6.0 INTEGRATED ENDANGERMENT ASSESSMENT

This section provides an integrated overview of the RMA EA program methods and results for both human and ecological receptors. Section 6.1 describes the procedures used to estimate the potential human health and ecological risks. Section 6.2 presents a summary and overview of the major findings of the human health and ecological assessments and evaluations of other potential risks at RMA. Section 6.3 discusses the limitations and uncertainties associated with the EA program results. Section 6.4 identifies the implications of uncertainty on the EA findings and of the EA findings on imminent human health and ecological risks. Section 6.5 discusses the relationship between the risk evaluations in the EA program and the potential cleanup goals for RMA.

6.1 METHODS TO ASSESS POTENTIAL RISK

Some of the chemical contaminants occurring at RMA were selected for consideration in the HHRC and the ERC based on evaluations of the frequency of detection and distribution of contaminants in environmental media. The toxicity of the contaminants to human and ecological receptors was also considered in order to ensure that all chemicals that could conceivably cause significant health or ecological risks were included. Appendix Sections B.1 and C.1 describe the procedures used to select these chemicals for consideration in the IEA/RC.

Potential human health risks were estimated on the basis of an exposure concentration exceedance of a human health risk-based criterion (i.e., PPLVs); whereas the potential ecological risks were estimated on the basis of a tissue concentration or dose exceedance of a toxicological threshold value (i.e., MATC or TRV, respectively). The basis of the risk estimations are summarized below.

6.1.1 Human Health Risk-Based Criteria

The two land-use options with which human health receptors are associated, open space (e.g., nature preserve, wildlife refuge, and recreational park development) and economic development (e.g., light industrial and commercial development), are consistent with the terms and conditions of the FFA (EPA 1989c) for RMA. To project potential risks tc human health under these options, chronic probabilistic criteria for human health were developed for five populations/subpopulations: biological workers, regulated/casual visitors, recreational visitors, industrial workers, and commercial workers. The chronic probabilistic PPLVs, both carcinogenic and noncarcinogenic, for the biological worker are presented in Table 6.1-1. With the exception of the biological worker, who was considered analogous in terms of exposure to the industrial worker for the open space land-use option, similar populations were the subject of acute and subchronic criteria development in the HHEA Addendum report (EBASCO 1992c). These criteria are summarized in Table 6.1-2 for the recreational visitor, the most important receptor for an acute/subchronic exposure scenario, and the biological/industrial worker.

Exposure routes to human receptors that were considered in the development of probabilistic PPLVs included direct soil exposure routes (i.e., ingestion, dermal contact, particulate inhalation), which are applicable to all populations, and the indirect exposure route (i.e., open and enclosed space soil vapor inhalation), which is applicable to all open space receptor subpopulations and the industrial worker population. An additional indirect exposure route, the enclosed space soil vapor inhalation route, was also evaluated for commercial and industrial workers. Dietary exposure routes (i.e., the ingestion of meat, dairy, produce, and fish) and groundwater exposure pathways were not considered due to land-use and other restrictions specified in the FFA. Dermal contact with metals in soils was not evaluated due to negligible contaminant absorption from this exposure route.

The chronic PPLVs summarized in Table 6.1-1 were computed using probabilistic and fixed model input parameters. Probabilistic soil PPLVs were computed for each of the five populations/subpopulations as a function of media intake rates, exposure times (frequencies and durations), partition coefficients, physiological parameters (breathing rates, body weights, skin surface areas), and absorption and toxicological parameters (critical toxicity values).

The acute and subchronic criteria summarized in Table 6.1-2 were computed using fixed (deterministic) model input parameters. Two factors should be considered when evaluating the results of the acute/subchronic analysis and, in particular, when comparing acute/subchronic deterministic PPLVs with corresponding chronic probabilistic PPLVs. First, for some parameters (e.g., oral and dermal absorption factors), the exposure assumptions used in the deterministic (fixed) acute/subchronic evaluation are different from those used in the probabilistic chronic analysis. Second, the applicability of toxicity criteria, such as the RfDs developed from long-term (i.e., chronic) toxicity studies but used to evaluate potential acute effects, may influence the acute/subchronic and chronic PPLV comparison.

6.1.2 Biota Toxicological Threshold Values

Target ecological receptors were selected for risk evaluation based on their status on federal threatened and endangered species lists, as economically important species, or as prey for such species; their abundance, home range, and distribution at RMA; and their contribution to the range of taxonomic groups and trophic levels within the RMA ecosystems. The existence of data on these receptors at RMA was also important. The five food webs selected as representative of RMA (i.e., those five food webs culminating in shorebirds and four top predators identified at RMA—bald eagle, American kestrel, great horned owl, and great blue heron) contained multiple food chains that originated from either soil, sediment, or surface water. Some of the food webs contained either terrestrial or aquatic food chains, while others contained both terrestrial and aquatic food chains. Each trophic level of the food web was represented by species that were common at RMA. Ingestion, primarily of food, but also of soil, sediment, and water, was considered the predominant exposure route in the ecological food-web model; other potential routes of exposure were implicitly incorporated through the use of measured RMA tissue concentration data for all but the top trophic boxes to develop BMFs. BMFs together with estimated exposure concentrations were used to predict tissue concentrations across RMA for comparison with toxicological threshold values. Toxicological threshold values were available for the following target ecological receptors: bald eagle, great horned owl, American kestrel, great blue heron, shorebird, water bird, small mammal and medium mammal. For these receptors, risks were calculated for the COCs.

Fourteen COCs were identified for biota but only 12 risk evaluations were done because aldrin and dieldrin and DDT and DDE were evaluated together because the first (parent) compound is readily metabolized to the second. The final BMFs used by terrestrial food chains in the model were computed according to three different approaches: Army, EPA, and Shell. In the Army's approach probabilistic and fixed input parameters—bioaccumulation factor and dietary fraction in terrestrial food chains and bioaccumulation factor, feeding rate, and dietary fraction in aquatic food chains—were quantified using literature data and then incorporated into a model to estimate probabilistic terrestrial and aquatic BMFs that were calibrated using site-specific tissue data. In the EPA and Shell approaches, site-specific tissue data were used directly but in different protocols to develop BMFs. The three BMF approaches are described in detail in Section 4.4 and Appendix Section C.1.6.1.2.

Risk calculations differed depending on whether a trophic box had only terrestrial food chains, only aquatic food chains, or both:

- For trophic boxes with terrestrial food chains, BMFs, however calculated, were multiplied by <ESC> values to predict tissue concentrations for each block in the RMA-wide grid; the comparison of each of these tissue concentrations to a toxicological threshold resulted in a calculation of potential risk.
- For trophic boxes with aquatic food chains, measured tissue concentrations were compared directly to a toxicological threshold to calculate potential risk.
- For trophic boxes with mixed food chains, potential risk was calculated from both terrestrial and aquatic sources.

Regardless of the type of food chains leading to a trophic box, calculations of potential risk to the trophic box also differed depending on whether or not the COC being evaluated was bioaccumulative:

- For the bioaccumulative COCs (aldrin/dieldrin, DDT/DDE, endrin, and mercury), both tissue- and dose-based calculations were performed and the more certain of these values used.
- For the remaining COCs, only dose-based calculations were performed. This application of the dose-based approach considered only contaminant uptake from abiotic media, not from food.

A few special cases that were outside these situations are described in Appendix Section C.1.6.2.3. Each risk calculation, except those for aquatic food chains and for nonbioaccumulative COCs, uses a BMF value. When a BMF value was used, calculations were done three times, using final values from each of the BMF approaches.

For the ERC, risks were quantified on the basis of HQs and HIs that do not represent probabilities, but rather estimates of the magnitude of ratio between a measure of exposure (tissue concentration or dose) and a toxicity threshold value considered to be protective (MATC or TRV). The HQ is a chemical-specific ratio; the HI is the sum of all HQs available for a particular trophic box. It is assumed that the magnitude of the potential adverse effect (risk) will be proportional to the magnitude of the HQ or HI. For the purposes of the ERC, an HQ or HI of 1.0 has been defined as the best estimate of the highest level of chronic exposure that is unlikely to result in adverse effects on the average individual of specific populations or subpopulations exposed chronically in the field. For values of HQ or HI greater than 1.0, the potential for adverse effects increases as the HQ or HI value increases. The range of uncertainty in these statements regarding HQs or HIs spans at least one order of magnitude. This uncertainty exists in both directions; hence, some risk may occur at HQ or HI values as low as 0.1, and no risk may occur at HQ or HI values as high as 10.

6.2 SUMMARY OF MAJOR FINDINGS

6.2.1 Potential Human Health Risks

The evaluation of exposure of the biological worker to contaminants in the Horizon 1 soil-depth interval (0 to 10 ft) was used to characterize potential risks to all human populations and subpopulations. Horizon 1 was used because it is at this interval that the estimated cancer risks and HIs were highest for the biological worker (as well as the industrial worker in the economic development land-use option). Moreover, the biological worker subpopulation is considered most reflective of anticipated future land uses at RMA (i.e., national wildlife refuge). Cancer risks and HIs were calculated on both a site-specific and boring-by-boring basis; the results of each of these evaluations are summarized below.

Figure 6-1 shows site cancer risks estimated from soil contamination in Horizon 1 for the biological worker. These results indicate that potential cancer risks are highest in, and exceedances of 10^{-4} total cancer risk levels are generally limited to, the following centrally located areas at RMA:

- Chemical Sewers (site SP10)
- Lime Basins (sites SP1E [Buried M-1 Pits] and NC1B [Section 36 Lime Basins])
- South Plants, with sites SP3A (ditch), SP1A (Central Processing Area), and SP3B (concrete salt storage pad) exhibiting the highest risks
- Former Basin F (site NC3)
- Sanitary/Process Water Sewers (site NC8A)
- Basin A (site NC1A)
- Shell Trenches (site C1A)

For noncarcinogenic endpoints, results for the site-specific analysis exhibit similar trends in that HIs calculated for the sites listed above all exceeded 1.0. However, exceedances (HI > 1.0) were also identified for the following areas:

- South Plants sites SP2A and SP2B (Tank Farm sites), SP4A (ditch), SP3C, SP1G, and SP2B (Balance of Areas)
- Sanitary Landfill (site W5D)
- Section 36 sites C1B (Balance of Areas) and C1C (Complex Trenches)
- Sites NP4 (Sand Creek Lateral) and NP5 (North Plants Agent Storage)
- Sites NC1E (located in Basin A) and S2B (Sand Creek Lateral)

The boring-by-boring evaluation, which was undertaken to supplement the site-specific evaluation, revealed similar trends relating to the magnitude and spatial distribution of estimated risks and HIs. Figure 6-2 shows the cancer risks estimated from soil contamination in Horizon 1 for the biological worker. The trends shown in this map basically parallel those described for the site-specific analysis in that exceedances of a 10^{-4} cancer risk level or an HI of 1.0 at individual borings are generally limited to the following areas located in the central portions of RMA: South Plants, Sewer System, the Lime Basins, Basin A, Former Basin F, and Shell Trenches. Isolated exceedances of a 10^{-4} cancer risk also occur at borings located in Basin C, the Sand Creek Lateral, North Plants agent storage areas, and the sanitary landfill near the Rail Classification/Maintenance Yard located in the western portion of RMA. These results should be interpreted with caution because they do not incorporate a realistic spatial or temporal averaging component (i.e., they do not represent chronic long-term exposures). However, this map does provide more detailed information reflecting the variability of risks in certain areas, and also highlights the number of site borings showing cancer risks or HIs less than (as well as exceeding) reference risk levels.

For all receptors evaluated in the HHRC, the major contaminants contributing to potential cancer risks were aldrin, DBCP, arsenic, and dieldrin. The major contaminants contributing to potential noncancer risks were aldrin, DBCP, and arsenic.

Both cancer and noncancer risks estimated for the biological worker and other open space land-use option receptors were attributed primarily to the direct soil exposure routes (i.e., soil ingestion and dermal absorption). The sensitivity analysis conducted for the HHRC revealed that the variability in the assumed duration of exposure, the soil ingestion rate, the relative oral and dermal absorption factors, and skin soil covering contribute the most to the uncertainty of the risk estimates calculated for biological and industrial workers.

6.2.2 Potential Ecological Risks

Five trophic boxes (i.e., American kestrel, great horned owl, small bird, medium mammal, and small mammal) were evaluated for potential risk from contaminant exposure through terrestrial food chains only because they do not feed on aquatic organisms. Three tropic boxes (i.e., bald eagle, great blue heron, and shorebird) were evaluated for contaminant exposure through terrestrial and aquatic food chains, and the water bird trophic box was evaluated for potential risk from contaminant exposure through aquatic food chains only. Aquatic HIs are the sum of HQs for aldrin/dieldrin, endrin, and DDT/DDE only due to the lack of data for the other COCs in tissue and lake water samples.

Terrestrial areas where all trophic boxes are expected to be at a potential risk (HI greater than 1.0) from all of the COCs combined are most of the interior sections of RMA and include South Plants; Basins A, B, C, D, and F; the Toxic Storage Yard, and the northernmost upland areas adjacent to Lake Mary, Lake Ladora, Upper Derby Lake, and Lower Derby Lake. Most of these specific sites also cause small areas of higher potential risk (HI greater than 10) from all of the COCs combined to all of the trophic boxes. Additionally, most of RMA presents a potential risk (HI greater than 1.0) from all of the COCs combined to at least one trophic box, and much of this potential risk is due to aldrin/dieldrin, endrin, DDT/DDE, and mercury.

All four trophic boxes receiving contaminant exposure through aquatic food chains exhibit a potential risk from aldrin/dieldrin, endrin, DDT/DDE, and mercury combined, and most of that potential risk stems from mercury. The great blue heron was the only one of these four trophic boxes that had a HI greater than 2.0 (HI equals 13) for the combined COCs stated above.

The potential risk computed for the metals as a group (i.e., metals HI greater than 1.0) and the HQ for mercury may be overestimated because it was assumed that all measured mercury concentrations, reported in analytical results as total mercury, were the more bioavailable and toxic form, methylmercury. Conversely, the potential risks from chlordane exposures may have been underestimated since tissue samples were not analyzed for chlordane (and so could not be modeled as a bioaccumulative COC).

6.2.3 Potential Risks from Other Hazards

Suspected locations of chemical warfare agents and UXO have been conservatively identified in a worst-case scenario of the geographic extent of potential occurrences. The areas identified for each hazard cover slightly less than 1 square mile (Figure 3.2-19). For both agent and UXO, the largest area identified is located inside Basin A. There are also small isolated areas of agent and UXO presence in the 10 easternmost sections at RMA. The FS will consider all such areas regardless of potential risk levels. The qualitative assessment developed for the HHRC identified areas of agent and UXO presence, as well as other areas at RMA that could not be quantitatively addressed in the HHRC due to lack of sampling. This evaluation did not identify any sites (i.e, those sites with no action designations) indicating potential risks that are not currently being addressed in the FS process.

6.3 LIMITATIONS, UNCERTAINTIES, AND INTERPRETATION OF THE ENDANGERMENT ASSESSMENT

The interpretation of the findings of the EA program must take place in the context of the inherent limitations and uncertainties surrounding the assessment, and then only after careful consideration of the key factors and assumptions that contribute to the uncertainty. Because previous sections, as well as the appendices, describe the major sources of uncertainty and the methods used to characterize human health and ecological risk in detail, these issues are only briefly reviewed here.

There are a number of inherent limitations and assumptions that need to be considered when evaluating the results of the risk assessment. These issues include the following:

- Limitations of the RMA chemical database
- Methods used to estimate exposure concentrations
- Uncertainties in human and ecological exposure scenarios
- Uncertainties in the models and parameters used to characterize risks

While it is difficult to estimate the exact degree to which specific assumptions and methods affect potential uncertainties and biases, several factors stand out as key contributors to these uncertainties for the human health and ecological assessments.

6.3.1 Qualifications of Risk Estimates to Human Health

Many of the major sources of uncertainty in the HHRC arise from the need to predict the general and specific behavior patterns of human receptors that affect exposures. Therefore, the results of the EA under the future land-use options are inherently somewhat uncertain. Uncertainty arises from the need to identify and characterize specific exposed populations. The frequency and duration of exposures and other time-dependent variables relating to future exposures for these populations may be associated with large amounts of uncertainty. This issue is addressed by the use of probabilistic methods (see Appendix E) to define exposure criteria (PPLVs) for the future populations. The probabilistic methods also address the other uncertainties associated with the assessment of contaminant intake for specific exposure routes. Included in this category are variables relating to transport through indirect exposure routes, receptor physiologic parameter values, and variables related to the absorption of contaminants through specific routes of exposure. This approach is designed to provide a reasonable but realistic degree of conservatism in the characterization of risks for the various exposed populations.

Another major uncertainty associated with the draft acute and subchronic PPLVs that were derived from the HHEA Addendum is attributable to the dose-response data used in the development of these criteria. For several chemicals (e.g., DDT), the toxicity values provided by the EPA were identical for acute, subchronic, and chronic exposures. Because chronic exposures should most appropriately be equated with the most conservative toxicity values to ensure adequate protectiveness from long-term exposures, a high degree of uncertainty must be attributed to the acute and subchronic draft PPLVs, which may not adequately reflect differences in toxicity between short- and long-term exposures.

The other major source of uncertainty in the HHRC is associated with the risk characterization models and the dose-response parameter values used in the calculation of chronic health risks.

In the case of both cancer and noncancer risk assessment, the dose-response models used (i.e., linearized multistage models for carcinogens and comparisons to reference doses [RfDs] for noncarcinogens) are major sources of uncertainty in the assessment of risks. In both cases, the approaches employed involve a degree of conservatism, i.e., the methods are designed to provide assurance that risks or the potential for adverse effects are not underestimated. In addition, the dose-response parameter values (cancer slope factors [CSFs] and RfDs) used in the assessments are also defined with a variable, and often a substantial degree of conservatism is built in to ensure that risks are not underestimated.

Finally, there is some degree of uncertainty associated with the assumption of additivity of adverse effects used to characterize both carcinogenic and noncarcinogenic health risks. Moreover, this approach may also add a degree of conservatism to the assessment, especially for noncarcinogenic effects. Nevertheless, the magnitude of this effect is likely to be less than the conservatism associated with the dose-response models for the individual COCs.

Taken in their entirety, the methods used to characterize human health risks at RMA are likely to be conservative. The magnitude of this potential bias cannot be estimated quantitatively, but could be substantial. It is important to acknowledge, however, that the methods used are consistent with current practice in risk assessment, as well as the latest EPA guidance on risk assessment (1989a).

6.3.2 Qualifications of Potential Risk to Biota

Because of the large area and variable contamination patterns across the RMA, the spatial distribution of tissue concentrations resulting from terrestrial food-web exposure was modeled based on exposure to contaminant concentrations in the soil. The basic model used to estimate risk assumed that contaminant concentrations in biota tissues were proportional to areal average soil concentrations, referred to as exposure area soil concentrations (ESC values), in the 0 to 1 ft soil-depth interval. BMF, the proportionality constant relating biota tissue concentrations to the estimated ESC (<ESC>), was estimated based on the observed relationship between tissue and soil concentrations, as well as a second model that describes trophic relationships within the food web. Sources of uncertainty in the estimation of terrestrial risk pertained to the following processes involved in the general modeling approach:

- Selection of target receptors
- Characterization of exposure routes and trophic relationships within the food web including prey fractions (FR), feeding rates (R), and bioaccumulation factors (BAFs)
- Development of toxicological threshold values (MATCs and TRVs)
- Representation of true exposure soil concentration as an areal average for the 0 to 1 ft soil-depth interval (i.e., as ESC)
- Representation of the relationship between tissue concentration and ESC as proportional
- Estimation of ESC based on soil concentration data
- Estimation of BMF
- HQ additivity assumption

Aquatic species were assumed to integrate their exposure over an entire lake, while predators were assumed to integrate their aquatic food-web exposure over an entire lake or over all lakes on RMA. Specifically, eagles and herons were assumed to be exposed to mean contaminant concentrations in aquatic prey tissue and water (through direct ingestion), where this mean is integrated over all lakes according to their areas and other parameters. Due to the predominance of water concentration data reported as below the certified reporting limit (BCRL) and the small contribution of water ingestion to contaminant intake, predator dose was estimated with the mean ingested water concentration set at its maximal limit, the CRL. In general, the number and spatial representation of prey tissue samples within each lake were adequate to provide a reasonable estimate of the mean concentrations to which predators were assumed exposed. In most cases, therefore, the exposure tissue and sediment concentrations were estimated directly from observed data, rather than through media-based models as was done to calculate terrestrial risk. For water birds and shorebirds, tissue concentrations and dose were estimated from observed water bird and shorebird tissue concentrations. The observed tissue concentrations for shorebirds were assumed to be representative of the population of shorebirds associated with a specific lake. The aquatic risk estimates were influenced by the following sources of uncertainty:

- Selection of target receptors
- Characterization of FR, R, and BAF for the eagle and heron
- Characterization of R and BAF for the shorebird and water bird (used to back-calculate dose from observed tissue concentrations)
- Development of toxicological threshold values (MATCs and TRVs)
- Estimation of lake-specific mean tissue and sediment concentrations based on observed data
- Extrapolation of mean tissue concentrations for two trophic box/chemical combinations where data was not available (aquatic invertebrates, DDT/DDE; amphibians, DDT/DDE)

6.4 PERSPECTIVE ON RMA RISK EVALUATIONS

6.4.1 Implications of Uncertainty for Risk Evaluation

In interpreting the numerical results of the EA program for RMA, it must be emphasized that the estimates of potential risk and their uncertainty considerations discussed above should be construed as a framework within which remediation decisions for RMA can be made. For example, based on the uncertainty evaluations performed, areas that differ by less than one order of magnitude in their level of risk may justifiably be considered to be essentially equivalent in the prioritization of remedial activity. In other words, care should be taken in defining remedial priorities among areas with HIs that vary only slightly from 1.0 (e.g., HI < 10), or for which excess carcinogenic risks are between the 10^{-4} and 10^{-6} cumulative risk range.

It would also be appropriate to consider the degree of conservatism used in the EA program as a factor in evaluating the need for, and extent of, remediation. First, both human health and ecological HIs are indicators of the <u>potential</u> adverse effects. Maps depicting the HIs show the relative magnitude of the potential risk areas based on an HI of 1.0 or 10. An HI of 1.0 has been defined as the best estimate of the highest level of chronic exposure that is unlikely to result in adverse effects on populations exposed chronically in the field. For values of HI greater than 1.0, the potential risk from adverse effects increases as the HI value increases. The range of uncertainty in these statements regarding HIs spans at least one order of magnitude. This uncertainty exists in both directions; hence, some risk may occur at values of HI as low as 0.1 and no risk may occur at values of HI as high as 10.

6.4.2 Implications of the Endangerment Assessment on Imminent Human Health and Ecological Risks

Based on the analysis described in previous sections of this report, it is apparent that potential risks may exist for both human and ecological health from contamination at RMA under the future land-use options, which does not imply that imminent or acute risks to human health or biota are widespread at RMA. For example, those areas with potential agent presence or with chemical concentrations that approach acutely toxic levels are quite limited in areal extent and are, moreover, restricted from uncontrolled access. Similarly, the existing data do not support the occurrence of widespread acute adverse effects of RMA contamination on biota. For example, fortuitous sampling has confirmed occasional instances of lethal effects, but no detailed population-trend studies have been performed to discern the overall impacts from contaminant exposure. RMA experiences immigration and emigration of wildlife, and these factors create dynamic changes in population numbers and cause complications in assessing population and community stability. However, differences between populations of some species on and off post are consistent with expectations based on the results of many of the flora and fauna surveys conducted at RMA (see Appendix Section C.5). While these studies have focused primarily on surveys of populations of various species, effects at the individual and population levels have also been addressed.

Many apparently healthy organisms collected at RMA carried tissue concentrations less than the whole-body MATCs for the COCs. Nevertheless, geometric mean tissue concentrations exceeded the whole-body MATCs for ten trophic box/COC combinations, of which four were for mercury, three were for dieldrin, two were for DDE, and one was for endrin. All of these MATC exceedances were for avian receptors except dieldrin in small mammals. For example, raptors collected during the Biota RI were necropsied and brains were analyzed for organochlorine pesticide residues (ESE 1989). In general, birds with high levels of organochlorine pesticides had little or no body fat, and often exhibited no obvious cause of death. Conversely, birds exhibiting an obvious cause of death (i.e., evidence of electrocution or shooting) tended to have low concentrations of the organochlorine pesticides and normal levels of body fat. These results indicate likely adverse impacts on individuals of some wildlife species at RMA, particularly birds at the upper trophic levels in regional food webs, as assumed by the food web exposure pathways model used to calculate risk.

The ecological measurement endpoints evaluated relative to potential risks neither reveal current adverse effects on reproductive success in birds or mammals, nor indicate that the measurement endpoint values are beyond the range of normal fluctuations. Comparisons of contaminated vs. uncontaminated areas of RMA and on-post vs. off-post areas for the same measurement endpoints did not reveal consistent associations between COC concentrations and populational effects. In general, the areas of potential risk identified by the IEA/RC report are consistent with areas of known or likely contamination previously identified.

6.5 RELATIONSHIP BETWEEN HHRC, ERC, AND POTENTIAL CLEANUP GOALS

While the information on the magnitude and areal extent of the potential risks provides critical information for making decisions regarding remedial goals, the actual process by which preliminary remediation goals are defined for various sites involves a number of factors, of which the risk-based criterion is only one. Among the additional factors that must be taken into account in selecting remedial alternatives are the following:

- Evaluation of the level of uncertainty and conservatism in the risk estimates
- Evaluation of the expected land uses, exposed populations, and habitats
- Decisions about facility- and site-wide acceptable risk levels
- Engineering feasibility of specific remedies
- Cost and cost-effectiveness of remedies as compared to other alternatives
- Adverse effects of specific remedies, especially on biota and habitats

- Technical limitations related to contaminant detection and measurement
- Naturally occurring concentrations of some COCs
- Applicable or relevant and appropriate regulatory requirements

The results of the baseline risk assessment, as presented in the IEA/RC, indicate that potential risks exist for both human and ecological receptors. Specifically, the contaminants that are the major contributors to the overall potential risks are similar for both receptor groups—organochlorine pesticides—and the areas that pose the greatest potential risks to both receptor groups are located in the central region of RMA. It is very important to remember that the potential risks presented in this report are baseline (i.e., they are based on the current and historical contamination evaluated under present or future land-use scenarios). However, data from some areas on RMA that have undergone interim remediation (e.g., capping to eliminate possible exposure pathways for receptors) were not revised to reflect the remediation; the actual risks are, thus, likely to be less than the baseline risks presented in the IEA/RC. Risk maps that reflect all existing (and future) areas of remediation would depict potential risk in a smaller area. For example, Figures 6.4-1 to 6.4-3 depict soil remediation scenarios that would eliminate the potential aldrin/dieldrin risk (i.e., reduce the aldrin/dieldrin HQ to 1.0 or less), based on the three approaches' great horned owl BMFs.

Although ecological risk-based cleanup criteria for RMA are not derived as part of the IEA/RC, the IEA/RC does provide information in Section 4.6 for the risk manager to consider when making risk-based soil cleanup decisions. Only when the risk-related contaminant issues are addressed in the FS can the ultimate decisions about cleanup goals be made. The final cleanup levels selected for a specific site or area may or may not be different from the risk-based human health criteria used to characterize potential risk.

Table 6.1-1 Chronic Probabilistic Risk-Based Soil Criteria for Biological Worker

Chemical	Human Health Soil Criteria (mg/kg): Chronic Probabilistic PPLV Biological Worker[1] (mg/kg) 10^{-4} Risk	Chronic Probabilistic PPLV Biological Worker[1] (mg/kg) 10^{-6} Risk	Chronic Probabilistic Noncarcinogenic PPLV[2] (mg/kg) Biological Worker
Aldrin	7.16E + 01	7.16E-01	7.12E + 01
Arsenic	4.17E + 02	4.17E + 00	4.76E + 02
Benzene	1.18E + 03	1.18E + 01	NA
Cadmium	5.01E + 03	5.01E + 01	5.29E + 02
Carbon Tetrachloride	2.51E + 00	2.51E + 00	3.63 + 01
Chlordane	3.72E + 02	3.72E + 00	5.51E + 01
Chloroacetic Acid	NA	NA	1.01E + 02
Chlorobenzene	NA	NA	9.66E + 02
Chloroform	4.82E + 03	4.82E + 01	4.41E + 02
Chromium	7.52E + 02	7.52E + 00	3.87E + 01
DDE	1.25E + 03	1.25E + 01	NA
DDT	1.35E + 03	1.35E + 01	4.09E + 02
Dicyclopentadiene	NA	NA	3.69E + 03
Dibromochloropropane	2.01E + 01	2.01E - 01	9.75E + 00
Dieldrin	4.14E + 01	4.14E - 01	5.77E + 01
Endrin	NA	NA	2.32E + 02
Hexachlorocyclopentadiene	NA	NA	1.06E + 03
Isodrin	NA	NA	5.24E + 01
Lead	NA	NA	2.17E + 03
Mercury	NA	NA	5.74E + 02
Methylene Chloride	3.53E + 03	3.53E + 01	3.11E + 03
Tetrachloroethylene	5.43E + 02	5.43E + 00	5.47E + 02
Toluene	NA	NA	9.46E + 03
Trichloroethylene	2.84E + 03	2.84E + 01	NA
1,1-Dichloroethylene	5.16E + 01	5.16E - 01	4.52E+02
1,1,2.2-Tetrachloroethane	1.45E + 02	1.45E + 00	NA
1,2-Dichloroethane	3.23E + 02	3.23E +00	NA

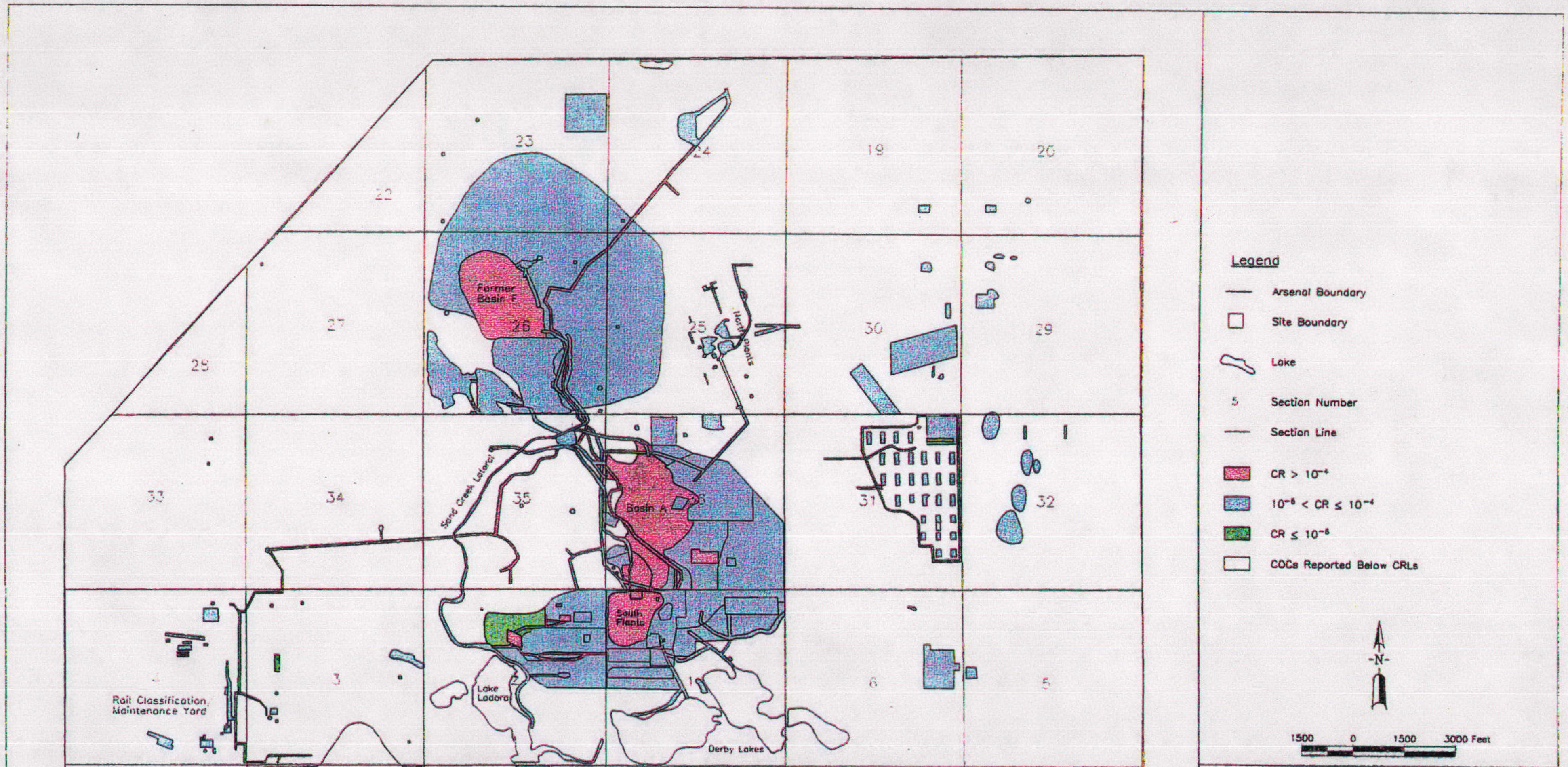
1 Values are 5th percentile PPLVs for the cumulative direct soil exposure pathways (ingestion, particulate inhalation, dermal contact) for the biological worker receptor
2 Noncarcinogenic PPLVs are based on an HI of 1.O.
NA Denotes not applicable

Table 6.1-2 Acute and Subchronic Deterministic Risk-Based Criteria for Recreational Visitor and Biological/Industrial Worker Receptors

	Recreational Visitor[1]		Biological/Industrial Worker	
Chemicals	Acute PPLV[2] (mg/kg)	Subchronic PPLV[2] (mg/kg)	Acute PPLV[2] (mg/kg)	Subchornic PPLV[2] (mg/kg)
Aldrin	3.8E+00	2.7E+01	5.6E+01	8.0E+01
Benzene	ND	ND	ND	ND
Carbon Tetrachloride	1.1E+04	1.4E+03	4.8E+04	1.2E+03
Chlordane	1.7E+02	1.2E+01	7.2E+02	1.0E+01
Chloroacetic Acid	ND	3.9E+03	ND	3.5E+03
Chlorobenzene	5.6E+03	3.9E+04	2.4E+04	3.5E+04
Chloroform	5.0E+03	2.0E+03	2.2E+04	1.7E+03
DDE	ND	ND	ND	ND
DDT	1.4E+01	9.8E+01	6.0E+01	8.7E+01
Dibromochloropropane (DBCP)	1.4E+02	ND	6.0E+-2	ND
1,2-Dichloroethane	ND	ND	ND	ND
1,1-Dichloroethylene	5.6E+03	1.8E+03	2.4E+04	1.6E+03
Dicyclopentadiene	ND	5.4E+04	ND	3.4E+04
Dieldrin	3.7E+00	2.6E+01	4.7E+01	6.8E+01
Endrin	5.6E+01	9.8E+01	2.4E+02	8.7E+01
Hexachlorocyclopentadiene	ND	1.3E+04	ND	8.8E+03
Isodrin	ND	ND	ND	ND
Methylene Chloride	2.8E+04	1.2E+04	1.2E+05	1.0E+04
1,1,2,2-Tetrachloroethylene	ND	ND	ND	ND
Tetrachloroethylene	5.6E+03	2.0E+04	2.4E+04	1.7E+04
Toluene	5.6E+04	3.9E+05	2.4E+05	3.5E+05
Trichloroethylene	6.7E+04	4.9E+05	2.9E+05	4.3E+05
Metals				
Arsenic	3.0E+02	2.7E+02	3.4E+03	6.7E+02
Cadmium	1.5E+02	1.4E+02	1.9E+03	3.4E+02
Chromium	3.8+03	2.4E+03	4.7E+04	7.2E+02
Lead	ND	ND	ND	ND
Mercury	7.7E+03	8.2E+01	9.4E+04	2.0E+02

1 Acute/subchronic PPLVs listed for the recreational visitor are equivalent to those calculated for the regualted/casual visitor (see Tables 3.2-7 and 3.2-8).

