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HEALTH RISK ANALYSIS FOR INGESTION OF CONTAMINANTS FROM EXISTING GROUNDWATER CONTAMINATION AT SELECTED UMTRA PROJECT SITES

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ABSTRACT

This study examines potential hazards to human health from the ingestion of chemicals in ground waters beneath and adjacent to four abandoned uranium mill-tailings sites: Gunnison, Colorado; Lakeview, Oregon; Monument Valley, Arizona; and Riverton, Wyoming. Chemicals of concern in the ground water near these sites include arsenic, cadmium, chromium, lead-210, molybdenum, nitrate, polonium-210, radium 226 and radium 228, selenium, sulfate, thorium-230, uranium and vanadium. Hazards to health were evaluated by implementing the method outlined in the Environmental Protection Agency's Superfund Public Health Evaluation Manual. Conservative assumptions in the method, and the effect of these on the risk estimates and EPA's indices of harm are discussed. Because the method has a number of built-in conservatisms, the estimated risks and indices only indicate sites and chemicals requiring further analysis. The chemicals and sites identified as presenting risk in this first screening step should be investigated in more detail. Necessary steps are given. Sites and chemicals identified as harmless in this initial screening can be eliminated from further consideration.

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1 INTRODUCTION

This study examines potential hazards to human health from ingestion of chemicals in ground waters beneath and adjacent to abandoned uranium mill-tailings sites: Riverton, Wyoming; Monument Valley, Arizona; Gunnison, Colorado; and Lakeview, Oregon. The contaminants studied are arsenic, cadmium, chromium VI, lead-210, molybdenum, nitrate, polonium-210, radium-226 and radium-228, selenium, sulfate, thorium-230, natural uranium, and vanadium. These sites and chemicals were selected for this analysis by the U.S. Department of Energy - Uranium Mill-tailings Remedial Action (DOE-UMTRA) Project Office in Albuquerque, New Mexico. Potential hazards to public health were evaluated by implementing the method used by the U.S. Environmental Protection Agency (EPA) at Superfund sites. Because of built-in conservatisms in this method, estimates which have large risks should only be used to indicate sites and chemicals requiring more detailed analysis. Conversely, sites and chemicals not indicating large risks can be eliminated from further consideration. The EPA method is essentially a screening procedure rather than an analysis of realistic risk.

2 APPROACH

Contaminants presenting potentially substantial hazards to public health at the four sites were identified using procedures outlined in the Superfund Public Health Evaluation Manual, here called the "Manual", (USEPA, 1986a) and in related reports prepared by EPA (USEPA, 1986b); the U.S. Agency for Toxic Substances and Disease Registry (ATSDR, undated); and the International Commission on Radiological Protection (ICRP 1977; ICRP 1979). The method outlined in these reports can be divided into three steps: Exposure Assessment, Dose Response Assessment, and Risk Characterization.

2.1 Exposure Assessment

The purpose of this step in hazard assessment is to estimate public exposure levels from consuming drinking water potentially impacted by chemicals leached from uranium mill-tailings sites. The Manual outlines a very conservative approach to estimate human exposures. More specifically, the Manual suggests that exposure estimates be based on the highest observed concentration for each chemical among all monitoring wells, irrespective of their location or distance from public wells, or public use. In this context, exposure estimates in this report are

based on: (i) the highest concentration of the identified chemicals detected in domestic, industrial, or agricultural receptor wells; (ii) the highest concentration of the identified chemicals detected in off-site monitoring wells; and (iii) the lowest observed concentrations in any background wells. Use of these measurements results in exposure estimates that are much larger than actual or potential exposures for several reasons. First, if large concentrations were measured in wells used for drinking water, use of these waters would be restricted. Monitor wells routinely show higher levels of contaminants than wells actually being used for drinking water. Second, use of the lowest observed background concentration may overestimate the contribution of any specific contaminant from the mill-tailings sites. Third, use of the maximum concentration detected in monitor and receptor wells overestimates the exposure because most wells contain much lower concentrations.

2.2 Dose-Response Assessment

Dose-response information is needed to evaluate hazards to human health associated with estimated exposure levels. The three toxicologic end-points in the Manual are the Acceptable Intake for Subchronic Exposure (AIS), the Acceptable Intake for Chronic Exposure (AIC), and the Carcinogenic Potency Factor.

The AIS represents the highest human intake rate of a chemical, expressed in milligrams ingested per day per kilogram of bodyweight (mg/day/kg), that does not cause adverse effects when exposure is short-term, but not acute. The AIS is usually based on subchronic animal studies.

The AIC represents the highest human intake of a chemical, expressed as mg/day/kg, that does not cause adverse effects when exposure is long-term (lifetime). The AIC is usually based on chronic animal studies.

The Carcinogenic Potency Factor represents the carcinogenic potential of a chemical, expressed as cancer risk per mg/day/kg for nonradiologic pollutants, and as cancer risk per pCi/day/kg for radiologic pollutants. In both, the risks are from life-long intake. The Potency Factor for non-radiological effects is based on extrapolations from human data, when available, or chronic animal studies; for radiological effects, they are based on models and extrapolations from human data.

The AIS, AIC and Potency Factors for the contaminants studied are shown in Table 1. In this screening study, dose-response coefficients developed by EPA or ICRP were used for arsenic, cadmium, chromium, lead-210, nitrate, polonium-210, radium 226, radium 228, thorium-230, and natural uranium. Independent estimates were developed for molybdenum, sulfate and vanadium

Table 1. Dose-Response Coefficients.

Chemical	AIS (mg/kg/day)	(mg/l)	AIC (mg/kg/day)	(mg/l)	Potency Factor EPA	ICRP
Arsenic	1.40E-03	0.050 DWHA	1.40E-03	0.050 DWHA	1.50E+01	
Cadmium	1.20E-03	0.043 DWHA	2.90E-04	0.010 HEA		
Chromium (III)	1.40E+01	490 Rfd	1.00E+00	52 Rfd		
Chromium (VI)	2.50E-02	0.870 HEA	5.00E-03	0.170 HEA		
Lead-210					1.40E-04	1.14E-03
Molybdenum			2.90E-03			
Nitrate	1.10E+01	44 DWHA	1.26E+00	44 DWHA		
Polonium-210					3.68E-04	3.65E-04
Radium-226					3.08E-04	2.47E-04
Radium-228					2.31E-04	2.77E-04
Selenium	3.20E-03	0.110 HEA	3.00E-03	1.00E-01 HEA		
Sulfate			4.00E+01			
Thorium-230					7.70E-05	1.18E-04
Uranium			1.70E-03	0.060	4.73E-05	5.49E-05
Vanadium	1.00E-02	0.350	2.00E-02	0.175 Rfd		

Definitions:

AIS - Acceptable Intake for Subchronic Exposure. The highest human intake of a chemical, expressed as mg/kg/day, that does not cause adverse effects when exposure is short-term (but not acute). The AIS is usually based on subchronic animal studies.

AIC - Acceptable Intake for Chronic Exposure. The highest human intake of a chemical, expressed as mg/kg/day, that does not cause adverse effects when exposure is long-term (lifetime). The AIC is usually based on chronic animal studies.

DWHA - EPA Drinking Water Health Advisory (1 day or lifetime limit).

HEA - Health Effects Assessment, prepared by the Environmental Criteria and Assessment Office, USEPA, Cincinnati, Ohio, 1985 (updated May, 1986)

Rfd - Agency-wide reference dose value, developed by an interoffice work group chaired by the Office of Research and Development, USEPA, Washington, DC, 1986.

(AIS only) because EPA has not done so (details on the derivations of these coefficients are given in Appendix A).

As with exposure assessment, the coefficients included in this study are also conservative. AIS and AIC values incorporate safety factors to extrapolate from "no observed effects levels" in animal and human studies to estimated intakes which are assumed to present minimal health risks. Similarly, carcinogenic potency factors are often based on extrapolations from studies in which laboratory animals were exposed to pollutant concentrations much higher than those measured in the general public. Section 4 details the conservatisms in these coefficients.

2.3 Risk Characterization

Risk Characterization combines the toxicologic and concentration data to estimate risks to human health associated with consumption of contaminated drinking water. Estimates are prepared for acute, chronic, and carcinogenic hazards. For acute and chronic hazards, ratios of the quantities of materials ingested vs. the quantities hazardous to human health are developed. Calculated ratios greater than 1.0 indicate that a potential hazard to health could arise from continued consumption of contaminated drinking water. For carcinogens, the estimated probability of an individual developing cancer is estimated. In this context, life-time risk estimates less than 10^{-6} often are viewed as *de minimus* by EPA and other regulatory agencies. Similarly, EPA and others often implement control requirements when risks exceed 10^{-4}. Risks in the range of 10^{-4} to 10^{-6} are reviewed on a case-by-case basis to determine whether controls are needed.

In this specific analysis, it is important to note that for arsenic, cadmium, molybdenum, uranium, and vanadium federal drinking water standards can be met, even though the ratio value of 1.0 maybe exceeded. This occurs when the calculated ratio is based on an intake or effect in children, or in adults not considered in the drinking water standard. Conversely, drinking water standards are more stringent than the ratio test for chromium, selenium, and sulfate. Similarly, for cancer risks, many of the chemicals studied exceed the 1×10^{-6} risk level for cancer, but are below the risk level implied by the drinking water standard. This occurs when the 1×10^{-6} risk level has not been used in the development of the standards, for example lead-210 and polonium-210.

3 SITE SPECIFIC ANALYSES

To evaluate potential hazards to health from chemicals in ground water beneath or adjacent to the four UMTRA sites, the EPA Superfund Manual method was implemented.

Inputs to the EPA method include concentration data for three different well types: receptor, monitor and background. Background wells are located upgradient of the site, and provide an estimate of the water quality near the site independent of any impact from the mill-tailings site. Receptor wells are domestic, agricultural or industrial wells located downgradient of the tailings site. These wells represent a real potential for exposure to contaminated water because they are being used. Monitor wells are wells located downgradient of the tailings pile, beginning just offsite. Relative to receptor wells, monitor wells are generally closer to the tailings pile, are more likely to be completed in shallow aquifers, and show higher levels of contamination.

Pollutant concentrations were measured in a number of wells, and some wells were sampled a number of times. These concentrations reflect random, and possible real variations in pollutant concentration among measurements, over time and space, and among different wells in the same class (background, monitoring, or receptor). Faced with a potentially large set of measurements for each of the three classes, and keeping with the conservative approach of the study, both the "gross" and "net" concentrations were used. The "gross" concentration was the maximum concentration detected for a particular contaminant in any monitor or receptor well. The "net" concentration was calculated as the highest receptor (or monitoring) well measurement minus the lowest background well measurement for that contaminant. This will overstate the impact of the tailings pile on the receptor or monitoring wells.

In interpreting any set of environmental measurements, how to handle measurements that were below the limits of detection (LOD) is always a question. It was decided to treat them as zero. Since the highest measurements were taken from the monitoring and receptor wells, this problem should not arise there unless the pollutant is consistently below LOD for all measurements. In that case, clearly there is no risk. The effect falls on the calculation of net exposure; when at least one measurement in a background well is below LOD, background is taken as zero for the calculation of net exposure. In that case, net exposure is calculated to equal gross exposure. This has a further conservative effect of overestimating the contribution of the tailings piles to exposure.

For each site and aquifer, exposure and intake levels were estimated using standard reference factors (e.g., children consume 1 liter per day of water and weigh 10 kilograms, and adults consume 2 liters per day of water and weigh 70 kilograms). Eight different intakes were estimated for each pollutant. Receptor Adult (Gross) and Receptor Child (Gross) represent the

estimated intakes for an adult and child drinking water from a "receptor well." Receptor Adult (Net) and Receptor Child (Net) also represent the estimated intakes for an adult and child drinking water from a "receptor well"; but in these calculations, the marginal increment over background wells is given. Parallel estimates were also developed for the Monitor Wells (Gross) and (Net). (Net) values are smaller than or equal to the (Gross) values; (Gross) and (Net) estimates are equal only when the contaminant was not detected in the background monitoring wells.

Concentration data for the calculations were abstracted from the Remedial Action Plans and Environmental Assessments for the four sites and from supplemental data provided by the Uranium Mill-tailings Project Office in Albuquerque, New Mexico. At each site, concentration data were compiled separately for each aquifer.

Calculated intake levels were then compared with defined AIS, AIC and Potency Factors to evaluate hazards presented by these materials. For the noncarcinogenic chemicals, a comparison was also made to current and proposed drinking water standards (See Appendix B). For the carcinogens lifetime cancer risks were calculated corresponding to drinking water standards. The compiled data and analyses for each site are given below. The data and analyses presented are all based on the maximum concentration for each pollutant in monitor and receptor wells.

3.1 Gunnison, Colorado

3.1.1 Ground Water Geology, Flow and Water Quality

The mill-tailings site at Gunnison, Colorado (Figure 1) overlies alluvial deposits produced by the confluence of the Gunnison and Tomichi Rivers. The general flow direction in the alluvium at Gunnison is south south-west. Anisotropies caused by buried stream channels may divert some flow from the general direction. No confining layer was detected during well drilling, but the existence of a semi-confining layer composed of silt and clay lenses is suspected based on the results of pump tests. High concentrations of contaminants are more common in shallow than deeper wells. This analysis treated the system impacted by the tailings pile as a single aquifer because the available data did not clearly differentiate between shallow and deep ground water zones.

Most of the native ground water in the area is potable. There is a reducing zone along the river that contains high levels of hydrogen sulfide. There are high concentrations of iron in the alluvial aquifer. High concentrations of nitrate near the pile probably result from a nearby sewage-treatment plant. Tailings-pore water from the Gunnison site contains high concentrations of uranium, sulfate, iron and heavy metals. A defined plume of sulfate and uranium has migrated from the pile and is impacting monitoring and domestic wells in the area.

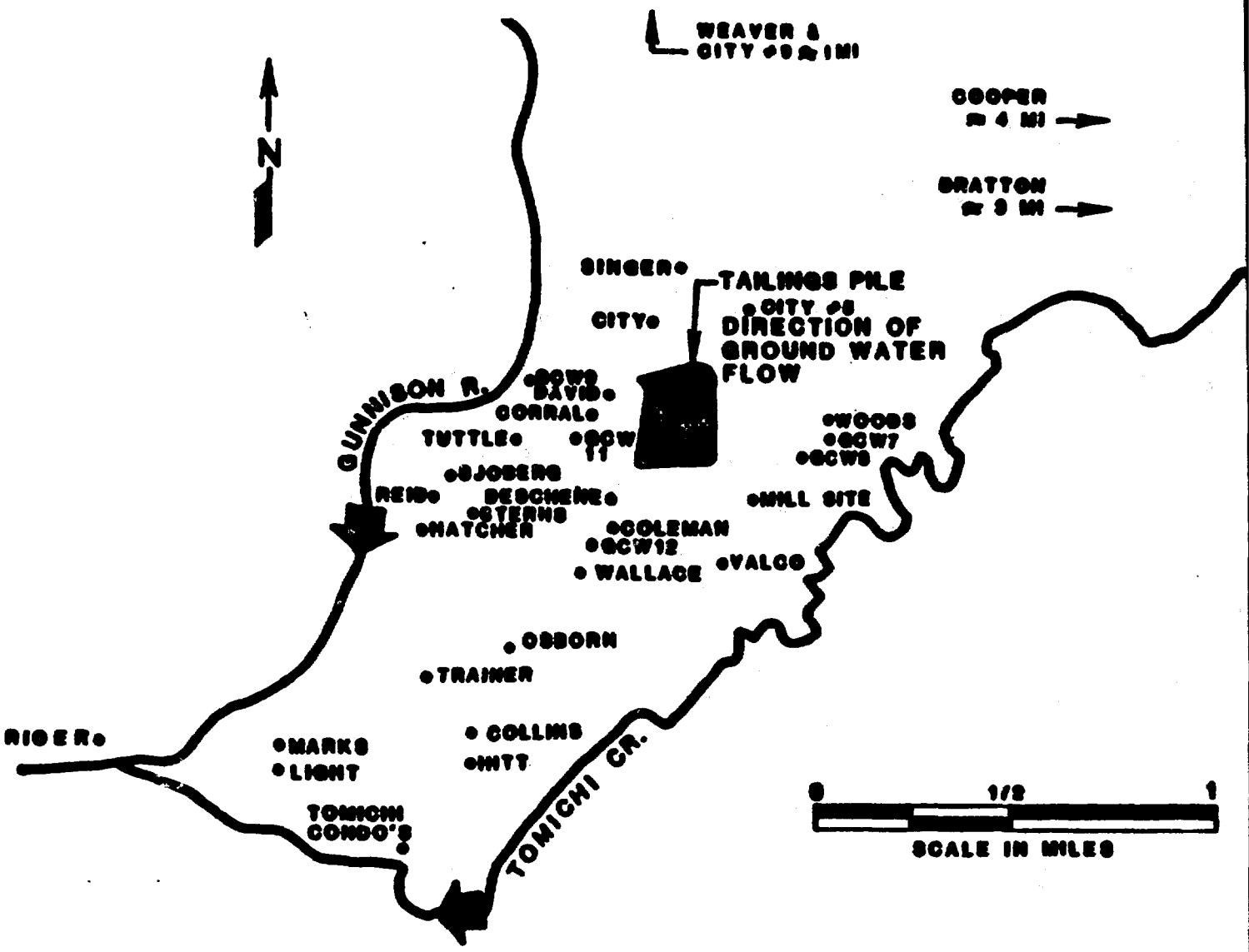

Figure 1. Mill-Tailings Site at Gunnison, Colorado.
(Domestic Wells Sampled; modified from DOE, 1984)

3.1.2 Water Use

Ground water is the major source of drinking water in the Gunnison area. The City of Gunnison has nine wells in the alluvial system. All of these wells are located upgradient of the tailings pile. Domestic wells are in the alluvium along the river. There are approximately 80 private, domestic wells downgradient of the tailings pile.

3.1.3 Risk Assessment

Appendix C presents compiled concentration data, ratios and risk estimates for monitor and receptor wells at Gunnison. At this site concentrations above detectable limits were measured at either receptor or monitor wells for all pollutants except cadmium and polonium. Concentrations of most pollutants were greater at monitor wells than at receptor wells. Minimum background concentrations for all measured pollutants, except sulfate and uranium, were below detectable levels.

Chronic/Subchronic Ratios and Drinking Water Standards - Only arsenic exceeded the ratio of 1.0 for AIS's (2.9 in the maximum monitor well). For the AIC's, the maximum monitor wells showed exceedances for arsenic (2.9), sulfate (2.3) and uranium (4.1). Molybdenum did not exceed the recommended ratio but was high in monitoring wells (1.0). The maximum receptor well for uranium exceeded the recommended ratio (7.1). Subtracting the minimum background concentrations detected from the maximum concentrations in monitor and receptor wells did not substantially change the calculated ratios.

Drinking water standards were exceeded in the maximum monitor wells for uranium and sulfate. The maximum receptor well exceeded drinking water standards for selenium and uranium. All other contaminants were below drinking water standards in receptor and monitor wells.

Cancer Risk Estimates - Based on a lifetime cancer risk of 1×10^{-6}, the maximum monitor wells at Gunnison are potentially of concern for arsenic (1.7×10^{-2}), radium 226+228 (3.6×10^{-5}, ICRP estimate) and uranium (7.4×10^{-5}, ICRP). These contaminants are also flagged using the less conservative risk level of 1×10^{-5}. The risk estimates calculated using drinking water standards are exceeded only for uranium.

For the maximum receptor wells, the 1×10^{-6} risk level is exceeded for lead-210 (1.1×10^{-4}, ICRP), radium 226+228 (4.4×10^{-6}), thorium-230 (3.0×10^{-6}, ICRP) and uranium (1.3×10^{-4}, ICRP). Compared to the 1×10^{-5} risk level, only lead-210 and uranium show exceedances in maximally contaminated receptor wells. The risk estimates based on drinking water standards were exceeded for uranium in monitor and receptor wells.

Subtracting the minimum background concentrations did not appreciably change the lifetime cancer risk estimates.

3.1.4 Summary

Contaminants exceeding the ratio of 1.0 and risk levels of 1×10^{-6} are arsenic, sulfate, uranium, and radium 226+228 in monitor wells, and uranium, lead-210, radium 226+228 and thorium-230 in receptor wells. For chronic and subchronic effects, contaminants flagged as exceeding both the ratio of 1.0 and the current or proposed drinking water standards include sulfate and uranium in monitor wells and uranium in receptor wells. For cancer, contaminants flagged as exceeding a lifetime risk estimate of 1×10^{-6} and the risk estimate based on drinking water standards include only uranium in receptor and monitor wells.

At Gunnison, the tailings pile has created a well defined plume of sulfate and uranium. Other contaminants flagged as exceeding standards, ratios and risk levels may come from the mill-tailings pile, but in less obvious patterns. These contaminants will require further investigation of concentration distributions to develop a reasonable estimate of exposure. A number of the contaminants flagged using this conservative approach may not show exceedances when more realistic estimates of background concentrations are used in the analysis.

The aquifer at Gunnison downgradient of the tailings site is used for drinking water. No municipal wells have been affected or are threatened by contamination from the tailings pile. However, approximately 80 private domestic wells have been or have the potential of being affected, primarily by elevated levels of uranium.

3.2 Lakeview, Oregon

3.2.1 Ground Water Geology, Flow and Water Quality

Ground water at the Lakeview mill-tailings site (Figure 2) is under unconfined to confined conditions. The ground water can be characterized as a multiple aquifer system with a general flow from the northeast to the southwest. A succession of leaky aquifers are separated by aquitards of varying thickness and lateral extent. Within the first 100 feet, ground water is under unconfined to semi-confined conditions within the unconsolidated deposits. Two ground water zones were investigated. The shallow zone is above 30 feet, and the deeper zone at 60-70 feet. There is a small potential for the downward migration of water from the shallow to the deeper zone. The site lies within a Known Geothermal Resource Area (KGRA) and a number of geothermal anomalies were observed.

