

8.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

The remedial alternatives were evaluated with respect to nine threshold, primary balancing, and modifying criteria as required by the NCP. The criteria are as follows:

Threshold Criteria

- Overall protection of human health and the environment
- Compliance with ARARs

Primary Balancing Criteria

- Long-term effectiveness and permanence
- Reduction of toxicity, mobility, or volume
- Short-term effectiveness
- Implementability
- Cost

Modifying Criteria

- State acceptance
- Community acceptance

Threshold criteria must be satisfied by the selected alternative. Primary balancing criteria are used to weigh trade-offs among alternatives. Modifying criteria may be used to alter a proposed remedial alternative. Brief descriptions of the evaluation criteria and the items considered when assessing alternatives with respect to each criterion are presented in the *summary of the comparative analysis of alternatives*.

The models simulating UFS groundwater flow and dissolved chemical transport were prepared for the analysis of alternatives and are approximate in nature. Because detailed models were not needed to compare the benefits of each remedial alternative, attempts were made to produce models that incorporate general features of groundwater flow and associated transport phenomena in the Offpost

Study Area. Nonetheless, the resulting models predicted flow and chemical transport phenomena that agree with historical and current hydrogeologic data and observed contaminant distributions. Because of the approximate nature of the models and the considerable uncertainty in the conceptual model and hydrogeologic parameters, none of the modeling results should be construed as accurate predictions of future contaminant distribution. Rather, the models and modeling results should be viewed as tools for assessing the relative merits of remedial alternatives. Although there are inherent uncertainties in the groundwater model, it is the tool being used to evaluate the alternatives, and predicted differences in remediation time frames are considered with respect to evaluating alternative effectiveness.

For the North Model, the following remedial action scenarios were simulated: (1) continued operation of the NBCS with improvements as necessary (Alternative N-2), (2) Offpost Groundwater Intercept and Treatment System (Alternative N-4), and (3) expansion of the Offpost Groundwater Intercept and Treatment System (Alternative N-5). The results of these simulations were evaluated on the basis of estimated remediation times measured on maximum concentrations versus time graphs. The range of estimated remediation times was based on attainment of the groundwater cleanup standards for DIMP, chloroform, and dieldrin, using a range of retardation factors. Although some remediation goals have changed since modelling was performed, these changes do not affect the assessment of the relative merits of the remedial alternatives.

For the Northwest Model, the remedial action scenario for continued operation of the NWBCS with improvements as necessary (Alternative NW-2) was simulated.

8.1 Comparative Analysis of Remedial Alternatives

The purpose of the comparative analysis is to identify the advantages and disadvantages of each alternative relative to the others. Critical tradeoffs were identified and used to assist in selection of the preferred remedy. Summaries of the detailed analysis of the North Plume Group and Northwest Plume Group alternatives are presented in Tables 8.1 and 8.2, respectively. A brief description of the

evaluation criteria and a comparison of each alternative with respect to the evaluation criteria is presented below. Components common to all of the alternatives were not evaluated in the comparative analysis.

8.1.1 Overall Protection of Human Health and the Environment

The criterion of overall protection of human health and the environment serves as a final check in assessing whether each alternative provides adequate protection of human health and the environment. This criterion was also used to evaluate how risks would be eliminated, reduced, or controlled through treatment, engineering, institutional controls, or other remedial activities.

North Plume Group Alternatives

Overall protection of human health and the environment would be provided by all alternatives with the exception of Alternative N-1. Alternatives N-4 and N-5 would provide greater protection than Alternative N-2 because extraction, treatment, and recharge systems within the North Plume Group would decrease organic contaminant concentrations and reduce potential risks within a shorter time period. Although groundwater modeling estimates that Alternative N-5 would achieve containment system remediation goals in a shorter time period than Alternative N-4 (10-20 years for Alternatives N-5 versus 15-30 years for Alternative N-4), the two alternatives are essentially equivalent with respect to providing protection of human health and the environment for the following reasons:

- Alternatives N-4 and N-5 both provide for active remediation of the First Creek and Northern paleochannel groundwater in approximately the same time period through removal of contaminated UFS groundwater, treatment of the organics in the contaminated groundwater using carbon absorption, and recharge of the treated groundwater using recharge wells and trenches.