2 Acute/subchornic criteria calculated using fixed (deterministic) exposure parameters, and based on an HI of 1.0.



Prepared for: U.S. Army Program Manager for Rocky Mountain Arsenal

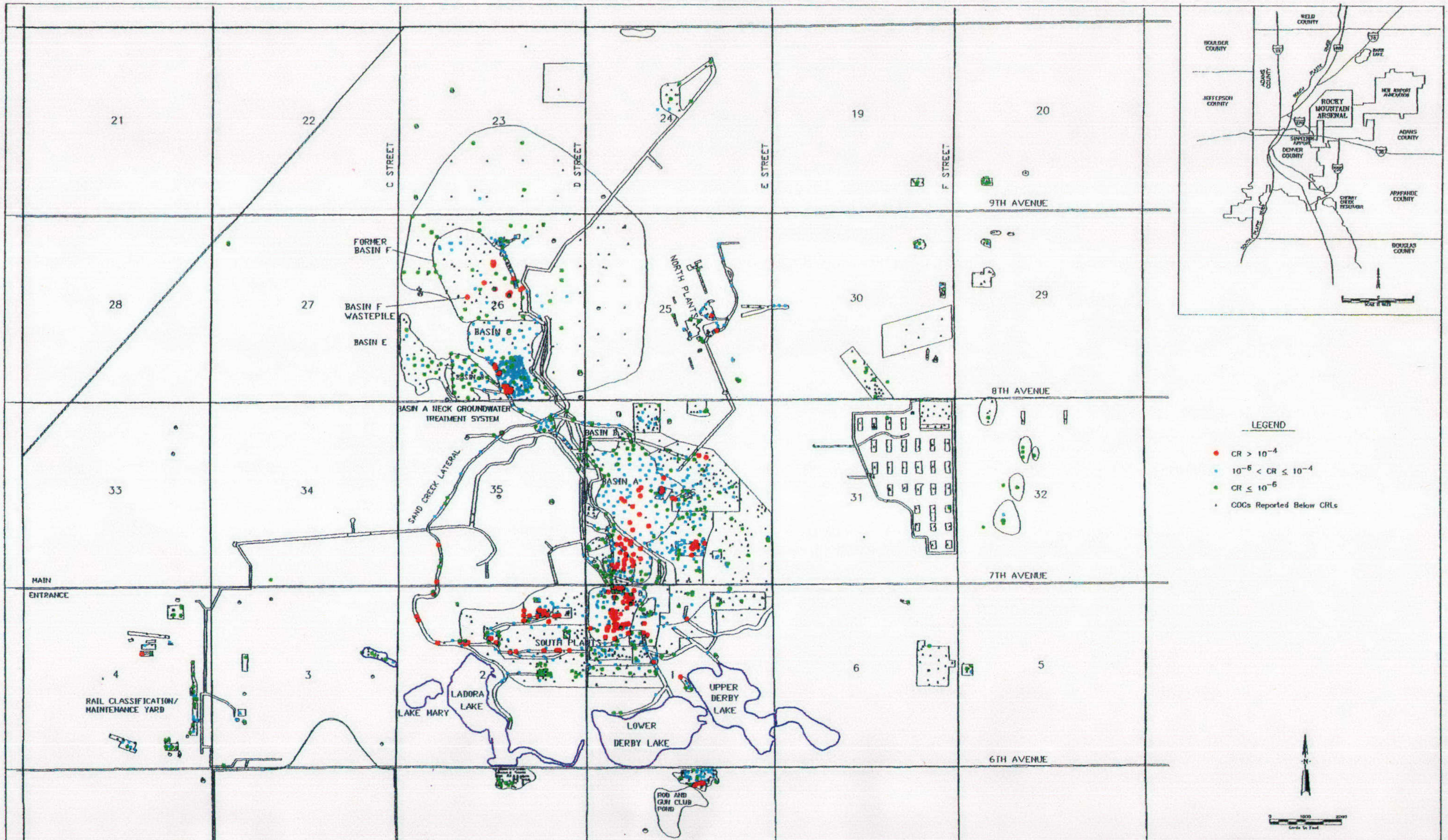
Prepared February, 1994

Figure 6-1

Map of Total Site Cancer Risks for Biological Worker, Horizon 1

Rocky Mountain Arsenal

Prepared by: Ebasco Services Incorporated



Prepared for:

U.S. Army Program Manager
for Rocky Mountain Arsenal

Prepared June, 1994

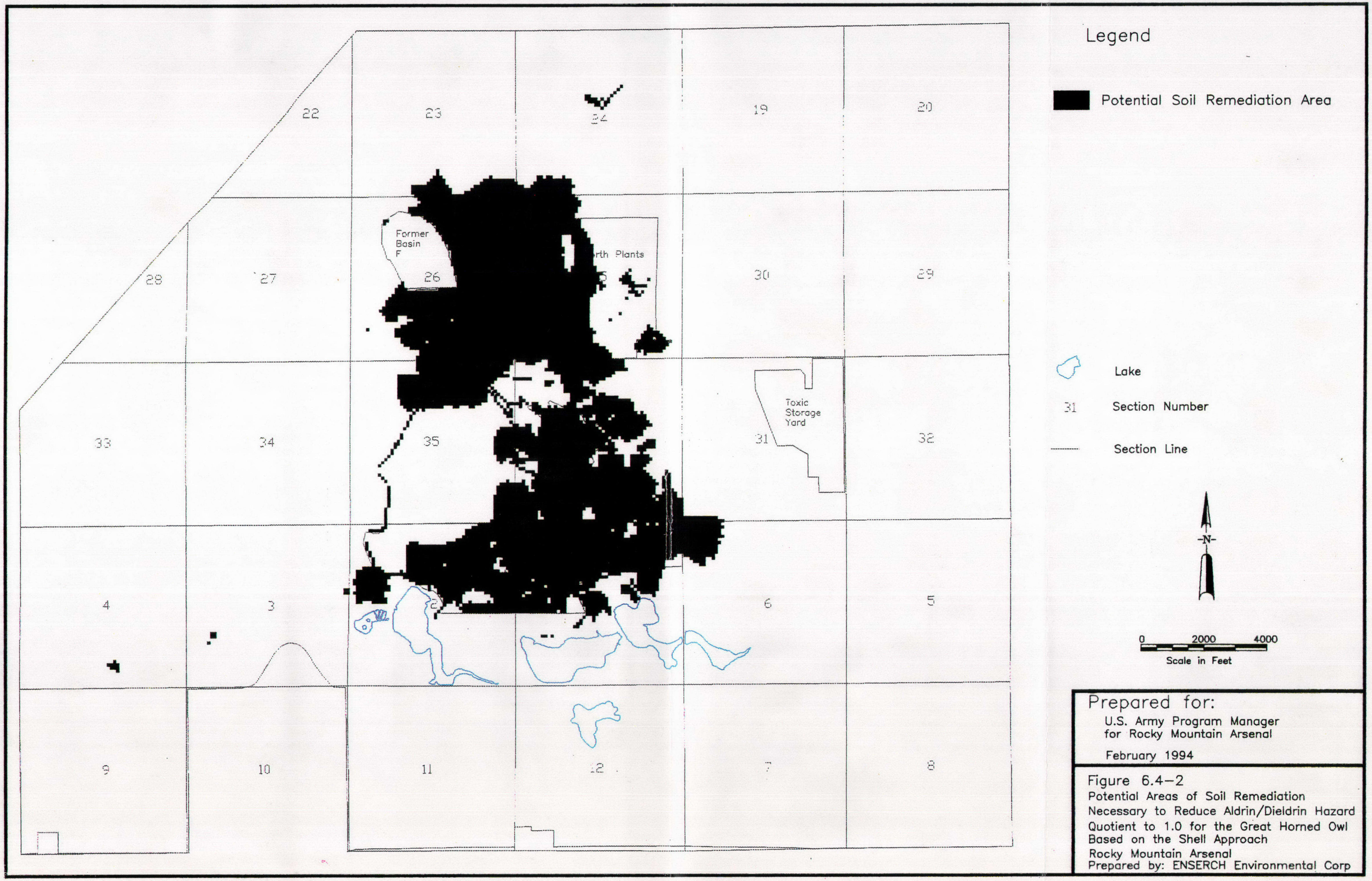
Figure 6–2

Map of Soil Boring – Specific Total Cancer Risks for Biological Worker, Horizon 1

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal
February 1994

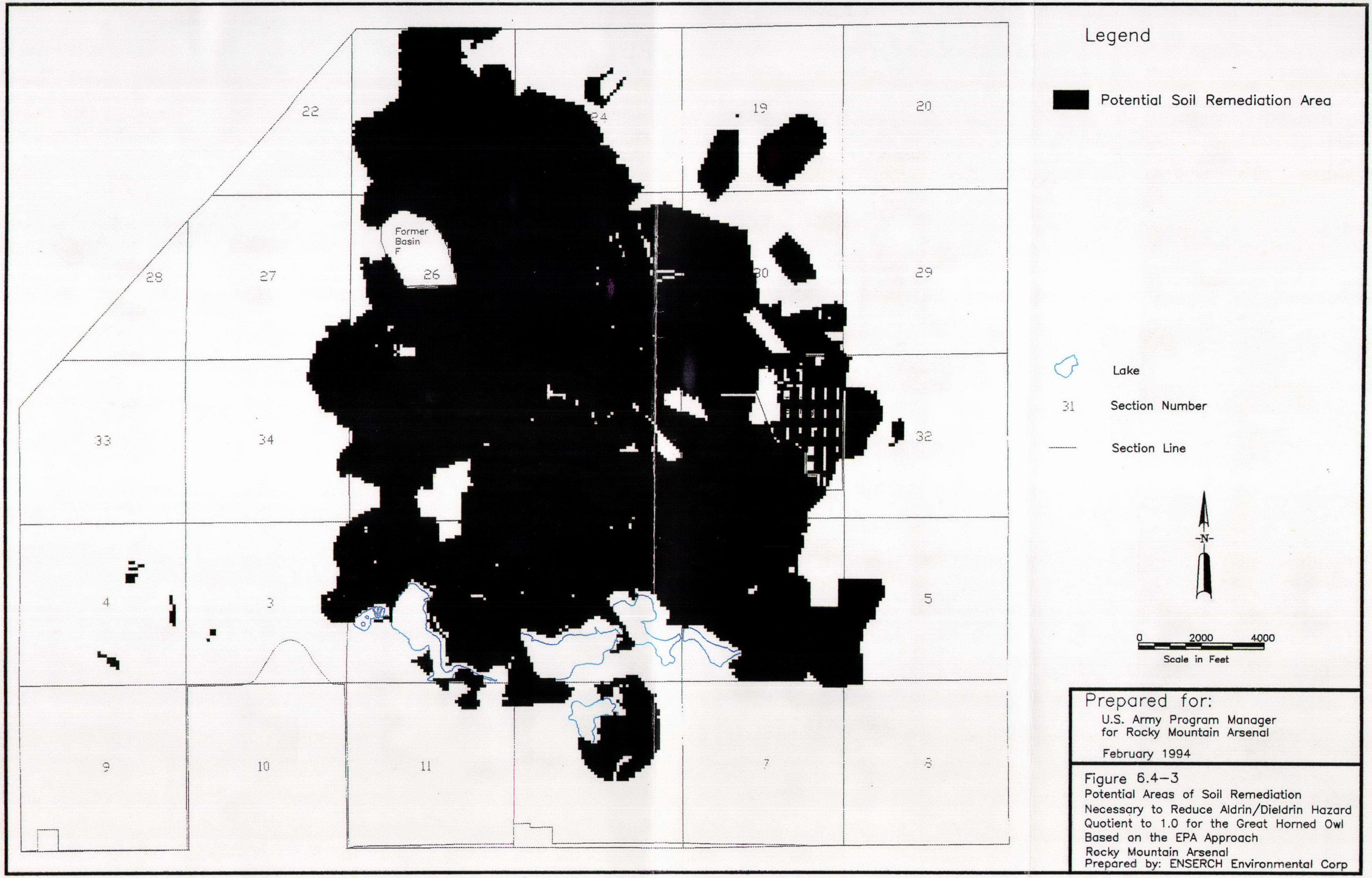
Figure 6.4-1
Potential Areas of Soil Remediation Necessary to Reduce Aldrin/Dieldrin Hazard Quotient to 1.0 for the Great Horned Owl Based on the Army Approach
Rocky Mountain Arsenal
Prepared by: ENSERCH Environmental Corp



Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

February 1994

Figure 6.4–2
Potential Areas of Soil Remediation Necessary to Reduce Aldrin/Dieldrin Hazard Quotient to 1.0 for the Great Horned Owl Based on the Shell Approach
Rocky Mountain Arsenal
Prepared by: ENSERCH Environmental Corp



Prepared for:
U.S. Army Program Manager
for Rocky Mountain Arsenal

February 1994

Figure 6.4–3
Potential Areas of Soil Remediation Necessary to Reduce Aldrin/Dieldrin Hazard Quotient to 1.0 for the Great Horned Owl Based on the EPA Approach
Rocky Mountain Arsenal
Prepared by: ENSERCH Environmental Corp

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APPENDIX A

OTHER PROGRAMS CONTRIBUTING TO THE INTEGRATED EXPOSURE ASSESSMENT/RISK CHARACTERIZATION

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LIST OF ACRONYMS AND SYMBOLS

ARAR	applicable or relevant and appropriate requirement
Army	U.S. Army
CLC2A	chloroacetic acid
CMP	Comprehensive Monitoring Program
COC	contaminant of concern
DBCP	dibromochloropropane
DCPD	dicyclopentadiene
DDE	dichlorodiphenyldichloroethene
DDT	dichlorodiphenyltrichloroethane
DIMP	diisopropylmethylphosphonate
DMMP	dimethylmethylphosphonate
EA	Endangerment Assessment
EPA	U.S. Environmental Protection Agency
ERC	ecological risk characterization
FS	feasibility study
ft	foot
GB	Sarin
GC	gas chromatography
GC/MS	gas chromatography/mass spectrometry
HCCPD	hexachlorocyclopentadiene
HE	high explosive
HHEA	Human Health Exposure Assessment
ICP	Inductively Coupled Plasma
IEA	Integrated Endangerment Assessment
IRA	Interim Response Action
OCP	organochlorine pesticides
PCB	polychlorinated biphenyl
PPLV	preliminary pollutant limit value
ppm	parts per million
RC	Risk Characterization
RI	Remedial Investigation
RMA	Rocky Mountain Arsenal
Shell	Shell Oil Company
USFWS	U.S. Fish and Wildlife Service
UXO	unexploded ordnance

A.1 INTRODUCTION

The Integrated Endangerment Assessment/Risk Characterization (IEA/RC) builds upon three previous evaluations at Rocky Mountain Arsenal (RMA)—the Remedial Investigation (RI), Comprehensive Monitoring Program (CMP), and Endangerment Assessment (EA). An overview of these programs at RMA is presented below. Reference to more detailed reports is provided for the reviewer requiring more specific information in relation to any of these programs.

A.2 REMEDIAL INVESTIGATION PROGRAM

Contaminants were initially introduced into the environmental media at RMA via liquid waste disposal in open basins, solid waste burial in trenches, accidental spills of feedstock and product chemicals, leakage from sewer and process water systems, emissions from permitted air stacks, and use of commercial chemical products during normal facility operation (EBASCO 1992). The RI program was initiated to determine the nature and extent of contamination from these various sources on RMA. Each of the different potential sources is identified in a conceptual site model for human health and biota (plants and animals) as shown in Figures A.2-1 and A.2-2, respectively. The RI program included a detailed study of chemical contamination in several environmental media—air, soils, groundwater, surface water, and biota—and consisted of historical document searches, personnel interviews, field inspections, sample collection and analysis, and various specialty studies such as soil gas and geophysical surveys, soil/water partitioning studies, aquifer tests, and others.

A.2.1 INVESTIGATIONS OF AIR, SOILS, GROUNDWATER, AND SURFACE WATER

During the RI of the on-post operable unit, the following samples were collected (EBASCO 1992):

Medium	Sampling Locations	Number of Samples
Air	13 Stations	886
Soils/Sediments	4,015 Bores, 39 Nonbores	9,692
Groundwater	619 Wells	1,982
Surface Water	27 Locations	297

The RI investigated more than 320 areas of suspected contamination and identified 178 contaminated sites at RMA. The bulk of these contaminated sites are in the central sections of RMA, in and around manufacturing complexes, in the solid waste disposal areas, and in the liquid waste disposal basins. Other contaminated sites include storage areas, maintenance areas, and sewer lines.

Samples were analyzed for as many as 60 target analytes and were also screened for nontarget analytes. Analytes included volatile and semivolatile organic compounds, pesticides, polychlorinated biphenyls (PCBs) and inorganic constituents. Compounds were determined by several different analytical methods: volatile and semivolatile organics by gas chromatography (GC) and gas chromatography/mass spectrometry (GC/MS) techniques, metals by atomic absorption techniques, U.S. Army (Army) chemical warfare agents by specialized surety instruments and techniques, and rocket fuels and their breakdown products by high-pressure liquid chromatography, GC/MS, and spectrophotometry techniques.

Each of the five abiotic environmental media investigated in the RI program was found to be impacted by contamination. The contaminants found included organochlorine pesticides, arsenic, mercury, volatile halogenated organics, volatile aromatic organics, volatile hydrocarbons, semivolatile halogenated organics, and dibromochloropropane (DBCP).

Although local volatilization and eolian (wind-dispersion) mechanisms have transported contaminants via the air medium, RI data show RMA air quality to be superior to that of nearby urban areas with respect to concentrations of pollutants regulated by the National Ambient Air Quality Standards. Detections of organochlorine pesticides in surficial soils, however, indicate that eolian processes have caused redistribution of contaminants in surficial soils.

Infiltration of contaminated water and liquid wastes from source areas transported contaminants into subsurface environments, including the unsaturated zone and the unconfined flow system (the shallow water table aquifer). The resultant groundwater contaminant plumes are moving towards the north and northwest boundaries of RMA where they are intercepted by boundary containment systems designed to prevent further migration of contaminated groundwater off post.

The results of the RI program for these media are documented in 216 contamination assessment reports, the data addenda from the Phase II investigation, and the data presentation reports prepared on a site-by-site basis; 4 RI reports addressing air, soils, water, and structures; and 7 study area reports that integrate the soils data with information from the other media reports on a geographic basis. For evaluation in the IEA/RC, study area report sites were further organized into site designation groups based on similarities in site characteristics and soil contamination patterns. Table A.2-1 lists all sites by site designation and presents a brief summary of site characteristics and contaminants of concern (COCs) within each designation, and Figure A.2-3 shows the location of the sites. For additional information about the RI, the reviewer is referred to the Remedial Investigation Summary Report (EBASCO 1992) for a more complete overview of the RI program, as well as to the series of specific reports discussed above.

The contaminant-specific RMA soils and groundwater data collected in the RI program were used as input to the Human Health Exposure Assessment (HHEA). Groundwater data served as input to the evaluation of vapor inhalation exposure pathways. To characterize human health risk in the IEA/RC report, information on contaminated soils collected during the RI program was used to assess risks to humans from soil exposures only, consistent with the use restrictions on groundwater specified in the Federal Facility Agreement (EPA 1989b). To characterize ecological risk in the IEA/RC report, chemical data from the RI program and information from the CMP (on soils, surface water, sediment, and biota) were used to evaluate ecological risks.

A.2.2 INVESTIGATIONS OF BIOTA

Biota assessment studies, called the Biota RI, were conducted in two phases as part of the RI. These studies determined the nature and extent of contamination in RMA biota and the effects of contamination on biota. Phase I focused on acquiring and reviewing available data, conducting brief site visits, and evaluating pertinent information from all sources. Phase II studied selected populations and COCs for biota, identified key receptors, evaluated potential adverse effects of contaminants on biota, investigated pathways of contaminant movement to and through biological systems, and also analyzed tissues from selected species to document current levels of specific target analytes.

Under the Biota RI program, chemicals were identified as potential COCs if they were found in biota sampled at RMA and/or if they satisfied all of the following criteria:

- Presence in the RMA environment above ambient concentrations in surface water and in groundwater and soils at depths of less than 20 feet (ft)
- Moderate or greater toxicity rating in the RMA Chemical Index (EBASCO 1988b)
- Moderate or greater production, use, or disposal volume at RMA
- Persistence in the environment

Based on these criteria, a list of 37 biota COCs was developed from the 63 analytes considered in the RI program for other exposure media (i.e., air, soils, groundwater, and surface water). Additional contaminants were included in the biota COC list as a result of discussions in the RMA Biota Assessment Committee meetings. Dimethylmethylphosphonate (DMMP) was included on the list because it is associated with diisopropylmethylphosphonate (DIMP), and because it may have been disposed in relatively high volumes. Methylphosphonic acid was included because it is toxic to plants, mobile in water, and persistent in the environment. Accordingly, 39 biota COCs were identified.

From the 39 biota COCs, seven chemicals were then selected as major COCs. For a chemical to be selected as a major COC, it had to meet both of the following criteria:

- Found in the physical environment for biota (in groundwater and soils at depths of less than 20 ft, and in surface water based on Phase I soil and water sampling results) at concentrations above background in an areal extent greater than 5 acres
- Rated moderate or greater in persistence, toxicity, and production, use, or disposal volume

The seven major COCs identified as a result of this process are aldrin, DBCP, dieldrin, endrin, isodrin, arsenic, and mercury. Table A.2-2 shows how the major COCs were distinguished from the other 32 COCs on the basis of the selection criteria. If production, use, or disposal volume data for a chemical were unavailable in the RMA Chemical Index, low volumes were assumed unless additional information indicated otherwise. Areal extent above background was estimated for some contaminants since in some cases data were reported for chemical groups rather than individual chemicals. Arsenic was selected as a major COC, although volume information was lacking, because other sources indicated that the volume was potentially high. Other contaminants were considered if prior studies indicated that they were detected at elevated concentrations in biological tissues. For example, mercury reportedly occurs in small volumes at RMA; however, a study of contamination in the Lower Lakes indicated that mercury was widespread in both plant and animal tissues.

Except for DBCP and isodrin, the major COCs became the target analytes for analysis in biota. DBCP and isodrin were excluded as target analytes because DBCP is rapidly metabolized and does not bioaccumulate significantly (ESE 1989), and because isodrin rapidly metabolizes in biological systems and the environment to endrin, which was already a target analyte. Dichlorodiphenyltrichloroethane (DDT) and dichlorodiphenyldichloroethene (DDE), however, were added as target analytes because they have high potential for bioaccumulation and public interest.

As indicated in Table A.2-3, contaminant levels were measured in 438 samples from organisms from sites of known or suspected contamination and from on- and off-post control sites. These samples were taken from species selected for sampling on the basis of their significance to wildlife identified as threatened, endangered, or candidate species; their potential consumption by humans; and their ecological value, i.e., contribution to the range of trophic levels, representation of higher trophic levels, and importance in regional ecosystems. Tissues were selected for chemical analysis based on 1) the probable fate of the organism within the food webs and those tissue portions determined most likely to be consumed by predators, 2) whether the organism was a target receptor, and 3) whether portions of the organisms could be consumed by humans.

Food web pathway models were used to evaluate potential effects of the major COCs on species at higher trophic or feeding levels, and thorough toxicity assessments were completed. The pathway analyses, toxicity data, and regulatory guidelines (i.e., applicable or relevant and appropriate requirements [ARARs]) were used to establish acceptable levels for the major COCs that could occur in the selected abiotic media without resulting in detectable adverse effects on biota. Toxicity data and ARARs were also used in a less extensive toxicity assessment to establish acceptable levels for the other 32 COCs. A preliminary comparison of these acceptable levels with levels found in abiotic media indicated exceedances. More detail on this program can be found in the Biota RI technical plan (ESE 1988) and the final Biota RI report (ESE 1989). A summary of this approach with comments by U.S. Environmental Protection Agency (EPA) peer reviewers is provided in a case study review document published by EPA (1993).

The approaches used in the Biota RI to develop acceptable contaminant concentration levels formed the basis of the approach in the ecological risk characterization (ERC). The Biota RI data on contaminant concentrations in biota tissue samples and abiotic media samples, as well as similar CMP data, were used in the ERC food-web model and to estimate risk to biota.

A.3 COMPREHENSIVE MONITORING PROGRAM

A.3.1 INVESTIGATIONS OF AIR, GROUNDWATER, AND SURFACE WATER

One of the objectives of the CMP was to collect baseline and long-term monitoring data for the air, groundwater, and surface water media at RMA. Data were used not only to evaluate changes in contaminant migration patterns, but also to evaluate impacts as a result of interim response actions (IRAs) or remedial actions.

A.3.1.1 Air Monitoring

The purpose of the CMP air monitoring element (the Air CMP) was to collect baseline data in continuation of a program established under the RI. The Air CMP was primarily used to determine ambient air quality levels at RMA in support of remedial actions and as a guide to evaluate their progress, but it also had several related objectives: (1) to verify and evaluate potential air quality hazards; (2) to verify that progress had been made to date in removing air contaminants resulting from previous activities; (3) to provide baseline data in order to evaluate progress during future remedial activities; (4) to develop real-time guidelines, standard procedures, and data collection methods, as appropriate, to indicate impacts of ongoing remedial actions; and (5) to validate and document database reliability. Moreover, Air CMP data were used to assess risks from IRAs at RMA and were considered in the characterization of human health risk in the IEA/RC report.

Air CMP data were retrieved using of a network of fixed and portable monitoring stations. The stations collected air samples and measured a 13-suite set of analytes. The network had three modes of operation: (1) year-round and routine seasonal baseline monitoring of particulate matter less than 10 microns in diameter, volatile organic compounds, semivolatile organic compounds, total suspended particulates, organochlorine pesticides, asbestos, specified metals, and gaseous pollutants; (2) "high-event" monitoring during specified meteorological conditions to measure peak concentrations of volatile and semivolatile organics, arsenic, and metals; and (3) remedial activity monitoring coordination and direct support in order to standardize and supplement air monitoring procedures for on-site remedial and construction activities.

A.3.1.2 Groundwater Monitoring

The groundwater monitoring element of the CMP (the Groundwater CMP) was designed to provide continual and long-term monitoring of groundwater at RMA and adjacent off-post areas. Data for the Groundwater CMP have been collected each year since fiscal year 1988. The nature and extent of the program is reevaluated annually, and network design, frequency of sampling, and analytical suites are changed as appropriate. Groundwater data were used to verify data and analyses previously obtained as part of the RI, to assess changes in the rate and extent of contaminant migration, to monitor the effects of remedial actions, and to meet regulatory requirements.

The Groundwater CMP relied upon the collection of water-level data to provide information about groundwater flow and the collection of water-quality data to provide information about contaminant distribution. These data were collected from a network of wells designed to sample the shallow water table aquifer, called the unconfined flow system, as well as deeper confined aquifers of the Denver Formation, called the confined flow system.

Data from the Groundwater CMP were used to assess exposures in the HHEA and the HHEA Addendum.

A.3.1.3 Surface Water Monitoring

In the surface water element of the CMP (the Surface Water CMP), both surface water quantity and surface water quality were routinely monitored.

Surface-water data were used to characterize risk to both humans and biota in the IEA/RC report. Surface water quantity and quality data are currently being used in the ongoing on-post operable unit feasibility study (FS) to evaluate land-use scenarios, environmental conditions, and remedial technology processes.

A.3.2 INVESTIGATIONS OF BIOTA

The purpose of the CMP biota monitoring element (the Biota CMP) was to provide further site-specific information concerning concentrations of COCs existing at RMA as compared to control sites, pathways of COC movement in biota, the extent of accumulation or magnification of COCs that occurs in these pathways, and changes in receptor-tissue COC concentrations relative to time and increasing distance from identified contaminant sources. The Biota CMP monitored biota tissues for COCs and conducted population surveys of prairie dogs. An independent selection process using more detailed toxicological criteria identified the same seven major COCs selected during the Biota RI.

Contaminant analyses were conducted on 1,410 biological samples representing 18 terrestrial taxa in 8 terrestrial areas and 14 aquatic taxa in 5 aquatic areas and were supplemented by 340 samples from terrestrial and aquatic control sites. A map of these biota areas is included in Appendix C, Section C.4. Species selection for tissue analysis was based on taxonomic group, trophic level, game species status, importance as a prey item for endangered species, threatened or endangered species status, distribution at RMA, home range relative to RMA, ability of the population to support collection, prior sampling under the Biota RI, and existence of other historical contaminant data. Tissues were selected for chemical analysis on the basis of location within the food web, the portion of the organism typically consumed, the size and type of the organism, and whether the organism was a target receptor prey species.

The analytical program results summarized the nature and extent of biota contamination geographically and taxonomically. Biota RI data and Biota CMP data (Tables A.2-3 and A.3-1) were analyzed using comparative statistics to quantify the variation among geographic areas, through time, and among taxonomic groupings. Detailed information can be found in the Biota CMP technical plan (RLSA 1988) and the Biota CMP annual reports for 1988, 1989, and 1990 (RLSA 1989, 1990, 1992).

The CMP data on concentrations of COCs in biota tissue samples and abiotic media samples, together with RI data, were used in the ERC food-web model and to calculate potential risk to biota at RMA.

A.4 ENDANGERMENT ASSESSMENT PROGRAM

The Endangered Assessment (EA) program consists of three major components: Contaminant Identification, Exposure/Toxicity Assessment, and IEA, as well as a fourth subcomponent, the RC. The Contaminant Identification and Exposure/Toxicity Assessment components (and HHEA Addendum) are discussed in the following section. The remaining component, the IEA, and its subcomponent, the RC, are the subject of this report.

A.4.1 CONTAMINANT IDENTIFICATION

Contaminant identification was the subject of a three-volume report (EBASCO 1988b) that addressed the following: (1) the selection of a subset of target analytes for evaluation in the RI and EA programs from an initial listing of more than 650 chemicals, (2) the evaluation of nontarget (tentatively identified) analytes in soils and groundwater for potential inclusion as target analytes in the RI and EA programs, and (3) a determination of potential chemical-specific ARARs. Each of these principal elements of the contaminant identification process is briefly discussed below.

Contaminants in the RI and EA programs were selected as target analytes if they satisfied all of the following criteria: (1) quantities handled or disposed at RMA, (2) acute toxicity and carcinogenic potential, (3) persistence in the environment, (4) identification as a breakdown product from Army surety agents, and (5) the presence of the chemical in other monitoring or investigatory programs ongoing at RMA. A total of 64 contaminants were identified as target analytes from a list of more than 650 chemical constituents. These target contaminants were subsequently evaluated in the HHEA report (EBASCO 1990). Target contaminants were further screened for biota in the Biota RI and CMP to identify COCs (see Sections A.2.2 and A.3.2 of this appendix).

The nontarget analyte screening involved an analysis of the nontarget fraction—tentatively identified compounds—for soil and groundwater samples and included the following activities: (1) reviewing and editing the Phase I RI nontarget analyte database, (2) assigning an origin to each constituent (i.e., removing those constituents considered naturally occurring, laboratory-derived contamination, or ubiquitous in the environment), and (3) considering acute toxicity and carcinogenic potential inclusive of chemicals with moderate-to-high toxicity or carcinogenicity. From this screen, 20 chemicals were identified for consideration in additional RI sampling programs and/or for potential evaluation as target analytes in the HHEA.

In addition to the specific objectives summarized above, the contaminant identification report (RMA Chemical Index) (EBASCO 1988b) was also intended to serve as a source of chemical-specific information (e.g., quantity used, quantity disposed, etc.) for compounds associated with historical operations at RMA.

A.4.2 EXPOSURE/TOXICITY ASSESSMENT

The Exposure/Toxicity Assessment component of the EA program was completed for human receptors in the HHEA and HHEA Addendum. Only the toxicity assessment portion was completed for ecological receptors in the final Biota RI report (ESE 1989). The following sections summarize these evaluations for both human and ecological receptors.

A.4.2.1 Human Health

The HHEA served as a basis for identifying COCs that would become the focus of a more detailed evaluation of risk during the IEA/RC and for making a preliminary identification of those sites requiring consideration in the FS (Priority 1 and 2 sites). The HHEA presented an analysis of land-use concepts for future consideration at RMA, unrestricted by the terms of the Federal Facility Agreement. Once these general concepts or scenarios were identified, information on regional development trends, constraints and practical limitations to development, opportunities for development, and public opinion were all analyzed to define possible land-use options.

Once land-use options were identified and the predominant exposed populations determined, various exposure scenarios (long-term vs. short-term exposures), exposure pathways, and applicable exposure parameters could be identified. A toxicity assessment was performed for each of the 64 COCs evaluated in the HHEA. The toxicity assessment consists of brief chemical profiles that summarize physical and chemical data, environmental fate information, toxicological information, and available dose-response data for the ingestion and inhalation routes of exposure.

Information from the toxicity assessment was then considered together with the exposure information to develop pathway-specific and cumulative draft preliminary pollutant limit values (PPLVs) for soils. The draft PPLVs were developed as human health risk-based soil criteria from which indices of exposure, areas of current PPLV exceedance, and future site risks could later be quantified.

Draft PPLVs were developed for a long-term (chronic) exposure scenario under the assumption that no additional COCs or areas of exceedance would be identified during the consideration of short-term exposures (given the conservative nature of the chronic draft PPLVs). Soil exposure pathways considered included soil ingestion, dermal contact, particulate inhalation, soil vapor inhalation in open spaces, and soil vapor inhalation in enclosed spaces. Additionally, vapor inhalation from contaminants in groundwater was also evaluated. The first three exposure pathways were evaluated for the 0- to 10-ft soil horizon in consideration of excavation activities (a conservative assumption for certain populations). The vapor exposure pathways were evaluated for the soil horizon ranging from 10 ft to the groundwater table.

The HHEA considered various draft PPLV values corresponding to a range of identified exposed populations that included regulated, casual, and recreational visitors and commercial and industrial workers. The draft PPLVs were estimated using exposure model parameters, called most-likely estimates, which were developed using past EPA risk assessment guidance (1989a) and using best professional judgment. Draft PPLVs were also developed considering reasonable maximum exposure model parameters developed by the EA Technical Subcommittee. This subcommittee is composed of the Army and its subcontractors and the Organizations and State. The Organizations and State serve as a reviewing panel for RMA and include representatives from the EPA, U.S. Fish and Wildlife Service (USFWS), Shell Oil Company (Shell), the Colorado Department of Health, and various subcontractors.

The 178 contaminated sites at RMA were individually evaluated in the HHEA. In the HHEA, maximum measured contaminant concentrations in soils (considering the occurrence of nontarget chemicals and the additivity of multiple chemicals) were compared with the health risk-based most-likely estimates (and for one site, the reasonable maximum exposure draft PPLV values) to determine which contaminants demonstrated exceedances. Additionally, vapor fluxes of groundwater contaminants measured at each site were compared with critical vapor fluxes to identify contaminants of significance in groundwater. Sites displaying exceedances of draft PPLVs were designated as Priority 1 sites, while sites displaying no exceedances of draft PPLVs were designated as Priority 2 sites. Contaminants of significance were identified for both types of sites. These evaluations resulted in the identification of 121 Priority 1 sites encompassing 38 COCs and 57 Priority 2 sites. COCs identified during the HHEA were more rigorously evaluated in the subsequent IEA/RC.

Following HHEA review, the Organizations and State requested that additional scenarios addressing short-term (acute and subchronic) exposures at additional soil depth intervals be incorporated into the HHEA to ensure that all appropriate COCs were identified for evaluation in the IEA/RC. Evaluation of the potential for groundwater vapor inhalation in enclosed spaces was also requested by the Organizations and State for those portions of RMA outside of the 178 evaluated sites. Additionally, it was agreed that an independent technical panel be convened to review the Army's vapor inhalation models since concern was expressed over their accuracy for predicting contaminant vapor fluxes. The Army agreed to perform the requested additional evaluations as an addendum to the HHEA.

Accordingly, the following four technical evaluations were performed as part of the HHEA Addendum:

- Development of noncarcinogenic acute and subchronic draft PPLVs for direct soil exposure pathways for each of the five populations evaluated in the HHEA and performance of a site-by-site exposure assessment for the 0- to 10-ft soil depth interval

- A site-by-site exposure assessment for acute, subchronic, and chronic exposure periods based on contaminants contained in the 0- to 1-ft soil depth interval to be performed for the regulated, casual, and recreational visitor populations

- A site-by-site exposure assessment for acute, subchronic, and chronic exposure periods based on contaminants contained in the 0- to 2-inch soil depth interval to be performed for each of the five populations evaluated in the HHEA

- An exposure evaluation of the enclosed space vapor inhalation pathway for acute, subchronic, and chronic scenarios to be performed for groundwater contaminants in areas outside of the designated sites (except where physical constraints exist) for the commercial and industrial worker populations.

The first three technical evaluations considered whether additional COCs were indicated for potential inclusion in the IEA/RC report on the basis of short-term (acute, subchronic) noncarcinogenic effects, and whether additional sites (and additional chemicals on these sites) displayed exceedances in addition to those identified in the HHEA report. Table A.4-1 summarizes the results of these evaluations. No new COCs were identified in the first three evaluations conducted for the HHEA Addendum.

The fourth technical evaluation incorporated modifications to the vapor inhalation exposure models based on the review of the models by an independent technical review panel (Jury et al. 1991). The enclosed space vapor inhalation evaluation considered whether groundwater wells outside of the sites exhibited exceedances of critical vapor fluxes for volatile contaminants based on maximum observed concentrations. Exceedances were evaluated for chronic, subchronic, and acute exposures. These evaluations revealed no exceedances of vapor fluxes for acute, subchronic, or chronic exposure scenarios. Therefore, no additional groundwater COCs were indicated beyond those identified in the HHEA report.

A.4.2.2 <u>Ecological Health</u>

A.4.2.2.1 Biota RI Final Report

The Biota RI report included a toxicity assessment with detailed toxicity profiles focusing on ecological receptors. The 39 COCs were divided into two groups, major COCs and other COCs. The seven major COCs were aldrin, arsenic, DBCP, dieldrin, endrin, isodrin, and mercury. The remaining 32 COCs constituted the other group of COCs.

Development of the toxicity profiles for the major COCs involved an extensive literature search, and included toxicity to aquatic life (plants, invertebrates, and fish) and terrestrial life (plants, invertebrates, birds, and mammals). Data for species occurring at RMA, especially waterfowl and raptors, were considered important and included when available. In addition to information on toxicity, data on bioconcentration and bioaccumulation factors were included. Other pertinent environmental fate data (e.g., persistence, partition coefficients) were incorporated into the toxicity profiles as well.

The toxicity profiles for the other COCs were less extensive, often because less toxicological and environmental fate information was available for them. However, these profiles also included specific data on the toxicity of a chemical to aquatic or terrestrial life as well as data to be used to determine bioaccumulative properties.

Food-web modeling using data collected both as part of the toxicity assessment and with existing on-post data was performed for the major COCs (Fordham and Reagan 1991). The modeling was designed to predict potential biomagnification effects and risk to top predator trophic levels that were not available for sampling, such as bald eagles. Biomagnification factors were predicted and compared to health-based residue concentrations termed the maximum allowable tissue concentration to determine preliminary source concentrations (i.e., acceptable levels) above which concentrations might pose a threat to ecological health.

The food-web modeling focused on potential ecological health effects from food-chain transfer of chemicals, although other exposure pathways were evaluated as well. For example, the toxicity profile information on toxic effects as a result of direct contact was used to evaluate the direct contact exposure pathway for aquatic life, terrestrial plants, and invertebrates with source media. Data for direct contact toxicity were expressed as water or soil concentrations. Toxicity resulting from surface water ingestion was also considered a major exposure pathway. Toxicity data related to surface water ingestion were not readily available from the literature reviewed. Accordingly, toxicity data on dietary exposure were divided by water intake rates per unit body weight per day to convert them to a water concentration.

Two pathways, dermal exposure and inhalation, were not quantitatively evaluated in the Biota RI. Dermal contact by birds or mammals was not considered to be an important exposure pathway compared to oral ingestion. In addition, toxicity information for wildlife species is very limited for this exposure pathway. Data derived from laboratory animals were not considered applicable because of the methods used to conduct most studies (e.g. shaving and abrading the animal's skin). Inhalation was also not considered to be a major exposure pathway based on results from the air monitoring studies, so extensive inhalation data were not included in the toxicity profiles.

An exposure assessment was not performed during the Biota RI because much of the abiotic data were unavailable when the draft and final Biota RI documents were being prepared. Accordingly, a quantitative exposure assessment is included as part of the ERC to fulfill the requirements of the EA program at RMA.

A.4.2.2.2 Other Ecological Study Programs

The Biota RI and the Biota CMP were developed by considering information from other ecological study programs. Since the early 1950s potential contamination of the flora and fauna at RMA and various aspects of the ecology of these organisms have been studied. These biota-related studies were prompted for various reasons. Initial studies were in response to reports of biota mortality and agricultural damage. In the 1950s, reports of on-post wildlife mortality and off-post agricultural damage prompted many studies and research projects designed to investigate the causes of the potential contamination. A number of chemical spills and resultant fish kills in the lakes region at RMA in the 1960s prompted a series of phytotoxicity studies, chemical contamination investigations, and a wildlife census. Subsequently, ecological investigations of broader scope were conducted in support of on-post contamination assessments and restoration planning programs that began in the 1970s. It was during the mid-1970s that the first comprehensive baseline surveys were conducted. Some of these studies had an RMA toxicological or ecological emphasis, while others were conducted at RMA in support of the proposed Stapleton International Airport expansion onto RMA property and county-wide wildlife habitat planning. Finally, more recent and on-going studies, initiated in the early 1980s, have been in support of active litigation between the State of Colorado, Shell, EPA, and the Army.

The biota-related studies have included chemical analyses, population surveys, phytotoxic response tests, baseline studies, and impact assessments on aquatic organisms, migratory waterfowl, aquatic and terrestrial plants, companion soils where biotic organisms are being studied, terrestrial animals, and micro- and macro-invertebrates. The various conclusions regarding the extent of contamination and potential effects on biota at RMA are summarized in the CMP technical plan (RLSA 1988) and provide a foundation for the consideration of current ecological status and health (see Appendix C, Section C.5).

A.5 REFERENCES

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Table A.2-1 Summary of Site Designations

Site Types	Sites	Description
Munitions Testing	CSA-2c CSA-2d ESA-1a ESA-1b ESA-1c ESA-1d ESA-4a ESA-4b ESA-4c ESA-5	These sites have similar site histories and uses, and are considered potential HE-filled UXO presence areas. The sites, predominantly located in the eastern portions of RMA, were used for testing or destruction of nonchemical munitions. These sites typically contain slag, debris, and potential UXO in the upper 1 ft of soil and therefore present physical hazards. Site ESA-4a may contain UXO at depths of up to 6 ft since it was an impact area for mortars.
Agent Storage	NPSA-2 NPSA-3 NPSA-5 NPSA-6	These sites have potential agent presence but do not contain human health exceedances except as isolated detections, and are located in the North Plants GB manufacturing area. These sites are presumed to contain agent because of historical use of agent and the presence of agent breakdown products, although agent itself has not been detected.
	ESA-3a ESA-3b ESA-3c ESA-3d ESA-3e ESA-3f ESA-3g ESA-3h ESA-3i ESA-3j ESA-3k	Sites in this set have potential agent presence but do not contain human health exceedances except as isolated detections. These sites are located in the storage areas in the eastern portion of RMA. These sites are presumed to contain agent because of historical use and the presence of agent breakdown products, although agent itself has not been detected.

Table A.2-1 Summary of Site Designations

Site Types	Sites	Description
Lake Sediments	NCSA-7 SSA-1b SSA-1c SSA-1d SSA-1e SSA-1f SSA-5b	Sites within this series group include sediments from lakes located in the southern portion of RMA and sediments from the North Bog, and were grouped together based on the potential risk they present to biotic receptors. Contamination has resulted from the influx of suspended solid- or dissolved-phase contaminants transported to the lakes by surface water or groundwater.
Ditches/Drainage Areas	CSA-2b ESA-6c NCSA-1c NCSA-1d NCSA-1f NCSA-2d NCSA-5d NCSA-8b NPSA-8c NPSA-9f SSA-2a SSA-2c SSA-5e WSA-1f	Sites with this designation have various disposal and release histories, and are contaminated with low levels of OCPs.
Basins (A-F)	NCSA-1a NCSA-1e	These two sites are located within the Basin A high-water line. Basin A contains soils and sediments that were in contact with organic and inorganic contaminants from manufacturing wastewater discharged to the basin. Contaminants are primarily OCPs and arsenic. These sites are also characterized by the potential presence of agent and agent-filled UXO.

Table A.2-1 Summary of Site Designations

Site Types	Sites	Description
Basin F Wastepile	Basin F Wastepile	This medium group consists of the Basin F Wastepile that was formed as a result of the Basin F Groundwater IRA. The IRA has included the transfer of Basin F liquids to temporary storage tanks, excavation of Basin F soils from below the original asphalt liner, and final grading, capping, and revegetation of the excavated area. The Basin F Wastepile consists of the excavated sediments and soils that are contaminated with high levels of organic compounds, arsenic, and metals. The concentrations of organics are inferred to be on the order of 1,000 to 10,000 ppm. This material also contains elevated levels of salts due to the high chloride content in wastewater stored in the former Basin F.
Basins (A-F)	NCSA-2a NCSA-2b NCSA-2c NCSA-5a	Sites within this series consist of four liquid disposal basins (Basins B, C, D, and E) that collected overflow water from Basin A. These sites are expected to contain somewhat elevated levels of salts resulting from the storage of wastewater with high chloride content. Primary soil contaminants are OCPs.
	NCSA-3	The former Basin F site consists of the former basin area, including the area beneath the Basin F Wastepile. Basin F received wastewaters through the chemical sewer system, and the site is expected to contain somewhat elevated levels of salts due to the high chloride content in the wastewater. Soil remaining in the former Basin F site contains high levels of OCPs, CLC2A, and DCPD.
	NCSA-4a NCSA-4b	These two sites are adjacent to the former Basin F, and consist of surficial soils and a deep-well disposal facility with associated piping. Soil contaminants are predominantly surficial distributions of OCPs.
Sewer Systems	NCSA-8a NCSA-8c SPSA-11 SPSA-12 WSA-7a WSA-7b	Sites within this series consist of sanitary and process water sewers. Soils around these sewer lines predominantly contain aldrin, dieldrin, and mercury.
	CSA-3 NCSA-6a NCSA-6b NPSA-1 SPSA-10	Sites within this series consist of chemical sewers. COCs in the soil include OCPs, volatile organic compounds, and CLC2A.

Site Types	Sites	Description
Disposal Trenches	CSA-1c	This site is characterized by trenches or pits that were filled with trash and manufacturing/military wastes. Wastes are suspected to consist of drums of solid and liquid material, wood, glass, metal, laboratory and manufacturing equipment, and miscellaneous material. This site is further characterized by the potential presence of agent and agent-filled UXO.
	CSA-1a	This site is characterized by trenches or pits that were filled with trash and manufacturing/military wastes in the area of the Shell Trenches. Wastes are suspected to consist of drums of solid and liquid material. IRA activities at this site have consisted of the placement of a soil cap across the entire site and a vertical barrier surrounding the site.
	SPSA-1f	This site was historically used for disposal of residual materials resulting from the production of HCCPD (hex bottoms). This material was buried in thin-gauge caustic barrels and in bulk.
Sanitary Landfills	CSA-1d ESA-2b SSA-4 WSA-2 WSA-3a WSA-3b WSA-3c WSA-3d WSA-5a WSA-5b WSA-5c WSA-5d	This site designation consists of sanitary landfills and inferred trenches that are predominantly located in the western portion of RMA. These sites contain trash and rubbish, but are not anticipated to contain drums of hazardous material, agent, or UXO. COCs present within these sites include OCPs and ICP metals.
Lime Basins	NCSA-1b	The Section 36 Lime Basins were used for the neutralization of process wastes related to agent production, and are characterized by soil/sludge mixtures with high pH levels and the potential presence of agent and OCPs. This site is distinguished by the higher percentages of OCPs. IRA activities at this site have consisted of the placement of a soil cap across the entire site.