Two different background geochemical facies exist at the Lakeview site; they interact differently with the seepage from the tailings pile and evaporation ponds. Low temperature background water has low or below detectable concentrations of most contaminants. The mill-tailings pile (and evaporation ponds) have caused a plume of sulfate in the shallow ground water. Sulfate downgradient of the site comes from the tailings pile (and evaporation ponds) and

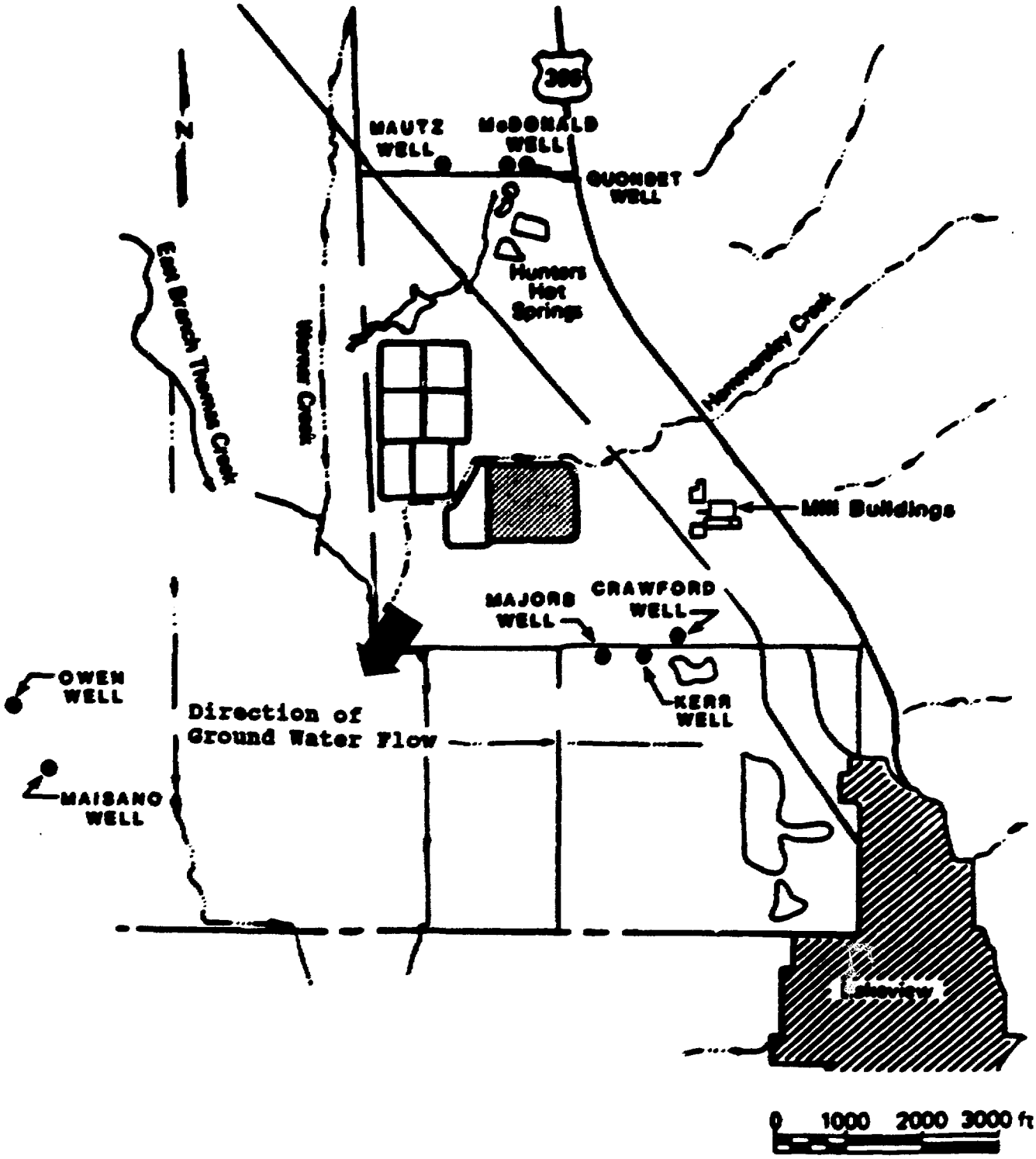

Figure 2. Mill-Tailings Site at Lakeview, Oregon.
(Offsite Well Locations; modified from DOE, 1985)

geothermal water. Geothermal background water is high in arsenic and sulfate. No sampled domestic wells have been affected, primarily because they are screened at depths of 100-300 feet.

3.2.2 Water Use

Ground water is the main source of drinking water in the Lakeview area. The city of Lakeview operates 12 municipal wells. These are completed at depths of 350 to 2050 feet and are located more than one mile south of the mill-tailings site. There are 97 registered wells within a 2-mile radius of the Lakeview site. Twelve of these are drilled above 50 feet, and all but one of these shallow wells is located more than 0.5 miles south of the site. Most wells in the area are drilled to a depth of 100-300 feet, and are used for domestic, stock and irrigation purposes. There are approximately 20 to 40 domestic wells in the sections adjacent to and downgradient of the Lakeview site.

3.2.3 Risk Assessment

Appendix C presents concentration data and risk estimates for shallow and deep ground water zones at Lakeview. There were no samples from shallow receptor wells downgradient of the Lakeview site.

At this site two ground water zones were investigated. In the shallow offsite monitor wells, concentrations above detectable limits were observed for all measured pollutants except lead and selenium. In contrast, in the deep zone only arsenic, nitrate and vanadium were detected in the maximum receptor wells. In the monitor wells, however, the situation reversed. All chemicals except lead, selenium and vanadium were found.

Chronic/Subchronic Risk and Drinking Water Standards - In the maximally contaminated shallow monitor wells, ratios for the AIS and AIC which exceeded the ratio of 1.0 included arsenic (7.1, 7.1), cadmium (2.6, 11), molybdenum (not applicable, 6.2) and sulfate (not applicable, 7.9). In maximum deep monitor wells, the AIS ratio of 1.0 was exceeded for arsenic (1.4). The ratio for AIC's was exceeded in deep monitor wells for arsenic (1.4), cadmium (2.1) and molybdenum (1.4). No receptor wells exceeded the 1.0 ratio for any contaminants. Subtraction of the minimum background concentrations for each contaminant did not affect the calculated ratios.

Drinking water standards were exceeded in shallow monitor wells for arsenic, cadmium, molybdenum and sulfate. Concentrations in maximum deep monitor wells exceeded the standards for sulfate. Concentrations of all contaminants studied were below drinking water standards for deep receptor wells.

Cancer Risk Estimates - For several chemicals, concentrations indicated a lifetime risk level exceeding 1×10^{-6} in the shallow monitor wells at Lakeview: arsenic (4.3×10^{-2}), polonium-210 (9.6×10^{-5}), radium 226+228 (2.3×10^{-5}, ICRP), thorium-230 (5.4×10^{-6}, ICRP), and uranium (3.2×10^{-6}, ICRP). A risk level of 1×10^{-5} was exceeded for arsenic, polonium-210,

and radium 226+228 in the shallow zone. The risk estimates based on drinking water standards are exceeded only for arsenic in shallow monitor wells.

Deep monitor wells at Lakeview exceed the 1 x 10^{-6} risk level for arsenic (8.6 x 10^{-3}), polonium-210 (4.6 x 10^{-5}), radium 226+228 (2.3 x 10^{-5}, ICRP), thorium-230 (1.1 x 10^{-5}, ICRP) and uranium (1.4 x 10^{-6}, ICRP). A risk level of 1 x 10^{-5} was exceeded for arsenic, polonium-210, radium 226+228 and thorium-230 in deep monitor wells. Deep receptor wells exceed the 1 x 10^{-6} risk level only for arsenic (4.7 x 10^{-3}). The risk estimates based on drinking water standards are not exceeded for any deep wells at Lakeview. The risk estimates are not appreciably affected by subtraction of the minimum background concentrations.

3.2.4 Summary

Contaminants exceeding the ratio of 1.0 for AIC or AIS and/or the 1 x 10^{-6} risk level for cancer include arsenic, cadmium, molybdenum, sulfate, uranium, polonium-210, radium 226+228 and thorium-230 in shallow monitor wells, and arsenic, cadmium, molybdenum, uranium, polonium-210, radium 226+228, and thorium-230 in deep monitor wells. Receptor wells exceeded the 1 x 10^{-6} risk level for arsenic .

For chronic and subchronic effects, contaminants flagged as exceeding both the drinking water standard and the 1.0 ratio include arsenic, cadmium, molybdenum, and sulfate in shallow monitors, and no contaminants in deep monitors or receptors. For cancer risk, only arsenic in shallow monitor wells exceeds the risk estimates based on drinking water standards and a lifetime risk estimate of 1 x 10^{-6}.

At Lakeview, the tailings pile has created a plume of sulfate in the ground water downgradient of the site. The sulfate detected in the monitoring wells has two sources - the mill-tailings pile (and evaporation ponds), and the background geothermal water. Elevated arsenic levels in shallow monitor wells may be wholly or partially due to the influence of the geothermal background water in the area. The other contaminants of potential concern may originate in the tailings pile, but a more detailed study of their distribution in background and impacted wells is needed to better estimate exposure. A number of the contaminants identified as being of concern in this conservative assessment may not show exceedances when more realistic estimates of background concentrations are used.

Contamination from the tailings pile is largely restricted to a shallow zone of less than 50 feet. No receptor wells have been impacted because the shallow zone is not used as a source of drinking water in the Lakeview area. Most domestic wells are screened at depths of 100 to 300 feet, and municipal wells at depths of 350 to 2050 feet.

3.3 Monument Valley, Arizona

3.3.1 Ground Water Geology, Flow and Water Quality

The mill-tailings site at Monument Valley, Arizona (Figure 3) overlies three aquifers. The uppermost aquifer consists of alluvium and dune sand. The Shinarump Member of the Chinle Formation underlies the alluvium. An aquitard separates the Shinarump from the deeper aquifer system, the DeChelly Sandstone. All three aquifers flow to the north. There is an upward hydraulic gradient from the DeChelly aquifer into the Shinarump and alluvial systems. This suggests that there is no force driving contaminated ground water down into the deeper aquifer.

Lysimeter samples from the tailings piles and an evaporation pond contain elevated concentrations of sulfate, nitrate, radium-226, uranium and vanadium. Soil and pore water extracts from the piles contain elevated levels of arsenic, cadmium, sulfate, uranium and vanadium.

Seepage from the tailings piles and evaporation pond has impacted ground water downgradient of the site. Plumes of sulfate, nitrate and uranium were identified in the alluvial system. The Shinarump and DeChelly aquifers have each shown elevated concentrations of contaminants in one well. For the most part, the deeper aquifers downgradient of the pile have not been affected.

3.3.2 Water Use

The area around Monument Valley is sparsely populated and there are no municipal wells tapping the aquifers. Some shallow domestic wells tap the alluvium upgradient of the tailings site, although these sometimes dry up. There are no residences within one mile downgradient of the site. Some residences 2.5 miles north of the site haul their water from 6 miles north. A residence three miles downgradient uses ground water for drinking water purposes. No existing water supplies appear to have been affected by the mill-tailings site.

3.3.3 Risk Assessment

Appendix C presents compiled concentration data and risk estimates for this site. There are no samples for receptor wells in any of the three aquifers near the Monument Valley site.

In the maximally contaminated wells the concentrations of all pollutants exceeded detection limits, except for selenium which was not detected in any of the three aquifers. In general, chemical concentrations in the sampled wells increased in the following way; DeChelly, Shinarump and Alluvium.

Chronic/Subchronic Ratios and Drinking Water Standards - In the alluvial monitor wells, the AIS ratio of 1.0 was exceeded for arsenic (1.1), cadmium (2.6), nitrate (36) and vanadium

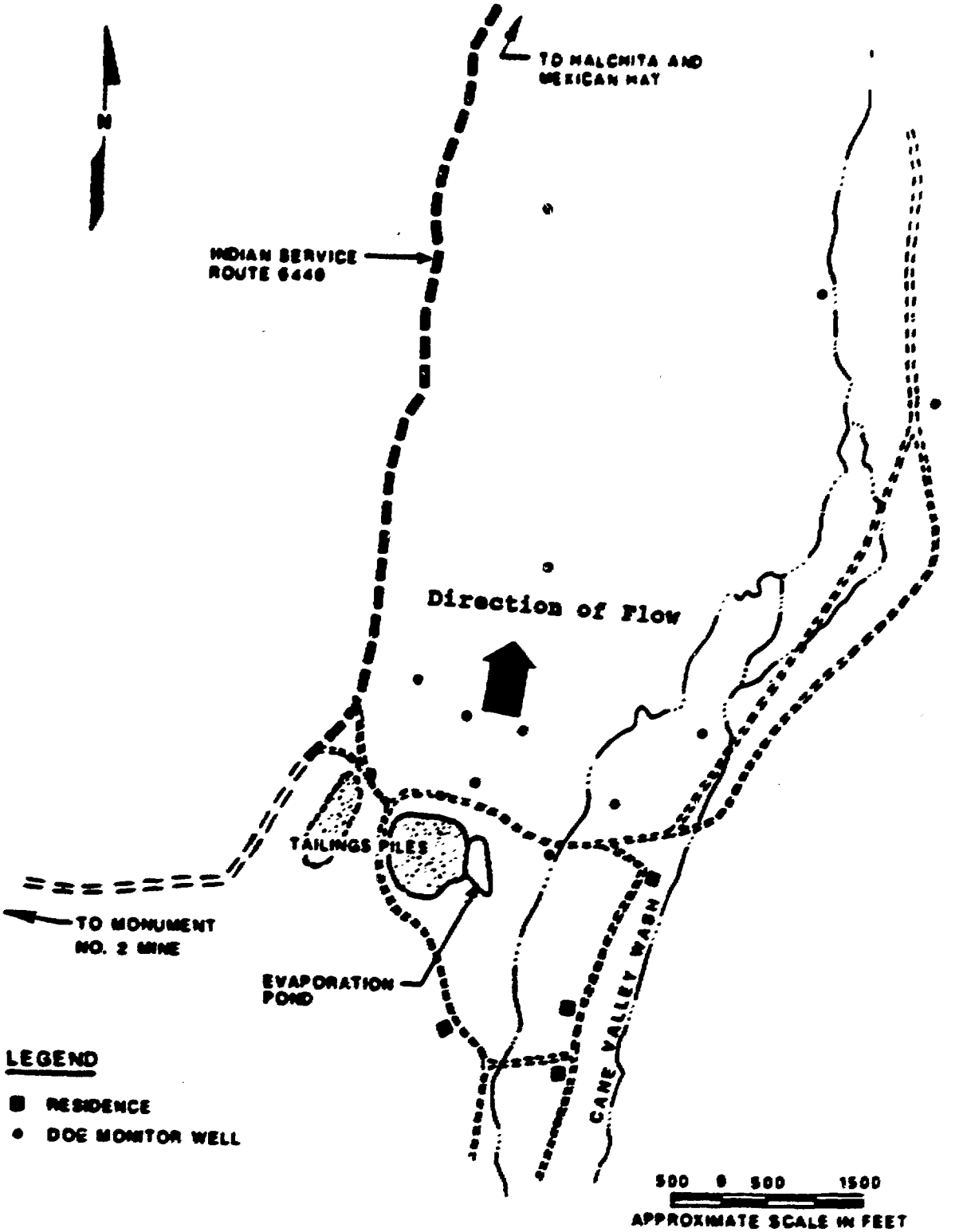

Figure 3. Mill-Tailings Site at Monument Valley, Arizona.
(Monitor Wells and Residences; modified from DOE, 1986)

(8.0). AIC ratios were exceeded in the alluvium for arsenic (1.1), cadmium (11), molybdenum (12.1), nitrate (36), sulfate (7.4), uranium (2.0), and vanadium (1.1).

Shinarump monitor wells exceeded the AIS ratios for vanadium (7.0) and the AIC ratio for cadmium (1.4), molybdenum (8.6), uranium (1.9) and vanadium (1.1). Monitor wells in the DeChelly aquifer exceeded the AIS ratio for vanadium (6.0), and the AIC ratio for molybdenum (9.0) and uranium (3.0). Subtraction of the minimum background concentrations measured for each aquifer did not appreciably change the calculated ratios.

Drinking water standards were exceeded in the maximum alluvial monitoring wells for cadmium, chromium, molybdenum, nitrate, selenium and sulfate. Monitor wells in the Shinarump aquifer exceeded drinking water standards for chromium, molybdenum and sulfate. Drinking water standards were exceeded for chromium, molybdenum and uranium in DeChelly monitor wells.

Cancer Risk - A lifetime risk estimate of 1×10^{-6} was exceeded in the alluvium at Monument Valley for arsenic (6.86×10^{-3}), lead-210 (5.9×10^{-5}, ICRP), polonium-210 (2.0×10^{-5}), radium 226+228 (1.7×10^{-5}), thorium-230 (2.7×10^{-6},ICRP), and uranium (3.7×10^{-5},ICRP). A 1×10^{-5} risk level was exceeded for arsenic, lead-210, polonium-210, radium 226+228 and uranium. No contaminants in alluvial monitor wells exceeded risk estimates based on drinking water standards.

In monitor wells screened in the Shinarump aquifer, the 1×10^{-6} risk level was exceeded for arsenic (2.1×10^{-3}), lead-210 (9.1×10^{-5}, ICRP), polonium-210 (3.2×10^{-6}), thorium-230 (3.7×10^{-6}, ICRP) and uranium (3.4×10^{-5}, ICRP). A 1×10^{-5} risk level was exceeded for arsenic, lead-210, radium 226&228 and uranium. None of the risk estimates based on drinking water standards are exceeded in maximally contaminated monitor wells in the Shinarump aquifer.

A risk level of 1×10^{-6} is exceeded for monitor wells tapping the DeChelly aquifer for arsenic (8.6×10^{-4}), lead-210 (5.5×10^{-5}, ICRP), polonium-210 (4.2×10^{-6}), radium 226+228 (1.3×10^{-5}), thorium-230 (1.7×10^{-6}, ICRP) and uranium (5.5×10^{-5}, ICRP). A 1×10^{-5} risk level is exceeded for arsenic, lead-210, radium 226+228 and uranium. Risk estimates based on drinking water standards are exceeded for uranium in DeChelly monitor wells.

Subtraction of minimum background concentrations in each aquifer did not change the risk estimates.

3.3.4 Summary

Contaminants exceeding the ratio of 1.0 for AIS and AIC's and/or the 1×10^{-6} risk level for cancer include: arsenic, cadmium, molybdenum, nitrate, sulfate, uranium, vanadium, lead-210, polonium-210, radium 226+228 and thorium-230 in the alluvium; cadmium, molybdenum, uranium, vanadium, arsenic, lead-210, polonium-210, radium 226+228 and thorium-230 in the

Shinarump; and molybdenum, uranium, vanadium, arsenic, lead-210, polonium-210, radium 226+228 and thorium-230 in the DeChelly.

For chronic and subchronic effects, contaminants flagged as exceeding both the drinking water standard and the 1.0 AIS or AIC ratio include cadmium, molybdenum, nitrate and sulfate in the alluvium, molybdenum in the Shinarump, and molybdenum and uranium in the DeChelly. For cancer risk, uranium in the maximally contaminated alluvial and DeChelly monitor wells exceeded both the 1×10^{-6} risk level and the risk level based on drinking water standards.

The tailings pile at Monument Valley has created a defined plume of nitrate, sulfate and uranium in the alluvial system. Other contaminants detected in alluvial monitor wells may be coming from the tailings pile, but the distribution of concentrations in background and impacted wells must be considered in order to develop a reasonable exposure estimate. A number of the contaminants flagged using this approach may not show exceedances when more realistic background concentrations are used in the analyses.

For the most part, the Shinarump and DeChelly aquifers have not been affected by the mill-tailings site. The elevated concentrations which cause the exceedances described above are in one or a few wells in the Shinarump and DeChelly, and do not reflect the general water quality in the deeper aquifers.

There are no municipal wells near Monument Valley. There are several shallow domestic wells upgradient of the site, and one three miles downgradient. No receptor wells were affected by the mill-tailings pile at Monument Valley.

3.4 Riverton, Wyoming

3.4.1 Ground Water Geology, Flow and Water Quality

Ground water in the Riverton area (Figure 4) is under unconfined and confined conditions. The unconfined system is in alluvial deposits and the uppermost sandstone beds of the Wind River Formation. The confined system is in the deeper sandstone beds of the Wind River Formation.

The flow direction in the alluvium is predominantly south to east, toward the Little Wind River. The local gradient in the confined system appears to correspond to that in the unconfined system.

The extent to which the unconfined and confined aquifers are hydraulically connected is not clear. In general, interbedded shale, siltstone and claystone confine the ground water in the sandstone beds and tend to restrict contaminant migration. There is, however, a downward vertical hydraulic gradient indicating the potential for downward flow.

