8.0 Comparative Analysis of Alternatives

The purpose of the comparative analysis is to identify the advantages and disadvantages of each alternative relative to the others and to identify the tradeoffs to be made in selecting the preferred alternatives. A preferred alternative was developed for each contaminated medium (groundwater, structures and soil) because the interactions among potential soil alternatives and water or structures alternatives were most effectively addressed in this manner.

The NCP identifies nine criteria to be used in the evaluation of remedial alternatives during the Detailed Analysis of Alternatives (Figure 8.0-1). Criteria 1 and 2 (Overall Protection of Human Health and the Environment, and Compliance with ARARs) are considered "threshold criteria" that must be met by the preferred alternative. Criteria 3 through 7 (Short-Term Effectiveness; Long-Term Effectiveness; Reduction of Toxicity, Mobility, or Volume through Treatment; Implementability; and Cost) are considered "balancing criteria" because they are used to achieve the best overall solution, taking into account technical, cost, institutional, and risk concerns. As required by EPA guidance, costs are compared on a present worth basis. The present worth cost is the amount of principal (in current dollars) needed to yield the total cost over the desired time frame; it accounts for interest gained on principal invested at the start of the project and the cost of inflation over the life of the project. Criteria 8 and 9 (State Acceptance and Community Acceptance) are used to evaluate the feasibility of implementing an alternative in terms of its acceptance by regulatory agencies and the community.

8.1 Comparative Analysis of Alternatives for Groundwater

The four groundwater alternatives compared in this section all include continued operation of the boundary containment and treatment systems that are currently operational at RMA. Three of the four alternatives (Alternatives 2, 3, and 4) involve continued operation of the existing IRAs, and two alternatives (Alternatives 3 and 4) include construction of additional on-post extraction and treatment systems. The No Action alternative (which involves discontinuing the existing boundary systems) was evaluated in the FS, but because it does not achieve the threshold criteria (overall protection of human health and the environment and compliance with ARARs), it was not retained as a potential remedy. A summary of the comparative analysis of the groundwater alternatives is provided in Table 8.1-1.

8.1.1 Overall Protection of Human Health and the Environment

All four groundwater alternatives are protective of human health and the environment because groundwater is treated at the RMA boundary and because restrictions for potable on-post water use imposed by the FFA are observed. Nonpotable uses of on-post groundwater were not anticipated and risk was therefore not considered in the HHRC for such uses. A risk evaluation would be performed prior to any future nonpotable use to ensure that such use is protective of human health and the environment.

A greater degree of protection is provided by Alternative 3 (Boundary Systems/IRAs/Dewatering), which reduces on-post migration through additional on-post extraction and treatment systems. The operation of the dewatering and extraction systems will reduce flow through Basin A Neck, reduce the South Plants groundwater mound, limit migration into the lakes, and prevent flow through the Section 36 bedrock ridge. Migration is also reduced by the on-post systems included in Alternatives 2 (Boundary Systems/IRAs) and 4 (Boundary Systems/IRAs/Intercept Systems). Because Alternative 4 includes an additional on-post system (the Section 36 Bedrock Ridge Extraction System), it is slightly more protective than Alternative 2. Alternatives 2 and 4 also result in a natural lowering of the water table in South Plants when combined with the soil covers or caps in this area. Lowering of the water table will reduce further spreading of contamination, thereby protecting human health and the environment. Alternative 1 (Boundary Systems) is adequately protective of human health and the environment, but is slightly less protective than the other three alternatives because it only addresses groundwater contamination at the boundaries. Site reviews will be conducted every 5 years to evaluate the effectiveness of the remedies and ensure protection of human health and the environment.

8.1.2 Compliance with ARARs

All four alternatives, if selected, are expected to meet chemical-specific ARARs identified for each treatment system and comply with action- and location-specific ARARs. The remediation goals for chloride and sulfate at the NBCS will be achieved through natural attenuation. The goal for sulfate will be the natural background concentration. Assessment of the chloride and sulfate concentrations will occur at the 5-year site review. Monitoring and assessment of NDMA contamination will occur in support of potential design refinement/design characterization to achieve the remediation goals specified for boundary groundwater treatment systems.

8.1.3 Long-Term Effectiveness and Permanence

All four alternatives provide a high degree of long-term effectiveness and permanence because operation of the boundary systems eliminates the potential for off-post exposure and because restrictions for potable on-post water use imposed by the FFA are observed. Nonpotable uses of on-post groundwater were not anticipated and risk was therefore not considered in the HHRC for such uses. A risk evaluation would be performed prior to any future nonpotable use to ensure that such use is protective of human health and the environment.

Boundary system operations are proven, effective, and reliable, and treatment residuals are safely disposed off post. All alternatives also reduce contaminant migration through passive dewatering, a result of a reduction of infiltration and removal of water from process and fire protection pipes in the areas of South Plants and Basin A that will be covered as a part of the selected soil remedy. Additionally, Alternative 2 reduces contaminant migration through operation of the IRAs. Alternative 3 achieves contaminant reduction through active dewatering as well as operation of the on-post IRAs. Alternative 4 reduces contaminant migration through continued operation of the IRAs and the Section 36 Bedrock Ridge Extraction System.

8.1.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Operation of the boundary systems, which is a component of all four alternatives, provides substantial reduction in toxicity, mobility, or volume through treatment of contaminated groundwater; approximately 1 billion gallons per year of water are currently being treated at the systems. Alternatives 2, 3, and 4 provide additional reduction in toxicity, mobility, or volume because they involve operation of the IRAs and additional on-post extraction/treatment systems. Compared to Alternative 1, Alternatives 2 and 4 treat approximately 170 million additional gallons per year, while Alternative 3 treats an additional 215 million gallons per year for the first 10 years and 190 million gallons per year for the next 20 years. On-post treatment under Alternatives 2, 3, or 4 will be continued until remediation is complete.

All alternatives achieve reductions in contaminant mobility and volume through passive dewatering, which is a result of installation of the soil covers or caps in the Basin A and South Plants areas. Mobility and volume are not reduced through treatment but through passive methods. Alternative 3 achieves the most rapid reduction in toxicity, mobility, or volume through active dewatering, which lowers the water table, thereby reducing migration and leaching of residual contamination from soil. Alternative 4 is slightly more effective in reducing toxicity than Alternative 2 because the additional volume of contaminated water that is extracted and treated is small. Alternative 4 also reduces or prevents the mobility of contaminants in groundwater, thus reducing/preventing their migration into the First Creek alluvial channel.