Site Types	Sites	Description
Lime Basins, cont'd	SPSA-1e	The Buried M-1 Pits were used for the neutralization of process wastes related to agent production, and are characterized by soil/sludge mixtures with high pH levels and the potential presence of agent, arsenic, and mercury. This site is distinguished by the higher percentages of volatile organic compounds and arsenic exceedance volumes.
South Plants	SPSA-1a	This site consists of the main processing area within South Plants. Contamination has resulted from chemical disposal, storage, manufacturing, and agent demilitarization. A wide range of COCs in the soil include volatile organic compounds, OCPs, arsenic, and mercury.
	SPSA-1d SPSA-2d SPSA-3a SPSA-4a SPSA-5a SPSA-7a SPSA-8b SPSA-9a	This series of sites consists of the drainage ditches within South Plants. Contamination has resulted from chemical disposal, storage, manufacturing, and agent demilitarization. COCs in the soil include primarily OCPs.
	SPSA-2a SPSA-2b	These two sites consist of the tank farm area within South Plants where contamination has resulted from chemical storage. COCs in the soil include aldrin and OCPs. These sites are further characterized by the potential for indirect exposure from DCPD vapors that have been discovered in the tank area.

Site Types	Sites	Description
South Plants cont'd	SPSA-1b SPSA-1c SPSA-1g SPSA-2c SPSA-2e SPSA-3b SPSA-3c SPSA-3d SPSA-3e SPSA-4b SPSA-5b SPSA-6 SPSA-7b SPSA-7c SPSA-8a SPSA-8c SPSA-9b SPSA-12a SPSA-12b	The remainder of the sites within South Plants have been placed in this subgroup. Contamination at these sites has resulted from chemical disposal, storage, and manufacturing and agent demilitarization. COCs in the soil primarily consist of OCPs and ICP metals. This series of sites is also characterized by the potential presence of HE-filled UXO.
Buried Sediments/ Ditches	SSA-3a SSA-3b	These two sites within the Buried Sediments/Ditches designation are related to buried lake sediments. These sites contain contaminated sediments that were dredged from the adjacent lakes (Lake Ladora and Derby Lakes), deposited in unlined ditches at their current locations, and covered with clean soil. COCs include OCPs.
	NCSA-5b NCSA-5c NPSA-4 SSA-2b WSA-6a	This series consists of the northern and southern segments of the Sand Creek Lateral that transported runoff from the South Plants Central Processing Area during storm events and snowmelt and drainage ditches used to transport water to and from the Secondary Basins and to drain the South Plants and North Plants process areas. COCs primarily consist of OCPs.

Site Types	Sites	Description
Undifferentiated	CSA-1b CSA-2a CSA-4	Sites within this series are located in the southeastern area of Section 36 in the Central Study Area. They do not have unique site-type characteristics or contamination patterns. COCs in the soil include OCPs and CLC2A. These sites are also characterized by the potential presence of agent-filled UXO.
	ESA-2a ESA-2c	These two sites consist of trenches that are located in Sections 30 and 32 in the Eastern Study Area. They do not have unique site-type characteristics or contamination patterns. COCs include chromium and lead. The sites are also characterized by the potential presence of HE-filled UXO.

Table A.2-1 Summary of Site Designations

Site Types	Sites	Description
RMA Balance of Areas	ESA-6a ESA-6b ESA-6d NCSA-1g NCSA-9a NCSA-9b NCSA-9c NCSA-9d NCSA-9e NCSA-9f NCSA-9g NCSA-9h NCSA-9i NCSA-9j NCSA-9k NCSA-9l NCSA-9m NCSA-9n NCSA-9o NCSA-9p NCSA-9q NCSA-9r NCSA-9s	This series consists of sites identified as isolated detections of organic and inorganic contaminants and low-level surficial OCP contamination. These sites could not be grouped in any of the previous site designations since site characteristics and soil contamination patterns are not consistent with any of the designations. This designation includes all on-post areas not considered as a separate site.

Table A.2-1 Summary of Site Designations

Site Types	Sites	Description
RMA Balance of Areas (cont.)	NPSA-7	
	NPSA-8a	
	NPSA-8b	
	NPSA-9a	
	NPSA-9b	
	NPSA-9c	
	SSA-1a	
	SSA-5a	
	SSA-5c	
	SSA-5d	
	WSA-1a	
	WSA-1b	
	WSA-1c	
	WSA-1d	
	WSA-1e	
	WSA-1g	
	WSA-4a	
	WSA-4b	
	WSA-6b	
	WSA-6c	
	WSA-6d	
	WSA-6e	
	WSA-8a	
	WSA-8b	
	WSA-8c	
	WSA-8d	
	WSA-8e	
	WSA-8f	

Table A.2-2 Separation of Major COCs from Other COCs

Rationale for Separation

Chemical	Volume on RMA At Least Moderate and	Persistence At Least Moderate and	Toxicity At Least Moderate and	In RMA and Environment* With Areal Extent Greater Than 5 Acres**	THUS Selected as Major COC
Aldrin	X (M,S)	X(H)	X (H)		X
Allyl chloride	-(L,S)	-(L)	X (H)		
Arsenic	-***	X(H)	X (H)		X
Atrazine	-	X(M)	X (M)	No	
Azodrin	X(M,S)	-(L)	X (M)		
Cadmium	-	-	X (H)	No	
Chlordane	-	X(H)	-(M, L)		
Chlorophenylmethyl sulfide	X(M)	X(M)	X (H, M)	No	
Chlorophenylmethyl sulfone	X(M)	X(H)	X (H)	No	
Chlorophenylmethyl sulfoxide	-(L)	X(M)	X (M)	No	
Chlorobenzene	-	X(H)	-(M, L)		
Chloroform	X(H)		X (H)	No	
Copper	-		H (H)	No	
Dibromochloropropane	X(M,S)		X (H)		X
Dichlorodiphenyldichloroethene	-		X (H)	Yes	****
Dichlorodiphenyltrichloroethane	-		-(M, L)		****
Dicyclopentadiene	X(HP,M,S)		X (H, M)	No	
Dieldrin	X(H,HP)		X (H)		X
Diisopropylmethylphosphonate	-(MP)		-(M, L)		
Dimethylmethylphosphonate	X(H)		-(L)		
Dithiane	-		-(M, L)	No	
Endrin	X(M)		X (H)		X
Ethylbenzene	-		-(M, L)		
Heptachlor	-		X (H)	No	
Heptachlor epoxide	-		X (H)	No	
Isodrin	X(M)		X (H)		X
Malathion	-		X(H)	No	
Mercury	-(S)		X (H)		X*****
Methyl parathion	-(L)		X (H, M)		
Methylphosphonic acid	X(M)		-(L)		
Mustard	-(NR)	X (H)	X (H)	No	
Nitrosodimethylamine	-	-	X (H)	No	
1,4-Oxathiane	-	-	X (M)	No	

Table A.2-2 Separation of Major COCs from Other COCs

	Rationale for Separation							
Chemical	Volume on RMA At Least Moderate	and	Persistence At Least Moderate	and	Toxicity At Least Moderate	and	In RMA and Environment* With Areal Extent Greater Than 5 Acres**	THUS Selected as Major COC
Oxychlordane			X (H)		-		No	
Parathion	-		-		X (H)		No	
Polychlorinated biphenyl	-		X (H)		-		No	
Toluene	X (H,S)		X (M)		X (H)			
Trichloroethylene	-		X (H)		X (H)			
Xylene	X (M,S)		-(L)		X (M)			

- Did not meet criteria, or data not available.
* Above ambient concentrations in soil and groundwater at depths of less than 20 feet and in surface water.
** Areal extent was calculated only for contaminants and not eliminated on the basis of other criteria; not all Phase I data were available for consideration in determining areal extent.
*** Sources apart from EBASCO (1988a) indicated volume potentially high.
**** Not identified as a major COC, but sampled in biota tissue during the Biota RI for other reasons.
Volume: H = high waste disposal (>720,000 lbs); M = moderate waste disposal (45,000 lbs<vol.<720,000 lbs)
L = low waste disposal (<45,000 lbs); S = spills, volume not rated
HP = high production (>396,850 lbs); MP = moderation production (48,049 lbs<vol.<720,000 lbs)
LP = low production (<48,049 lbs); NR = not able to rate
Persistence: H = high persistence, M = moderate persistence; L = low persistence
Toxicity: H = high toxicity; M = moderate toxicity; L = low toxicity

Table A.2-3 Summary of Biota RI Field Program, 1986*

	Total Number of Samples Analyzed		
Species/Group	RMA Samples	Control Samples	Total
Morning Glory	5	1	6
Common Sunflower	12	2	14
Earthworms	1	10	12
Grasshoppers	8	5	13
Desert Cottontail	7	14	21
Black-tailed Prairie Dog	19	23	42
Mourning Dove	3	0	3
Ring-necked Pheasant	47	30	77
Mule Deer	14	2	16
American Kestrel	44	19	63
Terrestrial Subtotal	161	106	267
Largemouth Bass	22	11	33
Bluegill	21	17	38
Northern Pike	5	0	5
Fathead Minnow	1	0	1
Black Bullhead	3	0	3
Aquatic Species	12	0	12
Aquatic Plankton	6	0	6
Mallard	13	24	37
Blue-wing Teal	3	0	3
Redhead	5	0	5
American Coot	9	0	9
Aquatic Subtotal	100	52	152
Fortuitous Samples	18	1	19
Total RI Samples	279	159	438

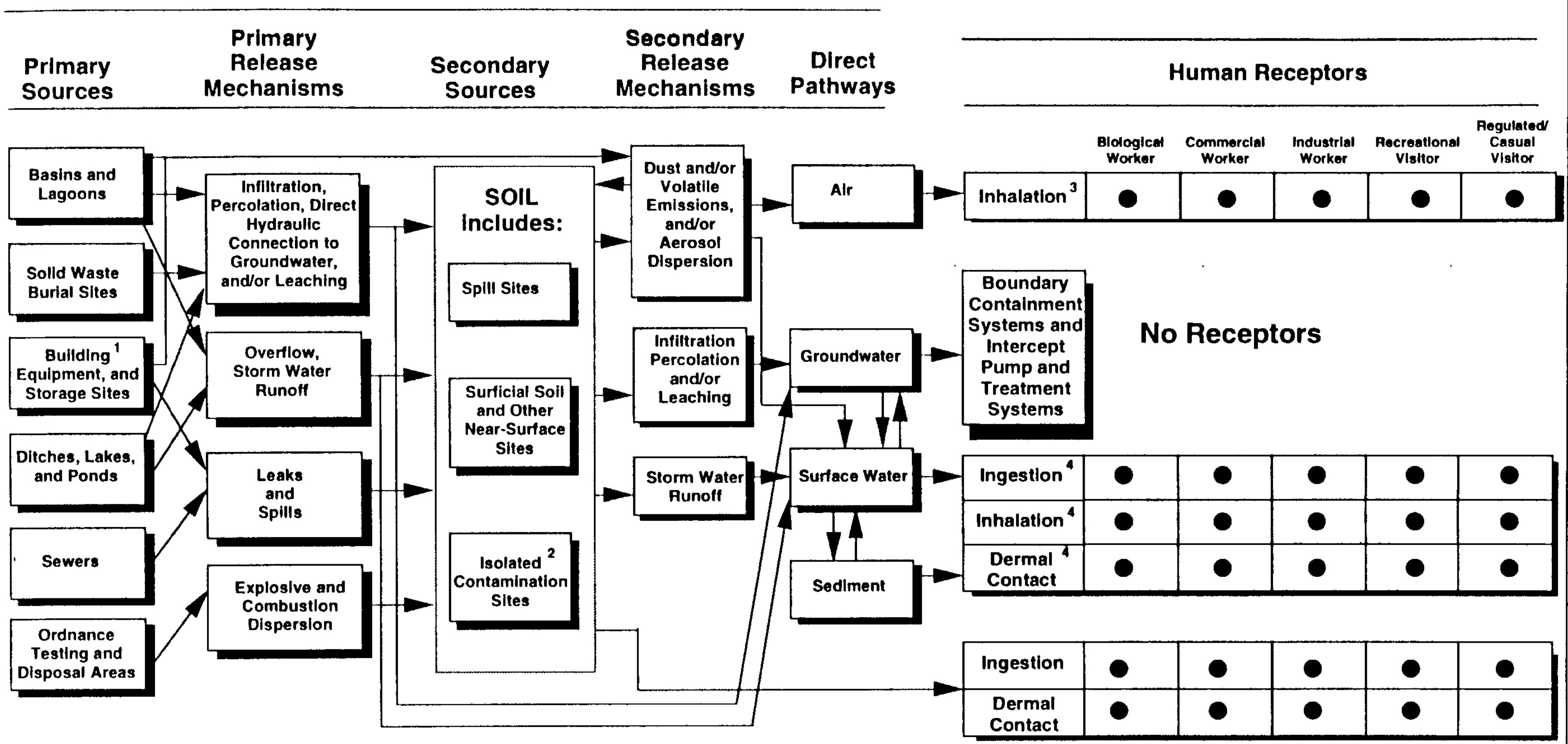
*Samples represent individuals collected for analysis.

Table A.3-1 Summary of Biota CMP Field Program, 1990			Page 1 of 1
		Total Number of Samples Analyzed	
Species/Group	RMA Samples	Control Samples	Total
Terrestrial Species			
Cheatgrass	65	16	81
Lactuca	14	2	16
Kochia	31	10	41
Sunflower	60	15	75
Earthworms	54	12	66
Ground Beetles	13	4	17
Grasshopper	66	12	78
Deer Mouse	75	15	90
Thirteen-lined Ground Squirrel	4	0	4
Desert Cottontail	16	5	21
Black-tailed Prairie Dog	95	20	115
Mourning Dove	68	10	78
Ring-necked Pheasant	88	26	114
Western Meadowlark	10	5	15
Mule Deer	20	12	32
American Kestrel	22	19	41
Burrowing Owl	7	0	7
Great Horned Owl	5	0	5
Terrestrial Subtotal	713	183	896
Aquatic Species			
Plankton	50	15	65
Coontail	12	5	17
Sago Pondweed	9	5	14
Leafy Pondweed	13	5	18
American Pondweed	39	15	54
Bluegill	45	14	59
Black/Brown Bullhead	16	11	27
Channel Catfish	12	15	27
Largemouth Bass	44	15	59
Northern Pike	7	10	17
Mallard	27	17	44
Blue-winged Teal	4	10	14
American Coot	18	15	33
Killdeer	10	5	15
Aquatic Sub-total	306	157	463
Fortuitous Samples	51	0	51
Total CMP Biota Samples	1,070	340	1,410

Table A.4-1 Results of the HHEA Addendum Analyses

Exposure Scenario Soil Depth	Most Exposed Population	Priority 1 Sites [1]	Priority 2 Sites	New COCs
Acute (0-10 feet)	Recreational	91	89	None
Subchronic (0-10 feet)	Recreational	80	100	None
Acute (0-1 foot)	Recreational	82	98	None
Subchronic (0-1 foot)	Recreational	68	112	None
Chronic (0-1 foot)	Recreational	96	84	None
Acute (0-2 inches)	Recreational	72	204	None
Subchronic (0-2 inches)	Recreational	14	262	None
Chronic (0-2 inches)	Industrial	205	71	None

1 The number of sites evaluated in the HHEA Addendum is greater than the 178 sites in the HHEA because five uncontaminated sites were not considered and Site ESA-2A was split into 7 new sites. Note also that for the 0- to 2-inch soil depth interval, the Priority designations are presented on a boring-specific (rather than a site-specific) basis.



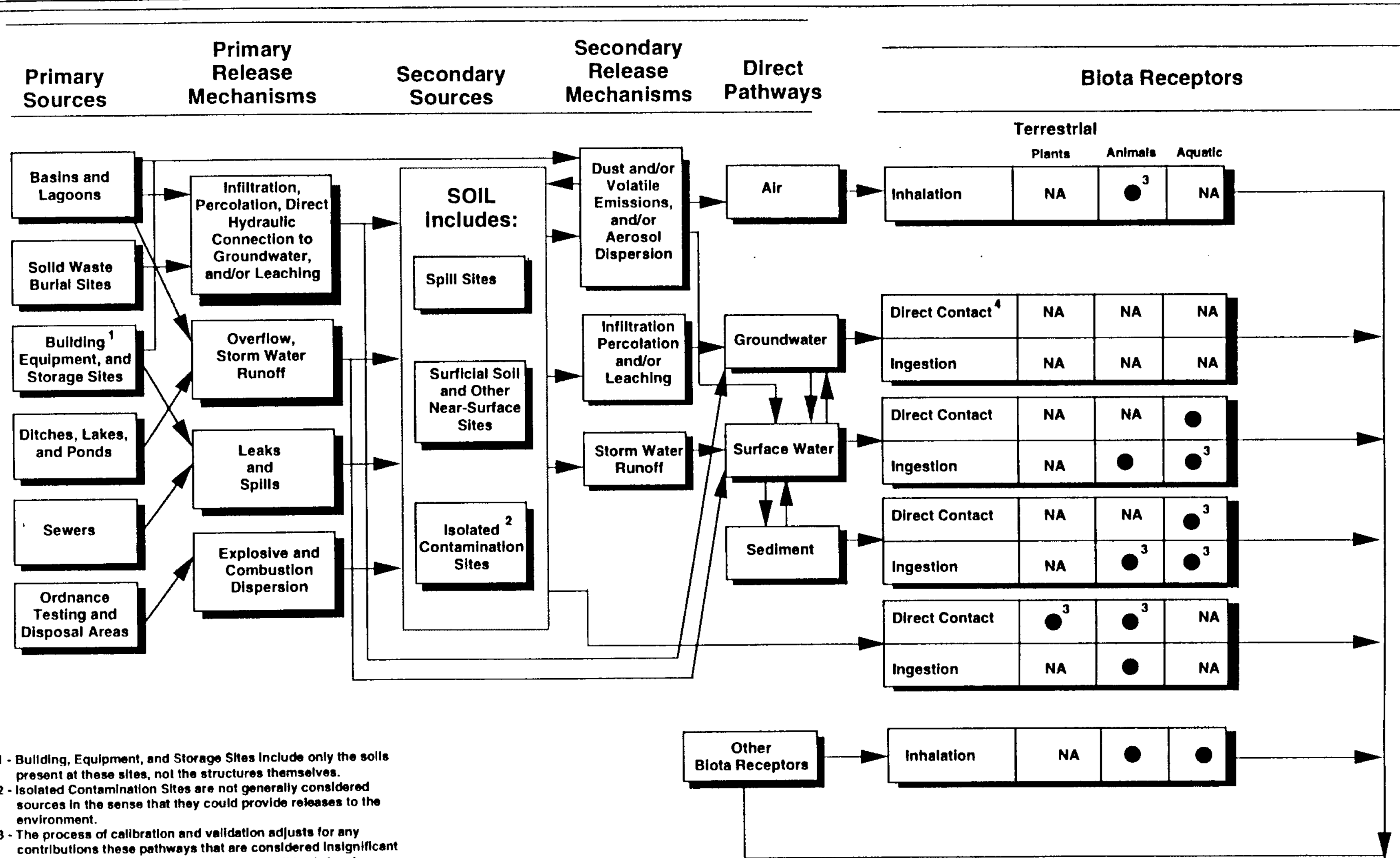
1 - Building, Equipment, and Storage Sites include only the soils present at these sites, not the structures themselves.
2 - Isolated Contamination Sites are not generally considered sources in the sense that they could provide releases to the environment.
3 - Enclosed space vapor inhalation evaluated for commercial and industrial populations only. Open space vapor inhalation evaluated for all populations except commercial workers.
4 - Only ephemeral lake sediments evaluated.

RMA IEA/RC A.2-1 2/94 eb

Figure A.2-1

Rocky Mountain Arsenal Site Conceptual Model for Human Receptors

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



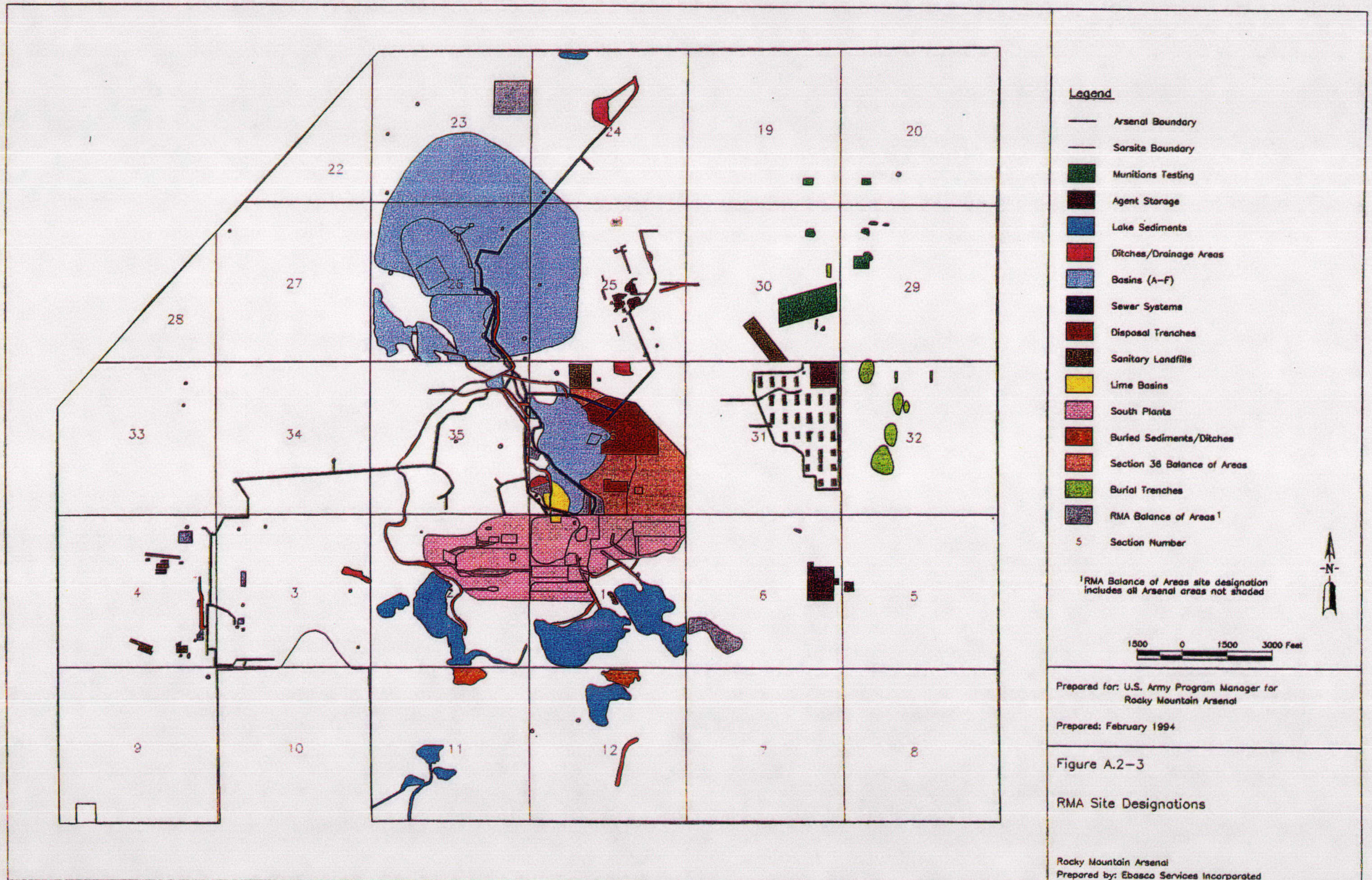
1 - Building, Equipment, and Storage Sites include only the soils present at these sites, not the structures themselves.
2 - Isolated Contamination Sites are not generally considered sources in the sense that they could provide releases to the environment.
3 - The process of calibration and validation adjusts for any contributions these pathways that are considered insignificant compared to ingestion might make to overall body burden.
4 - Only cottonwoods are expected to reach groundwater.

RMA IEA/RC A.2-1 2/94 eb

Figure A.2-2

Rocky Mountain Arsenal Site Conceptual Model for Biota Receptors

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated



Prepared for: U.S. Army Program Manager for Rocky Mountain Arsenal

Prepared: February 1994

Figure A.2–3

RMA Site Designations

Rocky Mountain Arsenal
Prepared by: Ebasco Services Incorporated

APPENDIX B

HUMAN HEALTH EVALUATIONS

TABLE OF CONTENTS*

* A more detailed Table of Contents, as well as lists of Tables, Figures, Attachments, and Acronyms and Abbreviations are included preceding each of the eight main Appendix Sections.

APPENDIX B
(SECTION B.1)

COMPUTATIONAL METHODOLOGY

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LIST OF ACRONYMS AND ABBREVIATIONS

AIC	acceptable intake chronic
ARIR	Air Remedial Investigation Report
Army	U.S. Department of the Army
ATM	atmospheres
BCRL	below certified reporting limit
BR	breathing rate
BRIR	Biota Remedial Investigation Report
BW	body weight
C	carcinogen
CAG	Cancer Assessment Group
CARs	Contamination Assessment Reports
cm	centimeter
cm^2/sec	centimeters squared per second
C_{max}	maximum site concentration
CMP	Comprehensive Monitoring Program
CNS	Central Nervous System
COCs	chemicals of concern
CPF	cancer potency factor
C_{rep}	representative site concentration
CRL	certified reporting limit
CSAR	Central Study Area Report
CSF	cancer slope factor
DBCP	dibromochloropropane
DCPD	dicyclopentadiene
DDE	dichlorodiphenyldichloroethene
DDT	dichlorodiphenyltrichloroethane
DIMP	diisopropylmethyl phosphonate
DINH	breathing rate
DMMP	dimethylmethyl phosphonate
DT	critical toxicity value
DW	exposure frequency
EA	Endangerment Assessment
EI	exposure index
EPA	U.S. Environmental Protection Agency
ESAR	Eastern Study Area Report
FAVN	time-averaged vapor flux
FFA	Federal Facility Agreement
ft	foot or feet
g/cm^3	grams per centimeters squared
G/mole	grams per mole
H	Henry's Law Constant

HCCPD	hexachlorocyclopentadiene
HEAST	Health Effects Assessment Summary Tables
HHEA	Human Health Exposure Assessment
HHEAA	Human Health Exposure Assessment Addendum
HHRC	Human Health Risk Characterization
HI	hazard index
HQ	hazard quotient
hrs/day	hours per day
IARC	International Agency for Research on Cancer
IEA/RC	Integrated Endangerment Assessment/Risk Characterization
IMPA	isopropylmethyl phosphonate
IRIS	Integrated Risk Information System
kg	kilogram
LD_{50}	lethal dose to 50 percent of the test population
L/kg	liters per kilogram
LL	lower limit
LOAEL	lowest observed adverse effects level
m	meter
m^3/day	cubic meters per day
m^3/hr	cubic meters per hour
mg	milligram
mg/cm^2/sec	milligrams per centimeters squared per second
NC	noncarcinogen
NCSAR	North Central Study Area Report
NOAEL	no observed adverse effect level
NPSAR	North Plants Study Area Report
OAS	Organization and State
OSTP	Office of Science and Technology Policy
PPLV	preliminary pollutant limit value
QA/QC	quality assurance/quality control
RAF	relative absorption factor
RAGS	Risk Assessment Guidance for Superfund
RCRA	Resource Conservation Recovery Act
RfC	reference concentration
RfD	reference dose
RI	Remedial Investigation
RISR	Remedial Investigation Summary Report
RL	risk level (carcinogens)
RMA	Rocky Mountain Arsenal
RSD	risk-specific dose
SAR	Study Area Report
SF	slope factor
SPPPLV	single pathway preliminary pollutant limit value
SPSAR	South Plants Study Area Report

LIST OF ACRONYMS AND ABBREVIATIONS
(continued)

SSAR	Southern Study Area Report
TE	exposure duration
UL	upper limit
t_d	dry out time
t_e	exposure period
TM	exposure time
UF	uncertainty factor
WOEC	weight of evidence category
WRIR	Water Remedial Investigation Report
WSAR	Western Study Area Report\
$\mu g/m^3$	micrograms per cubic meter

B.1 COMPUTATIONAL METHODOLOGY

B.1.1 INTRODUCTION

This appendix section presents the detailed computational approach used to develop risk-based criteria and to characterize the risks associated with potential human exposure to the chemicals of concern (COCs) at the Rocky Mountain Arsenal (RMA). The risk-based criteria are soil concentrations considered to be protective of human health given a defined set of exposure and toxicity assumptions. The criteria are referred to as preliminary pollutant limit values (PPLVs) in this evaluation.

The steps used to estimate PPLVs and risks are identified below:

1. Select the COCs.
2. Identify potentially exposed populations and their routes of chemical exposure.
3. Estimate chemical concentrations at the potential points of human exposure.
4. Select the exposure parameters.
5. Identify the toxicity parameters.
6. Compute the PPLVs.
7. Compute the risks.

Each of these steps is discussed in this section.

Latin Hypercube sampling is used to develop the PPLV and risk estimates. This technique provides a means of propagating the error or uncertainty through the assessment by statistically sampling a distribution (a range of parameter values) in a quantitative manner. The result of the Latin Hypercube sampling is a cumulative distribution function curve, which is used to choose a probabilistic PPLV based on a selected probability of exceedance of the PPLV. To conduct this evaluation, probability distributions were identified for most of the key variables (exposure parameters) in the PPLV equations, which are discussed in detail in Appendix Section B.3. The details of the Latin Hypercube sampling approach are provided in Appendix D, which also describes the Integrated Endangerment Assessment/Risk Characterization (IEA/RC) computer model that calculates the PPLV and risk estimates. The human health risk characterization (HHRC) results are provided in Appendix Section B.4 and Sections 3.2 and 3.3.

Extensive documentation already exists to support many aspects of the HHRC. Therefore, in this appendix, the discussions for some aspects of the computational methodology are fairly brief because the details are already provided in other published reports. However, for those aspects of the computational methodology that are not published in past reports, this appendix provides an in-depth presentation. Table B.1-1 cross-references specific sections in this report or other published reports where information regarding the computational approach can be obtained.

B.1.2 SELECTION OF CHEMICALS OF CONCERN

The first step in developing health-based criteria or in estimating risks is to select the COCs at the site. During the Human Health Exposure Assessment (HHEA), an initial list of 38 COCs at RMA was selected for evaluation (EBASCO 1990). The list was further refined to 27 COCs, listed in Table B.1-2, that are expected to contribute the majority of the projected risks at RMA. The 18 criteria used to select the COCs are listed below:

1. Include all COCs designated as Category A (Exposure Index [EI] > 10) in the HHEA. (Note: EIs are discussed in Section B.1.8.1.)
2. Include all COCs with carcinogenic weight of evidence category (WOEC) designations A or B. (Note: WOEC are discussed in Section B.1.6 and in Appendix E.)
3. Include all COCs with carcinogenic WOEC designation C <u>and</u> potency factors.
4. Consider treatability to exclude chemicals from the COC list.
5. Consider isolated detections to exclude chemicals.
6. Include all COCs listed on the Land Ban Disposal Restriction List.
7. Include all COCs with Resource Conservation and Recovery Act (RCRA) soil criteria.
8. Consider State's request to include diisopropylmethyl phosphonate (DIMP) and isopropylmethyl phosphonate (IMPA) (Note: DIMP and IMPA are predominantly groundwater contaminants and were therefore not included on the final COC list).
9. Group by chemical class to reduce COCs.
10. Consider frequency of detection.
11. Consider essential nutrients.
12. Consider concentration and toxicity.
13. Consider historical information.

14. Consider special exposure routes.
15. Consider U.S. Department of the Army agent degradation products.
16. Consider co-occurrence with other COCs to exclude chemicals.
17. Consider bioconcentration, mobility, and persistence.
18. Consider detections in laboratory blanks in comparison to concentrations detected on site. (Note: Fluoroacetic acid, which was considered a COC in previous drafts of the IEA/RC, has been removed as a COC in this analysis because on-post detections of this chemical were similar in concentration to detections in laboratory blanks.)

B.1.3 POTENTIALLY EXPOSED POPULATIONS AND ROUTES OF EXPOSURE

The PPLVs and risks are estimated for each COC by considering the potential land uses at RMA and the activities associated with the human populations who could be exposed to the COCs for each land use. For this evaluation, two land uses are considered: open space and economic development. Under the open space land use, three potentially exposed populations are evaluated: refuge workers, regulated/casual visitors, and recreational visitors. Specifically for these three populations, subpopulations representing individuals with the highest degree of potential exposure (i.e., the highest potential risk) are evaluated to ensure an appropriate level of conservatism in the risk assessment. These subpopulations are the following: biological workers (from the refuge worker population), local neighborhood regulated/casual visitors (from the general regulated/casual visitor population), and local neighborhood recreational visitors (from the general recreational visitor population). Under the economic development land use, the commercial and industrial worker populations are considered.

These populations and subpopulations can be exposed to COCs through a variety of exposure routes. Five potential routes of exposures are evaluated in this risk characterization. These routes include the direct exposure pathways of soil ingestion, dermal contact with soil, and particulate inhalation, and the indirect pathways of open and enclosed space vapor inhalation. Not all exposure pathways pertain to each potentially exposed population or subpopulation. The exposed populations and subpopulations and their respective exposure pathways are listed below:

Biological Worker: All direct pathways and open space vapor inhalation.

Local Neighborhood Regulated/Casual Visitor:	All direct pathways and open space vapor inhalation.
Local Neighborhood Recreational Visitor:	All direct pathways and open space vapor inhalation.
Commercial Worker:	All direct pathways and enclosed space vapor inhalation.
Industrial Worker:	All direct and indirect pathways.

No groundwater or consumptive (e.g., consumption of agricultural products grown in contaminated soils) exposure routes are evaluated; exposure via these routes is considered minimal or unlikely due to institutional controls on the use of the land.

The characteristics of the potentially exposed populations and subpopulations and the specific exposure routes evaluated for each group are presented in detail in Appendix Section B.2.

B.1.4 EXPOSURE POINT CONCENTRATIONS

The chemical concentration to which an individual could be exposed is known as the exposure point concentration. As described in Section B.1.8, exposure point concentrations are used in this evaluation to characterize site-related risks. Additionally, exposure point concentrations are used in the vapor inhalation PPLV models described in Section B.1.7.

Two different exposure point concentrations are used for each soil horizon at each site. First, to estimate site and boring risks, a maximum site concentration (C_{max}) is used. Use of the maximum concentration in the boring evaluations is intended to aid in the identification of potential hot spots that could require special consideration in the Feasibility Study. Second, a representative site concentration (C_{rep}) is used. Three different forms of C_{rep} can be used: $C_{rep,mean}$; $C_{rep,95th,upper}$; or $C_{rep,95th,lower}$. The forms $C_{rep,95th,upper}$ and $C_{rep,95th,lower}$ represent the 95th percentile upper and lower confidence intervals of the site sample mean concentration, $C_{rep,mean}$, respectively. To calculate $C_{rep,mean}$, a method for evaluating chemical concentrations that are below certified reporting limits (BCRL) was used to develop the data set. The procedures for evaluating BCRL data and for calculating $C_{rep,mean}$ and its confidence intervals ($C_{rep,95th,upper}$ and $C_{rep,95th,lower}$) are described below. For a more detailed discussion of C_{max} and C_{rep} calculations, see Appendix D.

B.1.4.1 Approach for Evaluating BCRL Data

The BCRL data points cannot be ignored in the estimation of a representative concentration. Removing them from the data set would tend to introduce an upward bias to the representative concentration if the concentration were estimated using only the remaining samples. On the other hand, arbitrarily assuming their concentrations to be zero would introduce a negative bias.

BCRL data were evaluated using the robust method (Helsel and Cohn 1988) or the U.S. Environmental Protection Agency (EPA) one-half certified reporting limit (CRFL) method. For sample sets with at least four valid detections ("hits"), the robust method was employed in estimating the concentrations for the BCRL samples. In this method, a lognormal distribution curve was first fit to the hits. The resulting curve was then used to estimate the concentrations of the BCRL samples. Concentration and risk calculations based on this method contain the smallest amount of uncertainty, and are classified as Type 1 calculations.

Sample sets with fewer than four hits were handled using the one-half CRL method. Using this method, BCRL sample concentrations were assumed to equal one-half the CRL. C_{rep} values calculated using this method are classified as Type 2 calculations. This is due to the greater level of uncertainty introduced by assuming the true concentration to be one-half the CRL.

B.1.4.2 Exposure Point Concentration Calculations

After the BCRL data were analyzed using the method described above, the resulting data set (consisting of the analyzed BCRL data and the detected soil concentrations) was used to calculate the sample mean ($C_{rep,mean}$) and its 95 percent standard statistical language upper and lower confidence limits ($C_{rep,95th,upper}$; $C_{rep,95th,lower}$), as described below.

B.1.4.2.1 $C_{rep.mean}$ and C_{max}

The lognormal-based formula for estimating the mean (Gilbert 1987) is unbiased only when the underlying distribution is lognormal. Because of the high proportion of BCRLs in the data set, there is considerable uncertainty about the fit of the data to a lognormal distribution. In light of this uncertainty, it is most defensible to estimate the true mean based on the sample mean and not to rely on the assumption of lognormality. Since the sample mean is an unbiased estimate of the population mean for all distribution types (lognormal, normal, etc.), $C_{rep.mean}$ was therefore used for each soil horizon at each site. Figure B.1-1 shows the flow diagram for site $C_{rep.mean}$ calculations, including the method for treating uncertainties associated with the use of BCRL sample data.

B.1.4.2.2 Bootstrap-Based Confidence Intervals

The bootstrap resampling method described in Noreen (1989) is one of the most recent developments in inferential statistics. It does not require any assumptions as to the type of distribution or degree of skewness and is therefore generally used when the underlying distribution type is uncertain. The procedure is as follows. A hypothetical sample of size N (the number of original data points) is drawn from the N data points with replacement. If replacement was not used, the new sample would equal the old one in a random order. Under replacement, each time a sample is drawn, it is replaced back into the data set and can therefore be drawn multiple times. A mean is calculated from this hypothetical sample. The entire process is repeated a large number of times (1,000 is used in the implementation of this method for the IEA/RC), each time calculating the mean. The resulting set of means is then sorted in ascending order. The lower 95 percent confidence interval is obtained by first finding the ordered sample that represents the 5th percentile of the means (i.e., sample number divided by number of means = .05). The midpoint between the 5th percentile sample and the next larger sample is then calculated. This midpoint represents the lower 95 percent confidence interval.

The upper 95 percent confidence interval is obtained the same way as the lower 95 percent lower confidence interval, except that instead of using the sample that represents 5 percent of the means, the sample that represents 95 percent of the means is used (i.e., sample number divided by number of means = 0.95). In this evaluation, the lower 95 percent confidence interval is obtained by calculating the midpoint of the 50th and 51st ordered sample out of 1,000, while the upper 95 percent limit is the midpoint of the 950th and 951st sample out of 1,000. With the lower limit (LL) and upper limit (UL) calculated in this way, the probability that the population mean is less than the LL is 0.05 (50/1,000). Similarly, the probability that the population mean is greater than the UL is also 0.05.

The theory behind the bootstrap estimate of confidence intervals is as follows. The original sample is assumed to be representative of the population and is then treated as though it was the population itself. Each sample with replacement represents a plausible outcome of drawing a random sample of size N from the population. In this evaluation, the observed sample could have turned out to have the values in any one of the 1,000 re-samples with equal probability and therefore could have implied any one of the 1,000 means. The bootstrap method uses the variability in the statistic of choice, in this case the sample mean, to describe the uncertainty in using this statistic to estimate the true mean. If the statistic is unbiased, and the sample is truly representative of the population, then the bootstrap confidence intervals will also be unbiased and accurate.

B.1.5 EXPOSURE PARAMETERS

The input parameters for the PPLV equations are based on assumptions regarding the extent to which people might be exposed to the COCs at a site. These exposure parameters are used to estimate PPLVs and risks for each of the five potential routes of human exposure to the COCs. Some exposure parameters, such as body weight and frequency of exposure, are applicable to all exposure routes. Other parameters, however, such as soil ingestion rate and molecular diffusivity, are used only for specific exposure routes. The 31 exposure parameters used in this analysis and the exposure routes they characterize are listed in Table B.1-3. This table also provides the specific appendix where each parameter is described in detail. A summary of the fixed values or distributional (i.e., probabilistic) characteristics used for each exposure parameter is presented in Tables B.1-4 through B.1-6. The data sources used to identify each exposure parameter are summarized in Tables B.1-7 and B.1-8, and are described in more detail in Appendix Section B.3.

B.1.6 TOXICITY PARAMETERS

The parameter used to specify COC critical toxicity value is referred to as "DT" in this evaluation. Although this parameter was identified as a candidate for developing a distribution based on the results of the importance analysis (Appendix Section B.3), these quantities were fixed at established EPA values, and are consistent with EPA risk assessment guidance (EPA 1989a). This section provides a general review of the methods used to establish EPA dose-response values for carcinogenic and noncarcinogenic chemicals, and presents the DT values used in this analysis for oral, inhalation, and dermal exposure. DT values for carcinogens, expressed as a dose per unit body weight (BW), are estimated using EPA toxicity values and a specific risk level (i.e., 10^{-6}). Toxicity values for noncarcinogens are already expressed in dose per unit body weight and therefore do not warrant additional conversion. The toxicity parameters for carcinogenic effects and noncarcinogenic effects are provided in Tables B.1-9 and B.1-10, respectively. A summary of the uncertainty associated with the noncarcinogenic toxicity parameters is provided in Table B.1-11. The uncertainties associated with the toxicity values are described further in Appendix E.

No dose-response data for the dermal exposure route have currently been developed by EPA. Therefore, to evaluate exposures and risks from this pathway, oral DT values were used. The relative absorption factor (RAF) introduced into the dermal single pathway preliminary pollutant limit value (SPPPLV) was intended to correct for the differing absorption efficiencies between the oral and dermal exposure routes such that a separate adjustment was not required.

B.1.6.1 Carcinogenic Effects

Carcinogenic critical toxicity values used in this evaluation were developed by the EPA Cancer Assessment Group (CAG) and were obtained from EPA-derived sources that include the Integrated Risk Information System (IRIS) database and the Health Effects Summary Tables (HEAST). Cancer slope factors (CSFs) are chemical-specific, experimentally derived potency values that are used to calculate the risk of cancer resulting from exposure to carcinogenic chemicals. A higher value implies a more potent carcinogen.