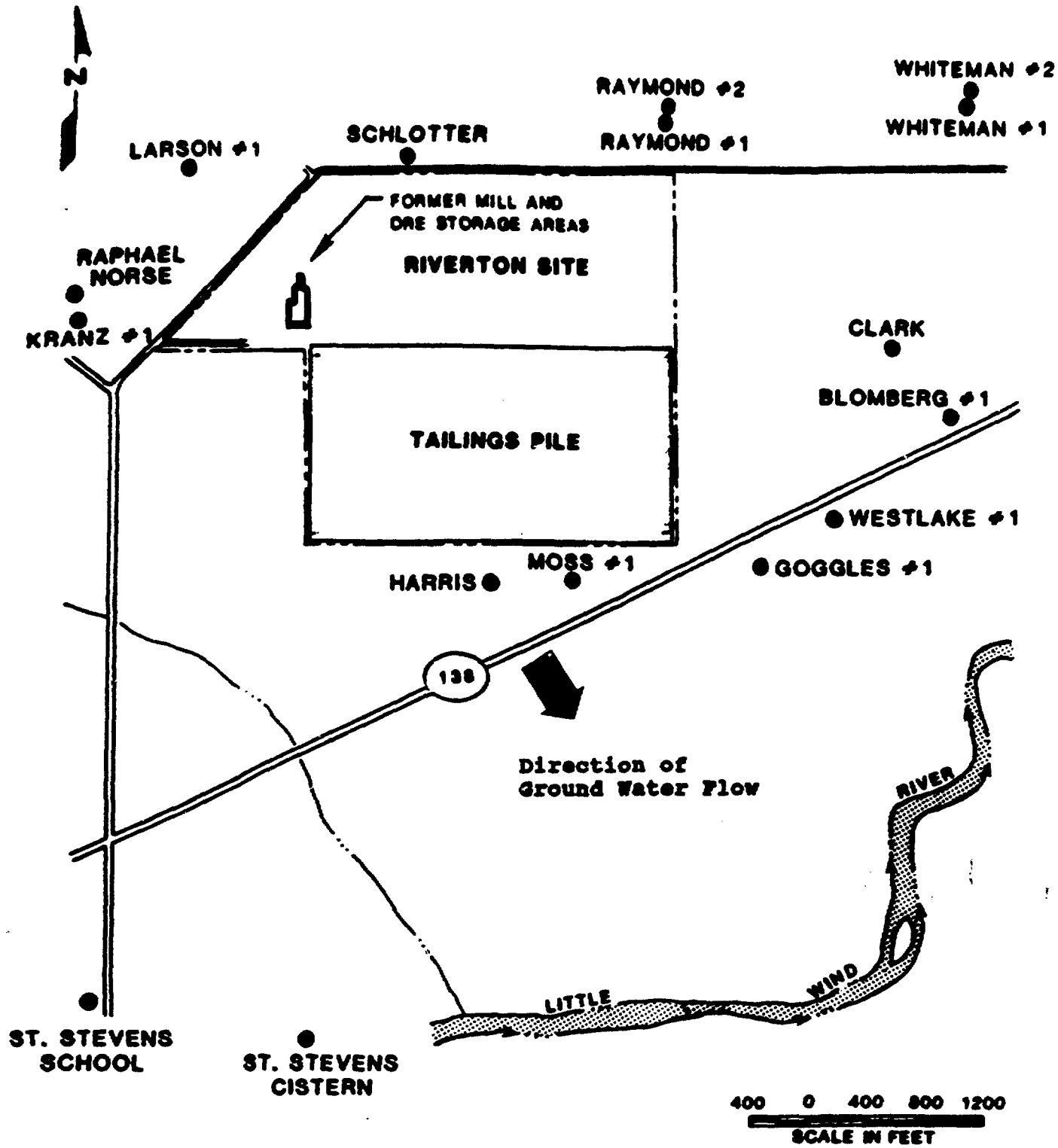

Figure 4. Mill-Tailings Site at Riverton, Wyoming
(Domestic Wells Sampled by DOE; modified from DOE, 1987)

Sulfate, molybdenum, uranium and other contaminants have moved from the tailings pile into the unconfined aquifer. There is also some evidence that the confined aquifer has been contaminated by water in the unconfined system. Contamination from the tailings pile is, however, largely restricted to the unconfined aquifer.

3.4.2 Water Use

Ground water from the unconfined aquifer is not the primary source for domestic, municipal or industrial use in the area because of poor quality and low quantity. Development of the unconfined aquifer is limited to areas upgradient of the site, and the water is used for irrigation and stock watering.

Because the unconfined aquifer has limited use the data used in this assessment is from monitoring wells only. No data are available for actual uses of the unconfined aquifer downgradient of the tailings pile.

The confined aquifer is the primary source of water in the Riverton area. There are a number of domestic wells downgradient of the mill-tailings site, and available data from these domestic wells are included in this assessment.

3.4.3 Risk Assessment

Appendix C gives the compiled concentration data and risk estimates for this site. In the monitor and receptor wells measured concentrations of all chemicals, except for cadmium in the confined receptor wells, exceeded the detection limits. In contrast, only lead, sulfate and thorium were measured in detectable concentrations in the confined background wells. Similarly, all chemicals, except chromium, were present in the maximum unconfined background wells.

Chronic/Subchronic Ratios and Drinking Water Standards - In the unconfined monitor wells, the AIS ratio of 1.0 was exceeded for selenium (1.1) and arsenic (1.4). AIC ratios were exceeded in maximum unconfined monitor wells for arsenic (1.4), cadmium (2.2), molybdenum (27.6), sulfate (15.0), selenium (1.2) and uranium (135.3).

In the confined aquifer, no monitor or receptor wells exceed the AIS ratio of 1.0 for any contaminant. Maximum confined monitors exceed the AIC ratio for molybdenum (5.5) and sulfate (3.3). Confined receptor wells exceed the AIC ratio for molybdenum (1.4), sulfate (1.7) and uranium (13.9).

Drinking water standards were exceeded in unconfined monitor wells for molybdenum, selenium, sulfate and uranium. Confined monitors exceeded drinking water standards for molybdenum, selenium and sulfate. Confined receptor wells exceeded drinking water standards for sulfate and uranium. Again, the risk estimates do not change in any large way from the addition or subtraction of the minimum background concentrations.

Cancer Risk - Maximally contaminated monitor wells screened in the unconfined aquifer at Riverton exceeded the 1 x 10^{-6} risk level for arsenic (8.6 x 10^{-3}), lead-210 (6.5 x 10^{-5}, ICRP), radium 226+228 (1.8 x 10^{-6}), thorium-230 (4.4 x 10^{-5}, ICRP) and uranium (2.6 x 10^{-3}, ICRP). A 1 x 10^{-5} risk level is exceeded for arsenic, lead-210, thorium-230 and uranium. In unconfined monitor wells risk levels based on drinking water standards are exceeded only for uranium.

In monitor wells tapping the confined aquifer at Riverton, the 1 x 10^{-6} risk level is exceeded for arsenic (2.6 x 10^{-3}), lead-210 (3.9 x 10^{-5}, ICRP), radium 226+228 (1.5 x 10^{-5}) and uranium (7.1 x 10^{-6}, ICRP). The 1 x 10^{-5} risk level is exceeded for arsenic, lead-210, and radium 226+228. In confined monitor wells none of the contaminants exceed risk levels based on drinking water standards.

Confined receptor wells exceed the 1 x 10^{-6} risk level for lead-210 (5.9 x 10^{-5}, ICRP), radium 226+228 (1.1 x 10^{-5}) and uranium (2.5 x 10^{-4}, ICRP). The 1 x 10^{-5} risk level is exceeded for lead-210, radium 226+228 and uranium. In confined monitor wells uranium exceeded risk levels based on drinking water standards.

3.4.4 Summary

Contaminants exceeding the recommended ratio of 1.0 for chronic and or subchronic effects, and/or the 1 x 10^{-6} lifetime risk level for cancer include arsenic, cadmium, molybdenum, sulfate, selenium, uranium, lead-210, radium 226+228 and thorium-230 in unconfined monitor wells; molybdenum, sulfate, arsenic, lead-210, radium 226+228 and uranium in confined monitors, and molybdenum, sulfate, uranium, lead-210 and radium 226+228 in confined receptors.

For chronic and subchronic effects, contaminants which exceeded both the drinking water standard and the 1.0 ratio include molybdenum, selenium, sulfate and uranium in unconfined monitors, molybdenum and sulfate in confined monitors, and uranium and sulfate in confined receptors. For cancer risk, the 1 x 10^{-6} risk level and the risk level based on drinking water standards were exceeded for uranium in unconfined monitor wells and confined receptors.

The tailings pile at Riverton has created plumes of uranium, molybdenum and sulfate in the unconfined system. There is also evidence of contamination in some confined wells. Other contaminants also show exceedances in wells in both aquifers, and these elevated concentrations may be caused by the pile. Some of the contaminants flagged in this conservative assessment may not be of concern when a more detailed analysis of background concentrations is performed.

The unconfined aquifer has been contaminated by the tailings pile. There is limited use of the upper, unconfined aquifer at Riverton, and no receptor wells were sampled. The confined aquifer is largely unaffected. A receptor well in the confined aquifer shows exceedances for several contaminants, but this well may draw water from the unconfined and confined aquifers.

4 DISCUSSION

Tables 2 - 4 summarize "Maximum Estimated Subchronic Health Risks", "Maximum Estimated Chronic Health Risks" and the "Maximum Estimated Cancer Risks" for all sites, chemicals, and wells (monitor and receptor). In interpreting these data, one must keep in mind the conservative assumptions on which they are based.

The first conservatism is in the exposure assessment. Ideally, actual concentrations and sources of each contaminant would be known for each aquifer and well used for drinking water. Surrounding each tailings site are several monitoring and background wells. To estimate contributions of the mill-tailings site to contaminant levels in monitoring wells, concentrations of each contaminant in the background ground water must be subtracted from the concentration of that contaminant in downgradient monitoring wells. There is a wide distribution of concentrations for each contaminant.

In this analysis a worst case estimate of exposure was developed for each contaminant at each site. The maximum concentration detected in monitor and receptor wells for each contaminant was used. Use of the maximum value is conservative because most ground water wells have lower concentrations. Using monitor wells is conservative because they are deliberately placed to intercept contaminated water, are usually closer to the site, and are often screened at shallower depths than receptor wells.

The analysis also took the conservative path of maximizing the calculated net contribution of the piles to ground water by subtracting the lowest background well measurement from the highest receptor or monitor well measurement. The difference between upgradient and downgradient wells is only a crude estimate of the contribution of the mill-tailings in any event. In some cases, there are factors which clearly distort downgradient-upgradient differences, e.g., the geothermal water high in arsenic and sulfate at Lakeview, Oregon. Even where downgradient-upgradient differences represent a reasonable way to estimate the contribution of the tailings piles, this conservative method of calculation clearly overestimates exposure. In fact, since the lower limit of detection varies among measurements, there are often measurements below the limit of detection, conservatively taken as zero. Thus, the net exposure is virtually always equal to the gross exposure.

The dose-response process also includes several conservatisms. In constructing an algorithm to predict the response of human populations to various levels of contaminants, clinical, controlled experimental, and epidemiological data describing the response of humans to the concentrations to which they are expected to be exposed would ideally be available. Such

Table 2. Maximum Estimated Subchronic Ratios[1]

Site/Aquifer	As	Cd	Cr	Mo	NO3	Se	SO4	U	V
Gunnison, CO									
Monitor/Alluvial	2.9	0	0	NA	0.8	0	NA*	NA*	0
Receptor/Alluvial	0	0	0	NA	0.1	0.2*	NA	NA*	0.1
Lakeview, OR									
Monitor/Shallow	7.1*	2.6*	0	NA*	0.4	0	NA*	NA	0.2
Receptor/Shallow	--	--	--	--	--	--	--	--	--
Monitor/Deep	1.4	0.5	0.1	NA	0	0	NA*	NA	0
Receptor/Deep	0.8	0	0	NA	0.1	0	NA	NA	0.4
Monument Valley, AZ									
Monitor/Alluvial	1.1	2.6*	0.1*	NA*	36.4*	0.1*	NA*	NA	**8**
Receptor/Alluvial	--	--	--	--	--	--	--	--	--
Monitor/Shinarump	0.4	0.3	0.1*	NA*	0.9	0	NA*	NA	**7**
Receptor/Shinarump	--	--	--	--	--	--	--	--	--
Monitor/DeChelly	0.1	0.3	0.1*	NA*	0.2	0	NA*	NA	**6**
Receptor/DeChelly	--	--	--	--	--	--	--	--	--
Riverton, WY									
Monitor/Unconfined	1.4	0.5	0	NA*	0.2	1.1*	NA*	NA*	0.1
Receptor/Unconfined	--	--	--		--	--	--	--	--
Monitor/Confined	0.4	0	0	NA*	0.7	0.1*	NA*	NA	0.6
Receptor/Confined	0	0	0	NA	0.5	0	NA*	NA*	0

[1] Ratios in bold exceed 1.0

NA Not applicable

-- No sample

* Drinking water standard exceeded

Table 3. Maximum Estimated Chronic Ratios[1]

Site/Aquifer	As	Cd	Cr	Mo	NO3	Se	SO4	U	V
Gunnison, CO									
Monitor/Alluvial	2.9	0	0.1	1	0.8	0	**2.3***	**4.1***	0
Receptor/Alluvial	0	0	0	0.1	0.1	**0.2***	0.5	**7.1***	0
Lakeview, OR									
Monitor/Shallow	**7.1***	**10.7***	0.2	**6.2***	0.3	0	**7.9***	0.2	0
Receptor/Shallow	--	--	--	--	--	--	--	--	--
Monitor/Deep	1.4	2.1	0.3	1.4	0	0	**0.8***	0.1	0
Receptor/Deep	0.8	0	0	0	0.1	0	0	0	0.1
Monument Valley, AZ									
Monitor/Alluvial	1.1	**10.7***	**0.5***	**12.1***	**36.3***	**0.2***	**7.4***	2	1.1
Receptor/Alluvial	--	--	--	--	--	--	--	--	--
Monitor/Shinarump	0.4	1.4	**0.4***	**8.6***	0.9	0	**0.6***	**1.9**	1.1
Receptor/Shinarump	--	--	--	--	--	--	--	--	--
Monitor/DeChelly	0.1	1	**0.3***	**9***	0.2	0	0.2	**3***	0.9
Receptor/DeChelly	--	--	--	--	--	--	--	--	--
Riverton, WY									
Monitor/Unconfined	1.4	2.2	0.2	**27.6***	0.2	**1.2***	**15***	**135.3***	0
Receptor/Unconfined	--	--	--	--	--	--	--	--	--
Monitor/Confined	0.4	0	0.2	**5.5***	0.7	**0.1***	**3.3***	0.4	0.1
Receptor/Confined	0	0	0	**1.4**	0.5	0	**1.7***	**13.9***	0

[1] Ratios in bold exceed 1.0

-- No sample

* Drinking water standard exceeded

Table 4. Maximum Estimated Cancer Risks[1]

Site/Aquifer	As	Pb-210	Po-210	Ra 226&228	Th-230	U
Gunnison, CO						
Monitor/Alluvial	1.7E-02	0.0E+00	--	3.6E-05	0.0E+00	7.4E-05*
Receptor/Alluvial	--	1.1E-04	--	4.4E-06	3.0E-06	1.3E-04*
Lakeview, OR						
Monitor/Shallow	4.3E-02*	0.0E+00	9.6E-05	2.3E-05	5.4E-06	3.2E-06
Receptor/Shallow	--	--	--	--	--	--
Monitor/Deep	8.6E-03	0.0E+00	4.6E-05	2.3E-05	1.1E-05	1.4E-06
Receptor/Deep	4.7E-03	0.0E+00	0.0E+00	0.0E+00	0.0E+00	0.0E+00
Monument Valley, AZ						
Monitor/Alluvial	6.9E-03	5.9E-05	2.0E-05	1.7E-05	2.7E-06	3.7E-05
Receptor/Alluvial	--	--	--	--	--	--
Monitor/Shinarump	2.1E-03	9.1E-05	3.2E-06	1.5E-05	3.7E-06	3.4E-05
Receptor/Shinarump	--	--	--	--	--	--
Monitor/DeChelly	8.6E-04	4.2E-06	4.2E-06	1.3E-05	1.7E-06	5.5E-05*
Receptor/DeChelly	--	--	--	--	--	--
Riverton, WY						
Monitor/Unconfined	8.6E-03	6.5E-05	--	1.8E-06	4.4E-05	2.5E-03*
Receptor/Unconfined	--	--	--	--	--	--
Monitor/Confined	2.6E-03	3.9E-05	0.0E+00	1.5E-05	6.7E-07	7.1E-06
Receptor/Confined	0.0E+00	5.9E-05	--	1.1E-05	1.4E-06	2.5E-04*
Calculated Risks[2]	2.1E-02	3.3E-03	7.4E-03	3.9E-05	NA	4.7E-05

[1] Lifetime cancer risk, maximum of EPA and ICRP estimate

[2] Risk estimates calculated using drinking water standards

* Exceeds risk estimates calculated using drinking water standards

-- No sample

NA Not available

information is rarely available; extrapolations to human health effects must often be based on limited data from animal studies.

It is important to discuss the method and implications of extrapolation from animal to man. This is done on the basis of rate of ingestion per unit body weight, i.e., (milligrams of chemical per day)/(kilogram body weight). This method of extrapolation is widely used in toxicology and medicine. There are disagreements over the precise scaling factor to be used. Some believe that the scaling factor should be in terms of body weight raised to the two-thirds power, for example. Whether this or simple body weight is the correct scaling factor cannot be determined in experiments comparing rats and mice, for example, but such a simple adjustment can make an order of magnitude difference when extrapolating from mouse to man. More importantly, advances made in the past decade in the science of pharmacokinetics enables these simple scaling factors to be replaced with physiologically based pharmacokinetic models when sufficient data are available. These take account of actual biological differences between two species in the metabolism and distribution of specific chemicals, substituting knowledge for arbitrary safety factors.

The AIS represents the highest human intake of a chemical that does not cause adverse effects in a short-term (10-90 days) exposure. The AIC represents the highest human intake of a chemical that does not cause adverse effects when exposure is long term, assumed to be chronic over a 70 year lifespan. The concept of an acceptable intake level is based on the assumption of a threshold effect. This is a commonly accepted biological theory; below a given dose level, a substance will have no effect on an individual, although this threshold level may vary among species and among individuals in the same species. The calculation of AIS and AIC values are designed to protect sensitive populations, with sensitivity depending on such diverse contaminant-dependent factors as age, sex, co-exposure to other pollutants, etc.

Although some AIS values are based on human studies, most are derived from short- term (10-90 day) animal studies. With chemicals lacking appropriate human data, the highest subchronic exposure level among animals causing no adverse effects, the no observed adverse effects level (NOAEL) is used. To extrapolate the animal NOAEL to a human AIS level, the NOAEL is divided by a safety factor, usually 10. To account for the fact that two individuals of the same species may not respond similarly to an identical exposure to a given chemical, the NOAEL is divided by an additional factor of 10. In general, an AIS is thus 100 times smaller than the highest concentration which had no observed adverse effect on animals. Thus, these calculations inherently assume that humans always are more responsive to chemicals than the studied animals.

For most chemicals, the AIC is also based on the NOAEL obtained from a survey of the animal toxicology literature. The chronic NOAEL is then reduced by the same two orders of

magnitude as the AIS. For some chemicals, chronic studies are not available. In this situation the subchronic NOAEL is divided by a third safety factor of 10 to compensate for the use of subchronic data to derive a chronic indicator of dose-response. In this case the value of the Acceptable Intake for Chronic Exposure may simply be 1/1000 of the highest no observable adverse effect level. Application of such safety factors in the absence of better data is conservative.

The risk characterization step compares exposure levels for each contaminant potentially derived from mill-tailings at each site in maximum concentration wells to acceptable limits (AIS or AIC). This risk characterization quotient is derived from two quantities designed to be conservative. This ratio addresses the degree of safety, and does not quantify risk in terms of expected probability of disease. A ratio of 1.1 does not mean the water will cause harm to someone drinking it, only that the margin of safety has been slightly reduced.

For carcinogenesis, regulatory agencies reject the use of effects thresholds. Instead, it is assumed that the dose-response function passes through zero, i.e., that even an incrementally small dose may produce an effect. Risk is estimated from potency factors which, unlike the AIS and AIC, can be used to estimate risk in terms of increased probability of disease.

EPA Interim Drinking Water Regulations for radionuclides are not based on limiting risk below a given level. Rather maximum concentrations reflect what was achievable, considering cost and feasibility. The regulations limit annual excess cancer mortality risk to less than 1.0×10^{-6} for each class of radionuclide (e.g., Ra-226 + Ra-226, natural uranium). This translates to an lifetime excess risk of about 7.0×10^{-5} for lifetime exposure at drinking water concentration standards. For example, the limit for man-made beta- and gamma-ray emitters in the Interim Drinking Water Standards is 4 mrem/y. If 285 excess cancer deaths per million rem is assumed, the excess lifetime risk will be 1.14×10^{-6} for one year of exposure averaged over the population, or 0.8×10^{-5} for a lifetime of exposure. This agrees with EPA's own calculation. Another example is the 5 pCi/l limit for Ra-226 and/or Ra-228. The lifetime excess risk for lifetime ingestion of 2 l/day at a concentration of 1 pCi/l is given by EPA as 8.8×10^{-6} and 6.6×10^{-6} for Ra-226 and Ra-228. The annual risk for 5 pCi/l is then about 0.55×10^{-6}.

5 CONCLUSIONS

The procedure used in this study was that outlined by the EPA in the Superfund Public Health Evaluation Manual. By its nature this approach overestimates the actual health risks. Because of the highly conservative assumptions used in the estimates of acceptable limits and potency factors, and with the highly conservative assumptions used in estimating dose, one may be

confident that contaminants which not present potential health risks in this screening analysis may be disregarded in future health risk evaluation for the studied UMTRA sites. On the other hand, chemicals identified in this screening analysis as presenting potential health risks may, in fact, be at levels that are still quite safe. Refined dose-response functions, exposure estimates, and demographic distributions are needed to analyze the potential health risks contributed by the contaminants which were not eliminated in this screening study.

6 RECOMMENDATIONS

Analyses conducted to-date are similar to those that would conducted by EPA. As noted, we consider this to be a screening-level analysis. Items identified in this initial screening step will undergo more detailed analysis to determine the accuracy of the calculated risk estimates and the benefits of different remediation options. Some approaches for evaluating the accuracy of the risk estimates are presented below.

