5.0 Focused Feasibility Study

The purpose of a CERCLA feasibility study is to develop, screen, and analyze potential remedial options for managing risk at uncontrolled hazardous waste sites (EPA 1988) in a manner that "reflect[s] the scope and complexity of the remedial action under consideration and the site problems being addressed" (EPA 1990). The feasibility study presented in this section is a focused feasibility study (FFS) because it follows more than 10 yr of remedial investigation, source removal, and an interim remedial action and because the changed site conditions since the 1998 draft FS (DOE 1998b) justify a streamlined process for developing and screening potential remedial components and forming the remedial alternatives to be analyzed in detail.

The purpose of this FFS is to complete feasibility study activities that were initiated during preparation of the 1998 draft FS by identifying and evaluating remedial alternatives for contaminated alluvial ground water and surface water associated with OU III. The 1998 draft FS eliminated remedial technologies and process options that were not viable based on general site characteristics and contaminant types. Technologies and process options that were screened out in 1998 are also not viable today; justification for eliminating those technologies and process options is provided in Section 5.4, "Identification and Evaluation of Applicable General Response Actions and Remedial Technologies," of this document.

The 1998 draft FS developed eight remedial alternatives, four of which were evaluated in the detailed analysis. The 1998 alternatives were assembled and evaluated on the basis of site conditions that have changed significantly. For example, the distributions and concentrations of contaminants in soil, sediment, and ground water are different as a result of excavation of contaminated soil, sediment, and debris for OU I (Section 2.1) and partial excavation along Montezuma Creek (Section 2.3). Also, the physical characteristics of the site that influence ground water flow, surface water flow, and contaminant fate and transport have changed significantly as a result of site restoration. Because these activities and changes began to occur in 1998, a final decision for ground water remediation could not be supported at that time. Instead, an interim remedial action was implemented to prevent exposure to contaminated ground water and reduce contaminant levels in ground water until the new site conditions could be evaluated. Components of the IRA that limit the relevance of the 1998 draft FS are (1) an institutional control that restricts ground water use, (2) a full-scale PRB treatability study, and (3) continued monitoring and characterization during and since site remediation and restoration. For these reasons, this FFS was prepared to replace, rather than finalize, the previous draft FS document.

5.1 ARARs

Federal and state ARARs for OU III ground water are identified in Section 1.5. Compilation of those ARARs assumed a wide range of possible remedies. Remedy-specific ARARs for each remedial alternative analyzed in detail in this FFS are cited in Section 5.6, "Detailed Analysis of Remedial Action Alternatives."

5.2 Remedial Action Objectives

The overall purpose of remedial action is to protect human health and the environment. Remedial action objectives (RAOs) are statements that represent the medium-specific goal for protecting human health and the environment. RAOs identify (1) the goal of remediation (e.g., acceptable

risk levels or compliance with an ARAR) for specific COCs, (2) exposure routes and receptors, and (3) an acceptable contaminant level or range of levels. RAOs specified for protecting human health are expressed both in terms of contaminant levels and exposure pathways because protection can be achieved through a reduction in contaminant concentrations as well as through a reduction or elimination of exposure pathways (EPA 1988).

The acceptable risk levels identified in the RAOs are based on the RME as required by the NCP (EPA 1990) and EPA policies (EPA 1991b). RME is defined as exposure well above average but still within the range of possible values. The CT risk is also provided for each alternative so that risk managers can evaluate a range of risk (EPA 1991b). CT uses exposure assumptions that result in average or best-estimate exposures with a tendency to still be slightly conservative. Site-specific CT and RME exposure factors were developed by DOE, EPA, and UDEQ and are presented in Section 4.1.3. For noncarcinogens, an HQ or HI value of 1.0 is the numeric indicator of the transition between acceptable and unacceptable risk levels (EPA 1989a). For carcinogens (including nonradionuclides and radionuclides), the preamble to the NCP specifies that as risks increase above 10^{-6} incremental lifetime cancer risk (ILCR), "they become less desirable, and the risk to individuals should generally not exceed 10^{-4}." The ILCR is the same as added cancer risk associated with contaminants at the site over the natural incidence of cancer.

Data collected since the 1998 RI show that concentrations of surface water and ground water COCs continue to exceed numeric standards established in ARARs. On the basis of that information, the baseline risk assessment indicates that (1) exposure to the COCs could result in risk to human health if the ground water ingestion pathway becomes complete, and (2) the overall risk to the environment is not considered to be significant under current conditions. Table 5–1 lists the COCs and indicates whether they exceed a numeric standard or pose an unacceptable risk to the environment and to human health based on a near-term exposure scenario for OU III.

