x	26	x	6032	] / [	80	x	9,490	]

DAD_{SD} = dermal absorbed dose (mg/kg-day)
DA_{event} = absorbed dose per event (mg/cm^2-event)
EF = exposure frequency (days/year)
ED = exposure duration (years)
na not applicable
EV = event frequency (events/day)
SSA_{SD} = skin surface area available for contact (cm^2)
BW = body weight
AT = averaging time

Table A11
Daily Intake Calculations: Adolescent Recreational Visitors
Dermal Absorbed Dose (DAD) of Chemicals in Sediment
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Equation	**DAD_{SD}**	**= [**	**DA_{event}**	**x**	**EF**	**x**	**ED**	**x**	**SSA_{SD}**	**] / [**	**BW**	**x**	**AT**	**]**
Units	**mg/kg-day**		**mg/cm^2-event**		**events/yr**		**years**		**cm^2**		**kg**		**days**	
CARCINOGENIC EFFECTS														
Aluminum	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	25,550	]
Antimony	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	25,550	]
Beryllium	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	25,550	]
Cadmium	3.23E-10	= [	3.90E-10	x	20	x	10	x	4683	] / [	44.3	x	25,550	]
Chromium	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	25,550	]
Copper	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	25,550	]
Manganese	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	25,550	]
Mercury	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	25,550	]
Molybdenum	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	25,550	]
Nickel	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	25,550	]
Selenium	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	25,550	]
Strontium	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	25,550	]
Uranium	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	25,550	]
Vanadium	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	25,550	]
1,3,5-Trinitrobenzene	1.18E-10	= [	1.43E-10	x	20	x	10	x	4683	] / [	44.3	x	25,550	]
1,3-Dinitrobenzene	1.61E-10	= [	1.95E-10	x	20	x	10	x	4683	] / [	44.3	x	25,550	]
2,4,6-Trinitrotoluene	1.99E-09	= [	2.40E-09	x	20	x	10	x	4683	] / [	44.3	x	25,550	]
2,4-Dinitrotoluene	1.65E-10	= [	1.99E-10	x	20	x	10	x	4683	] / [	44.3	x	25,550	]
2,6-Dinitrotoluene	6.14E-09	= [	7.43E-09	x	20	x	10	x	4683	] / [	44.3	x	25,550	]
Nitrobenzene	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	25,550	]
NONCARCINOGENIC EFFECTS														
Aluminum	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	3,650	]
Antimony	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	3,650	]
Beryllium	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	3,650	]
Cadmium	2.26E-09	= [	3.90E-10	x	20	x	10	x	4683	] / [	44.3	x	3,650	]
Chromium	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	3,650	]
Copper	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	3,650	]
Manganese	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	3,650	]
Mercury	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	3,650	]
Molybdenum	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	3,650	]
Nickel	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	3,650	]
Selenium	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	3,650	]
Strontium	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	3,650	]
Uranium	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	3,650	]
Vanadium	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	3,650	]
1,3,5-Trinitrobenzene	8.25E-10	= [	1.43E-10	x	20	x	10	x	4683	] / [	44.3	x	3,650	]
1,3-Dinitrobenzene	1.13E-09	= [	1.95E-10	x	20	x	10	x	4683	] / [	44.3	x	3,650	]
2,4,6-Trinitrotoluene	1.39E-08	= [	2.40E-09	x	20	x	10	x	4683	] / [	44.3	x	3,650	]
2,4-Dinitrotoluene	1.15E-09	= [	1.99E-10	x	20	x	10	x	4683	] / [	44.3	x	3,650	]
2,6-Dinitrotoluene	4.30E-08	= [	7.43E-09	x	20	x	10	x	4683	] / [	44.3	x	3,650	]
Nitrobenzene	na	= [	na	x	20	x	10	x	4683	] / [	44.3	x	3,650	]

DAD_{SD} = dermal absorbed dose (mg/kg-day)
DA_{event} = absorbed dose per event (mg/cm^2-event)
EF = exposure frequency (days/year)
ED = exposure duration (years)
na not applicable
EV = event frequency (events/day)
SSA_{SD} = skin surface area available for contact (cm^2)
BW = body weight
AT = averaging time

Table A12
Inhalation of Sediment - All Recreational Visitors
Apparent Diffusivity (D_A)
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Equation:	**D_A**	**= [(**	**$\theta_a^{10/3}$**	**x**	**D_i**	**x**	**H'**	**) + ((**	**$\theta_w^{10/3}$**	**x**	**D_w**	**) /**	**n^2**	**)] / [(**	**ρ_b**	**x**	**K_d**	**) +**	**θ_w**	**+ (**	**θ_a**	**x**	**H'**	**)]**
Units:	**cm^2/sec**		**L_{air}/L_{soil}**		**cm^2/sec**		**unitless**		**m^3/kg**		**cm^2/sec**		**unitless**		**g/cm^3**		**cm^3/g**						**unitless**	
Aluminum	na	= [(	0.015	x	-	x	-	) + ((	0.00179	x	-	) /	0.1884	)] / [(	1.5	x	1.50E+03	) +	0.2	+ (	0.28	x	-	)]
Antimony	na	= [(	0.015	x	-	x	-	) + ((	0.00179	x	-	) /	0.1884	)] / [(	1.5	x	4.50E+01	) +	0.2	+ (	0.28	x	-	)]
Beryllium	na	= [(	0.015	x	-	x	-	) + ((	0.00179	x	-	) /	0.1884	)] / [(	1.5	x	7.90E+02	) +	0.2	+ (	0.28	x	-	)]
Cadmium	na	= [(	0.015	x		x		) + ((	0.00179	x		) /	0.1884	)] / [(	1.5	x	7.50E+01	) +	0.2	+ (	0.28	x		)]
Chromium	na	= [(	0.015	x	-	x	-	) + ((	0.00179	x	-	) /	0.1884	)] / [(	1.5	x	1.90E+01	) +	0.2	+ (	0.28	x	-	)]
Copper	na	= [(	0.015	x	-	x	-	) + ((	0.00179	x	-	) /	0.1884	)] / [(	1.5	x	3.50E+01	) +	0.2	+ (	0.28	x	-	)]
Manganese	na	= [(	0.015	x	-	x	-	) + ((	0.00179	x	-	) /	0.1884	)] / [(	1.5	x	6.50E+01	) +	0.2	+ (	0.28	x	-	)]
Mercury	2.07E-06	= [(	0.015	x	3.07E-02	x	3.52E-01	) + ((	0.00179	x	6.30E-06	) /	0.1884	)] / [(	1.5	x	5.20E+01	) +	0.2	+ (	0.28	x	3.52E-01	)]
Molybdenum	na	= [(	0.015	x	-	x	-	) + ((	0.00179	x	-	) /	0.1884	)] / [(	1.5	x	2.00E+01	) +	0.2	+ (	0.28	x	-	)]
Nickel	na	= [(	0.015	x	-	x	-	) + ((	0.00179	x	-	) /	0.1884	)] / [(	1.5	x	6.50E+01	) +	0.2	+ (	0.28	x	-	)]
Selenium	na	= [(	0.015	x	-	x	-	) + ((	0.00179	x	-	) /	0.1884	)] / [(	1.5	x	5.00E+00	) +	0.2	+ (	0.28	x	-	)]
Strontium	na	= [(	0.015	x	-	x	-	) + ((	0.00179	x	-	) /	0.1884	)] / [(	1.5	x	3.50E+01	) +	0.2	+ (	0.28	x	-	)]
Uranium	na	= [(	0.015	x	-	x	-	) + ((	0.00179	x	-	) /	0.1884	)] / [(	1.5	x	4.50E+02	) +	0.2	+ (	0.28	x	-	)]
Vanadium	na	= [(	0.015	x	-	x	-	) + ((	0.00179	x	-	) /	0.1884	)] / [(	1.5	x	1.00E+03	) +	0.2	+ (	0.28	x	-	)]
1,3,5-Trinitrobenzene	na	= [(	0.015	x	2.90E-02	x	2.66E-07	) + ((	0.00179	x	7.69E-06	) /	0.1884	)] / [(	1.5	x	-	) +	0.2	+ (	0.28	x	2.66E-07	)]
1,3-Dinitrobenzene	na	= [(	0.015	x	4.85E-02	x	2.00E-06	) + ((	0.00179	x	9.21E-06	) /	0.1884	)] / [(	1.5	x	-	) +	0.2	+ (	0.28	x	2.00E-06	)]
2,4,6-Trinitrotoluene	na	= [(	0.015	x	2.95E-02	x	8.50E-07	) + ((	0.00179	x	7.92E-06	) /	0.1884	)] / [(	1.5	x	-	) +	0.2	+ (	0.28	x	8.50E-07	)]
2,4-Dinitrotoluene	na	= [(	0.015	x	3.75E-02	x	2.21E-06	) + ((	0.00179	x	7.90E-06	) /	0.1884	)] / [(	1.5	x	-	) +	0.2	+ (	0.28	x	2.21E-06	)]
2,6-Dinitrotoluene	na	= [(	0.015	x	3.70E-02	x	3.05E-05	) + ((	0.00179	x	7.76E-06	) /	0.1884	)] / [(	1.5	x	-	) +	0.2	+ (	0.28	x	3.05E-05	)]
Nitrobenzene	7.26E-06	= [(	0.015	x	6.81E-02	x	9.81E-04	) + ((	0.00179	x	9.45E-06	) /	0.1884	)] / [(	1.5	x	-	) +	0.2	+ (	0.28	x	9.81E-04	)]

Equation Source: USEPA. 2002. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites.* Office of Solid Waste and Emergency Response, OSWER 9355.4-24.

Parameters Source: USEPA RSL Parameter Tables, May 2014

D_A = apparent diffusivity

θ_a = air filled porosity (L_{air}/L_{soil}) = n - θ_w = 0.284

θ_w = water-filled porosity (L_{water}/L_{soil}) = 0.15

n = total soil porosity (L_{pore}/L_{soil}) = 1 - (ρ_b/ρ_s) = 0.434

ρ_b = dry soil bulk density (g/cm^3) = 1.5 g/cm^3

ρ_s = soil particle density (g/cm^3) = 2.65 g/cm^3

D_i = diffusivity in air (cm^2/sec), chemical specific

H' = Henrys law constant, unitless, chemical specific

D_w = diffusivity in water (cm^2/sec), chemical specific

K_d = soil-water partition coefficient, cm^3/g) = K_{OC} x f_{OC}, chemical specific

K_{OC} = soil organic carbon partition coefficient (cm^3 / g), chemical specific

f_{OC} = fraction organic carbon in soil (g/g), 0.006

"-" = no data available for this chemical

Table A13
Inhalation of Sediment - Adult Recreational Visitors
Volatilization Factor Calculations (VF)
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Equation:	**VF**	**= [**	**Q/C**	**x (**	**3.14**	**x**	**D_A**	**x**	**T**	**$)^{1/2}$**	**x**	**CF**	**] / (**	**2**	**x**	**ρ_b**	**x**	**D_A**	**)**
Units:	**m^3/kg**		**g/m^2-s per kg/m^3**				**cm^2/sec**		**sec**			**m^2/cm^2**						**cm^2/sec**	
Aluminum	na	= [	93.77	x (	3.14	x	na	x	8.20E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Antimony	na	= [	93.77	x (	3.14	x	na	x	8.20E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Beryllium	na	= [	93.77	x (	3.14	x	na	x	8.20E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Cadmium	na	= [	93.77	x (	3.14	x	na	x	8.20E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Chromium	na	= [	93.77	x (	3.14	x	na	x	8.20E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Copper	na	= [	93.77	x (	3.14	x	na	x	8.20E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Manganese	na	= [	93.77	x (	3.14	x	na	x	8.20E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Mercury	1.10E+05	= [	93.77	x (	3.14	x	2.07E-06	x	8.20E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	2.07E-06	)
Molybdenum	na	= [	93.77	x (	3.14	x	na	x	8.20E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Nickel	na	= [	93.77	x (	3.14	x	na	x	8.20E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Selenium	na	= [	93.77	x (	3.14	x	na	x	8.20E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Strontium	na	= [	93.77	x (	3.14	x	na	x	8.20E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Uranium	na	= [	93.77	x (	3.14	x	na	x	8.20E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Vanadium	na	= [	93.77	x (	3.14	x	na	x	8.20E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
1,3,5-Trinitrobenzene	na	= [	93.77	x (	3.14	x	na	x	8.20E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
1,3-Dinitrobenzene	na	= [	93.77	x (	3.14	x	na	x	8.20E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
2,4,6-Trinitrotoluene	na	= [	93.77	x (	3.14	x	na	x	8.20E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
2,4-Dinitrotoluene	na	= [	93.77	x (	3.14	x	na	x	8.20E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
2,6-Dinitrotoluene	na	= [	93.77	x (	3.14	x	na	x	8.20E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Nitrobenzene	5.89E+04	= [	93.77	x (	3.14	x	7.26E-06	x	8.20E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	7.26E-06	)

Source: USEPA. 2002. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites.* Office of Solid Waste and Emergency Response, OSWER 9355.4-24. Washington, DC.