Exposure Estimation - Current exposure estimates are based on the single highest reported concentration value in the receptor and monitor wells. Characterization of upgradient and downgradient pollutant concentrations can best be done by examining the full distribution of measurements, rather than their maximum or mean values. For each pollutant-aquifer combination which was calculated to pose a potential hazard, and for which no additional confounding sources are present that would invalidate an downgradient-upgradient difference as an estimate of the effect of the tailings pile, the full data set of measurements at each well should be determined. Wells within each class (background, monitoring, and receptor) should be grouped as necessary to form homogeneous groupings from which the groundwater pollutant concentrations for a specific geographical area can be characterized as a combined distribution. Exposure estimates will be developed differently for contaminants in a defined plume (often sulfate and uranium), and those not present in such an easily discernable pattern. The downgradient-upgradient difference can then be characterized as the difference of two or more distributions, using Monte Carlo or Latin Hypercube sampling techniques. This should allow the potential exposure (gross and net) to be estimated probabilistically. The results may then be expressed as a best estimate with an uncertainty range which is independent of any a priori assumptions of distribution, or as "conservative" estimates with any desired degree of conservatism.

In characterizing the distributions, special attention should be given to measurements that are below the limits of detection (LOD). The sensitivity of the results to these measurements can be determined by using selected case examples to make the calculation substituting either zero, half the LOD, or the LOD value itself as the measurement.

Dose-Response Estimation - Current critical toxicity values, are the for the most part, based on drinking water standards. The basis for these standards will be examined for excessive conservatism; and the uncertainty of the dose-response function estimated and combined with that of the exposure estimates. Alternative standards (e.g., World Health Organization Guidelines) will be identified and examined to determine their impacts on the critical values. All of the contaminants flagged as having potentially hazardous concentrations should be critically reviewed. As an example, a critical review of the EPA and ICRP cancer risk models used for setting drinking water concentration standards is presented in Appendix D.

Since carcinogen effects are estimated directly in increased risk, risk estimates from exposure to multiple carcinogens are considered additive; i.e., total risk = risk from chemical 1 + risk from chemical 2. This is an oversimplification; the actual combined effect will depend on the target organs of each carcinogen, the degree of interaction in metabolism and pharmacokinetics, the mechanism of carcinogenic effect, and the shape of the dose-response function. In most cases, too little will be known to carry this analysis of interaction very far, but some insights into the appropriateness of simply adding the risks may be gained from a review of the characteristics of the two contaminants and their interactions.

Noncarcinogen effects are based on threshold assumptions and expressed, not in quantitative risk, but in a ratio of exposure relative to a reference exposure level which includes safety factors. For noncarcinogens, the Manual recommends two steps: (1) simply add the intake ratios; if the result exceeds one there may be concern for a potential health risk. [Cumulative ratio = [(intake of chemical 1)/AIC1] + [(intake of chemical 2)/AIC2] + ... The different pollutants, however, may affect entirely different organ systems. Adding an exposure to a chemical which produces gastro-intestinal disease to an exposure to a teratogen adds to the overall kinds of potential effects possible, but if each is below the threshold of effect, no effect ever occurs. The additional exposure does not reduce the margin of safety for teratogenic effects at all, nor does the teratogen reduce the margin of safety for the gastrointestional effects. The second step recommended by the EPA manual, then, is to do the addition separately for each class of effect. A hazard potential is deemed to exist, then, if any one of the combined ratios exceeds one. Beyond this, however, other methods of combination might be considered instead of the simple addition of ratios, or additional biological information concerning the action of each contaminant in generating each class of effect might be considered in a more sophisticated model.

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APPENDIX A - Derivation of Dose-Response Coefficients: Acceptable Intake for Subchronic Exposure (AIS), the Acceptable Intake for Chronic Exposure (AIC), and Carcinogenic Potency Factor

SULFATE

Based on aesthetic effects, the current EPA secondary drinking water standard for sulfate is 250 mg/l. The World Health Organization has recommended a guideline level of sulfate in drinking water of 400 mg/l based on taste. Because of insufficient toxicology data, an Adjusted Acceptable Daily Intake (AADI) has not been calculated for sulfate. Likewise, primary drinking water regulations will not be promulgated by EPA at this time due to insufficient data on which to set a level for health protection.

In both animals and humans, soluble sulfate salts are absorbed from the intestine. Large doses are incompletely absorbed, have a cathartic effect and are continuously excreted in the urine. Diarrhea and dehydration are the only adverse health effects noted from exposure to high sulfate concentrations, and infants appear to be a more sensitive population than adults. Case histories which suggest that these adverse effects occur when infants consume formula made with well water containing more than 400 - 500 mg sulfate per liter of water have resulted in a guidance level of 400 mg/l sulfate for the protection of infants (USEPA, 1985).

An acceptable intake for chronic exposure (AIC) to sulfate in drinking water of 40 mg/kg/day was determined following the algorithms and examples for lead detailed in USEPA, 1986. The algorithm used to calculate the sulfate AIC is based on the 400 mg/l guidance level for infants (USEPA, 1985) and consumption of 1.0 liter water per day (NAS, 1977) by a standard 10 kg child (ICRP, 1975):

AIC = Guidance Level x 1 l/day / 10 kg;

AIC = 400. mg/l x 1 l/day / 10 kg;

AIC = 40. mg/kg/day for sulfate in drinking water.

REFERENCES

International Commission on Radiological Protection (ICRP). 1975. Report of the Task Group on Reference Man. New York: Pergammon Press.

National Academy of Science (NAS). 1977. Drinking Water and Health. NRC Press.

U.S. Environmental Protection Agency. 1985. National Primary Drinking Water Regulations; Synthetic Organic Chemicals, Inorganic Chemicals and Microorganisms; Proposed Rules. 50 FR 46936-47022 (Nov 13, 1985).

U.S. Environmental Protection Agency. 1986. Superfund Public Health Evaluation Manual. Washington, D.C.. EPA 540/1-86/060 (October, 1986).

MOLYBDENUM

An acceptable intake for chronic exposure (AIC) to molybdenum in drinking water of 0.0029 mg/kg/day was determined following the algorithms and examples for lead detailed in USEPA, 1986. For lead, the basis of the AIC calculation was the lead drinking water standard. Although a drinking water standard has not yet been proposed for molybdenum, a health advisory is currently under preparation (USEPA, 1985). EPA has, however, proposed a standard for molybdenum in ground water at uranium mill-tailing sites of 0.10 mg/l (USEPA, 1987) which is identical with the provisional Adjusted Acceptable Daily Intake (AADI) for molybdenum in drinking water developed by EPA under the Safe Drinking Water Act (USEPA, 1985). The proposed AADI is based on a human study (Chappell et al., 1979) in three communities (Denver, Breckenridge and Frisco) in which levels of plasma molybdenum remained within the normal range (5-34 ug Mo/l) among subjects consuming water not exceeding 0.2 mg Mo/l. The provisional AADI was determined by using the 0.2 mg/l as a no adverse effects level (NOAEL) and applying an uncertainty factor of 2, based on a human study with no noted adverse effects and consumption of 2 l/day. The authors of the report (Chappell et al., 1979) recommended a more conservative guideline of 0.05 mg/l. The algorithm used to calculate the molybdenum AIC assumed consumption of 2 liters water per day by a standard 70 kg man:

AIC = AADI x 2 l/day / 70 kg;

AIC = 0.10 mg/l x 2 l/day / 70 kg;

AIC =0.0029 mg/kg/day for molybdenum in drinking water.

REFERENCES

Chappell, W.R., R.R. Meglen, R. Moure-Eraso, C.C. Solomons, T.A. Tsongas, P.A. Walravens, and P.W. Winston. 1979. Human Health Effects of Molybdenum in Drinking Water. Cincinnati Ohio, EPA-600/1-79-006.

U.S. Environmental Protection Agency. 1985. National Primary Drinking Water Regulations; Synthetic Organic Chemicals, Inorganic Chemicals and Microorganisms; Proposed Rules. 50 FR 46936-47022 (Nov 13, 1985).

U.S. Environmental Protection Agency. 1986. Superfund Public Health Evaluation Manual. Washington, D.C.. EPA 540/1-86/060 (October, 1986).

U.S. Environmental Protection Agency. 1987. Standards for Remedial Actions at Inactive Uranium Processing Sites. 52 FR 36000-36008. (Sept 24, 1987).

VANADIUM

The algorithms used for calculating the two values are shown below. A long term study by Schroeder, et al. (1976) reported that no "inherent toxicity" was found "in terms of growth, survival, longevity, life span or pathological changes" in mice fed approximately 0.5 mg/kg/day vanadyl sulfate (0.43 mg/kg/day) from weaning until natural death. This is the highest chronic exposure published to date. The first algorithm, which introduces an animal-to-human safety factor of 100, generates the human AIC value of 0.005 mg/kg/day. This number agrees with a Soviet maximum intake limit based on a study done in 1961 (see Toxicology of Trace Elements, p.177). That study found that the threshold chronic exposure of impairment of reflex response in mice was 0.05 mg/kg/day of vanadium pentoxide (V_2O_5) or ammonium vanadate (NH_4VO_3). A chronic exposure (6 months) of 0.005 mg/kg/day in mice did not result in "functional disturbances of conditioned reflex activities." This value was taken as the maximum permissible dose from drinking water in the Soviet Union.

The Acceptable Intake for Subchronic Exposure (AIS) is based on two short term (3 months) studies on rats (Domingo et al., 1985; Parker and Sharma, 1978). In both studies, rats were fed vanadium salts at 5 and 50 ppm in drinking water. Neither study reported significant changes in body weight, organ weight, or hematocrit levels. However, each study reported vanadium accumulation in organs of rats fed 50 ppm, particularly in the kidneys, spleen, bones, and liver. No vanadium accumulation was noted for rats receiving 5 ppm in their drinking water. Parker and Sharma (1978) showed that vanadium levels in all organs except bones deplete rapidly once oral administration has been stopped. Domingo et al.(1985) reported that there were mild histopathological changes in the kidneys, spleen, and lungs of rats fed sodium metavanadate ($NaVO_3$) at both 5 and 50 ppm, and that lesions on the organs were dose dependent. Based on these data, a water concentration of 5 ppm was taken as the maximum subchronic exposure for rats. This concentration corresponds to a dose of 0.97 mg/kg/day. Adding in an animal-to-human safety factor of 100 gives a human AIS of 0.0097 or 0.01 mg/kg/day.

$$\begin{aligned} AIS &= AIS_{animal}/100 \\ &= 0.97 \text{ mg/kg/day}/100 \\ &= 0.0097 \text{ or } 0.1 \text{ mg/kg/day} \end{aligned}$$

REFERENCES

Domingo, J.L., Llobet, J.M., Tomas, J.M. "Short-term Toxicity Studies of Vanadium in Rats." J. App. Tox. 5(6):418. 1985.

Parker, R.D.R., and Sharma, R.P. "Accumulation and Depletion of Vanadium in Selected Tissues of Rats Treated with Vanadyl Sulfate and Sodium Orthovanadate." J. Env. Path. Tox. 2:235-45. 1978.

APPENDIX B - Federal Standards for Selected Constituents.

Appendix B. Federal Standards for Selected Constituents..

			Reference
Arsenic	0.05	mg/l	1
Cadmium	0.01	mg/l	1
Chromium	0.05	mg/l	1
Molybdenum	0.10	mg/l	2
Nitrate	44.0[a]	mg/l	2
Selenium	0.01	mg/l	1
Sulfate	250[b]	mg/l	3
Uranium	0.044	mg/l	2
Lead-210	100	pCi/l	4
Polonium-210	700	pCi/l	4
Radium-226 & -228	5.0	pCi/l	1

[a]Nitrate as nitrate.
[b]Secondary drinking water standard - for contaminant concentration that primarily affect aesthetic qualities.

References:
1. 40 CFR 192.32(a) (Final Rule for Active Sites)
2. 52 FR 36007 (Proposed Rule for Inactive Sites)
3. 50 FR 46979 (Proposed Rule for Drinking WAter)
4. 10 CFR 20, Appendix B, Table II, Column 2 (NRC Final Rule on Permissible Concentrations

APPENDIX C - Compiled Concentration Data, Ratios and Risk Estimates for Uranium Mill-tailings Sites

Site Name: Gunnison, CO, Alluvium

Measured Concentrations - Receptor Wells

Chemical	Units	RECEPTOR WELLS High Concen.	+/-
As	mg/l	-0.01	
Cd	mg/l	-0.01	
Cr VI	mg/l	-0.10	
Pb-210	pCi/l	3.50	1.30
Mo	mg/l	0.003	
NO3	mg/l	6.10	
Po-210	pCi/l		
Ra-226+8	pCi/l	0.50	
Se	mg/l	0.02	
SO4	mg/l	191.00	
Th-230	pCi/l	0.9	0.6
U	mg/l	0.12	
V	mg/l	0.01	
Ra-226	pCi/l	0.50	0.30
Ra-228	pCi/l		

Measured Concentrations - Monitor Wells

Chemical	Units	Monitor Wells High Concen.	+/-
As	mg/l	0.04	
Cd	mg/l	-0.001	
Cr VI	mg/l	0.01	
Pb-210	pCi/l	-1.50	
Mo	mg/l	0.03	
NO3	mg/l	36.00	
Po-210	pCi/l		
Ra-226+8	pCi/l	4.70	
Se	mg/l	-0.005	
SO4	mg/l	910.00	
Th-230	pCi/l	-1.00	
U	mg/l	0.069	
V	mg/l	-0.01	
Ra-226	pCi/l	1.00	
Ra-228	pCi/l	3.70	

Measured Concentrations - Background Wells

Chemical	Units	Background Wells Low Concen.	+/-
As	mg/l	-0.001	

60 |Cd	mg/l		-0.001		

61 |Cr VI	mg/l		-0.001		
62 |Pb-210	pCi/l		-1.5		
63 |Mo	mg/l		-0.001		
64 |NO3	mg/l				
65 |Po-210	pCi/l				
66 |Ra-226+8	pCi/l		-1.00		
67 |Se	mg/l		-0.002		
68 |SO4	mg/l		9.1		
69 |Th-230	pCi/l		-1.00		
70 |U	mg/l		0.0011		
71 |V	mg/l		-0.004		
72 |Ra-226	pCi/l		-1.00		
73 |Ra-228	pCi/l				
74 ----------		----------	----------	----------	

1

2 Site Name: Gunnison, CO, Alluvium

75

76 Calculated Water Intakes - Receptors

77 ---------- ----------

78 |	Adult	Child	Receptor	Receptor	Receptor	Receptor	Receptor	Receptor
79 |Chemical	In Factor	In Factor	Conc-Gross	Conc-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
80 |	(l/kg/day)	(l/kg/day)	(mg/l)	(mg/l)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)
81 |---------			----------		----------			
82 |As	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
83 |Cd	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
84 |Cr VI	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
85 |Pb-210	0.03	0.10	3.5	3.500	0.10	0.35	0.10	0.35
86 |Mo	0.03	0.10	0.0	0.003	0.00	0.00	0.00	0.00
87 |NO3	0.03	0.25	6.1	6.100	0.17	1.53	0.17	1.53
88 |Po-210	0.03	0.10						
89 |Ra-226+8	0.03	0.10	0.5	0.500	0.01	0.05	0.01	0.05
90 |Se	0.03	0.10	0.0	0.020	0.00	0.00	0.00	0.00
91 |SO4	0.03	0.10	191.0	181.900	5.46	19.10	5.20	18.19
92 |Th-230	0.03	0.10	0.9	0.900	0.03	0.09	0.03	0.09
93 |U	0.03	0.10	0.1	0.119	0.00	0.01	0.00	0.01
94 |V	0.03	0.10	0.0	0.010	0.00	0.00	0.00	0.00
95 |Ra-226	0.03	0.10	0.5	0.500	0.01	0.05	0.01	0.05
96 |Ra-228	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
97 ----------	----------							

98

99 Calculated Water Intakes - Monitor

100 ---------- ----------

101 |	Adult	Child	Monitor	Monitor	Monitor	Monitor	Monitor	Monitor
102 |Chemical	In Factor	In Factor	Conc-Gross	Conc-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
103 |	(l/kg/day)	(l/kg/day)	(mg/l)	(mg/l)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)
104 |---------			----------		----------			
105 |As	0.03	0.10	0.0	0.040	0.00	0.00	0.00	0.00
106 |Cd	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
107 |Cr VI	0.03	0.10	0.0	0.010	0.00	0.00	0.00	0.00

108	|Pb-210	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
109	|Mo	0.03	0.10	0.0	0.030	0.00	0.00	0.00	0.00
110	|NO3	0.03	0.25	36.0	36.000	1.03	9.00	1.03	9.00
111	|Po-210	0.03	0.10						
112	|Ra-226+8	0.03	0.10	4.7	4.700	0.13	0.47	0.13	0.47
113	|Se	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
114	|SO4	0.03	0.10	910.0	900.900	26.00	91.00	25.74	90.09

1

2 Site Name: Gunnison, CO, Alluvium

115	|Th-230	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
116	|U	0.03	0.10	0.1	0.068	0.00	0.01	0.00	0.01
117	|V	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
118	|Ra-226	0.03	0.10	1.0	1.000	0.03	0.10	0.03	0.10
119	|Ra-228	0.03	0.10	3.7	3.700	0.11	0.37	0.11	0.37

120 ---------- ----------

121

122 Calculated Risks - Subchronic

123 ----------

124	|	AIS								
125	|Chemical	Toxicity	Receptor	Receptor	Receptor	Receptor	Monitor	Monitor	Monitor	Monitor
126	|	(mg/kg/day)	Adult-Gross	Child-Gross	Adult-Net	Child-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
127	|---------									
128	|As	1.40E-03	0.0	0.0	0.0	0.0	0.8	2.9	0.8	2.9
129	|Cd	1.20E-03	NA	0.0	NA	0.0	NA	0.0	NA	0.0
130	|Cr VI	2.50E-02	0.0	NA	0.0	NA	0.0	NA	0.0	NA
131	|Pb-210		NA	NA	NA	NA	NA	NA	NA	NA
132	|Mo		NA	NA	NA	NA	NA	NA	NA	NA
133	|NO3	1.10E+01	NA	0.1	NA	0.1	NA	0.8	NA	0.8
134	|Po-210		NA	NA	NA	NA	NA	NA	NA	NA
135	|Ra-226+8		NA	NA	NA	NA	NA	NA	NA	NA
136	|Se	3.20E-03	0.2	NA	0.2	NA	0.0	NA	0.0	NA
137	|SO4		NA	NA	NA	NA	NA	NA	NA	NA
138	|Th-230		NA	NA	NA	NA	NA	NA	NA	NA
139	|U		NA	NA	NA	NA	NA	NA	NA	NA
140	|V	1.00E-02	0.0	0.1	0.0	0.1	0.0	0.0	0.0	0.0
141	|Ra-226		NA	NA	NA	NA	NA	NA	NA	NA
142	|Ra-228		NA	NA	NA	NA	NA	NA	NA	NA

143 ----------

144

145 Calculated Risks - Chronic

146 ----------

147	|	AIC								
148	|Chemical	Toxicity	Receptor	Receptor	Receptor	Receptor	Monitor	Monitor	Monitor	Monitor
149	|	(mg/kg/day)	Adult-Gross	Child-Gross	Adult-Net	Child-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
150	|---------									
151	|As	1.40E-03	0.0	0.0	0.0	0.0	0.8	2.9	0.8	2.9
152	|Cd	2.90E-04	0.0	NA	0.0	0.0	0.0	0.0	0.0	0.0
153	|Cr VI	5.00E-03	0.0	NA	0.0	NA	0.1	NA	0.1	NA
154	|Pb-210		NA	NA	NA	NA	NA	NA	NA	NA
155	|Mo	2.90E-03	0.0	0.1	0.0	0.1	0.3	1.0	0.3	1.0

156	|NO3	1.26E+00	0.1	NA	0.1	NA	0.8	NA	0.8	NA
157	|Po-210		NA	NA	NA	NA	NA	NA	NA	NA
158	|Ra-226+8		NA	NA	NA	NA	NA	NA	NA	NA
159	|Se	3.00E-03	0.2	NA	0.2	NA	0.0	NA	0.0	NA
160	|SO4	4.00E+01	NA	0.5	NA	0.5	NA	2.3	NA	2.3
161	|Th-230		NA	NA	NA	NA	NA	NA	NA	NA
162	|U	1.70E-03	2.0	7.1	2.0	7.0	1.2	4.1	1.1	4.0
163	|V	2.00E-02	0.0	NA	0.0	NA	0.0	NA	0.0	NA
164	|Ra-226		NA	NA	NA	NA	NA	NA	NA	NA
165	|Ra-228		NA	NA	NA	NA	NA	NA	NA	NA

166 ----------

167

168 Calculated Risks - Cancer/EPA Potency Estimates

1

2 Site Name: Gunnison, CO, Alluvium

169 ----------

170	|	Potency				
171	|Chemical	(mg/kg/day)	Receptor	Receptor	Monitor	Monitor
172	|	(pCi/kg/day)	Adult-Gross	Adult-Net	Adult-Gross	Adult-Net
173	|---------					
174	|As	1.50E+01	0.00E+00	0.00E+00	1.71E-02	1.71E-02
175	|Cd	NA	NA	NA	NA	NA
176	|Cr VI	NA	NA	NA	NA	NA
177	|Pb-210	1.40E-04	1.40E-05	1.40E-05	0.00E+00	0.00E+00
178	|Mo	NA	NA	NA	NA	NA
179	|NO3	NA	NA	NA	NA	NA
180	|Po-210	3.68E-04				
181	|Ra-226+8		4.40E-06	4.40E-06	3.32E-05	3.32E-05
182	|Se	NA	NA	NA	NA	NA
183	|SO4	NA	NA	NA	NA	NA
184	|Th-230	7.70E-05	1.98E-06	1.98E-06	0.00E+00	0.00E+00
185	|U-nat	4.73E-05	1.11E-04	1.10E-04	6.36E-05	6.26E-05
186	|V	NA	NA	NA	NA	NA
187	|Ra-226	3.08E-04	4.40E-06	4.40E-06	8.80E-06	8.80E-06
188	|Ra-228	2.31E-04	0.00E+00	0.00E+00	2.44E-05	2.44E-05

