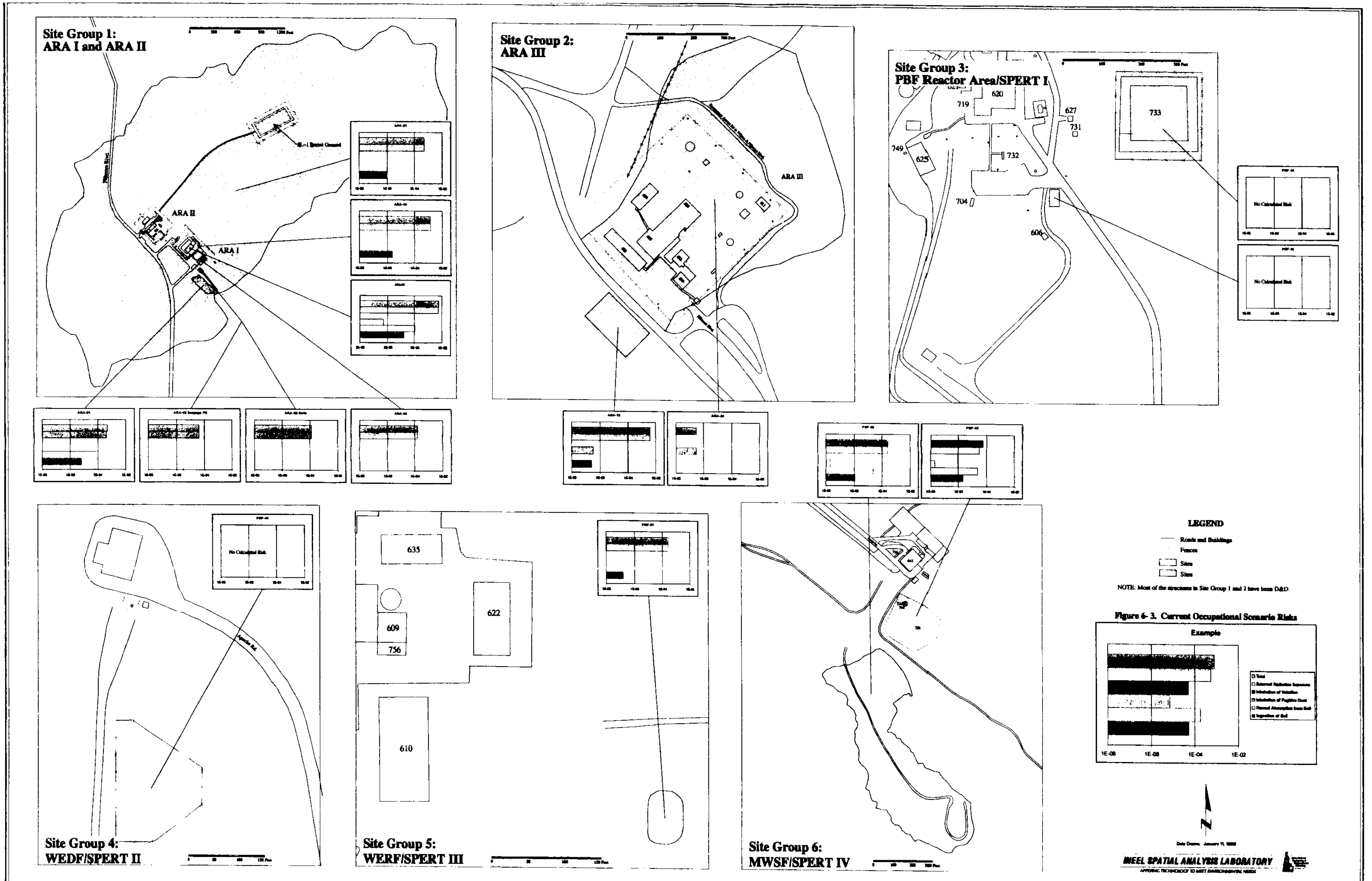

Figure 6-3. Current Occupational Scenario Risks

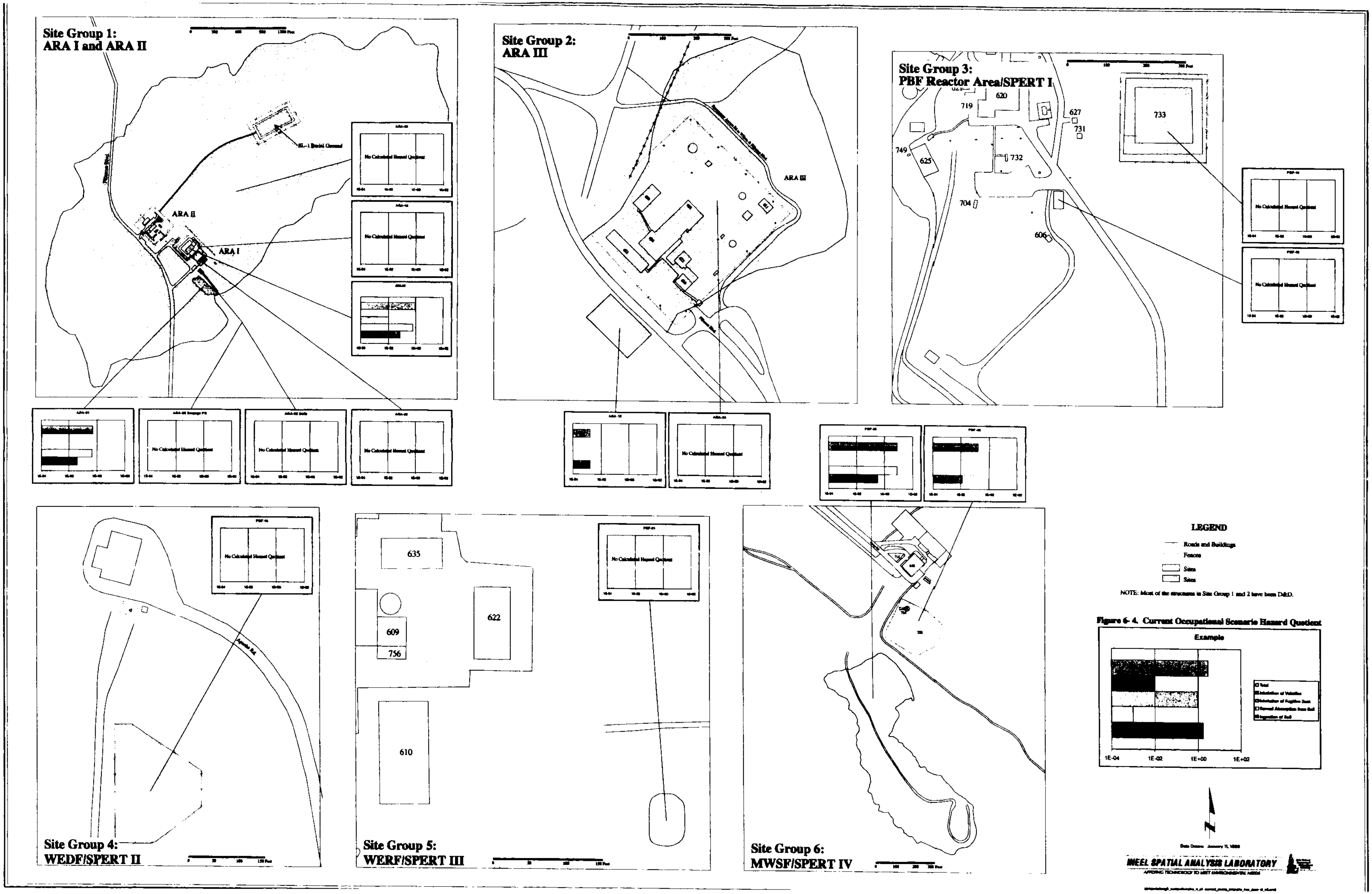

Figure 6-4. Current Occupational Scenario Hazard Quotient

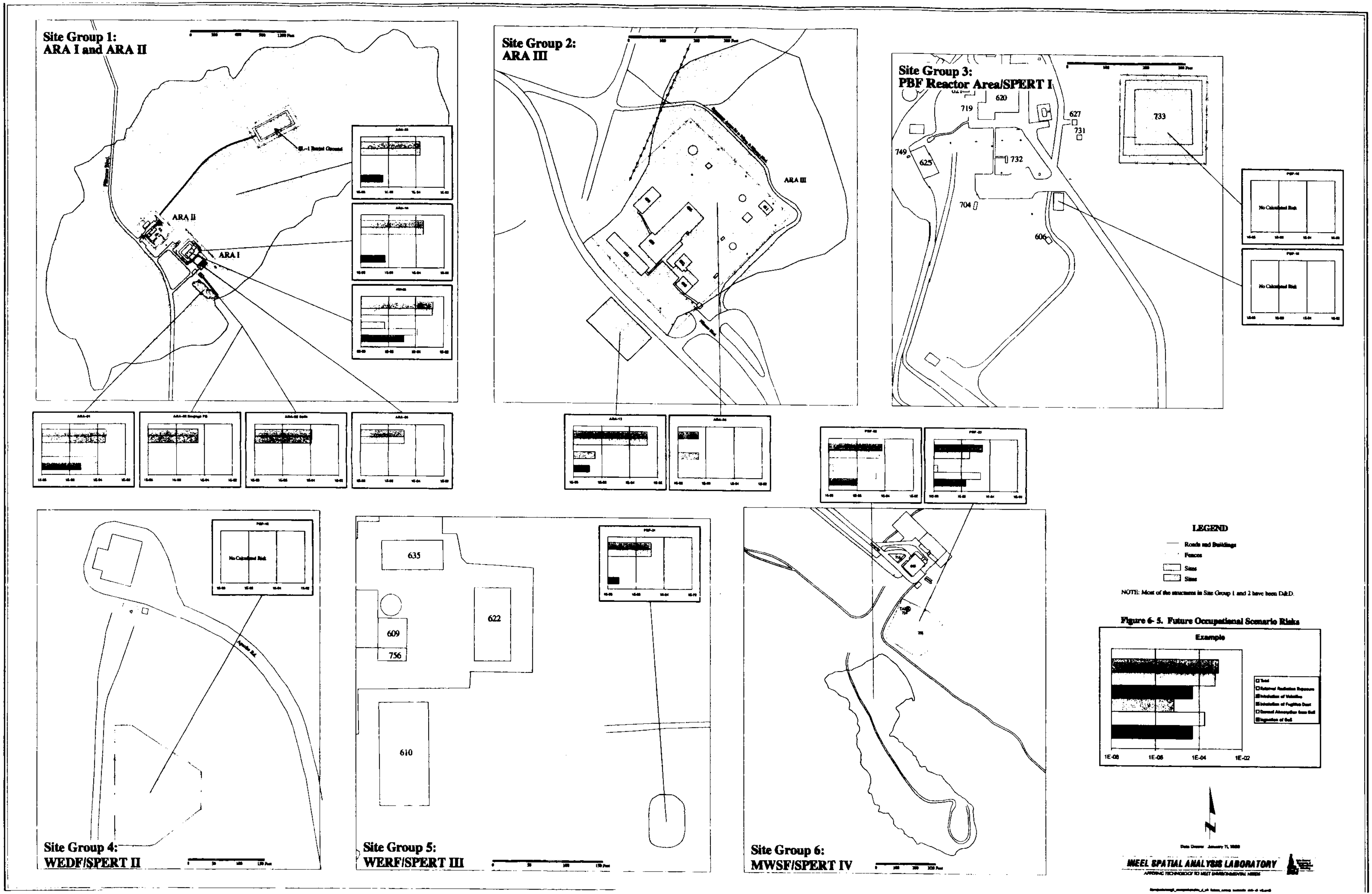

Figure 6-5. Future Occupational Scenario Risks

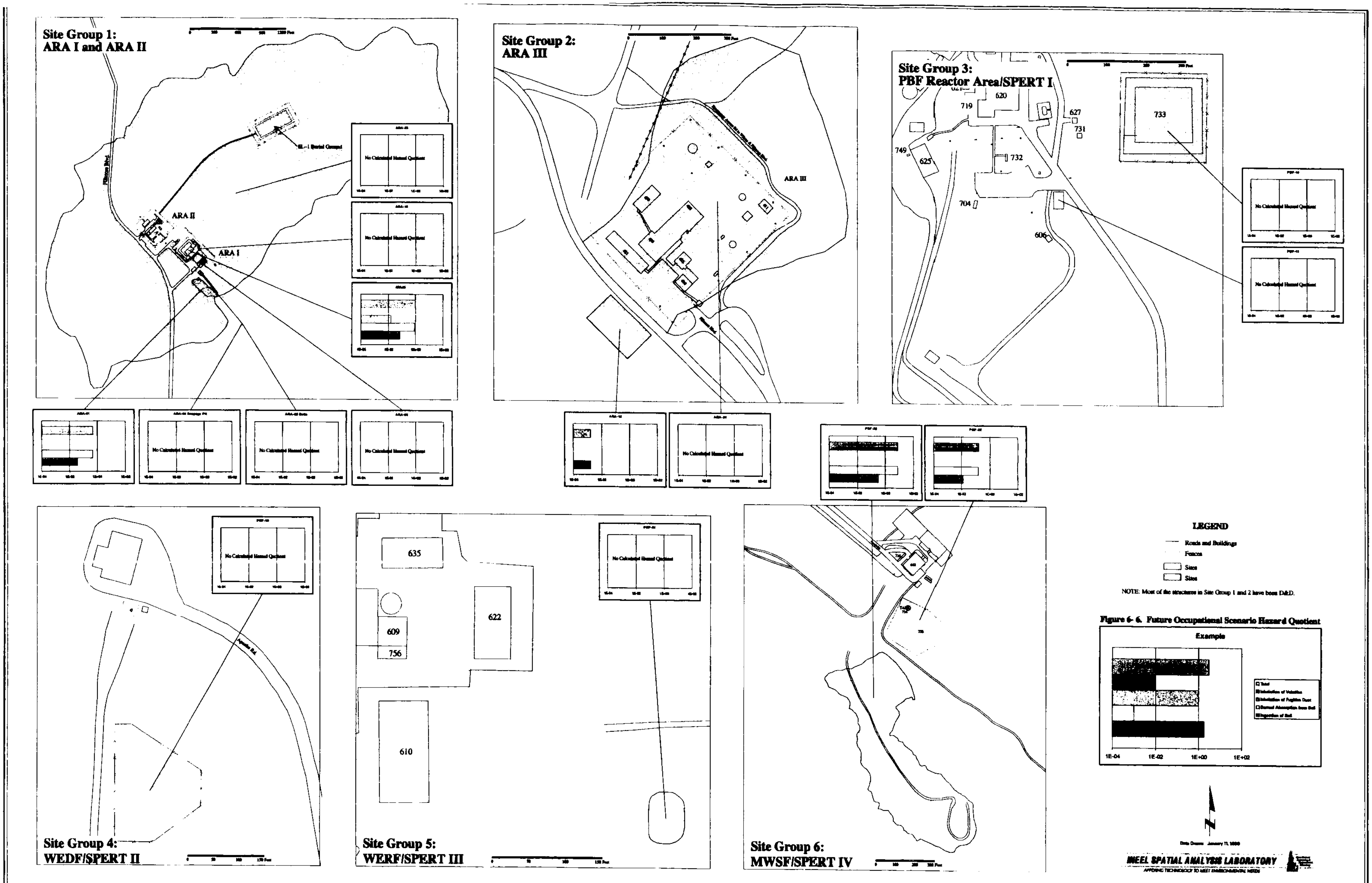

Figure 6- 6. Future Occupational Scenario Hazard Quotient

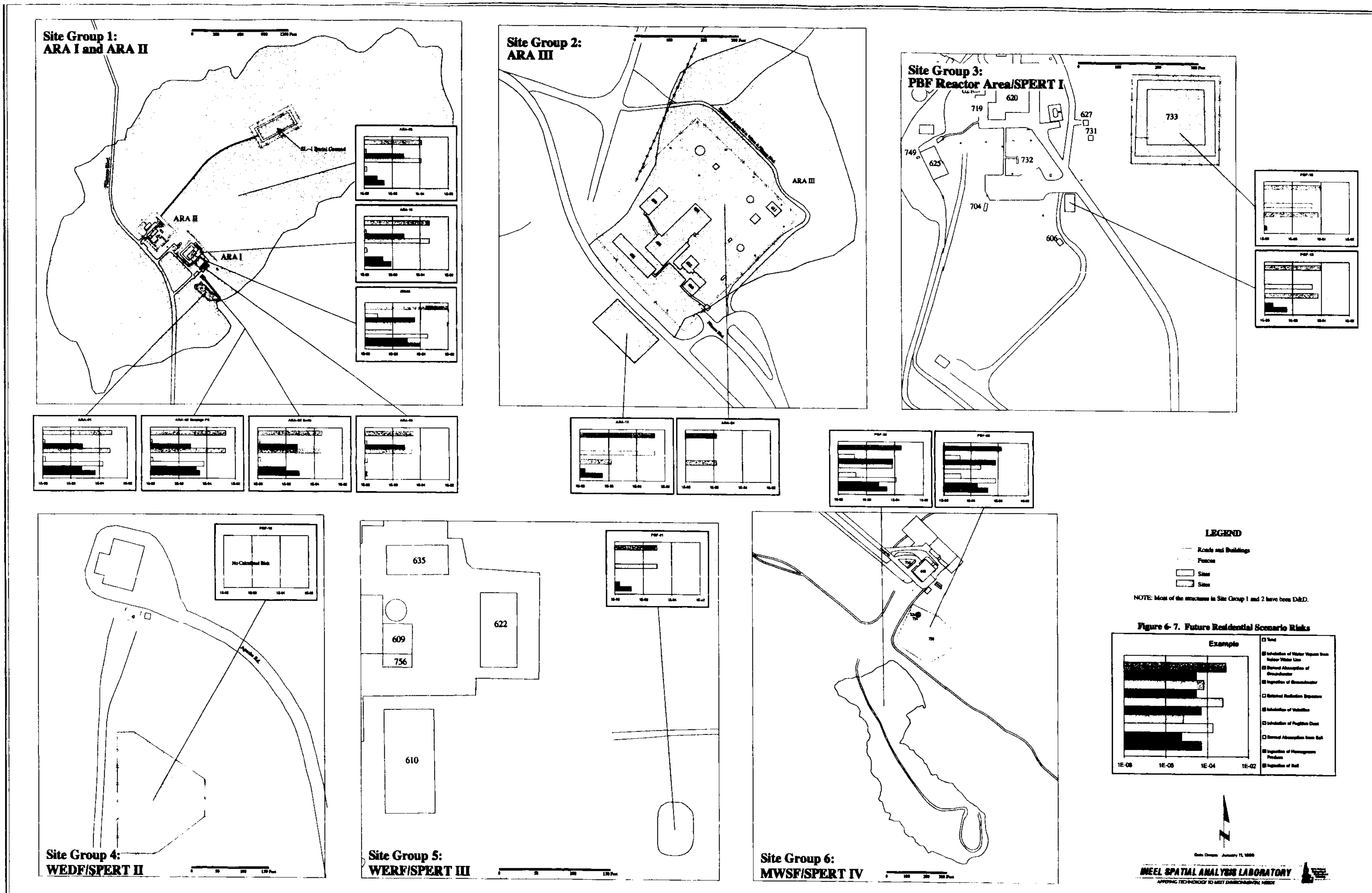

Figure 6-7. Future Residential Scenario Risks

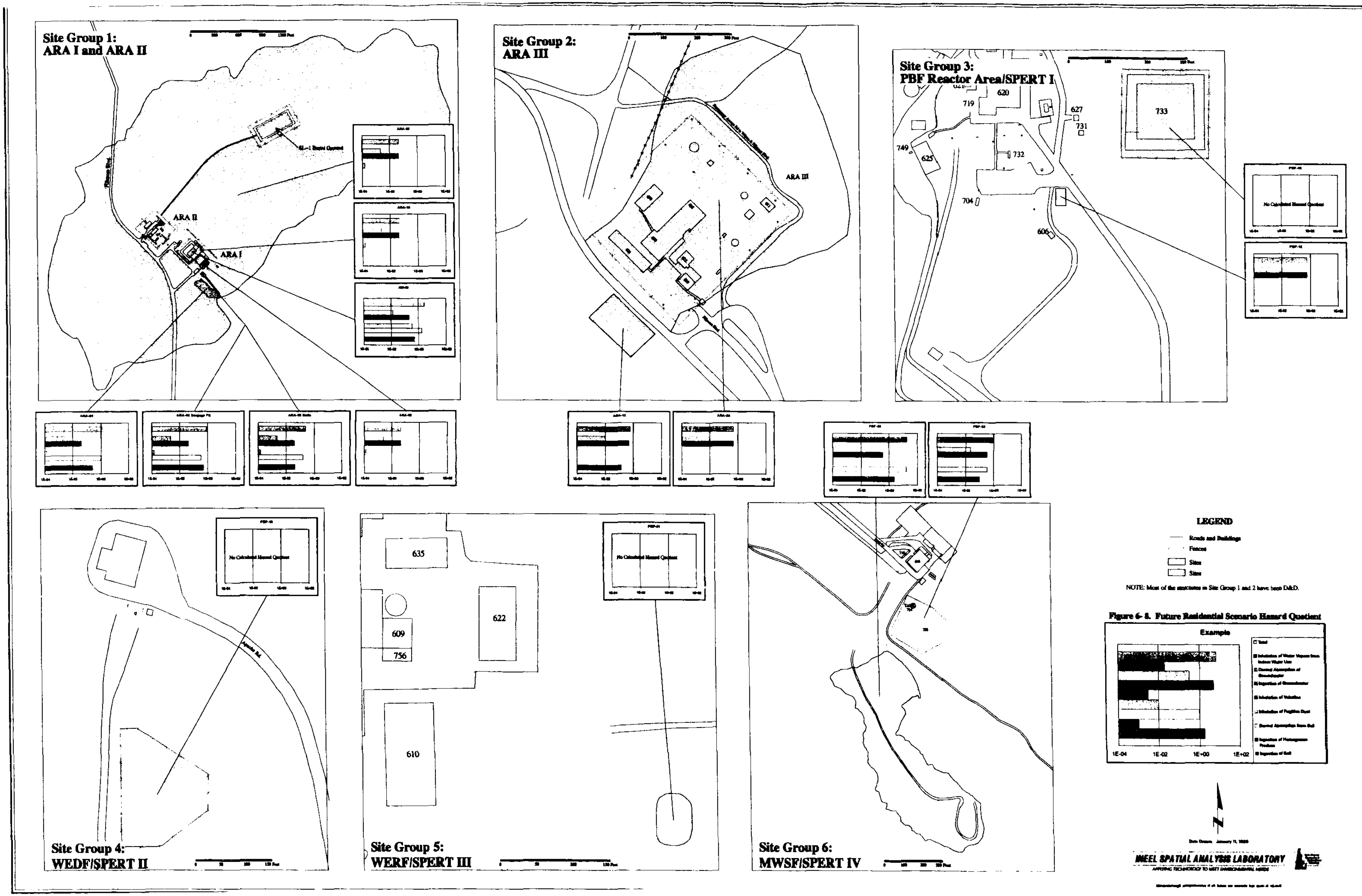

Figure 6-8. Future Residential Scenario Hazard Quotient

6.5 Uncertainty Analysis

The risk assessment results presented in this BRA are very dependent on the methodologies described in Section 6.2. These analysis methods were developed over a period of several years by INEEL risk management and risk assessment professionals to provide realistic, yet conservative estimates of human health risks at WAG 5. Nonetheless, if different risk assessment methods had been used, the BRA likely would have produced different risk assessment results. To ensure that the risk estimates are conservative, health protective assumptions that tend to bound the plausible upper limits of human health risks are used throughout the BRA. Therefore, risk estimates that may be calculated by other risk assessment methods are not likely to be significantly higher than the estimates presented in Section 6.4.

The BRA results in Appendix B are useful for evaluating which WAG 5 sites require remediation because the results are calculated in a consistent manner. The consistency allows for direct comparison of the risk assessment results for a given site with the results for every other site included in the evaluation. Changes in a given assumption used in the evaluation would, in general, produce similar changes in the risk results for all of the sites evaluated. As described in the remainder of this section, the BRA results include inherent uncertainty, but despite this uncertainty, consistency of analysis makes the results useful for making remediation decisions.