VF = volatilazation factor

Q/C = inverse of mean concentration at center of source (g/m2-s per kg/m3), default value for 0.5 acre source

D_A = apparent diffusivity (cm^2/sec)

T = exposure interval (sec), 26 years

CF = conversion factor, 10^{-4} m^2/cm^2

ρ_b = dry soil bulk density (g/cm^3) = 1.5 g/cm^3

Table A14
Inhalation of Sediment - Adolescent Recreational Visitors
Volatilization Factor Calculations (VF)
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Equation:	**VF**	**= [**	**Q/C**	**x (**	**3.14**	**x**	**AD**	**x**	**T**	**$)^{1/2}$**	**x**	**CF**	**] / (**	**2**	**x**	**ρ_b**	**x**	**AD**	**)**
Units:	**m^3/kg**		**g/m^2-s per kg/m^3**				**cm^2/sec**		**sec**			**m^2/cm^2**						**cm^2/sec**	
Aluminum	na	= [	93.77	x (	3.14	x	na	x	3.15E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Antimony	na	= [	93.77	x (	3.14	x	na	x	3.15E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Beryllium	na	= [	93.77	x (	3.14	x	na	x	3.15E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Cadmium	na	= [	93.77	x (	3.14	x	na	x	3.15E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Chromium	na	= [	93.77	x (	3.14	x	na	x	3.15E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Copper	na	= [	93.77	x (	3.14	x	na	x	3.15E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Manganese	na	= [	93.77	x (	3.14	x	na	x	3.15E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Mercury	6.83E+04	= [	93.77	x (	3.14	x	2.07E-06	x	3.15E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	2.07E-06	)
Molybdenum	na	= [	93.77	x (	3.14	x	na	x	3.15E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Nickel	na	= [	93.77	x (	3.14	x	na	x	3.15E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Selenium	na	= [	93.77	x (	3.14	x	na	x	3.15E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Strontium	na	= [	93.77	x (	3.14	x	na	x	3.15E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Uranium	na	= [	93.77	x (	3.14	x	na	x	3.15E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Vanadium	na	= [	93.77	x (	3.14	x	na	x	3.15E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
1,3,5-Trinitrobenzene	na	= [	93.77	x (	3.14	x	na	x	3.15E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
1,3-Dinitrobenzene	na	= [	93.77	x (	3.14	x	na	x	3.15E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
2,4,6-Trinitrotoluene	na	= [	93.77	x (	3.14	x	na	x	3.15E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
2,4-Dinitrotoluene	na	= [	93.77	x (	3.14	x	na	x	3.15E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
2,6-Dinitrotoluene	na	= [	93.77	x (	3.14	x	na	x	3.15E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	na	)
Nitrobenzene	3.65E+04	= [	93.77	x (	3.14	x	7.26E-06	x	3.15E+08	$)^{1/2}$	x	1.00E-04	] / (	2	x	1.5	x	7.26E-06	)

Source: USEPA. 2002. *Supplemental Guidance for Developing Soil Screening Levels for Superfund Sites.* Office of Solid Waste and Emergency Response, OSWER 9355.4-24. Washington, DC.

VF = volatilazation factor

Q/C = inverse of mean concentration at center of source (g/m2-s per kg/m3), default value for 0.5 acre source

AD = apparent diffusivity (cm^2/sec)

T = exposure interval (sec), 10 years

CF = conversion factor, 10^{-4} m^2/cm^2

ρ_b = dry soil bulk density (g/cm^3) = 1.5 g/cm^3

Table A15
Inhalation of Chemicals in Sediment - Adult Recreational Visitors
Chemical Concentrations in Air Calculations (CA)
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Equation	CA	=	C_{SD}	x	CF	x [(1 /	PEF	) + (1 /	VF	)]
Units	µg/m^3		mg/kg		µg/mg		m^3/kg		m^3/kg	
Aluminum	1.10E-02	=	1.50E+04	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Antimony	1.18E-05	=	1.60E+01	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Beryllium	1.03E-06	=	1.40E+00	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Cadmium	9.56E-07	=	1.30E+00	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Chromium	1.40E-05	=	1.90E+01	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Copper	1.76E-05	=	2.40E+01	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Manganese	6.18E-04	=	8.40E+02	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Mercury	9.08E-04	=	1.00E-01	x	1000	x [(1 /	1.36E+09	) + (1 /	1.10E+05	)]
Molybdenum	1.47E-06	=	2.00E+00	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Nickel	1.69E-05	=	2.30E+01	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Selenium	2.87E-06	=	3.90E+00	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Strontium	4.26E-05	=	5.80E+01	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Uranium	9.56E-06	=	1.30E+01	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Vanadium	2.65E-05	=	3.60E+01	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
1,3,5-Trinitrobenzene	1.84E-08	=	2.50E-02	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
1,3-Dinitrobenzene	4.78E-09	=	6.50E-03	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
2,4,6-Trinitrotoluene	1.84E-07	=	2.50E-01	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
2,4-Dinitrotoluene	4.78E-09	=	6.50E-03	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
2,6-Dinitrotoluene	1.84E-07	=	2.50E-01	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Nitrobenzene	4.25E-03	=	2.50E-01	x	1000	x [(1 /	1.36E+09	) + (1 /	5.89E+04	)]

CA = chemical concentration in air
C_{SD} = chemical concentration in soil
CF = conversion factor, 1000 µg/mg
PEF = particulate emission factor
VF = volatilization factor

Table A16
Inhalation of Chemicals in Sediment - Adolescent Recreational Visitors
Chemical Concentrations in Air Calculations (CA)
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Equation	CA	=	C_{SD}	x	CF	x [(1 /	PEF	) + (1 /	VF	)]
Units	$\mu g/m^3$		mg/kg		µg/mg		m^3/kg		m^3/kg	
Aluminum	1.10E-02	=	1.50E+04	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Antimony	1.18E-05	=	1.60E+01	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Beryllium	1.03E-06	=	1.40E+00	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Cadmium	9.56E-07	=	1.30E+00	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Chromium	1.40E-05	=	1.90E+01	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Copper	1.76E-05	=	2.40E+01	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Manganese	6.18E-04	=	8.40E+02	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Mercury	1.46E-03	=	1.00E-01	x	1000	x [(1 /	1.36E+09	) + (1 /	6.83E+04	)]
Molybdenum	1.47E-06	=	2.00E+00	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Nickel	1.69E-05	=	2.30E+01	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Selenium	2.87E-06	=	3.90E+00	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Strontium	4.26E-05	=	5.80E+01	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Uranium	9.56E-06	=	1.30E+01	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Vanadium	2.65E-05	=	3.60E+01	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
1,3,5-Trinitrobenzene	1.84E-08	=	2.50E-02	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
1,3-Dinitrobenzene	4.78E-09	=	6.50E-03	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
2,4,6-Trinitrotoluene	1.84E-07	=	2.50E-01	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
2,4-Dinitrotoluene	4.78E-09	=	6.50E-03	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
2,6-Dinitrotoluene	1.84E-07	=	2.50E-01	x	1000	x [(1 /	1.36E+09	) + (1 /	na	)]
Nitrobenzene	6.85E-03	=	2.50E-01	x	1000	x [(1 /	1.36E+09	) + (1 /	3.65E+04	)]

CA = chemical concentration in air
C_{SD} = chemical concentration in soil
CF = conversion factor, 1000 µg/mg
PEF = particulate emission factor
VF = volatilization factor

Table A17
Inhalation of Chemicals in Sediment - Adult Recreational Visitors
Exposure Concentration (EC) of Chemical in Air
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Equation	EC	= [	CA	x	ET	x	EF	x	ED	x	CF	] / [	AT	]
Units	μg/m^3		μg/m^3		hours/day		days/year		years		days/hour		days	
CARCINOGENIC EFFECTS														
Aluminum	3.77E-05	= [	1.10E-02	x	4	x	20	x	26	x	0.042	] / [	25,550	]
Antimony	4.02E-08	= [	1.18E-05	x	4	x	20	x	26	x	0.042	] / [	25,550	]
Beryllium	3.52E-09	= [	1.03E-06	x	4	x	20	x	26	x	0.042	] / [	25,550	]
Cadmium	3.27E-09	= [	9.56E-07	x	4	x	20	x	26	x	0.042	] / [	25,550	]
Chromium	4.78E-08	= [	1.40E-05	x	4	x	20	x	26	x	0.042	] / [	25,550	]
Copper	6.03E-08	= [	1.76E-05	x	4	x	20	x	26	x	0.042	] / [	25,550	]
Manganese	2.11E-06	= [	6.18E-04	x	4	x	20	x	26	x	0.042	] / [	25,550	]
Mercury	3.10E-06	= [	9.08E-04	x	4	x	20	x	26	x	0.042	] / [	25,550	]
Molybdenum	5.03E-09	= [	1.47E-06	x	4	x	20	x	26	x	0.042	] / [	25,550	]
Nickel	5.78E-08	= [	1.69E-05	x	4	x	20	x	26	x	0.042	] / [	25,550	]
Selenium	9.80E-09	= [	2.87E-06	x	4	x	20	x	26	x	0.042	] / [	25,550	]
Strontium	1.46E-07	= [	4.26E-05	x	4	x	20	x	26	x	0.042	] / [	25,550	]
Uranium	3.27E-08	= [	9.56E-06	x	4	x	20	x	26	x	0.042	] / [	25,550	]
Vanadium	9.05E-08	= [	2.65E-05	x	4	x	20	x	26	x	0.042	] / [	25,550	]
1,3,5-Trinitrobenzene	6.29E-11	= [	1.84E-08	x	4	x	20	x	26	x	0.042	] / [	25,550	]
1,3-Dinitrobenzene	1.63E-11	= [	4.78E-09	x	4	x	20	x	26	x	0.042	] / [	25,550	]
2,4,6-Trinitrotoluene	6.29E-10	= [	1.84E-07	x	4	x	20	x	26	x	0.042	] / [	25,550	]
2,4-Dinitrotoluene	1.63E-11	= [	4.78E-09	x	4	x	20	x	26	x	0.042	] / [	25,550	]
2,6-Dinitrotoluene	6.29E-10	= [	1.84E-07	x	4	x	20	x	26	x	0.042	] / [	25,550	]
Nitrobenzene	1.45E-05	= [	4.25E-03	x	4	x	20	x	26	x	0.042	] / [	25,550	]
NONCARCINOGENIC EFFECTS														
Aluminum	1.02E-04	= [	1.10E-02	x	4	x	20	x	26		0.042	] / [	9,490	]
Antimony	1.08E-07	= [	1.18E-05	x	4	x	20	x	26		0.042	] / [	9,490	]
Beryllium	9.48E-09	= [	1.03E-06	x	4	x	20	x	26		0.042	] / [	9,490	]
Cadmium	8.80E-09	= [	9.56E-07	x	4	x	20	x	26		0.042	] / [	9,490	]
Chromium	1.29E-07	= [	1.40E-05	x	4	x	20	x	26		0.042	] / [	9,490	]
Copper	1.62E-07	= [	1.76E-05	x	4	x	20	x	26		0.042	] / [	9,490	]
Manganese	5.69E-06	= [	6.18E-04	x	4	x	20	x	26		0.042	] / [	9,490	]
Mercury	8.36E-06	= [	9.08E-04	x	4	x	20	x	26		0.042	] / [	9,490	]
Molybdenum	1.35E-08	= [	1.47E-06	x	4	x	20	x	26		0.042	] / [	9,490	]
Nickel	1.56E-07	= [	1.69E-05	x	4	x	20	x	26		0.042	] / [	9,490	]
Selenium	2.64E-08	= [	2.87E-06	x	4	x	20	x	26		0.042	] / [	9,490	]
Strontium	3.93E-07	= [	4.26E-05	x	4	x	20	x	26		0.042	] / [	9,490	]
Uranium	8.80E-08	= [	9.56E-06	x	4	x	20	x	26		0.042	] / [	9,490	]
Vanadium	2.44E-07	= [	2.65E-05	x	4	x	20	x	26		0.042	] / [	9,490	]
1,3,5-Trinitrobenzene	1.69E-10	= [	1.84E-08	x	4	x	20	x	26		0.042	] / [	9,490	]
1,3-Dinitrobenzene	4.40E-11	= [	4.78E-09	x	4	x	20	x	26		0.042	] / [	9,490	]
2,4,6-Trinitrotoluene	1.69E-09	= [	1.84E-07	x	4	x	20	x	26		0.042	] / [	9,490	]
2,4-Dinitrotoluene	4.40E-11	= [	4.78E-09	x	4	x	20	x	26		0.042	] / [	9,490	]
2,6-Dinitrotoluene	1.69E-09	= [	1.84E-07	x	4	x	20	x	26		0.042	] / [	9,490	]
Nitrobenzene	3.91E-05	= [	4.25E-03	x	4	x	20	x	26		0.042	] / [	9,490	]