189 ----------

190

191 Calculated Risks - Cancer/ICRP Potency Estimates

192 ----------

193	|	Potency				
194	|Chemical	(mg/kg/day)	Receptor	Receptor	Monitor	Monitor
195	|	(pCi/kg/day)	Adult-Gross	Gross-Net	Adult-Gross	Adult-Net
196	|---------					
197	|As	1.50E+01	0.00E+00	0.00E+00	1.71E-02	1.71E-02
198	|Cd	NA	NA	NA	NA	NA
199	|Cr VI	NA	NA	NA	NA	NA
200	|Pb-210	1.14E-03	1.14E-04	1.14E-04	0.00E+00	0.00E+00
201	|Mo	NA	NA	NA	NA	NA
202	|NO3	NA	NA	NA	NA	NA
203	|Po-210	3.65E-04				

204	|Ra-226+D		3.53E-06	3.53E-06	3.63E-05	3.63E-05
205	|Se	NA	NA	NA	NA	NA
206	|SO4	NA	NA	NA	NA	NA
207	|Th-230	1.18E-04	3.03E-06	3.03E-06	0.00E+00	0.00E+00
208	|U-nat	5.49E-05	1.28E-04	1.27E-04	7.38E-05	7.26E-05
209	|V	NA	NA	NA	NA	NA
210	|Ra-226	2.47E-04	3.53E-06	3.53E-06	7.06E-06	7.06E-06
211	|Ra-228	2.77E-04	0.00E+00	0.00E+00	2.93E-05	2.93E-05
212	----------					

Site Name: Lakeview, OR, Shallow

Measured Concentrations - Receptor Wells

Chemical	Units	RECEPTOR WELLS High Concen.	+/-
As	mg/l		
Cd	mg/l		
Cr VI	mg/l		
Pb-210	pCi/l		
Mo	mg/l		
NO3	mg/l		
Po-210	pCi/l		
Ra-226+8	pCi/l		
Se	mg/l		
SO4	mg/l		
Th-230	pCi/l		
U	mg/l		
V	mg/l		
Ra-226	pCi/l		
Ra-228	pCi/l		

Measured Concentrations - Monitor Wells

Chemical	Units	Monitor Wells High Concen.	+/-
As	mg/l	0.10	
Cd	mg/l	0.031	
Cr VI	mg/l	0.04	
Pb-210	pCi/l	-1.00	
Mo	mg/l	0.18	
NO3	mg/l	14.00	
Po-210	pCi/l	9.10	1.80
Ra-226+8	pCi/l	2.9	
Se	mg/l	-0.005	
SO4	mg/l	3150	
Th-230	pCi/l	1.6	0.4
U	mg/l	0.003	
V	mg/l	0.02	
Ra-226	pCi/l	0.5	0.2
Ra-228	pCi/l	2.4	0.9

Measured Concentrations - Background Wells

Chemical	Units	Background Wells Low Concen.	+/-
As	mg/l	-0.01	

60 |Cd	mg/l		-0.001

1			
2 Site Name: Lakeview, OR, Shallow			
61 |Cr VI	mg/l		-0.010
62 |Pb-210	pCi/l		-1.00
63 |Mo	mg/l		-0.010
64 |NO3	mg/l		-1.00
65 |Po-210	pCi/l		-0.50
66 |Ra-226+8	pCi/l		-1.00
67 |Se	mg/l		-0.005
68 |SO4	mg/l		3.00
69 |Th-230	pCi/l		-1.00
70 |U	mg/l		-0.001
71 |V	mg/l		-0.05
72 |Ra-226	pCi/l		-1.00
73 |Ra-228	pCi/l		-1.00
74 ----------		----------	---------- ----------
75			
76 Calculated Water Intakes - Receptors			
77 ----------		----------	

78 |	Adult	Child	Receptor	Receptor	Receptor	Receptor	Receptor	Receptor
79 |Chemical	In Factor	In Factor	Conc-Gross	Conc-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
80 |	(l/kg/day)	(l/kg/day)	(mg/l)	(mg/l)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)
81 |---			----------		----------	----------	----------	----------
82 |As	0.03	0.20						
83 |Cd	0.03	0.20						
84 |Cr VI	0.03	0.20						
85 |Pb-210	0.03	0.20						
86 |Mo	0.03	0.20						
87 |NO3	0.03	0.35						
88 |Po-210	0.03	0.20						
89 |Ra-226+8	0.03	0.20						
90 |Se	0.03	0.20						
91 |SO4	0.03	0.20						
92 |Th-230	0.03	0.20						
93 |U	0.03	0.20						
94 |V	0.03	0.20						
95 |Ra-226	0.03	0.20						
96 |Ra-228	0.03	0.20						
97 ----------	----------	----------						
98								
99 Calculated Water Intakes - Monitor								
100 ----------		----------						

101 |	Adult	Child	Monitor	Monitor	Monitor	Monitor	Monitor	Monitor
102 |Chemical	In Factor	In Factor	Conc-Gross	Conc-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
103 |	(l/kg/day)	(l/kg/day)	(mg/l)	(mg/l)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)
104 |---			----------		----------	----------	----------	----------
105 |As	0.03	0.20	0.1	0.100	0.00	0.02	0.00	0.02
106 |Cd	0.03	0.20	0.0	0.031	0.00	0.01	0.00	0.01
107 |Cr VI	0.03	0.20	0.0	0.040	0.00	0.01	0.00	0.01

108	|Pb-210	0.03	0.20	0.0	0.000	0.00	0.00	0.00	0.00
109	|Mo	0.03	0.20	0.2	0.180	0.01	0.04	0.01	0.04
110	|NO3	0.03	0.35	14.0	14.000	0.40	4.90	0.40	4.90
111	|Po-210	0.03	0.20	9.1	9.100	0.26	1.82	0.26	1.82
112	|Ra-226+8	0.03	0.20	2.9	2.900	0.08	0.58	0.08	0.58
113	|Se	0.03	0.20	0.0	0.000	0.00	0.00	0.00	0.00
114	|SO4	0.03	0.20	3150.0	3147.000	90.00	630.00	89.91	629.40

1

2 Site Name: Lakeview, OR, Shallow

115	|Th-230	0.03	0.20	1.6	1.600	0.05	0.32	0.05	0.32
116	|U	0.03	0.20	0.0	0.003	0.00	0.00	0.00	0.00
117	|V	0.03	0.20	0.0	0.020	0.00	0.00	0.00	0.00
118	|Ra-226	0.03	0.20	0.5	0.500	0.01	0.10	0.01	0.10
119	|Ra-228	0.03	0.20	2.4	2.400	0.07	0.48	0.07	0.48

120 ---------- ----------

121

122 Calculated Risks - Subchronic

123 ----------

124	|	AIC								
125	|Chemical	Toxicity	Receptor	Receptor	Receptor	Receptor	Monitor	Monitor	Monitor	Monitor
126	|	(mg/kg/day)	Adult-Gross	Child-Gross	Adult-Net	Child-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
127	|---------									
128	|As	1.40E-03					2.0	14.3	2.0	14.3
129	|Cd	1.20E-03					NA	5.2	NA	5.2
130	|Cr VI	2.50E-02					0.0	NA	0.0	NA
131	|Pb-210						NA	NA	NA	NA
132	|Mo						NA	NA	NA	NA
133	|NO3	1.10E+01					NA	0.4	NA	0.4
134	|Po-210						NA	NA	NA	NA
135	|Ra-226+8						NA	NA	NA	NA
136	|Se	3.20E-03					0.0	NA	0.0	NA
137	|SO4						NA	NA	NA	NA
138	|Th-230						NA	NA	NA	NA
139	|U						NA	NA	NA	NA
140	|V	1.00E-02					0.1	0.4	0.1	0.4
141	|Ra-226						NA	NA	NA	NA
142	|Ra-228						NA	NA	NA	NA

143 ----------

144

145 Calculated Risks - Chronic

146 ----------

147	|	AIC								
148	|Chemical	Toxicity	Receptor	Receptor	Receptor	Receptor	Monitor	Monitor	Monitor	Monitor
149	|	(mg/kg/day)	Adult-Gross	Child-Gross	Adult-Net	Child-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
150	|---------									
151	|As	1.40E-03					2.0	14.3	2.0	14.3
152	|Cd	2.90E-04					3.1	21.4	3.1	21.4
153	|Cr VI	5.00E-03					0.2	NA	0.2	NA
154	|Pb-210						NA	NA	NA	NA
155	|Mo	2.90E-03					1.8	12.4	1.8	12.4

156 |NO3	1.26E+00			0.3	NA	0.3	NA
157 |Po-210				NA	NA	NA	NA
158 |Ra-226+8				NA	NA	NA	NA
159 |Se	3.00E-03			0.0	NA	0.0	NA
160 |SO4	4.00E+01			NA	15.8	NA	15.7
161 |Th-230				NA	NA	NA	NA
162 |U	1.70E-03			0.1	0.4	0.1	0.4
163 |V	2.00E-02			0.0	NA	0.0	NA
164 |Ra-226				NA	NA	NA	NA
165 |Ra-228				NA	NA	NA	NA

166 ----------

167

168 Calculated Risks - Cancer/EPA Potency Estimates

1

2 Site Name: Lakeview, OR, Shallow

169 ----------

170 |	Potency				
171 |Chemical	(mg/kg/day)	Receptor	Receptor	Monitor	Monitor
172 |	(pCi/kg/day)	Adult-Gross	Adult-Net	Adult-Gross	Adult-Net
173 |---------					
174 |As	1.50E+01			4.29E-02	4.29E-02
175 |Cd	NA			NA	NA
176 |Cr VI	NA			NA	NA
177 |Pb-210	1.40E-04			0.00E+00	0.00E+00
178 |Mo	NA			NA	NA
179 |NO3	NA			NA	NA
180 |Po-210	3.68E-04			9.57E-05	9.57E-05
181 |Ra-226+8				2.02E-05	2.02E-05
182 |Se	NA			NA	NA
183 |SO4	NA			NA	NA
184 |Th-230	7.70E-05			3.52E-06	3.52E-06
185 |U-nat	4.73E-05			2.76E-06	2.76E-06
186 |V	NA			NA	NA
187 |Ra-226	3.08E-04			4.40E-06	4.40E-06
188 |Ra-228	2.31E-04			1.58E-05	1.58E-05

189 ----------

190

191 Calculated Risks - Cancer/ICRP Potency Estimates

192 ----------

193 |	Potency				
194 |Chemical	(mg/kg/day)	Receptor	Receptor	Monitor	Monitor
195 |	(pCi/kg/day)	Adult-Gross	Gross-Net	Adult-Gross	Adult-Net
196 |---------					
197 |As	1.50E+01			4.29E-02	4.29E-02
198 |Cd	NA			NA	NA
199 |Cr VI	NA			NA	NA
200 |Pb-210	1.14E-03			0.00E+00	0.00E+00
201 |Mo	NA			NA	NA
202 |NO3	NA			NA	NA
203 |Po-210	3.65E-04			9.49E-05	9.49E-05

204	|Ra-226+D		2.25E-05	2.25E-05
205	|Se	NA	NA	NA
206	|SO4	NA	NA	NA
207	|Th-230	1.18E-04	5.39E-06	5.39E-06
208	|U-nat	5.49E-05	3.21E-06	3.21E-06
209	|V	NA	NA	NA
210	|Ra-226	2.47E-04	3.53E-06	3.53E-06
211	|Ra-228	2.77E-04	1.90E-05	1.90E-05
212	----------			

Site Name: Lakeview, OR, Deep

Measured Concentrations - Receptor Wells

Chemical	Units	RECEPTOR WELLS High Concen.	+/-
As	mg/l	0.011	
Cd	mg/l	-0.001	
Cr VI	mg/l	-0.01	
Pb-210	pCi/l	-1.20	
Mo	mg/l	-0.05	
NO3	mg/l	6.00	
Po-210	pCi/l	-0.50	
Ra-226+8	pCi/l	-1.00	
Se	mg/l	-0.005	
SO4	mg/l	14.00	
Th-230	pCi/l	-1.00	
U	mg/l	-0.001	
V	mg/l	0.04	
Ra-226	pCi/l	-1.00	
Ra-228	pCi/l	-1.00	

Measured Concentrations - Monitor Wells

Chemical	Units	Monitor Wells High Concen.	+/-
As	mg/l	0.02	
Cd	mg/l	0.006	
Cr VI	mg/l	0.05	
Pb-210	pCi/l	-1.00	
Mo	mg/l	0.04	
NO3	mg/l	2.2	
Po-210	pCi/l	4.40	
Ra-226+8	pCi/l	2.9	
Se	mg/l	-0.005	
SO4	mg/l	330.00	
Th-230	pCi/l	3.2	0.7
U	mg/l	0.0013	
V	mg/l	-0.01	
Ra-226	pCi/l	0.0	0.1
Ra-228	pCi/l	2.9	1.4

Measured Concentrations - Background Wells

Chemical	Units	Background Wells Low Concen.	+/-
As	mg/l	-0.01	

40	|Cd	mg/l		-0.001	
1					
2	Site Name: Lakeview, OR, Deep				
61	|Cr VI	mg/l		-0.01	
62	|Pb-210	pCi/l		-1.00	
63	|Mo	mg/l		-0.01	
64	|NO3	mg/l		-1.00	
65	|Po-210	pCi/l		-0.50	
66	|Ra-226+8	pCi/l		-1.00	
67	|Se	mg/l		-0.005	
68	|SO4	mg/l		31.00	
69	|Th-230	pCi/l		-1.00	
70	|U	mg/l		-0.001	
71	|V	mg/l		-0.01	
72	|Ra-226	pCi/l		-1.00	
73	|Ra-228	pCi/l		-1.00	
74	----------		----------	----------	----------
75					
76	Calculated Water Intakes - Receptors				
77	----------	----------			

78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97
|	|Chemical	Adult In Factor (l/kg/day)	Child In Factor (l/kg/day)	Receptor Conc-Gross (mg/l)	Receptor Conc-Net (mg/l)	Receptor Adult-Gross (mg/kg/day)	Receptor Child-Gross (mg/kg/day)	Receptor Adult-Net (mg/kg/day)	Receptor Child-Net (mg/kg/day)
|---				----------		----------			
|As	0.03	0.10	0.0	0.011	0.00	0.00	0.00	0.00
|Cd	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
|Cr VI	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
|Pb-210	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
|Mo	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
|NO3	0.03	0.25	6.0	6.000	0.17	1.50	0.17	1.50
|Po-210	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
|Ra-226+8	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
|Se	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
|SO4	0.03	0.10	14.0	-17.000	0.40	1.40	-0.49	-1.70
|Th-230	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
|U	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
|V	0.03	0.10	0.0	0.040	0.00	0.00	0.00	0.00
|Ra-226	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
|Ra-228	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00

98 |

99 Calculated Water Intakes - Monitor

100 ---------- ----------

101	102	103	104	105	106	107
|	|Chemical	Adult In Factor (l/kg/day)	Child In Factor (l/kg/day)	Monitor Conc-Gross (mg/l)	Monitor Conc-Net (mg/l)	Monitor Adult-Gross (mg/kg/day)	Monitor Child-Gross (mg/kg/day)	Monitor Adult-Net (mg/kg/day)	Monitor Child-Net (mg/kg/day)
|---				----------		----------			
|As	0.03	0.10	0.0	0.020	0.00	0.00	0.00	0.00
|Cd	0.03	0.10	0.0	0.006	0.00	0.00	0.00	0.00
|Cr VI	0.03	0.10	0.1	0.050	0.00	0.01	0.00	0.01

108 |Pb-210	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
109 |Mo	0.03	0.10	0.0	0.040	0.00	0.00	0.00	0.00
110 |NO3	0.03	0.25	2.2	2.200	0.06	0.55	0.06	0.55
111 |Po-210	0.03	0.10	4.4	4.400	0.13	0.44	0.13	0.44
112 |Ra-226+8	0.03	0.10	2.9	2.900	0.08	0.29	0.08	0.29
113 |Se	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
114 |SO4	0.03	0.10	330.0	299.000	9.43	33.00	8.54	29.90

1

2 Site Name: Lakeview, OR, Deep

115 |Th-230	0.03	0.10	3.2	3.200	0.09	0.32	0.09	0.32
116 |U	0.03	0.10	0.0	0.001	0.00	0.00	0.00	0.00
117 |V	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
118 |Ra-226	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
119 |Ra-228	0.03	0.10	2.9	2.900	0.08	0.29	0.08	0.29

120 ---------- ----------

121

122 Calculated Risks - Subchronic

123 ----------

124 |	AIS								
125 |Chemical	Toxicity	Receptor	Receptor	Receptor	Receptor	Monitor	Monitor	Monitor	Monitor
126 |	(mg/kg/day)	Adult-Gross	Child-Gross	Adult-Net	Child-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
127 |---------									
128 |As	1.40E-03	0.2	0.8	0.2	0.8	0.4	1.4	0.4	1.4
129 |Cd	1.20E-03	NA	0.0	NA	0.0	NA	0.5	NA	0.5
130 |Cr VI	2.50E-02	0.0	NA	0.0	NA	0.1	NA	0.1	NA
131 |Pb-210		NA	NA	NA	NA	NA	NA	NA	NA
132 |Mo		NA	NA	NA	NA	NA	NA	NA	NA
133 |NO3	1.10E+01	NA	0.1	NA	0.1	NA	0.1	NA	0.1
134 |Po-210		NA	NA	NA	NA	NA	NA	NA	NA
135 |Ra-226+8		NA	NA	NA	NA	NA	NA	NA	NA
136 |Se	3.20E-03	0.0	NA	0.0	NA	0.0	NA	0.0	NA
137 |SO4		NA	NA	NA	NA	NA	NA	NA	NA
138 |Th-230		NA	NA	NA	NA	NA	NA	NA	NA
139 |U		NA	NA	NA	NA	NA	NA	NA	NA
140 |V	1.00E-02	0.1	0.4	0.1	0.4	0.0	0.0	0.0	0.0
141 |Ra-226		NA	NA	NA	NA	NA	NA	NA	NA
142 |Ra-228		NA	NA	NA	NA	NA	NA	NA	NA

143 ----------

144

145 Calculated Risks - Chronic

146 ----------

147 |	AIC								
148 |Chemical	Toxicity	Receptor	Receptor	Receptor	Receptor	Monitor	Monitor	Monitor	Monitor
149 |	(mg/kg/day)	Adult-Gross	Child-Gross	Adult-Net	Child-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
150 |---------									
151 |As	1.40E-03	0.2	0.8	0.2	0.8	0.4	1.4	0.4	1.4
152 |Cd	2.90E-04	0.0	NA	0.0	0.0	0.6	2.1	0.6	2.1
153 |Cr VI	5.00E-03	0.0	NA	0.0	NA	0.3	NA	0.3	NA
154 |Pb-210		NA	NA	NA	NA	NA	NA	NA	NA
155 |Mo	2.90E-03	0.0	0.0	0.0	0.0	0.4	1.4	0.4	1.4

156 |NO3	1.26E+00	0.1	NA	0.1	NA	0.0	NA	0.0	NA
157 |Po-210		NA	NA	NA	NA	NA	NA	NA	NA
158 |Ra-226+8		NA	NA	NA	NA	NA	NA	NA	NA
159 |Se	3.00E-03	0.0	NA	0.0	NA	0.0	NA	0.0	NA
160 |SO4	4.00E+01	NA	0.0	NA	0.0	NA	0.8	NA	0.7
161 |Th-230		NA	NA	NA	NA	NA	NA	NA	NA
162 |U	1.70E-03	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.1
163 |V	2.00E-02	0.1	NA	0.1	NA	0.0	NA	0.0	NA
164 |Ra-226		NA	NA	NA	NA	NA	NA	NA	NA
165 |Ra-228		NA	NA	NA	NA	NA	NA	NA	NA

166 ----------

167

168 Calculated Risks - Cancer/EPA Potency Estimates

1

2 Site Name: Lakeview, OR, Deep

169 ----------

170 |	Potency				
171 |Chemical	(mg/kg/day)	Receptor	Receptor	Monitor	Monitor
172 |	(pCi/kg/day)	Adult-Gross	Adult-Net	Adult-Gross	Adult-Net
173 |---					
174 |As	1.50E+01	4.71E-03	4.71E-03	8.57E-03	8.57E-03
175 |Cd	NA	NA	NA	NA	NA
176 |Cr VI	NA	NA	NA	NA	NA
177 |Pb-210	1.40E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
178 |Mo	NA	NA	NA	NA	NA
179 |NO3	NA	NA	NA	NA	NA
180 |Po-210	3.68E-04	0.00E+00	0.00E+00	4.63E-05	4.63E-05
181 |Ra-226+8		0.00E+00	0.00E+00	1.91E-05	1.91E-05
182 |Se	NA	NA	NA	NA	NA
183 |SO4	NA	NA	NA	NA	NA
184 |Th-230	7.70E-05	0.00E+00	0.00E+00	7.04E-06	7.04E-06
185 |U-nat	4.73E-05	0.00E+00	0.00E+00	1.20E-06	1.20E-06
186 |V	NA	NA	NA	NA	NA
187 |Ra-226	3.08E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
188 |Ra-228	2.31E-04	0.00E+00	0.00E+00	1.91E-05	1.91E-05

189 ----------

190

191 Calculated Risks - Cancer/ICRP Potency Estimates

192 ----------

193 |	Potency				
194 |Chemical	(mg/kg/day)	Receptor	Receptor	Monitor	Monitor
195 |	(pCi/kg/day)	Adult-Gross	Gross-Net	Adult-Gross	Adult-Net
196 |---					
197 |As	1.50E+01	4.71E-03	4.71E-03	8.57E-03	8.57E-03
198 |Cd	NA	NA	NA	NA	NA
199 |Cr VI	NA	NA	NA	NA	NA
200 |Pb-210	1.14E-03	0.00E+00	0.00E+00	0.00E+00	0.00E+00
201 |Mo	NA	NA	NA	NA	NA
202 |NO3	NA	NA	NA	NA	NA
203 |Po-210	3.65E-04	0.00E+00	0.00E+00	4.59E-05	4.59E-05