5.2.1 Ground Water RAOs

Utah ground water standards classify the alluvial aquifer as Class II ground water, which means it is not currently a source of drinking water but could be a potential source of drinking water in the future. Because alluvial ground water is not presently being used as a drinking water source, the risk to human health does not exceed the risk range of 10^{-4} to 10^{-6} ILCR or an HI of 1.0. However, risks exceed 1×10^{-4} under the near-term and future-use residential scenario if daily consumption of contaminated ground water is assumed. This potential risk and exceedance of numeric standards in ARARs form the basis for evaluating remedial actions for OU III ground water. No unacceptable risk to receptors from OU III ground water was identified in the ERA. As a result, RAOs for OU III ground water are defined to protect human health on the basis of the risk range for carcinogens and HI for noncarcinogens specified in the NCP, maximum contaminant levels specified in the SDWA, or the State standards specified in "Administrative Rules for Ground Water Quality Protection," R317-6, U.A.C.

Table 5–1. Comparison of COCs to Numeric Standards and Risk-Based Goals

COC	Utah Surface Water Standard Exceeded?	Ground Water Standard(s) Exceeded?	Human Health Concern?[a]	Ecological Concern?
Arsenic	No[b]	Yes	Yes	No
Manganese	No numeric standard	No numeric standard	Yes[g]	No
Molybdenum	No numeric standard	Yes	No	No
Nitrate as N	Yes[c]	Yes	No	No
Selenium	Yes[d]	Yes	No	Possible concern; concentration trends will be reevaluated prior to next CERCLA 5-year review.
Uranium	No numeric standard	Yes	Yes	No
Vanadium	No numeric standard	No numeric standard	Yes	No
Gross Alpha	No[e]	Yes	Not quantifiable	No
Gross Beta	No[f]	Standard is a dose, not an activity	Not quantifiable	No

[a]Assumes that the ground water ingestion pathway is complete at the wells used in the risk assessment (wells 92–09 and 92–11).
[b]Arsenic does not exceed the current most stringent surface water standard (50 µg/L). However, if the standard is revised to be consistent with the SDWA standard for arsenic, the standard would be exceeded at seep 2 only.
[c]Nitrate as nitrogen exceeds the domestic and recreational/aesthetic standard (4 mg/L) only at seep 3 and is believed to be due to an off-site source.
[d]Utah criterion for protection of aquatic wildlife (5 µg/L) is exceeded in Montezuma Creek and at seeps on the Millsite.
[e]Gross alpha concentrations in Montezuma Creek do not exceed the gross alpha standard adjusted by excluding the contribution from uranium.
[f]Utah surface water criterion (50 pCi/L) has only been exceeded twice since 1996.
[g]Manganese concentrations downgradient of the Millsite are not a human health concern; manganese concentrations on the Millsite would be a human health concern if there was a complete exposure pathway.

The ground water management policy (Section 2.4.1) prohibits domestic use of the alluvial aquifer within the Monticello Ground Water Restricted Area (Figure 2–1) which includes the Millsite. The quitclaim deed that transfers the Millsite to the city of Monticello for use as a public park prohibits use of any ground water within the boundary of the Millsite for the purpose of human consumption. This restriction placed on the quitclaim deed provides a second institutional control that protects human health by preventing development of on-site wells for potable consumption.

The following RAOs were developed for OU III alluvial ground water:

- Prevent ingestion of alluvial ground water that contains carcinogenic COCs posing an ILCR greater than 1×10^{-4} or that has concentrations exceeding federal or State ground water standards.
- Prevent ingestion of alluvial ground water that contains noncarcinogenic COCs posing an HI or HQ greater than 1.0 or that has concentrations exceeding federal or State ground water standards.

These RAOs will be achieved when COC concentrations in ground water meet PRGs (Section 5.3).

5.2.2 Surface Water RAOs

Contamination associated with OU III surface water does not cause excess risk to human health or the environment; therefore, RAOs were not developed on the basis of risk to human health or ecological receptors. Concentrations of COCs in some surface water samples taken from

locations on the Millsite exceeded the State surface water standards in "Standards of Quality for Waters of the State," R317-2, U.A.C. These standards designate Montezuma Creek as Domestic Use–1C, Agricultural Use–4, and Aquatic Wildlife–3A Surface Water. Relevant standards are listed in Section 5.3. Because concentrations of some COCs exceed State standards, a single RAO was developed for surface water. The RAO for OU III surface water is to achieve compliance with State surface water standards for COCs in Montezuma Creek.