Uncertainty in this BRA is produced by uncertainty factors in the following four stages of analysis:

1. Data collection and evaluation

2. Exposure assessment

3. Toxicity assessment

4. Risk characterization.

In the following subsections, each of these four stages is discussed in more detail, and a discussion of risks from potential future releases from co-located facilities at WAG 5 is presented in Section 6.5.5.

6.5.1 Data Collection and Evaluation Uncertainties

Uncertainties associated with data collection and evaluation are produced by variability in observed concentrations from sampling design and implementation, laboratory analysis methods, seasonality, contaminant levels, and natural concentration. Making the most effective use of sampling data involves quantifying these uncertainties.

The effect of uncertainty introduced from sample collection and analysis is reduced by basing risk estimates on the 95% UCL of the mean for the WAG 5 COPC concentration estimates. The resulting concentration estimates, used to estimate intakes, are an upper-bound estimate of the concentrations observed at the retained sites. This approach provides protection for human health and accounts for the uncertainty introduced by sampling, analysis, seasonality, and natural variation.

A major assumption included in the BRA analysis is that all significant sources of contamination at WAG 5 have been identified and sampled. If a source of contamination has not been identified and sampled, the risks from the contamination are not included in the BRA.

One of the first steps in the BRA was a review of sites and screening contaminants (see Section 3.4). The purpose of the review was to help focus the BRA on sites and contaminants that are likely to produce adverse human health effects. The process was designed to be conservative so that all sites and contaminants that have a reasonable potential for causing adverse human health effects would be evaluated in the