204	|Ra-226+D		0.00E+00	0.00E+00	2.30E-05	2.30E-05
205	|Se	NA	NA	NA	NA	NA
206	|SO4	NA	NA	NA	NA	NA
207	|Th-230	1.18E-04	0.00E+00	0.00E+00	1.08E-05	1.08E-05
208	|U-nat	5.49E-05	0.00E+00	0.00E+00	1.39E-06	1.39E-06
209	|V	NA	NA	NA	NA	NA
210	|Ra-226	2.47E-04	0.00E+00	0.00E+00	0.00E+00	0.00E+00
211	|Ra-228	2.77E-04	0.00E+00	0.00E+00	2.30E-05	2.30E-05
212	----------					

Site Name: Monument Valley, AZ, Alluvium

Measured Concentrations - Receptor Wells

Chemical	Units	RECEPTOR WELLS High Concen.	+/-
As	mg/l		
Cd	mg/l		
Cr VI	mg/l		
Pb-210	pCi/l		
Mo	mg/l		
NO3	mg/l		
Po-210	pCi/l		
Ra-226+8	pCi/l		
Se	mg/l		
SO4	mg/l		
Th-230	pCi/l		
U	mg/l		
V	mg/l		
Ra-226	pCi/l		
Ra-228	pCi/l		

Measured Concentrations - Monitor Wells

Chemical	Units	Monitor Wells High Concen.	+/-
As	mg/l	0.016	
Cd	mg/l	0.031	
Cr VI	mg/l	0.09	
Pb-210	pCi/l	1.8	1.1
Mo	mg/l	0.35	
NO3	mg/l	1600	
Po-210	pCi/l	1.9	0.9
Ra-226+8	pCi/l	2.2	
Se	mg/l	0.016	
SO4	mg/l	2960	
Th-230	pCi/l	0.8	1.1
U	mg/l	0.0343	
V	mg/l	0.80	
Ra-226	pCi/l	0.3	0.2
Ra-228	pCi/l	1.9	0.9

Measured Concentrations - Background Wells

Chemical	Units	Background Wells Low Concen.	+/-
As	mg/l	-0.001	

60	|Cd	mg/l	-0.001		
1					
2	Site Name: Monument Valley, AZ, Alluvium				
61	|Cr VI	mg/l	-0.01		
62	|Pb-210	pCi/l	0.0	1	
63	|Mo	mg/l	0.0		
64	|NO3	mg/l	-1		
65	|Po-210	pCi/l	0.0	0.5	
66	|Ra-226+8	pCi/l	0.0		
67	|Se	mg/l	-0.005		
68	|SO4	mg/l	55.80		
69	|Th-230	pCi/l	0.00	0.6	
70	|U	mg/l	0.0025		
71	|V	mg/l	-0.01		
72	|Ra-226	pCi/l	0.0	0.2	
73	|Ra-228	pCi/l	0.0	0.7	
74	----------		----------	----------	----------
75					
76	Calculated Water Intakes - Receptors				
77	----------	----------			

78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93	94	95	96	97	98
|	|Chemical	|	|---	|As	|Cd	|Cr VI	|Pb-210	|Mo	|NO3	|Po-210	|Ra-226+8	|Se	|SO4	|Th-230	|U	|V	|Ra-226	|Ra-228	----------
Adult In Factor	(l/kg/day)		---	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	
Child In Factor	(l/kg/day)		----------	0.10	0.10	0.10	0.10	0.10	0.25	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	
Receptor Conc-Gross	(mg/l)		----------																	
Receptor Conc-Net	(mg/l)																			
Receptor Adult-Gross	(mg/kg/day)		----------																	
Receptor Child-Gross	(mg/kg/day)																			
Receptor Adult-Net	(mg/kg/day)																			
Receptor Child-Net	(mg/kg/day)																			

99	Calculated Water Intakes - Monitor								
100	----------	----------							
101	|	Adult	Child	Monitor	Monitor	Monitor	Monitor	Monitor	Monitor
102	|Chemical	In Factor	In Factor	Conc-Gross	Conc-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
103	|	(l/kg/day)	(l/kg/day)	(mg/l)	(mg/l)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)
104	|---	---	----------	----------		----------			
105	|As	0.03	0.10	0.0	0.016	0.00	0.00	0.00	0.00
106	|Cd	0.03	0.10	0.0	0.031	0.00	0.00	0.00	0.00
107	|Cr VI	0.03	0.10	0.1	0.090	0.00	0.01	0.00	0.01

108	|Pb-210	0.03	0.10	1.8	1.800	0.05	0.18	0.05	0.18
109	|Mo	0.03	0.10	0.4	0.350	0.01	0.04	0.01	0.04
110	|NO3	0.03	0.25	1600.0	1600.000	45.71	400.00	45.71	400.00
111	|Po-210	0.03	0.10	1.9	1.900	0.05	0.19	0.05	0.19
112	|Ra-226+8	0.03	0.10	2.2	2.200	0.06	0.22	0.06	0.22
113	|Se	0.03	0.10	0.0	0.016	0.00	0.00	0.00	0.00
114	|SO4	0.03	0.10	2960.0	2904.200	84.57	296.00	82.97	290.42

1

2 Site Name: Monument Valley, AZ, Alluvium

115	|Th-230	0.03	0.10	0.8	0.800	0.02	0.08	0.02	0.08
116	|U	0.03	0.10	0.0	0.032	0.00	0.00	0.00	0.00
117	|V	0.03	0.10	0.8	0.800	0.02	0.08	0.02	0.08
118	|Ra-226	0.03	0.10	0.3	0.300	0.01	0.03	0.01	0.03
119	|Ra-228	0.03	0.10	1.9	1.900	0.05	0.19	0.05	0.19

120 ---------- ----------

121

122 Calculated Risks - Subchronic

123 ----------

124	|	AIS								
125	|Chemical	Toxicity	Receptor	Receptor	Receptor	Receptor	Monitor	Monitor	Monitor	Monitor
126	|	(mg/kg/day)	Adult-Gross	Child-Gross	Adult-Net	Child-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
127	|---------									
128	|As	1.40E-03					0.3	1.1	0.3	1.
129	|Cd	1.20E-03					NA	2.6	NA	2.
130	|Cr VI	2.50E-02					0.1	NA	0.1	N
131	|Pb-210						NA	NA	NA	N
132	|Mo						NA	NA	NA	N
133	|NO3	1.10E+01					NA	36.4	NA	36.
134	|Po-210						NA	NA	NA	N
135	|Ra-226+8						NA	NA	NA	N
136	|Se	3.20E-03					0.1	NA	0.1	N
137	|SO4						NA	NA	NA	N
138	|Th-230						NA	NA	NA	N
139	|U						NA	NA	NA	N
140	|V	1.00E-02					2.3	8.0	2.3	8.
141	|Ra-226						NA	NA	NA	N
142	|Ra-228						NA	NA	NA	N

143 ----------

144

145 Calculated Risks - Chronic

146 ----------

147	|	AIC								
148	|Chemical	Toxicity	Receptor	Receptor	Receptor	Receptor	Monitor	Monitor	Monitor	Monitor
149	|	(mg/kg/day)	Adult-Gross	Child-Gross	Adult-Net	Child-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
150	|---------									
151	|As	1.40E-03					0.3	1.1	0.3	1
152	|Cd	2.90E-04					3.1	10.7	3.1	10
153	|Cr VI	5.00E-03					0.5	NA	0.5	
154	|Pb-210						NA	NA	NA	
155	|Mo	2.90E-03					3.4	12.1	3.4	12

156 |NO3	1.26E+00			36.3	NA	36.3	NA
157 |Po-210				NA	NA	NA	NA
158 |Ra-226+8				NA	NA	NA	NA
159 |Se	3.00E-03			0.2	NA	0.2	NA
160 |SO4	4.00E+01			NA	7.4	NA	7.3
161 |Th-230				NA	NA	NA	NA
162 |U	1.70E-03			0.6	2.0	0.5	1.9
163 |V	2.00E-02			1.1	NA	1.1	NA
164 |Ra-226				NA	NA	NA	NA
165 |Ra-228				NA	NA	NA	NA

166 ----------

167

168 Calculated Risks - Cancer/EPA Potency Estimates

1

2 Site Name: Monument Valley, AZ, Alluvium

169 ----------

170 |	Potency				
171 |Chemical	(mg/kg/day)	Receptor	Receptor	Monitor	Monitor
172 |	(pCi/kg/day)	Adult-Gross	Adult-Net	Adult-Gross	Adult-Net
173 |---					
174 |As	1.50E+01			6.86E-03	6.86E-03
175 |Cd	NA			NA	NA
176 |Cr VI	NA			NA	NA
177 |Pb-210	1.40E-04			7.20E-06	7.20E-06
178 |Mo	NA			NA	NA
179 |NO3	NA			NA	NA
180 |Po-210	3.68E-04			2.00E-05	2.00E-05
181 |Ra-226+8				1.52E-05	1.52E-05
182 |Se	NA			NA	NA
183 |SO4	NA			NA	NA
184 |Th-230	7.70E-05			1.76E-06	1.76E-06
185 |U-nat	4.73E-05			3.16E-05	2.93E-05
186 |V	NA			NA	NA
187 |Ra-226	3.08E-04			2.64E-06	2.64E-06
188 |Ra-228	2.31E-04			1.25E-05	1.25E-05

189 ----------

190

191 Calculated Risks - Cancer/ICRP Potency Estimates

192 ----------

193 |	Potency				
194 |Chemical	(mg/kg/day)	Receptor	Receptor	Monitor	Monitor
195 |	(pCi/kg/day)	Adult-Gross	Gross-Net	Adult-Gross	Adult-Net
196 |---					
197 |As	1.50E+01			6.86E-03	6.86E-03
198 |Cd	NA			NA	NA
199 |Cr VI	NA			NA	NA
200 |Pb-210	1.14E-03			5.86E-05	5.86E-05
201 |Mo	NA			NA	NA
202 |NO3	NA			NA	NA
203 |Po-210	3.65E-04			1.98E-05	1.98E-05

204	|Ra-226+D		1.72E-05	1.72E-05
205	|Se	NA	NA	NA
206	|SO4	NA	NA	NA
207	|Th-230	1.18E-04	2.70E-06	2.70E-06
208	|U-nat	5.49E-05	3.67E-05	3.40E-05
209	|V	NA	NA	NA
210	|Ra-226	2.47E-04	2.12E-06	2.12E-06
211	|Ra-228	2.77E-04	1.50E-05	1.50E-05
212	----------			

Site Name: Monument Valley, AZ, Shinarump

Measured Concentrations - Receptor Wells

Chemical	Units	RECEPTOR WELLS High Concen.	+/-
As	mg/l		
Cd	mg/l		
Cr VI	mg/l		
Pb-210	pCi/l		
Mo	mg/l		
NO3	mg/l		
Po-210	pCi/l		
Ra-226+8	pCi/l		
Se	mg/l		
SO4	mg/l		
Th-230	pCi/l		
U	mg/l		
V	mg/l		
Ra-226	pCi/l		
Ra-228	pCi/l		

Measured Concentrations - Monitor Wells

Chemical	Units	Monitor Wells High Concen.	+/-
As	mg/l	0.005	
Cd	mg/l	0.004	
Cr VI	mg/l	0.07	
Pb-210	pCi/l	2.8	1.3
Mo	mg/l	0.25	
NO3	mg/l	40.00	
Po-210	pCi/l	0.3	0.6
Ra-226+8	pCi/l	1.80	
Se	mg/l	-0.005	
SO4	mg/l	255	
Th-230	pCi/l	1.1	0.6
U	mg/l	0.0315	
V	mg/l	0.7	
Ra-226	pCi/l	1.60	0.5
Ra-228	pCi/l	0.20	1.40

Measured Concentrations - Background Wells

Chemical	Units	Background Wells Low Concen.	+/-
As	mg/l	-0.01	

60 |Cd	mg/l		-0.001		

Site Name: Monument Valley, AZ, Shinarump

61 |Cr VI	mg/l		-0.01		
62 |Pb-210	pCi/l		0.1	1.30	
63 |Mo	mg/l		-0.01		
64 |NO3	mg/l		-1		
65 |Po-210	pCi/l		0	0.6	
66 |Ra-226+8	pCi/l		0.1		
67 |Se	mg/l		-0.005		
68 |SO4	mg/l		53.1		
69 |Th-230	pCi/l		0.0	0.2	
70 |U	mg/l		-0.0003		
71 |V	mg/l		-0.01		
72 |Ra-226	pCi/l		0.1	0.20	
73 |Ra-228	pCi/l		0.00	0.90	

Calculated Water Intakes - Receptors

Chemical	Adult In Factor (l/kg/day)	Child In Factor (l/kg/day)	Receptor Conc-Gross (mg/l)	Receptor Conc-Net (mg/l)	Receptor Adult-Gross (mg/kg/day)	Receptor Child-Gross (mg/kg/day)	Receptor Adult-Net (mg/kg/day)	Receptor Child-Net (mg/kg/day)
As	0.03	0.10						
Cd	0.03	0.10						
Cr VI	0.03	0.10						
Pb-210	0.03	0.10						
Mo	0.03	0.10						
NO3	0.03	0.25						
Po-210	0.03	0.10						
Ra-226+8	0.03	0.10						
Se	0.03	0.10						
SO4	0.03	0.10						
Th-230	0.03	0.10						
U	0.03	0.10						
V	0.03	0.10						
Ra-226	0.03	0.10						
Ra-228	0.03	0.10						

Calculated Water Intakes - Monitor

Chemical	Adult In Factor (l/kg/day)	Child In Factor (l/kg/day)	Monitor Conc-Gross (mg/l)	Monitor Conc-Net (mg/l)	Monitor Adult-Gross (mg/kg/day)	Monitor Child-Gross (mg/kg/day)	Monitor Adult-Net (mg/kg/day)	Monitor Child-Net (mg/kg/day)
As	0.03	0.10	0.0	0.005	0.00	0.00	0.00	0.00
Cd	0.03	0.10	0.0	0.004	0.00	0.00	0.00	0.00
Cr VI	0.03	0.10	0.1	0.070	0.00	0.01	0.00	0.01

108	|Pb-210	0.03	0.10	2.8	2.700	0.08	0.28	0.08	0.27
109	|Mo	0.03	0.10	0.3	0.250	0.01	0.03	0.01	0.03
110	|NO3	0.03	0.25	40.0	40.000	1.14	10.00	1.14	10.00
111	|Po-210	0.03	0.10	0.3	0.300	0.01	0.03	0.01	0.03
112	|Ra-226+8	0.03	0.10	1.8	1.700	0.05	0.18	0.05	0.17
113	|Se	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
114	|SO4	0.03	0.10	255.0	201.900	7.29	25.50	5.77	20.19

1

2 Site Name: Monument Valley, AZ, Shinarump

115	|Th-230	0.03	0.10	1.1	1.100	0.03	0.11	0.03	0.11
116	|U	0.03	0.10	0.0	0.032	0.00	0.00	0.00	0.00
117	|V	0.03	0.10	0.7	0.700	0.02	0.07	0.02	0.07
118	|Ra-226	0.03	0.10	1.6	1.500	0.05	0.16	0.04	0.15
119	|Ra-228	0.03	0.10	0.2	0.200	0.01	0.02	0.01	0.02

120 ---------- ----------

121

122 Calculated Risks - Subchronic

123 ----------

124	|	AIS								
125	|Chemical	Toxicity	Receptor	Receptor	Receptor	Receptor	Monitor	Monitor	Monitor	Monitor
126	|	(mg/kg/day)	Adult-Gross	Child-Gross	Adult-Net	Child-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
127	|---------									
128	|As	1.40E-03					0.1	0.4	0.1	0.4
129	|Cd	1.20E-03					NA	0.3	NA	0.3
130	|Cr VI	2.50E-02					0.1	NA	0.1	NA
131	|Pb-210						NA	NA	NA	NA
132	|Mo						NA	NA	NA	NA
133	|NO3	1.10E+01					NA	0.9	NA	0.9
134	|Po-210						NA	NA	NA	NA
135	|Ra-226+8						NA	NA	NA	NA
136	|Se	3.20E-03					0.0	NA	0.0	NA
137	|SO4						NA	NA	NA	NA
138	|Th-230						NA	NA	NA	NA
139	|U						NA	NA	NA	NA
140	|V	1.00E-02					2.0	7.0	2.0	7.0
141	|Ra-226						NA	NA	NA	NA
142	|Ra-228						NA	NA	NA	NA

143 ----------

144

145 Calculated Risks - Chronic

146 ----------

147	|	AIC								
148	|Chemical	Toxicity	Receptor	Receptor	Receptor	Receptor	Monitor	Monitor	Monitor	Monitor
149	|	(mg/kg/day)	Adult-Gross	Child-Gross	Adult-Net	Child-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
150	|---------									
151	|As	1.40E-03					0.1	0.4	0.1	0.4
152	|Cd	2.90E-04					0.4	1.4	0.4	1.4
153	|Cr VI	5.00E-03					0.4	NA	0.4	NA
154	|Pb-210						NA	NA	NA	NA
155	|Mo	2.90E-03					2.5	8.6	2.5	8.6

156 |NO3	1.26E+00			0.9	NA	0.9	NA
157 |Po-210				NA	NA	NA	NA
158 |Ra-226+8				NA	NA	NA	NA
159 |Se	3.00E-03			0.0	NA	0.0	NA
160 |SO4	4.00E+01			NA	0.6	NA	0.6
161 |Th-230				NA	NA	NA	NA
162 |U	1.70E-03			0.5	1.9	0.5	1.9
163 |V	2.00E-02			1.0	NA	1.0	NA
164 |Ra-226				NA	NA	NA	NA
165 |Ra-228				NA	NA	NA	NA
166 ----------							
167							
168 Calculated Risks - Cancer/EPA Potency Estimates							
1							
2 Site Name: Monument Valley, AZ, Shinarump							
169 ----------							
170 |	Potency						
171 |Chemical	(mg/kg/day)	Receptor	Receptor	Monitor	Monitor		
172 |	(pCi/kg/day)	Adult-Gross	Adult-Net	Adult-Gross	Adult-Net		
173 |---------							
174 |As	1.50E+01			2.14E-03	2.14E-03		
175 |Cd	NA			NA	NA		
176 |Cr VI	NA			NA	NA		
177 |Pb-210	1.40E-04			1.12E-05	1.08E-05		
178 |Mo	NA			NA	NA		
179 |NO3	NA			NA	NA		
180 |Po-210	3.68E-04			3.15E-06	3.15E-06		
181 |Ra-226+8				1.54E-05	1.45E-05		
182 |Se	NA			NA	NA		
183 |SO4	NA			NA	NA		
184 |Th-230	7.70E-05			2.42E-06	2.42E-06		
185 |U-nat	4.75E-05			2.90E-05	2.90E-05		
186 |V	NA			NA	NA		
187 |Ra-226	3.08E-04			1.41E-05	1.32E-05		
188 |Ra-228	2.31E-04			1.32E-06	1.32E-06		
189 ----------							
190							
191 Calculated Risks - Cancer/ICRP Potency Estimates							
192 ----------							
193 |	Potency						
194 |Chemical	(mg/kg/day)	Receptor	Receptor	Monitor	Monitor		
195 |	(pCi/kg/day)	Adult-Gross	Gross-Net	Adult-Gross	Adult-Net		
196 |---------							
197 |As	1.50E+01			2.14E-03	2.14E-03		
198 |Cd	NA			NA	NA		
199 |Cr VI	NA			NA	NA		
200 |Pb-210	1.14E-03			9.12E-05	8.79E-05		
201 |Mo	NA			NA	NA		
202 |NO3	NA			NA	NA		
203 |Po-210	3.65E-04			3.13E-06	3.13E-06		

204	|Ra-226+8		1.29E-05	1.22E-05
205	|Se	NA	NA	NA
206	|SO4	NA	NA	NA
207	|Th-230	1.18E-04	3.71E-06	3.71E-06
208	|U-nat	5.49E-05	3.37E-05	3.37E-05
209	|V	NA	NA	NA
210	|Ra-226	2.47E-04	1.13E-05	1.06E-05
211	|Ra-228	2.77E-04	1.58E-06	1.58E-06
212	----------			

Site Name: Monument Valley, AZ, DeChelly

Measured Concentrations - Receptor Wells

Chemical	Units	RECEPTOR WELLS High Concen.	+/-
As	mg/l		
Cd	mg/l		
Cr VI	mg/l		
Pb-210	pCi/l		
Mo	mg/l		
NO3	mg/l		
Po-210	pCi/l		
Ra-226+8	pCi/l		
Se	mg/l		
SO4	mg/l		
Th-230	pCi/l		
U	mg/l		
V	mg/l		
Ra-226	pCi/l		
Ra-228	pCi/l		

Measured Concentrations - Monitor Wells

Chemical	Units	Monitor Wells High Concen.	+/-
As	mg/l	0.002	
Cd	mg/l	0.003	
Cr VI	mg/l	0.06	
Pb-210	pCi/l	1.7	1.9
Mo	mg/l	0.26	
NO3	mg/l	8.86	
Po-210	pCi/l	0.40	0.90
Ra-226+8	pCi/l	1.50	
Se	mg/l	-0.005	
SO4	mg/l	88.5	
Th-230	pCi/l	0.5	0.4
U	mg/l	0.0514	
V	mg/l	0.6	
Ra-226	pCi/l	1.50	0.50
Ra-228	pCi/l	0.00	2.10

Measured Concentrations - Background Wells

Chemical	Units	Background Wells Low Concen.	+/-
As	mg/l	-0.01	

60	|Cd	mg/l		-0.001	

1					
2	Site Name: Monument Valley, AZ, DeChelly				
61	|Cr VI	mg/l		-0.01	
62	|Pb-210	pCi/l		0.0	1.00
63	|Mo	mg/l		-0.01	
64	|NO3	mg/l		-1	
65	|Po-210	pCi/l		0.0	
66	|Ra-226+8	pCi/l		0.0	
67	|Se	mg/l		-0.005	
68	|SO4	mg/l		13.2	
69	|Th-230	pCi/l		0.00	0.30
70	|U	mg/l		0.0012	
71	|V	mg/l		-0.01	
72	|Ra-226	pCi/l		0.0	0.20
73	|Ra-228	pCi/l		0.0	1.10
74	----------		----------	----------	----------
75					
76	Calculated Water Intakes - Receptors				
77	----------	----------			