EC = exposure concentration
CA = chemical concentration in air
ET = exposure time
EF = exposure frequency
ED = exposure duration
CF = conversion factor (1 day/24 hours)
AT = averaging time

Table A18
Inhalation of Chemicals in Sediment - Adolescent Recreational Visitors
Exposure Concentration (EC) of Chemical in Air
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Equation	EC	= [	CA	x	ET	x	EF	x	ED	x	CF	] / [	AT	]
Units	μg/m^3		μg/m^3		hours/day		days/year		years		days/hour		days	
CARCINOGENIC EFFECTS														
Aluminum	1.45E-05	= [	1.10E-02	x	4	x	20	x	10	x	0.042	] / [	25,550	]
Antimony	1.55E-08	= [	1.18E-05	x	4	x	20	x	10	x	0.042	] / [	25,550	]
Beryllium	1.35E-09	= [	1.03E-06	x	4	x	20	x	10	x	0.042	] / [	25,550	]
Cadmium	#VALUE!	= [	9.56E-07	x	4	x	t	x	10	x	0.042	] / [	25,550	]
Chromium	1.84E-08	= [	1.40E-05	x	4	x	20	x	10	x	0.042	] / [	25,550	]
Copper	2.32E-08	= [	1.76E-05	x	4	x	20	x	10	x	0.042	] / [	25,550	]
Manganese	8.12E-07	= [	6.18E-04	x	4	x	20	x	10	x	0.042	] / [	25,550	]
Mercury	1.92E-06	= [	1.46E-03	x	4	x	20	x	10	x	0.042	] / [	25,550	]
Molybdenum	1.93E-09	= [	1.47E-06	x	4	x	20	x	10	x	0.042	] / [	25,550	]
Nickel	2.22E-08	= [	1.69E-05	x	4	x	20	x	10	x	0.042	] / [	25,550	]
Selenium	3.77E-09	= [	2.87E-06	x	4	x	20	x	10	x	0.042	] / [	25,550	]
Strontium	5.61E-08	= [	4.26E-05	x	4	x	20	x	10	x	0.042	] / [	25,550	]
Uranium	1.26E-08	= [	9.56E-06	x	4	x	20	x	10	x	0.042	] / [	25,550	]
Vanadium	3.48E-08	= [	2.65E-05	x	4	x	20	x	10	x	0.042	] / [	25,550	]
1,3,5-Trinitrobenzene	2.42E-11	= [	1.84E-08	x	4	x	20	x	10	x	0.042	] / [	25,550	]
1,3-Dinitrobenzene	6.29E-12	= [	4.78E-09	x	4	x	20	x	10	x	0.042	] / [	25,550	]
2,4,6-Trinitrotoluene	2.42E-10	= [	1.84E-07	x	4	x	20	x	10	x	0.042	] / [	25,550	]
2,4-Dinitrotoluene	6.29E-12	= [	4.78E-09	x	4	x	20	x	10	x	0.042	] / [	25,550	]
2,6-Dinitrotoluene	2.42E-10	= [	1.84E-07	x	4	x	20	x	10	x	0.042	] / [	25,550	]
Nitrobenzene	9.01E-06	= [	6.85E-03	x	4	x	20	x	10	x	0.042	] / [	25,550	]
NONCARCINOGENIC EFFECTS														
Aluminum	1.02E-04	= [	1.10E-02	x	4	x	20	x	10		0.042	] / [	3,650	]
Antimony	1.08E-07	= [	1.18E-05	x	4	x	20	x	10		0.042	] / [	3,650	]
Beryllium	9.48E-09	= [	1.03E-06	x	4	x	20	x	10		0.042	] / [	3,650	]
Cadmium	8.80E-09	= [	9.56E-07	x	4	x	20	x	10		0.042	] / [	3,650	]
Chromium	1.29E-07	= [	1.40E-05	x	4	x	20	x	10		0.042	] / [	3,650	]
Copper	1.62E-07	= [	1.76E-05	x	4	x	20	x	10		0.042	] / [	3,650	]
Manganese	5.69E-06	= [	6.18E-04	x	4	x	20	x	10		0.042	] / [	3,650	]
Mercury	1.35E-05	= [	1.46E-03	x	4	x	20	x	10		0.042	] / [	3,650	]
Molybdenum	1.35E-08	= [	1.47E-06	x	4	x	20	x	10		0.042	] / [	3,650	]
Nickel	1.56E-07	= [	1.69E-05	x	4	x	20	x	10		0.042	] / [	3,650	]
Selenium	2.64E-08	= [	2.87E-06	x	4	x	20	x	10		0.042	] / [	3,650	]
Strontium	3.93E-07	= [	4.26E-05	x	4	x	20	x	10		0.042	] / [	3,650	]
Uranium	8.80E-08	= [	9.56E-06	x	4	x	20	x	10		0.042	] / [	3,650	]
Vanadium	2.44E-07	= [	2.65E-05	x	4	x	20	x	10		0.042	] / [	3,650	]
1,3,5-Trinitrobenzene	1.69E-10	= [	1.84E-08	x	4	x	20	x	10		0.042	] / [	3,650	]
1,3-Dinitrobenzene	4.40E-11	= [	4.78E-09	x	4	x	20	x	10		0.042	] / [	3,650	]
2,4,6-Trinitrotoluene	1.69E-09	= [	1.84E-07	x	4	x	20	x	10		0.042	] / [	3,650	]
2,4-Dinitrotoluene	4.40E-11	= [	4.78E-09	x	4	x	20	x	10		0.042	] / [	3,650	]
2,6-Dinitrotoluene	1.69E-09	= [	1.84E-07	x	4	x	20	x	10		0.042	] / [	3,650	]
Nitrobenzene	6.31E-05	= [	6.85E-03	x	4	x	20	x	10		0.042	] / [	3,650	]

EC = exposure concentration
CA = chemical concentration in air
ET = exposure time
EF = exposure frequency
ED = exposure duration
CF = conversion factor (1 day/24 hours)
AT = averaging time

Table A19
Daily Intake Calculations: Adult Recreational Visitor
Ingestion of Chemicals in Fish Tissue
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Equation	$DI_{F\text{-}Ing}$	= [	C_F	x	IR_F	x	CF	x	EF	x	ED	] / [	BW	x	AT	]
Units	mg/kg-day		mg/kg		g/day		kg/g		days/yr		yr		kg		days	
CARCINOGENIC EFFECTS																
Arsenic	1.58E-05	= [	8.50E-02	x	41.8	x	1.0E-03	x	350	x	26	] / [	80	x	25,550	]
Mercury	2.61E-05	= [	1.40E-01	x	41.8	x	1.0E-03	x	350	x	26	] / [	80	x	25,550	]
Uranium	1.47E-06	= [	7.90E-03	x	41.8	x	1.0E-03	x	350	x	26	] / [	80	x	25,550	]
NONCARCINOGENIC EFFECTS																
Arsenic	4.26E-05	= [	8.50E-02	x	41.8	x	1.0E-03	x	350	x	26	] / [	80	x	9,490	]
Mercury	7.01E-05	= [	1.40E-01	x	41.8	x	1.0E-03	x	350	x	26	] / [	80	x	9,490	]
Uranium	3.96E-06	= [	7.90E-03	x	41.8	x	1.0E-03	x	350	x	26	] / [	80	x	9,490	]

$DI_{F\text{-}Ing}$ = daily chemical intake via soil ingestion
C_F = chemical concentration in fish tissue
IR_F = fish ingestion rate
CF = conversion factor, 1 kg/10^3mg
EF = exposure frequency
ED = exposure duration
BW = body weight
AT = averaging time

Table A20
Daily Intake Calculations: Adolescent Recreational Visitor
Ingestion of Chemicals in Fish Tissue
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Equation	DI_{F-Ing}	= [	C_F	x	IR_F	x	CF	x	EF	x	ED	] / [	BW	x	AT	]
Units	mg/kg-day		mg/kg		g/day		kg/g		days/yr		yr		kg		days	
CARCINOGENIC EFFECTS																
Arsenic	5.05E-06	= [	8.50E-02	x	19.2	x	1.00E-03	x	350	x	10	] / [	44.3	x	25,550	]
Mercury	8.31E-06	= [	1.40E-01	x	19.2	x	1.00E-03	x	350	x	10	] / [	44.3	x	25,550	]
Uranium	4.69E-07	= [	7.90E-03	x	19.2	x	1.00E-03	x	350	x	10	] / [	44.3	x	25,550	]
NONCARCINOGENIC EFFECTS																
Arsenic	3.53E-05	= [	8.50E-02	x	19.2	x	1.00E-03	x	350	x	10	] / [	44.3	x	3,650	]
Mercury	5.82E-05	= [	1.40E-01	x	19.2	x	1.00E-03	x	350	x	10	] / [	44.3	x	3,650	]
Uranium	3.28E-06	= [	7.90E-03	x	19.2	x	1.00E-03	x	350	x	10	] / [	44.3	x	3,650	]

DI_{F-Ing} = daily chemical intake via soil ingestion
C_F = chemical concentration in fish tissue
IR_F = fish ingestion rate
CF = conversion factor, 1 kg/10^3mg
EF = exposure frequency
ED = exposure duration
BW = body weight
AT = averaging time

Table A21
Risk Characterization
Adult Recreational Visitors - All Chemical Exposure Pathways
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