Both alternatives also provide a significant reduction in potential risk in approximately the same time period through organic contaminant removal and treatment by the Offpost Groundwater Intercept and Treatment System.

Northwest Plume Group Alternatives

Alternative NW-1 would not be protective of human health and the environment because the NWBCS would cease operation. Overall protection of human health and the environment would be provided

by Alternative NW-2. Alternative NW-2 would decrease contaminant concentrations and reduce potential risks associated with groundwater entering the Offpost Study Area north of the NWBCS. Recharge of groundwater treated at the NWBCS would reduce contaminant concentrations in the Northwest Plume Group through flushing with treated groundwater. Groundwater modeling estimates that Alternative NW-2 would achieve groundwater containment system remediation goals in approximately three to eight years. Alternative NW-1 would not likely achieve groundwater containment system remediation goals because operation of the NWBCS would cease.

8.1.2 Compliance With Applicable or Relevant and Appropriate Requirements

The criterion of compliance with ARARs is used to assess whether each alternative will attain ARARs. The comparative analysis describes how each alternative exceeds, attains, or does not attain these requirements. Other information such as advisories, criteria, or guidance documents have been considered where appropriate during the ARARs analysis (see Section 10.0).

North Plume Group Alternatives

Compliance with chemical-specific ARARs would be achieved by all alternatives with the exception of Alternative N-1. Cleanup standards for Offpost OU groundwater include Safe Drinking Water Act MCLs and CBSGs. Groundwater modeling estimates that chemical-specific ARARs would be achieved in the shortest time by Alternative N-5, followed by Alternative N-4, followed by Alternative N-2.

Compliance with location-specific and action-specific ARARs will be achieved by all treatment alternatives. Because no remediation would take place under Alternative N-1, there would be no federal and state location- or action-specific ARARs. Inorganic standards for chloride and sulfate will be met by natural attenuation consistent with the onpost remedial action.

Northwest Plume Group Alternatives

Compliance with chemical-specific ARARs would be achieved only by Alternative NW-2. Groundwater modeling indicates that Alternative NW-2 would achieve chemical-specific ARARs in approxi-

mately three to eight years. Alternative NW-2 would comply with location- and action-specific ARARs.

8.1.3 Long-term Effectiveness and Permanence

The long-term effectiveness and permanence criterion addresses the risk remaining at the site after response objectives have been met. Components of the criterion that were addressed for each alternative are as follows:

- Magnitude of residual risk at the end of remedial activities
- Adequacy and reliability of controls that are used to manage either treatment residuals or untreated materials that remain at the site

North Plume Group Alternatives

Comparison of North Plume Group alternatives with respect to long-term effectiveness and permanence indicates that each alternative, except Alternative N-1, provides a high degree of effectiveness and permanence. However, Alternative N-4 is superior to Alternative N-5 because using full-scale operating data as the basis for identifying the need for placing additional wells and trenches and identifying the optimum locations will enhance long-term system performance. All of the alternatives with the exception of the No Action alternative would reduce potential risk and address exposure pathways by reducing COC concentrations in the North Plume Group. Under the No Action alternative, potential risks would likely increase after ceasing operation of the NBCS.

Northwest Plume Group Alternatives

Comparison of the Northwest Plume Group alternatives with respect to long-term effectiveness and permanence indicates that Alternative NW-2 reduces potential risk and addresses exposure pathways by reducing COC concentrations in the Northwest Plume Group. Under the No Action alternative, potential risks would likely increase after ceasing operation of the NWBCS.

8.1.4 Reduction in Toxicity, Mobility, or Volume

The reduction of toxicity, mobility, or volume criterion addresses the statutory preference for selecting remedial actions that permanently and significantly reduce toxicity, mobility, or volume of hazardous materials at the site. This preference is satisfied when treatment is used to reduce principal risks through destruction or irreversible reductions of toxicity, mobility, and/or volume.