BRA. If in fact the process was not conservative enough and sites or contaminants that could cause adverse human health effects were inappropriately omitted, then the BRA risk results presented in Appendix B would be underestimated. A contamination source would have to be small to be inappropriately screened. Therefore, any underestimation of risk would be slight if a site or contaminant were inappropriately screened.

The contaminant screening process described in Section 3.4 used the EPA Region 3 risk-based concentrations as a screening criterion (EPA October 1995). These concentrations were calculated based on a risk of 1E-06 and an HQ of 1. The text included with the Region 3 screening tables recommends using one-tenth of the concentrations shown in the tables as the basis for contaminant screening.

This recommendation was not adopted in the WAG 5 BRA for two reasons. First, remedial decisions at the INEEL are generally based on the residential risk level of 1E-04. In other words, if a site's estimated residential risk exceeds a value of 1E-04, the site is typically considered for remedial action. The 1E-04 risk level is two orders of magnitude higher than the 1E-06 risk level that was used to calculate the Region 3 risk-based concentration, so the 1E-06 risk-based concentrations are adequately protective.

Second, the BRA methodologies for noncarcinogens are sufficiently conservative to preclude inappropriate remedial decisions that might result from screening contaminants. For example, the noncarcinogenic assessment used in the BRA implements upper-bound values for all exposure factors and treats all noncarcinogenic health effects additively (i.e., all noncarcinogens were assumed to produce adverse health impacts in the same organ). Decay of noncarcinogens in the environment is not considered. These conservative methods tend to produce upper-bound HQ estimates for all COPCs that passed the screening process and to increase the chance that a given site would be considered for remediation. As a result, any potential nonconservative effects on the BRA that could have been produced by screening based on an HQ of 1 are more than offset by the conservative nature of the noncarcinogenic risk assessment.