8.1.5 Short-Term Effectiveness

All four alternatives are protective of workers, the community, and the environment during the construction and implementation phases. Alternative 2 has the least impact as it is already in place and involves no additional actions. Alternatives 1 and 4 have minimal potential impacts. For Alternative 1, these impacts are associated with demolition of the existing IRAs; for Alternative 4, they are associated with drilling and construction of the Section 36 Bedrock Ridge Extraction System. Alternative 3 involves more intrusive activities than the other three alternatives, but it can still be implemented within a fairly short time period and with minimal negative impact to workers, the community, and the environment.

8.1.6 Implementability

Alternative 2 is most easily implemented because it involves continued operation of all existing systems without any additional construction or demolition. Alternatives 1 and 4 are slightly more difficult to implement than Alternative 2 because they involve installation of a small extraction and piping system (Alternative 4) or demolition of the existing IRAs (Alternative 1). Alternative 3 is the most difficult to implement since it requires installation of horizontal well networks and a new treatment system. All of the alternatives use available technologies that are both technically and administratively implementable, although horizontal wells are an innovative technology. The monitoring systems included in each alternative will allow evaluation of the effectiveness of the remedy, and additional actions could be implemented readily if monitoring indicated that ARARs were not being met.

8.1.7 Cost

The total present worth costs for the groundwater alternatives range from $80 million to $130 million (1995 dollars). Alternative 1 has the lowest cost at $80 million, Alternatives 2 and 4 have comparable present worth costs at $98 million and $104 million, respectively, and Alternative 3 is the most expensive alternative at $130 million. A breakdown of O&M costs for the components of each alternative is presented in Table 7.2-2.

8.1.8 State Acceptance

The state of Colorado has been actively involved throughout the RI/FS and remedy selection process for the On-Post Operable Unit. The state was provided the opportunity to comment on the RI/FS documents and on the Proposed Plan, and has taken part in numerous public meetings, including the public meeting on November 18, 1995, to inform the public of the content of the Proposed Plan. Written comments received from the state during the public comment period indicate their concern about the water-supply issue, the Medical Monitoring Program, the Trust Fund, and hydraulic control of the lakes in the South Lakes area.

Responses to the state's comments are provided in the Responsiveness Summary (Section 12).

8.1.9 Community Acceptance

Interested members of the public, including individual citizens, representatives of the local communities, and representatives of national groups, have been actively involved in reviewing the FS and evaluating potential remedial alternatives for the past 2 years as a result of the outreach program described in Section 3. The preferred groundwater alternative for the On-Post Operable Unit was presented to the public in the Proposed Plan, which provides a brief summary of all of the alternatives evaluated during the Detailed Analysis of Alternatives phase of the FS. The original comment period of 60 days was extended to 90 days at the request of some commenters.

The concerns expressed by the public included the water-supply issue, the adequacy of the selected remedy and the monitoring program, the implementation of the Medical Monitoring Program, the establishment of the Trust Fund, and presence of NDMA in groundwater.

Responses to the communities comments are provided in the Responsiveness Summary. (Section 12).

8.1.10 Conclusions

All four groundwater alternatives provide adequate protection of human health and the environment through continued operation of the boundary systems. Alternative 3 is more protective than the other alternatives because it removes the largest amount of contaminants and most rapidly reduces the potential for additional on-post migration. Alternative 4 is more protective than Alternative 2 because it involves additional treatment beyond the existing IRAs, and Alternative 2 is more protective than Alternative 1.

All alternatives will comply with ARARs and all provide equivalent long-term effectiveness and permanence. Alternative 3 provides the greatest reduction in toxicity, mobility, or volume through treatment, but it is less effective in the short term and less implementable than the other three alternatives because it involves construction of new extraction and treatment systems. Alternative 4 provides a greater reduction in toxicity, mobility, or volume through treatment than Alternatives 1 or 2, but it is slightly less effective in the short term and is slightly less implementable than Alternative 2. The short-term effectiveness and implementability of Alternative 1 is similar to that of Alternative 4, but Alternative 1 provides the least reduction in toxicity, mobility, or volume through treatment of contaminated groundwater.

Alternative 1 has the lowest present worth cost because all existing IRAs are discontinued, while Alternative 3 has the highest cost because it involves the most new construction and treatment. The costs of Alternatives 2 and 4 lie between Alternatives 1 and 3. Alternative 4 provides a small amount of additional treatment compared to Alternative 2 at a slightly higher cost.

Alternative 4 is superior to the other groundwater remedial alternatives for the On-Post Operable Unit for the following principal reasons:

- Alternative 4 is preferable to Alternatives 1 and 2 because it provides additional reduction of toxicity, mobility, or volume of contaminated groundwater at a reasonable cost and with minimal short-term effects. It is also readily implementable.
- Although Alternative 3 provides greater reduction of toxicity, mobility, and volume than Alternative 4, it is less readily implementable than Alternative 4. Furthermore, when considered in conjunction with the preferred soil alternative and the continued operation of the boundary groundwater containment and treatment systems, Alternative 3 provides limited added benefit compared to Alternative 4 at a higher cost.

8.2 Comparative Analysis of Alternatives For Structures

The three structures alternatives compared in this section involve removing all No Future Use structures and disposing the debris in the on-post hazardous waste landfill. All structures alternatives include the completion or continuation of structures IRAs as described in Section 7.3.3. The ultimate disposal method for the structures medium groups is chosen based on the following approach:

- The Agent History Group must be disposed in the hazardous waste landfill to comply with Army regulations.
- The Significant Contamination History Group contains structures with use histories that indicate a possibility of significant contamination. This group is disposed in the hazardous waste landfill.
- For the Other Contamination History Group, the disposal options include capping in place, consolidation in Basin A, or disposal in the on-post hazardous waste landfill.

The No Action Alternative (which involves leaving all structures in place) was evaluated in the FS, but it was not retained as a potential remedy because it did not achieve a threshold criterion (overall protection of human health and the environment). A summary of the comparative analysis of the structures alternatives is provided in Table 8.2-1.

8.2.1 Overall Protection of Human Health and the Environment

All three structures alternatives are protective of human health and the environment because all potentially contaminated structures are demolished and disposed to prevent exposure to humans or wildlife. Alternative 3 (Landfill) is slightly more protective than Alternative 2 (Landfill/Consolidate) because all structural debris is placed in the on-post hazardous waste landfill. Alternative 2 is in turn slightly more protective than Alternative 1 (Landfill/Cap in Place) because the debris that is not landfilled is consolidated at one location under a thick soil cover that includes a layer of concrete. Agent-contaminated debris is treated as necessary under all three alternatives, but other treatment is not undertaken because there is a potential for increased worker exposures at no added benefit.