78	|	Adult	Child	Receptor	Receptor	Receptor	Receptor	Receptor	Receptor
79	|Chemical	In Factor	In Factor	Conc-Gross	Conc-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
80	|	(l/kg/day)	(l/kg/day)	(mg/l)	(mg/l)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)
81	|---			----------		----------			
82	|As	0.03	0.10						
83	|Cd	0.03	0.10						
84	|Cr VI	0.03	0.10						
85	|Pb-210	0.03	0.10						
86	|Mo	0.03	0.10						
87	|NO3	0.03	0.25						
88	|Po-210	0.03	0.10						
89	|Ra-226+8	0.03	0.10						
90	|Se	0.03	0.10						
91	|SO4	0.03	0.10						
92	|Th-230	0.03	0.10						
93	|U	0.03	0.10						
94	|V	0.03	0.10						
95	|Ra-226	0.03	0.10						
96	|Ra-228	0.03	0.10						
97	----------	----------							
98									
99	Calculated Water Intakes - Monitor								
100	----------	----------							

101	|	Adult	Child	Monitor	Monitor	Monitor	Monitor	Monitor	Monitor
102	|Chemical	In Factor	In Factor	Conc-Gross	Conc-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
103	|	(l/kg/day)	(l/kg/day)	(mg/l)	(mg/l)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)
104	|---			----------		----------			
105	|As	0.03	0.10	0.0	0.002	0.00	0.00	0.00	0.00
106	|Cd	0.03	0.10	0.0	0.003	0.00	0.00	0.00	0.00
107	|Cr VI	0.03	0.10	0.1	0.060	0.00	0.01	0.00	0.01

108	|Pb-210	0.03	0.10	1.7	1.700	0.05	0.17	0.05	0.17
109	|Mo	0.03	0.10	0.3	0.260	0.01	0.03	0.01	0.03
110	|NO3	0.03	0.25	8.9	8.860	0.25	2.22	0.25	2.22
111	|Po-210	0.03	0.10	0.4	0.400	0.01	0.04	0.01	0.04
112	|Ra-226+8	0.03	0.10	1.5	1.500	0.04	0.15	0.04	0.15
113	|Se	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
114	|SO4	0.03	0.10	88.5	75.300	2.53	8.85	2.15	7.53

1

2 Site Name: Monument Valley, AZ, DeChelly

115	|Th-230	0.03	0.10	0.5	0.500	0.01	0.05	0.01	0.05
116	|U	0.03	0.10	0.1	0.050	0.00	0.01	0.00	0.01
117	|V	0.03	0.10	0.6	0.600	0.02	0.06	0.02	0.06
118	|Ra-226	0.03	0.10	1.5	1.500	0.04	0.15	0.04	0.15
119	|Ra-228	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00

120 ---------- ----------

121

122 Calculated Risks - Subchronic

123 ----------

124	|	AIS								
125	|Chemical	Toxicity	Receptor	Receptor	Receptor	Receptor	Monitor	Monitor	Monitor	Monitor
126	|	(mg/kg/day)	Adult-Gross	Child-Gross	Adult-Net	Child-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
127	|---------									
128	|As	1.40E-03					0.0	0.1	0.0	
129	|Cd	1.20E-03					NA	0.3	NA	
130	|Cr VI	2.50E-02					0.1	NA	0.1	
131	|Pb-210						NA	NA	NA	
132	|Mo						NA	NA	NA	
133	|NO3	1.10E+01					NA	0.2	NA	
134	|Po-210						NA	NA	NA	
135	|Ra-226+8						NA	NA	NA	
136	|Se	3.20E-03					0.0	NA	0.0	
137	|SO4						NA	NA	NA	
138	|Th-230						NA	NA	NA	
139	|U						NA	NA	NA	
140	|V	1.00E-02					1.7	6.0	1.7	
141	|Ra-226						NA	NA	NA	
142	|Ra-228						NA	NA	NA	

143 ----------

144

145 Calculated Risks - Chronic

146 ----------

147	|	AIC								
148	|Chemical	Toxicity	Receptor	Receptor	Receptor	Receptor	Monitor	Monitor	Monitor	Monitor
149	|	(mg/kg/day)	Adult-Gross	Child-Gross	Adult-Net	Child-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
150	|---------									
151	|As	1.40E-03					0.0	0.1	0.0	
152	|Cd	2.90E-04					0.3	1.0	0.3	
153	|Cr VI	5.00E-03					0.3	NA	0.3	
154	|Pb-210						NA	NA	NA	
155	|Mo	2.90E-03					2.6	9.0	2.6	

156 |NO3	1.26E+00			0.2	NA	0.2	NA
157 |Pe-210				NA	NA	NA	NA
158 |Ra-226+8				NA	NA	NA	NA
159 |Se	3.00E-03			0.0	NA	0.0	NA
160 |SO4	4.00E+01			NA	0.2	NA	0.2
161 |Th-230				NA	NA	NA	NA
162 |U	1.70E-03			0.9	3.0	0.8	3.0
163 |V	2.00E-02			0.9	NA	0.9	NA
164 |Ra-226				NA	NA	NA	NA
165 |Ra-228				NA	NA	NA	NA

166 ----------

167

168 Calculated Risks - Cancer/EPA Potency Estimates

1

2 Site Name: Monument Valley, AZ, DeChelly

169 ----------

	Potency				
170 |					
171 |Chemical	(mg/kg/day)	Receptor	Receptor	Monitor	Monitor
172 |	(pCi/kg/day)	Adult-Gross	Adult-Net	Adult-Gross	Adult-Net
173 |---------					
174 |As	1.50E+01			8.57E-04	8.57E-04
175 |Cd	NA			NA	NA
176 |Cr VI	NA			NA	NA
177 |Pb-210	1.40E-04			6.80E-06	6.80E-06
178 |Mo	NA			NA	NA
179 |NO3	NA			NA	NA
180 |Po-210	3.68E-04			4.21E-06	4.21E-06
181 |Ra-226+8				1.32E-05	1.32E-05
182 |Se	NA			NA	NA
183 |SO4	NA			NA	NA
184 |Th-230	7.70E-05			1.10E-06	1.10E-06
185 |U-nat	4.73E-05			4.74E-05	4.63E-05
186 |V	NA			NA	NA
187 |Ra-226	3.08E-04			1.32E-05	1.32E-05
188 |Ra-228	2.31E-04			0.00E+00	0.00E+00

189 ----------

190

191 Calculated Risks - Cancer/ICRP Potency Estimates

192 ----------

	Potency				
193 |					
194 |Chemical	(mg/kg/day)	Receptor	Receptor	Monitor	Monitor
195 |	(pCi/kg/day)	Adult-Gross	Gross-Net	Adult-Gross	Adult-Net
196 |---------					
197 |As	1.50E+01			8.57E-04	8.57E-04
198 |Cd	NA			NA	NA
199 |Cr VI	NA			NA	NA
200 |Pb-210	1.14E-03			5.54E-05	5.54E-05
201 |Mo	NA			NA	NA
202 |NO3	NA			NA	NA
203 |Po-210	3.65E-04			4.17E-06	4.17E-06

204	|Ra-226+D		1.06E-05	1.06E-05
205	|Se	NA	NA	NA
206	|SO4	NA	NA	NA
207	|Th-230	1.18E-04	1.69E-06	1.69E-06
208	|U-nat	5.49E-05	5.50E-05	5.37E-05
209	|V	NA	NA	NA
210	|Ra-226	2.47E-04	1.06E-05	1.06E-05
211	|Ra-228	2.77E-04	0.00E+00	0.00E+00
212	----------			

Site Name: Riverton, WY, Unconfined

Measured Concentrations - Receptor Wells

Chemical	Units	RECEPTOR WELLS High Concen.	+/-
As	mg/l		
Cd	mg/l		
Cr VI	mg/l		
Pb-210	pCi/l		
Mo	mg/l		
NO3	mg/l		
Po-210	pCi/l		
Ra-226+8	pCi/l		
Se	mg/l		
SO4	mg/l		
Th-230	pCi/l		
U	mg/l		
V	mg/l		
Ra-226	pCi/l		
Ra-228	pCi/l		

Measured Concentrations - Monitor Wells

Chemical	Units	Monitor Wells High Concen.	+/-
As	mg/l	0.020	
Cd	mg/l	0.0065	
Cr VI	mg/l	0.031	
Pb-210	pCi/l	2.0	
Mo	mg/l	0.800	
NO3	mg/l	10.5	
Po-210	pCi/l		
Ra-226+8	pCi/l	0.2	
Se	mg/l	0.127	
SO4	mg/l	6000	
Th-230	pCi/l	13	
U	mg/l	2.300	
V	mg/l	0.010	
Ra-226	pCi/l	0.2	
Ra-228	pCi/l		

Measured Concentrations - Background Wells

Chemical	Units	Background Wells Low Concen.	+/-
As	mg/l	0.007	-0.01

60 |Cd	mg/l	-0.005		-0.001		

1						
2 Site Name: Riverton, WY, Unconfined						
61 |Cr VI	mg/l	-0.01		-0.01		
62 |Pb-210	pCi/l	0.90	0.90	-1.5		
63 |Mo	mg/l	1.38		-0.01		
64 |NO3	mg/l	13.00		-0.1		
65 |Po-210	pCi/l	0.10	0.60	0.0		
66 |Ra-226+8	pCi/l	0.2		0.0		
67 |Se	mg/l	0.005		-0.005		
68 |SO4	mg/l	582		33		
69 |Th-230	pCi/l	0.5	0.6	-1		
70 |U	mg/l	0.0156		-0.003		
71 |V	mg/l	0.04		-0.01		
72 |Ra-226	pCi/l	0.2	0.2	0.0	0.3	
73 |Ra-228	pCi/l	0.00	0.90	0.00	0.9	
74 ----------			----------	----------	----------	
75						
76 Calculated Water Intakes - Receptors						
77 ----------		----------				

78 |	Adult	Child	Receptor	Receptor	Receptor	Receptor	Receptor	Receptor
79 |Chemical	In Factor	In Factor	Conc-Gross	Conc-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
80 |	(l/kg/day)	(l/kg/day)	(mg/l)	(mg/l)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)
81 |---------			----------		----------			
82 |As	0.03	0.10						
83 |Cd	0.03	0.10						
84 |Cr VI	0.03	0.10						
85 |Pb-210	0.03	0.10						
86 |Mo	0.03	0.10						
87 |NO3	0.03	0.25						
88 |Po-210	0.03	0.10						
89 |Ra-226+8	0.03	0.10						
90 |Se	0.03	0.10						
91 |SO4	0.03	0.10						
92 |Th-230	0.03	0.10						
93 |U	0.03	0.10						
94 |V	0.03	0.10						
95 |Ra-226	0.03	0.10						
96 |Ra-228	0.03	0.10						
97 ----------		----------						
98								
99 Calculated Water Intakes - Monitor								
100 ----------		----------						

101 |	Adult	Child	Monitor	Monitor	Monitor	Monitor	Monitor	Monitor
102 |Chemical	In Factor	In Factor	Conc-Gross	Conc-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
103 |	(l/kg/day)	(l/kg/day)	(mg/l)	(mg/l)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)
104 |---------			----------		----------			
105 |As	0.03	0.10	0.0	0.020	0.00	0.00	0.00	0.00
106 |Cd	0.03	0.10	0.0	0.007	0.00	0.00	0.00	0.00
107 |Cr VI	0.03	0.10	0.0	0.031	0.00	0.00	0.00	0.00

108	|Pb-210	0.03	0.10	2.0	2.000	0.06	0.20	0.06	0.20
109	|Mo	0.03	0.10	0.8	0.800	0.02	0.08	0.02	0.08
110	|NO3	0.03	0.25	10.5	10.500	0.30	2.63	0.30	2.63
111	|Po-210	0.03	0.10						
112	|Ra-226+8	0.03	0.10	0.2	0.200	0.01	0.02	0.01	0.02
113	|Se	0.03	0.10	0.1	0.127	0.00	0.01	0.00	0.01
114	|SO4	0.03	0.10	6000.0	5967.000	171.42	600.00	170.48	596.70

1

2 Site Name: Riverton, WY, Unconfined

115	|Th-230	0.03	0.10	13.0	13.000	0.37	1.30	0.37	1.30
116	|U	0.03	0.10	2.3	2.300	0.07	0.23	0.07	0.23
117	|V	0.03	0.10	0.0	0.010	0.00	0.00	0.00	0.00
118	|Ra-226	0.03	0.10	0.2	0.200	0.01	0.02	0.01	0.02
119	|Ra-228	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00

120 ---------- ----------

121

122 Calculated Risks - Subchronic

123 ----------

124	|	AIS								
125	|Chemical	Toxicity	Receptor	Receptor	Receptor	Receptor	Monitor	Monitor	Monitor	Monitor
126	|	(mg/kg/day)	Adult-Gross	Child-Gross	Adult-Net	Child-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
127	|---------									
128	|As	1.40E-03					0.4	1.4	0.4	1.4
129	|Cd	1.20E-03					NA	0.5	NA	0.5
130	|Cr VI	2.50E-02					0.0	NA	0.0	NA
131	|Pb-210						NA	NA	NA	NA
132	|Mo						NA	NA	NA	NA
133	|NO3	1.10E+01					NA	0.2	NA	0.2
134	|Po-210									
135	|Ra-226+8						NA	NA	NA	NA
136	|Se	3.20E-03					1.1	NA	1.1	NA
137	|SO4						NA	NA	NA	NA
138	|Th-230						NA	NA	NA	NA
139	|U						NA	NA	NA	NA
140	|V	1.00E-02					0.0	0.1	0.0	0.1
141	|Ra-226						NA	NA	NA	NA
142	|Ra-228						NA	NA	NA	NA

143 ----------

144

145 Calculated Risks - Chronic

146 ----------

147	|	AIC								
148	|Chemical	Toxicity	Receptor	Receptor	Receptor	Receptor	Monitor	Monitor	Monitor	Monitor
149	|	(mg/kg/day)	Adult-Gross	Child-Gross	Adult-Net	Child-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
150	|---------									
151	|As	1.40E-03					0.4	1.4	0.4	1.4
152	|Cd	2.90E-04					0.6	2.2	0.6	2.2
153	|Cr VI	5.00E-03					0.2	NA	0.2	NA
154	|Pb-210						NA	NA	NA	NA
155	|Mo	2.90E-03					7.9	27.6	7.9	27.6

156 |NO3	1.26E+00			0.2	NA	0.2	NA
157 |Po-210							
158 |Ra-226+8				NA	NA	NA	NA
159 |Se	3.00E-03			1.2	NA	1.2	NA
160 |SO4	4.00E+01			NA	15.0	NA	14.9
161 |Th-230				NA	NA	NA	NA
162 |U	1.70E-03			38.7	135.3	38.7	135.3
163 |V	2.00E-02			0.0	NA	0.0	NA
164 |Ra-226				NA	NA	NA	NA
165 |Ra-228				NA	NA	NA	NA

166 ----------

167

168 Calculated Risks - Cancer/EPA Potency Estimates

1

2 Site Name: Riverton, WY, Unconfined

169 ----------

170 |	Potency				
171 |Chemical	(mg/kg/day)	Receptor	Receptor	Monitor	Monitor
172 |	(pCi/kg/day)	Adult-Gross	Adult-Net	Adult-Gross	Adult-Net
173 |---------					
174 |As	1.50E+01			8.57E-03	8.57E-03
175 |Cd	NA			NA	NA
176 |Cr VI	NA			NA	NA
177 |Pb-210	1.40E-04			8.00E-06	8.00E-06
178 |Mo	NA			NA	NA
179 |NO3	NA			NA	NA
180 |Po-210	3.68E-04				
181 |Ra-226+8				1.76E-06	1.76E-06
182 |Se	NA			NA	NA
183 |SO4	NA			NA	NA
184 |Th-230	7.70E-05			2.86E-05	2.86E-05
185 |U-nat	4.73E-05			2.12E-03	2.12E-03
186 |V	NA			NA	NA
187 |Ra-226	3.08E-04			1.76E-06	1.76E-06
188 |Ra-228	2.31E-04			0.00E+00	0.00E+00

189 ----------

190

191 Calculated Risks - Cancer/ICRP Potency Estimates

192 ----------

193 |	Potency				
194 |Chemical	(mg/kg/day)	Receptor	Receptor	Monitor	Monitor
195 |	(pCi/kg/day)	Adult-Gross	Gross-Net	Adult-Gross	Adult-Net
196 |---------					
197 |As	1.50E+01			8.57E-03	8.57E-03
198 |Cd	NA			NA	NA
199 |Cr VI	NA			NA	NA
200 |Pb-210	1.14E-03			6.51E-05	6.51E-05
201 |Mo	NA			NA	NA
202 |NO3	NA			NA	NA
203 |Po-210	3.65E-04				

204	|Ra-226+D		1.61E-06	1.61E-06
205	|Se	NA	NA	NA
206	|SO4	NA	NA	NA
207	|Th-230	1.18E-04	4.38E-05	4.38E-05
208	|U-nat	5.49E-05	2.46E-03	2.46E-03
209	|V	NA	NA	NA
210	|Ra-226	2.47E-04	1.41E-06	1.41E-06
211	|Ra-228	2.77E-04	0.00E+00	0.00E+00
212	----------			

Site Name: Riverton, WY, Confined

Measured Concentrations - Receptor Wells

Chemical	Units	RECEPTOR WELLS High Concen.	+/-
As	mg/l	-0.10	
Cd	mg/l	-0.005	
Cr VI	mg/l	-0.010	
Pb-210	pCi/l	1.8	
Mo	mg/l	0.040	
NO3	mg/l	22.0	
Po-210	pCi/l		
Ra-226+8	pCi/l	1.4	
Se	mg/l	-0.005	
SO4	mg/l	691	
Th-230	pCi/l	0.4	
U	mg/l	0.2370	
V	mg/l	-0.010	
Ra-226	pCi/l	0.7	0.4
Ra-228	pCi/l	0.7	

Measured Concentrations - Monitor Wells

Chemical	Units	Monitor Wells High Concen.	+/-
As	mg/l	0.006	
Cd	mg/l	-0.005	
Cr VI	mg/l	0.03	
Pb-210	pCi/l	1.20	0.9
Mo	mg/l	0.16	
NO3	mg/l	31.00	
Po-210	pCi/l	0	0.6
Ra-226+8	pCi/l	1.9	
Se	mg/l	0.015	
SO4	mg/l	1300	
Th-230	pCi/l	0.2	0.5
U	mg/l	0.0066	
V	mg/l	0.060	
Ra-226	pCi/l	1.0	0.4
Ra-228	pCi/l	0.9	1.3

Measured Concentrations - Background Wells

Chemical	Units	Background Wells Low Concen.	+/-
As	mg/l	-0.001	

60 |Cd	mg/l		-0.001		

1

2 Site Name: Riverton, WY, Confined

61 |Cr VI	mg/l		-0.001		
62 |Pb-210	pCi/l		0.0	1.3	
63 |Mo	mg/l		-0.001		
64 |NO3	mg/l		-0.1		
65 |Po-210	pCi/l		0.0		
66 |Ra-226+8	pCi/l		-1.0		
67 |Se	mg/l		-0.002		
68 |SO4	mg/l		80.3		
69 |Th-230	pCi/l		0.0	0.0004	
70 |U	mg/l		-0.0003		
71 |V	mg/l		-0.004		
72 |Ra-226	pCi/l		-1.0		
73 |Ra-228	pCi/l		-1		
74 ----------		----------	----------	----------	

75

76 Calculated Water Intakes - Receptors

77 ---------- ----------

78 |	Adult	Child	Receptor	Receptor	Receptor	Receptor	Receptor	Receptor
79 |Chemical	In Factor	In Factor	Conc-Gross	Conc-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
80 |	(l/kg/day)	(l/kg/day)	(mg/l)	(mg/l)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)
81 |---------			----------		----------			
82 |As	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
83 |Cd	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
84 |Cr VI	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
85 |Pb-210	0.03	0.10	1.8	1.800	0.05	0.18	0.05	0.18
86 |Mo	0.03	0.10	0.0	0.040	0.00	0.00	0.00	0.00
87 |NO3	0.03	0.25	22.0	22.000	0.63	5.50	0.63	5.50
88 |Po-210	0.03	0.10						
89 |Ra-226+8	0.03	0.10	1.4	1.400	0.04	0.14	0.04	0.14
90 |Se	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
91 |SO4	0.03	0.10	691.0	610.700	19.74	69.10	17.45	61.07
92 |Th-230	0.03	0.10	0.4	0.400	0.01	0.04	0.01	0.04
93 |U	0.03	0.10	0.2	0.237	0.01	0.02	0.01	0.02
94 |V	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
95 |Ra-226	0.03	0.10	0.7	0.700	0.02	0.07	0.02	0.07
96 |Ra-228	0.03	0.10	0.7	0.700	0.02	0.07	0.02	0.07
97 ----------	----------							

98

99 Calculated Water Intakes - Monitor

100 ---------- ----------

101 |	Adult	Child	Monitor	Monitor	Monitor	Monitor	Monitor	Monitor
102 |Chemical	In Factor	In Factor	Conc-Gross	Conc-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
103 |	(l/kg/day)	(l/kg/day)	(mg/l)	(mg/l)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)	(mg/kg/day)
104 |---------			----------		----------			
105 |As	0.03	0.10	0.0	0.006	0.00	0.00	0.00	0.00
106 |Cd	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
107 |Cr VI	0.03	0.10	0.0	0.030	0.00	0.00	0.00	0.00