The risks from contamination at three sites were not evaluated in the BRA. First, ARA-23 (radiologically contaminated soils and subsurface structures in and around ARA-I and ARA-II) includes known radionuclide contamination that was not evaluated in the BRA. The risks reported in Appendix B for this site are based exclusively on contaminant concentrations detected in the surface soils surrounding ARA-I and ARA-II. The contamination associated with the buried structures is fixed to the surfaces of the buried SL-1 Reactor foundation and underground utilities. Because the fixed contamination is not expected to migrate away from the buried materials, the contamination is not expected to cause exposures to humans or ecological receptors at the sites. In addition, sampling of the SL-1 concrete foundation was conducted during April 1998, and the radiological contamination on the foundation was found to be negligible (see Oertel 1998 in Appendix J). Therefore, risks for the site are not calculated.

Second, the ARA-16 tank contains highly contaminated liquid and sludge waste that was not included in the BRA. The risks reported in Appendix B for this site are based exclusively on contaminant concentrations detected in the soils surrounding the tank. There is currently no evidence that the tank has leaked, but if a leak ever occurred, the risks at the sites would likely become much more severe. The waste inside the tanks was excluded from evaluation in the BRA because the primary goal of the BRA is to evaluate risks from past releases at WAG 5. Evaluation of a hypothetical future release from the tank is beyond the scope of the BRA. Nonetheless, removal or stabilization of the waste contained in this tank will be an important aspect of any remedial action that may be planned at ARA-16.