The general theory behind the development of cancer is that "a small number of molecular events can evoke changes in a single cell that can lead to uncontrolled cellular proliferation, and eventually, to a clinical state of disease" (EPA 1989a, p. 7–10). For carcinogens, therefore, it is assumed that any level of exposure to a chemical poses "a finite probability, however small, of generating carcinogenic response" (EPA 1989a, p. 7–10).

The dose-response assessment for carcinogenic chemicals is generally a two-step process. Initially, the substance is assigned a WOEC that reflects the likelihood that the chemical will cause cancer in humans according to the strength of the supporting human and/or animal data. The WOECs, which are defined by EPA and which are generally consistent with those defined by the International Agency for Research on Cancer (IARC), are presented below (EPA 1989a):

Group A — Human carcinogen

Group B — Probable human carcinogen

- B1 — At least limited evidence of carcinogenicity to humans
- B2 — A combination of sufficient evidence of carcinogenicity in animals and inadequate evidence of such in humans

Group C — Possible human carcinogen (limited evidence of carcinogenicity in animals in the absence of human data)

Group D — Cannot be classified as to human carcinogenicity

Group E — Evidence of noncarcinogenicity in humans (no evidence of carcinogenicity in at least two animal tests deemed technically adequate by EPA in different species or in both epidemiological and animal studies)

In the second stage of the dose-response evaluation, a slope factor (SF) is derived for chemicals with WOECs of A, B1, or B2. Also, SFs are sometimes derived for chemicals with a WOEC of C. The SFs are derived from one of several mathematical models that were developed to extrapolate from carcinogenic responses observed at high doses to responses expected at low doses. As discussed in Risk Assessment Guidance for Superfund (RAGS), different extrapolation methods may provide a reasonable fit to the observed data but may lead to large differences in the projected risk at low doses (EPA 1989a). Consistent with the EPA Guidelines for Carcinogen Risk Assessment (1986b) and the principles outlined in Chemical Carcinogens: A Review of the Science and Its Associated Principles (Office of Science and Technology Policy [OSTP] 1985), the choice of a low dose extrapolation model by EPA is governed by consistency with current understanding of the mechanisms of carcinogenesis, and not solely on goodness-of-fit to the observed tumor data (EPA 1989a). When data are limited, and when uncertainty exists regarding the mechanisms of carcinogenic action, the EPA guidelines and OSTP principles suggest that models or procedures that incorporate low dose linearity are preferred when compatible with the limited information available.

EPA most often derives SFs using the linearized multistage model, which is more conservative than most models available. To ensure protectiveness, CSFs are typically derived from the 95 percent upper confidence limit of the dose-response curve. Among the other models available for low dose extrapolation are the Weibull, probit, logit, one-hit, and gamma multihit models, as well as various time-to-tumor models.

Oral and inhalation SFs were available for the same 16 of the 27 COCs, as well as for hexavalent chromium, which is not considered carcinogenic from the oral route. Due to the use of the linearized multistage model for low dose extrapolation for most of the COCs (benzene, chromium VI, and arsenic are exceptions) and the selection of the upper 95 percent confidence interval on the SF, the critical values for carcinogenicity are most likely to represent overestimates of potential carcinogenic potency. Additionally, with the exceptions listed, the SFs represent exposures derived from animal dose-response data and are therefore more uncertain than those SFs derived from human data. SFs for arsenic, chromium (VI), and benzene were based on estimates of potential carcinogenic potency from human exposure.

SFs are used to compute risk-specific doses (RSDs) for a given carcinogenic chemical (which are represented by the parameter DT). The RSD is computed as shown in equation (1):

$$DT = \frac{\text{Reference Cancer Risk Level}}{SF} \quad (1)$$

where the RSD is in units of milligrams per kilogram per day (mg/kg/day), the reference cancer risk level represents a given cancer probability (unitless), and the SF represents the slope of the dose-response curve for carcinogens as discussed above $(mg/kg\text{-}day)^{-1}$. In this evaluation, the reference cancer risk level can vary from one excess cancer per ten thousand persons (10^{-4}) to one excess cancer in one million persons (10^{-6}). SFs and RSDs (based on 10^{-6}) are summarized in Table B.1-9 for the COCs for both the oral and inhalation routes. Also included in this table is information on the WOEC, the tumor site identified from the selected toxicological study, and the reference for that study.

B.1.6.2 Noncarcinogenic Effects

Noncarcinogenic effects, or any health impact other than cancer, may result from acute, subchronic, or chronic exposures. For most noncarcinogenic effects, protective mechanisms within an individual are assumed to exist that must be overcome before an adverse effect is elicited. The level above which effects may be elicited (or below which no effect is elicited) is referred to as a threshold level. Examples of noncarcinogenic effects include (but are not limited to) the following: central nervous system disorders (e.g., neurological damage or impairment), blood disorders (e.g., anemia), organ toxicity (e.g., kidney, liver, heart, etc.) and reproductive toxicity (e.g., gametotoxicity, fetal toxicity, etc.).

In developing dose-response values for noncarcinogenic effects (i.e., the reference dose or RfD), EPA's goal is to identify the highest no observed adverse effect level (NOAEL) (i.e., the upper bound of the tolerance range) or the lowest observed adverse effect level (LOAEL) from well-designed human or animal studies. To account for uncertainty associated with the toxicity studies, one or more order-of-magnitude uncertainty factors (UFs) are incorporated to adjust this level based on considerations of the following: (1) duration of the experimental exposure, (2) effects elicited (if any), (3) extrapolation of the data to other species (i.e., interspecies variability, such as extrapolation to humans), and (4) sensitive subgroups (i.e., intraspecies variability). A UF of 10 or less indicates that the hazard quotient or PPLV is likely to be accurate within one order of magnitude with respect to its toxicity criteria, while a UF of 1,000 indicates three orders of magnitude of uncertainty and conservativism built into the toxicity value (and thus the corresponding hazard quotient or PPLV). In addition to UFs, modifying factors varying between a value of 1 and 10 are sometimes incorporated in the derivation of the RfD if additional considerations are necessary.

EPA uses the following general formula to derive an RfD:

$$RfD = \frac{\text{NOAEL or LOAEL}}{\text{Uncertainty} * \text{Modification Factors}} \qquad (2)$$

RfDs are generally reported as a function of the administered dosage rather than an absorbed dosage (due to convention). The RfDs have been developed primarily by the EPA Reference Dose Workgroup. The RfDs used in this evaluation address chronic exposures only. Acute and subchronic exposures from RMA media are evaluated as part of the HHEA Addendum report and are summarized in Appendix Section B.6 as well as Section 3.2.4.

RfDs are summarized in Table B.1-10 for COCs for both the oral and inhalation exposure routes. Also presented in Table B.1-10 is information on the critical health effects; the uncertainty and modification factors used in deriving the RfD, as determined by the EPA; and the reference for the critical toxicity study. In Table B.1-10, dose-response values for chemicals referenced to EPA's HEAST do not have supporting information summarized since these data are not provided in HEAST. The HEAST values are considered interim quantities pending verification by the EPA Reference Dose Workgroup and subsequent addition to IRIS. Additional information on the RfDs, including the adequacy of the database to derive the RfD and the confidence assigned by the EPA in both the critical toxicity study (i.e., a measure of the quality of the study) and the resulting RfD, is summarized in Table B.1-11.

Oral RfDs were available for 20 of the 27 COCs, while only 7 inhalation reference concentrations (RfCs) were available (not including the surrogate RfDs and RfCs used for isodrin and lead, described below). When oral RfDs were available and inhalation RfCs were not, the oral RfDs were extrapolated to the inhalation pathway directly; therefore, less confidence is associated with the inhalation critical toxicity values for these chemicals. Oral RfDs were extrapolated for evaluating dermal exposures. Relative absorption factors were incorporated to address differing absorption efficiencies between oral and dermal pathways. Due to the lack of dermal dose-response data, the critical toxicity values for the dermal pathway are not considered reliable dose-response estimates.

B.1.6.2.1 Noncarcinogens Lacking EPA Toxicity Estimates

There are 2 of the 27 COCs (isodrin and lead) that lack a noncarcinogenic DT value for either oral or inhalation exposure routes. The basis for the DT values for isodrin and lead is taken from Volume II of the HHEA report, Appendix A (EBASCO 1990) and is summarized below. In its review of the value developed for isodrin in the HHEA report, EPA's Environmental Criteria and Assessment Office noted that no other information than that used by EBASCO was available for dose-response assessment.

For isodrin, the DT value was derived from an acute oral toxicity value lethal dose to 50 percent of the test population (LD_{50}) in female rats (7.0 mg/kg/day). The DT was computed as the product of the acute value and an application factor of 1×10^{-5} (Layton et al. 1987). The application factor allows the derivation of an interim acceptable long-term intake rate DT based on the results of acute tests (LD_{50}) in the absence of more suitable long-term studies (i.e., NOAEL studies). The application factor corresponds to the cumulative percentile on a lognormal distribution of $NOAEL/LD_{50}$ ratios for various chemicals. The percentile was chosen to reduce the probability that the calculated dose rate would be above a toxic level; the 5th cumulative percentile was used by Layton et al. (1987) and was found to be equal to 10^{-3}. The application factor also includes a UF of 100 to address interspecies and intraspecies variability. The resulting DT value was 7.0×10^{-5} mg/kg/day.

For lead, the oral and inhalation DT values were based on Acceptable Intake Chronic (AIC) estimates reported in the Superfund Public Health Evaluation Manual (EPA 1986a). These values are 1.4×10^{-3} mg/kg-day for oral exposures and 4.3×10^{-4} mg/kg-day for inhalation exposures. Details of the underlying studies were not available, nor was information on the type of UFs incorporated in the intake estimates. The EPA is currently evaluating the available data to derive RfDs for lead; however, it is unknown when the values may be available. Rather than proceed without any dose-response values for this chemical in lieu of a qualitative assessment, previously published EPA values were used to provide some measure of quantifiable risk at RMA.

B.1.7 PRELIMINARY POLLUTANT LIMIT VALUE DEVELOPMENT

PPLVs are risk-based soil concentrations that are considered protective of human health given a defined set of exposure and toxicity assumptions. For noncarcinogens, PPLVs are defined as soil concentrations unlikely to pose adverse health effects. For carcinogens, PPLVs are defined as soil concentrations protective of human health at a specified cancer risk level. PPLVs are a function of media intake rates, exposure frequencies and durations, partition coefficients, physiological parameters (e.g., breathing rates, body weights, skin surface areas), pharmacokinetic parameters (contaminant absorption fractions), and toxicological parameters (critical toxicity values). In this analysis, probabilistic soil PPLVs were computed for each of the five potentially exposed populations described in Section B.1.3.

PPLVs are based on a computational framework originally established by Rosenblatt et al. (1982/RTIC 84125R01), Dacre et al. (1980), Rosenblatt et al. (1986), and Small (1984). The methodology as adapted to RMA enhances the Rosenblatt et al. work, and is consistent with EPA risk assessment guidance (EPA 1988, 1989a, b). The derivation of the general mathematical expression for PPLVs is shown below in equations (3) through (5):

$$\text{Intake Rate} = \text{Soil Intake Rate} * \frac{\text{Soil Concentration}}{\text{BW}} \tag{3}$$

Substituting DT for contaminant intake rate and solving for soil concentration yields:

$$\text{Soil Concentration} = \text{DT} * \frac{\text{BW}}{\text{Soil Intake or Contact Rate}} \tag{4}$$

Defining the single-pathway PPLV as soil concentration yields:

$$\text{SPPPLV} = \text{DT} * \frac{\text{BW}}{\text{Soil Intake or Contact Rate}} \tag{5}$$

where:

	SPPPLV	= Single pathway preliminary pollutant limit value for soil (mg/kg)
	DT	= Critical toxicity value that is unlikely to have an adverse effect on human health or that is unlikely to pose a cancer risk greater than a predetermined risk level (mg/kg/day)
	BW	= Body weight (kg)

Because exposure to contaminants could occur from a number of exposure routes, a cumulative PPLV is calculated over all SPPPLVs. For the soil exposure evaluations at RMA, there are five possible soil exposure SPPPLVs: soil ingestion, soil dermal contact, particulate inhalation, open space soil vapor inhalation, and enclosed space soil vapor inhalation. A cumulative probabilistic PPLV that incorporates all of these exposure routes is calculated using the formula recommended by Rosenblatt et al. (1982/RTIC 84125R01), which is shown in equation (6):

$$\text{PPLV} = \frac{1}{\left(\frac{1}{\text{SPPPLV}_{\text{ING}}}\right) + \left(\frac{1}{\text{SPPPLV}_{\text{INH}}}\right) + \left(\frac{1}{\text{SPPPLV}_{\text{DRM}}}\right) + \left(\frac{1}{\text{SPPPLV}_{\text{OPEN SPACE}}}\right) + \left(\frac{1}{\text{SPPLV}_{\text{ENCLOSED SPACE}}}\right)} \tag{6}$$

Equation (6) can be re-written as:

where:

$$PPLV = \frac{1}{\left(\frac{1}{PPLV_{DIRECT}}\right) + \left(\frac{1}{PPLV_{INDIRECT}}\right)} \tag{7}$$

$$PPLV_{DIRECT} = \frac{1}{\left(\frac{1}{SPPPLV_{ING}}\right) + \left(\frac{1}{SPPPLV_{INH}}\right) + \left(\frac{1}{SPPPLV_{DRM}}\right)}$$

= Cumulative PPLV for direct exposure pathways

$$PPLV_{INDIRECT} = \frac{1}{\left(\frac{1}{SPPPLV_{OPEN\ SPACE}}\right) + \left(\frac{1}{SPPPLV_{ENCLOSED\ SPACE}}\right)}$$

= Cumulative PPLV for indirect exposure pathways

PPLVs are calculated separately for each exposed population. Equations (6) and (7), when applied to each exposed population, only use the exposure pathways that correspond to that population (described in Section B.1.3). For example, the PPLV equations for the biological worker would not include the enclosed space PPLV.

Although a detailed discussion of the PPLV computational methodology is presented in Volume IV of the HHEA report (EBASCO 1990), several modifications to the computational framework were made after the publication of the HHEA report. These revisions, made in response to comments received on the HHEA report, either enhance the original computational framework or are required for the incorporation of the quantitative uncertainty analysis. The revised approach for the direct and indirect exposure SPPPLVs is summarized below. These PPLV equations are used in the computer code and are shown in detail in Attachment D-1 of Appendix D.

B.1.7.1 Direct SPPPLV Equations

SPPPLVs were developed for all direct exposure pathways: soil ingestion, dermal contact, and particulate inhalation. The specific ingestion, dermal contact, and inhalation SPPPLV equations for worker populations (i.e, biological, commercial, and industrial workers) are presented in equations (8) through (13) below.

Ingestion Route:

$$SPPPLV_{ING(C)} = \frac{BW * DT_{ING} * 10^6}{SI * RAF_{ING} * (\frac{DW}{365}) * (\frac{TE}{70}) * (\frac{TM}{8})} \tag{8}$$

$$SPPPLV_{ING(NC)} = \frac{BW * DT_{ING} * 10^6}{SI * RAF_{ING} * (\frac{DW}{365}) * (\frac{TM}{8})} \tag{9}$$

Dermal Contact Route:

$$SPPPLV_{DRM(C)} = \frac{BW * DT_{ING} * 10^6}{SX * SC * RAF_{DRM} * (\frac{DW}{365}) * (\frac{TE}{70})} \tag{10}$$

$$SPPPLV_{DRM(NC)} = \frac{BW * DT_{ING} * 10^6}{SX * SC * RAF_{DRM} * (\frac{DW}{365})} \tag{11}$$

Particulate Inhalation Route:

$$SPPPLV_{inh(C)} = \frac{BW * DT_{INH} * 10^6}{DINH * CSS * FR * (\frac{DW}{365}) * (\frac{TE}{70}) * TM} \tag{12}$$

$$SPPLV_{inh(NC)} = \frac{BW * DT_{INH} * 10^6}{DINH * CSS * FR * (\frac{DW}{365}) * TM} \tag{13}$$

where:

where:	BW	= Body weight (kg)
	DT_{ING}	= Oral toxicity value (specific to carcinogens/noncarcinogens)
	DT_{INH}	= Inhalation toxicity value (specific to carcinogens/noncarcinogens)
	10^6	= Conversion factor (mg/kg)
	SX	= Skin surface area exposed centimeter squared (cm^2)
	SC	= Skin soil covering (mg/cm^2)
	DINH	= Air inhalation rate cubic meters per hour (m^3/hr)
	CSS	= Dust loading factor micrograms per cubic meter ($\mu g/m^3$)
	FR	= Fraction retained (unitless)
	RAF_{DRM}	= Relative absorption factor-dermal (fraction)
	RAF_{ING}	= Relative absorption factor-oral (fraction)
	DW	= Exposure frequency [(days exposed per year) /(365 days/year)-unitless]
	TE	= Exposure duration [(years exposed per lifetime) /(70 years/lifetime)-unitless]
	TM	= Exposure time (hours/day) (Note: For soil ingestion for visitor populations, TM is divided by 8, as discussed in Section B.1.7.3.)
	SI	= Soil ingestion rate (mg/day)
	$SPPPLV_{DRM}$	= Single pathway preliminary pollutant limit value (dermal) (mg/kg)
	$SPPPLV_{ING}$	= Single pathway preliminary pollutant limit value (oral) (mg/kg)
	$SPPPLV_{INH}$	= Single pathway preliminary pollutant limit value (particulate inhalation) (mg/kg)
	C	= Carcinogen
	NC	= Noncarcinogen

To account for age-dependent exposure parameters in the visitor populations, the computer code for the visitor population SPPPLV equations is written in multiple steps. In the first step, the age-dependent variables (i.e., body weight and intake/contact rate) are isolated and are used to estimate an intermediate intake factor as indicated in equation (14). Next, the intermediate intake factor is inserted into the SPPPLV equation as shown in equation (15) for carcinogens and equation (16) for noncarcinogens. Equations (14), (15), and (16) are general equations applicable to the three direct exposure routes. Note that TM is not used for the dermal contact SPPPLV, and TM/8 replaces TM for the visitor populations' ingestion SPPPLV. All equation parameters are defined above.

$$\text{Intermediate Intake} = \sum_{i=1}^{Maxage} \frac{Body\ Weight_i\ (kg)}{(Ingestion\ or\ Contact\ Rate)} \tag{14}$$

$$\text{SPPPLV}_{(c)} = DT\left(\frac{mg}{kg\text{-}day}\right) * \frac{\left(\dfrac{Intermediate\ Intake}{Maxage}\right) * (10^6)}{(RAF\ or\ FR) * \left(\dfrac{DW}{365}\right) * (TM) * \left(\dfrac{TE}{70}\right)} \tag{15}$$

$$\text{SPPPLV}_{(NC)} = DT\left(\frac{mg}{kg\text{-}day}\right) * \frac{\left(\dfrac{Intermediate\ Intake}{Maxage}\right) * (10^6)}{(RAF\ or\ FR) * \left(\dfrac{DW}{365}\right) * (TM)} \tag{16}$$

B.1.7.2 Indirect PPLV Equations

Indirect soil vapor exposure SPPPLVs are developed for both open and enclosed spaces. Open space SPPPLVs are calculated for all exposed populations except the commercial worker. Enclosed space SPPLVs are calculated for the commercial and industrial worker populations only. Unlike the direct pathway SPPPLV equations, the indirect equations do not account for age-specific parameters in the visitor populations. Instead, adult values are used. A summary of the open and enclosed space vapor models is provided below.

B.1.7.2.1 Open Space Vapor Equations

The SPPPLV for the open space vapor inhalation model is a function of the critical flux, the long-term, time-averaged chemical flux, and the representative site soil concentration, as shown in equation (17):

$$SPPPLV = \left(\frac{F_{crit}}{FAVN}\right) * C_{soil}\ (mg/kg) \tag{17}$$

where: C_{soil} = Representative site soil concentration (mg/kg)

The critical flux equation for the open space model is shown in equations (18) and (19):

$$F_{crit(NC)} = DT_{inh(NC)} * \frac{BW}{\left(DINH * TM * FR * \frac{DW}{365} * \frac{x_d}{F_o}\right)} \tag{18}$$

$$F_{crit(C)} = DT_{inh(C)} * \frac{BW}{\left(DINH * TM * FR * \frac{DW}{365} * \frac{TE}{70} * \frac{x_d}{F_o}\right)} \tag{19}$$

where:

	$F_{crit(NC)}$	= Critical flux for noncarcinogenic chemical milligrams per centimeters squared per second ($mg/cm^2/sec$) (Note: unit conversion factors are not shown)
	$F_{crit(C)}$	= Critical flux for carcinogenic chemical ($mg/cm^2/sec$) (Note: unit conversion factors are not shown)
	$DT_{inh(NC)}$	= Noncarcinogenic inhalation DT value (mg/kg/day)
	$DT_{inh(C)}$	= Carcinogenic inhalation DT value (mg/kg/day)
	BW	= Body weight (kg)
	DINH	= Air inhalation rate (m^3/hr)
	TM	= Exposure time hours per day (hrs/day)
	FR	= Fraction of vapors retained in pulmonary tract (unitless)
	DW/365	= Exposure frequency (days per year at site/days per year-unitless)
	TE/70	= Exposure duration (years exposed per lifetime years)
	x_d/F_o	= Wind dispersion factor at downwind receptor ($(mg/m^3)/(mg/m^2/day)$)

In the open space model, the contaminant vapor is assumed to diffuse through the unsaturated soil in uniform layers following Fick's Law. Two forms of the diffusive flux equation were used in the open space model: long term and mass balance. The chemical flux (FAVN) was calculated using the long-term equation if t_d, the dry out time (equation 20), was greater than t_e, the exposure period (equation 21). Otherwise, the mass balance approach was used. The long-term FAVN calculation is presented in equation (22).

$$t_d\ (\text{sec}) = \frac{(h\ (m)^2 - d\ (m)^2)}{2D\left(\dfrac{cm^2}{\text{sec}}\right)} * \frac{C_B\ (g/cm^3)}{C_W\ (g/cm^3)} \tag{20}$$

$$t_e\ (\text{sec}) = TE\ (yrs) * 3.15E{+}07\ (\text{sec}/yr) \tag{21}$$

$$FAVN_{lt} = \frac{C_B}{t} * \left(\sqrt{d^2 + \frac{2 * t * D * C_W}{C_B}} - d\right) \tag{22}$$

If the contaminant vapor is determined to be saturated, C_W is replaced by $C_{W,sat}$. For cases in which the ratio $C_{W,sat}/C_B$ becomes extremely small such that the expression inside the parentheses in equation (22) cannot be distinguished from zero in a double-precision computer variable, the following expression for long-term FAVN is substituted for equation (22):

$$FAVN_{lt} = \frac{D*C_W}{d} \tag{22a}$$

The mass balance FAVN calculation is shown in equation (23):

$$FAVN_{MB} = \frac{(h\ (cm) - d\ (cm)) * C_B\ (g/cm^3)}{t_e\ (\text{sec})} \tag{23}$$

where:

	$FAVN_{lt}$	= Long-term, time-averaged contaminant flux (mg/cm^2/sec) (Note: conversion factors not shown)
	$FAVN_{MB}$	= Mass balance, time-averaged contaminant flux (mg/cm^2/sec) (Note: conversion factors not shown)
	C_B	= Bulk soil concentration grams per centimeters cubed (g/cm^3)
	d	= Depth to top of contaminated soil layer (cm)
	C_W	= Contaminant concentration in pore water (mg/cm^3)
	$C_{W,sat}$	= Pore water contaminant concentration corresponding to a saturated vapor phase (mg/cm^3)
	D	= Diffusivity of contaminant through soil (cm^2/sec)
	t_e	= Exposure period (seconds)
	t_d	= Time for contaminated layer to dry out (seconds)
	h	= Depth to bottom of contaminated soil layer (cm)

B.1.7.2.2 Enclosed Space Vapor Equations

Like the open space vapor model, the enclosed space vapor inhalation model is a function of the critical flux, the long-term, time-averaged chemical flux, and the representative site soil concentration, as shown in equation (24):

$$SPPPLV = \left(\frac{f_{crit}}{FAVN}\right) * C_{soil}\ (mg/kg) \tag{24}$$

where: C_{soil} = Representative site soil concentration (mg/kg)

The critical flux equation for the enclosed space model is shown in equations (25) and (26):

$$F_{crit(NC)} = DT_{inh(NC)} * BW * \frac{VAR}{\left(DINH * TM * FR * TAC * \left(\frac{DW}{365}\right) * FHB\right)} \tag{25}$$

$$F_{crit(C)} = DT_{inh(C)} * BW * \frac{VAR}{\left(DINH * TM * FR * TAC * \left(\frac{DW}{365}\right) * \left(\frac{TE}{70}\right) * FHB\right)} \tag{26}$$

where:

TAC	=	Time per basement air exchange (days/air change)
VAR	=	Volume to area ratio for basement (meters)
FHB	=	Fraction of daily hours spent in basement
$DT_{inh\ (nc)}$	=	Noncarcinogenic inhalation DT value (mg/kg/day)
$DT_{inh\ (c)}$	=	Carcinogenic inhalation DT value (mg/kg/day)
DINH	=	Air inhalation rate (m^3/hr)
TM	=	Time exposure (hrs/day)
FR	=	Fraction of vapors retained in pulmonary tract (unitless)
DW/365	=	Exposure frequency (days per year at site/days per year-unitless)

TE/70	= Exposure duration (years exposed/lifetime years-unitless)
BW	= Body weight (kg)
	and all other terms are as defined for equations (22) and (23) above

Two types of vapor fluxes were used in the enclosed space vapor model: the diffusive flux, FAVN(1), and the convective flux, FAVN(2). Two cases for computing the total time-averaged chemical flux, designated as FAVN, were developed based on FAVN(1) and/or FAVN(2). The selected case was predicated upon the location of the contaminated layer in relation to the basement structure. The two approaches are described below.

Case 1

Case 1 occurs when the depth to contaminated soil is more than 1 meter (m) below the basement floor and 2 m from the walls. Flux of the contaminants in this case is assumed to be completely diffusive, and so FAVN is determined solely by FAVN(1). FAVN(1) follows the same transport processes as the open space model. The enclosed space model neglects the building resistance to gas flow, so its calculations are the same except that h is replaced by h′ and d is replaced by d′. The FAVN(1) calculations are shown in equations (27), (27a), and (28), and the FAVN calculation is shown in equation (29).

$$\text{FAVN}(1)_{lt} = \frac{C_B}{t_e} * \left(\sqrt{d'^2 + \frac{2 * t_e * D * C_W}{C_B}} - d' \right) \qquad (27)$$

$$\text{FAVN}(1)_{lt} = \frac{D * C_W}{d'} \qquad (27a)$$

$$\text{FAVN}(1)_{\text{MB}} = \frac{(h'\ (cm) - d'\ (cm)) * C_B\ (g/cm^3)}{t_e\ (\text{sec})} \qquad (28)$$

$$FAVN = FAVN(1) \tag{29}$$

where:

	$FAVN(1)_{lt}$	= Long-term, time-averaged diffusive contaminant flux ($mg/cm^2/sec$) (Note: conversion factors not shown)
	$FAVN(1)_{MB}$	= Mass balance, time-averaged, diffusive contaminant flux ($mg/cm^2/sec$)
	FAVN	= Total time-averaged chemical flux
	C_B	= Bulk soil concentration (g/cm^3)
	d'	= Depth from basement floor to top of contaminated soil layer (cm)
	C_W	= Contaminant concentration in pore water (mg/cm^3)
	D	= Diffusivity of contaminant through soil (cm^2/sec)
	t_e	= Exposure Period (seconds)
	t_d	= Time for contaminant layer to dry out
	h'	= Depth from basement floor to bottom of contaminated soil layer (cm)

Case 2

Case 2 occurs when all or part of the contaminated soil lies within 1 m of the basement floor or within 2 m of the basement walls. This volume of soil around the basement is called the zone of influence. It is assumed that contaminant vapors in this region will be transferred, or convected, into the basement at a rate proportional to the ventilation rate of the basement air. The equation for this convective flux (FAVN(2)) is shown in equation (30):

$$FAVN(2) = \left[\frac{T_z}{t} * \frac{f*Qa}{Rg*A}\right] * C_B * (1-e^{-\frac{t_e}{T_z}}) \tag{30}$$

where:

	FAVN(2)	= Convective flux ($mg/cm^2/sec$) (Note: unit conversion factors are not shown)
	T_z	= (Rg*Vs)/(f*Qa) = Time for depletion of contaminant in zone of influence (sec)
	f	= Indoor concentration in the basement
	Qa	= Ventilation rate of the basement (cm^3/sec)

C_B	= Bulk concentration in soil (mg/cm^3)
t_e	= Exposure period (sec)
Rg	= Soil gas partition coefficient = $(\theta+\rho*F_{oc}*K_{oc})/H$ (dimensionless)
A	= Area of the basement floor (cm^2)
e	= Exponential
F_{oc}	= Fraction of organic carbon in soil
K_{oc}	= Soil to water partition coefficient, normalized to organic carbon
H	= Henry's Law constant
θ	= Soil moisture content (dimensionless)
ρ	= Soil density (g/cm^3)

The indoor vapor concentration in the basement is a fixed fractional value (f = 0.0034) derived from a literature survey of radon infiltration experiments.

In Case 2, the diffusive flux from below the zone of influence, as well as the convective flux from within the zone of influence, may contribute to the overall flux (FAVN) of contaminants into the basement. Three subcases for Case 2 describe the possible combinations of fluxes to calculate FAVN. The selection of a particular subcase depends upon which method (FAVN(1) or FAVN(2)) produces the higher flux throughout the exposure period. This is accomplished mathematically by comparing the diffusive and convective fluxes. This comparison is calculated using equation (31):

$$T_d = \frac{Rg * Vs}{f * Qa} * \ln\left(\frac{f * Qa * 100}{A * D}\right) \tag{31}$$

where:

T_d	= Time at which the convective/diffusive flux into building equals that predicted by the diffusive model (sec)
Rg	= Soil gas partition coefficient: $(\theta + \rho * F_{oc} * K_{oc})/H$ (dimensionless)
Vs	= Soil volume within zone of influence: 8 m*(L+W) + (LW*1 m depth) (cm^3)
Qa	= Ventilation rate of the basement (cm^3/sec)
A	= Area of the basement floor (cm^2)
D	= Depth of the basement (cm)
f	= Indoor concentration in the basement
F_{oc}	= Fraction of organic carbon in soil
K_{oc}	= Soil to water partition coefficient, normalized to organic carbon

H	= Henry's Law constant
θ	= Soil moisture content (dimensionless)
ρ	= Soil density (g/cm^3)
100	= Basement depth (cm)

This equation is based on the assumption that the contaminant concentration driving the FAVN(1) flux does not diminish with time, and that the contaminant concentration (within the zone of influence) driving the FAVN(2) flux diminishes with time. T_d is the time at which both fluxes would be equal, assuming that the instantaneous convective flux is greater than the diffusive flux at $t = 0$. By comparing T_d with the exposure time, the particular subcase of Case 2 is determined.

Subcase 1

If the diffusive method results in a greater flux than the convective method at time zero (i.e., $T_d \leq 0$), then the model uses FAVN(1) at a distance of $d' = 1$ m to calculate FAVN. The flux equations used for Subcase 1 are shown in equations (27), (27a), (28), and (29) above (see Case 1).

Subcase 2

If the convective flux is greater than the diffusive flux for the duration of the exposure (i.e., $T_d > t_e$), then the convective flux equation, FAVN(2), is used (see equation 30 above) to calculate FAVN with $t = t_e$. The FAVN calculation (equation (32)) for Subcase 2 is shown below:

$$FAVN = FAVN(2) \tag{32}$$

Subcase 3

If the diffusive method results in a greater flux than the convective flux after some time has elapsed (i.e, $0 < T_d < t_e$), then the model computes FAVN with a time-weighted average of the convective flux and the diffusive flux. The FAVN equation for Subcase 3 is shown in equation (33):

$$FAVN = \left(\frac{T_d}{t_e} * FAVN(2)\right) + \left(1 - \frac{T_d}{t_e} * FAVN(1)\right) \tag{33}$$

where: FAVN(1) is calculated with $t = t_e - T_d$ and $d' = 100$ cm and FAVN(2) is calculated with $t = T_d$.

The SPPLV equations for the open space and enclosed space vapor models assume a linear relationship between soil concentration, C_B, and flux, FAVN. However, this is not always the case. The IEA/RC computer model runs a check to show deviations from linearity in the SPPPLV equations. A further explanation of this linearity check is described in Appendix E, Section E.7.3. Information on where to find data regarding linearity checks is found in Appendix Section D.1.2.1.6.

B.1.7.3 PPLV Updates from HHEA

Revisions to the PPLV methodology have occurred since the publication of the HHEA report (EBASCO 1990). The major revisions to the methodology are described below.

B.1.7.3.1 PPLV Computational Methodology

Revisions to the direct soil exposure pathway PPLV equations from the computational framework used in the HHEA report include the following: (1) modification of the soil intake parameter calculations for regulated/casual and recreational visitors to accommodate multiple age groups; (2) addition of the RAF into the dermal and ingestion pathway SPPPLVs for all populations; (3) explicit addition of the exposure time parameter (TM) to commercial and industrial worker particulate inhalation SPPPLVs, as well as conversion of breathing rates (for all populations to a common unit (cubic meters per hour [m^3/hour]); (4) removal of the dermal pathway SPPPLV in the calculation of cumulative PPLVs for metals; and (5) addition of a correction factor of 8 to the soil ingestion pathway for the visitor populations for time spent at RMA. The specific exposure parameters are discussed in Appendix Section B.3.

B.1.7.3.2 Open Space Vapor Model PPLVs

Revisions to the open space vapor exposure pathway SPPPLV equations from the computational framework used in the HHEA report include the following: (1) deletion of the inhalation absorption term in the critical flux equation; (2) explicit addition of the TM parameter to the critical flux equations and conversion of breathing rates to common units; (3) replacement of the fixed exposure period of 70 years with a distribution; (4) deletion of the saturated vapor correction to the bulk soil concentration, C_B; and (5) addition of a limiting equation for $FAVN_{lt}$ when the ratio of the saturated pore water concentration to the bulk soil concentration, $(C_{W,sat}/C_B)$, approximates zero.

B.1.7.3.3 Enclosed Space Vapor Model PPLVs

Revisions to the enclosed space vapor exposure pathway SPPPLV equations from the computational framework used in the HHEA report include the following: (1) deletion of the inhalation absorption term in the critical flux equation, (2) addition of the TM parameter to the critical flux equation, (3) addition of a parameter quantifying the fraction of time spent in a basement to the critical flux equation, (4) replacement of the fixed exposure period of 70 years to a distribution, 5) deletion of the saturated vapor correction to C_B, (6) addition of a limiting equation for $FAVN_{lt}$ when $C_{w,sat}/C_B$ approximates zero, (7) correction of the FAVN(2) equation from an instantaneous flux equation to a time-averaged flux equation, (8) modification in the minimum depth to the top of the contaminated soil layer, and (9) modification in the approach for computing FAVN in consideration of the location of the contaminated soil layer.

B.1.8 RISK CHARACTERIZATION

The approach for quantifying chronic carcinogenic and noncarcinogenic risks in the IEA/RC using cumulative PPLVs and an EI is discussed in the following sections. Additive carcinogenic and noncarcinogenic site risks are calculated in the computer model for each of the four soil horizons: soil horizon 0 (0 to 1 foot [ft]; direct pathways only), soil horizon 1 (0 to 10 ft; direct and indirect pathways), soil horizon 2 (10 ft to groundwater; indirect pathways only), and surficial soils (0 to 2 inches; direct pathways only). Additive carcinogenic and noncarcinogenic site risks are also calculated for each of the five exposed populations (described in Section B.1.3).

Additive risks are defined as the cumulative risk of a potential adverse health effect occurring as a result of exposure to one or more chemicals from one or more exposure pathways at each site. Noncarcinogenic risk estimates are discussed in Section B.1.8.2 and carcinogenic risk estimates are discussed in Section B.1.8.3.

B.1.8.1 Calculation of Exposure Indices

EIs are estimated in this evaluation by dividing the estimated chemical concentration at RMA by the chemical concentration for which no adverse health effect is anticipated (i.e., the PPLV). An EI is computed separately for each chemical for each of the five exposed populations in each of the four soil horizons at each site.

For surficial soils and soil horizon 0, the chemical-specific site EI is computed as shown in equation (34):

$$EI_{site,i,j} = \frac{C_{rep(i,j)}}{PPLV_{Direct(i,j)}} \tag{34}$$

For soil horizons 1 and 2, the chemical-specific site EI calculations are computed as shown in equations (35) and (36):

Calculation of horizon 1 EI:

$$EI_{site,H1,i,j} = \frac{C_{rep(H1,i,j)}}{\dfrac{1}{\left(\dfrac{1}{PPLV_{Direct(H1,i,j)}} + \dfrac{1}{PPLV_{Indirect(H1,i,j)}}\right)}} \tag{35}$$

Calculation of horizon 2 EI:

$$EI_{site,H2,i,j} = \frac{C_{rep(H2,i,j)}}{PPLV_{Indirect(H2,i,j)}} \quad (36)$$

where:

$EI_{(site,H1,i,j)}$	=	Site exposure index for exposed population i for contaminant j in soil horizon 1
$C_{rep(H1,i,j)}$	=	Site representative concentration for exposed population i for contaminant j in soil horizon 1
$PPLV_{Direct(H1,i,j)}$	=	Site cumulative PPLV for direct pathways for exposed population i for contaminant j
$PPLV_{Indirect(H1,i,j)}$	=	Cumulative PPLV for indirect pathways for exposed population i for contaminant j in soil horizon 1

The horizon-specific EI quantities are also computed for each site using C_{max} instead of C_{rep}. (Note: surficial soil data contain only a single value that may or may not constitute a maximum.) Horizon-specific EI values are contained in output tables that can be accessed through the IEA/RC computer model.

B.1.8.2 Noncarcinogenic Health Effects

Noncarcinogenic health threats are estimated in this evaluation by the hazard quotient (HQ), which is equivalent to the EI described in Section B.1.8.1. If more than one noncarcinogenic COC is being evaluated, the HQs are summed to determine whether exposure to a combination of chemicals poses a health concern. The sum of the HQs is known as a hazard index (HI) as shown in equation (37). The total (additive) site noncarconogenic health threat is then estimated by the HI:

$$HI_{ij} = \Sigma HQ_{ijk} \quad (37)$$

where: HI_{ij} = Site hazard index for exposed population i in soil horizon j
HQ_{ijk} = Site hazard quotient (equivalent to exposure index) for exposed population i in soil horizon j for contaminant k

HQs and HIs are expressed as numbers above or below a threshold of 1.0. Values less than 1.0 (i.e., the chemical or combined chemical concentration at a site is less than its respective PPLV), are considered unlikely to pose a noncarcinogenic health hazard to individuals under the given exposure conditions.

HIs estimated in this evaluation were not segregated by toxic endpoint, and so could overestimate the potential for adverse noncarcinogenic health effects on any one target organ or system. Typically, for HIs that exceed 1.0, chemicals with the potential to adversely affect similar organs or systems in the body are first segregated from the original HI and their individual HQs added to form a new HI.

B.1.8.3 Carcinogenic Risk

Cancer risks are an estimation of the probability that a person will develop cancer from exposure to a carcinogenic chemical. A risk level of 1 x 10^{-6} represents a probability of 1 in 1,000,000 that an individual could contract cancer due the potential carcinogen under a defined set of exposure assumptions. A risk level of 10^{-4} (1 in 10,000) to 10^{-6} (1 in 1,000,000) is often used as a benchmark by regulatory agencies.

Cancer risks are based on PPLVs, which are averaged over a person's lifetime and are directly related to the degree of exposure. Therefore, longer-term exposure to a carcinogen will result in higher risks than shorter-term exposure to the same carcinogen if all other exposure assumptions are held constant.

Carcinogenic risks are calculated in the same way as noncarcinogenic risks except that carcinogenic risks include a reference risk level term (RL), either 10^{-4} or 10^{-6}, to account for the probability. A site risk level is calculated for each exposed population for each chemical in each soil horizon at each site. The calculation for the site risk level is shown in equation (38). The total (additive) site cancer risk for each exposed population for each soil horizon is then estimated by the sum of the site risk levels as shown in equation (39).

$$RL_{site,i,j,k} = EI_{i,j,k} * RL_{reference,k} = \frac{C_{s,i,j,k}}{PPLV_{i,j}} * RL_{reference,k} \tag{38}$$

$$Risk_{site,i,j} = \sum RL_{i,j,k} = \sum \left[\frac{C_{s,i,j,k}}{PPLV_{i,j,k}} \right] * RL_{reference,k} \tag{39}$$

where $RL_{site,i,j,k}$ = Site risk level for exposed population i for contaminant k in soil horizon j

$RL_{reference,k}$ = Reference risk level for contaminant k

$EI_{i,j,k}$ = Site exposure index for exposed population i for contaminant k in soil horizon j

$C_{s,i,j,k}$ = = Site soil contaminant concentration (C_{rep} or C_{max}) for exposed population i for contaminant k in soil horizon j

$PPLV_{i,j,k}$ = Site cumulative PPLV for exposed population i for contaminant k in soil horizon j

$Risk_{site,i,j}$ = Site risk for exposed population i for soil horizon j

The derivation of equations (38) and (39), described below in equations (40) through (47), is consistent with the definition of carcinogenic risk contained in EPA's Risk Assessment Guidance for Superfund (1989a):

$$\text{Chronic Daily Intake} = \frac{\text{Site Risk Level}}{\text{Slope Factor}} \tag{40}$$

Consider also that

$$Risk\ Specific\ Dose = \frac{Reference\ Risk\ Level}{Slope\ Factor} \tag{41}$$

where: Chronic Daily Intake = The contaminant dose received from contaminants in a given soil horizon by an exposed individual at a given RMA site

Site Risk Level = The probability of contracting cancer for a given site chemical in a given soil horizon

Slope Factor = A plausible upperbound estimate of a response per unit intake of a chemical over a lifetime

Risk-Specific Dose = The amount of chemical an individual may take in on a daily basis that is associated with a specified reference cancer risk level

Taking the ratio of equations (40) and (41):

$$\frac{\text{Chronic Daily Intake}}{\text{Risk-Specific Dose}} = \frac{\text{Site Risk Level}}{\text{Reference Risk Level}} \tag{42}$$

A similar expression to equation (42) can be derived using PPLVs and site concentrations as follows:

$$\text{Chronic Daily Intake} = \text{Concentration} * \frac{\text{Intake Rate}}{\text{Body Weight}} \tag{43}$$

$$\text{Risk-Specific Dose} = \text{Risk-Specific Concentration} * \frac{\text{Intake Rate}}{\text{Body Weight}} \tag{44}$$

where: Concentration	=	The concentration of a contaminant in a given soil horizon at a site on the RMA
Intake Rate	=	The rate at which a contaminant is taken up by an individual in contact with a given environmental medium
Risk-Specific Concentration	=	A concentration of contaminant in a given soil horizon that is associated with a specified cancer risk level (i.e., the PPLV)

Again, taking the ratio of equations (43) and (44):

$$\frac{\text{Chronic Daily Intake}}{\text{Risk-Specific Dose}} = \frac{\text{Site Concentration}}{\text{PPLV}} \tag{45}$$

Combining equations (42) and (45):

$$\frac{\text{Site Concentration}}{\text{PPLV}} = \frac{\text{Site Risk Level}}{\text{Reference Risk Level}} \tag{46}$$

Converting equation (46) into an expression with notations corresponding to those of equations (38) and (39):

$$\frac{C_{s,i,j,k}}{PPLV_{i,j,k}} = \frac{RL_{site,i,j,k}}{RL_{reference,k}} \tag{47}$$

where: $C_{s,i,j,k}$ = The soil contaminant concentration for exposed population i in soil horizon j (C_{rep} or C_{max}) of contaminant k

$RL_{site,i,j,k}$ = The site risk level for exposed population i for contaminant k in soil horizon j

$RL_{reference,k}$ = The reference cancer risk level specified for contaminant k (10^{-4} to 10^{-6})

$PPLV_{i,j,k}$ = The site cumulative PPLV for exposed population i in soil horizon j for contaminant k

It is important to note that cancer risks are expressed as probabilities, whereas noncancer health threat estimates are expressed as numbers above or below a threshold value of 1. This is because noncarcinogens are thought to have an exposure threshold below which a dose is assumed not to have an adverse effect. Therefore, although they are computed almost identically, a cancer risk estimate is not directly comparable to a noncancer health threat estimate.