8.2.2 Compliance with ARARs

All three structures alternatives comply with the chemical-, action- and location-specific ARARs listed in Appendix A.

8.2.3 Long-Term Effectiveness and Permanence

All three structures alternatives provide adequate long-term effectiveness and permanence. Removal and disposal of the structures involves significantly less long-term risk than leaving the structures in place and restricting access to them. Additionally, the majority of the structures must be removed to accommodate the soil remedial alternatives. Because structure debris is contained by capping or landfilling, there is low residual risk.

Because high levels of contamination are not expected to be associated with the majority of the structures, the long-term risks associated with waste management are expected to be low. Adequate controls are provided, and the permanence of the solution is verified by long-term monitoring. Alternatives 2 and 3 are slightly more effective in the long term than Alternative 1 because the structural debris is consolidated into central locations (the landfill and, for Alternative 2, Basin A) rather than remaining dispersed under several caps that require additional long-term maintenance.

8.2.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

All three structures alternatives reduce contaminant toxicity, mobility, or volume through treatment. Demolition of structures reduces the standing volume. Capping or landfilling the structural debris reduces the mobility of contaminants through engineering controls, although this reduction may be compromised should the cap or landfill leak. Caustic washing irreversibly reduces the toxicity, mobility, and volume of Army chemical agent through treatment, but produces a hazardous liquid sidestream that will be treated on post. Alternative 3 is slightly more effective in reducing mobility than Alternative 2 because the structural debris is contained in a landfill, and Alternative 2 is slightly more effective in reducing mobility than Alternative 1 because the debris is consolidated into two central locations rather than dispersed under several caps that require additional long-term maintenance.

8.2.5 Short-Term Effectiveness

All three structures alternatives provide equal short-term effectiveness. Air monitoring and dust controls are required during demolition, transportation, and disposal. Worker protection will be required for physical hazards associated with dismantling and for chemical hazards associated with caustic washing and handling of agent-contaminated debris. Remediation is completed within 3 to 4 years under all three alternatives. Because high levels of contamination are not expected to be associated with the majority of the structures, the risks associated with short-term worker and community exposure are expected to be low for all alternatives.

There are unique concerns for structures with potential Army chemical agent presence. After demolishing the structures, caustic washing is administered to debris, as necessary, and the debris is disposed in the on-post hazardous waste landfill to comply with Army agent regulations. Because the highest probability of encountering agent residues is in process piping and tanks, which are currently being treated and removed as part of the chemical process-related IRA activities, the potential for encountering agent associated with building materials is low. Thus, short-term risks during such remediation activities are considered low for all alternatives.

8.2.6 Implementability

All three structures alternatives are generally technically and administratively feasible, although Alternatives 2 and 3 are more implementable because there are regulatory concerns with capping structural debris in place (Alternative 1). Implementation of structures remediation will require coordination with the remediation scheduled for other environmental media. However, because the time frame during which structures are to be demolished is relatively short, structures remediation should not hinder the remainder of the remediation efforts. The structures demolition must begin in the areas in which soil remediation is planned so that the soil remediation schedule is not delayed. Structures covered under any chemical weapons agreements may need to be removed to comply with the requirements of these agreements.

Significant Contamination History Group and Agent History Group structural debris will be placed into the on-post hazardous waste landfill as demolition proceeds. Accordingly, the landfill must be constructed and in operation prior to the commencement of demolition activities. Other Contamination History Group debris may be placed in the Basin A consolidation area, which requires minimal preparation; in the on-post hazardous waste landfill, which must be ready before demolition begins; or in the areas to be capped, which require minimal preparation. In general, structures must be removed before the soil remedy can be implemented.

8.2.7 Cost

The present worth costs (1995 dollars) are similar for all three alternatives ($106 million for Alternative 1, $104 million for Alternative 2, and $109 million for Alternative 3) because the alternatives only differ with regard to the disposal method for the Other Contamination History Group debris. There are several ongoing structures IRAs whose costs also contribute significantly to the total cost of structures remediation. The total estimated structures IRA costs are $76,000,000, of which $41,000,000 will be spent by the completion of the ROD (and is not included in the above costs), and an additional $35,000,000 will be spent in post-ROD removal actions (not included in the above costs). A breakdown of capital and O&M costs for the components of each alternative is presented in Table 7.3-2.

8.2.8 State Acceptance

The state has been actively involved throughout the RI/FS and remedy selection process for the On-Post Operable Unit. The state was provided the opportunity to comment on the RI/FS documents and on the Proposed Plan, and has taken part in numerous public meetings, including the public meeting on November 18, 1995, to inform the public of the content of the Proposed Plan. Written comments received from the state during the public comment period indicate that there were no major concerns regarding the structures remedy.

Responses to the state's comments are provided in the Responsiveness Summary (Section 12).

8.2.9 Community Acceptance

Interested members of the public, including individual citizens, representatives of the local communities, and representatives of national groups, have been actively involved in reviewing the FS and evaluating potential remedial alternatives for the past 2 years as a result of the outreach program described in Section 3. The preferred structures alternative for the On-Post Operable Unit was presented to the public in the Proposed Plan, which provides a brief summary of all of the alternatives evaluated during the Detailed Analysis of Alternatives phase of the FS. This original comment period of 60 days was extended to 90 days at the request of some commenters.

The concerns expressed by the public included questions with regards to the adequacy of the structures sampling and analytical program. Responses to the community's comments are provided in the Responsiveness Summary (Section 12).

8.2.10 Conclusions

All three structures alternatives provide adequate protection of human health and the environment. Treatment technologies are generally not included because of the exposure risks to workers and the limited benefits for all but the Agent History Group. On-post hazardous waste landfilling for the Significant Contamination History Group is a protective remedy that is included in all three alternatives. The long-term effectiveness of Alternatives 2 and 3 is higher than Alternative 1, which relies on caps in several disposal locations. All three alternatives are equivalent with respect to reduction of toxicity, mobility, or volume through treatment or engineering controls and short-term effectiveness. For Alternative 1, regulatory concerns remain about capping Other Contamination History Group debris in place, which makes its implementibility less certain. Consolidation or landfilling of Other Contamination History Group debris (under Alternatives 2 and 3, respectively) is implementable and cost effective.