Third, ARA-06, the SL-1 Burial Ground, was not evaluated further in the WAG 5 comprehensive RI/FS. An engineered cover was placed over the site in compliance with the SL-1 Record of Decision (DOE-ID 1996) for the remedial action to inhibit releases via the soil and pathways. Risks via the groundwater ingestion pathway were shown to remain below 1E-04 even if contaminant inventories were tripled and infiltration were assumed to equal total precipitation (see Magnuson and Sondrup 1998 in Appendix J). Therefore, the remedial action is assumed to be sufficiently protective of human health and the environment to preclude further investigation.

All of the sites evaluated in the BRA have varying levels of uncertainty associated with the contaminant concentrations evaluated in the BRA. In addition, all of the evaluated concentrations were estimated using conservative assumptions about the nature and extent of contamination at the various sites. The concentration term uncertainties and conservative assumptions are summarized in Table 6-2.

As discussed in Section 6.2.3, the sampling results for all the retained sites were assumed to be lognormally distributed. This assumption is in accordance with guidance presented in EPA 1992. In general, this assumption causes the 95% UCL calculations to produce higher average concentration estimates than would be produced if the sampling results were assumed to be normally distributed. If the sampling results for a given site were normally distributed, the calculated risks for the site would be overestimated as a result of the lognormal distribution assumption.

Only soil sampling data were considered in the risk assessments for ARA-23 and ARA-12. The in situ gamma survey data for these two sites were not considered in the risk assessment because the data could not be validated to the same level as the soil sampling data. However, the gamma survey data are high quality data, even though results were not subjected to a formal validation process. Therefore, a sensitivity analysis was performed to estimate the risk posed by the Cs-137 contamination that was detected by the surveys.

The in situ gamma survey collected more than 69,000 measurements at ARA-I and -II, and more than 13,000 measurements at ARA-III (see Josten 1997 in Appendix J). The data are summarized in Figures 4-20 and 4-25. These figures were created by overlaying the survey data with a 2 by 2-ft square grid, matching the data with the grid squares, and contouring the results of the matching analysis. The matching analysis was performed based on the number of survey data points that fell into each square. For example, if a given square contained only one data point, the Cs-137 concentration associated with the data point was assigned to the square. If a square contained more than one data point, the Cs-137 concentration associated with the average of the data points was assigned to the square. Finally, if a square did not contain any data points, a Cs-137 concentration based on a linear interpolation of the nearest data points was assigned to the square. This analysis method allowed the 69,000 data points for ARA-I and –II to be mapped onto 94,494 squares and the 13,000 data points at ARA-III to be mapped onto 12,725 squares.

The concentrations that were assigned to the grid squares were used to calculate average Cs-137 concentrations for the sites. For ARA-23 at ARA-I and -II the average concentration was calculated by considering all of the grid squares with assigned concentrations that were greater than or equal to zero. At ARA-III, on the other hand, the average concentration was calculated by considering only the grid squares with assigned concentrations that were greater than or equal to 5 pCi/g. This average concentration is considered to be representative of the hotspot contamination in the southwest corner of the site (see Figure 4-26).

Table 6-2. Summary of uncertainties and conservative assumptions for the WAG 5 BRA.

Site	Uncertainties and Conservative Assumptions
ARA-01: ARA-I Chemical Evaporation Pond	The 95% upper confidence level (UCL) or maximum contaminant concentrations are assumed to exist over the entire surface of the pond. This conservative assumption probably causes the calculated risks at the site to be overestimated.
	In the absence of historical disposal data, the contaminant masses associated with the site were estimated based on source term volume and detected concentrations. This approach may underestimate the risk.
	Sampling was conducted to the soil/basalt interface at a depth of 2 ft. The residential scenario risks were calculated assuming all 2 ft of soil would be excavated. This assumption may overestimate risks.
ARA-02: ARA-I Sanitary Waste Leach Field and Seepage Pit	The source terms specific to the two sources associated with this site (i.e., the seepage pit and the septic tank soils) are assumed to exist over the entire surface of the two separate areas of the site. This conservative assumption probably causes an overestimation of the calculated risks at the site. However, the pipeline between the seepage pit and the septic tanks is assumed intact, which may underestimate the source term and the resultant risks.
	No attempt was made to estimate the amount of contamination that may have been released to the subsurface over the operational lifetime of the seepage pit. Only the current concentrations in the existing sludge were evaluated. Therefore, risks associated with past releases from the seepage pit are underestimated.
	For the seepage pit evaluation, data from the seepage pit sludge were combined with the soil samples outside the pit for risk assessment purposes. This overestimates the risk for the types of contaminants found outside the tank when only the soil sample data are used.
ARA-03: ARA-I Pad near ARA-627	Cs-137, the only contaminant retained after the contaminant screening process, was detected at a depth of 3 ft bgs. It was conservatively assumed that the entire soil profile was contaminated to a depth of 10 ft at the same concentrations as detected at 3 ft.
	Only six samples were used to determine the contaminant concentration that was assumed to exist over the entire surface of the site. This relatively small amount of data could produce an overestimation or underestimation of risk at the site.
ARA-16: ARA-I Radionuclide Tank	The 95% UCL or maximum contaminant concentrations are assumed to exist over the entire surface of the site. The site area (660 ft^2) was conservatively assumed to equal the area of the grid for the 1997 sampling. This assumption may overestimate the risks for the site.

Table 6-2. (continued).

Site	Uncertainties and Conservative Assumptions
ARA-23: Radiologically Contaminated Soils and Subsurface Structures In and Around ARA-I and ARA-II	Three aspects of the ARA-23 radionuclide source term calculations impact the results of the site risk assessment. First, 95% UCL or maximum contaminant concentrations are assumed to exist over the nearly 170,000 m^2 site area. The true contaminant soil concentrations may be less than the 95% UCL or maximum detected concentrations over much of the site, so this assumption may overestimate the risks for the site. Second, the GPRS survey (see Section 4.2.1.6) indicated an area of Cs-137 contamination was not considered during the calculation of the average Cs-137 concentration for the site. The GPRS survey was used to identify the 10 pCi/g Cs-137 isopleth for the site, and the Cs-137 samples evaluated in the BRA were collected at this isopleth. The survey indicated high levels of contamination within this isopleth, but soil samples were not collected to verify this indication. Omission of the contamination within the isopleth probably produces an underestimation of the site's average Cs-137 concentration, and a corresponding underestimation of the site's risk. Finally, sampling at the site was performed down to a depth of only 2 ft. Contamination was detected at this depth; therefore, the risk assessment conservatively assumed contamination extended all the way to a depth of 2 ft below ground surface. Because the transport mechanism operative at this site is windblown deposition, the contamination is probably concentrated in the top few inches of surface soil. Therefore, this assumption may overestimate risks for the site.
ARA-12: ARA-III Radioactive Waste Leach Pond	The 95% UCL or maximum contaminant concentrations are assumed to exist over the entire site. This conservative assumption would probably lead to an overestimation of risk. Sampling was performed to the soil/basalt interface at depths of up to 7 ft. The residential scenario risks were calculated assuming that all 7 ft of soil would be excavated. This assumption may overestimate risks. In the absence of historical disposal data, the contaminant masses associated with the site were estimated based on source term volume and detected concentrations. This approach may underestimate the risk. The hotspot detected during the GPRS survey was not sampled. Including of the GPRS data for the area at the southwest corner of ARA-12 would have shown a risk for Cs-137 at locations in which contaminant concentrations exceeded the 23 pCi/g. Therefore, risk is underestimated for ARA-12.