	Carcinogenic Effects					Noncarcinogenic Effects				
Equation	**DI**	**x**	**SF**	**=**	**CR**	**DI**	**/**	**RfD**	**=**	**HQ**
Units	**mg/kg-day**		**$(mg/kg\text{-}day)^{-1}$**		**unitless**	**mg/kg-day**		**mg/kg-day**		**unitless**
Surface Water Ingestion										
Aluminum	1.26E-04	x	-	=	na	3.40E-04	/	1.0E+00	=	3.40E-04
Arsenic	1.57E-07	x	1.5E+00	=	2.357E-07	4.23E-07	/	3.0E-04	=	1.41E-03
Nickel	2.53E-07	x	-	=	na	6.81E-07	/	2.0E-02	=	3.40E-05
Strontium	4.70E-06	x	-	=	na	1.26E-05	/	6.0E-01	=	2.11E-05
Uranium	4.52E-06	x	-	=	na	1.22E-05	/	2.0E-04	=	6.08E-02
Zinc	1.54E-06	x	-	=	na	4.13E-06	/	3.0E-01	=	1.38E-05
1,3,5-Trinitrobenzene	7.23E-10	x	-	=	na	1.95E-09	/	3.0E-02	=	6.48E-08
2,4,6-Trinitrotoluene	1.21E-09	x	3.0E-02	=	3.63E-11	3.26E-09	/	5.0E-04	=	6.52E-06
2,4-Dinitrotoluene	6.68E-10	x	3.1E-01	=	2.07E-10	1.80E-09	/	2.0E-03	=	9.00E-07
2,6-Dinitrotoluene	4.70E-10	x	1.5E+00	=	7.04E-10	1.26E-09	/	3.0E-04	=	4.21E-06
			Pathway total =		2.37E-07			Pathway total =		6.26E-02
Dermal Absorption of Chemicals in Surface Water										
Aluminum	3.50E-05	x	-	=	na	9.42E-05	/	1.0E+00	=	9.42E-05
Arsenic	4.35E-08	x	1.5E+00	=	6.52E-08	1.17E-07	/	3.0E-04	=	3.90E-04
Nickel	1.40E-08	x	-	=	na	3.77E-08	/	8.0E-04	=	4.71E-05
Strontium	1.30E-06	x	-	=	na	3.50E-06	/	6.0E-01	=	5.83E-06
Uranium	1.25E-06	x	-	=	na	3.37E-06	/	2.0E-04	=	1.68E-02
Zinc	2.55E-07	x	-	=	na	6.86E-07	/	3.0E-01	=	2.29E-06
1,3,5-Trinitrobenzene	4.30E-10	x	-	=	na	1.16E-09	/	3.0E-02	=	3.86E-08
2,4,6-Trinitrotoluene	1.25E-09	x	3.0E-02	=	3.75E-11	3.37E-09	/	5.0E-04	=	6.73E-06
2,4-Dinitrotoluene	1.65E-09	x	3.1E-01	=	5.12E-10	4.45E-09	/	2.0E-03	=	2.23E-06
2,6-Dinitrotoluene	1.40E-09	x	1.5E+00	=	2.09E-09	3.76E-09	/	3.0E-04	=	1.25E-05
			Pathway total =		6.79E-08			Pathway total =		1.74E-02
Ingestion of Sediment										
Aluminum	3.82E-04	x	-	=	na	1.03E-03	/	1.0E+00	=	1.03E-03
Antimony	4.07E-07	x	-	=	na	1.10E-06	/	4.0E-04	=	2.74E-03
Beryllium	3.56E-08	x	-	=	na	9.59E-08	/	2.0E-03	=	4.79E-05
Cadmium	3.31E-08	x	-	=	na	8.90E-08	/	1.0E-03	=	8.90E-05
Chromium	4.83E-07	x	5.0E-01	=	2.42E-07	1.30E-06	/	3.0E-03	=	4.34E-04
Copper	6.11E-07	x	-	=	na	1.64E-06	/	4.0E-02	=	4.11E-05
Manganese	2.14E-05	x	-	=	na	5.75E-05	/	2.4E-02	=	2.40E-03
Mercury	2.54E-09	x	-	=	na	6.85E-09	/	-	=	na
Molybdenum	5.09E-08	x	-	=	na	1.37E-07	/	5.0E-03	=	2.74E-05
Nickel	5.85E-07	x	-	=	na	1.58E-06	/	2.0E-02	=	7.88E-05
Selenium	9.92E-08	x	-	=	na	2.67E-07	/	5.0E-03	=	5.34E-05
Strontium	1.48E-06	x	-	=	na	3.97E-06	/	6.0E-01	=	6.62E-06
Uranium	3.31E-07	x	-	=	na	8.90E-07	/	2.0E-04	=	4.45E-03
Vanadium	9.16E-07	x	-	=	na	2.47E-06	/	5.0E-03	=	4.93E-04
1,3,5-Trinitrobenzene	6.36E-10	x	-	=	na	1.71E-09	/	3.0E-02	=	5.71E-08
1,3-Dinitrobenzene	1.65E-10	x	-	=	na	4.45E-10	/	1.0E-04	=	4.45E-06
2,4,6-Trinitrotoluene	6.36E-09	x	3.0E-02	=	1.91E-10	1.71E-08	/	5.0E-04	=	3.42E-05
2,4-Dinitrotoluene	1.65E-10	x	3.1E-01	=	5.13E-11	4.45E-10	/	2.0E-03	=	2.23E-07
2,6-Dinitrotoluene	6.36E-09	x	1.5E+00	=	9.54E-09	1.71E-08	/	3.0E-04	=	5.71E-05
Nitrobenzene	6.36E-09	x	-	=	na	1.71E-08	/	2.0E-03	=	8.56E-06
			Pathway total =		2.51E-07			Pathway total =		1.20E-02

Table A21
Risk Characterization
Adult Recreational Visitors - All Chemical Exposure Pathways
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

	Carcinogenic Effects					Noncarcinogenic Effects				
Equation	**DI**	**x**	**SF**	**=**	**CR**	**DI**	**/**	**RfD**	**=**	**HQ**
Units	**mg/kg-day**		**$(mg/kg\text{-}day)^{-1}$**		**unitless**	**mg/kg-day**		**mg/kg-day**		**unitless**
Dermal Absorption of Chemicals in Sediment										
Aluminum	na	x	-	=	na	na	/	1.0E+00	=	na
Antimony	na	x	-	=	na	na	/	6.0E-05	=	na
Beryllium	na	x	-	=	na	na	/	1.4E-05	=	na
Cadmium	5.98E-10	x	-	=	na	1.61E-09	/	2.5E-05	=	6.45E-05
Chromium	na	x	2.0E+01	=	na	na	/	7.5E-05	=	na
Copper	na	x	-	=	na	na	/	4.0E-02	=	na
Manganese	na	x	-	=	na	na	/	9.6E-04	=	na
Mercury	na	x	-	=	na	na	/	-	=	na
Molybdenum	na	x	-	=	na	na	/	5.0E-03	=	na
Nickel	na	x	-	=	na	na	/	8.0E-04	=	na
Selenium	na	x	-	=	na	na	/	5.0E-03	=	na
Strontium	na	x	-	=	na	na	/	6.0E-01	=	na
Uranium	na	x	-	=	na	na	/	2.0E-04	=	na
Vanadium	na	x	-	=	na	na	/	1.3E-04	=	na
1,3,5-Trinitrobenzene	2.19E-10	x	-	=	na	5.89E-10	/	3.0E-02	=	1.96E-08
1,3-Dinitrobenzene	2.99E-10	x	-	=	na	8.06E-10	/	1.0E-04	=	8.06E-06
2,4,6-Trinitrotoluene	3.68E-09	x	3.0E-02	=	1.10E-10	9.92E-09	/	5.0E-04	=	1.98E-05
2,4-Dinitrotoluene	3.05E-10	x	3.1E-01	=	9.46E-11	8.22E-10	/	2.0E-03	=	4.11E-07
2,6-Dinitrotoluene	1.14E-08	x	1.5E+00	=	1.71E-08	3.07E-08	/	3.0E-04	=	1.02E-04
Nitrobenzene	na	x	-	=	na	na	/	2.0E-03	=	na
			Pathway total =		1.73E-08			Pathway total =		1.95E-04
Inalation of Chemicals in Sediment*										
Aluminum	3.77E-05	x	-	=	na	1.02E-04	/	5.0E+00	=	2.03E-05
Antimony	4.02E-08	x	-	=	na	1.08E-07	/	-	=	na
Beryllium	3.52E-09	x	2.4E-03	=	8.45E-12	9.48E-09	/	2.0E-02	=	4.74E-07
Cadmium	3.27E-09	x	1.8E-03	=	5.88E-12	8.80E-09	/	1.0E-02	=	8.80E-07
Chromium	4.78E-08	x	8.4E-02	=	4.01E-09	1.29E-07	/	1.0E-01	=	1.29E-06
Copper	6.03E-08	x	-	=	na	1.62E-07	/	-	=	na
Manganese	2.11E-06	x	-	=	na	5.69E-06	/	5.0E-02	=	1.14E-04
Mercury	3.10E-06	x	-	=	na	8.36E-06	/	3.0E-01	=	2.79E-05
Molybdenum	5.03E-09	x	-	=	na	1.35E-08	/	-	=	na
Nickel	5.78E-08	x	2.6E-04	=	1.50E-11	1.56E-07	/	9.0E-02	=	1.73E-06
Selenium	9.80E-09	x	-	=	na	2.64E-08	/	2.0E+01	=	1.32E-09
Strontium	1.46E-07	x	-	=	na	3.93E-07	/	-	=	na
Uranium	3.27E-08	x	-	=	na	8.80E-08	/	4.0E-02	=	2.20E-06
Vanadium	9.05E-08	x	-	=	na	2.44E-07	/	1.0E-01	=	2.44E-06
1,3,5-Trinitrobenzene	6.29E-11	x	-	=	na	1.69E-10	/	-	=	na
1,3-Dinitrobenzene	1.63E-11	x	-	=	na	4.40E-11	/	-	=	na
2,4,6-Trinitrotoluene	6.29E-10	x	-	=	na	1.69E-09	/	-	=	na
2,4-Dinitrotoluene	1.63E-11	x	8.9E-05	=	1.45E-15	4.40E-11	/	-	=	na
2,6-Dinitrotoluene	6.29E-10	x	-	=	na	1.69E-09	/	-	=	na
Nitrobenzene	1.45E-05	x	4.0E-05	=	5.81E-10	3.91E-05	/	9.0E+00	=	4.35E-06
			Pathway total =		4.62E-09			Pathway total =		1.75E-04

Table A21
Risk Characterization
Adult Recreational Visitors - All Chemical Exposure Pathways
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