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Information	Program Title	Reference[2]	Section No.(s)
1.0 INTRODUCTION			
1.1 OVERVIEW			
• General Problem	EA	IEA/RC	1.0
• Objectives	EA	IEA/RC	1.1; 3.0
1.2 SITE BACKGROUND	RI		
• Description			
—General		RISR (EBASCO 1992b)	Exec. Summary; 1.0; Table RISR 1.2-2; Plate RISR 2.0-1
—by Area		SARs: WSAR, NCSAR, ESAR, SSAR, SPSAR, NPSAR, CSAR	1.2
—by Individual Site		Technical Plans for RMA On-Post Operable Unit	For list of, see RISR, Table RISR 1.4-1; in each Technical Plan, Section 1.0
		CARS and Phase II Data Addendum Reports	For list of, see RISR, Table RISR 1.4-3; for each CAR, Section 1.0
• Map	EA	IEA/RC	1.2 (Figures 1.2-1 and 1.2-2)
—General	RI	RISR (EBASCO 1992b)	Plate RISR 2.0-1; Figures RISR 2.1-1, 2.2-1, 2.2-2
—by Area		SARs	SSAR and NPSAR–Figures SSA and NPSA 3.2-1; ESAR–Figure ESA 3.4-28; SPSAR–Figure SPSA 3.4-30; WSAR–Plate WSA 3.4-1; NCSAR–Plate NCSA 3.4-18; and CSAR–Plate CSA 3.4-22
—by Individual Sites		Technical plans for RMA On-Post Operable Unit	For list of, See RISR, Table RISR 1.4-1
• History	RI		
—General: ownership, operations, contamination		RISR (EBASCO 1992b)	1.3
—by Area: ownership, operations, contamination		SARs: WSAR, NCSAR, ESAR, SSAR, SPSAR, NPSAR, CSAR	1.3

Table B.1-1 Guide to Locating Risk Assessment Information[1]

Information	Program Title	Reference[2]	Section No.(s)
—by Individual Sites: ownership, operations, contamination		Technical Plans for RMA On-Post Operable Unit	For list of, see RISR, Table RISR 1.4-1; in each Technical Plan, Section 1.0
• Site Reference Points	RI	RISR (EBASCO 1992b)	Plate RISR 1.3-1; Plate A3.3-1; Figure RISR C.1-1
• Geographic Location	EA	IEA/RC	1.2 (Figure 1.2-1)
—Off-Site Areas of Interest	RI	RISR (EBASCO 1992b)	Figure RISR 1.0-2
• General Sampling Locations and Media	RI	RISR (EBASCO 1992b) Note: see also CARs, Phase II Data Addendum Reports, SARs, WRIR, ARIR, and BRIR	<u>Soils</u>: Figures RISR A3.1-2, RISR A3.1-13: RISR D1.1-1; D2.1-1 <u>Sewers</u>: Figures RISR A3.1-25 and -26 <u>Surface Water</u>: Figure RISR A3.2-1 <u>Groundwater</u>: Unconfined Flow System: Figure RISR A3.2-4; Confined Flow System: Figure RISR A3.2-20, Plates RISR B.2-1 & -2 <u>Structures</u>: A3.3.2–A3.3.5, Plate RISR A3.3-1 <u>Air</u>: Figure RISR A3.4-1 <u>Biota</u>: Figure RISR A3.5-1
1.3 SCOPE OF RISK ASSESSMENT	EA	IEA/RC	3.0 (Introduction); 3.1.2
1.4 REPORT ORGANIZATION	EA	IEA/RC	1.3
2.0 CHEMICALS OF CONCERN			
2.1 SITE-SPECIFIC DATA COLLECTION CONSIDERATIONS			
• Historical Information Relevant to Data Collection	RI	RMACCPMT 1983	1.2 (Volumes I and II)

Information	Program Title	Reference[2]	Section No.(s)
• Preliminary Identification of Human Receptors	EA	HHEA (EBASCO 1990)	
		Volume I	3.0
		Volume IV	2.0
		IEA/RC	3.1.2
• Background Sampling (Note: no specific background sampling conducted as part of RMA RI for any media except biota)	RI	ESE 1987	2.4; Appendix C
		RISR (EBASCO 1992b)	Soils: A2; A2.1; A2.1.2; Figure RISR A2.5-1
		BRIR (ESE 1989)	3.2
• Sampling Location and Media	RI	RISR (EBASCO 1992b)	A2
		RMACCPMT 1983	Volumes I and II, Chapter 6
		RMACCPMT 1984	Chapter 3
		Technical plans for RMA On-post Operable Unit (site and medium specific)	For list of, see RISR, Table RISR 1.4-1
		ESE 1987	2.1.1–2.1.3
• Sampling Methods	RI	RISR (EBASCO 1992b)	A2
		Technical plans for RMA On-post Operable Unit	For list of by media, see: RISR, Table RISR 1.4-1
		EBASCO 1985a	Entire report for sampling methodologies for all media (Vol. 1)
• QA/QC Methods	RI	RISR (EBASCO 1992b)	A2
		EBASCO 1985c	Entire report for QA/QC methods for all media (Volume II)
		EBASCO 1985b	Entire report for analytical methods for all media (Volume IV)
		Technical plans for RMA on-post operable unit	For list of by media, see: RISR, Table RISR 1.4-1
		EBASCO 1988	3.3; 3.4; 4.2
		EBASCO 1988	2.0; 4.0
• Special Analytical Services	RI		

Table B.1-1 Guide to Locating Risk Assessment Information[1]

Information	Program Title	Reference[2]	Section No.(s)
2.2 SITE-SPECIFIC DATA EVALUATION CONSIDERATIONS			
• Approach	RI	RISR (EBASCO 1992b)	A2; Appendix B
• QA/QC Methods During Evaluation	RI	EBASCO 1988 SARs	4.2 2.0
• General Data Uncertainty	RI	EBASCO 1988 RISR (EBASCO 1992b) ARIR (ESE 1988) BRIR (ESE 1989) WRIR (EBASCO 1989)	2.0; 4.0 A2; A3.5.3 3.1.3 5.2 (5.2.1-5.2.6) Appendix F: 4.3
2.3 ENVIRONMENTAL AREA OR OPERABLE UNIT 1			
• Media-specific Sample Collection Strategy	RI	RISR (EBASCO 1992b)	A2
• Data from Site Investigation	RI	RISR SARs CARs and Phase II Data Addendum Reports WRIR (EBASCO 1989) ARIR (ESE 1988) BRIR (ESE 1989)	1.4; Table RISR 1.4-3; A-3 2.0 For list of, see RISR, Table RISR 1.4-3. CARs present data for each specific site for soil and water media (in most cases) 3.0 4.0 5.0 (Volume II)
• Analytical Methods	RI CMP	EBASCO 1988 RLSA 1989, 1990, 1991	4.0 CMP reports generally contain a section discussing the analytical programs employed, for example: RLSA 1989: Section 4.5
• Quantitation Limits	RI	SARs	2.0

Table B.1-1 Guide to Locating Risk Assessment Information[1]

Information	Program Title	Reference[2]	Section No.(s)
• Qualified and Coded Data	RI	CARs & Phase II Data Addendum Reports	3.0 ; 4.0
• Blanks	RI	RISR (EBASCO 1992b)	A2
• Tentatively Identified Compounds	RI	RISR (EBASCO 1992b)	A2
• Comparisons with Background	RI	ESE 1987	2.4 ; Appendix C
• Further Reduction in Number of Chemicals	EA	EBASCO 1988	1.3 (Volume I)
• Data Limitations and Uncertainties	RI	RI technical plans and program report products as defined in the Federal Facility Agreement (FFA) for the Rocky Mountain Arsenal, 1989d	See: Comments and Responses sections for RI Technical Plans, RI reports, and other investigation reports subject to OAS review
	EA	IEA/RC	5.0
2.4 SUMMARY OF CHEMICALS OF POTENTIAL CONCERN	EA	EBASCO 1988 IEA/RC	Table 2 (Volume I) Appendix B.1 (B.1.1 and Table B.1-2); 3.1.1
3.0 EXPOSURE ASSESSMENT			
3.1 EXPOSURE SETTING			
• Physical Setting	RI	RISR (EBASCO 1992b)	A1
—Climate			A.1.2
—Vegetation			A.1.6.1
—Soil Type			A.1.4
—Surface Hydrology			A.1.5.1
—Groundwater Hydrology			A.1.5.3; A.1.5.4
• Potentially Exposed Populations	EA	HHEA (EBASCO 1990)	
		Volume I	3.0
		Volume IV	2.0
		IEA/RC	Appendix B.2; 3.1

Table B.1-1 Guide to Locating Risk Assessment Information[1]

Information	Program Title	Reference[2]	Section No.(s)
—Current Land Use		HHEA (EBASCO 1990) IEA/RC	7.0 (Volume I) 3.1; Appendix B.2
—Future Land Use		HHEA (EBASCO 1990) IEA/RC	3.2 (Volume I) Appendix B.2; 3.1
—Subpopulations of Concern		HHEA (EBASCO 1990) IEA/RC	2.0 (Volume IV) Appendix B.2; 3.1
3.2 IDENTIFY EXPOSURE PATHWAYS			
• Sources/Receiving Media	EA	IEA/RC	2.2
• Fate and Transport	EA	HHEA (EBASCO 1990)	Volume II; 4.5 & 4.6 (Volume IV)
• Exposure Points/Routes	EA	HHEA (EBASCO 1990) IEA/RC	2.0 (Volume IV) Appendix B.2; 3.1
• Integration of Source/Release/Fate/ Exposure Points and Routes	EA	IEA/RC	3.1.2
• Summary of Exposure Pathways	EA	HHEA (EBASCO 1990) IEA/RC	2.0 (Volume IV) Appendix B.2; 3.1
3.3 QUANTIFICATION OF EXPOSURE			
• Exposure Concentrations —Approach —Site Specific	EA	IEA/RC	 Appendix B.1, 3.13 RC Code
• Chemical Intakes —PPLV Development	EA	HHEA (EBASCO 1990); IEA/RC HHEA (EBASCO 1990) IEA/RC	Volume IV Appendix B.1, 3.1.6
—Equivalence of PPLV to Intake Approach		HHEA (EBASCO 1990)	3.0, Volume IV
—PPLV Summary		HHEA (EBASCO 1990) IEA/RC	Volumes V, VII 3.2

Information	Program Title	Reference[2]	Section No.(s)
3.4 UNCERTAINTIES			
• Land Use	EA	IEA/RC	5.3, Appendix E.4
• Sampling/Analysis	EA	IEA/RC	5.1, Appendix E.2
• Exposures Evaluated	EA	IEA/RC	5.3, 5.4, Appendix E.5 and E.9
• Modeling	EA	IEA/RC	5.0; Appendix E
• Parameter Values	EA	IEA/RC	5.0, 3.0, Appendix B.3
3.5 SUMMARY OF EXPOSURE (EXPOSURE INDICES)			
• Soils (all Depths)	EA	HHEA; HHEAA; IEA/RC	
—Draft PPLVs (chronic EIs)		HHEA (EBASCO 1990)	Vol. V, VII
—Draft PPLVs (acute, subchronic EIs)		HHEAA (EBASCO 1992a)	Vol. I
—Probabilistic PPLVs (chronic EIs)		IEA/RC	RC Code
• Surficial Soils	EA	HHEAA; IEA/RC	
—Draft PPLVs (chronic EIs)		HHEAA (EBASCO 1992a)	Vol. I
—Draft PPLVs (acute, subchronic EIs)		HHEAA (EBASCO 1992a)	Vol. I
—Probabilistic PPLVs (chronic EIs)		IEA/RC	RC Code
• Soils (0–1 foot)	EA	HHEAA; IEA/RC	
—Draft PPLVs (chronic EIs)		HHEAA (EBASCO 1992a)	Vol. I
—Draft PPLVs (acute, subchronic EIs)		HHEAA (EBASCO 1992a)	Vol. I
—Probabilistic PPLVs (chronic EIs)		IEA/RC	RC Code

Table B.1-1 Guide to Locating Risk Assessment Information[1]

Information	Program Title	Reference[2]	Section No.(s)
4.0 TOXICITY ASSESSMENT			
4.1 NONCARCINOGENIC TOXICITY DATA			
• Appropriate Exposure Scenarios (acute, etc.)	EA	HHEAA (EBASCO 1992a)	Vol. I
• RfDs	EA	HHEA; HHEAA; IEA/RC	
—Draft PPLVs (chronic)		HHEA (EBASCO 1990)	Appendix. A. (Volume II)
—Draft PPLVs (acute, subchronic)		HHEAA (EBASCO 1992a)	Vol. I
—Probabilistic PPLVs		IEA/RC	Appendix B.1
• Health Advisory Data	EA	HHEAA (EBASCO 1992a)	Vol. I
• Database/Critical Effect Summary	EA	HHEA; IEA/RC	
—Draft PPLVs (chronic)		HHEA (EBASCO 1990)	Vols. II & III
—Draft PPLVs (acute, subchronic)		HHEAA (EBASCO 1992a)	Vol. II
—Probabilistic PPLVs (chronic)		IEA/RC	Appendix B.1
• Effects at Higher Dosages	EA	HHEA (EBASCO 1990)	Vols. II & III
	EA	IEA/RC	Appendix B.3.3
• Consideration of Absorption Efficiency			
4.2 CARCINOGENIC TOXICITY DATA			
• Lifetime averaging	EA	HHEA (EBASCO 1990)	4.1; 4.3 (Volume IV)
• Slope factors	EA	HHEA; IEA/RC	
—Draft PPLVs (Chronic)		HHEA (EBASCO 1990)	Volumes II & III
—Probabilistic PPLVs		IEA/RC	Appendix B.1
• Weight of Evidence	EA	HHEA; IEA/RC	
—Draft PPLVs		HHEA (EBASCO 1990)	Appendix A & B
—Probabilistic PPLVs		IEA/RC	Appendix B.1

Table B.1-1 Guide to Locating Risk Assessment Information[1]

Information		Program Title	Reference[2]	Section No.(s)
	• Cancer type	EA	IEA/RC	Appendix B.1
4.3	CHEMICALS LACKING EPA DOSE-RESPONSE VALUES		HHEAA; HHEA; IEA/RC	
	• Draft deterministic PPLVs (chronic)	EA	HHEA (EBASCO 1990)	Volumes I & II (Appendix A)
	• Draft PPLVs (acute, subchronic)	EA	HHEAA (EBASCO 1992a) IEA/RC	Volume I Appendix B.6
	• Probabilistic PPLVs	EA	IEA/RC	Appendix B.1
	• Review by ECAO —Draft PPLVs (chronic) —Draft PPLVs (acute, subchronic)	EA	HHEA; HHEAA HHEA (EBASCO 1990) HHEAA (EBASCO 1992a)	Report Comments Appendix F
	• Qualitative Evaluation	EA	IEA/RC	5.0, Appendix E
	• Documentation of Other Toxicity Values Used	EA	HHEA (EBASCO 1990) IEA/RC	Volumes I & II Appendix B.1
4.4	UNCERTAINTIES IN TOXICITY DATA			
	• Quality of Individual Studies	EA	IEA/RC	Appendix B.1, Appendix E
	• Completeness of Database	EA	IEA/RC	Appendix B.1, Appendix E
4.5	SUMMARY OF TOXICITY DATA	EA	IEA/RC	Appendix B.1
5.0	RISK CHARACTERIZATION			
5.1	CURRENT LAND USE	EA	See Future Land Use	See Future Land Use

Table B.1-1 Guide to Locating Risk Assessment Information[1]

Information	Program Title	Reference[2]	Section No.(s)
5.2 FUTURE LAND USE			
• Carcinogenic Risk (Individual Substances)	EA	IEA/RC	RC Code; Appendix B.4; 3.2
• Chronic HQ (Individual Substances)	EA	IEA/RC	RC Code; Appendix B.4; 3.2
• Subchronic HQ (Individual Substances)	EA	HHEAA (EBASCO 1992a)	Volume I
• Carcinogenic Risk (Multiple Substances)	EA	IEA/RC	Appendix B.4; 3.2
• Chronic HI (Multiple Substances)	EA	IEA/RC	Appendix B.4; 3.2
• Subchronic HI (Multiple Substances)	EA	HHEAA (EBASCO 1992a)	Volume I
• Segregation of HIs	NA	NA	NA
• Chronic HI (Multiple Pathways)	EA	IEA/RC	Appendix B.4
• Carcinogenic Risk (Multiple Pathways)	EA	IEA/RC	Appendix B.4
5.3 UNCERTAINTIES			
• Site Specific	EA	IEA/RC	
—Physical Setting			5.3, Appendix E.4
—Model Assumptions			5.0, Appendix E
—Parameter Values			5.0, Appendix E
• Summary of Toxicity Assessment Uncertainty —Identify Potential Health Effects —Derivation of Toxicity Values —Synergistic /Antagonistic Interactions	EA	IEA/RC	Appendix E.10; Appendix E.6

Table B.1-1 Guide to Locating Risk Assessment Information[1]

Information		Program Title	Reference[2]	Section No.(s)
	—Uncertainty in Less Than Lifetime Exposure			
5.4	SUMMARY DISCUSSION AND TABULATION OF THE RC			
	• Key Contaminants and Exposure Pathways	EA	IEA/RC	3.1
	• Types of Health Risks of Concern	EA	IEA/RC	Appendix B.1
	• Confidence in Quantitative Data Used to Estimate Risk	EA	IEA/RC	3.0; 5.0; Appendix E
	• Qualitative Information on Toxicity	EA	IEA/RC	5.0; Appendix E; Appendix B.1
	• Confidence in Exposure Parameters for Key Pathways	EA	IEA/RC	5.0; Appendix E; Appendix B.3
	• Magnitude of the Cancer and NoncancerRisk Estimates	EA	IEA/RC	3.0; 6.0; Appendix B.4
	• Major Factors Driving Risk	EA	IEA/RC	3.0; 6.0; Appendix B.4
	• Major Factors Contributing to Uncertainty	EA	IEA/RC	5.0; Appendix E
	• Exposed Population Characteristics	EA	IEA/RC	3.1.2; Appendix B.2
6.0	SUMMARY			
6.1	CHEMICALS OF POTENTIAL CONCERN	EA	IEA/RC	Appendix B.1; 3.0; 6.0
6.2	EXPOSURE ASSESSMENT	EA	HHEA; HHEAA; IEA/RC	Appendix B.1; 3.1
6.3	TOXICITY ASSESSMENT	EA	IEA/RC	Appendix B.1

Table B.1-1 Guide to Locating Risk Assessment Information[1]

Information		Program Title	Reference[2]	Section No.(s)
6.3	TOXICITY ASSESSMENT	EA	IEA/RC	Appendix B.1
6.4	RISK CHARACTERIZATION	EA	IEA/RC	3.2; 6.0
	• Draft PPLVs (chronic)		HHEA (EBASCO 1990); IEA/RC	Volumes V & VII; 6.0
	• Draft PPLVs (acute, subchronic)	EA	HHEAA (EBASCO 1992a); IEA/RC	Volume I; 6.0; Appendix B.6; 3.2.4
	• Probabilistic PPLVs	EA	IEA/RC	RC Code; 3.0; 6.0

[1] This risk assessment information is as specified in EPA's Suggested Outline for a Baseline Risk Assessment (1989a).

[2] References cited may be found in Section B.1.9.

ARIR	Air Remedial Investigation Report
BRIR	Biota Remedial Investigation Report
CARs	Contamination Assessment Reports
CSAR	Central Study Area Report
EA	Endangerment Assessment
ESAR	Eastern Study Area Report
HHEA	Human Health Exposure Assessment
HHEAA	Human Health Exposure Assessment Addendum
HI	Hazard Index
HQ	Hazard Quotient
IEA/RC	Integrated Endangerment Assessment/Risk Characterization
NCSAR	North Central Study Area Report
NPSAR	North Plants Study Area Report
RI	Remedial Investigation
RISR	Remedial Investigation Summary Report
SAR	Study Area Report
SPSAR	South Plants Study Area Report
SSAR	Southern Study Area Report
WRIR	Water Remedial Investigation Report
WSAR	Western Study Area Report
RMACCPMT	Rocky Mountain Arsenal Contamination Control Program Manager's Team
RLSA	R. L. Stollar Associates
CMP	Comprehensive Monitoring Program

Aldrin
Arsenic
Benzene
Cadmium
Carbon Tetrachloride
Chlordane
Chloroacetic Acid*
Chlorobenzene
Chloroform
Chromium
DDE
DDT
Dibromochloropropane
1,2-Dichloroethane
1,1-Dichloroethylene
Dicyclopentadiene
Dieldrin
Endrin
Hexachlorocyclopentadiene
Isodrin
Lead
Mercury
Methylene Chloride
1,1,2,2-Tetrachloroethane
Tetrachloroethylene
Toluene
Trichloroethylene

Total Number of COCs = 27

* State requested addition as a Chemical of Concern.

Table B.1-3 Summary of Exposure Parameters and Routes

Exposure Parameter	Appendix Reference	Fixed (F) or Probabilistic (P)	Exposure Routes: Direct Routes: Soil Ingestion	Direct Routes: Particulate Inhalation	Direct Routes: Dermal Contact	Indirect Routes: Open Space Vapor Inhalation	Indirect Routes: Enclosed Space Vapor Inhalation
Soil Ingestion (SI)	B.3.1	P	X				
Dermal Contact Parameters	B.3.2						
Skin Surface Area (SX)		F			X		
Skin Soil Covering (SC)		P			X		
Relative Absorption Factor (RAF)	B.3.3	P	X		X		
Inhalation Parameters	B.3.4	F		X		X	X
Breathing Rate (DINH)		F					
Respiratory Disposition (FR or RD)		F					
Dust Loading Factor (CSS)	B.3.5	P		X			
Body Weight (BW)	B.3.6	F	X	X	X	X	X
Time Dependent Variables (TDVs)	B.3.7	P	X	X	X	X	X
Exposure Frequency (DW)		P					
Exposure Duration (TE)		P					
Daily Exposure Time (TM)		P					
Basement Parameters	B.3.8	P and F					X
Depth (D)		F					
Length (L)		P					
Width (W)		P					
Area (A)		P					
Volume (V)		P					
Ventilation Rate (of Basement) (Qa)		P					

Exposure Parameter	Appendix Reference	Fixed (F) or Probabilistic (P)	Exposure Routes: Direct Routes: Soil Ingestion	Particulate Inhalation	Dermal Contact	Indirect Routes: Open Space Vapor Inhalation	Enclosed Space Vapor Inhalation
Time For Air Exchange (TAC)		P					
Volume/Area Ratio (VAR)		P					
Chemical-Specific Parameters	B.3.9	P and F				X	X
Fraction Organic Carbon in Soils (Foc)		P					
Fraction Organic Carbon in Sediments (Foc)		P					
Molecular Weight (MW)		F					
Molecular Diffusivity (D)		F					
Soil/Water Partition Coefficient (Kow)		P					
Henry's Law Constant (H)		P					
Vapor Pressure (Pvp)		P					
Soil Characteristic Parameters	B.3.10	P and F				X	X
Soil Temperature (T)		F					
Soil Moisture (Q)		P					
Soil Porosity (PT)		P					
Soil Density (SD)		P					

Table B.1-4 Age-Specific Parameter Values

Age		Breathing Rate (BR or DINH) (m^3/hour)						Body Weight		Skin Surface Area (cm^2)				
		R/C	REC	BIO	COM	IND		(kg)		R/C	REC	BIO	COM	IND
0>1	F	0.23	0.23	NA	NA	NA	F	8.9	F	1580	1940	NA	NA	NA
1>2	F	0.67	0.67	NA	NA	NA	F	11	F	1620	2160	NA	NA	NA
2>3	F	0.86	0.86	NA	NA	NA	F	13	F	1780	1780	NA	NA	NA
3>4	F	1	1	NA	NA	NA	F	15	F	2110	2110	NA	NA	NA
4>5	F	1.2	2.1	NA	NA	NA	F	16.9	F	2310	2310	NA	NA	NA
5>6	F	1.4	2.4	NA	NA	NA	F	19.1	F	2440	2440	NA	NA	NA
6>7	F	1.6	3.0	NA	NA	NA	F	21.5	F	2580	2580	NA	NA	NA
7>8	F	1.8	3.4	NA	NA	NA	F	24	F	2760	2760	NA	NA	NA
8>9	F	2	3.5	NA	NA	NA	F	27.3	F	2970	2970	NA	NA	NA
9>10	F	2.1	4.0	NA	NA	NA	F	29.7	F	3170	3170	NA	NA	NA
10>11	F	1.6	3.1	NA	NA	NA	F	34.4	F	3400	3400	NA	NA	NA
11>12	F	1.5	3.1	NA	NA	NA	F	38.2	F	3630	3630	NA	NA	NA
12>13	F	1.4	3.4	NA	NA	NA	F	43.7	F	3860	3860	NA	NA	NA
13>14	F	1.5	3.8	NA	NA	NA	F	48.2	F	3970	3970	NA	NA	NA
14>15	F	1.5	4.2	NA	NA	NA	F	54.1	F	4150	4160	NA	NA	NA
15>16	F	1.5	4.1	NA	NA	NA	F	57.1	F	4320	4320	NA	NA	NA
16>17	F	1.9	4.8	NA	NA	NA	F	59.5	F	4480	4480	NA	NA	NA
17>18	F	1.4	4.9	NA	NA	NA	F	62	F	4780	4780	NA	NA	NA
18>75	F	1.3	3.6	2.1	0.83	2.1	F	68.7	F	4790	4790	3270	1550	3270

Table B.1-4 Age-Specific Parameter Values

Age	Soil Covering (mg/cm^2)																			
	R/C				REC				BIO				COM				IND			
		mean	50%	95%		mean	50%	95%		mean	50%	95%		mean	50%	95%		mean	50%	95%
0<1	B	0.02	0.02	0.03	B	0.02	0.02	0.03		NA	NA	NA		NA	NA	NA		NA	NA	NA
1<2	A	0.5	0.27	1.66	A	0.5	0.27	1.66		NA	NA	NA		NA	NA	NA		NA	NA	NA
2<3	A	0.5	0.27	1.66	A	0.5	0.27	1.66		NA	NA	NA		NA	NA	NA		NA	NA	NA
3<4	A	0.5	0.27	1.66	A	0.5	0.27	1.66		NA	NA	NA		NA	NA	NA		NA	NA	NA
4<5	A	0.5	0.27	1.66	A	0.5	0.27	1.66		NA	NA	NA		NA	NA	NA		NA	NA	NA
5<6	A	0.5	0.27	1.66	A	0.5	0.27	1.66		NA	NA	NA		NA	NA	NA		NA	NA	NA
7<8	A	0.206	0.183	0.409	B	0.86	0.86	1.32		NA	NA	NA		NA	NA	NA		NA	NA	NA
9<10	A	0.206	0.183	0.409	B	0.86	0.86	1.32		NA	NA	NA		NA	NA	NA		NA	NA	NA
10<11	A	0.206	0.183	0.409	B	0.86	0.86	1.32		NA	NA	NA		NA	NA	NA		NA	NA	NA
11<12	A	0.206	0.183	0.409	B	0.86	0.86	1.32		NA	NA	NA		NA	NA	NA		NA	NA	NA
12<13	A	0.206	0.183	0.409	B	0.86	0.86	1.32		NA	NA	NA		NA	NA	NA		NA	NA	NA
13<14	A	0.206	0.183	0.409	B	0.86	0.86	1.32		NA	NA	NA		NA	NA	NA		NA	NA	NA
14<15	A	0.206	0.183	0.409	B	0.86	0.86	1.32		NA	NA	NA		NA	NA	NA		NA	NA	NA
15<16	A	0.206	0.183	0.409	B	0.86	0.86	1.32		NA	NA	NA		NA	NA	NA		NA	NA	NA
16<17	A	0.206	0.183	0.409	B	0.86	0.86	1.32		NA	NA	NA		NA	NA	NA		NA	NA	NA
17<18	A	0.206	0.183	0.409	B	0.86	0.86	1.32		NA	NA	NA		NA	NA	NA		NA	NA	NA
18<75	A	0.206	0.183	0.409	A	0.57	0.53	0.98	A	0.407	0.364	0.793	B	0.056	0.056	0.079	A	0.517	0.463	1.00

Table B.1-4 Age-Specific Parameter Values

Age	Soil Ingestion (mg/cm^2)														
	R/C			REC			BIO			COM			IND		
	mean	50%	95%	mean	50%	95%	mean	50%	95%	mean	50%	95%	mean	50%	95%
0<1	F 1.0	NA	NA	F 1.0	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
1<2	A 73.4	53	200	A 73.4	53	200	NA	NA	NA	NA	NA	NA	NA	NA	NA
2<3	A 73.4	53	200	A 73.4	53	200	NA	NA	NA	NA	NA	NA	NA	NA	NA
3<4	A 73.4	53	200	A 73.4	53	200	NA	NA	NA	NA	NA	NA	NA	NA	NA
4<5	A 73.4	53	200	A 73.4	53	200	NA	NA	NA	NA	NA	NA	NA	NA	NA
5<6	A 73.4	53	200	A 73.4	53	200	NA	NA	NA	NA	NA	NA	NA	NA	NA
7<8	A 73.4	53	200	A 73.4	53	200	NA	NA	NA	NA	NA	NA	NA	NA	NA
9<10	A 36.7	26.5	100	A 36.7	26.5	100	NA	NA	NA	NA	NA	NA	NA	NA	NA
10<11	A 36.7	26.5	100	A 36.7	26.5	100	NA	NA	NA	NA	NA	NA	NA	NA	NA
11<12	A 36.7	26.5	100	A 36.7	26.5	100	NA	NA	NA	NA	NA	NA	NA	NA	NA
12<13	A 36.7	26.5	100	A 36.7	26.5	100	NA	NA	NA	NA	NA	NA	NA	NA	NA
13<14	A 36.7	26.5	100	A 36.7	26.5	100	NA	NA	NA	NA	NA	NA	NA	NA	NA
14<15	A 36.7	26.5	100	A 36.7	26.5	100	NA	NA	NA	NA	NA	NA	NA	NA	NA
15<16	A 36.7	26.5	100	A 36.7	26.5	100	NA	NA	NA	NA	NA	NA	NA	NA	NA
16<17	A 36.7	26.5	100	A 36.7	26.5	100	NA	NA	NA	NA	NA	NA	NA	NA	NA
17<18	A 36.7	26.5	100	A 36.7	26.5	100	NA	NA	NA	NA	NA	NA	NA	NA	NA
18<75	A 36.7	26.5	100	A 36.7	26.5	100	A 40.3	30	106	A 13.0	10	33	A 18.2	13	50

Table B.1-4 Age-Specific Parameter Values

Age	Dust Loading Factor (ug/m^3) R/C mean	R/C 50%	R/C 95%	REC mean	REC 50%	REC 95%	BIO mean	BIO 50%	BIO 95%	COM mean	COM 50%	COM 95%	IND mean	IND 50%	IND 95%
0<1	23.60	20.50	49.20	23.60	20.50	49.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
1<2	23.60	20.50	49.20	23.60	20.50	49.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
2<3	23.60	20.50	49.20	23.60	20.50	49.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
3<4	23.60	20.50	49.20	23.60	20.50	49.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
4<5	23.60	20.50	49.20	23.60	20.50	49.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
5<6	23.60	20.50	49.20	23.60	20.50	49.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
7<8	23.60	20.50	49.20	23.60	20.50	49.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
9<10	23.60	20.50	49.20	23.60	20.50	49.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
10<11	23.60	20.50	49.20	23.60	20.50	49.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
11<12	23.60	20.50	49.20	23.60	20.50	49.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
12<13	23.60	20.50	49.20	23.60	20.50	49.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
13<14	23.60	20.50	49.20	23.60	20.50	49.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
14<15	23.60	20.50	49.20	23.60	20.50	49.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
15<16	23.60	20.50	49.20	23.60	20.50	49.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
16<17	23.60	20.50	49.20	23.60	20.50	49.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
17<18	23.60	20.50	49.20	23.60	20.50	49.20	NA	NA	NA	NA	NA	NA	NA	NA	NA
18<75	A 23.60	20.50	49.20	A 23.60	20.50	49.20	A 56.21	48.50	117.64	A 5.47	4.60	12.08	A 23.65	20.53	49.26

(A)	Lognormal distribution	COM	Commercial Worker	REC	Recreational Visitor
(B)	Normal distribution	DINH	Breathing Rate		
(F)	Fixed Value	IND	Industrial Worker		
BIO	Biological Worker	NA	Not Applicable		
BR	Breathing Rate	R/C	Regulated/Casual Visitor		

Table B.1-5 Time-Dependent and Other Parameter Values

Parameter	Distribution Family	Value Mean	50%	95%
Exposure Time (TM) (hours/day)				
Reg/casual visitor	Lognormal	2.47	1.87	6.34
Recreational visitor	Lognormal	1.8	1.38	4.96
Biological worker	Fixed Value	8		
Commercial worker	Normal	7.42	7.42	12.8
Industrial worker	Normal	7.42	7.42	12.8
Exposure Frequency (DW) (days/year)				
Reg/casual visitor	Lognormal	34.9	29.6	76.1
Recreational visitor	Lognormal	63.14	43.3	181
Biological worker	Normal	225	225	242
Commercial worker	Normal	236	236	241
Industrial worker	Normal	236	236	241
Exposure Duration (TE) (years)				
Reg/casual visitor	Lognormal	10.1	5.45	33.8
Recreational visitor	Lognormal	10.1	5.45	33.7
Biological worker	Truncated Normal	7.18	7.18	18.7
Commercial worker	Lognormal	4.38	2.32	14.8
Industrial worker	Lognormal	4.38	2.32	14.8
Basement				
Length (m)	Uniform	10	10	16.3
Width (m)	Uniform	8.5	8.5	13.45
Ventilation Flow Rate (cm^3/sec)	Triangular	617500	617500	1008960
Percent Organic Carbon (fraction) (Aquatic) in Sediments	Lognormal	0.1197716	0.1039339	0.2496338
Percent Organic Carbon (fraction) (Terrestrial) in Sediments	Lognormal	0.0038779	0.003735	0.0058623
Soil Density	Normal	1.45315	1.45315	1.752022
Soil Porosity (fraction)	Normal	0.45164	0.45164	0.5644193
Soil Temperature (celsius)	Fixed Value	9.9		
Soil Moisture (unitless)	Exponential	0.07099	0.04921	0.2126
Respiratory Deposition				
Vapor (fraction)	Fixed Value	1		
Particulate (fraction)	Fixed Value	0.85		

cm^3/sec Cubic centimeters per second

Table B-1.6 Chemical-Specific Parameter Values

Chemical	Molecular Weight (g/mole)	Molecular Diffusivity (cm^2/sec)	Soil/Water Partition Coefficient (L/kg)			Vapor Pressure (ATM)			Henry's Law Constant (unitless)		
			Mean	50%	95%	Mean	50%	95%	Mean	50%	95%
Aldrin	F 364.3	F 0.0407	A 298100	151800	1027000	A 5.84E-08	2.78E-08	2.07E-07	D 0.000306	0.0003033	0.0005831
Arsenic	F 74.92	F NA	A 179.9	55.76	691	NA	NA	NA	NA	NA	NA
Benzene	F 78.11	F 0.0819	A 19034	158.1	461.3	E 0.104	0.107	0.1514207	E 0.00533	0.00533	0.007074
Cadmium	F 112.4	F NA	A 169.9	59.2	645.2	NA	NA	NA	NA	NA	NA
Carbon Tetrachloride	F 153.8	F 0.0750	A 513	457.1	1007	E 0.124	0.124	0.159	E 0.0237	0.0237	0.0356600
Chlordane	F 409.8	F 0.0404	A 280900	156900	925600	A 1.76E-07	4.14E-08	6.79E-07	A 0.0002760	0.0001186	0.0010061
Chloroacetic Acid	F 94.5	F NA	A 1.787	1.66	3.125	B 0.0004323	0.0004323	0.0008136	A 1.28E-08	8.36E-09	3.81E-08
Chlorobenzene	F 112.5	F 0.0676	A 611.3	508.9	1378	C 0.0151	0.0151833	0.0166427	E 0.00363	0.00363	0.0044410
Chloroform	F 119.4	F 0.0834	A 86.01	81.29	141.3	W 0.241	0.241	0.3084536	E 0.0031	0.0031	0.0042152
Chromium (VI)	F 52	F NA	A 20.91	11.16	70.52	NA	NA	NA	NA	NA	NA
DDE	F 318	F 0.00440	A 667800	579500	1392000	W 8.69E-09	8.69E-09	1.07E-08	D 7.35E-04	7..28E-04	1.41E-03
DDT	F 354.5	F 0.0423	A 1425000	653400	5099000	A 4.82E-10	3.41E-10	1.34E-09	D 3.49E-05	3.47E-05	6.03E-05
Dibromochloropropane	F 236.4	F 0.0600	A 310.2	245.4	756.5	B 0.0053025	0.0053025	0.0099803	A 6.61E-04	6.55E-04	1.27E-03
1,2-Dichloroethane	F 98.96	F 0.0856	A 38.45	36.17	64.31	E 0.0825	0.0825	0.122	A 0.0033426	0.0031828	0.0053260

Table B-1.6 Chemical-Specific Parameter Values

Chemical	MW (g/mole)	Molecular Diffusivity (cm^2/sec)	Soil/Water Partition Coefficient (L/kg) Mean	50%	95%	Vapor Pressure (ATM) Mean	50%	95%	Henry's Law Constant (unitless) Mean	50%	90%
1,1-Dichloroethylene	F 96.95	F 0.0744	A 63.13	59.57	104.4	A 0.763	0.763	0.8791	A 0.01598	0.01485	0.02792
DCPD	F 132.2	F 0.0562	A 274300	153300	904200	B 0.009292	0.009292	0.0174892	A 0.0539400	0.0330400	0.168400
Dieldrin	F 380.9	F 0.0416	A 64170	42190	190300	A 3.44E-09	1.38E-09	1.27E-08	D 3.51E-05	3.48E-05	6.85E-05
Endrin	F 380.9	F 0.0416	A 201600	140100	569900	D 2.50E-09	2.48E-09	4.62E-09	D 4.71E-06	4.67E-06	8.81E-06
HCCPD	F 273	F 0.0522	A 274300	153300	904200	E 0.000107	0.000107	0.0001481	A 0.0225900	0.021068	0.0389100
Isodrin	F 364.9	F 0.407	A 298100	151800	1027000	A 5.84E-08	2.78E-08	2.07E-07	D 0.000306	0.000304	0.000583
Lead	F 207.2	F NA	A 6386000	3371	2012000	NA	NA	NA	NA	NA	NA
Mercury	F 200.6	F NA	A 149.1	115.3	375.8	NA	NA	NA	NA	NA	NA
Methylene Chloride	F 84.94	F 0.0958	A 14.97	14.13	24.75	C 0.3347	0.327	0.5479	E 0.00236	0.00236	0.0035476
1,1,2,2-Tetrachloro-ethane	F 167.9	F 0.0958	A 14.97	14.13	24.75	C 0.00725	0.00725	0.0100956	E 0.000415	0.000415	0.0005565
Tetrachloroethylene	F 165.9	F 0.00798	A 577.8	457.1	1409	E 0.0207	0.0207	0.0282022	D 0.0185	0.0184	0.0334
Toluene	F 92.13	F 0.0736	A 494.5	417.4	1088	C 0.0323333	0.0328564	0.0399016	C 0.00625	0.0063042	0.0068655
Trichloroethylene	F 131.4	0.0749	A 455.9	317.4	1287	E 0.0826	0.0826	0.1.27	C 0.0092333	0.0093961	0.0125647