Alternative 2 is superior to the other structures alternatives for the On-Post Operable Unit for the following principal reasons:

- Alternatives 2 and 3 are preferable to Alternative 1 because they are more implementable and structural debris is consolidated into one or two disposal locations.
- Alternative 2 is more desirable than Alternative 3 because the Other Contamination History Group structural debris is used as fill in Basin A, reducing the amount of clean borrow needed and reducing the total volume to be landfilled. This alternative is also slightly less costly than Alternative 3.

8.3 Comparative Analysis of Alternatives for Soil

The five soil alternatives that are compared in this section involve a combination of containment (as a principal element) and treatment technologies to reduce contamination. A summary of the comparative analysis of the soil alternatives is provided in Table 8.3-1.

As described in Section 7.1.3, the criteria for evaluating soil contamination helped focus the evaluation of potential remedial activities on areas of highest risk to human health and the environment. Alternatives were developed to include treatment of principal threat volumes, where practicable, with containment or institutional controls being enacted for the balance of the exceedance areas. The sheer volume of contaminated soil present on the site precludes a remedy in which all contaminants could be excavated and cost effectively treated.

8.3.1 Overall Protection of Human Health and the Environment

The five alternatives for soil provide overall protection of human health through a combination of containment and treatment. Alternatives 1 (Caps/Covers), 2 (Landfill/Caps), and 3 (Landfill) provide for protection of human health primarily through containment of human health exceedances, which interrupts exposure pathways and reduces the migration of contaminants to groundwater and the atmosphere. Alternatives 4 (Consolidation/Caps/Treatment/Landfill) and 5 (Caps/Treatment/Landfill) address portions of the most contaminated soil through treatment, but still rely on capping and landfilling to protect human health in the majority of the contaminated areas.

Under each of the five alternatives, the protection of wildlife is generally accomplished through containment of portions of the core areas of RMA that may pose a risk to biota by capping, covering, or landfilling. These actions interrupt the potential for biota exposure, and also prevent burrowing animals from coming into contact with contaminated soil. Outside the core area, these alternatives address surficial soil with low levels of contamination using two different approaches. Alternative 5 includes the treatment of approximately 1,600 acres through agricultural practices, which reduces the level of OCPs in near-surface soil but results in the disturbance of habitat over widespread areas of RMA. The other four alternatives address low-level surficial soil contamination by continued monitoring only, thereby avoiding the disruption of wildlife in these areas during remedial activities and habitat restoration.

Alternatives 3, 4, and 5 are more protective than Alternatives 1 or 2 because larger volumes of contaminated soil are contained in a secure landfill and/or treated. Alternatives 3 and 4 offer equivalent overall protectiveness because there is a tradeoff between landfilling a greater total volume under Alternative 3 versus landfilling the Basin F Wastepile and treating more material under Alternative 4. Alternative 5 is more protective than the other alternatives because more material is treated.

8.3.2 Compliance with ARARs

Each of the five alternatives complies with chemical-, action-, and location-specific ARARs. The number of ARARs, and the difficulties associated with demonstrating compliance with these ARARs, are substantially higher for Alternative 5 based on the complexity of the alternative and the use of thermal treatment technologies.

8.3.3 Long-Term Effectiveness and Permanence

Each of the five alternatives results in minimal residual risk based on the adequacy and reliability of controls offered by each alternative. All five alternatives rely on containment of a significant portion of the contaminated soil to protect human health and the environment, requiring long-term maintenance and monitoring activities. Long-term management also includes access restrictions to capped and covered areas to ensure the integrity of the containment systems. Alternatives 4 and 5 leave smaller volumes of contaminated soil (approximately 8 percent and 40 percent of the human health exceedance volume, respectively, are treated) with lower levels of contamination requiring long-term controls; however, these alternatives still rely on containment of large volumes of contaminated soil (92 and 60 percent, respectively). Alternative 5 also includes the treatment of approximately 1,600 acres through agricultural practices, which reduces the level of OCPs in near-surface soil but results in the disturbance of habitat over widespread areas of RMA. The containment systems for the five alternatives are adequate and reliable for long-term protection of human health and the environment.

Alternative 1 addresses both highly contaminated soil and large volumes of contaminated soil through containment in place. The installation of caps/covers provides adequate protection for human health and wildlife by eliminating exposure to contaminated soil. The caps provide long-term reduction in the migration of contaminants to groundwater. Based on the operation of the existing groundwater systems and the groundwater removal systems to be installed as part of the selected water alternative, this alternative provides long-term effectiveness and a low residual risk. A residual risk may exist for biota because surficial soil that may pose a risk to biota is left in place and monitored. However, widespread areas of wildlife habitat are not disturbed to address this residual risk.

Alternatives 2 and 3 both rely on containment systems that effectively protect humans and biota from exposure to contaminated soil. The bottom liner of a landfill controls the migration of leachate. Landfill covers and caps both provide long-term protection by preventing infiltration into the contaminated materials and releases to the atmosphere. These two alternatives provide similar levels of long-term protection and minimal long-term risks, although landfilling does provide, by virtue of the liner, an increased level of containment than a cap does. Both of these alternatives involve potential risk for biota because surficial soil that may pose a risk to biota is left in place and monitored; however, widespread areas of habitat are not disturbed to address this residual risk.

Alternatives 4 and 5 treat portions of the most contaminated soil, thereby reducing the level of contamination in the soil requiring long-term controls. However, both alternatives use similar containment systems as the other three alternatives to address large volumes of lower-level contamination (92 percent and 60 percent of the human health exceedance volume, respectively). Alternative 5 does treat a larger volume of soil, primarily through treatment of the Basin F Wastepile, but still relies on containment of a large volume of soil to provide long-term protection. Alternatives 4 and 5 provide similar levels of long-term protection, but do not eliminate the need for long-term monitoring and maintenance of capped and landfilled areas.

8.3.4 Reduction of Toxicity, Mobility, or Volume Through Treatment

Alternatives 4 and 5 provide the greatest reduction in toxicity, mobility, or volume through treatment. These alternatives permanently reduce the toxicity, mobility, or volume of contaminated soil through treatment of 207,000 and 1.1 million BCY of soil, respectively, and they reduce the mobility of contaminants in the remaining soil through containment with caps, soil covers, and landfills. The other three alternatives provide reduction in mobility through containment; however, Alternative 1 provides somewhat lower reduction in mobility because Alternatives 2 and 3 include landfilling of some of the contaminated soil, which provides some measure of additional containment of contaminants and reduction in mobility compared to capping. Ultimately, however, all containment alternatives rely on the effectiveness of the caps and soil covers to reduce infiltration.