	Carcinogenic Effects					Noncarcinogenic Effects				
Equation	**DI**	**x**	**SF**	**=**	**CR**	**DI**	**/**	**RfD**	**=**	**HQ**
Units	**mg/kg-day**		**$(mg/kg\text{-}day)^{-1}$**		**unitless**	**mg/kg-day**		**mg/kg-day**		**unitless**
Ingestion of Fish										
Arsenic	1.58E-05	x	1.5E+00	=	2.37E-05	4.26E-05	/	3.00E-04	=	1.42E-01
Mercury	2.61E-05	x	-	=	na	7.01E-05	/	-	=	na
Uranium	1.47E-06	x	-	=	na	3.96E-06	/	2.00E-04	=	1.98E-02
			Pathway total =		2.37E-05			Pathway total =		1.62E-01
Chemical Totals										
Aluminum			Sum of all pathways	=	na			Sum of all pathways	=	1.48E-03
Antimony			Sum of all pathways	=	na			Sum of all pathways	=	2.74E-03
Arsenic			Sum of all pathways	=	2.40E-05			Sum of all pathways	=	1.44E-01
Beryllium			Sum of all pathways	=	8.45E-12			Sum of all pathways	=	4.84E-05
Cadmium			Sum of all pathways	=	5.88E-12			Sum of all pathways	=	8.99E-05
Chromium			Sum of all pathways	=	2.46E-07			Sum of all pathways	=	4.35E-04
Copper			Sum of all pathways	=	na			Sum of all pathways	=	4.11E-05
Manganese			Sum of all pathways	=	na			Sum of all pathways	=	2.51E-03
Mercury			Sum of all pathways	=	na			Sum of all pathways	=	2.79E-05
Molybdenum			Sum of all pathways	=	na			Sum of all pathways	=	2.74E-05
Nickel			Sum of all pathways	=	1.50E-11			Sum of all pathways	=	1.62E-04
Selenium			Sum of all pathways	=	na			Sum of all pathways	=	5.34E-05
Strontium			Sum of all pathways	=	na			Sum of all pathways	=	3.35E-05
Uranium			Sum of all pathways	=	na			Sum of all pathways	=	1.02E-01
Vanadium			Sum of all pathways	=	na			Sum of all pathways	=	4.96E-04
Zinc			Sum of all pathways	=	na			Sum of all pathways	=	1.61E-05
1,3,5-Trinitrobenzene			Sum of all pathways	=	na			Sum of all pathways	=	1.80E-07
1,3-Dinitrobenzene			Sum of all pathways	=	na			Sum of all pathways	=	1.25E-05
2,4,6-Trinitrotoluene			Sum of all pathways	=	3.75E-10			Sum of all pathways	=	6.73E-05
2,4-Dinitrotoluene			Sum of all pathways	=	8.65E-10			Sum of all pathways	=	3.76E-06
2,6-Dinitrotoluene			Sum of all pathways	=	2.94E-08			Sum of all pathways	=	1.76E-04
Nitrobenzene			Sum of all pathways	=	5.81E-10			Sum of all pathways	=	1.29E-05
	Total Carcinogenic Risk					Total Noncarcinogenic Risk				
	All Pathways and Chemicals			=	2.43E-05	All Pathways and Chemicals			=	2.54E-01

DI = Chemical Daily Intake
SF = Cancer Slope Factor
CR = Cancer Risk
RfD = Noncancer Reference Dose
HQ = Hazard Quotient
*For the inhalation pathway, the Inhalation Unit Risk (IUR) is used as the carcinogenic toxicity factor, with units of $(\mu g/m^3)^{-1}$ and the reference concentration (RfC) is used as the noncarcinogenic toxicity factor, with units of $\mu g/m^3$.
na = not applicable

Table A22
Risk Characterization
Adolescent Recreational Visitors - All Chemical Exposure Pathways
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

	Carcinogenic Effects							Noncarcinogenic Effects				
Equation	**DI**	**x**	**SF**	**x**	**ADAF***	**=**	**CR**	**DI**	**/**	**RfD**	**=**	**HQ**
Units	**mg/kg-day**		**$(mg/kg\text{-}day)^{-1}$**		**unitless**		**unitless**	**mg/kg-day**		**mg/kg-day**		**unitless**
Surface Water Ingestion												
Aluminum	1.48E-04	x	-			=	na	1.04E-03	/	1.00E+00	=	1.04E-03
Arsenic	1.84E-07	x	1.50E+00			=	2.77E-07	1.29E-06	/	3.00E-04	=	4.30E-03
Nickel	2.97E-07	x	-			=	na	2.08E-06	/	2.00E-02	=	1.04E-04
Strontium	5.51E-06	x	-			=	na	3.86E-05	/	6.00E-01	=	6.43E-05
Uranium	5.30E-06	x	-			=	na	3.71E-05	/	2.00E-04	=	1.86E-01
Zinc	1.80E-06	x	-			=	na	1.26E-05	/	3.00E-01	=	4.21E-05
1,3,5-Trinitrobenzene	8.48E-10	x	-			=	na	5.94E-09	/	3.00E-02	=	1.98E-07
2,4,6-Trinitrotoluene	1.42E-09	x	3.00E-02			=	4.26E-11	9.94E-09	/	5.00E-04	=	1.99E-05
2,4-Dinitrotoluene	7.85E-10	x	3.10E-01			=	2.43E-10	5.49E-09	/	2.00E-03	=	2.75E-06
2,6-Dinitrotoluene	5.51E-10	x	1.50E+00			=	8.27E-10	3.86E-09	/	3.00E-04	=	1.29E-05
					Pathway total	=	2.78E-07			Pathway total	=	1.91E-01
Dermal Absorption of Chemicals in Surface Water												
Aluminum	1.65E-05	x	-			=	na	1.16E-04	/	1.00E+00	=	1.16E-04
Arsenic	2.05E-08	x	1.50E+00			=	3.08E-08	1.44E-07	/	3.00E-04	=	4.79E-04
Nickel	6.61E-09	x	-			=	na	4.62E-08	/	8.00E-04	=	5.78E-05
Strontium	6.13E-07	x	-			=	na	4.29E-06	/	6.00E-01	=	7.16E-06
Uranium	5.90E-07	x	-			=	na	4.13E-06	/	2.00E-04	=	2.06E-02
Zinc	1.20E-07	x	-			=	na	8.42E-07	/	3.00E-01	=	2.81E-06
1,3,5-Trinitrobenzene	2.03E-10	x	-			=	na	1.42E-09	/	3.00E-02	=	4.73E-08
2,4,6-Trinitrotoluene	5.90E-10	x	3.00E-02			=	1.77E-11	4.13E-09	/	5.00E-04	=	8.26E-06
2,4-Dinitrotoluene	7.80E-10	x	3.10E-01			=	2.42E-10	5.46E-09	/	2.00E-03	=	2.73E-06
2,6-Dinitrotoluene	6.58E-10	x	1.50E+00			=	9.88E-10	4.61E-09	/	3.00E-04	=	1.54E-05
					Pathway total	=	3.20E-08			Pathway total	=	2.13E-02
Ingestion of Sediment												
Aluminum	2.65E-04	x	-			=	na	1.86E-03	/	1.00E+00	=	1.86E-03
Antimony	2.83E-07	x	-			=	na	1.98E-06	/	4.00E-04	=	4.95E-03
Beryllium	2.47E-08	x	-			=	na	1.73E-07	/	2.00E-03	=	8.66E-05
Cadmium	2.30E-08	x	-			=	na	1.61E-07	/	1.00E-03	=	1.61E-04
Chromium	3.36E-07	x	5.00E-01	x	3	=	5.04E-07	2.35E-06	/	3.00E-03	=	7.83E-04
Copper	4.24E-07	x	-			=	na	2.97E-06	/	4.00E-02	=	7.42E-05
Manganese	1.48E-05	x	-			=	na	1.04E-04	/	2.40E-02	=	4.33E-03
Mercury	1.77E-09	x	-			=	na	1.24E-08	/	-	=	na
Molybdenum	3.53E-08	x	-			=	na	2.47E-07	/	5.00E-03	=	4.95E-05
Nickel	4.06E-07	x	-			=	na	2.84E-06	/	2.00E-02	=	1.42E-04
Selenium	6.89E-08	x	-			=	na	4.82E-07	/	5.00E-03	=	9.65E-05
Strontium	1.02E-06	x	-			=	na	7.17E-06	/	6.00E-01	=	1.20E-05
Uranium	2.30E-07	x	-			=	na	1.61E-06	/	2.00E-04	=	8.04E-03
Vanadium	6.36E-07	x	-			=	na	4.45E-06	/	5.00E-03	=	8.91E-04
1,3,5-Trinitrobenzene	4.42E-10	x	-			=	na	3.09E-09	/	3.00E-02	=	1.03E-07
1,3-Dinitrobenzene	1.15E-10	x	-			=	na	8.04E-10	/	1.00E-04	=	8.04E-06
2,4,6-Trinitrotoluene	4.42E-09	x	3.00E-02			=	1.33E-10	3.09E-08	/	5.00E-04	=	6.18E-05
2,4-Dinitrotoluene	1.15E-10	x	3.10E-01			=	3.56E-11	8.04E-10	/	2.00E-03	=	4.02E-07
2,6-Dinitrotoluene	4.42E-09	x	1.50E+00			=	6.63E-09	3.09E-08	/	3.00E-04	=	1.03E-04
Nitrobenzene	4.42E-09	x	-			=	na	3.09E-08	/	2.00E-03	=	1.55E-05
					Pathway total	=	5.10E-07			Pathway total	=	2.17E-02

Table A22
Risk Characterization
Adolescent Recreational Visitors - All Chemical Exposure Pathways
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

	Carcinogenic Effects							Noncarcinogenic Effects				
Equation	**DI**	**x**	**SF**	**x**	**ADAF***	**=**	**CR**	**DI**	**/**	**RfD**	**=**	**HQ**
Units	**mg/kg-day**		**$(mg/kg\text{-}day)^{-1}$**		**unitless**		**unitless**	**mg/kg-day**		**mg/kg-day**		**unitless**
Dermal Absorption of Chemicals in Sediment												
Aluminum	na	x	-			=	na	na	/	1.00E+00	=	na
Antimony	na	x	-			=	na	na	/	6.00E-05	=	na
Beryllium	na	x	-			=	na	na	/	1.40E-05	=	na
Cadmium	3.23E-10	x	-			=	na	2.26E-09	/	2.50E-05	=	9.04E-05
Chromium	na	x	2.00E+01	x	3	=	na	na	/	7.50E-05	=	na
Copper	na	x	-			=	na	na	/	4.00E-02	=	na
Manganese	na	x	-			=	na	na	/	9.60E-04	=	na
Mercury	na	x	-			=	na	na	/	-	=	na
Molybdenum	na	x	-			=	na	na	/	5.00E-03	=	na
Nickel	na	x	-			=	na	na	/	8.00E-04	=	na
Selenium	na	x	-			=	na	na	/	5.00E-03	=	na
Strontium	na	x	-			=	na	na	/	6.00E-01	=	na
Uranium	na	x	-			=	na	na	/	2.00E-04	=	na
Vanadium	na	x	-			=	na	na	/	1.30E-04	=	na
1,3,5-Trinitrobenzene	1.18E-10	x	-			=	na	8.25E-10	/	3.00E-02	=	2.75E-08
1,3-Dinitrobenzene	1.61E-10	x	-			=	na	1.13E-09	/	1.00E-04	=	1.13E-05
2,4,6-Trinitrotoluene	1.99E-09	x	3.00E-02			=	5.96E-11	1.39E-08	/	5.00E-04	=	2.78E-05
2,4-Dinitrotoluene	1.65E-10	x	3.10E-01			=	5.10E-11	1.15E-09	/	2.00E-03	=	5.76E-07
2,6-Dinitrotoluene	6.14E-09	x	1.50E+00			=	9.22E-09	4.30E-08	/	3.00E-04	=	1.43E-04
Nitrobenzene	na	x	-			=	na	na	/	2.00E-03	=	na
					Pathway total =		9.33E-09			Pathway total =		2.73E-04
Inhalation of Chemicals in Sediment**												
Aluminum	1.45E-05	x	-			=	na	1.02E-04	/	5.00E+00	=	2.03E-05
Antimony	1.55E-08	x	-			=	na	1.08E-07	/	-	=	na
Beryllium	1.35E-09	x	2.40E-03			=	3.25E-12	9.48E-09	/	2.00E-02	=	4.74E-07
Cadmium	#VALUE!	x	1.80E-03			=	na	8.80E-09	/	1.00E-02	=	8.80E-07
Chromium	1.84E-08	x	8.40E-02	x	3	=	4.63E-09	1.29E-07	/	1.00E-01	=	1.29E-06
Copper	2.32E-08	x	-			=	na	1.62E-07	/	-	=	na
Manganese	8.12E-07	x	-			=	na	5.69E-06	/	5.00E-02	=	1.14E-04
Mercury	1.92E-06	x	-			=	na	1.35E-05	/	3.00E-01	=	4.49E-05
Molybdenum	1.93E-09	x	-			=	na	1.35E-08	/	-	=	na
Nickel	2.22E-08	x	2.60E-04			=	5.78E-12	1.56E-07	/	9.00E-02	=	1.73E-06
Selenium	3.77E-09	x	-			=	na	2.64E-08	/	2.00E+01	=	1.32E-09
Strontium	5.61E-08	x	-			=	na	3.93E-07	/	-	=	na
Uranium	1.26E-08	x	-			=	na	8.80E-08	/	4.00E-02	=	2.20E-06
Vanadium	3.48E-08	x	-			=	na	2.44E-07	/	1.00E-01	=	2.44E-06
1,3,5-Trinitrobenzene	2.42E-11	x	-			=	na	1.69E-10	/	-	=	na
1,3-Dinitrobenzene	6.29E-12	x	-			=	na	4.40E-11	/	-	=	na
2,4,6-Trinitrotoluene	2.42E-10	x	-			=	na	1.69E-09	/	-	=	na
2,4-Dinitrotoluene	6.29E-12	x	8.90E-05			=	5.59E-16	4.40E-11	/	-	=	na
2,6-Dinitrotoluene	2.42E-10	x	-			=	na	1.69E-09	/	-	=	na
Nitrobenzene	9.01E-06	x	4.00E-05			=	3.60E-10	6.31E-05	/	9.00E+00	=	7.01E-06
					Pathway total =		5.00E-09			Pathway total =		1.95E-04
Ingestion of Fish												
Arsenic	5.05E-06	x	1.50E+00			=	7.57E-06	3.53E-05	/	3.00E-04	=	1.18E-01
Mercury	8.31E-06	x	-			=	na	5.82E-05	/	-	=	na
Uranium	4.69E-07	x	-			=	na	3.28E-06	/	2.00E-04	=	1.64E-02
					Pathway total =		7.57E-06			Pathway total =		1.34E-01