North Plume Group Alternatives

All North Plume Group alternatives with the exception of the No Action alternative would reduce the toxicity, mobility, and volume of contaminated groundwater entering the Offpost OU north of the NBCS. Groundwater contaminant concentrations under the No Action alternative would likely increase. Alternatives N-4 and N-5 would provide the greatest reduction in toxicity, mobility, and volume of contaminated groundwater, through extraction, treatment, and recharge within the North Plume Group. As stated previously, the uncertainty associated with the remediation time frames estimated by the groundwater modeling suggests that, in practical terms, the estimated time frames for both Alternatives N-4 and N-5 are essentially equivalent. Further, the intensive short-term groundwater monitoring component of Alternative N-4 would allow for full-scale performance data regarding the reduction of contaminant concentrations. Such data would be necessary to assess the need for and optimum location of any modifications to Alternative N-4.

Northwest Plume Group Alternatives

Alternative NW-2 would reduce the toxicity, mobility, and volume of contaminated groundwater entering the Offpost OU northwest of the NWBCS through extraction, treatment, and recharge. Groundwater contaminant concentrations under the No Action alternative would likely increase; thus toxicity, mobility, or volume would not be reduced.

8.1.5 Short-term Effectiveness

The short-term effectiveness criterion addresses the protection of human health and the environment during the construction and implementation phase. The following factors were addressed during the evaluation process:

- Protection of the community during remedial actions - This factor addresses any risk that results from implementation of the proposed remedial alternative, such as dust from excavation or transportation of hazardous material.

Protection of the workers during remedial actions - This factor assesses threats that may be posed to workers and the effectiveness and reliability of measures to be taken.

Environmental impacts of the remedial action - This factor addresses the potential adverse environmental impacts that may result from construction and implementation of a remedial alternative and evaluates the reliability of mitigation measures, if necessary, to prevent or reduce potential impacts.

- Time lapse before achievement of response objectives - This factor includes an estimate of the time required to achieve protection for the site.

North Plume Group Alternatives

Assessment of the North Plume Group alternatives with respect to protection of the community and workers, short-term adverse environmental impacts, and implementation period indicates that the No Action alternative and Alternative N-2 are slightly better than the alternatives with active remediation components. However, during the implementation period, Alternatives N-4 and N-5 would be able to minimize adverse short-term impacts through standard engineering controls and adherence to standard health and safety practices.

Northwest Plume Group Alternatives

The assessment of the two Northwest Plume Group alternatives with respect to protection of the community and workers, short-term adverse environmental impacts, and implementation period shows that the No Action alternative and Alternative NW-2 are essentially equivalent except that the discontinued operation of the NWBCS, as part of the No Action alternative, has an adverse environmental impact. Neither alternative, with the exception noted above, has significant short-term effectiveness issues.

8.1.6 Implementability

The implementability criterion evaluates the technical and administrative feasibility of implementing each alternative, and it addresses the availability of required services and materials during

Comparative Analysis of Alternatives

implementation of the alternative. The following factors were addressed during the evaluation process:

- Construction and operation - This factor considers the technical difficulties and the unknowns associated with the technology.
- Reliability of the technology - This factor considers the likelihood that problems associated with implementation may result in schedule delays.
- Implementing additional remedial action - This factor is not applicable to the alternatives developed because the alternatives considered are not interim measures.
- Monitoring the effectiveness of the remedy - This factor addresses the ability to evaluate the effectiveness of the remedy and includes an evaluation of the risks of exposure should monitoring be insufficient to detect a system failure.
- Coordination with other offices and agencies needed to implement remedial alternatives (e.g., obtaining necessary permits for offsite activities)
- Availability of necessary equipment, specialists, services and materials, and adequate offsite treatment, storage, and disposal services

North Plume Group Alternatives

All North Plume Group alternatives evaluated would be technically feasible to implement. The No Action alternative and Alternative N-2 would be the easiest to implement with respect to technical feasibility because the monitoring wells have already been installed and the NBCS system is currently operational. Alternative N-4 is constructed and is fully operational. However, Alternative N-5 would require additional design and construction. All treatment alternatives would use carbon adsorption treatment, which has been demonstrated at the boundary containment systems to be a reliable groundwater treatment process option. Groundwater monitoring is a component of all four alternatives and would provide information regarding the effectiveness of each alternative.