108	|Pb-210	0.03	0.10	1.2	1.200	0.03	0.12	0.03	0.12
109	|Mo	0.03	0.10	0.2	0.160	0.00	0.02	0.00	0.02
110	|NO3	0.03	0.25	31.0	31.000	0.89	7.75	0.89	7.75
111	|Po-210	0.03	0.10	0.0	0.000	0.00	0.00	0.00	0.00
112	|Ra-226+8	0.03	0.10	1.9	1.900	0.05	0.19	0.05	0.19
113	|Se	0.03	0.10	0.0	0.015	0.00	0.00	0.00	0.00
114	|SO4	0.03	0.10	1300.0	1219.700	37.14	130.00	34.85	121.97

1

2 Site Name: Riverton, WY, Confined

115	|Th-230	0.03	0.10	0.2	0.200	0.01	0.02	0.01	0.02
116	|U	0.03	0.10	0.0	0.007	0.00	0.00	0.00	0.00
117	|V	0.03	0.10	0.1	0.060	0.00	0.01	0.00	0.01
118	|Ra-226	0.03	0.10	1.0	1.000	0.03	0.10	0.03	0.10
119	|Ra-228	0.03	0.10	0.9	0.900	0.03	0.09	0.03	0.09

120 ---------- ----------

121

122 Calculated Risks - Subchronic

123 ----------

126	|	AIS								
125	|Chemical	Toxicity	Receptor	Receptor	Receptor	Receptor	Monitor	Monitor	Monitor	Monitor
126	|	(mg/kg/day)	Adult-Gross	Child-Gross	Adult-Net	Child-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
127	|---------									
128	|As	1.40E-03	0.0	0.0	0.0	0.0	0.1	0.4	0.1	0
129	|Cd	1.20E-03	NA	0.0	NA	0.0	NA	0.0	NA	0
130	|Cr VI	2.50E-02	0.0	NA	0.0	NA	0.0	NA	0.0	
131	|Pb-210		NA	NA	NA	NA	NA	NA	NA	
132	|Mo		NA	NA	NA	NA	NA	NA	NA	
133	|NO3	1.10E+01	NA	0.5	NA	0.5	NA	0.7	NA	0
134	|Po-210						NA	NA	NA	
135	|Ra-226+8		NA	NA	NA	NA	NA	NA	NA	
136	|Se	3.20E-03	0.0	NA	0.0	NA	0.1	NA	0.1	
137	|SO4		NA	NA	NA	NA	NA	NA	NA	
138	|Th-230		NA	NA	NA	NA	NA	NA	NA	
139	|U		NA	NA	NA	NA	NA	NA	NA	
140	|V	1.00E-02	0.0	0.0	0.0	0.0	0.2	0.6	0.2	
141	|Ra-226		NA	NA	NA	NA	NA	NA	NA	
142	|Ra-228		NA	NA	NA	NA	NA	NA	NA	

143 ----------

144

145 Calculated Risks - Chronic

146 ----------

147	|	AIC								
148	|Chemical	Toxicity	Receptor	Receptor	Receptor	Receptor	Monitor	Monitor	Monitor	Monitor
149	|	(mg/kg/day)	Adult-Gross	Child-Gross	Adult-Net	Child-Net	Adult-Gross	Child-Gross	Adult-Net	Child-Net
150	|---------									
151	|As	1.40E-03	0.0	0.0	0.0	0.0	0.1	0.4	0.1	
152	|Cd	2.90E-04	0.0	NA	0.0	0.0	0.0	0.0	0.0	
153	|Cr VI	5.00E-03	0.0	NA	0.0	NA	0.2	NA	0.2	
154	|Pb-210		NA	NA	NA	NA	NA	NA	NA	
155	|Mo	2.90E-03	0.4	1.4	0.4	1.4	1.6	5.5	1.6	

156 |NO3	1.26E+00	0.5	NA	0.5	NA	0.7	NA	0.7	NA
157 |Pe-210						NA	NA	NA	NA
158 |Ra-226+8		NA	NA	NA	NA	NA	NA	NA	NA
159 |Se	3.00E-03	0.0	NA	0.0	NA	0.1	NA	0.1	NA
160 |SO4	4.00E+01	NA	1.7	NA	1.5	NA	3.3	NA	3.0
161 |Th-230		NA	NA	NA	NA	NA	NA	NA	NA
162 |U	1.70E-03	4.0	13.9	4.0	13.9	0.1	0.4	0.1	0.4
163 |V	2.00E-02	0.0	NA	0.0	NA	0.1	NA	0.1	NA
164 |Ra-226		NA	NA	NA	NA	NA	NA	NA	NA
165 |Ra-228		NA	NA	NA	NA	NA	NA	NA	NA

166 ----------

167

168 Calculated Risks - Cancer/EPA Potency Estimates

1

2 Site Name: Riverton, WY, Confined

169 ----------

170 |	Potency				
171 |Chemical	(mg/kg/day)	Receptor	Receptor	Monitor	Monitor
172 |	(pCi/kg/day)	Adult-Gross	Adult-Net	Adult-Gross	Adult-Net
173 |---------					
174 |As	1.50E+01	0.00E+00	0.00E+00	2.57E-03	2.57E-03
175 |Cd	NA	NA	NA	NA	NA
176 |Cr VI	NA	NA	NA	NA	NA
177 |Pb-210	1.40E-04	7.20E-06	7.20E-06	4.80E-06	4.80E-06
178 |Mo	NA	NA	NA	NA	NA
179 |NO3	NA	NA	NA	NA	NA
180 |Po-210	3.68E-04			0.00E+00	0.00E+00
181 |Ra-226+8		1.08E-05	1.08E-05	1.47E-05	1.47E-05
182 |Se	NA	NA	NA	NA	NA
183 |SO4	NA	NA	NA	NA	NA
184 |Th-230	7.70E-05	8.80E-07	8.80E-07	4.40E-07	4.40E-07
185 |U-nat	4.73E-05	2.18E-04	2.18E-04	6.08E-06	6.08E-06
186 |V	NA	NA	NA	NA	NA
187 |Ra-226	3.08E-04	6.16E-06	6.16E-06	8.80E-06	8.80E-06
188 |Ra-228	2.31E-04	4.62E-06	4.62E-06	5.94E-06	5.94E-06

189 ----------

190

191 Calculated Risks - Cancer/ICRP Potency Estimates

192 ----------

193 |	Potency				
194 |Chemical	(mg/kg/day)	Receptor	Receptor	Monitor	Monitor
195 |	(pCi/kg/day)	Adult-Gross	Gross-Net	Adult-Gross	Adult-Net
196 |---------					
197 |As	1.50E+01	0.00E+00	0.00E+00	2.57E-03	2.57E-03
198 |Cd	NA	NA	NA	NA	NA
199 |Cr VI	NA	NA	NA	NA	NA
200 |Pb-210	1.14E-03	5.86E-05	5.86E-05	3.91E-05	3.91E-05
201 |Mo	NA	NA	NA	NA	NA
202 |NO3	NA	NA	NA	NA	NA
203 |Po-210	3.65E-04			0.00E+00	0.00E+00

204	|Ra-226+B		1.05E-05	1.05E-05	1.42E-05	1.42E-05
205	|Se	NA	NA	NA	NA	NA
206	|SO4	NA	NA	NA	NA	NA
207	|Th-230	1.18E-04	1.35E-06	1.35E-06	6.74E-07	6.74E-07
208	|U-nat	5.49E-05	2.53E-04	2.53E-04	7.06E-06	7.06E-06
209	|V	NA	NA	NA	NA	NA
210	|Ra-226	2.47E-04	4.94E-06	4.94E-06	7.06E-06	7.06E-06
211	|Ra-228	2.77E-04	5.54E-06	5.54E-06	7.12E-06	7.12E-06
212	----------					

APPENDIX D - Critical Evaluation of EPA and ICRP Cancer Risk Models

Preliminary evaluation of the EPA and ICRP model predictions shows that they may be in error by large amounts. For illustration, only a brief discussion of radium-226 will be made in this paper. Table D-1 gives the lifetime excess risk of ingesting 2 pCi per day of radium-226 for life as predicted by the EPA model [51FR34859]. In particular the distribution of cancers should be noted. The EPA model predicts comparable amounts for leukemia, bone sarcoma, and other neoplasms (42%, 10%, and 48% respectively).

In contrast, evaluation of direct human data shows a different magnitude of effect and a different distribution by site. Follow-up of radium dial painters found significant excess bone sarcomas and carcinomas of the paranasal sinuses and mastoid air cells. The latter may be due to radon-222 which is the first decay product of radium-226. The best fits of the data by the BEIR IV Committee are a pure quadratic function versus systemic intake of Ra-226 for bone sarcoma and a linear function for sinus cavity carcinomas. An alternate form for bone sarcomas would be a threshold at intake levels well above possible environmental exposures. Excess leukemia and other neoplasms were not observed even at the high levels of exposure suffered. Table D-1 shows the predictions of the dose-response functions derived by BEIR IV at 1 pCi/l. (The uncertainty due to extrapolating to such low exposures is very large.) They are completely different from the EPA predictions both in magnitude and organ distribution.

These observations are important in terms of uranium drinking water standards as well. Since no direct evidence is available on the effects of ingesting uranium, regulation of uranium concentrations is based on analogy with radium [51FR34846].

TABLE D-1
Risk per pCi/l for Radium-226 (f_1=0.20)

Organ	Effect	Lifetime Risk per Million Persons	
		EPA	BEIR IV
Red Bone Marrow	Leukemia	3.74	~ 0
Endosteal Bone	Bone Cancer	0.88	1.4 E-04
Sinus Cavities		0.	1.8 E-02
Other		4.18	~ 0

BEIR IV CHAPTER IV MODEL OF BONE SARCOMA FROM RA-226 INTAKE

Systemic intake is summed through a given year.
The excess risk in that year is then calculated.
The calculation then proceeds to the next year.

Unity life table through age 70

1 pCi/l	drinking water concentration
2 l/day	consumption rate
365.25 d/y	days per year
730.5 pCi/y	annual consumption
7.305E-04 uCi/y	
0.2	f1 -- gut absorption factor
1.461E-04	annual systemic intake

*** Bone Sarcomas ***

I = (6.8 +- 0.6) 10E-08 DE+02

(excess only, no cell killing)

I	bone sarcomas per person year at risk
D	systemic intake in microcuries

6.80E-08 quadratic dose coefficient

age	cum D	(cum D)E+02 5 years	lagged	risk/y	cum risk
0	0.000E+00	0.000E+00	0.000E+00	0.00E+00	0.00E+00
1	1.461E-04	2.135E-08	0.000E+00	0.00E+00	0.00E+00
2	2.922E-04	8.538E-08	0.000E+00	0.00E+00	0.00E+00
3	4.383E-04	1.921E-07	0.000E+00	0.00E+00	0.00E+00
4	5.844E-04	3.415E-07	0.000E+00	0.00E+00	0.00E+00
5	7.305E-04	5.336E-07	0.000E+00	0.00E+00	0.00E+00
6	8.766E-04	7.684E-07	2.135E-08	1.45E-15	1.45E-15
7	1.023E-03	1.046E-06	8.538E-08	5.81E-15	7.26E-15
8	1.169E-03	1.366E-06	1.921E-07	1.31E-14	2.03E-14
9	1.315E-03	1.729E-06	3.415E-07	2.32E-14	4.35E-14
10	1.461E-03	2.135E-06	5.336E-07	3.63E-14	7.98E-14
11	1.607E-03	2.583E-06	7.684E-07	5.23E-14	1.32E-13
12	1.753E-03	3.074E-06	1.046E-06	7.11E-14	2.03E-13
13	1.899E-03	3.607E-06	1.366E-06	9.29E-14	2.96E-13
14	2.045E-03	4.184E-06	1.729E-06	1.18E-13	4.14E-13
15	2.192E-03	4.803E-06	2.135E-06	1.45E-13	5.59E-13

16	2.338E-03	5.464E-06	2.583E-06	1.76E-13	7.34E-13
17	2.484E-03	6.169E-06	3.074E-06	2.09E-13	9.43E-13
18	2.630E-03	6.916E-06	3.607E-06	2.45E-13	1.19E-12
19	2.776E-03	7.706E-06	4.184E-06	2.84E-13	1.47E-12
20	2.922E-03	8.538E-06	4.803E-06	3.27E-13	1.80E-12
21	3.068E-03	9.413E-06	5.464E-06	3.72E-13	2.17E-12
22	3.214E-03	1.033E-05	6.169E-06	4.19E-13	2.59E-12
23	3.360E-03	1.129E-05	6.916E-06	4.70E-13	3.06E-12
24	3.506E-03	1.229E-05	7.706E-06	5.24E-13	3.59E-12
25	3.653E-03	1.334E-05	8.538E-06	5.81E-13	4.17E-12
26	3.799E-03	1.443E-05	9.413E-06	6.40E-13	4.81E-12
27	3.945E-03	1.556E-05	1.033E-05	7.03E-13	5.51E-12
28	4.091E-03	1.673E-05	1.129E-05	7.68E-13	6.28E-12
29	4.237E-03	1.795E-05	1.229E-05	8.36E-13	7.11E-12
30	4.383E-03	1.921E-05	1.334E-05	9.07E-13	8.02E-12
31	4.529E-03	2.051E-05	1.443E-05	9.81E-13	9.00E-12
32	4.675E-03	2.186E-05	1.556E-05	1.06E-12	1.01E-11
33	4.821E-03	2.324E-05	1.673E-05	1.14E-12	1.12E-11
34	4.967E-03	2.468E-05	1.795E-05	1.22E-12	1.24E-11
35	5.114E-03	2.615E-05	1.921E-05	1.31E-12	1.37E-11
36	5.260E-03	2.766E-05	2.051E-05	1.39E-12	1.51E-11
37	5.406E-03	2.922E-05	2.186E-05	1.49E-12	1.66E-11
38	5.552E-03	3.082E-05	2.324E-05	1.58E-12	1.82E-11
39	5.698E-03	3.247E-05	2.468E-05	1.68E-12	1.99E-11
40	5.844E-03	3.415E-05	2.615E-05	1.78E-12	2.16E-11
41	5.990E-03	3.588E-05	2.766E-05	1.88E-12	2.35E-11
42	6.136E-03	3.765E-05	2.922E-05	1.99E-12	2.55E-11
43	6.282E-03	3.947E-05	3.082E-05	2.10E-12	2.76E-11
44	6.428E-03	4.132E-05	3.247E-05	2.21E-12	2.98E-11
45	6.574E-03	4.322E-05	3.415E-05	2.32E-12	3.21E-11
46	6.721E-03	4.517E-05	3.588E-05	2.44E-12	3.46E-11
47	6.867E-03	4.715E-05	3.765E-05	2.56E-12	3.71E-11
48	7.013E-03	4.918E-05	3.947E-05	2.68E-12	3.98E-11
49	7.159E-03	5.125E-05	4.132E-05	2.81E-12	4.26E-11
50	7.305E-03	5.336E-05	4.322E-05	2.94E-12	4.56E-11
51	7.451E-03	5.552E-05	4.517E-05	3.07E-12	4.86E-11
52	7.597E-03	5.772E-05	4.715E-05	3.21E-12	5.18E-11
53	7.743E-03	5.996E-05	4.918E-05	3.34E-12	5.52E-11
54	7.889E-03	6.224E-05	5.125E-05	3.48E-12	5.87E-11
55	8.035E-03	6.457E-05	5.336E-05	3.63E-12	6.23E-11
56	8.182E-03	6.694E-05	5.552E-05	3.78E-12	6.61E-11
57	8.328E-03	6.935E-05	5.772E-05	3.92E-12	7.00E-11
58	8.474E-03	7.181E-05	5.996E-05	4.08E-12	7.41E-11
59	8.620E-03	7.430E-05	6.224E-05	4.23E-12	7.83E-11
60	8.766E-03	7.684E-05	6.457E-05	4.39E-12	8.27E-11
61	8.912E-03	7.943E-05	6.694E-05	4.55E-12	8.73E-11
62	9.058E-03	8.205E-05	6.935E-05	4.72E-12	9.20E-11
63	9.204E-03	8.472E-05	7.181E-05	4.88E-12	9.69E-11
64	9.350E-03	8.743E-05	7.430E-05	5.05E-12	1.02E-10
65	9.496E-03	9.018E-05	7.684E-05	5.23E-12	1.07E-10
66	9.643E-03	9.298E-05	7.943E-05	5.40E-12	1.13E-10

67	9.789E-03	9.582E-05	8.205E-05	5.58E-12	1.18E-10
68	9.935E-03	9.870E-05	8.472E-05	5.76E-12	1.24E-10
69	1.008E-02	1.016E-04	8.743E-05	5.95E-12	1.30E-10
70	1.023E-02	1.046E-04	9.018E-05	6.13E-12	1.36E-10

*** Paranasal Sinus and Mastoid Air Cell Carcinomas ***

I = (1.6 +- 0.2) 10E-05 D

(excess only, no cell killing)

I carcinomas per person year at risk
D systemic intake in microcuries

1.60E-05 linear dose coefficient

age	cum D	lagged 10 years	risk/y	cum risk
0	0.000E+00	0.000E+00	0.00E+00	0.00E+00
1	1.461E-04	0.000E+00	0.00E+00	0.00E+00
2	2.922E-04	0.000E+00	0.00E+00	0.00E+00
3	4.383E-04	0.000E+00	0.00E+00	0.00E+00
4	5.844E-04	0.000E+00	0.00E+00	0.00E+00
5	7.305E-04	0.000E+00	0.00E+00	0.00E+00
6	8.766E-04	0.000E+00	0.00E+00	0.00E+00
7	1.023E-03	0.000E+00	0.00E+00	0.00E+00
8	1.169E-03	0.000E+00	0.00E+00	0.00E+00
9	1.315E-03	0.000E+00	0.00E+00	0.00E+00
10	1.461E-03	0.000E+00	0.00E+00	0.00E+00
11	1.607E-03	1.461E-04	9.93E-12	9.93E-12
12	1.753E-03	2.922E-04	1.99E-11	2.98E-11
13	1.899E-03	4.383E-04	2.98E-11	5.96E-11
14	2.045E-03	5.844E-04	3.97E-11	9.93E-11
15	2.192E-03	7.305E-04	4.97E-11	1.49E-10
16	2.338E-03	8.766E-04	5.96E-11	2.09E-10
17	2.484E-03	1.023E-03	6.95E-11	2.78E-10
18	2.630E-03	1.169E-03	7.95E-11	3.58E-10
19	2.776E-03	1.315E-03	8.94E-11	4.47E-10
20	2.922E-03	1.461E-03	9.93E-11	5.46E-10
21	3.068E-03	1.607E-03	1.09E-10	6.56E-10
22	3.214E-03	1.753E-03	1.19E-10	7.75E-10
23	3.360E-03	1.899E-03	1.29E-10	9.04E-10
24	3.506E-03	2.045E-03	1.39E-10	1.04E-09
25	3.653E-03	2.192E-03	1.49E-10	1.19E-09
26	3.799E-03	2.338E-03	1.59E-10	1.35E-09
27	3.945E-03	2.484E-03	1.69E-10	1.52E-09
28	4.091E-03	2.630E-03	1.79E-10	1.70E-09
29	4.237E-03	2.776E-03	1.89E-10	1.89E-09
30	4.383E-03	2.922E-03	1.99E-10	2.09E-09
31	4.529E-03	3.068E-03	2.09E-10	2.29E-09
32	4.675E-03	3.214E-03	2.19E-10	2.51E-09

33	4.821E-03	3.360E-03	2.29E-10	2.74E-09
34	4.967E-03	3.506E-03	2.38E-10	2.98E-09
35	5.114E-03	3.653E-03	2.48E-10	3.23E-09
36	5.260E-03	3.799E-03	2.58E-10	3.49E-09
37	5.406E-03	3.945E-03	2.68E-10	3.76E-09
38	5.552E-03	4.091E-03	2.78E-10	4.03E-09
39	5.698E-03	4.237E-03	2.88E-10	4.32E-09
40	5.844E-03	4.383E-03	2.98E-10	4.62E-09
41	5.990E-03	4.529E-03	3.08E-10	4.93E-09
42	6.136E-03	4.675E-03	3.18E-10	5.25E-09
43	6.282E-03	4.821E-03	3.28E-10	5.57E-09
44	6.428E-03	4.967E-03	3.38E-10	5.91E-09
45	6.574E-03	5.114E-03	3.48E-10	6.26E-09
46	6.721E-03	5.260E-03	3.58E-10	6.62E-09
47	6.867E-03	5.406E-03	3.68E-10	6.98E-09
48	7.013E-03	5.552E-03	3.78E-10	7.36E-09
49	7.159E-03	5.698E-03	3.87E-10	7.75E-09
50	7.305E-03	5.844E-03	3.97E-10	8.15E-09
51	7.451E-03	5.990E-03	4.07E-10	8.55E-09
52	7.597E-03	6.136E-03	4.17E-10	8.97E-09
53	7.743E-03	6.282E-03	4.27E-10	9.40E-09
54	7.889E-03	6.428E-03	4.37E-10	9.84E-09
55	8.035E-03	6.574E-03	4.47E-10	1.03E-08
56	8.182E-03	6.721E-03	4.57E-10	1.07E-08
57	8.328E-03	6.867E-03	4.67E-10	1.12E-08
58	8.474E-03	7.013E-03	4.77E-10	1.17E-08
59	8.620E-03	7.159E-03	4.87E-10	1.22E-08
60	8.766E-03	7.305E-03	4.97E-10	1.27E-08
61	8.912E-03	7.451E-03	5.07E-10	1.32E-08
62	9.058E-03	7.597E-03	5.17E-10	1.37E-08
63	9.204E-03	7.743E-03	5.27E-10	1.42E-08
64	9.350E-03	7.889E-03	5.36E-10	1.48E-08
65	9.496E-03	8.035E-03	5.46E-10	1.53E-08
66	9.643E-03	8.182E-03	5.56E-10	1.59E-08
67	9.789E-03	8.328E-03	5.66E-10	1.64E-08
68	9.935E-03	8.474E-03	5.76E-10	1.70E-08
69	1.008E-02	8.620E-03	5.86E-10	1.76E-08
70	1.023E-02	8.766E-03	5.96E-10	1.82E-08