Table A22
Risk Characterization
Adolescent Recreational Visitors - All Chemical Exposure Pathways
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

	Carcinogenic Effects								Noncarcinogenic Effects				
Equation	**DI**	**x**	**SF**	**x**	**ADAF***	**=**	**CR**		**DI**	**/**	**RfD**	**=**	**HQ**
Units	**mg/kg-day**		**(mg/kg-day)$^{-1}$**		**unitless**		**unitless**		**mg/kg-day**		**mg/kg-day**		**unitless**
Chemical Totals													
Aluminum			Sum of all pathways			=	na		Sum of all pathways			=	3.03E-03
Antimony			Sum of all pathways			=	na		Sum of all pathways			=	4.95E-03
Arsenic			Sum of all pathways			=	7.88E-06		Sum of all pathways			=	1.23E-01
Beryllium			Sum of all pathways			=	3.25E-12		Sum of all pathways			=	8.71E-05
Cadmium			Sum of all pathways			=	na		Sum of all pathways			=	1.62E-04
Chromium			Sum of all pathways			=	5.08E-07		Sum of all pathways			=	7.85E-04
Copper			Sum of all pathways			=	na		Sum of all pathways			=	7.42E-05
Manganese			Sum of all pathways			=	na		Sum of all pathways			=	4.44E-03
Mercury			Sum of all pathways			=	na		Sum of all pathways			=	4.49E-05
Molybdenum			Sum of all pathways			=	na		Sum of all pathways			=	4.95E-05
Nickel			Sum of all pathways			=	5.78E-12		Sum of all pathways			=	3.06E-04
Selenium			Sum of all pathways			=	na		Sum of all pathways			=	9.65E-05
Strontium			Sum of all pathways			=	na		Sum of all pathways			=	8.34E-05
Uranium			Sum of all pathways			=	na		Sum of all pathways			=	2.31E-01
Vanadium			Sum of all pathways			=	na		Sum of all pathways			=	8.93E-04
Zinc			Sum of all pathways			=	na		Sum of all pathways			=	4.49E-05
1,3,5-Trinitrobenzene			Sum of all pathways			=	na		Sum of all pathways			=	3.76E-07
1,3-Dinitrobenzene			Sum of all pathways			=	na		Sum of all pathways			=	1.93E-05
2,4,6-Trinitrotoluene			Sum of all pathways			=	2.52E-10		Sum of all pathways			=	1.18E-04
2,4-Dinitrotoluene			Sum of all pathways			=	5.72E-10		Sum of all pathways			=	6.45E-06
2,6-Dinitrotoluene			Sum of all pathways			=	1.77E-08		Sum of all pathways			=	2.75E-04
Nitrobenzene			Sum of all pathways			=	3.60E-10		Sum of all pathways			=	2.25E-05
			Total Carcinogenic Risk						Total Noncarcinogenic Risk				
			All Pathways and Chemicals			=	8.40E-06		All Pathways and Chemical			=	3.69E-01

DI = Chemical Daily Intake
SF = Cancer Slope Factor
CR = Cancer Risk
RfD = Noncancer Reference Dose
HQ = Hazard Quotient
*ADAF = age-dependent adjustment factor; only required for chemicals which demonstrate a mutagenic mode of action
**For the inhalation pathway, the Inhalation Unit Risk (IUR) is used as the carcinogenic toxicity factor, with units of $(\mu g/m^3)^{-1}$ and the reference concentration (RfC) is used as the noncarcinogenic toxicity factor, with units of $\mu g/m^3$.
na = not applicable

APPENDIX B

RADIOLOGICAL PRG CALCULATOR OUTPUT FILES
INTAKE AND RISK FOR RADIOLIGICAL EXPOSURE PATHWAYS

Table B1.a
Site-Specific: Adults
Recreator Surface Water Inputs - Secular Equilibrium
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

/HTML"Output to Spreadsheet

/HTML"Output to PDF

*** Inputted values different from Recreator defaults are highlighted.**

Variable	Recreator Surface Water Default Value	Form-input Value
$DFA_{rec-adj}$ (age-adjusted immersion factor - recreator) hr	0	520
ED_{rec} (exposure duration - recreator) yr	0	26
ED_{rec-a} (exposure duration - recreator adult) yr	0	26
ED_{rec-c} (exposure duration - recreator child) yr	0	0
EF_{rec-a} (exposure frequency - recreator adult) day/yr	0	20
EF_{rec-c} (exposure frequency - recreator child) day/yr	0	0
$ET_{event-rec-a}$ (exposure time - recreator adult) hr/event	0	1
$ET_{event-rec-c}$ (exposure time - recreator child) hr/event	0	0
EV_{rec-a} (number of bathing events per day - recreator adult) event/day	0	1
EV_{rec-c} (number of bathing events per day - recreator child) event/day	0	1
$IFW_{rec-adj}$ (age-adjusted water intake rate - recreator) L	0	36.92
IRW_{rec-a} (water intake rate - recreator adult) L/hr	0.071	0.071
IRW_{rec-c} (water intake rate - recreator child) L/hr	0.12	0.12
TR (target cancer risk) unitless	0.000001	0.000001

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Table B1.b
Site-Specific: Adults
Recreator Individual Contribution PRGs for Surface Water - Secular Equilibrium
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Isotope	Parent	Fractional Contribution of Progeny	Water Ingestion Slope Factor (risk/pCi)	Immersion Slope Factor (risk/yr per pCi/L)	Ingestion PRG TR=0.000001 (pCi/L)	Immersion PRG TR=0.000001 (pCi/L)	Total PRG TR=0.000001 (pCi/L)	Total PRG TR=0.000001 (mg/L)
Th-231	U-235	1.00E+00	2.19E-12	8.89E-14	1.23E+04	1.90E+08	**1.23E+04**	1.53E-19
U-235	U-235	1.00E+00	6.96E-11	1.39E-12	3.89E+02	1.21E+07	**3.89E+02**	1.19E-06
Pa-234	U-238	1.60E-03	2.07E-12	1.35E-11	8.17E+06	7.77E+08	**8.09E+06**	6.20E-23
Pa-234m	U-238	1.00E+00	0.00E+00	1.82E-13	-	9.25E+07	**9.25E+07**	1.58E-26
Th-234	U-238	1.00E+00	2.31E-11	6.39E-14	1.17E+03	2.64E+08	**1.17E+03**	3.69E-17
U-234	U-238	1.00E+00	7.07E-11	1.17E-15	3.83E+02	1.44E+10	**3.83E+02**	4.20E-10
U-238	U-238	1.00E+00	6.40E-11	5.98E-16	4.23E+02	2.82E+10	**4.23E+02**	7.04E-06

Output generated 15MAR2019:12:46:06

Table B1.c
Site-Specific: Adults
Recreator Individual Risk Contributions for Surface Water - Secular Equilibrium
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Isotope	Water Ingestion Slope Factor (risk/pCi)	Immersion Slope Factor (risk/yr per pCi/L)	Concentration (pCi/L)	Water Ingestion Slope Factor (risk/pCi)	Immersion Slope Factor (risk/yr per pCi/L)	Ingestion CDI (pCi)	Immersion CDI (pCi)	Ingestion Risk	Immersion Risk	Total Tapwater Risk
Th-231	2.19E-12	8.89E-14	4.25	2.19E-12	8.89E-14	157	2.52E-01	3.44E-10	2.24E-14	**3.44E-10**
U-235	6.96E-11	1.39E-12	4.25	6.96E-11	1.39E-12	157	2.52E-01	1.09E-08	3.51E-13	**1.09E-08**
Pa-234	2.07E-12	1.35E-11	85	2.07E-12	1.35E-11	3140	5.05E+00	1.04E-11	1.09E-13	**1.05E-11**
Pa-234m	0.00E+00	1.82E-13	85	0.00E+00	1.82E-13	3140	5.05E+00	0.00E+00	9.19E-13	**9.19E-13**
Th-234	2.31E-11	6.39E-14	85	2.31E-11	6.39E-14	3140	5.05E+00	7.25E-08	3.22E-13	**7.25E-08**
U-234	7.07E-11	1.17E-15	85	7.07E-11	1.17E-15	3140	5.05E+00	2.22E-07	5.89E-15	**2.22E-07**
U-238	6.40E-11	5.98E-16	85	6.40E-11	5.98E-16	3140	5.05E+00	2.01E-07	3.02E-15	**2.01E-07**

Output generated 15MAR2019:12:46:06

Table B2.a
Site-Specific: Adolescents
Recreator Surface Water Inputs - Secular Equilibrium
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

/HTML"Output to Spreadsheet

/HTML"Output to PDF

*** Inputted values different from Recreator defaults are highlighted.**

Variable	Recreator Surface Water Default Value	Form-input Value
$DFA_{rec-adj}$ (age-adjusted immersion factor - recreator) hr	0	200
ED_{rec} (exposure duration - recreator) yr	0	10
ED_{rec-a} (exposure duration - recreator adult) yr	0	0
ED_{rec-c} (exposure duration - recreator child) yr	0	10
EF_{rec-a} (exposure frequency - recreator adult) day/yr	0	0
EF_{rec-c} (exposure frequency - recreator child) day/yr	0	20
$ET_{event-rec-a}$ (exposure time - recreator adult) hr/event	0	0
$ET_{event-rec-c}$ (exposure time - recreator child) hr/event	0	1
EV_{rec-a} (number of bathing events per day - recreator adult) event/day	0	1
EV_{rec-c} (number of bathing events per day - recreator child) event/day	0	1
$IFW_{rec-adj}$ (age-adjusted water intake rate - recreator) L	0	24
IRW_{rec-a} (water intake rate - recreator adult) L/hr	0.071	0.071
IRW_{rec-c} (water intake rate - recreator child) L/hr	0.12	0.12
TR (target cancer risk) unitless	0.000001	0.000001