All alternatives with the exception of the No Action alternative would be administratively feasible. It is unlikely that the regulatory agencies or the public would accept shutdown of the NBCS as proposed under the No Action alternative. Additionally, the Army will not cease operating the NBCS until cleanup certification. Each of the three treatment alternatives would meet federal and state substantive requirements for recharging the treated groundwater to the UFS.

The No Action alternative and Alternative N-2 would not require additional equipment and services. The implementation of Alternative N-5 would not be limited with respect to availability of services and materials. Contractors with the equipment and knowledge to construct and implement this alternative are readily available. The remedial systems of Alternative N-4 were completed in June 1993.

Northwest Plume Group Alternatives

Both Northwest Plume Group alternatives evaluated would be technically feasible to implement. The No Action alternative and Alternative NW-2 would be implementable with respect to technical feasibility because the monitoring wells have already been installed and the NWBCS is currently operational. Alternative NW-2 would use carbon adsorption treatment, which has been demonstrated at the boundary containment systems to be a reliable groundwater treatment process option. Groundwater monitoring is a component of both alternatives and would provide information regarding the effectiveness of each alternative.

The No Action alternative would not be administratively feasible. It is unlikely that the regulatory agencies or the public would accept shutdown of the NWBCS as proposed under the No Action alternative. Additionally, the Army does not intend to cease operating the NWBCS.

Alternative NW-2 would meet federal and state substantive requirements for recharging the treated groundwater to the UFS. Neither alternative would require additional equipment and services.

8.1.7 Cost

The cost criterion evaluates both capital costs and any long-term costs required to operate and maintain an alternative. Cost estimates for each alternative were based on vendor information, cost estimating guides, review of published cost data at previous sites, and operation and maintenance costs at the boundary containment systems.

North Plume Group Alternatives

The total present worth costs range from \$4.1 to \$6.0 million for Alternative N-1 to \$56.5 to \$63.1 million for Alternative N-4. The present worth costs are nearly identical for Alternatives N-4 and N-5 because the additional capital expenditures required for Alternative N-5 are balanced by the additional operation and maintenance (O&M) costs incurred through the estimated 10-year differences in remediation timeframe for Alternative N-4.

The additional capital expenditure of approximately \$2.7 million for Alternative N-5 as compared to Alternative N-4 points out the importance of collecting additional full-scale operating data to aid in decision-making regarding any necessary expansion of the Offpost Groundwater Intercept and Treatment System. Collection of full-scale data on contaminant transport and actual plume remediation time frames through the intensive short-term monitoring program is currently being conducted. This monitoring program will provide data for use in any system expansion decision-making regarding the potential need for and placement of improvements to Alternative N-4 to reduce the remediation timeframe and/or efficiency.

Northwest Plume Group Alternatives

The total present worth costs range from \$0.6 to \$1.3 million for Alternative NW-1 to \$12.4 to \$13.1 million for Alternative NW-2.

8.1.8 State Acceptance

State acceptance evaluates technical and administrative concerns the State may communicate in its comments concerning each alternative. The State has been actively involved throughout the RI/FS and remedy selection process for the Offpost OU. The State was provided the opportunity to comment on the RI/FS document and proposed plan, and took part in the public meeting held to inform the public on the proposed plan. Written comments from the state received during the public comment period indicate that the State prefers Alternative N-5 or a slightly modified version of Alternative N-5 over Alternative N-4 because of the addition of several wells and trenches for

enhanced contaminant removal. Responses to the State's concerns on this and other issues are provided in Appendix A - Responsiveness Summary.