8.3.5 Short-Term Effectiveness

The short-term effectiveness of the five alternatives is primarily governed by the risks posed during remedial actions and the time required until remediation goals are achieved. Short-term effectiveness decreases as a result of the increase in risks during remedial actions and the longer time frames for implementation of the more complex remedial alternatives.

Alternatives 1 and 2 have minimal to low short-term risks as the central portions of RMA (with high levels of contamination) are capped in place. Thus, the risks to workers and the surrounding community from the excavation, transportation, and treatment/disposal of soil with high-level contamination are avoided. The implementation time of these alternatives is approximately 17 and 16 years, respectively. Alternative 2 includes the landfilling of 2 million BCY of contaminated soil (instead of containment in place), but the risks associated with excavation, transportation, and disposal of this soil are not significantly increased compared to capping based on the low levels of contamination in the soil to be landfilled. These two alternatives address soil in the core area of RMA that may pose a risk to biota through containment, but do not entail additional remedial actions for surficial soil that may pose a risk to biota, which is left in place and monitored. In this manner, widespread areas of habitat are not disturbed to address soil with a low residual risk.

The other three alternatives involve excavation and treatment/disposal of portions of the most contaminated soil, which increases the short-term risks to workers and the community. Alternative 4 removes a smaller volume of highly contaminated soil, and therefore exhibits lower risks due to excavation, transportation, and disposal activities than Alternatives 3 or 5, which present the highest short-term risk to workers and the community. Under these alternatives, the largest volume of highly contaminated areas is excavated for treatment and/or disposal, requiring specialized vapor- and odor-suppression measures to minimize the release of contaminants. The implementation time frame for Alternative 5 is the longest at approximately 28 years. Although steps can be taken to control short-term risks during remedial actions under these three alternatives, the short-term effectiveness for these alternatives is lower than for Alternatives 1 or 2. Negative-pressure vapor enclosures are one approach to controlling vapors and odors that may be emitted from several areas to be excavated under Alternatives 3, 4, and 5. Work within enclosures would require extensive worker protection and could present significant hazards to workers. Although the air within the enclosure is collected and treated, or, where an enclosure was not used, other measures could be taken to mitigate short-term risks, the short-term risks of contaminant release associated with excavating these areas cannot be completely eliminated.

8.3.6 Implementability

The implementability of the five alternatives varies from easy for Alternatives 1 and 2, which are readily constructed using common construction equipment, to difficult for Alternative 5. This alternative presents difficulties in the construction and operation of the treatment technologies, which have not been implemented at any other site in the country at the scale required at RMA. The implementability of Alternatives 3 and 4 is moderate.

Alternatives 1 and 2 are both considered easy to implement because they consist of the proven and available technologies of capping and landfilling and because they do not require the use of vapor controls. Alternatives 3 and 4 involve a similar level of difficulty in the excavation, transportation, and disposal of large volumes of highly contaminated soil. Alternative 4, which makes use of readily available mobile equipment for treatment of soil by solidification/stabilization, is implementable. Implementability of the innovative thermal technology for the Hex Pit will be determined during remedial design treatability testing. Consolidation of some soil potentially posing risk to biota (as a source of gradefill) decreases the cost and disruption of habitat for borrow areas. Alternative 5 is the most difficult to implement and requires the longest time frame based on the difficulties with implementation of vapor controls, if necessary, and treatment technologies. There is a high level of uncertainty in the performance of thermal technologies on the complex contaminant mixtures and high salt levels in some principal threat soil, leading to a potential for failure to meet the treatment specifications and a potential for extensive shut-down time to modify and maintain the system.

8.3.7 Cost

The estimated present worth cost (in 1995 dollars) for Alternative 2 is the lowest at $276 million. The present worth cost for Alternative 1 is estimated to be $386 million, followed by Alternatives 3 and 4 at $384 and $401 million, respectively. The estimated present worth cost for Alternative 5 is the highest at $542 million for soil remediation. A breakdown of capital and O&M costs for the components of each alternative is presented in Table 7.4-2.

The greatest overall cost uncertainty is associated with the remediation of soil, and the uncertainty is higher for alternatives that include excavation and treatment than for alternatives that minimize the handling of highly contaminated soil through containment in place. The level of cost uncertainty is relatively low for Alternatives 1, 2, and 4 because demonstrated construction and excavation technologies are used. The cost uncertainty associated with Alternative 3 is moderate as demonstrated technologies are used for containment, although large volumes of highly contaminated soil are excavated. Alternative 5 entails the highest degree of cost uncertainty due to the use of complex treatment technologies and the excavation, transportation, treatment, and disposal of large volumes of highly contaminated soil.

8.3.8 State Acceptance

The state has been actively involved throughout the RI/FS and remedy selection process for the On-Post Operable Unit. The state was provided the opportunity to comment on the RI/FS documents and on the Proposed Plan, and has taken part in numerous public meetings, including the public meeting on November 18, 1995, to inform the public of the content of the Proposed Plan. Written comments received from the state during the public comment period indicate their concerns about the Medical Monitoring Program, the Trust Fund, and treatment of the Hex Pit.

Responses to the state's comments are provided in the Responsiveness Summary (Section 12).

8.3.9 Community Acceptance

Interested members of the public, including individual citizens, representatives of the local communities, and representatives of national groups, have been actively involved in reviewing the FS and evaluating potential remedial alternatives for the past 2 years as a result of the outreach program described in Section 3. The preferred soil alternative for the On-Post Operable Unit was presented to the public in the Proposed Plan, which provides a brief summary of all of the alternatives evaluated during the Detailed Analysis of Alternatives phase of the FS. The original comment period of 60 days was extended to 90 days at the request of some commenters.

The concerns expressed by the public included questions related to the Medical Monitoring Program, the Trust Fund, the adequacy of the selection remedy and the monitoring program, and concerns regarding the potential presence of dioxin. Responses to the community's comments are provided in the Responsiveness Summary (Section 12).