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Table B2.b
Site-Specific: Adolescents
Recreator Individual Contribution PRGs for Surface Water - Secular Equilibrium
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Isotope	Parent	Fractional Contribution of Progeny	Water Ingestion Slope Factor (risk/pCi)	Immersion Slope Factor (risk/yr per pCi/L)	Ingestion PRG TR=0.000001 (pCi/L)	Immersion PRG TR=0.000001 (pCi/L)	Total PRG TR=0.000001 (pCi/L)	Total PRG TR=0.000001 (mg/L)
Th-231	U-235	1.00E+00	2.19E-12	8.89E-14	1.90E+04	4.93E+08	**1.90E+04**	9.92E-20
U-235	U-235	1.00E+00	6.96E-11	1.39E-12	5.99E+02	3.15E+07	**5.99E+02**	7.73E-07
Pa-234	U-238	1.60E-03	2.07E-12	1.35E-11	1.26E+07	2.02E+09	**1.25E+07**	4.01E-23
Pa-234m	U-238	1.00E+00	0.00E+00	1.82E-13	-	2.40E+08	**2.40E+08**	6.07E-27
Th-234	U-238	1.00E+00	2.31E-11	6.39E-14	1.80E+03	6.86E+08	**1.80E+03**	2.40E-17
U-234	U-238	1.00E+00	7.07E-11	1.17E-15	5.90E+02	3.75E+10	**5.90E+02**	2.73E-10
U-238	U-238	1.00E+00	6.40E-11	5.98E-16	6.51E+02	7.33E+10	**6.51E+02**	4.57E-06

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Table B2.c
Site-Specific: Adolescents
Recreator Individual Risk Contributions for Surface Water - Secular Equilibrium
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Isotope	Water Ingestion Slope Factor (risk/pCi)	Immersion Slope Factor (risk/yr per pCi/L)	Concentration (pCi/L)	Water Ingestion Slope Factor (risk/pCi)	Immersion Slope Factor (risk/yr per pCi/L)	Ingestion CDI (pCi)	Immersion CDI (pCi)	Ingestion Risk	Immersion Risk	Total Tapwater Risk
Th-231	2.19E-12	8.89E-14	4.25	2.19E-12	8.89E-14	102	9.70E-02	2.24E-10	8.62E-15	**2.24E-10**
U-235	6.96E-11	1.39E-12	4.25	6.96E-11	1.39E-12	102	9.70E-02	7.10E-09	1.35E-13	**7.10E-09**
Pa-234	2.07E-12	1.35E-11	85	2.07E-12	1.35E-11	2040	1.94E+00	6.76E-12	4.21E-14	**6.81E-12**
Pa-234m	0.00E+00	1.82E-13	85	0.00E+00	1.82E-13	2040	1.94E+00	0.00E+00	3.53E-13	**3.53E-13**
Th-234	2.31E-11	6.39E-14	85	2.31E-11	6.39E-14	2040	1.94E+00	4.71E-08	1.24E-13	**4.71E-08**
U-234	7.07E-11	1.17E-15	85	7.07E-11	1.17E-15	2040	1.94E+00	1.44E-07	2.26E-15	**1.44E-07**
U-238	6.40E-11	5.98E-16	85	6.40E-11	5.98E-16	2040	1.94E+00	1.31E-07	1.16E-15	**1.31E-07**

Output generated 15MAR2019:13:01:15

Table B3.a
Site-Specific: Adults
Recreator Soil (Sediment) Inputs - Secular Equilibrium
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

/HTML"Output to Spreadsheet
/HTML"Output to PDF
*** Inputted values different from Recreator defaults are highlighted.**

Variable	Recreator Soil Default Value	Form-input Value
A (PEF Dispersion Constant)	16.2302	16.2302
B (PEF Dispersion Constant)	18.7762	18.7762
City (Climate Zone)	Default	Default
C (PEF Dispersion Constant)	216.108	216.108
F(x) (function dependent on U_m/U_t) unitless	0.194	0.194
PEF (particulate emission factor) m^3/kg	1359344438	1359344438
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77	93.77
A_s (acres)	0.5	0.5
ED_{rec} (exposure duration - recreator) yr	0	26
ED_{rec-a} (exposure duration - recreator adult) yr	0	26
ED_{resc-c} (exposure duration - recreator child) yr	0	0
EF_{rec} (exposure frequency - recreator) day/yr	0	20
EF_{rec-a} (exposure frequency - recreator adult) day/yr	0	20
EF_{rec-c} (exposure frequency - recreator child) day/yr	0	0
ET_{rec} (exposure time - recreator) hr/day	0	4
ET_{rec-a} (exposure time - recreator) hr/day	0	4
ET_{rec-c} (exposure time - recreator) hr/day	0	0
$IFA_{rec-adj}$ (age-adjusted inhalation rate - recreator) m^3	0	4854.72
$IFS_{rec-adj}$ (age-adjusted soil intake rate - recreator) mg	0	52000
IRA_{rec-a} (inhalation rate - recreator adult) m^3/day	20	56.016
IRA_{rec-c} (inhalation rate - recreator child) m^3/day	10	10
IRS_{rec-a} (soil intake rate - recreator adult) mg/day	100	100
IRS_{rec-c} (soil intake rate - recreator child) mg/day	200	200
t_{rec} (time - recreator) yr	0	26
TR (target cancer risk) unitless	0.000001	0.000001
U_m (mean annual wind speed) m/s	4.69	4.69
U_t (equivalent threshold value)	11.32	11.32
V (fraction of vegetative cover) unitless	0.5	0.5

Output generated 13FEB2019:15:37:04

Table B3.b
Site-Specific: Adults
Recreator Individual Contribution PRGs for Soil (Sediment) - Secular Equilibrium
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Isotope	Parent	Fractional Contribution of Progeny	ICRP Lung Absorption Type	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/yr per pCi/g)	Soil Ingestion Slope Factor (risk/pCi)	Particulate Emission Factor (m^3/kg)	Lambda (1/yr)	Halflife (yr)	200005 m^2 Soil Volume Area Correction Factor	0 cm Soil Volume Gamma Shielding Factor	Ingestion PRG TR=0.000001 (pCi/g)	Inhalation PRG TR=0.000001 (pCi/g)	External Exposure PRG TR=0.000001 (pCi/g)	Total PRG TR=0.000001 (pCi/g)	Total PRG TR=0.000001 (mg/kg)
Th-231	U-235	1.00E+00	S	1.50E-12	2.49E-08	5.96E-12	1.36E+09	2.38E+02	2.91E-03	1.00E+00	1.00E+00	3.23E+03	1.86E+08	1.69E+02	**1.61E+02**	1.17E-14
U-235	U-235	1.00E+00	S	2.50E-08	5.51E-07	1.48E-10	1.36E+09	9.84E-10	7.04E+08	9.46E-01	1.00E+00	1.30E+02	1.12E+04	8.08E+00	**7.60E+00**	6.09E-02
Pa-234	U-238	1.60E-03	S	1.20E-12	6.62E-06	5.37E-12	1.36E+09	9.06E+02	7.65E-04	9.60E-01	1.00E+00	2.24E+06	1.46E+11	4.14E+02	**4.14E+02**	1.21E-15
Pa-234m	U-238	1.00E+00	-	0.00E+00	9.06E-08	0.00E+00	1.36E+09	3.11E+05	2.23E-06	9.49E-01	1.00E+00	-	-	4.90E+01	**4.90E+01**	2.98E-17
Th-234	U-238	1.00E+00	S	3.08E-11	1.77E-08	6.25E-11	1.36E+09	1.05E+01	6.60E-02	1.00E+00	1.00E+00	3.08E+02	9.10E+06	2.37E+02	**1.34E+02**	3.23E-13
U-234	U-238	1.00E+00	S	2.78E-08	2.53E-10	1.48E-10	1.36E+09	2.82E-06	2.46E+05	1.00E+00	1.00E+00	1.30E+02	1.01E+04	1.66E+04	**1.27E+02**	1.27E-06
U-238	U-238	1.00E+00	S	2.36E-08	1.24E-10	1.34E-10	1.36E+09	1.55E-10	4.47E+09	1.00E+00	1.00E+00	1.43E+02	1.18E+04	3.40E+04	**1.41E+02**	2.11E-02

Output generated 13FEB2019:15:37:04

Table B3.c
Site-Specific: Adults
Recreator Individual Risk Contributions for Soil (Sediment) - Secular Equilibrium
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Isotope	ICRP Lung Absorption Type	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/yr per pCi/g)	Soil Ingestion Slope Factor (risk/pCi)	Concentration (pCi/g)	Particulate Emission Factor (m^3/kg)	Lambda (1/yr)	Halflife (yr)	200005 m^2 Soil Volume Area Correction Factor	0 cm Soil Volume Gamma Shielding Factor	Ingestion CDI (pCi)	Inhalation CDI (pCi)	External Exposure CDI (pCi)	Ingestion Risk	Inhalation Risk	External Exposure Risk	Total Risk
Th-231	S	1.50E-12	2.49E-08	5.96E-12	0.225	1.36E+09	2.38E+02	2.91E-03	1.00E+00	1.00E+00	12	0	0	6.97E-11	1.21E-15	1.33E-09	**1.40E-09**
U-235	S	2.50E-08	5.51E-07	1.48E-10	0.225	1.36E+09	9.84E-10	7.04E+08	9.46E-01	1.00E+00	12	0	0	1.73E-09	2.01E-11	2.79E-08	**2.96E-08**
Pa-234	S	1.20E-12	6.62E-06	5.37E-12	4.5	1.36E+09	9.06E+02	7.65E-04	9.60E-01	1.00E+00	234	0	1	2.01E-12	3.08E-17	1.09E-08	**1.09E-08**
Pa-234m	-	0.00E+00	9.06E-08	0.00E+00	4.5	1.36E+09	3.11E+05	2.23E-06	9.49E-01	1.00E+00	234	0	1	0.00E+00	0.00E+00	9.19E-08	**9.19E-08**
Th-234	S	3.08E-11	1.77E-08	6.25E-11	4.5	1.36E+09	1.05E+01	6.60E-02	1.00E+00	1.00E+00	234	0	1	1.46E-08	4.95E-13	1.90E-08	**3.36E-08**
U-234	S	2.78E-08	2.53E-10	1.48E-10	4.5	1.36E+09	2.82E-06	2.46E+05	1.00E+00	1.00E+00	234	0	1	3.47E-08	4.47E-10	2.71E-10	**3.54E-08**
U-238	S	2.36E-08	1.24E-10	1.34E-10	4.5	1.36E+09	1.55E-10	4.47E+09	1.00E+00	1.00E+00	234	0	1	3.14E-08	3.80E-10	1.32E-10	**3.19E-08**

Output generated 13FEB2019:15:37:04

Table B4.a
Site-Specific: Adolescents
Recreator Soil (Sediment) Inputs - Secular Equilibrium
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