Additional discussions were held between the U.S. Army, Shell Oil Company, the State of Colorado, the U.S. EPA, and the U.S. Fish and Wildlife Service following the issuance of the Offpost proposed plan regarding the remedy for both the Offpost and Onpost OUs. As a result of these discussions, the State of Colorado and the other parties have agreed to the remedy as described in *Agreement for a Conceptual Remedy for the Cleanup of the Rocky Mountain Arsenal (Conceptual Remedy Agreement)*. Each party has agreed to support the conceptual remedy as the preferred remedial alternative and to support the proposed plan based on the elements of the conceptual remedy.

8.1.9 Community Acceptance

The preferred alternative for the Offpost OU was presented to the public in a Proposed Plan, which provides a brief summary of all of the alternatives evaluated during the detailed analysis of alternatives in the FS. In accordance with the NCP, the public had an opportunity to review and comment on the selected remedial alternatives presented in the Proposed Plan. The concerns expressed included (1) soil remediation issues, (2) DIMP groundwater cleanup standard, (3) why expansion of the Offpost Groundwater Intercept and Treatment System was not selected, (4) the presence of DIMP immediately downgradient of the Offpost Groundwater Intercept and Treatment System in the First Creek area, and (5) the classification of potential future land use. The public's comments are addressed in the attached responsiveness summary (Appendix A). Community participation was also included during the Conceptual Remedy Agreement negotiations.

8.2 Conclusions of the Comparative Analysis of Alternatives

The conclusions of the comparative analysis of groundwater alternatives for the North and Northwest Plume Groups are summarized below.

Comparative Analysis of Alternatives

In terms of overall protection of human health and the environment, compliance with ARARs, effectiveness, and reduction of toxicity, mobility, or volume, Alternatives N-4 and N-5 are superior to Alternatives N-1 and N-2. Alternative N-4 is equal to Alternative N-2 in implementability. Alternative N-4 is more readily implementable than Alternatives N-1 and N-5 because Alternative N-1 would not be administratively feasible, and Alternative N-5 would require a second design and construction phase. Alternatives N-4 and N-5 are approximately equal in cost when compared to each other and higher in cost when compared to Alternatives N-1 and N-2. Therefore, Alternatives N-4 and N-5 were identified as being superior to Alternatives N-1 and N-2. Alternatives N-4 and N-5 are essentially equivalent with respect to evaluation of compliance with ARARs, short-term effectiveness, and reduction in toxicity, mobility, or volume.

Alternative N-4 was demonstrated to be superior to Alternative N-5 with respect to the detailed analysis criteria for the following reasons:

- The remedial system in Alternative N-4 is designed to effectively address groundwater contamination within the North Plume Group on the basis of all available data. The Offpost Groundwater Intercept and Treatment System is designed similar to the existing boundary containment systems in that monitoring data is being evaluated to assess whether any improvements are necessary. The intensive short-term groundwater monitoring program included under Alternative N-4 adds flexibility through providing information that will be used to identify any necessary or beneficial improvements to the Offpost Groundwater Intercept and Treatment System and provides information about the optimal location of additional wells or trenches. Because the estimates of remediation time frames developed for the groundwater alternatives are uncertain, additional capital expenditures are not justified until actual full-scale data is available.
- Alternative N-4 is superior to Alternative N-5 with respect to long-term effectiveness and permanence. The combination of full-scale operational data from the Offpost Groundwater Intercept and Treatment System and future possible system modifications will result in an optimized treatment system. Immediate placement of additional wells and trenches in Alternative N-5, based on groundwater modeling results, would not be based on the more accurate empirical data.
- Alternative N-4 is more readily implementable than Alternative N-5 because implementation of Alternative N-5 would require additional remedial design and construction. Operation of Alternative N-4 would start immediately.

Alternative NW-2 ranks above Alternative NW-1 in all criteria except cost; however, the additional costs are not prohibitive in light of the reduction in time for remediation.