8.3.10 Conclusions

Alternative 1 provides the level of protection of human health and wildlife required under CERCLA by preventing exposures to contaminated soil. In addition, this alternative has minimal short-term risks since the central portions of RMA (with high levels of contamination) are capped in place, thereby avoiding the risks from excavation, transportation, and treatment/disposal of soil with high-level contamination. The mobility of the contaminants is reduced by minimizing the amount of infiltration that may mobilize the contaminants from the soil to the groundwater and eliminating the airborne migration pathway. However, no action is taken to reduce the toxicity or volume of the contaminated soil. The implementation time frame for Alternative 1 is less than the other alternatives, although its cost is higher than Alternative 2. The overall effectiveness of Alternative 1 is somewhat lower than the other alternatives based on the lower reduction in mobility resulting from capping as compared to landfilling or the destruction of contaminants through treatment. However, all alternatives rely on capping/landfilling of the majority of the contaminated soil to provide long-term risk reduction.

Alternative 2 protects humans and biota by providing a physical barrier, through capping and landfilling, to prevent exposures and reduce the amount of infiltration that may mobilize contaminants to groundwater. Caps/covers and landfills provide effective containment of the contaminated soil. The contaminated soil from the outlying sections of RMA that is landfilled poses a minor risk to workers and the community during excavation and transportation due to the low level of contamination in the soil. Soil in the core area of RMA with high levels of contamination (such as the Basin A, Disposal Trenches, and Basin F Medium Groups and South Plants Central Processing Area Subgroup) is left in place and capped. The mobility of the contaminants in these areas is further reduced by minimizing the infiltration through the contaminated soil and eliminating the airborne migration pathway. The overall effectiveness of Alternative 2 is high because it provides effective containment of the contaminants by balancing the short-term risks of excavation with long-term effectiveness.

Alternative 3 protects humans and biota by providing a physical barrier that prevents exposure through landfilling and capping. However, significant risks are posed to workers and the community during excavation and transportation of large volumes of highly contaminated soil. Although vapor- and odor-suppression measures are used during the excavation of several sites, the short-term risks associated with excavation of contaminated soil cannot be completely eliminated. The mobility of the contaminants is eliminated by placing the contaminated soil in the landfill, but no action is taken to reduce the toxicity or volume of the contaminated soil. The overall effectiveness of Alternative 3 is moderate because it provides low long-term risk but entails high short-term risks during excavation and transportation of highly contaminated soil.

Alternative 4 protects humans and biota by treating some principal threat materials and providing a physical barrier (i.e., caps, soil covers, and landfill) to prevent exposure. Mobility of the contaminants is reduced by minimizing the amount of infiltration into the contaminated soil below the caps or in the landfill. The toxicity and mobility of contaminated soil is reduced through treatment of some principal threats by solidification/stabilization. Increased short-term risks are posed to workers and the community during excavation, transportation, and landfill of highly contaminated soil. The risks associated with excavation are reduced, but are not eliminated, through the use of vapor- and odor-suppression measures at several excavation areas. In addition, placement of soil excavated from the Basin F Wastepile and Section 36 Lime Basins in a triple-lined landfill cell provides added assurance of containment. The consolidation of 1.5 million BCY of contaminated soil in Basin A, Basin F, and the South Plants Central Processing Area prior to capping these sites lowers the cost of obtaining borrow materials and reduces the area disturbed for borrow. The implementability of this alternative is moderate because highly contaminated soil is excavated. However, the overall effectiveness of Alternative 4 is high because it provides low long-term risk, compensating for the increased short-term risk during excavation.

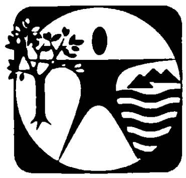
Alternative 5 treats areas of highly contaminated soil, thereby reducing the contaminant toxicity, mobility, or volume. However, workers and the community are exposed to the highest short-term risks under Alternative 5 (compared to other alternatives) during excavation, transportation, and treatment. Although vapor- and odor-suppression measures are used during the excavation of several sites, the short-term risks associated with excavation of highly contaminated soil cannot be completely eliminated. The mobility of the contaminants is minimized by placing the contaminated soil in a landfill. However, this alternative has a low overall effectiveness based on the high short-term risks during remedial actions and the longer time frame (a minimum of 14 years) until actions are completed. In addition, the implementability of this alternative is very difficult because of the large volume of highly contaminated soil (including the Basin F Wastepile) to be treated by thermal treatment.

Alternative 4 is superior to the other soil remedial alternatives for the On-Post Operable Unit for the following principal reasons:

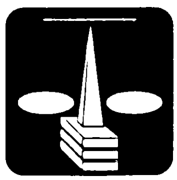
- Alternative 4 is preferable to Alternatives 1, 2, and 3 because it provides additional reduction of toxicity, mobility, or volume of contaminated soil through some treatment with minimal short-term effects and more secure containment of the Basin F Wastepile materials in a new triple-lined landfill cells. Alternative 4 is also readily implementable.

- Although Alternative 5 provides greater reduction of toxicity, mobility, or volume through more treatment than Alternative 4, it is much less readily implementable than Alternative 4 because the treatment technologies identified have never been used at the scale required at RMA. Furthermore, Alternative 5 is significantly more costly than Alternative 4, and the uncertainty of execution related to schedule and budget is much higher for Alternative 5 than for Alternative 4.

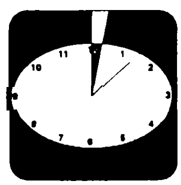
1 Overall Protection of Human Health and the Environment addresses whether or not a remedy provides adequate protection and describes how risks posed through each pathway are eliminated, reduced, or controlled.



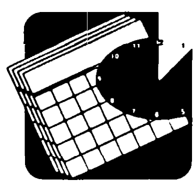
2 Compliance with Applicable or Relevant and Appropriate Requirements (ARARs) addresses whether or not a remedy will meet all federal and state environmental laws and standards and/or provides grounds for a waiver.



3 Short-Term Effectiveness addresses the period of time needed to complete the remedy and any adverse effects to human health and the environment that may be caused during the construction and implementation of the remedy.

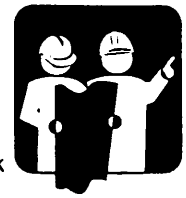


4 Long-Term Effectiveness and Permanence refers to the ability of a remedy to provide reliable protection of human health and the environment over time.



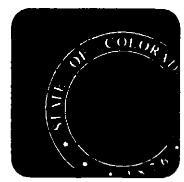
5 Reduction of Toxicity, Mobility, or Volume through Treatment refers to the preference for a remedy that through treatment reduces health hazards, the movement of contaminants, or the quantity of contaminants at the site.