Table B-1.6 Chemical-Specific Parameter Values

Chemical	RAF Dermal (RfD) Mean		RAF Dermal (RfD) 50%	RAF Dermal (RfD) 95%	RAF Dermal (CPF) Mean		RAF Dermal (CPF) 50%	RAF Dermal (CPF) 95%	RAF Oral (RfD) Mean		RAF Oral (RfD) 50%	RAF Oral (RfD) 95%	RAF Oral (CPF) Mean		RAF Oral (CPF) 50%	RAF Oral (CPF) 95%
Aldrin	B	0.00291	0.00291	0.00497	B	0.00291	0.00291	0.00497	B	0.45	0.45	0.63	B	0.45	0.45	0.63
Arsenic		NA	NA	NA		NA	NA	NA	B	0.71	0.71	0.971	B	0.71	0.71	0.971
Benzene	B	0.775	0.775	0.9775	B	0.775	0.775	0.9775	B	0.805	0.805	0.9805	B	0.805	0.805	0.9805
Cadmium		NA	NA	NA		NA	NA	NA	F	1	1	1		NA	NA	NA
Carbon Tetrachloride	B	0.845	0.845	0.9845	B	0.845	0.845	0.9845	B	0.84	0.84	0.984	B	0.84	0.84	0.984
Chlordane	B	0.023	0.023	0.041	B	0.023	0.023	0.041	B	0.805	0.805	0.9805	B	0.805	0.805	0.9805
Chloroacetic Acid	B	0.845	0.845	0.9845		NA	NA	NA	B	0.84	0.84	0.984		NA	NA	NA
Chlorobenzene	N	0.845	0.845	0.9845	B	0.845	0.845	0.9845	B	0.84	0.84	0.984		NA	NA	NA
Chloroform	B	0.75	0.75	0.93	B	0.845	0.845	0.9845	B	0.84	0.84	0.984	B	0.74	0.74	0.92
Chromium (VI)		NA	NA	NA		NA	NA	NA	F	1	1	1	F	1	1	1
DDE	B	0.022	0.022	0.04	B	0.022	0.022	0.04	B	0.805	0.805	0.9805	B	0.805	0.805	0.9805
DDT	B	0.022	0.022	0.04	B	0.022	0.022	0.04	B	0.805	0.805	0.9805	B	0.805	0.805	0.9805
Dibromochloropropane	B	0.845	0.845	0.9845	B	0.845	0.845	0.9845	B	NA	NA	NA	B	0.84	0.84	0.984
1,2-Dichloroethane	B	0.845	0.845	0.9845	B	0.845	0.845	0.9845	B	NA	NA	NA	B	0.84	0.84	0.984
1,1-Dichloroethylene	B	0.845	0.845	0.9845	B	0.845	0.845	0.9845	B	0.84	0.84	0.984	B	0.84	0.84	0.984

Table B-1.6 Chemical-Specific Parameter Values

Chemical	RAF Dermal (RfD) Mean	RAF Dermal (RfD) 50%	RAF Dermal (RfD) 95%	RAF Dermal (CPF) Mean	RAF Dermal (CPF) 50%	RAF Dermal (CPF) 95%	RAF Oral (RfD) Mean	RAF Oral (RfD) 50%	RAF Oral (RfD) 95%	RAF Oral (CPF) Mean	RAF Oral (CPF) 50%	RAF Oral (CPF) 95%
DCPD	B 0.022	0.022	0.04	NA	NA	NA	B 0.805	0.805	0.9805	NA	NA	NA
Dieldrin	B 0.0056	0.0056	0.00956	B 0.0056	0.0056	0.00956	B 0.8	0.8	0.98	B 0.8	0.8	0.98
Endrin	B 0.022	0.022	0.04	NA	NA	NA	B 0.805	0.805	0.9805	NA	NA	NA
HCCPD	B 0.058	0.058	0.076	NA	NA	NA	B 0.805	0.805	0.9805	NA	NA	NA
Isodrin	B 0.022	0.022	0.04	NA	NA	NA	B 0.805	0.805	0.9805	NA	NA	NA
Lead	NA	NA	NA	NA	NA	NA	B 0.65	0.65	0.964	NA	NA	NA
Mercury	NA	NA	NA	NA	NA	NA	B 0.545	0.545	0.9545	NA	NA	NA
Methylene Chloride	B 0.845	0.845	0.9845	B 0.845	0.845	0.9845	B 0.84	0.84	0.984	B 0.84	0.84	0.984
1,1,2,2-Tetrachloro-ethane	B 0.845	0.845	0.9845	B 0.845	0.845	0.9845	B 0.84	0.84	0.984	B 0.84	0.84	0.984
Tetrachloroethylene	B 0.845	0.845	0.9845	B 0.845	0.845	0.9845	B 0.84	0.84	0.984	B 0.84	0.84	0.984
Toluene	B 0.91	0.91	0.991	NA	NA	NA	B 0.88	0.88	0.988	NA	NA	NA
Trichloroethylene	B 0.845	0.845	0.9845	B 0.74	0.74	0.92	B 0.84	0.84	0.984	B 0.73	0.73	0.91

(A) Lognormal Distribution
(B) Uniform Distribution
(C) Triangular Distribution
(D) Uniform-Triangular Distribution
(E) Normal Distribution
(F) Fixed
(G) The cancer potency factor (CPF) relative absorption factor (RAF) differs from the reference dose (RfD) RAF.
ATM Atmospheres
cm^2/sec Centimeters squared per second
DDE Dichlorodiphenyldichloroethene
DDT Dichlorodiphenyltrichloroethane
g/mole Gram per mole
HCCPD Hexachlorocyclopentadiene
L/kg Liters per kilogram
NA Not Applicable

Table B.1-7 Summary of Data Sources for PPLV Direct and Indirect Equation Parameters

Parameter	Data Source (s)
Basement Parameters	
Area	Professional Judgment
Volume	Professional Judgment
Volume/Area Ratio	Professional Judgment
Depth	Professional Judgment
Ventilation Rate	Commerce City and Denver 1988 Uniform Building Codes Handbook
Time for Air Exchange	Computed as function of ventilation and basement volume
Body Weight	EPA 1989c —Exposure Factors Handbook
Breathing Rate (BR, DINH, RB)	Professional Judgment EPA, 1985a
Density of RMA Soils	RMA Specific —Walsh and Associates, 1988 —Soil Conservation Service, 1987
Dust Loading Factor (CSS)	General Literature Arsenal Specific —Comprehensive Monitoring Program
Henry's Law Constant	General Literature
Molecular Weight	General Literature
Percent Organic in Aquatic Sediments	Arsenal Specific —Walsh and Associates, 1988
Fraction Organic Carbon in Soils	Arsenal Specific —Walsh and Associates, 1988

Table B.1-7 Summary of Data Sources for PPLV Direct and Indirect Equation Parameters

Parameter	Data Source (s)
Refuge Worker Time-Dependent Variables	Arsenal Specific (Shell 1991) —Shell/Army Refuge Worker Survey
Relative Absorption Factor (RAF)	
Dermal	General Literature EPA 1991a —Interim Guidance for Dermal Exposure Assessment
Oral	General Literature
Respiratory Disposition	General Literature EPA 1982 —Air Quality Criteria for Particulate Matter and Sulfur Oxides (Denver specific data)
Soil Covering	General Literature Professional Judgment EPA 1991a —Interim Guidance for Dermal Exposure Assessment
Soil Ingestion	General Literature Professional Judgment EPA 1991b —Risk Assessment Guidance (OSWER Directive)
Soil Moisture Content	RMA Specific —Comprehensive Monitoring Program —Remedial Investigation for RMA
Soil Temperature	Regional Annual Average Temperature
Soil to Water Partition Coefficient (K_{oc}) Normalized to Organic Carbon	General Literature

Table B.1-7 Summary of Data Sources for PPLV Direct and Indirect Equation Parameters

Parameter	Data Source (s)
Skin Surface Area (SX)	Professional Judgment EPA, 1985a
Time Dependent Variables (TDVs)	See Table B.1-8 for TDV data sources
Total Soil Porosity	Calculated from soil and particle density
Vapor Pressure	General Literature

Table B.1-8 Summary of Data Sources for PPLV Direct and Indirect Equation Parameters, Time-Dependent Variables

Population	TM (hrs/day)	DW (days/yr)	TE (yrs/lifetime)
—Regulated/Casual and Recreational Visitors	National —U.S. Bureau Outdoor Recreation, 1973 —Walsh, 1986 Regional —National Park Service, 1984 —National Sporting Goods Assoc., (NSGA), 1989 RMA Specific —Estimates of Visitors to Alternative Recreational Surface Uses Proposed for RMA (THK 1990)	National — Gallup, 1986 NSGA 1989 Regional — Visitor's Survey, DPOR, 1989 — National Parks Service, 1984	Regional —Residential Energy Use Survey PSCo, 1989
Commercial/ Industrial Visitor	EPA —Exposure Factors Handbook, 1989c General Literature	Denver Specific —Mountain States Employers Council (MSEC) 1981-1990	MSEC 1981-1990 National —Bureau of Labor Statistics 1990 —Bureau of the Census 1987
Biological Worker	Shell/Army Refuge Worker Survey (see Appendix B.2)	Shell/Army Refuge Worker Survey (see Appendix B.2)	Shell/Army Refuge Worker Survey (see Appendix B.2)

Table B.1-9 Carcinogenic Dose Response Data (DT)

Chemical	Weight of Evidence Classification (WOEC) (1)	Exposure Route	Cancer Potency Factor (CPF) (1/mg/kg/day)	DT: Risk Specific Doses (RSD) (mg/kg/day)(2)	Tumor Site	CPF Source (3)	Reference Study (4)
Aldrin	B2	oral	1.70E+01	5.90E-08	liver	IRIS	(A)
		inhalation	1.70E+01	5.90E-08	liver	IRIS	(B)
Arsenic	A	oral	1.75E+00	5.70E-07	skin	IRIS, '92	(C)
		inhalation	1.5E+01	6.70E-08	resp. tract	IRIS	(D)
Benzene	A	oral	2.90E-02	3.40E-05	leukemia	IRIS	(E)
		inhalation	2.90E-02	3.40E-05	leukemia	IRIS	(E)
Cadmium	B1	oral	NA(5)	NA	NA	NA	NA
		inhalation	6.30E+00	1.60E-07	resp. tract	IRIS	(F)
Carbon Tetrachloride	B2	oral	1.30E-01	7.70E-6	liver	IRIS	(G)
		inhalation	5.25E-02	1.90E-05	liver	IRIS	(G)
Chlordane	B2	oral	1.30E+00	7.70E-07	liver	IRIS	(H)
		inhalation	1.30E+00	7.70E-07	liver	IRIS	(H)
Chloroacetic Acid	NE (6)	oral	NA	NA	NA	NA	NA
		inhalation	NA	NA	NA	NA	NA
Chlorobenzene	D	oral	NA	NA	NA	NA	NA
		inhalation	NA	NA	NA	NA	NA
Chloroform	B2	oral	6.10E-03	1.60E-04	kidney	IRIS	(I)
		inhalation	8.00E-02	1.20E-05	liver	IRIS	(J)
Chromium (VI)	A	oral	NA	NA	NA	NA	NA
		inhalation	4.20E+01	2.40E-08	lung	IRIS	(K)
DDE	B2	oral	3.40E-01	2.90E-06	liver	IRIS	(L)
		inhalation	3.40E-01 (7)	2.90E-06	NA	NA	NA
DDT	B2	oral	3.40E-01	2.90E-06	liver	IRIS	(M)
		inhalation	3.40E-01	2.90E-06	liver	IRIS	(M)
Dibromochloropropane (DBCP)	B2	oral	1.40E+00	7.10E-07	multiple	HEAST	(N)
		inhalation	2.40E-03	4.20E-04	multiple	HEAST	(O)
1,2-Dichloroethane	B2	oral	9.10E-02	1.10E-05	circulatory	IRIS	(P)
		inhalation	9.10E-02	1.10E-05	circulatory	IRIS	(P)
1,1-Dichloroethylene	C	oral	6.00E-01	1.70E-06	kidney	IRIS	(Q)
		inhalation	1.80E-01	5.70E-06	kidney	IRIS	(R)
Dicyclopentadiene (DCPD)	NE	oral	NA	NA	NA	NA	NA
		inhalation	NA	NA	NA	NA	NA
Dieldrin	B2	oral	1.60E+01	6.20E-08	liver	IRIS	(S)
		inhalation	1.60E+01	6.20E-08	liver	IRIS	(S)

Table B.1-9 Carcinogenic Dose Response Data (DT)

Chemical	Weight of Evidence Classification (WOEC) (1)	Exposure Route	Cancer Potency Factor (CPF) (1/mg/kg/day)	DT: Risk Specific Doses (RSD) (mg/kg/day)(2)	Tumor Site	CPF Source (3)	Reference Study (4)
Endrin	D	oral	NA	NA	NA	NA	NA
		inhalation	NA	NA	NA	NA	NA
Hexachlorocyclopentadiene (HHCPD)	D	oral	NA	NA	NA	NA	NA
		inhalation	NA	NA	NA	NA	NA
Isodrin	NE	oral	NA	NA	NA	NA	NA
		inhalation	NA	NA	NA	NA	NA
Lead	B2	oral	NA	NA	Renal	NA	NA
		inhalation	NA	NA	NA	NA	NA
Mercury	D	oral	NA	NA	NA	NA	NA
		inhalation	NA	NA	NA	NA	NA
Methylene Chloride	B2	oral	7.50E-03	1.30E-04	liver	IRIS	(T)
		inhalation	1.60E-03	6.10E-04	lung, liver	IRIS	(U)
1,1,2,2-Tetrachloroethane	C	oral	2.00E-01	5.00E-06	liver	IRIS	(P)
		inhalation	2.00E-01	5.00E-06	liver	IRIS	(P)
Tetrachloroethylene	B2	oral	5.10E-02	2.00E-05	liver	HEAST (FY'91)	(V)
		inhalation	1.80E-03	5.50E-04	liver, leuk	HEAST (FY'91)	(U)
Toluene	D	oral	NA	NA	NA	NA	NA
		inhalation	NA	NA	NA	NA	NA
Trichloroethylene	B2	oral	1.10E-02	9.10E-05	liver	HEAST (FY'90)	(W)
		inhalation	5.90E-03	1.70E-04	lung	HEAST (FY'90)	(X)

(1) Classification system for characterizing the extent to which data indicate chemical is a carcinogen. Classification ranges from "A" (human carcinogen) to "E" (noncarcinogen).

(2) For carcinogens, DT = RSD. RSD is a dose that is estimated to result in a 10^{-6} risk level. RSD = 10^{-6}/CPF.

(3) Sources: EPA (1993); EPA (1992) except where otherwise noted.

Table B.1-9 Carcinogenic Dose Response Data (DT)

Chemical	Weight of Evidence Classification (WOEC) (1)	Exposure Route	Cancer Potency Factor (CPF) (1/mg/kg/day)	DT: Risk Specific Doses (RSD) (mg/kg/day)(2)	Tumor Site	CPF Source (3)	Reference Study (4)

(4) CPF Reference Study/Information Source:

(A) Davis, 1965; Epstein, 1975; NCI, 1976a.
(B) Davis and Fitzhugh, 1962; Epstein, 1975; Davis, 1965; EPA, 1993.
(C) Tseng et al., 1977. Based on this study, a unit risk of 5E-5/ug/L was proposed. This unit risk was used to calculate CPF. No specific oral CPF is provided in EPA, 1993
(D) Brown and Chu, 1983a,b,c; Lee-Feldstein, 1983; Higgins, 1982; EPA, 1993.
(E) Ott et al., 1978; Rinsky et al., 1981; Wong et al.,1983; EPA, 1993
(F) Thun et al., 1985; EPA, 1985b.
(G) Della Porta et al., 1961; Edwards, et al., 1942; NCI, 1976a,b; EPA, 1993.
(H) Velsicol, 1973; EPA, 1993.
(I) Jorgenson et al., 1985.
(J) EPA, 1993.
(K) Mancuso, 1975.
(L) Tomatis et al., 1974; Rossi et al., 1983; and EPA, 1993.
(M) Turusov et al., 1973; Terracini et al., 1973; Thorpe and Walker, 1973; Tomatis and Turusov, 1975; Cabral et al., 1982; Rossi et al., 1977.
(N) EPA, 1993.
(O) EPA, 1993; HEAST (1992).
(P) EPA, 1993.
(Q) NTP, 1982.
(R) Maltoni et al., 1977, 1985.
(S) Davis, 1965; Meierhenry et al., 1983; NCI, 1976a, b; Walker et al., 1972; Thorpe and Walker, 1973; Tennekes et al., 1981.
(T) National Coffee Association, 1982; EPA, 1993.
(U) EPA, 1993.
(V) EPA, 1993.
(W) NCI, 1976a,b; NTP, 1982.
(X) Maltoni et al., 1986; Fukuda et al., 1983.

(5) NA denotes Not Applicable.

(6) NE denotes no Weight of Evidence Classification Assigned.

(7) Inhalation CSF for DDE not available. Value shown is direct extrapolation from oral pathway.

Table B.1-10 Chronic Noncarcinogenic Dose-Response Data (CT)

Chemical	Route of Exposure	DT: Chronic RfD (mg/kg/day)	RFD Source (1)	Critical Effect	Uncertainty Factor (2)	Modifying Factor (3)	Reference Study (4)	
Aldrin	oral	3.00E-05	IRIS	Liver	1000	1	(A)	
	inhalation	3.00E-05 (5)	NA (6)	NA	NA	NA	NA	
Arsenic	oral	3.00E-04	IRIS	Skin	3	1	(B)	
	inhalation	3.00E-04 (5)	NA	NA	NA	NA	NA	
Benzene	oral	NA	NA	NA	NA	NA	NA	
	inhalation	NA	NA	NA	NA	NA	NA	
Cadmium	oral, water	5.00E-04	IRIS	Renal Cortex	10	1	(C)	
	oral, food	1.00E-03	IRIS	Renal Cortex	10	1	(C)	
Carbon Tetrachloride	oral	7.00E-04	IRIS	Liver	1000	1	(D)	
	NA	7.00E-04 (5)	NA	NA	NA	NA	NA	
Chlordane	oral	6.00E-05	IRIS	Liver	1000	1	(E)	
	inhalation	6.00E-05 (5)	NA	NA	NA	NA	NA	
Chloroacetic Acid	oral	2.00E-03	HEAST	Heart	10,000	NA	(F)	
	inhalation	2.00E-03 (5)	NA	NA	NA	NA	NA	
Chlorobenzene	oral	2.00E-02	IRIS	Liver and Kidney	1000	1	(G)	
	inhalation	5.00E-03	HEAST	Liver and Kidney	10,000	NA	(H)	
Chloroform	oral	1.00E-02	IRIS	Liver	1000	1	(I)	
	inhalation	1.00E-02 (5)	NA	NA	NA	NA	NA	
Chromium (VI)	oral	5.00E-03	IRIS	None	500	1	(J)	
	inhalation	6.00E-07	HEAST (FY'91)	Nasal mucosa atrophy	300	NA	(K)	
DDE	oral	NA	NA	NA	NA	NA	NA	
	inhalation	NA	NA	NA	NA	NA	NA	
DDT	oral	5.00E-04	IRIS	Liver	100	1	(L)	
	inhalation	5.00E-04 (5)	NA	NA	NA	NA	NA	
Dibromochloropropane	oral	2.00E-04	NA	NA	NA	NA	NA	
(DBCP)	inhalation	6.00E-05 (7)	IRIS	Testicular	1000	1	(M)	
1,2-Dichlorethane	oral	NA	NA	NA	NA	NA	NA	
	inhalation	NA	NA	NA	NA	NA	NA	
1,1-Dichloroethylene	oral	9.00E-03	IRIS	Liver	1000	1	(N)	
Dicyclopentadiene	inhalation	9.00E-03 (5)	NA	NA	NA	NA	NA	
Dibromochloropropane	oral	3.00E-02	HEAST	None	1000	NA	(O)	
(DCPD)		inhalation	6.00E-05	HEAST	Liver	10000	NA	(P)
Dieldrin	oral	5.00E-05	IRIS	Liver	100	1	(Q)	
	inhalation	5.00E-05 (5)	NA	NA	NA	NA	NA	
Endrin	oral	3.00E-04	IRIS	Liver and CNS	100	1	(R)	
	inhalation	3.00E-04 (5)	NA	NA	NA	NA	NA	

Table B.1-10 Chronic Noncarcinogenic Dose-Response Data (CT)

Chemical	Route of Exposure	DT: Chronic RfD (mg/kg/day)	RFD Source (1)	Critical Effect	Uncertainty Factor (2)	Modifying Factor (3)	Reference Study (4)
Hexachlorocyclopentadiene	oral	7.0E-03	IRIS	Stomach	1000	1	(S)
(HCCPD)	inhalation	2.00E-05	HEAST	Respiratory Tract	1000	NA	(T)
Isodrin	oral	7.0E-05	Ebasco 1990	NA	NA	NA	NA
	inhalation	7.0E-05	Ebasco 1990	NA	NA	NA	NA
Lead	oral	1.4E-03	EPA 1986a	NA	NA	NA	NA
	inhalation	4.3E-04	EPA 1986a	NA	NA	NA	NA
Mercury	oral	3.00E-04	HEAST	Kidney	1000	NA	(U)
	inhalation	9.00E-05 (7)	HEAST	Neurologic	30	1	(V)
Methylene Chloride	oral	6.00E-02	IRIS	Liver	100	1	(W)
	inhalation	8.6E-01	HEAST	Liver	100	NA	(X)
1,1,2,2-Tetrachloroethane	oral	NA	NA	NA	NA	NA	NA
	inhalation	NA	NA	NA	NA	NA	NA
Tetrachloroethylene	oral	1.00E-02	IRIS	Liver and Body Weight	1000	1	(Y)
	inhalation	1.00E-02 (5)	HEAST	NA	100	NA	NA
Toluene	oral	2.00E-01	IRIS	Liver and Kidney	1000	1	(Z)
	inhalation	1.10E-01 (7)	IRIS	CNS and Nose	300	1	(AA)
Trichloroethylene	oral	NA	NA	NA	NA	NA	NA
	inhalation	NA	NA	NA	NA	NA	NA

(1) Sources: EPA (1993); EPA (1992), unless otherwise noted.

(2) Factor used to derive RfD from NOAEL. Uncertainty factors generally consist of multiples of 10, with each factor representing a specific area of uncertainty in the data.

(3) Factor used to reflect additional uncertainty in critical study and entire database for the chemical not explicity addressed by the uncertainty factor.

(4) RfD Reference Studies:
- (A) Fitzhugh et al., 1964
- (B) Tseng, 1977
- (C) EPA, 1985b
- (D) Bruckner et al., 1986
- (E) Velsicol Chemical Corp., 1983a, b
- (F) IRDC, 1982

Chemical	Route of Exposure	DT: Chronic RfD (mg/kg/day)	RFD Source (1)	Critical Effect	Uncertainty Factor (2)	Modifying Factor (3)	Reference Study (4)

(G) Monsanto Co., 1967; Knapp et al., 1971
(H) Dilley, 1977; EPA, 1989c
(I) Heywood et al., 1979
(J) Mackenzie et al., 1958
(K) Lindberg and Hedenstiema, 1983
(L) Laug et al., 1950
(M) Rao, K.S.; Burek, F; Murry, et al., 1982
(N) Quast et al., 1983
(O) Litton Bionetics, 1980
(P) Dodd et al., 1982
(Q) Walker et al., 1969
(R) Velsicol Chemical Corp., 1969
(S) Adbo et al., 1984
(T) Batelle West Laboratories, 1984
(U) Druet et al., 1978; Bernaudin et al., 1981; Andres, 1984
(V) Fawer et al., 1983 Piikivi and Tolonen, 1989; Piikivi, 1989
(W) National Coffee Association, 1982
(X) Nitschke et al., 1988
(Y) Buben and O'Flaherty, 1985
(Z) NTP, 1989
(AA) Foo et al., 1990; NTP, 1989

(5) Inhalation RfD for chemical not available. Value shown is direct extrapolation from oral pathway.

(6) NA denotes Not Available.

(7) Inhalation RfD extrapolated from RfC, assuming 20m^3/day inhalation and 70kg body weight.

Table B.1-11 Summary of EPA Confidence in IRIS Chronic Reference Doses (1)

Chemical	Route of Exposure	Confidence in Critical Toxicity Study	Confidence in Response Value	Confidence in Database	Comments
Aldrin (2)	Oral	Medium	Medium	Medium	Study lacks some toxicological parameters; database lacks NOELs; chronic data for sensitive species (dogs) lacking
Arsenic	Oral	Medium	Medium	Medium	Doses not well characterized and other contaminants present; problems with all supporting epidemiological studies
Cadmium	Oral, Water	N/A(3)	High	High	NOAEL from several studies
	Oral, Food	N/A	High	High	NOAEL from several studies
Carbon Tetrachloride	Oral	High	Medium	Medium	Four additional subchronic studies support RfD, but reproductive or teratogenic endpoints not well investigated
Chlordane	Oral	Medium	Low	Low	Lack of adequate reproductive and chronic studies in second mammalian species; endpoint sensitivity inadequate
Chlorobenzene	Oral	Medium	Medium	Medium	Reference study (subchronic) provided NOAEL and LOAEL; several other studies provide supporting data but do not provide adequate toxicity assessment
Chloroform	Oral	Medium	Medium	Medium	No NOAEL determined from reference study; two treatment doses; several studies have a LOAEL but a NOEL was not found
Chromium(VI)	Oral	Low	Low	Low	Few test animals in study; small number of parameters measured and lack of toxic effect at the highest dose tested; other studies of low quality; lack of teratogenic/reproductive endpoints
DDT	Oral	Medium	Medium	Medium	Primary study has a short duration; database only moderately supportive of critical effect and magnitude; lacks a clear NOEL for reproductive effects
Dibromochloropropane (DBCP)	Inhalation	Medium	Medium	Medium	Lacks evaluation of respiratory effects; limited reproductive studies; uncertainty about occurrence of respiratory tract effects compared to testicular effects
1,1-Dichloroethylene	Oral	Medium	Medium	Medium	Corroborative chronic and subchronic oral bioassays exist

Table B.1-11 Summary of EPA Confidence in IRIS Chronic Reference Doses (1)

Chemical	Route of Exposure	Confidence in Critical Toxicity Study	Confidence in Response Value	Confidence in Database	Comments
Dieldrin(2)	Oral	Low	Medium	Medium	Principal study is old; lack of specific study design information; wide range of doses employed; lack of reproductive studies; chronic toxicity evaluation supports critical effect (if not the magnitude of effects)
Endrin	Oral	Medium	Medium	Medium	Principal study design is of average quality; lack of reproductive data
Hexachlorocyclopenta-diene (HCCPD)	Oral	Medium	Low	Low	Principal study is of short duration; no chronic oral toxicological studies
Methylene Chloride	Oral	High	Medium	Medium	Only a few studies support the NOAEL
Tetrachloroethylene	Oral	Low	Medium	Medium	No one study combines the features desired for an RfD study; lack of complete histopathological examination at the NOAEL in the mouse study; lack of reproductive and teratogenic endpoints for oral exposure
Toluene	Oral	High	Medium	Medium	Lack of reproductive study; oral studies are all subchronic; critical study is only a 13-week duration
	Inhalation	Medium	Medium	Medium	NOAEL not established; chronic human data not available for neurotoxicity or irritation endpoints; reproductive/developmental studies in 3 species not comprehensive in endpoint evaluation

(1) Only those chemicals of concern having oral or inhalation RfDs in EPA (1993) are shown in this table.
(2) A more comprehensive discussion of the uncertainty associated with aldrin and dieldrin is presented in Appendix E, Section E.6.1.
(3) N/A denotes Not Available.

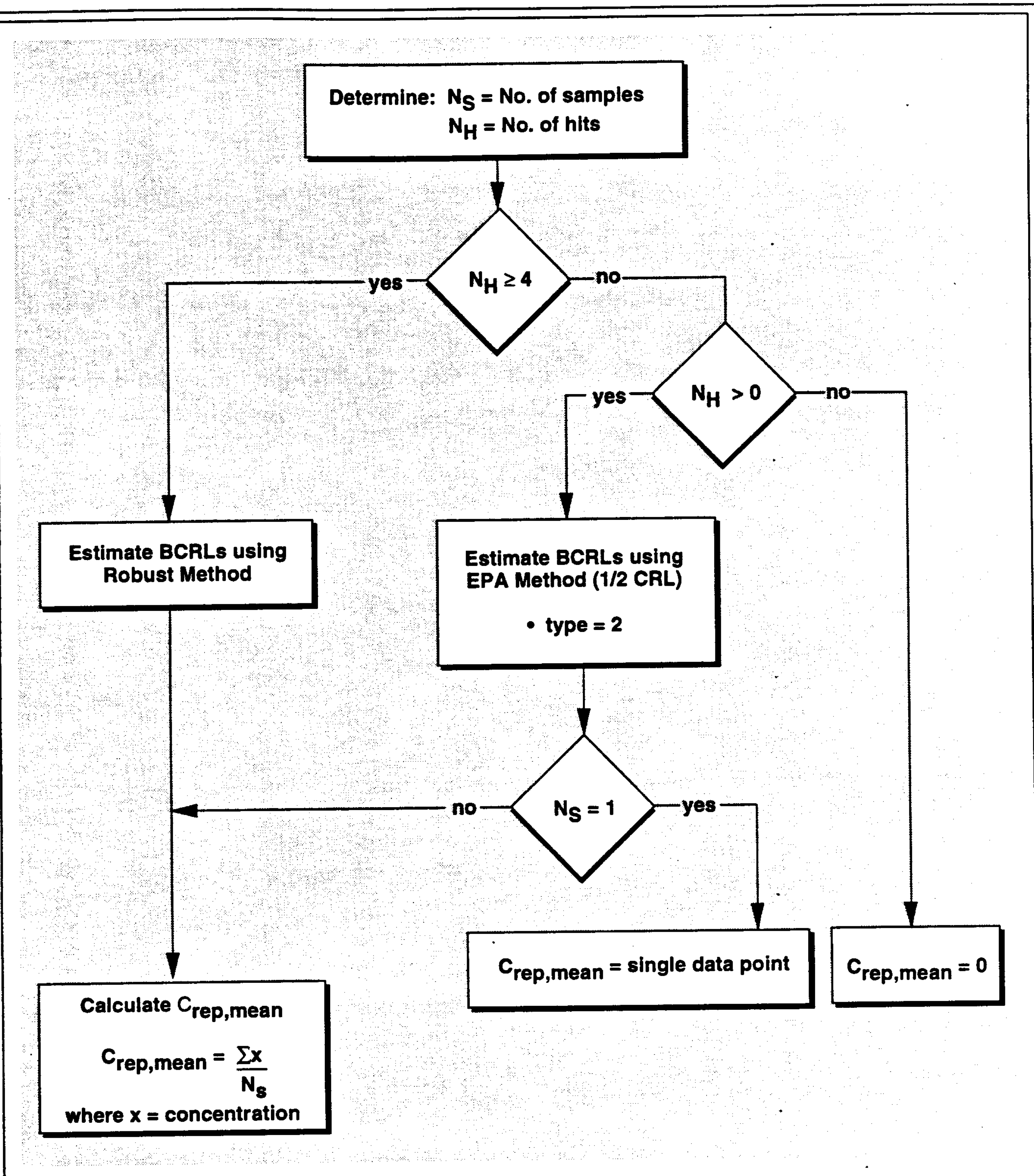

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Figure B.1-I

Calculation of $C_{rep,mean}$ Including Evaluation of BCRLs

APPENDIX B

(SECTION B.2)

POTENTIALLY EXPOSED POPULATIONS

TABLE OF CONTENTS

LIST OF TABLES

LIST OF ATTACHMENTS

LIST OF ACRONYMS AND ABBREVIATIONS

ARC	Archaeologist
BT	Biological Technician
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
EEO	Engineering Equipment Operator
EPA	U.S. Environmental Protection Agency
°F	Degrees Fahrenheit
FMO	Fire Management Officer
FOR	Forester
MM	Maintenance Mechanic
RMA	Rocky Mountain Arsenal
Shell	Shell Oil Company
SRO	Supervisory Refuge Operations Specialist
TE	Exposure Duration
USFWS	U.S. Fish and Wildlife Service
WB	Wildlife Biologist
WS	Work Supervisor

B.2.1 INTRODUCTION

Open space and economic development land-use options have been proposed for Rocky Mountain Arsenal (RMA) once remediation activities are complete. Under the open space option, two land uses are evaluated: use as a national wildlife refuge by the U.S. Fish and Wildlife Service (USFWS) and use as a recreational park. Under the economic development option, two land uses are evaluated: use for commercial establishments and use for industry.

Certain populations are expected to use the site if the land were developed for economic purposes or used as open space. Under the open space wildlife refuge scenario, the land is expected to be used by regulated/casual visitors and by refuge workers. Under the open space recreational park scenario, recreational visitors are expected to use the land. The most exposed subpopulations of the open space land-use scenario are evaluated in this report. Evaluation of the subpopulations gives the level of conservatism requested by the U.S. Environmental Protection Agency (EPA) since the most exposed subpopulations are assumed to have a higher exposure frequency than the population as a whole and are therefore assumed to be at higher risk. The most exposed subpopulations for the regulated/casual and recreational visitor populations are those individuals who live in proximity to RMA and use the land more frequently than people who live several miles away. The number of individuals comprising these "neighborhood" visitor subpopulations was not estimated or defined and is qualitative due to the lack of data specific to such a subpopulation. For the refuge worker population, the subpopulation of concern is biological workers, who are characterized as spending more than 50 percent of their work time outdoors. Under the commercial development scenario, commercial workers are expected to use the land, while under the industrial development scenario, industrial workers are expected to use the land.

Each of these potentially exposed populations or subpopulations is described in this appendix. The description of the refuge worker population (and the biological worker subpopulation) includes the results of a survey used to assess the potential types of activities in which this population and the biological worker subpopulation could be engaged.

B.2.2 OPEN SPACE LAND USE

Under the open space land-use option, three potentially exposed subpopulations are evaluated in the HHRC. The biological worker subpopulation is evaluated for the wildlife refuge worker population. The neighborhood regulated/casual visitor subpopulation is evaluated for the regulated/casual visitor population, and the neighborhood recreational visitor subpopulation is evaluated for the recreational visitor population. These subpopulations were chosen because they represent a maximally exposed subpopulation of the overall populations projected to use the open space at RMA.

B.2.2.1 Biological Workers

The biological worker is a subpopulation of the wildlife refuge worker population projected to frequent RMA under the open space land-use scenario. This subpopulation is characterized as spending more than 50 percent of the time outdoors engaged in activities that may increase its members' potential exposure to RMA soils. Individuals in this subpopulation are representative of several job categories including equipment operators, maintenance workers and mechanics, wildlife biologists and habitat management specialists, biological technicians, and others.

B.2.2.2 Regulated/Casual Visitors

The regulated/casual visitor represents a potentially exposed population under the open space land-use scenario in which RMA is used as a nature preserve or wildlife refuge. These visitors would likely be members of the general public or school groups. Activities of the regulated visitor could include bus tours and research-oriented study with limited sightseeing and photography. Activities of the casual visitor could include picnicking, bird watching, photography, limited hiking, and catch-and-release fishing. Because both types of visitors are assumed to participate in essentially similar activities in terms of exposure potential, the same exposure scenarios are used for both potentially exposed populations. The neighborhood subpopulation of the regulated/casual visitor is assumed to participate in the activities described above, but with greater frequency because they live closer to RMA.

B.2.2.3 Recreational Visitors

The recreational visitor represents a potentially exposed population under the open space land-use scenario for a recreational park. Under the recreational park scenario, RMA would have an extensive variety of recreational support facilities such as interpretive centers, trails, parking areas, picnic tables, restrooms, and athletic facilities. This scenario implies the most intense use under the open space concept as compared to the regulated/casual visitor population described above. Activities for the recreational visitor could include biking, hiking, jogging, picnicking, fishing, cross country skiing, field sports (e.g., baseball, soccer), etc. The neighborhood subpopulation of the recreational visitor population is assumed to participate in the activities described above, but with greater frequency because they live closer to RMA.

B.2.3 ECONOMIC DEVELOPMENT LAND USE

Under the economic development land use option, two potentially exposed populations are evaluated: commercial workers and industrial workers. These populations are described below.

B.2.3.1 Commercial Workers

The commercial worker represents a potentially exposed population under the economic development land-use scenario. Commercial workers are defined as white collar and may be employed as managers, sales representatives, and clerical and technical staff. These workers would spend most of their time working indoors in a retail or an office setting. Commercial development could include retail, wholesale and service establishments, office and public use buildings, police stations, administrative facilities, air cargo businesses, trucking, rental car bases, or other similar establishments.

B.2.3.2 Industrial Workers

Based on the presence of predominantly light industry in the areas immediately adjacent to RMA, light industrial activities are considered realistic for RMA in the future under an economic development land-use scenario. Light industry could include warehousing, packaging plants, and assembly and finishing plants, and involve activities such as warehousing, light manufacturing, assembly, and finishing and packaging plants. A majority of the time spent by industrial workers is likely to be indoors.

B.2.4 REFUGE WORKER SURVEY

In order to obtain data regarding the refuge worker population and the biological worker subpopulation of the refuge worker population, surveys and site visits to currently operating national wildlife refuges were conducted. The refuge selection process, survey methods, and results are discussed below. This text is taken from the Refuge Worker Exposure Assessment, which was drafted originally by Shell in 1991, and edited subsequently by Shell, the U.S. Army, and EBASCO (Shell 1991).

B.2.4.1 Refuge Selection

A list of 14 candidate National Wildlife Refuges that would have one or more important characteristics similar to RMA was provided to the U.S. Army and Shell Oil Company (Shell) by USFWS. This list provided the name, location, and number of full-time employees; budget, acreage, and visitation figures; distance to an urban area; and percentage of the budget used for information and recreation.

A subset of six refuges on the initial list was chosen, based on similarity to RMA, for telephone screening. The six refuges were chosen because of their proximity to urban development, similarity in size and physical characteristics, similarity of biota species and diversity, and comparable environmental education and public use. The focus on environmental education and "open spaces for the public benefit" reflects the goal of the organizations as described in Section 2.6 of the Federal Facility Agreement (EPA 1989).

Maury Wright of the Region VI USFWS office contacted each of the six refuge managers to make introductions and briefly explain why the study was being conducted. The telephone screening resulted in the selection of three refuges for on-site surveys. These three refuges were selected on the basis of comparability, relevance, and applicability to RMA. Because each refuge is unique, no one refuge could be expected to represent all the important characteristics exhibited by RMA. Where concomitant conditions differed, the conditions that did prevail on selected refuges were considered to provide a generally conservative bias in data interpretation. The refuges chosen for on-site visits were Minnesota Valley in Bloomington, Minnesota; Malheur National Wildlife Refuge in Burns, Oregon; and Crab Orchard National Wildlife Refuge in Marion, Illinois.

A description of the six refuges chosen for telephone screening and the rationale for the selection or rejection of the refuges for on-site surveys is provided below. Further information on the three refuges chosen for on-site visits is provided in Attachment B.2-2.

B.2.4.1.1 Rationale for Rejection of Refuge Visit Sites

Three refuges were screened by telephone but were not chosen for on-site visits. These three refuges (San Francisco Bay, Kesterson, and Tinicum) are described below.

San Francisco Bay Refuge

The San Francisco Bay Refuge is the nation's largest urban refuge. It consists of approximately 17,000 acres, about 80 percent of which is restricted to public access. Much of the property exists as salt water tidal marsh, mudflats, evaporative salt ponds operated by private industry, freshwater tidal slough, or uplands. Habitat of two endangered species (Salt Marsh Harvest Mouse and California Clapper Rail) is similarly off limits. An expansive public use/environmental education program includes a visitor's center, an environmental education center with interactive exhibits about the Bay environment, and a boardwalk/pier complex from which one may view the refuge. Fishing from the piers is allowed. Wildlife species include more than 200 birds, harbor seals, fish and shellfish, and a few mammals. Burrowing animal populations (e.g., red fox, ground squirrels) are limited by the predominance of marsh and mudflats. Invasive activities are limited for the same reason: even the latrines are aboveground. According to the refuge manager, most invasive activities consist of driving piles for piers and boardwalks, an activity that is usually completed by an outside contractor.

There are 26 staff positions, including 3 maintenance personnel. Since the latter are thought to have greater exposure time to soils than those in other USFWS job categories, it was necessary that some members of this group be experienced in work at the refuge and available for interviews. Two of the maintenance personnel at the refuge, however, had lengths of service of 2 days and 2 weeks; the third was terminating within the next week after 2 years of service. The turnover experience, according to the refuge manager was "unusual" (high) due to the proximity of the urban area and employment alternatives it offers.

In rejecting this refuge for survey, it was concluded that a predominantly marsh-type ecosystem would not have a realm of invasive activities comparable to the semiarid ecosystem at RMA. Additionally, the diversity and number of mammalian species relevant to RMA is limited at the refuge. Finally, the lack of availability of experienced key maintenance personnel precluded the gathering of activity type and duration information with some degree of historical perspective.

Kesterson Refuge Complex

The Kesterson Refuge is actually a "complex" of 5 refuges within a 25-mile radius, i.e., San Luis (7,500 acres), Kesterson (12,000 acres), Merced (2,500 acres), San Juaquin (800 acres), and Grasslands (20,000 and 30,000 acres). Its staff of 17, including 5 maintenance personnel, service all the refuges in the complex. Many are involved in Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) remedial activities at Kesterson Reservoir. This complex is the only one in California without a visitor's center or a formal public-use program, although self-guided tours are available. According to the visitor's guide for National Wildlife Refuges, published by USFWS, this complex has neither an environmental study area nor maintained foot or biking trails.

The Kesterson Refuge itself was turned over to USFWS after it had been purchased by the Department of Justice. Bioconcentration of selenium as a result of agricultural runoff was believed to have had toxic effects on biota. The refuge manager outlined an "anti-wildlife program" using pyrotechnics, noise, and hazing to keep birds away from the reservoir. Otherwise, the wildlife is "very different, very diverse." The refuges represent 40 percent of the wetlands left in California. One refuge in the complex has a herd of elk, another has several endangered species. Ground squirrels abound, and predators include hawks and owls.

In rejecting this refuge for survey, it was concluded that the geographic discontinuity and number of resources devoted primarily to remedial activities are too problematic for it to be compared to RMA. While some refuges in the complex are closer to residential development than others, none constitute a truly "urban refuge." The public-use and environmental education programs are in incipient stages and would not produce relevant data from which to draw activity and duration conclusions applicable to RMA. The wildlife diversity offers some comparability, but does not, in itself, outweigh the other contraindications for selection of this refuge.