Table 6-2. (continued).

Site	Uncertainties and Conservative Assumptions
ARA-24: Surface Soils around ARA-III	The risk assessment for this site of area of about 400,000 ft^2 was based on eight data points. The effect of assuming that eight data points adequately characterize the entire site is unknown. The only contaminant remaining after screening was Pu-238 and its detected concentration is assumed to exist over the entire surface of the site. This assumption would probably cause an overestimation of risk. Though Pu-238 was detected in the upper 4 in. at a single sample location, contamination is assumed to exist in the soil to a depth of 10 ft., causing a probable overestimation of risk.
PBF-05: PBF Reactor Area Warm Waste Injection Well	Because there is no evidence of soil contamination to a depth of 10 ft, the contaminants that were injected into the vadose zone were assumed to affect the groundwater only. If soil contamination to a depth of 10 ft exists, the surface pathway risks would be underestimated.
PBF-10: PBF Reactor Area Evaporation Pond	In 1994, the pond was excavated to the liner and the berm pushed into the pond. The pond did not contaminate the berm material; therefore, the top 7 ft of soil now existing at the site is assumed to be clean. Sampling at the site did not indicate that the liner leaked, but the risk assessment assumed that 2 ft of soil beneath the liner was contaminated to the same levels as the pond sediment above the liner. This assumption probably overestimates risk at the site. In the absence of historical disposal data, the contaminant masses associated with the site were estimated based on source term volume and detected concentrations. This approach may underestimate the risk.
PBF-12: SPERT-I Leach Pond	Currently, 8 ft of clean soil is mounded over the site. However, for the residential scenario, it is assumed that the contamination below 8 ft exists over the entire area of the site and that the contamination assumed for the lower part of the 10 ft deep surface soils will be exposed. An overestimation of risk could result.
PBF-16: SPERT-II Leach Pond	A characterization performed in 1983 reported maximum concentrations of hazardous substances in the upper foot of soil. Lead was the only contaminant remaining after the contaminant screening. No toxicity information is available for lead; therefore, a quantitative estimate of risk for the site could not be developed. It was assumed that this maximum concentration exists over the entire area of the pond to a depth of 10 ft. This assumption probably would cause the qualitative risks to be overemphasized. In the absence of historical disposal data, the contaminant masses associated with the site were estimated based on source term volume and detected concentrations. This approach may underestimate the risk.

Table 6-2. (continued).

Site	Uncertainties and Conservative Assumptions
PBF-21: PBF SPERT-III Large Leach Pond	The site has been backfilled, but the contaminants that were retained during the screening exist at depths of 5 to 8 ft. These contaminants are conservatively assumed to exist across the entire area of the leach pond. For the residential scenario, the lower contaminated interval to a depth of 10 ft is assumed to be available to the receptor. This assumption probably overestimates risk. In the absence of historical disposal data, the contaminant masses associated with the site were estimated based on source term volume and detected concentrations. This approach may underestimate the risk.
PBF-22: PBF SPERT-IV Leach Pond	The 95% UCL or maximum contaminant concentrations are assumed to exist over the entire surface of the pond. This conservative assumption probably causes the calculated risks at the site to be overestimated. In the absence of historical disposal data, the contaminant masses associated with the site were estimated based on source term volume and detected concentrations. This approach may underestimate the risk.
PBF-26: PBF SPERT-IV Lake	The maximum detected concentrations were assumed for the entire source volume to a depth of 10 ft. This assumption could cause an overestimation of risk or an underestimation of risk. The risk is overestimated because only three positive detections were made for the Aroclor 1254 and multiple nondetections were not used in the data set. The extent of contamination is probably much smaller than the areal extent used for risk assessment purposes, and concentrations are much lower than those evaluated. The lake has a very large surface area; therefore, the site sampling may not have been extensive enough to detect all areas of contamination. If undetected contamination exists at the site, the calculated risks for the site may be underestimated. In the absence of historical disposal data, the contaminant masses associated with the site were estimated based on source term volume and detected concentrations. This approach may underestimate the risk.

The calculations produced an average Cs-137 concentration estimate of 55.5 pCi/g for ARA-23 at ARA-I and -II and 47.4 pCi/g for the southwest corner of ARA-12 at ARA-III. The external exposure risks associated with these concentrations are 4E-04 and 2E-04, respectively.

6.5.2 Exposure Assessment

Uncertainties associated with the exposure assessment are produced by characterizing transport, dispersion, and transformation of COPCs in the environment, establishing exposure settings, and deriving estimates of chronic intake. The initial characterization that defines the exposure setting for a site involves many professional judgments and assumptions. Definition of the physical setting, population characteristics, and selection of the chemicals included in the risk assessment are examples of areas for which a quantitative estimate of uncertainty cannot be achieved because of the inherent reliance on professional judgment.

An aspect of the risk assessment that tends to exaggerate risk results is the evaluation of contaminants with background concentrations that produce calculated risks in excess of 1E-06. Two examples of this type of contaminant are arsenic and beryllium. Both contaminants are commonly detected in INEEL soils at concentrations that are slightly higher than accepted risk-based concentrations. However, neither contaminant is associated with known waste producing processes at WAG 5 and they both have very high toxicity constants. For these reasons, arsenic and beryllium were not included in the risk assessment for some sites in which they have been detected. If the detected arsenic and beryllium concentrations are in fact anthropogenic (i.e., produced by operations at the sites), the risk results for the sites would be underestimated.

Biotic transport is included in the preliminary conceptual site model (DOE-ID 1997) as a release mechanism because of the possibility that burrowing animals and nonagricultural plant uptake could transport contamination from depth up to the ground surface. The potential for biotic uptake was acknowledged in the WAG 5 RI/BRA, but biotic uptake modeling was not performed to quantify the effects of biotic uptake because most contaminant exposures calculated in the RI/BRA were based on average soil concentrations that were measured in the depth interval from 0 to 10 ft. In general, plants and animals at the WAG 5 sites would not come into contact with soils that are at depths greater than 3 m (10 ft) below ground surface; therefore, biotic uptake generally will not affect the average concentrations used to calculate site exposures. To illustrate this point, consider a burrowing animal that moves contamination from a depth of 1 m (3 ft) up to the surface at a given site. The activity of this animal will not affect the calculated average concentrations from 0 to 10 ft because the animal will simply be redistributing contamination within the site's depth interval from 0 to 10 ft.

The case in which biotic activity could affect the average concentrations used to calculate exposures in the RI/BRA is associated with the occupational exposure scenario. Most of the occupational scenario soil pathways and all of the occupational scenario air pathways were evaluated using average contaminant concentrations measured in the top 15 cm (6 in.) of soil. Including the effects of biotic uptake could change these average concentrations.

Despite the fact that the occupational exposure scenario average concentrations could be affected by biotic uptake, biotic uptake modeling was not performed to support the occupational scenario analysis for four reasons:

1. The occupational scenario evaluates a 100-year period of time when institutional controls will be in place at some of the WAG 5 sites. These controls will probably discourage biotic activity that would move large amounts of contamination to the surface.