6 Implementability refers to the technical and administrative feasibility of a remedy. This includes the availability of materials and services needed to carry out a remedy. also includes coordination of federal, state, and local governments to work together to clean up the site.



7 Cost evaluates the estimated capital, operating, and maintenance costs of each alternative in comparison to other equally protective alternatives.

8 State Acceptance indicates whether the state agrees with, opposes, or has no comment on the preferred alternative.



9 Community Acceptance includes determining which components of the alternatives interested persons in the community support, have reservations about, or oppose. This assessment may not be completed until public comments on the Proposed Plan are reviewed.

Figure 8.0-1

Cleanup Evaluation Criteria

Rocky Mountain Arsenal
Prepared by Foster Wheeler Environmental Corporation

Table 8.1-1 Comparative Analysis of Water Alternatives

Criteria	Alternative 1 Boundary Systems	Alternative 2 Boundary Systems/ IRAs (No Additional Action)	Alternative 3 Boundary Systems/ IRAs/Dewatering	Alternative 4 Boundary Systems/ IRAs/Intercept Systems
Overall Protection of Human Health and the Environment	*Protective.* Provides protection through operation of boundary systems.	*Protective.* Provides protection through operation of boundary systems and minimizes on-post migration through operation of IRAs.	*Protective.* Provides protection through boundary systems and minimizes on-post migration through operation of IRAs and additional on-post systems.	*Protective.* Provides protection through boundary systems and minimizes on-post migration through operation of IRAs and additional on-post systems.
Compliance with ARARs	*Complies* with action-, chemical-, and location-specific ARARs through active treatment and natural attenuation of inorganics.	*Complies* with action-, chemical-, and location-specific ARARs through active treatment and natural attenuation of inorganics.	*Complies* with action-, chemical-, and location-specific ARARs through active treatment and natural attenuation of inorganics.	*Complies* with action-, chemical-, and location-specific ARARs through active treatment and natural attenuation of inorganics.
Long-Term Effectiveness and Permanence	*Low residual risk.* Potential for off-post exposure is lowered. No on-post exposure due to FFA restrictions. Long-term monitoring required; contaminant migration reduced through passive dewatering.	*Low residual risk.* Potential for off-post exposure is lowered. No on-post exposure due to FFA restrictions. Long-term monitoring required; contaminant migration reduced through IRAs, source capture, and passive dewatering.	*Low residual risk.* Potential for off-post exposure is lowered. No on-post exposure due to FFA restrictions. Long-term monitoring required; contaminant migration reduced through IRAs, source capture, and active dewatering.	*Low residual risk.* Potential for off-post exposure is lowered. No on-post exposure due to FFA restrictions. Long-term monitoring required; contaminant migration reduced through IRAs, source capture, and passive dewatering.
Reduction of Toxicity, Mobility, or Volume (TMV)	*TMV reduced at boundary.* Contaminants removed by GAC adsorption, reducing toxicity and volume.	*TMV reduced at boundary and on post.* Contaminants removed by GAC adsorption and air stripping, reducing toxicity and volume; source capture at Basin A Neck and passive dewatering limit migration.	*TMV reduced at boundary and on post.* Contaminants removed by GAC adsorption and air stripping, reducing toxicity and volume; dewatering and source capture significantly limit migration and mobility.	*TMV reduced at boundary and on post.* Contaminants removed by GAC adsorption and air stripping, reducing toxicity and volume; source capture and passive dewatering limit mobility.

Selected alternative

Table 8.1-1 Comparative Analysis of Water Alternatives

Criteria	Alternative 1 Boundary Systems	Alternative 2 Boundary Systems/ IRAs (No Additional Action)	Alternative 3 Boundary Systems/ IRAs/Dewatering	Alternative 4 Boundary Systems/ IRAs/Intercept Systems
Short-Term Effectiveness	*Effective*. Minimal negative impact; achieves RAOs.	*Effective*. No additional impact associated with continued operation; achieves RAOs.	*Effective*. Minimal negative impact associated with installation of dewatering system; achieves RAOs.	*Effective*. Minimal negative impact associated with installation of extraction system; achieves RAOs.
Implementability	*Technically and administratively feasible*.	*Technically and administratively feasible*. No additional construction involved.	*Technically and administratively feasible*. Treatment by proven technologies except for in situ biological treatment in South Plants.	*Technically and administratively feasible*. Treatment by proven technologies.
Present Worth Cost	$80 million	$98 million	$130 million	$104 million
Conclusion	*Not selected*. Meets evaluation criteria, but provides less protection than other alternatives.	*Not selected*. Meets evaluation criteria, but does not provide additional control and protection beyond what is currently in place.	*Not selected*. Meets evaluation criteria and provides additional on-post controls, but at higher cost than the other alternatives.	*Selected*. Meets evaluation criteria and is consistent with the proposed soil alternative. Provides adequate on-post controls at minimal added cost.

Selected alternative

Table 8.2-1 Comparative Analysis of Structures Alternatives

Criteria	Alternative 1 Landfill/Cap in Place	**Alternative 2 Landfill/Consolidate**	Alternative 3 Landfill
Overall Protection of Human Health and the Environment	*Protective*. Debris is contained by capping or landfilling. Agent debris is treated as necessary.	***Protective*. Debris is contained by consolidation or landfilling. Agent debris is treated as necessary.**	*Protective*. Debris is contained by landfilling. Agent debris is treated as necessary.
Compliance with ARARs	*Complies* with action-, chemical-, and location-specific ARARs.	***Compies* with action-, chemical-, and location-specific ARARs.**	*Complies* with action-, chemical-, and location-specific ARARs.
Long-Term Effectiveness and Permanence	*Low residual risk*. Structural debris is contained by capping or landfilling. Adequate controls; long-term monitoring is required. Habitat is improved at site but limited at landfill.	***Low residual risk*. Structural debris is containeby consolidation or landfilling. Adequate controls; long-term monitoring is required. Habitat is improved at site but limited at landfill.**	*Low residual risk*. Structural debris is contained by landfilling. Adequate controls; long-term monitoring is required. Habitat is improved at site but limited at landfill.
Reduction of Toxicity, Mobility, or Volume (TMV)	*TMV Reduced*. Capping or landfilling reduces mobility. Reduction in mobility may be reversed if cap or landfill leaks. Caustic wash irreversibly reduces TMV of agent, but produces a hazardous liquid sidestream that must be treated.	***TMV Reduced*. Consolidation or landfilling reduces mobility. Reduction in mobility reversed if consolidation area or landfill leaks. Caustic wash irreversibly reduces TMV of agent, but produces a hazardous liquid sidestream that must be treated.**	*TMV Reduced*. Landfilling reduces mobility. Reduction in mobility may be reversed if landfill leaks. Caustic wash irreversibly reduces TMV of agent, but produces a hazardous liquid side-stream that must be treated.