Tinicum

Tinicum is a 920-acre refuge located in Philadelphia, Pennsylvania. According to its refuge manager, it is "the most urbanized refuge:" there are 5.4 million people within a 50-mile range of the refuge. Congressionally mandated a refuge 20 years ago, much of the area consists of tidally and nontidally influenced marsh. It has a fairly well developed public-use and environmental education program. Possible groundwater contamination due to either an old sanitary landfill or nearby gasoline stations is currently being investigated by EPA; that portion of the refuge is closed to the public.

There is a staff of eight at the refuge, but it is "in transition," according to the refuge manager. There has been almost a complete turnover, with six transfers in the past year. The staff includes two maintenance workers, but minimal invasive activities take place. An outside contractor performed construction of a new maintenance/storage building that is currently serving as the environmental education center. Nevertheless, there are few facilities associated with the refuge according to refuge management.

More than 280 species of birds, many migratory within the Atlantic Flyway, have been recorded at Tinicum. Populations of small mammals include opossums, raccoons, and muskrats.

In rejecting this refuge for survey, it was concluded that its small size and staff would not provide information of relevance to predicting potential exposure at RMA. Further, the tenure of the staff at Tinicum would not provide familiarity with that refuge's historical or long-range operations and activities. The presence of the tidal marsh and limited population of mammals also suggest significantly different conditions than those at RMA, and its environmental education program is recently established and is in a growth mode. Finally, the lack of invasive activities performed by USFWS personnel precludes assessment of that important element.

B.2.4.1.2 Rationale for Selection of Refuge Visit Sites

The three refuges chosen for on-site surveys are described below.

Minnesota Valley National Wildlife Refuge

Minnesota Valley National Wildlife Refuge in Bloomington, Minnesota is comprised of seven units located along either side of a 34-mile stretch of the Minnesota River (the river itself is not included in the refuge). As of 1991, this refuge encompassed more than 7,340 acres. It is bordered by a recreation area and state trail managed by city and county governments and the Minnesota Department of Natural Resources. The refuge's current staff numbers 22, including 2 maintenance personnel who perform most of the invasive activities. Turnover is reported to be moderate due to other opportunities offered by the surrounding urban area.

The refuge is located entirely within a flood plain. It is comprised of marsh, grasslands, and forests. Most areas are open to the public during daylight hours only. Restricted access areas include heron rookeries and the property leased from the Northern States Power Country.

The environmental education program is well developed and is centered around an 8,000-square-foot visitor's center/classroom/auditorium complex. Slide shows and interactive exhibits foster enthusiasm for the ecology of the refuge. The goal to "get visitors out on the refuge" is achieved by interpretive foot tours, auto tours, maps of the refuge, and special events. Many students make field trips to the facility. Trails for hiking, biking, horseback riding, and cross country skiing traverse the refuge and will eventually link up with the 72-mile state trail system. The refuge hosts some 140,000 visitors a year.

More than 250 species of birds use the area, either year round or during migration. There are 50 species of mammals that also inhabit the refuge including burrowing species such as gophers, badgers, voles, woodchucks and squirrels, and 30 species of reptiles and amphibians. Habitat manipulation, wildlife habitat and species surveys, duck banding, co-op farming, and planned burning are all performed for wildlife conservation purposes. As at other refuges, most research projects involve the bird populations. Current projects include reproductive strategies of mallards, biological control of leafy spurge, survey of black terns, and the effect of certain bacteria on aquatic invertebrate communities.

Other uses of the refuge are arranged through a special-use permit system. Permits issued last year included permission to gather soil and water samples, plant co-op farms, and perform fish surveys, pile tests, bridge surveys, and topographic surveys. Archaeological sites are known to be present.

The range of flow in the Minnesota River is large, and flooding is not uncommon. Therefore, installing or maintaining dikes, performing erosion control measures, regrading refuge roads damaged by floodwaters, and other activities all comprise much of the workload of the site's two maintenance personnel. According to the refuge's veteran engineering equipment operator, some 70 percent of the time spent in activities involving exposure to soils at depth (greater than 2 inches) is directly or indirectly related to the presence of the refuge in a flood plain.

This refuge was selected for survey because it is comparable in size to RMA, it has a diversity of biota, it has a well-developed environmental education program, and it is an urban refuge. The length of service of the staff, association with many universities and support groups, and its visibility all favored selection of this refuge. It is recognized that its location entirely within a floodplain involves numerous "invasive" activities that may not be carried out at RMA. However, the concomitant increased exposure impacts the assessment in a conservative manner.

Malheur National Wildlife Refuge

Malheur National Wildlife Refuge in Burns, Oregon was established in 1908 and is located in a remote area in southeastern Oregon. Most of its 185,000 acres consists of lakes or marshes, a dry alkali lake bed, meadows, and grasslands. The overall elevation of the refuge is 4,100 feet above mean sea level, and precipitation averages 9 inches a year. A higher water table than might be expected in an arid, sandy environs (approximately 5 feet) is found throughout much of the refuge, and lake levels fluctuate widely from year to year as a function of the quantity of snowmelt. This environment has created an opportunity and requirement for extensive manipulation of the lakes and wetlands. Consequently, the frequency and duration of invasive activities reflect its unique geography. The area lies within a glacial basin that has no outlet; snowmelt flowing into the basin replenishes the Malheur and Harney lakes.

The current staff numbers about 20, including 5 maintenance personnel. Turnover among the maintenance and administrative staff is low. The interview process was complicated by the size of the refuge and the fact that many personnel occupy satellite quarters.

Located in the Pacific Flyway, 300 species of migratory and resident birds populate the area. Birdwatching is an extremely popular activity at the refuge; and many of its 50,000 annual visitors visit for that purpose alone. More than 50 species of mammals are found at the refuge including beaver, muskrat, deer, coyotes, rabbits, squirrels, badgers, cows (under grazing permits), otter, mink, and antelope. Habitat survey and manipulation, bird banding, farming and grazing permits, prescribed burning, and bird surveys are the main focus of the wildlife conservation activities at the refuge.

Environmental education and public-use components include bus tours, auto tours, fishing, hunting, wildlife interpretive tours, and a museum. Visitors observe wildlife and takes photographs. Special events, such as the Annual Waterfowl Festival, bring large numbers of visitors to the site. Overnight camping is not allowed on the refuge, but is permitted on surrounding Bureau of Land Management lands. Many other environmental education programs are conducted through the Malheur Field Station as discussed below.

The Malheur Field Station is operated by a consortium of 17 colleges and universities. Research is carried out by graduate students and academic researchers as well as other agencies and natural resource organizations. As with other refuges, research emphasizes avian species. Current studies listed in the annual narrative report include willow flycatcher reproductive success, effects of land use on duck pairs, response of willows to prescribed burning, color markings of sandhill cranes, effects of prescribed burning on sandhill cranes, environmental contamination and reproductive success of waterfowl, population trends of small mammals, and assessment of fish migration.

Archaeological sites have been exposed at Malheur Lake as reservoir levels have dropped. Only minor excavation is performed in conjunction with these investigations. In 1990, the staff included a full-time archaeologist.

In 1990, volunteers logged 3,046 hours at Malheur. Their many tasks included bird banding, painting, habitat surveys, nest counts, bookkeeping, signmaking, cleaning, photography, and carpentry.

This refuge was selected for the survey because it has a climate that is comparable to that at RMA, it has diverse biota that is comparable to that at RMA, and it has an environmental education program. The length of service of the staff, the association of the field station with universities, and its history as an operating refuge all favored selection of this refuge. It is recognized that the geology and hydrology of the area is very different from RMA, and that its manipulation for wildlife conservation purposes may imply more frequent "invasive" activities than might be expected at RMA. However, the concomitant increased exposure impacts the assessment in a conservative manner.

Crab Orchard National Wildlife Refuge

The Crab Orchard National Wildlife Refuge in Marion, Illinois was established in 1947 when Congress combined the Illinois Ordnance Project with the Crab Orchard Lake Project. The prioritized objectives of the refuge included wildlife conservation, recreation, agriculture, and industry. Its 43,550 acres include 21,000 forested acres, 3 large lakes, nearly 50 small ponds, farmed land, and grazing lands. The refuge has more than 1 million visitors per year, including users of recreational facilities provided by concessionaires.

Environmental education and public-use components include bus tours, auto tours, fishing, hunting, an interpretive learning center, and wildlife interpretive tours. Visitors participate in wildlife observation and photography. Many other environmental education programs are conducted through the Touch of Nature Environmental Center described below.

Current refuge staff numbers about 35, including part-time positions. Of this staff number, maintenance personnel occupy about 13 positions. Turnover has been low, especially for this latter group. The proportionately larger number of maintenance personnel (compared to other refuges) is due to the requirement that USFWS provides certain services including water, sewer, water treatment, road maintenance, snow removal, groundskeeping, and law enforcement to the industrial permittees and recreational concessionaires. The refuge manager estimates that 20 percent of all staff operations are linked solely to providing services to non-USFWS recipients as described below.

The refuge is required to provide water and sewer treatment to a nearby off-refuge prison. To meet these demands, the refuge operates and maintains some 125 miles of underground water lines as well as a water treatment plant. According to the refuge manager, some 20 percent of the total staff activities are devoted to industrial operations, and as much as 50 percent of the maintenance activities directly or indirectly support these operations. Such industrial leases are unique to USFWS. Also at Crab Orchard, much of the land around its three lakes is leased to and/or operated by a concessionaire but supported by USFWS personnel.

A variety of industries operate in the eastern portion of the refuge by permit from USFWS. This aspect, unique to refuges, fulfills a congressional requirement made at the time the refuge was established. The operations utilize some 1.2 million square feet for light warehousing and employ approximately 1,500 persons. These operations are located at the periphery of a 22,000-acre sanctuary established for waterfowl migration.

The western portion of the refuge provides facilities for public recreation and wildlife management. Water areas are an important part of the refuge's wildlife and recreation program. Crab Orchard Dam, completed in 1938, forms a 7,000-acre lake with a shoreline of 127 miles. There are also two man-made lakes on the refuge, Little Grassy Lake (1,000 acres) and Devil's Kitchen (810 acres). The recreational facilities around these lakes, including boat rentals and maintenance, swimming, and camping, are operated by concessionaires. Such uses of this National Wildlife Refuge are "very atypical" according to the refuge manager. Intense recreational use, especially camping, imposes stresses on the facilities, the repair of which then becomes the responsibility of USFWS. Intense recreational use is considered incompatible with the USFWS's mandate to protect wildlife, which is especially impacted by night use. Nonetheless, USFWS supports the recreational uses (and the concessionaires) by maintaining roads and providing utilities, law enforcement services, and weed control, etc.

Certain land formerly under the control of USFWS and within the boundaries of the refuge has been transferred to Southern Illinois University. Southern Illinois University operates the Touch of Nature Environmental Education Center for graduate studies, youth camps, and other groups (e.g., Outward Bound). The land transfer was undertaken because of lack of compatibility of the center's operation with wildlife conservation, and because certain other lands owned by Southern Illinois University were taken in trade. Yet more land around Little Grassy Lake is leased to the Boy Scouts and Girl Scouts for purposes of their programs, including camping. These programs are independent of the environmental education program offered by the refuge.

Industrial operations prior to the establishment of the refuge resulted in heavy metal and polychlorinated biphenyl contamination. A Record of Decision is in place and studies continue. Public access to these areas is not allowed. Potential archaeological sites are numerous since Native Americans are known to have inhabited the shorelines of Crab Orchard Creek and other locations.

The refuge is located in the center of the Mississippi Flyway. Approximately 150,000 geese winter annually at the refuge, and some 240 other species of birds inhabit the area. Raptors include the bald eagle, red-shouldered hawk, peregrine falcon, broadwing hawk, Cooper's hawk, and kestrels. Populations of mammals include ground hogs, ground squirrels, rats, muskrats, deer, coyotes, rabbits, and others. Habitat survey and manipulation, bird banding, farming and grazing permits, prescribed burning, and bird surveys are the main focus of the wildlife conservation activities at the refuge.

Mammals are not studied as extensively as birds are according to the refuge manager. Current research projects include bluebird nesting success, whistling of bobwhite males, and resource exploitation patterns of coyotes. Average temperatures range from -15°F to 107°F, which is comparable to RMA. Average precipitation is variable (38 inches in 1989 and 64 inches in 1990), but is higher than that recorded at RMA.

This refuge was selected for the survey because it has a sanctuary that is comparable in size to that at RMA, it has a diversity of biota, it has an established environmental education program, and it has comparable residential development nearby. It is recognized that the presence of the industrial operations and the concessionaire's recreational development do bias the activities of the USFWS staff, but the increased exposure is thought to impact the assessment in a conservative manner. The length of service of the staff, the history of the refuge, the association with Southern Illinois University for environmental education programs, and the presence of archaeological sites all favored selection of this site.

B.2.4.2 Survey Methods

The three wildlife refuges were visited by a Shell subcontractor and a U.S. Army representative between October 2 and 8, 1991. An Army representative and Shell subcontractor visited Malheur and Crab Orchard. The Shell subcontractor visited Minnesota Valley. The visitor center at each refuge was toured to provide an overview of its ecology. Annual narrative reports at each refuge were reviewed for physical descriptors, i.e., known biota species, staff size and professions, research projects underway, completed maintenance activities, or other relevant information.

B.2.4.2.1 Survey Participant Selection

In selecting individuals to be interviewed, the organization chart for the refuge was reviewed to identify workers roughly representative of the relative frequencies of different occupations (e.g., wildlife biologist, maintenance worker) at the refuge. Some emphasis was placed on job categories requiring that significant time be spent outdoors, while job categories expected to entail entirely indoor work were not included in the sample. Four individuals were subsequently interviewed by the Shell subcontractor by telephone because they were unavailable at the time of the visit.

B.2.4.2.2 Survey Format and Questions

The survey was designed to elicit objective responses in a format that would allow logical grouping of data. Elements considered in the design of the survey included its length, wording of questions, and the order of the questions. The questions proved to be easily comprehensible to the respondents based on a very low number of requests for clarification and the ease with which it was administered. A sample survey form is provided as Attachment B.2-1.

Defined job categories exist at each of the National Wildlife Refuges. The number and type of job categories vary with the size, revenues, complexity, special uses, and public-use components at a given refuge. Activities within identical or comparable job categories vary according to the type of refuge, its location, species of biota present, geography, potential for archaeological sites, and public-use/environmental education components. To accurately predict what these job categories and their concomitant activities would be at RMA, USFWS recommended that job descriptions, task duration, and frequency data be gathered.

The draft survey questionnaire requested information on activity type and duration for three soil depths: 0 to 2 inches, 0 to 12 inches, and greater than 12 inches. Each respondent was also asked how long he or she had served with USFWS in order to calculate the number of hours expected to be worked given vacation time accrued according to USFWS policy. Information about time spent away from the job was also requested. Responses regarding length of service at each refuge and various positions held with USFWS provided data to calculate the exposure duration (TE) variable, which is further described in Section B.3.7.

Data were also gathered to obtain information regarding exposures for the subpopulation of volunteers, outside contractors, students, and other academic researchers at the refuges. This subpopulation represents persons who are not employed by USFWS, but who may nonetheless be exposed under a refuge land-use scenario. The exposure potential for this subpopulation was found to be primarily limited to acute and subchronic exposures and is not discussed further in this appendix.

B.2.4.2.3 Recording Protocol

Activities were recorded by the surveyor as reported by respondents. Minor distinctions were corrected to allow pooling of data (e.g., "planned" or "prescribed" burning referred to the same program, and "mowing" or "cutting" were reported as the same activity). Judgments were conservatively made where a range was reported. For example, if disking involved depths of 2 inches to 8 inches, the activity was listed in the 0- to 12-inch soil-depth category. If a fencing activity was reported, exposure was listed as time spent at a particular soil depth, although a great deal of this time is spent in transporting and staging materials, stringing wire, or nailing. Fence posts that are braced by rock cribs at the surface, however, were included in the surficial soil category.

Frequency and duration information was recorded as provided by the respondents. No attempt was made to correct the information during the interview. For example, if total hours per year given for all activities exceeded or fell short of total hours per year worked, it was recorded as given.

B.2.4.3 Survey Results

The survey was designed to characterize the population of all refuge workers having some outdoor activity (i.e., excluding office staff). In addition, the survey identifies and provides information on a subpopulation of workers, referred to as biological/maintenance workers, who spend at least half of their time outdoors. The survey data were used to characterize probabilistic distributions for both the refuge worker and biological worker for the time-dependent variables as described in Section B.3.7. Additionally, the survey provided information on worker activities used as input to develop distributions for the soil intake parameters including soil covering, breathing rate, soil ingestion, and dust loading. The results presented below show the types and durations of activities in which refuge workers are involved. A brief discussion of general information regarding wildlife refuges is also provided.

B.2.4.3.1 Reported Activities

The following activities were reported by respondents in the exposure categories listed below. No priority or frequency is implied by the order in which the activities appear. Within a soil depth, the activities are partitioned into two groups. These two groups are identified herein as "Middle Exposure Level Activities" and "Higher Exposure Level Activities." These labels are intended to convey relative levels of exposure to soil and do not indicate whether the exposures are "high" or "low" in absolute terms or in terms of possible health effects. The middle exposure level activities are believed to correspond to activities with greater levels of exposure than indoor administrative or clerical-type activities, which are referred herein as "indoor" activities. Moreover, the "middle" activities are expected to correspond to activities with lower levels of exposure than the higher exposure level activities. Hence, the middle exposure level activities correspond to activities with levels of exposure somewhere in between (but not necessarily halfway in between) the lesser levels of exposure for indoor activities and the greater levels of exposure for the higher exposure level activities.

The specific activities included in the "middle" and "higher" soil exposure groups are explicitly identified in Attachment B.2-2 of this appendix. Primarily, the middle exposure level activities involve being outside and observing, monitoring, or evaluating. The higher exposure level activities involve actively disturbing the soil (e.g., soil sampling, trail maintenance, irrigation or pipeline maintenance, benthic sampling, mowing, road grading, building dikes or firebreaks, disking, planting, and digging holes).

Indoor Activities

Administration	Budgeting Supervision
Data Entry	Program Planning Meetings
Scheduling	Public Relations Correspondence
Telephone	Mail Management
Visitor Center Duty	Bookstore/Giftshop Paperwork
Procurement	Office Supplies Permit Issue
Mailing	Accounting Training
Public Education	Classes Staffing
Recruiting	Interviews EPA Reports

Indoor Activities

Tour of Exhibits	Talks Presentations
Catalog Artifacts	Read Inventories
USFWS Regional Relations	Interagency Relations
Graphic Information System	Volunteer Program Management
Law Enforcement	Visitor Center Operations
Off-Refuge Activities	Fire Program Management

Contract Administration
Outside Contractor Management
Indoor Painting
Indoor Building Maintenance
Property Management
Timber Sales Program
Contaminant Investigation Oversight
Study Design/Methodology/ Analysis of Results

Outdoor Activities—Surficial Soils (0 to 2 inches)

Middle Exposure Category

Snow Removal
Outdoors Painting
Monitor Volunteers/Interns/YCC
Inspection/Planning
Walking/Monitoring/Observing
Sewer Plant Maintenance
Carpentry/Repairs
Indoor Maintenance
Spray Herbicides
Driving On-Refuge
Deciduous Vegetation Survey
Refuge Maintenance
Prescribed Burning
Repair Equipment
Gravel Excavation
Fencing (laterals only)

Outdoor Activities—Surficial Soils (0 to 2 inches)

Train Volunteers Outdoors
Place Rip-Rap
Property Maintenance
Equipment Maintenance
Wetlands Survey
Dike Reinforcement
Repair Vandalism Damage
Mowing/Brush Cutting
Interpretive Program Assistance
Litter Cleanup
Environmental Games (Public Use)
Giving Tours
Survey/Monitor Site
Observe Contractors
Hiking Tours
Assist Biologist
Waterfowl Survey and Census
Monitor Road Work
Ride All-Terrain Vehicles/
Co-op Farming Oversight

Horseback
Environmental Education Tours
Songbird Surveys
Pedestrian Surveys
Field Trips
Habitat Surveys
Photography
Trail Tours
Walking Water Lines
Wildlife and Plant Surveys
Observe Burning
Survey for Mapping
Property Checks
Crop Checks/Observe Harvest
Timber Inventories
Inspect Dams

<u>Outdoor Activities—Surficial Soils (0 to 2 inches)</u>

Higher Exposure Categories

Benthic Samples
Irrigation
Trail Maintenance
Wetlands Management
Bird Banding
Prescribed Burning
Surficial Soil Sampling
Wildlife Surveys (species/habitat)
Surface Grading/Blading
Seeding
Crop Harvest
Collecting Artifacts
Observe Co-op Farming
Area Cleanup

<u>Outdoor Activities—Soils (0 to 12 inches)</u>

Middle Exposure Categories

Observe Trail Construction
Monitor Co-op Farming
Excavate Gravel
Wildlife Habitat Survey
Monitor Firebreak Installation
Observe Archaeological Digs
Observe Earthmoving/Excavation
Predator Survey
Dike Maintenance Monitoring

Outdoor Activities—Soils (0 to 12 inches)

Higher Exposure Categories

- Install Firebreaks
- Grade/Blade Roads
- Demolition of Buildings
- Waterline Maintenance
- Repair Dikes
- Recover Artifacts
- Soil Samples in Burn Areas
- Post Hole Installation
- Repair/Clean Water Control Structures
- Beaver Dam/Muskrat Den Clearing
- Disking for Farming
- Wetlands Maintenance
- Dig Irrigation Ditches
- Dig Duck Ponds/Dikes
- Tree Planting
- Refuge Farming
- Install Concrete Pads

Outdoor Activities—Soils (greater than 12 inches)

Middle Exposure Activities

- Observe Gravel Pit Operations
- Monitor Burns and Firebreaks
- Monitor Fill Operations
- Monitor Construction
- Monitor Trenching/Waterline Repair

Outdoor Activities—Soils (greater than 12 inches)

Higher Exposure Activities

- Build/Repair Dikes
- Install/Replace Sewer Line
- Excavate Impoundments
- Soil Profile Cleaning
- Trench Installation
- Dirtmoving
- Wetlands Restoration
- Build/Repair Water Control Structures
- Build Trails
- Posthole Installation
- Grading
- Tree Planting
- Ditch Installation
- Dike Repair
- Repair Waterline Breaks

B.2.4.3.2 Proportional Allocation of Hours Among Different Activities

The survey data provide information pertaining to individual activities and the number of hours per year that a refuge worker is involved in these activities. The information on individual activities is presented below, followed by a discussion of the biological worker subpopulation.

The number of hours per year spent in each of the activities identified by the interviewed refuge workers is given in Attachment B.2-2. Each of the 33 refuge workers was asked to identify his or her current job category as well as the titles/job descriptions previously held with USFWS. For his or her current job category, the respondent was asked to list five main activities performed that would involve exposure to soil 0 to 2 inches below ground surface in terms of time allocation. The same question was asked for the other two soil depth categories. The respondent was also asked if there were any additional activities. These answers were also included. The number of hours per year spent in each of the activities identified in response to these three questions is given in Attachment B.2-2 for each individual refuge worker interviewed. The raw data are reported separately for each individual and each soil depth category in Attachment B.2-2.

Table B.2-1 indicates the total number of hours per year that each of the 33 refuge workers spent at the refuge. For each of these individual workers, Table B.2-1 also indicates the percentages of that total time that were reported to be spent in activities in each of the groupings of activities by expected exposure level.

If the refuge workers would have been able to precisely describe how they spent their time, then the sum of their percentages would have been 100 percent. However, the respondents were not that accurate. For example, the percentages summed to as high as 163 percent. The data are recorded herein as they were given by the respondents without any external adjustments. Thus, the data contain uncertainty regarding the recall of the respondents, but do not contain any assumptions about how the responses might have been normalized.

The percentage for indoor activities comes directly from the worker's response to the question "Indoors/Outdoors ratio (percent)." The percentage for middle exposure level activities and 0 to 2-inch soil depth category is calculated by summing the hours for all activities in the middle level exposure activity group identified in the respondent's answers to the question on activities involving exposure to soils in the 0- to 2-inch soil depth category and then dividing that sum by the total hours per year. The other percentages are calculated analogously. The percentages are reported in Table B.2-1 separately for each interviewed refuge worker.

In order to facilitate different evaluations of activity types and durations (i.e., the time-dependent variables discussed in Section B.3.7), the activity time percentages that are presented separately for each individual and each job category in Table B.2-1 are also presented in several alternative formats in Tables B.2-2 through B.2-14. The organization of Tables B.2-2 through B.2-14 is as follows:

- Tables B.2-2 through B.2-7 each refer to a specific soil depth category and a specific type of activity (indoor, middle exposure level, or higher exposure level).

- Tables B.2-8 through B.2-10 refer only to higher exposure level activities at different soil depths:

  Table B.2-8: > 12 inches
  Table B.2-9: > 12 inches or 0 to 12 inches
  Table B.2-10: > 12 inches or 0 to 12 inches or 0 to 2 inches

- Tables B.2-11 through B.2-13 refer to both middle and higher exposure level activities:

  Table B.2-11: > 12 inches
  Table B.2-12: > 12 inches or 0 to 12 inches
  Table B.2-13: > 12 inches or 0 to 12 inches or 0 to 2 inches

- Table B.2-14 refers to the normalized proportions of the time spent at a refuge for three types of refuge workers at specific soil depths.

In Table B.2-1, the observed activity time percentages are ordered by job category. In Tables B.2-2 through B.2-14, the observed activity time percentages are ordered from smallest to largest among all 33 interviewed refuge workers, and the corresponding cumulative distribution functions are given. For instance, Table B.2-2 indicates that the range of the percentage of time spent performing indoor activities is reported to be from 10 percent to 90 percent of the total hours per year spent on the refuge. Approximately 30 percent of the respondents spend no more than 25 percent of their time in indoor activities. Approximately 25 percent of the interviewed refuge workers spend at least 80 percent of their time in indoor activities. The individual percentages in Table B.2-1 are summed in order to determine the percentages of the time spent performing tasks at more than one type of activity level or at more than one soil depth.

Workers in the following job categories have the majority of exposure potential, as indicated by the percentage of time spent in outdoors and in higher exposure activities (Table B.2-1):

Job Category	Definition	Number of Workers
EEO	Engineering Equipment Operator/Tractor Operator	4
MM	Maintenance Mechanic	3
WB	Wildlife Biologist/Habitat Management Specialist	3
BT	Biological Technician/Assistant Biologist	3
WS	Work or Maintenance Supervisor	2
ARC	Archaeologist/Assistant Archaeologist	2
SRO	Supervisory Refuge Operations Specialist	1
FOR	Forester	1
FMO	Fire Management Officer	1
		TOTAL: 20

This result is supported by the qualitative impressions given during the interviews and by the quantitative data in Table B.2-1 through B.2-14. Nearly all of the workers in the above-referenced categories reported that they spent up to 50 percent of their time indoors. One wildlife biologist who reported spending 60 percent of the time indoors also reported a relatively high percentage of time (24 percent) spent in higher exposure activities, and was therefore included on the list. One outdoor recreational planner who reported spending 50 percent of the time indoors was excluded from the list because the other two outdoor recreational planners surveyed spent substantially more time indoors and reported no time spent in higher exposure activities. Some workers on the list who reported spending up to 50 percent of their time indoors also reported spending less than 50 percent of their time outdoors (i.e., the amount of time added to less than 100 percent). These workers were included in the above-referenced list because they generally reported significant proportions of time spent performing intrusive activities.

The biological worker subpopulation was defined as those workers whose jobs require them to spend more than 50 percent of time outdoors. The individuals identified in the above-referenced list were used as a sample of the biological worker subpopulation.

B.2.4.3.3 General Information Regarding Refuges

Common objectives at National Wildlife Refuges are protecting wildlife, promoting species diversity and abundance, and preserving and restoring appropriate habitat. Regional and federal mandates to increase public-use and environmental education components are perceived differently by individual refuge management, but recreational uses are generally regarded as a lower priority than wildlife conservation. Thus, for almost all of the more than 450 refuges within the National Wildlife Refuge system, camping and unrestricted or evening access are prohibited because they are incompatible with the primary objective of wildlife conservation.

Much emphasis on migratory waterfowl and raptors is apparent, and not coincidentally, most refuges are located along the major north-south flyways across the United States. At each of the visited refuges, the majority of the research projects listed in the annual narrative reports studied birds, and only an occasional study focused on mammals, fish, or vegetation. One USFWS refuge manager commented that mammals are "not significant and are not studied much," provided there is adequate food supply for the raptors.

Habitat manipulation is practiced to the extent necessary to meet the goal of attracting migratory and other birds. This may entail creating and maintaining wetlands, ponds, lakes, and other water bodies. Water levels are manipulated to control submergent and emergent vegetation, provide nesting areas, discourage carp, etc. Water control structures—dikes, trenches, and other devices—are built and maintained to allow water-level control. Every 5 to 10 years, accumulations of silt may be removed by backhoe or loader where the water supply or discharge creates blockage from accumulations of this type.

Refuges permit and sometimes encourage farming to create high-protein food sources for birds. In a co-op farming scenario, a percentage of the crops are harvested by the permittee and an agreed percentage is left in the field for migratory and resident birds. In contract farming, permits are issued for the use of refuge lands to raise of crops for the sole use of the farmer. In refuge farming, USFWS personnel plant and maintain crops for wildlife.

Grassland manipulation is practiced to maintain habitat for nesting birds, browsers (e.g., deer, elk), and populations of small mammals. Planned burning is practiced every 5 to 10 years where necessary to prevent woody bushes and trees from converting the grasslands. In drier climates such as that found at RMA, there is less threat of such conversion, so prescribed burning may not be necessary. The refuges occasionally receive complaints during periods of burning, which can occur daily for 2 weeks in the spring and fall.

Each refuge practices herbicide control by spraying where necessary to control undesirable species (e.g., purple loosestrife) or growth in unwanted areas (e.g., trails, parking lots). Brand-name herbicides used include Tordor®, Rodeo®, and Roundup®, but the final choice is left to the individual refuge. Insecticides have been considered, but have not been recently used in the surveyed refuges, even in areas where mosquitos breed.

B.2.5 REFERENCES

RTIC 89068R01

EPA. 1989. Federal Facility Agreement for the Rocky Mountain Arsenal.

Shell (Shell Oil Company). 1991. Draft Refuge Worker Activities Assessment. Prepared with Program Management Office Rocky Mountain Arsenal and EBASCO Services, Inc.

Table B.2-1 The Total Number of Hours per Year Spent on the Refuge and the Percentages of Time Spent in Different Types of Activities

Job Categories	Total Hrs/Yr	% Time Indoors	% Time in Middle and Higher Exposure Activity					
			Soil Depth: 0-2"		Soil Depth: 0-12"		Soil Depth:<12"	
Engineering Equipment Operator/Crane/Tractor Operator; M: 1/3, MV: 1/1, CO: 2/5 (# Interviewed /# In Job Category)								
* M-B (Eng. Equip. Oper.)	1760	20	M: 34%	H: 16%	M:	H: 17%	M:	H: 31%
* MV-C (Eng. Equip. Oper.)	1816	10	M: 49%	H:	M:	H: 27%	M:	H: 20%
* CO-L (Eng. Equip. Oper.)	1816	15	M: 26%	H: 18%	M:	H: 19%	M:	H: 17%
* CO-J (Tractor Oper.)	1786	10	M: 15%	H: 63%	M:	H: 5%	M:	H: 9%
Maintenance Mechanic/Worker; M: 1/2, MV: 1/1, CO: 1/3 (# Interviewed /# In Job Category)								
* M-A (Maintenance Mech.)	1840	10	M: 57%	H: 34%	M:	H:	M:	H: 1%
* MV-F (Main. Mech.)	1920	25	M: 49%	H: 4%	M:	H: 1%	M:	H: 2%
* CO-I (Main. Mech.)	1880	25	M: 46%	H:	M:	H: 1%	M:	H: 6%
Habitat Management Specialist/Wildlife Biologist; M:1/2, MV: 1/1, CO:1/1 (# Interviewed /# In Job Category)								
* M-F (Habitat Mgt. Specialist)	1786	50	M: 47%	H:	M: 8%	H:	M:	H: 0.4%
* MV-B (Wild. Biol.)	1680	60	M: 9%	H: 24%	M:	H:	M:	H:
* CO-F (Wild. Biol.)	1840	33	M: 39%	H: 30%	M:	H: 16%	M:	H: 1%
Biological Technician/Assistant Biologist; M: 1/1, MV: 1/1, CO: 1/1 (# Interviewed /# In Job Category)								
* M-H (Wild. Biol. Asst.)	1760	40	M: 40%	H:	M:	H: 2%	M:	H:
* MV-A (Biol. Tech.)	1904	30	M: 42%	H: 56%	M: 1%	H: 6%	M: 0.46%	H:
* CO-C (Biol. Tech.)	1880	20	M: 34%	H: 6%	M:	H: 24%	M:	H: 2%
Work Supervisor/Maintenance Supervisor; M: 1/1, MV: 0/0, CO: 1/1 (# Interviewed /# In Job Category)								
* M-J (Work Supr.)	1780	20	M: 48%	H: 4%	M:	H:	M:	H: 12%
* CO-K (Main. Supr.)	1610	25	M: 48%	H:	M:	H: 1%	M:	H: 2%
Archaeologist; M: 1/1, MV: 0/0, CO 0/0 (# Interviewed /# In Job Category)								
* M-C (Archaeologist)	1770	50	M: 100%	H:	M: 2%	H: 8%	M:	H: 5%
Assistant Archaeologist; M: 1/1 MV: 0/0 CO: 0/0 (# Interviewed /# In Job Category)								
* M-K (Asst. Arch.)	1920	50	M: 35%	H: 19%	M:	H:	M:	H:

Table B.2-1 The Total Number of Hours per Year Spent on the Refuge and the Percentages of Time Spent in Different Types of Activities

Job Categories	Total Hrs/Yr	% Time Indoors	% Time in Middle and Higher Exposure Activity Soil Depth: 0-2"	Soil Depth: 0-12"	Soil Depth:<12"
Refuge Manager; M: 1/1, MV: 1/1, CO: 1/1 (# Interviewed /# In Job Category)					
M-D (Ref. Mgr.)	1316	90	M: 8% H:	M: 0.2% H:	M: 0.8% H:
MV-E (Ref. Mgr.)	1848	90	M: 14% H:	M: H: 0.2%	M: H:
CO-G (Ref. Mgr.)	1656	60	M: 44% H:10%	M: 0.3% H: 1%	M: 7% H:
Assistant Refuge Manager/Deputy Manager; M: 1/1, MV: 0/0, CO: 1/1 (# Interviewed /# In Job Category)					
M-G (Asst. Ref. Mgr.)	1786	70	M: 29% H:	M: 2% H:	M: 6% H:
CO-B (Supr. Ref. Operations Spec.)*	1692	40	M: 43% H:	M: 0.3% H: 0.6%	M: 9% H:
Refuge Operations Specialist; M: 0/0, MV: 1/2, CO: 0/0 (# Interviewed /# In Job Category)					
MV-D (Ref. Operations Spec.)	1864	85	M: 15% H:	M: H:	M: H:
Outdoor Recreation Planner; M: 1/1, MV: 1/3, CO: 1/2 (# Interviewed /# In Job Category)					
M-E (Outdoor Recreation Planner)	1728	50	M: 25% H:	M: H: 7%	M: H: 10%
MV-J (Outdoor Rec Planner)	1760	80	M: 19% H:	M: H:	M: H:
CO-D (Outdoor Recreation Planner	790	90	M: 10% H:	M: H:	M: H:
Forester; M: 0/0, MV: 0/0, CO: 1/1 (# Interviewed /# In Job Category)					
CO-E (Forester)*	1740	50	M: 36% H:	M: H: 3%	M: H:
Administrative Officer/Asst.; M: 0/0, MV: 0/1, CO: 1/1					
CO-A (Admin. Officer)	1692	70	M: 5% H:	M: H: 0.9%	M: H:
Refuge Guide; M: 0/0, MV: 3/3, CO: 1/2 (# Interviewed /# In Job Category)					
MV-G (Ref. Guide)	1920	80	M: 14% H:	M: H:	M: H:
MV-H (Ref. Guide)	1920	80	M: 46% H:	M: H:	M: H:
MV-I Ref. Guide)	1824	80	M: 22% H:	M: H:	M: H:
CO-H (Ref. Guide)	1920	90	M: 6% H:	M: H: 0.6%	M: H:

Table B.2-1 The Total Number of Hours per Year Spent on the Refuge and the Percentages of Time Spent in Different Types of Activities

Job Categories	Total Hrs/Yr		% Time in Middle and Higher Exposure Activity Soil Depth: 0-2"		Soil Depth: 0-12"		Soil Depth>12"	
Refuge Fire Management Officer; M: 1/1, MV: 0/0, CO: 0/0 (# Interviewed /# In Job Category)								
M-I (Ref. Fire Mgt. Officer)*	1824.	50 .	M: 29%	H: .	M: 0.4%	H: .	M: 2% .	H:

M = Malheur, Oregon; MV - Minnesota Valley, Minnesota; CO = Crab Orchard, Illinois
* Denotes a refuge worker in the subpopulation of biological/maintenance workers.

Table B.2-2 Observed Probability Distribution of the Time Spent in Indoor Activities by Refuge Workers Currently Working at Crab Orchard, Illinois; Malheur, Oregon; and Minnesota Valley, Minnesota

Rank Order	Percentage of Time Spent in These Activities	Cumulative Probability	Job Categories with Highest Potential Exposure
1	10.0%	.0303	EEO
2	10.0%	.0606	EEO
3	10.0%	.0909	MM
4	15.0%	.1212	EEO
5	20.0%	.1515	EEO
6	20.0%	.1818	–
7	20.0%	.2121	BT
8	25.0%	.2424	MM
9	25.0%	.2727	MM
10	25.0%	.3030	–
11	30.0%	.3333	
12	33.0%	.3636	
13	40.0%	.3939	
14	40.0%	.4242	
15	50.0%	.4545	
16	50.0%	.4848	
17	50.0%	.5152	
18	50.0%	.5455	
19	50.0%	.5758	
20	50.0%	.6061	
21	60.0%	.6364	
22	60.0%	.6667	
23	70.0%	.6970	
24	70.0%	.7273	
25	80.0%	.7576	
26	80.0%	.7879	
27	80.0%	.8182	
28	80.0%	.8485	
29	85.0%	.8788	
30	90.0%	.9091	
31	90.0%	.9394	
32	90.0%	.9697	
33	90.0%	1.0000	

EEO Engineering Equipment Operator
MM Maintenance Mechanic
WB Wildlife Biologist/Habitat Management Specialist
ET Biological Technician/Assistant Biologist
– A job category other than the four job categories (EEO, MM, WB, BT) with the highest exposure potential

Table B.2-3 Observed Probability Distribution of the Time Spent in Middle Exposure Activities for 0- to 2-inch Soil Depth by Refuge Workers Currently Working at Crab Orchard, Illinois; Malheur, Oregon; and Minnesota Valley, Minnesota

Rank Order	Percentage of Time Spent in These Activities	Cumulative Probability
1	5.0%	.0303
2	6.0%	.0606
3	8.0%	.0909
4	9.0%	.1212
5	10.0%	.1515
6	14.0%	.1818
7	14.0%	.2121
8	15.0%	.2424
9	15.0%	.2727
10	19.0%	.3030
11	22.0%	.3333
12	25.0%	.3636
13	26.0%	.3939
14	29.0%	.4242
15	29.0%	.4545
16	34.0%	.4848
17	34.0%	.5152
18	35.0%	.5455
19	36.0%	.5758
20	39.0%	.6061
21	40.0%	.6364
22	42.0%	.6667
23	43.0%	.6970
24	44.0%	.7273
25	46.0%	.7576
26	46.0%	.7879
27	47.0%	.8182
28	48.0%	.8485
29	48.0%	.8788
30	49.0%	.9091
31	49.0%	.9394
32	57.0%	.9697
33	100.0%	1.0000

Table B.2-4 Observed Probability Distribution of the Time Spent in Higher Exposure Activities for 0- to 2-inch Soil Depth by Refuge Workers Currently Working at Crab Orchard, Illinois; Malheur, Oregon; and Minnesota Valley, Minnesota

Rank Order	Percentage of Time Spent in These Activities	Cumulative Probability	Job Categories with Highest Potential Exposure
1	0.0%	.0303	
2	0.0%	.0606	
3	0.0%	.0909	
4	0.0%	.1212	
5	0.0%	.1515	
6	0.0%	.1818	
7	0.0%	.2121	
8	0.0%	.2424	
9	0.0%	.2727	
10	0.0%	.3030	
11	0.0%	.3333	
12	0.0%	.3636	
13	0.0%	.3939	
14	0.0%	.4242	
15	0.0%	.4545	
16	0.0%	.4848	
17	0.0%	.5152	
18	0.0%	.5455	
19	0.0%	.5758	
20	0.0%	.6061	
21	0.0%	.6364	
22	4.0%	.6667	
23	4.0%	.6970	
24	6.0%	.7273	
25	10.0%	.7576	
26	16.0%	.7879	EEO
27	18.0%	.8182	EEO
28	19.0%	.8485	–
29	24.0%	.8788	WB
30	30.0%	.9091	WB
31	34.0%	.9394	MM
32	56.0%	.9697	–
33	63.0%	1.0000	EEO

EEO Engineering Equipment Operator
MM Maintenance Mechanic
WB Wildlife Biologist/Habitat Management Specialist
BT Biological Technician/Assistant Biologist

– A job category other than the four job categories (EEO, MM, WB, BT) with the highest exposure potential.