2. The 100-year time period is a relatively short interval for the movement of contamination. Some contamination may be moved to the surface during this period, but the amount of transported contamination is expected to be small.

3. Many of the WAG 5 sites were created by surface releases of contamination. Biotic activity would tend to move clean soil from depth that would reduce the average concentrations from 0 to 6 in. at these sites.

4. All of the exposure parameters used in the occupational risk calculations were upper-bound values in accordance with EPA risk assessment guidance. These values cause the risk results to be upper-bound estimates, even if some of the concentration terms used at some of the sites were slightly underestimated. Not modeling biotic uptake in the occupational scenario evaluation is a source of uncertainty in the occupational scenario risk results, but this uncertainty is expected to be small in comparison to other uncertainties associated with the site concentration terms.

The only contaminant loss mechanism considered in the BRA is radioactive decay. Other loss mechanisms such as leaching and wind erosion are assumed to be negligible. The reason for this assumption is that environmental sampling has shown that most contaminants do not migrate from most INEEL sites. As a result of this observation, very few studies have been performed to evaluate these mechanisms. Therefore, very little site specific information is available to estimate the exact effects of these removal mechanisms.

Omitting removal mechanisms other than radioactive decay tends to overestimate risk for all exposure routes because it leads to assuming a given mass of contaminant will cause exposures by multiple exposure routes. For example, leaching is omitted in the soil pathway analysis even though leaching is the mechanism that produces the contamination evaluated in the groundwater pathway analysis. As a result of the omission, a given mass of contamination can affect both the soil pathway and groundwater pathway risk results. Upper-bound infiltration and contaminant leachability assumptions are used in the groundwater pathway analysis to estimate future groundwater contaminant concentrations. Applying these same upper-bound assumptions to the soil pathway analysis likely would produce an underestimation of soil pathway risks. To avoid this possibility, leaching is omitted from the soil pathway analysis, so that upper-bound risk results are calculated for both the soil pathway and groundwater pathway exposure routes.

One of the purposes of the BRA is to estimate upper-bound risks from WAG 5 contaminant releases based on best available site specific information. Omitting removal mechanisms that have not been studied on a site-specific basis and that are likely to produce only small errors in the calculated risk results is consistent with this objective.

The residential exposure scenario evaluated in the BRA incorporates the assumption that potential future residents will dig into the contaminated sites at WAG 5 and spread the contaminated soil around their homes. As a result, the scenario simulates future residential exposure to average contaminant concentrations that exist in the top 3 m (10 ft) of the sites. This assumption is referred to as the residential intrusion assumption (see Section 6.2.3).

The intrusion assumption generally produces upper-bound risk estimates for release sites that have contamination located beneath the shallow surface soils. Averaging the deeper contamination with the shallow contamination produces an upper-bound estimate of the site's exposure point soil concentration. The intrusion assumption, however, does not produce upper-bound exposure estimates at sites that only have shallow surface contamination.

At a shallow surface release site, soil pathway risk estimates that are calculated using the 0 to 0.5-ft average concentration for a given contaminant would be higher than the estimates presented in the BRA. Specifically, the increase in the risk estimates would be equal to the ratio of the contaminant's 0 to 0.5-ft concentration. For example, if a site had a 0 to 0.5-ft average concentration for a given contaminant of 100 mg/kg, a 0 to 10-ft average concentration of 10 mg/kg, and a calculated residential soil ingestion risk equal to 1E-06, the soil ingestion risk that would be calculated using the 0 to 0.5-ft average concentration would equal 1E-05 [1E-06 × (100 mg/kg)/(10 mg/kg) = 1E-05]. This example illustrates that the depth of intrusion for potential future residents is a significant source of uncertainty in the BRA exposure assessment. WAG 5 sites in which the intrusion assumption may not be conservative can be identified by comparing the 0 to 0.5-ft concentration for a given COPC, as shown in Section 4 and Appendix B, to the 0 to 10-ft average concentration for the contaminant.

All of the contaminants at some of the WAG 5 release sites (e.g., ARA-10, PBF-04, PBF-31, and PBF-32) were eliminated from consideration in the BRA by the contaminant screening process. Because all of the contaminants at these sites were eliminated, the sites themselves also were eliminated from further consideration. If the contaminant screening process was not conservative enough, there is a possibility that the eliminated contaminants could produce adverse health impacts at the eliminated sites. If this situation occurred, the risks and hazard quotients presented in Section 6.4 would be slightly underestimated.

PBF-08, the PBF Reactor Area corrosive waste sump, also was eliminated as a site of potential concern. It is believed that no soil contamination exists at the site, even though soil sampling outside the sump has not been conducted and sampling inside the sump showed high concentrations of chromium and Cs-137 in the sludge. A remedial action was completed during which all contaminants within the sump were removed and the concrete walls and bottom of the sump were decontaminated. There was no evidence that the concrete walls and floor had degraded; therefore PBF-08 was eliminated from further consideration in the BRA.

Finally, ARA-06, the SL-1 Burial Ground, was eliminated as a site of potential concern. The potential risks to workers and future residents at ARA-06 were estimated in an RI/FS at levels above the 1E-04 risk range for the external exposure and soil ingestion exposure routes. Therefore, a cap was constructed over the area in a remedial action designed to provide containment and shielding and to prevent inadvertent intrusion. Risks from groundwater ingestion were estimated to be 1E-06 in the RI/FS; therefore, the remedial action did not address the groundwater pathway. Groundwater risks for the site were further evaluated in a sensitivity study (see Magnuson and Sondrup 1998 in Appendix J) for the three groundwater contaminants of potential concern (Tc-99, H-3, and Pu-239). In the sensitivity analysis, the source term inventories were increased by factors of 2 and 3, and the simulated infiltration rate was doubled to roughly equal the annual precipitation rate. Because the resulting risk estimates for groundwater ingestion remained less than 2E-06, ARA-06 was not retained for further evaluation in the WAG 5 RI/BRA.

6.5.3 Toxicity Assessment

Several important measures of toxicity are needed to conduct an assessment of risk to human health. Reference doses are applied to the oral and inhalation exposure to evaluate noncarcinogenic and developmental effects, and SFs are applied to the oral and inhalation exposures to carcinogens. Reference doses are derived from NOAELs or LOAELs, and the application of uncertainty factors and modifying factors. Uncertainty factors are used to account for the variation in sensitivity of human subpopulations and the uncertainty inherent in extrapolation of the results of animal studies to humans while modifying factors account for additional uncertainties in the studies used to derive the NOAEL or LOAEL. Uncertainty associated with SFs is accounted for by an assigned weight-of-evidence rating that reflects the likelihood of the toxicant being a human carcinogen. Weight-of-evidence classifications are tabulated in Table B-21 in Appendix B.

6.5.4 Risk Characterization

The last step in the risk assessment is risk characterization. As discussed in Section 6.4, risk characterization is the process of integrating the results of the exposure and toxicity assessments. The uncertainties defined throughout the analysis process are combined and presented as part of the risk characterization to provide an understanding of the overall uncertainty in the estimate of risk. This qualitative assessment of uncertainty is presented in Table 6-3. See Tables B-68 through B-94 in Appendix B for a complete presentation of the risk estimates and Section 8 for a summary of WAG 5 risks.

Because some of the contaminants detected at the WAG 5 release sites do not have available toxicity information (e.g., lead, chloride, sulfate, and orthophosphate), risks and hazard quotients could not be calculated for these contaminants. As a result, if the contaminants have the potential for producing adverse health impacts, the risks and hazard quotients at the release sites that contain these contaminants may be underestimated.