Selected alternative

Table 8.2-1 Comparative Analysis of Structures Alternatives

Criteria	Alternative 1 Landfill/Cap in Place	**Alternative 2 Landfill/Consolidate**	Alternative 3 Landfill
Short-Term Effectiveness	*Effective*. Dust controls needed for demolition. Worker protection necessary for physical hazards associated with dismantling and for chemical hazards associated with caustic washing and handling agent-contaminated debris. Habitat improved at site, limited at disposal areas. RAOs achieved in 3 to 4 years.	***Effective*. Dust controls needed for demolition. Worker protection necessary for physical hazards associated with dismantling and for chemical hazards associated with caustic washing and handlig agent-contaminated debris. Habitat improved at site, limited at disposal areas. RAOs achieved in 3 to years.**	*Effective*. Dust controls needed for demolition. Worker protection necessary for physical hazards associated with dismantling and for chemical hazards associated with caustic washing and handling agent-contaminated debris. Habitat improved at site, limited at disposal areas. RAOs achieved in 3 to 4 years.
Implementability	*Technically and administratively feasible*. Regulatory concerns with capping.	***Technically and administratively feasible*.**	*Technically and administratively feasible*.
Present Worth Cost[1]	$106 million	**$104 million**	$109 million
Conclusion	*Not selected*. Meets evaluation criteria and is consistent with soil remedial alternatives. Not identified as the preferred alternative due to regulatory concerns over capping debris from Other Contamination History structures.	***Selected*. Meets evaluation criteria and is consistent with soil remedial alternatives.**	*Not selected*. Meets evaluation criteria and is consistent with soil remedial alternatives. Not identified as the preferred alternative because it is less cost effective than Alternative 2.

Selected alternative

[1]These costs do not include $35 million in post ROD removal actions.

Table 8.3-1 Comparative Analysis of Soil Alternatives

Criteria	Alternative 1 Caps/Covers	Alternative 2 Landfill/Caps	Alternative 3 Landfill	Alternative 4 Consolidation/Caps/ Treatment/Landfill	Alternative 5 Caps/Treatment/ Landfill
Overall Protection of Human Health and the Environment	*Protective*. Exposures to humans and animals prevented by containing contaminated soil in place.	*Protective*. Exposures to humans and animals prevented by containing contaminated soil in place.	*Protective*. Exposures to humans and animals prevented by containing contaminated soil in place.	*Protective*. Exposures to humans and animals prevented by containing contaminated soil in place and by treating some of the principal threat volume.	*Protective*. Exposures to humans and animals prevented by containing contaminated soil in place and by treating principal threat volume.
Compliance with ARARs	*Complies* with action-, chemical-, and location-specific ARARs.	*Complies* with action-, chemical-, and location-specific ARARs.	*Complies* with action-, chemical-, and location-specific ARARs.	*Complies* with action-, chemical-, and location-specific ARARs.	*Complies* with action-, chemical-, and location-specific ARARs. More difficult due to action-specific ARARs regarding treatment.
Long-Term Effectiveness and Permanence	*Minimal residual risk*. Relies on caps and groundwater controls to prevent migration and exposure.	*Minimal residual risk*. Relies primarily on caps and groundwater controls, with some landfilling, to prevent migration and exposure.	*Minimal residual risk*. Relies on landfilling, with some caps and groundwater controls to prevent migration and exposure.	*Minimal residual risk*. Relies on treatment of some highly contaminated soil, groundwater controls, and capping/landfilling to prevent migration and exposure.	*Minimal residual risk*. Relies on treatment of most of the highly contaminated soil and landfilling/capping to prevent migration and exposure.
Reduction of Toxicity, Mobility, or Volume (TMV)	*TMV Reduced*. Mobility reduced through containment; no toxicity or volume reduction.	*TMV Reduced*. Mobility reduced through containment; no toxicity or volume reduction.	*TMV Reduced*. Mobility reduced through containment; no toxicity or volume reduction	*TMV Reduced*. TMV of some highly contaminated soil reduced through treatment; relies on containment for most mobility reduction.	*TMV Reduced*. TMV of the most highly contaminated soil reduced through treatment; relies on containment for additional mobility reduction.

Selected alternative

Table 8.3-1 Comparative Analysis of Soil Alternatives

Criteria	Alternative 1 Caps/Covers	Alternative 2 Landfill/Caps	Alternative 3 Landfill	Alternative 4 Consolidation/Caps/ Treatment/Landfill	Alternative 5 Caps/Treatment/ Landfill
Short-Term Effectiveness	*Effective.* Minimal short-term risk. No excavation or potential releases.	*Effective.* Low short-term risk. High-risk sites not excavated; minimal potential for releases.	*Effective.* Moderate short-term risk. All sites excavated and transported with high potential for releases.	*Effective.* Moderate short-term risk. Some high-risk sites excavated and transported; moderate potential for releases.	*Effective.* Higher short-term risk. Most high-risk sites excavated, transported, and treated; large volumes of less contaminated soil moved; high potential for releases.
Implementability	*Implementable.* Easy to construct caps on schedule; short time to complete.	*Implementable.* Easy to construct caps and landfill for soil with low levels of contamination; short time to complete.	*Moderate implementability.* Construction and permitting of large landfill for highly contaminated material may delay schedule.	*Moderate implementability.* Construction and permitting of large landfill for highly contaminated material may delay schedule.	*Difficult implementability.* Construction and permitting of large landfill and thermal treatment facility may delay schedule. Problems in excavation, treatment, and emissions control; longest time to complete.
Present Worth Cost	Total: $386 million	Total: $276 million	Total: $384 million	Total: $401 million	Total: $542 million
Conclusion	*Not selected.* Higher long-term risks and no substantial cost savings compared to other alternatives.	*Not selected.* Higher long-term risk, although low cost.	*Not selected.* High short-term risks without improving long-term protection, which ultimately relies on containment.	*Selected.* Cost effective; balances short-term risks with higher long-term protection.	*Not selected.* High cost, short-term risks, and difficult to implement.

Selected alternative