Table B.2-5 Observed Probability Distribution of the Time Spent in Middle Exposure Activities for 0- to 12-inch Soil Depth by Refuge Workers Currently Working at Crab Orchard, Illinois; Malheur, Oregon; and Minnesota Valley, Minnesota

Rank Order	Percentage of Time Spent in These Activities	Cumulative Probability
1	0.0%	.0303
2	0.0%	.0606
3	0.0%	.0909
4	0.0%	.1212
5	0.0%	.1515
6	0.0%	.1818
7	0.0%	.2121
8	0.0%	.2424
9	0.0%	.2727
10	0.0%	.3030
11	0.0%	.3333
12	0.0%	.3636
13	0.0%	.3939
14	0.0%	.4242
15	0.0%	.4545
16	0.0%	.4848
17	0.0%	.5152
18	0.0%	.5455
19	0.0%	.5758
20	0.0%	.6061
21	0.0%	.6364
22	0.0%	.6667
23	0.0%	.6970
24	0.0%	.7273
25	0.0%	.7576
26	0.2%	.7879
27	0.3%	.8182
28	0.3%	.8485
29	0.4%	.8788
30	1.0%	.9091
31	2.0%	.9394
32	2.0%	.9697
33	8.0%	1.0000

Table B.2-6 Observed Probability Distribution of the Time Spent in Higher Exposure Activities for 0- to 12-inch Soil Depth by Refuge Workers Currently Working at Crab Orchard, Illinois; Malheur, Oregon; and Minnesota Valley, Minnesota

Rank Order	Percentage of Time Spent in These Activities	Cumulative Probability	Job Categories with Highest Potential Exposure
1	0.0%	.0303	
2	0.0%	.0606	
3	0.0%	.0909	
4	0.0%	.1212	
5	0.0%	.1515	
6	0.0%	.1818	
7	0.0%	.2121	
8	0.0%	.2424	
9	0.0%	.2727	
10	0.0%	.3030	
11	0.0%	.3333	
12	0.0%	.3636	
13	0.0%	.3939	
14	0.0%	.4242	
15	0.2%	.4545	
16	0.6%	.4848	
17	0.6%	.5152	
18	0.9%	.5455	
19	1.0%	.5758	
20	1.0%	.6061	
21	1.0%	.6364	
22	1.0%	.6667	
23	2.0%	.6970	
24	3.0%	.7273	
25	5.0%	.7576	
26	6.0%	.7879	
27	7.0%	.8182	
28	8.0%	.8485	
29	16.0%	.8788	WB
30	17.0%	.9091	EEO
31	19.0%	.9394	EEO
32	24.0%	.9697	BT
33	27.0%	1.0000	EEO

EEO Engineering Equipment Operator
MM Maintenance Mechanic
WB Wildlife Biologist/Habitat Management Specialist
BT Biological Technician/Assistant Biologist

\- A job category other than the four job categories (EEO, MM, WB, BT) with the highest exposure potential.

Table B.2-7 Observed Probability Distribution of the Time Spent in Middle Exposure Activities for Soil Depths Greater Than 12 inches by Refuge Workers Currently Working at Crab Orchard, Illinois; Malheur, Oregon; and Minnesota Valley, Minnesota

Rank Order	Percentage of Time Spent in These Activities	Cumulative Probability
1	0.0%	.0303
2	0.0%	.0606
3	0.0%	.0909
4	0.0%	.1212
5	0.0%	.1515
6	0.0%	.1818
7	0.0%	.2121
8	0.0%	.2424
9	0.0%	.2727
10	0.0%	.3030
11	0.0%	.3333
12	0.0%	.3636
13	0.0%	.3939
14	0.0%	.4242
15	0.0%	.4545
16	0.0%	.4848
17	0.0%	.5152
18	0.0%	.5455
19	0.0%	.5758
20	0.0%	.6061
21	0.0%	.6364
22	0.0%	.6667
23	0.0%	.6970
24	0.0%	.7273
25	0.0%	.7576
26	0.0%	.7879
27	0.0%	.8182
28	0.4%	.8485
29	0.8%	.8788
30	2.0%	.9091
31	6.0%	.9394
32	7.0%	.9697
33	9.0%	1.0000

Table B.2-8 Observed Probability Distribution of the Time Spent in Higher Exposure Activities for Soil Depths Greater Than 12 inches by Refuge Workers Currently Working at Crab Orchard, Illinois; Malheur, Oregon; and Minnesota Valley, Minnesota

Rank Order	Percentage of Time Spent in These Activities	Cumulative Probability	Job Categories with Highest Potential Exposure
1	0.0%	.0303	
2	0.0%	.0606	
3	0.0%	.0909	
4	0.0%	.1212	
5	0.0%	.1515	
6	0.0%	.1818	
7	0.0%	.2121	
8	0.0%	.2424	
9	0.0%	.2727	
10	0.0%	.3030	
11	0.0%	.3333	
12	0.0%	.3636	
13	0.0%	.3939	
14	0.0%	.4242	
15	0.0%	.4545	
16	0.0%	.4848	
17	0.0%	.5152	
18	0.0%	.5455	
19	0.0%	.5758	
20	0.4%	.6061	
21	1.0%	.6364	
22	1.0%	.6667	
23	2.0%	.6970	
24	2.0%	.7273	
25	2.0%	.7576	
26	5.0%	.7879	
27	6.0%	.8182	
28	9.0%	.8485	EEO
29	10.0%	.8788	–
30	12.0%	.9091	–
31	17.0%	.9394	EEO
32	20.0%	.9697	EEO
33	31.0%	1.0000	EEO

EEO Engineering Equipment Operator
MM Maintenance Mechanic
WB Wildlife Biologist/Habitat Management Specialist
BT Biological Technician/Assistant Biologist

– A job category other than the four job categories (EEO, MM, WB, BT) with the highest exposure potential.

Table B.2-9 Observed Probability Distribution of the Time Spent in Higher Exposure Activities for Soil Depths 0 to 12 inches or Greater Than 12 inches by Refuge Workers Currently Working at Crab Orchard, Illinois; Malheur, Oregon; and Minnesota Valley, Minnesota

Rank Order	Percentage of Time Spent in These Activities	Cumulative Probability	Job Categories with Highest Potential Exposure
1	0.0%	.0303	
2	0.0%	.0606	
3	0.0%	.0909	
4	0.0%	.1212	
5	0.0%	.1515	
6	0.0%	.1818	
7	0.0%	.2121	
8	0.0%	.2424	
9	0.0%	.2727	
10	0.0%	.3030	
11	0.0%	.3333	
12	0.2%	.3636	
13	0.4%	.3939	
14	0.6%	.4242	
15	0.6%	.4545	
16	0.9%	.4848	
17	1.0%	.5152	
18	1.0%	.5455	
19	2.0%	.5758	
20	3.4%	.6061	
21	3.0%	.6364	
22	3.0%	.6667	
23	6.0%	.6970	
24	7.0%	.7273	
25	12.0%	.7576	
26	13.0%	.7879	
27	14.0%	.8182	
28	17.0%	.8485	
29	17.0%	.8788	
30	26.0%	.9091	BT
31	36.0%	.9394	EEO
32	47.0%	.9697	EEO
33	48.0%	1.0000	EEO

EEO Engineering Equipment Operator
MM Maintenance Mechanic
WB Wildlife Biologist/Habitat Management Specialist
BT Biological Technician/Assistant Biologist

– A job category other than the four job categories (EEO, MM, WB, BT) with the highest exposure potential.

Table B.2-10 Observed Probability Distribution of the Time Spent in Higher Exposure Activities for Soil Depths 0 to 2 inches, 0 to 12 inches, or Greater Than 12 inches by Refuge Workers Currently Working at Crab Orchard, Illinois; Malheur, Oregon; and Minnesota Valley, Minnesota

Rank Order	Percentage of Time Spent in These Activities	Cumulative Probability	Job Categories with Highest Potential Exposure
1	0.0%	.0303	
2	0.0%	.0606	
3	0.0%	.0909	
4	0.0%	.1212	
5	0.0%	.1515	
6	0.0%	.1818	
7	0.0%	.2121	
8	0.0%	.2424	
9	0.0%	.2727	
10	0.2%	.3030	
11	0.4%	.3333	
12	0.6%	.3636	
13	0.6%	.3939	
14	0.9%	.4242	
15	2.0%	.4545	
16	3.0%	.4848	
17	3.0%	.5152	
18	7.0%	.5455	
19	7.0%	.5758	
20	11.0%	.6061	
21	13.0%	.6364	
22	16.0%	.6667	
23	17.0%	.6970	
24	19.0%	.7273	
25	24.0%	.7576	WB
26	32.0%	.7879	BT
27	35.0%	.8182	MM
28	47.0%	.8485	WB
29	47.0%	.8788	EEO
30	54.0%	.9091	EEO
31	62.0%	.9394	BT
32	64.0%	.9697	EEO
33	77.0%	1.0000	EEO

EEO Engineering Equipment Operator
MM Maintenance Mechanic
WB Wildlife Biologist/Habitat Management Specialist
BT Biological Technician/Assistant Biologist

– A job category other than the four job categories (EEO, MM, WB, BT) with the highest exposure potential.

Table B.2-11 Observed Probability Distribution of the Time Spent in Exposure Activities for Soil Depth Greater Than 12 inches by Refuge Workers Currently Working at Crab Orchard, Illinois; Malheur, Oregon; and Minnesota Valley, Minnesota*

Rank Order	Percentage of Time Spent in These Activities	Cumulative Probability
1	0.0%	.0303
2	0.0%	.0606
3	0.0%	.0909
4	0.0%	.1212
5	0.0%	.1515
6	0.0%	.1818
7	0.0%	.2121
8	0.0%	.2424
9	0.0%	.2727
10	0.0%	.3030
11	0.0%	.3333
12	0.0%	.3636
13	0.0%	.3939
14	0.4%	.4242
15	0.4%	.4545
16	0.8%	.4848
17	1.0%	.5152
18	1.0%	.5455
19	2.0%	.5758
20	2.0%	.6061
21	2.0%	.6364
22	2.0%	.6667
23	5.0%	.6970
24	6.0%	.7273
25	6.0%	.7576
26	7.0%	.7879
27	9.0%	.8182
28	9.0%	.8485
29	10.0%	.8788
30	12.0%	.9091
31	17.0%	.9394
32	20.0%	.9697
33	31.0%	1.0000

* These activities are the "middle exposure level activities" and "higher exposure level activities" combined.

Table B.2-12 Observed Probability Distribution of the Time Spent in Exposure Activities for Soil Depths 0 to 12 inches or Greater Than 12 inches by Refuge Workers Currently Working at Crab Orchard, Illinois; Malheur, Oregon; and Minnesota Valley, Minnesota*

Rank Order	Percentage of Time Spent in These Activities	Cumulative Probability
1	0.0%	.0303
2	0.0%	.0606
3	0.0%	.0909
4	0.0%	.1212
5	0.0%	.1515
6	0.0%	.1818
7	0.0%	.2121
8	0.0%	.2424
9	0.2%	.2727
10	0.6%	.3030
11	0.9%	.3333
12	1.0%	.3636
13	1.0%	.3939
14	2.0%	.4242
15	2.4%	.4545
16	3.0%	.4848
17	3.0%	.5152
18	3.0%	.5455
19	7.0%	.5758
20	7.4%	.6061
21	8.0%	.6364
22	8.3%	.6667
23	8.4%	.6970
24	9.9%	.7273
25	12.0%	.7576
26	14.0%	.7879
27	15.0%	.8182
28	17.0%	.8485
29	17.0%	.8788
30	26.0%	.9091
31	36.0%	.9394
32	47.0%	.9697
33	48.0%	1.0000

* These activities are the "middle exposure level activities" and "higher exposure level activities" combined.

Table B.2-13 Observed Probability Distribution of the Time Spent in Exposure Activities for Soil Depths 0 to 2 inches, 0 to 12 inches, or Greater Than 12 inches by Refuge Workers Currently Working at Crab Orchard, Illinois; Malheur, Oregon; and Minnesota Valley, Minnesota*

Rank Order	Percentage of Time Spent in These Activities	Cumulative Probability
1	5.9%	.0303
2	6.6%	.0606
3	9.0%	.0909
4	10.0%	.1212
5	14.0%	.1515
6	14.2%	.1818
7	15.0%	.2121
8	19.0%	.2424
9	22.0%	.2727
10	31.4%	.3030
11	33.0%	.3333
12	37.0%	.3636
13	39.0%	.3939
14	42.0%	.4242
15	42.0%	.4545
16	46.0%	.4848
17	51.0%	.5152
18	52.9%	.5455
19	53.0%	.5758
20	54.0%	.6061
21	55.4%	.6364
22	56.0%	.6667
23	62.3%	.6970
24	64.0%	.7273
25	66.0%	.7576
26	80.0%	.7879
27	86.0%	.8182
28	92.0%	.8485
29	92.0%	.8788
30	96.0%	.9091
31	98.0%	.9394
32	105.4%	.9697
33	115.0%	1.0000

* These activities are the "middle exposure level activities" and "higher exposure level activities" combined.

Table B.2-14 Normalized Proportions of the Time Spent by the Refuge Worker in Three General Types of Refuge Worker Activities: Combined Activities for Soil Depths 0 to 2 inches, 0 to 12 inches, or Greater Than 12 inches (Refuge Workers Currently Working at Crab Orchard, Illinois; Malheur, Oregon; and Minnesota Valley, Minnesota)

Individuals	(Job Category)	% Time Indoors	% Time Middle Exposure Activity, (M) or Higher (H) Exposure Activity: Soil Depth 0-2"		Soil Depth 0-12"		Soil Depth >12"		Ps: Indoors	Middle	Higher
*M-B	(Eng. Equip. Oper.)	20.0	M: 34.0	H: 16.0	M: .0	H: 17.0	M: .0	H: 31.0	.1695	.2881	.5424
*MV-C	(Eng. Equip. Oper.)	10.0	M: 49.0	H: .0	M: .0	H: 27.0	M: .0	H: 20.0	.0943	.4623	.4434
*CO-L	(Eng. Equip. Oper.)	15.0	M: 26.0	H: 18.0	M: .0	H: 19.0	M: .0	H: 17.0	.1579	.2737	.5684
*CO-J	(Tractor Oper.)	10.0	M: 15.0	H: 63.0	M: .0	H: 5.0	M: .0	H: 9.0	.0980	.1471	.7549
*M-A	(Main. Mech)	10.0	M: 57.0	H: 34.0	M: .0	H: .0	M: .0	H: 1.0	.0980	.5588	.3431
*MV-F	(Main. Mech)	25.0	M: 49.0	H: 4.0	M: .0	H: 1.0	M: .0	H: 2.0	.3086	.6049	.0864
*C0-I	(Main. Mech)	25.0	M: 46.0	H: .0	M: .0	H: 1.0	M: .0	H: 6.0	.3205	.5897	.0897
*M-F	(Habitat Mgt. Specialist)	50.0	M: 47.0	H: .0	M: 8.0	H: .0	M: .0	H: .4	.4744	.5218	.0038
*MV-B	(Wild. Biol.)	60.0	M: 9.0	H: 24.0	M: .0	H: .0	M: .0	H: .0	.6452	.0968	.2581
*CO-F	(Wild. Biol.)	33.0	M: 39.0	H: 30.0	M: .0	H: 16.0	M: .0	H: 1.0	.2773	.3277	.3950
*M-N	(Wild. Biol. Asst.)	40.0	M: 40.0	H: .0	M: .0	H: 2.0	M: .0	H: .0	.4878	.4878	.0244
*MV-A	(Bio. Tech)	30.0	M: 42.0	H: 56.0	M: 1.0	H: 6.0	M: .4	H: .0	.2216	.3205	.4579
*CO-C	(Bio. Tech.)	20.0	M: 34.0	H: 6.0	M: .0	H: 24.0	M: .0	H: 2.0	.2326	.3953	.3721
*M-J	(Work Supr.)	20.0	M: 48.0	H: 4.0	M: .0	H: 0	M: .0	H: 12.0	.2381	.5714	.1905
*CO-K	(Main. Supr.)	25.0	M: 48.0	H: .0	M: .0	H: 1.0	M: .0	H: 2.0	.3289	.6316	.0395
*M-C	(Archaeologist)	50.0	M: 100.0	H: .0	M: 2.0	H: 8.0	M: .0	H: 5.0	.3030	.6182	.0788
*M-K	(Asst. Arch.)	50.0	M: 35.0	H: 19.0	M: .0	H: .0	M: .0	H: .0	.4808	.3365	.1827
M-D	(Ref. Mgr.)	90.0	M: 8.0	H: .0	M: .2	H: 0	M: .8	H: .0	.9091	.0909	.0000
MV-E	(Ref. Mgr.)	90.0	M: 14.0	H: .0	M: .0	H: .2	M: .0	H: .0	.8637	.1344	.0019
CO-G	(Ref. Mgr.)	60.0	M: 44.0	H: 10.0	M: .3	H: 1.0	M: 7.0	H: .0	.4906	.4195	.0899
M-G	(Asst. Ref. Mgr.)	70.0	M: 29.0	H: .0	M: 2.0	H: .0	M: 6.0	H: .0	.6542	.3458	.0000
*CO-B	(Supr. Ref. Oper.)	40.0	M: 43.00	H: .0	M: 3	H: .6	M: 9.0	H: .0	.4306	.5630	.0065
MV-D	(Ref. Operations Spec.)	85.0	M: 15.0	H: .0	M: .0	H: .0	M: .0	H: .0	.8500	.1500	.0000
M-E	(Outdoor Rec. Planner)	50.0	M: 25.0	H: 0	M: .0	H: 7.0	M: .0	H: 10.0	.5435	.2717	.1848
MV-J	(Outdoor Rec. Planner)	80.0	M: 19.0	H: 0	M: .0	H: .0	M: .0	H: .0	.8081	.1919	.0000
CO-D	(Outdoor Rec. Planner)	90.0	M: 10.0	H: 0	M: .0	H: .0	M: .0	H: .0	.9000	.1000	.0000
*CO-E	(Forester)	50.0	M: 36.0	H: 0	M: .0	H: 3.0	M: .0	H: .0	.5618	.4045	.0337
CO-A	(Admin. Officer)	70.0	M: 5.0	H: 0	M: .0	H: .9	M: .0	H: .0	.9223	.0659	.0119
MV-G	(Ref. Guide)	80.0	M: 14.0	H: 0	M: .0	H: .0	M: .0	H: .0	.8511	.1489	.0000
MV-N	(Ref. Guide)	80.0	M: 46.0	H: 0	M: .0	H: .0	M: .0	H: .0	.6349	.3651	.0000
MV-I	(Ref. Guide)	80.0	M: 22.0	H: 0	M: .0	H: .0	M: .0	H: .0	.7843	.2157	.0000
CO-N	(Ref. Guide)	90.0	M: 6.0	H: 0	M: .0	H: .6	M: .0	H: .0	.9317	.0621	.0062
*M-I	(Fire Mgt. Officer)	50.0	M: 29.0	H: 0	M: .4	H: .0	M: 2.0	H: .0	.6143	.3857	.0000

M = Malheur, Oregon; MV = Minnesota Valley, Minnesota; CO = Crab Orchard, Illinois
* Denotes a refuge worker in the subpopulation of biological and maintenance workers.

ATTACHMENT B.2-1
SAMPLE SURVEY FORM

REFUGE WORKER EXPOSURE ASSESSMENT SURVEY QUESTIONNAIRE	
REFUGE:	DATE: TIME:

CURRENT USFWS JOB CATEGORY	USFWS PERSONNEL	INTERVIEWER AND AFFILIATION	OBSERVER AND AFFILIATION

#	QUESTION	RESPONSE
1 (a)	Length of service with USFWS (yrs/mos)	
1 (b)	Length of service at this refuge (yrs/mos)	
1 (c)	Describe employment with USFWS if not continuous (yrs/mos) for each tenure	
1 (d)	Starting age with USFWS (yrs)	
1 (e)	Current age (yrs)	
1 (f)	Gender (M or F)	

#	QUESTION	RESPONSE
2	Miles you live from refuge	
3	What titles/job descriptions held with the USFWS and length of service for each	
4	List job categories reporting to you. If representative of that job category is not available for interview, ask ? for each category of this manager.	
5	Indoors/outdoors ratio (%)	

#	QUESTION	RESPONSE
6 (a)	For each job category, list five main activities performed in terms of time allocation. Comment on seasonal effect	
6 (b)	For each job category, list five main activities performed that would involve exposure to soil 0-2" in terms of time allocation. Comment on Seasonal effect.	

#	QUESTION	RESPONSE
6 (c)	For each job category, list five main activities performed that would involve exposure to soil 0-12" in terms of time allocation. Comment on seasonal effect	
6 (b)	For each job category, list five main activities performed that would involve exposure to soil > 12" in terms of time allocation. Comment on Seasonal effect.	

#	QUESTION	RESPONSE
6 (e)	Requirement to camp outside, overnight on the refuge	
7	Time spent off refuge in the conduct of job	
8 (a)	Time spent inside a vehicle on the refuge	
8 (b)	Vehicle is open, closed, or Air conditioned?	
9 (a)	Years you expect to be employed at this refuge?	
9 (b)	Years you expect to be employed by USFWS? What positions could you expect to hold?	

#	QUESTION	RESPONSE
12	Volunteer or student (non-USFWS) activities over the last five years, including duration, frequency and soil depth.	
13	Volunteer or student (non-USFWS) activities over the next five years, including duration, frequency and soil depth.	

#	QUESTION	RESPONSE
10	Outside contractor (non-USFWS) activities over the last five years, including duration, frequency, and soil depth.	
11	Outside contractor (non-USFWS) activities over the next five years, including duration, frequency and soil depth.	

ATTACHMENT B.2-2
INDIVIDUAL ACTIVITY DURATION DATA

This attachment contains the survey data on the individual "outdoor" activities and the number of hours per year that a refuge worker spends doing these individual activities. Each of the 33 interviewed refuge workers were asked to identify their current job category as well as the titles/job descriptions held with USFWS. For each job category, the respondent was asked to list five main activities performed that would involve exposure to the 0- to 2-inch soil depth category in terms of time allocation. The same question was asked for the 0- to 12-inch soil depth and also for soils at depths of more than 12 inches. The number of hours per year spent in each of the activities identified in response to these three questions is given in this attachment for each individual refuge worker interviewed. The raw data are reported separately for each individual and each soil depth (0-2", 0-12", and > 12").

Within a soil depth category, the activities are partitioned into two groups. These two groups are labeled herein as "Middle Exposure Level Activities" and "Higher Exposure Level Activities." These labels are used for identification purposes herein and were not used during the interviews. These labels are intended to convey relative levels of exposure to soil and do not indicate whether the exposures are "high" or "low" in absolute terms or in terms of possible health effects. The middle exposure level activities are believed to correspond to activities with greater levels of exposure than indoor, administrative-type activities, which are referred to herein as simply "indoor" activities. Similarly, the "middle" activities are also expected to correspond to activities with lower levels of exposure than the higher exposure level activities. The middle exposure level activities correspond to activities with levels of exposure somewhere in between (but not necessarily halfway between) the lesser levels of exposure for indoor activities and the greater levels of exposure for the higher exposure level activities. The specific activities included in the "middle" and "higher" groups are explicitly identified in the tables of Appendix Section B.2. Primarily, the middle exposure level activities involve observing, monitoring, surveying, or driving. The higher exposure level activities involve actively disturbing the soil, e.g., soil sampling, trail maintenance, irrigation or pipeline maintenance, benthic samples, mowing, road grading, building dikes or firebreaks, disking, planting, or digging postholes.

If there are no entries in a table for a particular refuge worker, then that refuge worker did not report any hours as being spent on any such activity.

The data are reported herein exactly as they were given by the respondents without any external adjustments or modifications. Accordingly, the data contain uncertainty regarding the recall of the respondents, but not any assumptions about how the responses might have been normalized. For example, the sum of the number of hours reported as being spent in outdoor activities often exceeded the total number of hours reported as being spent outdoors. Although the refuge worker's response to the question regarding"Indoors/Outdoors ratio (%)" can be combined with his or her reported total "Hrs/Yr" spent on the refuge to give an estimate of the total number of hours spent outdoors, it was not assumed that this estimate was more accurate than the respondent's recall of time spent on individual activities.

Table B.2att2-1 Observed Number of Activity Hours for Refuge Workers at Crab Orchard, Illinois; Malheur, Oregon; and Minnesota Valley, Minnesota

Middle Exposure Level Activities

Soil Depth 0-2"

M-A (Maintenance Mech.) building equipment maintenance (383 hrs.)
M-A (Maintenance Mech.) driving (634 hrs.)
M-A (Maintenance Mech.) gravel (25 hrs.)
M-B (Eng. Equip. Oper.) driving (165 hrs.)
M-B (Eng. Equip. Oper.) fencing (70 hrs.)
M-B (Eng. Equip. Oper.) prescribed burning (80 hrs.)
M-B (Eng. Equip. Oper.) building maintenance (280 hrs.)
M-C (Archaeologist) survey/monitor sites (1290 hrs.)
M-C (Archaeologist) driving (480 hrs.)
M-D (Ref. Mgr.) driving (50 hrs.)
M-D (Ref. Mgr.) observe contractors (49 hrs.)
M-E (Outdoor Recreation Planner) driving (216 hrs.)
M-E (Outdoor Recreation Planner) hiking/tours (216 hrs.)
M-F (Habitat Mgmt. Specialist) assist biol/survey (45 hrs.)
M-F (Habitat Mgmt. Specialist) driving (178 hrs.)
M-F (Habitat Mgmt. Specialist) coop farming oversight (270 hrs.)
M-F (Habitat Mgmt. Specialist) horseback/ATV riding (357 hrs.)
M-G (Asst. Ref. Mgr.) driving (45 hrs.)
M-G (Asst. Ref. Mgr.) monitor road work, etc. (76 hrs.)
M-G (Asst. Ref. Mgr.) ATV/hiking (400 hrs.)
M-H (Wild. Biol.) environmental educ. tours (40 hrs.)
M-H (Wild. Biol.) wildlife and plant surveys (272 hrs.)
M-H (Wild. Biol.) driving (396 hrs.)
M-I (Ref. Fire Mgt. Officer) driving/incl. surveys (365 hrs.)
M-I (Ref. Fire Mgt. Officer) observe burning (120 hrs.)
M-I (Ref. Fire Mgt. Officer) wildlife surveys (36 hrs.)
M-J (Working Supr.) driving (854 hrs.)
M-K (Asst. Arch.) pedestrian surveys. monitoring, surveying for mapping (630 hrs.)
M-K (Asst. Arch.) field trips (40 hrs.)
MV-A (Bio. Tech.) driving (266 hrs.)
MV-A (Bio. Tech.) burning (70 hrs.)
MV-A (Bio. Tech.) refuge maintenance (350 hrs.)
MV-A (Bio. Tech.) spray (105 hrs.)
MV-A (Bio. Tech.) wetlands restoration (survey) (5 hrs.)
MV-B (Wild. Biol.) veg survey (64 hrs.)
MV-B (Wild. Biol.) prescribed burning (80 hrs.)
MV-C (Eng. Equip. Oper.) place rib-rap/dike enforcement (175 hrs.)

MV-C (Eng. Equip. Oper.) prescribed burning (110 hrs.)
MV-C (Eng. Equip. Oper.) repair equipment/vandalism/maintenance of property (329 hrs.)
MV-C (Eng. Equip. Oper.) driving (227 hrs.)
MV-C (Eng. Equip. Oper.) snow removal (42 hrs.)
MV-D (Ref. Oper. Spec.) monitor/evaluating activities (243 hrs.)
MV-D (Ref. Oper. Spec.) driving (39 hrs.)
MV-E (Ref. Mgr.) monitor/writing/evaluate activities (124 hrs.)
MV-E (Ref. Mgr.) driving (46 hrs.)
MV-E (Ref. Mgr.) monitoring prescribed burning (90 hrs.)
MV-F (Main. Mech.) driving (216 hrs.)
MV-F (Main. Mech.) spraying (13 hrs.)
MV-F (Main. Mech.) equipment maintenance (264 hrs.)
MV-F (Main. Mech.) painting (65 hrs.)
MV-F (Main. Mech.) snow plows (390 hrs.)
MV-G (Ref. Guide) assist in interpretive program (30 hrs.)
MV-G (Ref. Guide) bird banding (248 hrs.)
MV-H (Ref. Guide) interpretive program (864 hrs.)
MV-H (Ref. Guide) bird banding (16 hrs.)
MV-I (Ref. Guide) train volunteers/project (120 hrs.)
MV-I (Ref. Guide) litter cleanups (15 hrs.)
MV-I (Ref. Guide) driving (27 hrs.)
MV-I (Ref. Guide) environmental games for interpretive programs (120 hrs.)
MV-I (Ref. Guide) tours (120 hrs.)
MV-J (Outdoor Rec. Planner) driving (127 hrs.)
MV-J (Outdoor Rec. Planner) giving tours (50 hrs.)
MV-J (Outdoor Rec. Planner) prescribed burning (105 hrs.)
MV-J (Outdoor Rec. Planner) inspection/planning (45 hrs.)
CO-A (Admin. Officer) driving (50 hrs.)
CO-A (Admin. Officer) prescribed burning (40 hrs.)
CO-A (Admin. Officer) property checks (130 hrs.)
CO-B (Ref.Operations Spec.) driving (102 hrs.)
CO-B (Ref. Operations Spec.) prescribed burns (25 hrs.)
CO-B (Ref. Operations Spec.) habitat survey (203 hrs.)
CO-B (Ref. Operations Spec.) monitoring field work, property checks, walking (406 hrs.)
CO-C (Biol. Tech) crop checks/observe harvest/yield calculations/driving (639 hrs.)
CO-D (Outdoor Rec. Planner) interpretive walks/photography (100 hrs.)
CO-D (Outdoor Rec. Planner) monitor volunteers/interns/YCC (80 hrs.)
CO-E (FOR) prescribed burning (100 hrs.)
CO-E (FOR) marking timber/forest inventories (160 hrs.)
CO-E (FOR) interpretive walks (12 hrs.)
CO-E (FOR) driving (347 hrs.)
CO-F (Wild. Biol.) survey and census, mostly waterfowl (480 hrs.)
CO-F (Wild. Biol.) driving (243 hrs.)
CO-G (Ref. Mgr.) driving (207 hrs.)

CO-G (Ref. Mgr.) prescribed burns (40 hrs.)
CO-G (Ref. Mgr.) walking/property review (212 hrs.)
CO-G (Ref. Mgr.) walking/monitoring/observing (265 hrs.)
CO-H (Ref. Guide) driving including tours (96 hrs.)
CO-H (Ref. Guide) trail tours (10 hrs.)
CO-I (Main. Mech.) inspect dams/piezometer (120 hrs.)
CO-I (Main. Mech.) sewer treatment plant maintenance (384 hrs.)
CO-I (Main. Mech.) carpentry/painting/repairs (352 hrs.)
CO-J (Tractor Oper.) driving (85 hrs.)
CO-J (Tractor Oper.) indoor maintenance (179 hrs.)
CO-K (Main. Supr.) driving (575 hrs.)
CO-K (Main. Supr.) walking water lines (28 hrs.)
CO-K (Main. Supr.) mowing, brush cutting (140 hrs.)
CO-K (Main. Supr.) prescribed burning (20 hrs.)
CO-K (Main. Supr.) snow plowing (10 hrs.)
CO-L (Eng. Equip. Oper.) driving (192 hrs.)
CO-L (Eng. Equip. Oper.) indoor carpentry/main. (272 hrs.)
CO-L (Eng. Equip. Oper.) snow plowing (14 hrs.)

Table B.2att2-2 Observed Number of Activity Hours for Refuge Workers at Crab Orchard, Illinois; Malheur, Oregon; and Minnesota Valley, Minnesota

Higher Exposure Level Activities

Soil Depth: 0-2"

M-A (Maintenance Mech.) irrigation (634 hrs.)
M-B (Eng. Equip. Oper.) irrigation (240 hrs.)
M-B (Eng. Equip. Oper.) mowing (35 hrs.)
M-C (Archaeologist)
M-D (Ref. Mgr.)
M-E (Outdoor Recreation Planner)
M-F (Habitat Mgt. Specialist)
M-G (Asst. Ref. Mgr.)
M-H (Wild. Biol.)
M-I (Ref. Fire Mgt. Officer)
M-J (Work Supr.) surface grading (72 hrs.)
M-K (Asst. Arch.) collecting surface artifacts (360 hrs.)
MV-A (Bio. Tech.) benthic samples (96 hrs.)
MV-A (Bio. Tech.) wildlife surveys (species/habitats) (1,050 hrs.)
MV-B (Wild. Bio.) wildlife surveys (species/habitats) (300 hrs.)
MV-B (Wild. Bio.) benthic samples (96 hrs.)
MV-C (Eng. Equip. Oper.)
MV-D (Ref. Operations Spec.)
MV-E (Ref. Mgr.)
MV-F (Main. Mech.) trail maintenance (72 hrs.)
MV-F (Main. Mech.) mowing (1,368 hrs.)
MV-G (Ref. Guide)
MV-H (Ref. Guide)
MV-I (Ref. Guide)
MV-J (Outdoor Rec. Planner)
CO-A (Admin. Officer)
CO-B (Ref. Operations Spec.)
CO-C (Biol. Tech.) mowing (113 hrs.)
CO-D (Outdoor Recreation Planner)
CO-E (FOR.)
CO-F (Wild. Biol.) seeding (80 hrs.)
CO-F (Wild. Biol.) wetlands mgt. (240 hrs.)
CO-F (Wild. Biol.) observe coop farming (224 hrs.)
CO-G (Ref. Mgr.) surficial soil sampling (164 hrs.)
CO-H (Ref. Guide)
CO-I (Main. Mech.)
CO-J (Tractor Oper.) area cleanup (45 hrs.)

CO-J (Tractor Oper.) mowing (1,050 hrs.)
CO-J (Tractor Oper.) corn cutting (28 hrs.)
CO-K (Main. Supr.)
CO-L (Eng. Equip. Oper.) blading roads (255 hrs.)
CO-L (Eng. Equip. Oper.) mowing (70 hrs.)

Table B.2att2-3 Observed Number of Activity Hours for Refuge Workers at Crab Orchard, Illinois; Malheur, Oregon; and Minnesota Valley, Minnesota

Middle Exposure Level Activities

Soil Depth: 0-12"

M-A (Maintenance Mech.)
M-B (Eng. Equip. Oper.)
M-C (Archaeologist) observe earth moving (40 hrs.)
M-D (Ref. Mgr.) observing archaeological digs (3 hrs.)
M-E (Outdoor Recreation Planner)
M-F (Habitat Mgt. Specialist) wildlife & habitat survey (143 hrs.)
M-G (Asst. Ref. Mgr.) dike maintenance monitoring (40 hrs.)
M-H (Wild. Biol.)
M-I (Ref. Fire Mgt. Officer) monitor firebreaks (8 hrs.)
M-J (Work Supr.)
M-K (Asst. Arch.)
MV-A (Bio. Tech.) predator survey (24 hrs.)
MV-B (Wild. Biol.)
MV-C (Eng. Equip. Oper.)
MV-D (Ref. Operations Spec.)
MV-E (Ref. Mgr.)
MV-F (Main. Mech.)
MV-G (Ref. Guide)
MV-H (Ref. Guide)
MV-I (Ref. Guide)
MV-J (Outdoor Rec. Planner)
CO-A (Admin. Officer)
CO-B (Ref. Operations Spec.) monitoring plowed fields (5)
CO-C (Biol. Tech.)
CO-D (Outdoor Recreation Planner)
CO-E (FOR.)
CO-F (Wild. Biol.)
CO-G (Ref. Mgr.) walking over farmed area (5)
CO-H (Ref. Guide)
CO-I (Main. Mech.)
CO-J (Tractor Oper.)
CO-K (Main. Supr.)
CO-L (Eng. Equip. Oper.)

Table B.2att2-4 Observed Number of Activity Hours for Refuge Workers at Crab Orchard, Illinois; Malheur, Oregon; and Minnesota Valley, Minnesota

Higher Exposure Level Activities

Soil Depth: 0-12"

M-A (Maintenance Mech.)
M-B (Eng. Equip. Oper.) blade roads (140 hrs.)
M-B (Eng. Equip. Oper.) excavate gravel (160 hrs.)
M-C (Archaeologist) recover artifacts (150 hrs.)
M-D (Ref. Mgr.)
M-E (Outdoor Recreation Planner) tree planting (120 hrs.)
M-F (Habitat Mgt. Specialist)
M-G (Asst. Ref. Mgr.)
M-H (Wild. Biol.) soil samples in burn areas
M-I (Ref. Fire Mgt. Officer)
M-J (Work Supr.)
M-K (Asst. Arch.)
MV-A (Bio. Tech.) firebreaks (8 hrs.)
MV-A (Bio. Tech.) beaver dam/muskrat dams clearing (104 hrs.)
MV-B (Wild. Biol.)
MV-C (Eng. Equip. Oper.) firebreaks (70 hrs.)
MV-C (Eng. Equip. Oper.) grading roads (168 hrs.)
MV-C (Eng. Equip. Oper.) clean up buildings
MV-D (Ref. Operations Spec.)
MV-E (Ref. Mgr.) firebreaks (4 hrs.)
MV-F (Main. Mech.) disking (20 hrs.)
MV-G (Ref. Guide)
MV-H (Ref. Guide)
MV-I (Ref. Guide)
MV-J (Outdoor Rec. Planner)
CO-A (Admin. Officer)firebreaks (15 hrs.)
CO-B (Ref. Operations Spec.) firebreaks (10 hrs.)
CO-C (Biol. Tech.) disking/wetlands restoration (451 hrs.)
CO-D (Outdoor Recreation Planner)
CO-E (FOR.) tree planting (60 hrs.)
CO-F (Wild. Biol.) beaver dam/muskrat dam cleaning (135 hrs.)
CO-F (Wild. Biol.) refuge farming (96 hrs.)
CO-F (Wild. Biol.) tree planting (64 hrs.)
CO-G (Ref. Mgr.) firebreaks (20 hrs.)
CO-H (Ref. Guide) post holes (12 hrs.)
CO-I (Main. Mech.) installing concrete pad (8 hrs.)
CO-J (Tractor Oper.) water line maintenance (85 hrs.)

CO-K (Main. Supr.) disking (20 hrs.)
CO-L (Eng. Equip. Oper.) ditching (140 hrs.)
CO-L (Eng. Equip. Oper.) wetlands mgt. (210 hrs.)

Table B.2att2-5 Observed Number of Activity Hours for Refuge Workers at Crab Orchard, Illinois; Malheur, Oregon; and Minnesota Valley, Minnesota.

Middle Exposure Level Activities

Soil Depth: >12"

M-A (Maintenance Mech.)
M-B (Eng. Equip. Oper.)
M-C (Archaeologist)
M-D (Ref. Mgr.) observe gravel pit operations (monitor controls) (10 hrs.)
M-E (Outdoor Recreation Planner)
M-F (Habitat Mgt. Specialist)
M-G (Asst. Ref. Mgr.) monitor construction (104 hrs.)
M-H (Wild. Biol.)
M-I (Ref. Fire Mgt. Officer) monitor burns and firebreaks (28 hrs.)
M-J (Work Supr.)
M-K (Asst. Arch.)
MV-A (Bio. Tech.) surveys wetlands during restoration (7 hrs.)
MV-B (Wild. Biol.)
MV-C (Eng. Equip. Oper.)
MV-D (Ref. Operations Spec.)
MV-E (Ref. Mgr.)
MV-F (Main. Mech.)
MV-G (Ref. Guide)
MV-H (Ref. Guide)
MV-I (Ref. Guide)
MV-J (Outdoor Rec. Planner)
CO-A (Admin. Officer)
CO-B (Ref. Operations Spec.) monitor trenching/water line repair (152 hrs.)
CO-C (Biol. Tech.)
CO-D (Outdoor Recreation Planner)
CO-E (FOR.)
CO-F (Wild. Biol.)
CO-G (Ref. Mgr.) oversight of water line maintenance/fill operations/trenching (119 hrs.)
CO-H (Ref. Guide)
CO-I (Main. Mech.)
CO-J (Tractor Oper.)
CO-K (Main. Supr.)
CO-L (Eng. Equip. Oper.)

Table B.2att2-6 Observed Number of Activity Hours for Refuge Workers at Crab Orchard, Illinois; Malheur, Oregon; and Minnesota Valley, Minnesota

Higher Exposure Level Activities

Soil Depth > 12"

M-A (Maintenance Mech.) post holes (16 hrs.)
M-B (Eng. Equip. Oper.) waterline Maintenance (80 hrs.)
M-B (Eng. Equip. Oper.) dig irrigation ditches/repair dikes (60 hrs.)
M-B (Eng. Equip. Oper.) dig duck ponds/dikes (240 hrs.)
M-B (Eng. Equip. Oper.) dig road from quarry (160 hrs.)
M-C (Archaeologist) soil profile cleaning (80 hrs.)
M-D (Ref. Mgr.)
M-E (Outdoor Recreation Planner) sign posts (180 hrs.)
M-F (Habitat Mgt. Specialist) tree planting (8 hrs.)
M-G (Asst. Ref. Mgr.)
M-H (Wild. Biol.)
M-I (Ref. Fire Mgt. Officer)
M-J (Work Supr.) trenching/fence posts/ditching/impoundment construction/dirt moving/grading (214 hrs.)
M-K (Asst. Arch.)
MV-A (Bio. Tech.)
MV-B (Wild. Biol.)
MV-C (Eng. Equip. Oper.) build/repair dike/water control structures/trails (288 hrs.)
MV-C (Eng. Equip. Oper.) excavate impoundments (70 hrs.)
MV-D (Ref. Operations Spec.)
MV-E (Ref. Mgr.)
MV-F (Main. Mech.) postholes (4 hrs.)
MV-F (Main. Mech.) grading/dike repair (33 hrs.)
MV-G (Ref. Guide)
MV-H (Ref. Guide)
MV-I (Ref. Guide)
MV-J (Outdoor Rec. Planner)
CO-A (Admin. Officer)
CO-B (Ref. Operations Spec.)
CO-C (Biol. Tech.) wetlands restoration (45 hrs.)
CO-D (Outdoor Recreation Planner)
CO-E (FOR.)
CO-F (Wild. Biol.) fence posts (21 hrs.)
CO-G (Ref. Mgr.)
CO-H (Ref. Guide)
CO-I (Main. Mech.) sign posts (31 hrs.)
CO-I (Main. Mech.) control waterline breakdown (80 hrs.)

CO-J (Tractor Oper.) repair waterline breaks (152 hrs.)
CO-K (Main. Supr.) repair waterline breaks (30 hrs.)
CO-L (Eng. Equip. Oper.) ditches for roads (35 hrs.)
CO-L (Eng. Equip. Oper.) repair waterline breaks (105 hrs.)
CO-L (Eng. Equip. Oper.) trenching/pond installation (105 hrs.)
CO-L (Eng. Equip. Oper.) install/replace sewer lines (70 hrs.)