/HTML"Output to Spreadsheet

/HTML"Output to PDF

*** Inputted values different from Recreator defaults are highlighted.**

Variable	Recreator Soil Default Value	Form-input Value
A (PEF Dispersion Constant)	16.2302	16.2302
B (PEF Dispersion Constant)	18.7762	18.7762
City (Climate Zone)	Default	Default
C (PEF Dispersion Constant)	216.108	216.108
F(x) (function dependent on U_m/U_t) unitless	0.194	0.194
PEF (particulate emission factor) m^3/kg	1359344438	1359344438
Q/C_{wind} (g/m^2-s per kg/m^3)	93.77	93.77
A_s (acres)	0.5	0.5
ED_{rec} (exposure duration - recreator) yr	0	10
ED_{rec-a} (exposure duration - recreator adult) yr	0	0
ED_{resc-c} (exposure duration - recreator child) yr	0	10
EF_{rec} (exposure frequency - recreator) day/yr	0	20
EF_{rec-a} (exposure frequency - recreator adult) day/yr	0	0
EF_{rec-c} (exposure frequency - recreator child) day/yr	0	20
ET_{rec} (exposure time - recreator) hr/day	0	4
ET_{rec-a} (exposure time - recreator) hr/day	0	0
ET_{rec-c} (exposure time - recreator) hr/day	0	4
$IFA_{rec-adj}$ (age-adjusted inhalation rate - recreator) m^3	0	1512
$IFS_{rec-adj}$ (age-adjusted soil intake rate - recreator) mg	0	20000
IRA_{rec-a} (inhalation rate - recreator adult) m^3/day	20	0
IRA_{rec-c} (inhalation rate - recreator child) m^3/day	10	45.36
IRS_{rec-a} (soil intake rate - recreator adult) mg/day	100	0
IRS_{rec-c} (soil intake rate - recreator child) mg/day	200	100
t_{rec} (time - recreator) yr	0	10
TR (target cancer risk) unitless	0.000001	0.000001
U_m (mean annual wind speed) m/s	4.69	4.69
U_t (equivalent threshold value)	11.32	11.32
V (fraction of vegetative cover) unitless	0.5	0.5

Output generated 14FEB2019:16:04:12

Table B4.b
Site-Specific: Adolescents
Recreator Individual Contribution PRGs for Soil (Sediment) - Secular Equilibrium
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Isotope	Parent	Fractional Contribution of Progeny	ICRP Lung Absorption Type	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/yr per pCi/g)	Soil Ingestion Slope Factor (risk/pCi)	Particulate Emission Factor (m^3/kg)	Lambda (1/yr)	Halflife (yr)	200005 m^2 Soil Volume Area Correction Factor	0 cm Soil Volume Gamma Shielding Factor	Ingestion PRG TR=0.000001 (pCi/g)	Inhalation PRG TR=0.000001 (pCi/g)	External Exposure PRG TR=0.000001 (pCi/g)	Total PRG TR=0.000001 (pCi/g)	Total PRG TR=0.000001 (mg/kg)
Th-231	U-235	1.00E+00	S	1.50E-12	2.49E-08	5.96E-12	1.36E+09	2.38E+02	2.91E-03	1.00E+00	1.00E+00	8.39E+03	5.98E+08	4.40E+02	**4.18E+02**	4.50E-15
U-235	U-235	1.00E+00	S	2.50E-08	5.51E-07	1.48E-10	1.36E+09	9.84E-10	7.04E+08	9.46E-01	1.00E+00	3.39E+02	3.59E+04	2.10E+01	**1.98E+01**	2.34E-02
Pa-234	U-238	1.60E-03	S	1.20E-12	6.62E-06	5.37E-12	1.36E+09	9.06E+02	7.65E-04	9.60E-01	1.00E+00	5.82E+06	4.69E+11	1.08E+03	**1.08E+03**	4.66E-16
Pa-234m	U-238	1.00E+00	-	0.00E+00	9.06E-08	0.00E+00	1.36E+09	3.11E+05	2.23E-06	9.49E-01	1.00E+00	-	-	1.27E+02	**1.27E+02**	1.15E-17
Th-234	U-238	1.00E+00	S	3.08E-11	1.77E-08	6.25E-11	1.36E+09	1.05E+01	6.60E-02	1.00E+00	1.00E+00	8.00E+02	2.92E+07	6.17E+02	**3.48E+02**	1.24E-13
U-234	U-238	1.00E+00	S	2.78E-08	2.53E-10	1.48E-10	1.36E+09	2.82E-06	2.46E+05	1.00E+00	1.00E+00	3.37E+02	3.23E+04	4.32E+04	**3.31E+02**	4.86E-07
U-238	U-238	1.00E+00	S	2.36E-08	1.24E-10	1.34E-10	1.36E+09	1.55E-10	4.47E+09	1.00E+00	1.00E+00	3.72E+02	3.80E+04	8.85E+04	**3.67E+02**	8.11E-03

Output generated 14FEB2019:16:04:12

Table B4.c
Site-Specific: Adolescents
Recreator Individual Risk Contributions for Soil (Sediment)- Secular Equilibrium
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Isotope	ICRP Lung Absorption Type	Inhalation Slope Factor (risk/pCi)	External Exposure Slope Factor (risk/yr per pCi/g)	Soil Ingestion Slope Factor (risk/pCi)	Concentration (pCi/g)	Particulate Emission Factor (m^3/kg)	Lambda (1/yr)	Halflife (yr)	200005 m^2 Soil Volume Area Correction Factor	0 cm Soil Volume Gamma Shielding Factor	Ingestion CDI (pCi)	Inhalation CDI (pCi)	External Exposure CDI (pCi)	Ingestion Risk	Inhalation Risk	External Exposure Risk	Total Risk
Th-231	S	1.50E-12	2.49E-08	5.96E-12	0.225	1.36E+09	2.38E+02	2.91E-03	1.00E+00	1.00E+00	5	0	0	2.68E-11	3.76E-16	5.11E-10	**5.38E-10**
U-235	S	2.50E-08	5.51E-07	1.48E-10	0.225	1.36E+09	9.84E-10	7.04E+08	9.46E-01	1.00E+00	5	0	0	6.64E-10	6.26E-12	1.07E-08	**1.14E-08**
Pa-234	S	1.20E-12	6.62E-06	5.37E-12	4.5	1.36E+09	9.06E+02	7.65E-04	9.60E-01	1.00E+00	90	0	0	7.73E-13	9.60E-18	4.18E-09	**4.18E-09**
Pa-234m	-	0.00E+00	9.06E-08	0.00E+00	4.5	1.36E+09	3.11E+05	2.23E-06	9.49E-01	1.00E+00	90	0	0	0.00E+00	0.00E+00	3.54E-08	**3.54E-08**
Th-234	S	3.08E-11	1.77E-08	6.25E-11	4.5	1.36E+09	1.05E+01	6.60E-02	1.00E+00	1.00E+00	90	0	0	5.63E-09	1.54E-13	7.29E-09	**1.29E-08**
U-234	S	2.78E-08	2.53E-10	1.48E-10	4.5	1.36E+09	2.82E-06	2.46E+05	1.00E+00	1.00E+00	90	0	0	1.34E-08	1.39E-10	1.04E-10	**1.36E-08**
U-238	S	2.36E-08	1.24E-10	1.34E-10	4.5	1.36E+09	1.55E-10	4.47E+09	1.00E+00	1.00E+00	90	0	0	1.21E-08	1.18E-10	5.09E-11	**1.23E-08**

Output generated 14FEB2019:16:04:12

Table B5.a
Site-Specific: Adults
Resident Contaminated Fish Inputs - Secular Equilibrium
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

/HTML"Output to Spreadsheet

/HTML"Output to PDF

*** Inputted values different from Resident defaults are highlighted.**

Variable	Resident Contaminated Fish Default Value	Form-input Value
$CF_{res\text{-}fish}$ (contaminated fish fraction) unitless	1	1
ED_{res} (exposure duration - resident) yr	26	26
EF_{res} (exposure frequency - resident) day/yr	350	350
$IRFI_{res\text{-}a}$ (fish ingestion rate - adult) mg/day	54000	41800
TR (target cancer risk) unitless	0.000001	0.000001

Output generated 15MAR2019:13:12:23

Table B5.b
Site-Specific: Adults
Resident Individual Contribution PRGs for Contaminated Fish - Secular Equilibrium
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Isotope	Parent	Fractional Contribution of Progeny	Food Ingestion Slope Factor (risk/pCi)	Ingestion of Fish PRG TR=1E-06 (pCi/g)	Ingestion of Fish PRG TR=1E-06 (mg/kg)
Th-231	U-235	1.00E+00	3.22E-12	**8.18E-01**	2.30E-12
U-235	U-235	1.00E+00	9.44E-11	**2.79E-02**	1.66E+01
Pa-234	U-238	1.60E-03	3.00E-12	**5.48E+02**	9.15E-16
Pa-234m	U-238	1.00E+00	0.00E+00	**-**	-
Th-234	U-238	1.00E+00	3.39E-11	**7.75E-02**	5.58E-10
U-234	U-238	1.00E+00	9.55E-11	**2.75E-02**	5.84E-03
U-238	U-238	1.00E+00	8.66E-11	**3.04E-02**	9.81E+01

Output generated 15MAR2019:13:12:23

Table B5.c
Site-Specific: Adults
Resident Individual Risk Contributions for Contaminated Fish - Secular Equilibrium
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Isotope	Food Ingestion Slope Factor (risk/pCi)	Concentration (pCi/g)	Fish CDI (pCi)	Fish Risk
Th-231	3.22E-12	0.0001425	54	**1.74E-10**
U-235	9.44E-11	0.0001425	54	**5.11E-09**
Pa-234	3.00E-12	0.00285	1080	**5.20E-12**
Pa-234m	0.00E+00	0.00285	1080	**0.00E+00**
Th-234	3.39E-11	0.00285	1080	**3.68E-08**
U-234	9.55E-11	0.00285	1080	**1.03E-07**
U-238	8.66E-11	0.00285	1080	**9.39E-08**

Output generated 15MAR2019:13:12:23

Table B6.a
Site-Specific: Adolescents
Resident Contaminated Fish Inputs - Secular Equilibrium
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

/HTML"Output to Spreadsheet

/HTML"Output to PDF

*** Inputted values different from Resident defaults are highlighted.**

Variable	Resident Contaminated Fish Default Value	Form-input Value
$CF_{res-fish}$ (contaminated fish fraction) unitless	1	1
ED_{res} (exposure duration - resident) yr	26	10
EF_{res} (exposure frequency - resident) day/yr	350	350
$IRFI_{res-a}$ (fish ingestion rate - adult) mg/day	54000	19200
TR (target cancer risk) unitless	0.000001	0.000001

Output generated 15MAR2019:13:18:31

Table B6.b
Site-Specific: Adolsecents
Resident Individual Contribution PRGs for Contaminated Fish - Secular Equilibrium
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Isotope	Parent	Fractional Contribution of Progeny	Food Ingestion Slope Factor (risk/pCi)	Ingestion of Fish PRG TR=0.000001 (pCi/g)	Ingestion of Fish PRG TR=0.000001 (mg/kg)
Th-231	U-235	1.00E+00	3.22E-12	**4.63E+00**	4.07E-13
U-235	U-235	1.00E+00	9.44E-11	**1.58E-01**	2.94E+00
Pa-234	U-238	1.60E-03	3.00E-12	**3.10E+03**	1.62E-16
Pa-234m	U-238	1.00E+00	0.00E+00	**-**	-
Th-234	U-238	1.00E+00	3.39E-11	**4.39E-01**	9.86E-11
U-234	U-238	1.00E+00	9.55E-11	**1.56E-01**	1.03E-03
U-238	U-238	1.00E+00	8.66E-11	**1.72E-01**	1.73E+01

Output generated 15MAR2019:13:18:31

Table B6.c
Site-Specific: Adolescents
Resident Individual Risk Contributions for Contaminated Fish - Secular Equilibrium
Femme Osage Slough
Weldon Spring Quarry/Plant/Pits Site, St. Charles, Missouri

Isotope	Food Ingestion Slope Factor (risk/pCi)	Concentration (pCi/g)	Fish CDI (pCi)	Fish Risk
Th-231	3.22E-12	0.0001425	10	**3.08E-11**
U-235	9.44E-11	0.0001425	10	**9.03E-10**
Pa-234	3.00E-12	0.00285	192	**9.20E-13**
Pa-234m	0.00E+00	0.00285	192	**0.00E+00**
Th-234	3.39E-11	0.00285	192	**6.50E-09**
U-234	9.55E-11	0.00285	192	**1.83E-08**
U-238	8.66E-11	0.00285	192	**1.66E-08**

Output generated 15MAR2019:13:18:31