6.5.5 Uncertainties in the Facilities Assessment Analysis.

As discussed in Appendix C and summarized in Section 3, the facilities assessment analysis examined the potential contributions to risk from discontinued, ongoing, and future operations at WAG 5. Buildings and structures with a history of releases not under current, appropriate management controls and those that possess the potential to impact cumulative risk at WAG 5 sites would be retained for consideration in the BRA. However, no such facilities or structures were identified in the facilities assessment analysis for PBF or ARA.

Management controls are adequate to address contaminant releases from PBF, an active operational area, to the environment from facility activities. All historical releases have either been remediated in the past or have been identified with a WAG 5 CERCLA site.

The ARA-I, -II, and -III facilities are undergoing D&D. When D&D is complete, WAG 5 will resume management of ARA and evaluate any potential residual risk. Though a reactor foundation, some buried pipes, and other minor structures will be abandoned in place, these structures are already identified with WAG 5 CERCLA sites at ARA. Use of the ARA-IV facility is limited to occasional explosives testing and measures are in place to ensure that any contaminants released to the environment as a consequence of current activities will be appropriately addressed.

The facilities assessment analysis did not identify any additional sites for evaluation in the WAG 5 comprehensive RI/BRA. The analysis was based on the assumptions that appropriate management controls will be maintained and enforced to ensure future protection of human health and the environment and that all significant historical releases within WAG 5 have been identified. The uncertainty associated with these two assumptions cannot be quantified but is considered very low in a qualitative sense.

Table 6-3. BRA human health assessment uncertainty factors.

Uncertainty Factor	Effect of Uncertainty	Comment
Source term assumptions	May overestimate risk	All contaminants are assumed to be completely available for transportation away from the source zone. In reality, some contaminants may be chemically or physically bound to the source zone and unavailable for transport.
Natural infiltration rate	May overestimate risk	A conservative value of 10 cm/year was used for this parameter.
Moisture content	May overestimate or underestimate risk	Soil moisture contents vary seasonally in the upper vadose zone and may be subject to measurement error.
Water table fluctuations	May slightly overestimate or underestimate risk	The average value used is expected to be representative of the depth over the 30-year exposure period.
Mass of contaminants in soils estimated by assuming a uniform contamination concentration in the source zone.	May overestimate or underestimate risk	There is a possibility that most of the mass of a given contaminant at a given site may exist in a hotspot that was not detected by sampling. If this condition existed, the mass of the contaminant used in the analysis might be underestimated. However, 95% upper confidence levels (UCLs) or maximum detected contamination were used for all mass calculations. These concentrations are assumed to exist at every point in each waste site; therefore, the mass of contaminants used in the analysis is probably overestimated.
Plug flow assumption in groundwater transport	Could overestimate or underestimate risk	Plug flow models are conservative relative to concentrations because dispersion is neglected, and mass fluxes from the source to the aquifer differ only by the time delay in the unsaturated zone (the magnitude of the flux remains unchanged). For nonradiological contaminants, the plug flow assumption is conservative because dispersion is not allowed to dilute the contaminant groundwater concentrations. For radionuclides, the plug flow assumption may or may not be conservative. Based on actual travel time, the radionuclide groundwater concentrations could be over or underestimated because a longer travel time allows for more decay. If the concentration decrease from the travel time delay is larger than the neglected dilution from dispersion, the model will not be conservative.
No migration of contaminants from the soil source prior to 1994	Could overestimate or underestimate risk	The effect of not modeling contaminant migration from the soil before 1994 is dependent on the contaminant half-life, radioactive ingrowth, and mobility characteristics.
Chemical form assumptions	Could overestimate or underestimate risk	In general, the methods and inputs used in contaminant migration calculations, including assumptions about chemical forms of contaminants, were chosen to err on the protective side. All contaminant concentration and mass are assumed available for transport. This assumption results in a probable overestimate of risk.

Table 6-3. (continued).

Uncertainty Factor	Effect of Uncertainty	Comment
Exposure scenario assumptions	May overestimate risk	The likelihood of future scenarios has been qualitatively evaluated as follows: Resident—improbable Industrial—credible. The likelihood of future onsite residential development is small. If future residential use of this site does not occur, then the risk estimates calculated for future on-site residents are likely to overestimate the true risk associated with future use of this site.
Exposure parameter assumptions	May overestimate risk	Assumptions about media intake, population characteristics, and exposure patterns may not characterize actual exposures.
Receptor locations	May overestimate risk	Groundwater ingestion risks are calculated for a point at the downgradient edge of an equivalent rectangular area. The groundwater risk at this point is assumed to be the risk from groundwater ingestion at every point within WAG 5 boundaries. Changing the receptor location will only affect the risks calculated for the groundwater pathway because all other risks are site-specific or assumed constant at every point within the WAG 5 boundaries.
For the groundwater pathway analysis, all contaminants were assumed to be homogeneously distributed in a large mass of soil.	May overestimate or underestimate risk	The total mass of each contaminant of potential concern (COPC) is assumed to be homogeneously distributed in the soil volume beneath WAG 5. This assumption tends to maximize the estimated groundwater concentrations produced by the contaminant inventories because homogeneously distributed contaminants would not have to travel far to reach a groundwater well drilled anywhere within the WAG 5 boundary. However, groundwater concentrations may be underestimated for a large mass of contamination (located in a small area with a groundwater well drilled directly downgradient).
The entire inventory of each contaminant is assumed to be available for transport along each pathway	May overestimate risk	Only a portion of each contaminant's inventory will be transported by each pathway.
Exposure duration	May overestimate risk	The assumption that an individual will work or reside at a site for 25 or 30 years is conservative. Short-term exposures involve comparison to subchronic toxicity values, which are generally less restrictive than chronic values.
Noncontaminant-specific constants (not dependent on contaminant properties)	May overestimate risk	Conservative or upper bound values were used for all parameters incorporated into intake calculations.
Exclusion of some hypothetical pathways from the exposure scenarios	May underestimate risk	Exposure pathways are considered for each scenario and eliminated only if the pathway is either incomplete or negligible compared to other evaluated pathways.
Model does not consider biotic decay	May overestimate risk	Biotic decay would tend to reduce contamination over time.
Occupational intake value for inhalation is conservative	Slightly overestimates risk	Standard exposure factors for inhalation have the same value for occupational as for residential scenarios though occupational workers would not be onsite all day.

Table 6-3. (continued).

Uncertainty Factor	Effect of Uncertainty	Comment
Use of cancer slope factors	May overestimate risk	Slope factors are associated with upper 95th percentile confidence limits. They are considered unlikely to underestimate true risk.
Toxicity values derived primarily from animal studies	May overestimate or underestimate risk	Extrapolation from animal to humans may induce error from differences in absorption, pharmacokinetics, target organs, enzymes, and population variability.
Toxicity values derived primarily from high doses; most exposures are at low doses	May overestimate or underestimate risk	Assumes linearity at low doses. Tend to have conservative exposure assumptions.
Toxicity values and classification of carcinogens	May overestimate or underestimate risk	Not all values represent the same degree of certainty. All are subject to change as new evidence becomes available.
Lack of slope factors	May underestimate risk	COPCs without slope factors, may or may not be carcinogenic through the oral pathway.

6.6 References

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