Contamination in Montezuma Creek is primarily due to discharge of contaminated ground water, although limited contamination may be due to contaminated sediments from supplemental standards areas that were not remediated. Selenium contamination in seeps along the northern boundary of the Millsite is attributed to off-site sources over which there is little control at the present. Selenium contamination in Wetland 3 is attributed to both the off-site sources and to on-site sources which have contaminated on-site ground water which is then discharged to surface water. As a result, OU III surface water does not warrant the development of remedial alternatives specifically to achieve the RAO. The RAO for surface water will be achieved through restoration of ground water.

5.3 Preliminary Remediation Goals, Area of Attainment, and Remediation Time Frame

PRGs, area of attainment, and remediation time frame are interrelated concepts. PRGs are the acceptable levels for COCs in contaminated ground water and surface water associated with OU III based on risk (human health or ecological) or ARARs. PRGs are developed during the RI/FS process to ensure that analytical data collected have appropriate detection limits and to provide a basis for comparing alternatives. PRGs can be modified during the RI/FS process and eventually result in cleanup levels presented in the ROD. The area of attainment for OU III ground water is the area over which RAOs will be achieved. The areas of attainment can be further refined by the NCP, which states "For ground water, remediation levels should generally be attained throughout the contaminated plume, or at and beyond the edge of the waste management areas when waste is left in place" (55 *Federal Register* 8713). Remediation time frame is defined as the period of time required to achieve RAOs in ground water at all locations within the area of attainment.

5.3.1 Ground Water PRGs

Ground water PRGs were developed for OU III COCs on the basis of human health risk and exceedance of standards established by ARARs. Ecological receptors are not exposed to ground water, and, therefore, ecological risk was not considered during development of ground water PRGs. Table 5–2 lists the ground water PRGs, which are based on the assumption that ground water on and downgradient of the Millsite may eventually be used as a source of drinking water. Downgradient of the Millsite, alluvial ground water is not currently used as a drinking water source, and such use of alluvial ground water is unlikely in the future. On the Millsite, the institutional controls presently restrict the development of wells for potable use and future use is unlikely given the proximity to the municipal water system.

Sodium and sulfate were identified as default COCs because no toxicity or regulatory information is available from standard EPA sources to support the risk assessment. Both sodium and sulfate can be toxic at excessive doses, but it is likely that the effects from exposure to these analytes at concentrations seen at this site would be less than the effects from other COCs

(e.g., uranium). Because sodium and sulfate likely would cause significantly less risk than other COCs and quantitative evaluation of the risk is not possible, PRGs were not developed for sodium or sulfate.

Table 5–2. OU III Ground Water PRGs

COC	PRG	PRG Reference
Arsenic	10 µg/L	SDWA
Manganese	880 µg/L	Risk based (HI = 1.0); developed by UDEQ
Molybdenum	100 µg/L	UMTRCA
Nitrate (as N)	10 mg/L	SDWA
Selenium	50 µg/L	SDWA
Uranium	30 µg/L	SDWA
Vanadium	330 µg/L	Risk based (HI = 1.0); EPA Region 3 RBC
U-234/238	30 pCi/L	UMTRCA
Gross Alpha	15 pCi/L	SDWA

NA = Not Applicable

A PRG also was not developed for U-235 because this isotope causes significantly less risk than U-234 and U-238, and compliance with the PRG established for U-234 and U-238 will result in safe levels of U-235. In addition, regulatory standards have not been set for U-235, whereas they have been set for U-234 and U-238. A concentration-based PRG does not exist in the OU III ARARs for gross beta, nor could a risk-based PRG be developed because gross beta is only an indicator of the type of radioactive emission, and, thus, quantifiable risk factors are not available (these are only available for specific isotopes such as U-234 and U-238).

5.3.2 Surface Water PRGs

The PRGs for surface water (Table 5–3) are the State surface water standards, "Standards of Quality for Waters of the State," R317-2, U.A.C. Table 5–3 only lists those COCs that have an established standard, because exposure to surface water does not result in significant human health risk. OU III surface water does not warrant development of remedial alternatives to achieve the RAO because surface water is expected to improve based on its relation to ground water. All remedial alternatives developed for OU III ground water will include provisions for monitoring contaminant concentrations in Montezuma Creek to ensure that the PRGs for surface water listed in Table 5–3 are met within an acceptable remediation time frame.

Table 5–3. Surface Water Preliminary Remediation Goals

COC	Utah Surface Water Standard			SDWA	PRG
	Domestic Use 1C	Agricultural Use 4	Aquatic-Wildlife 3A		
Arsenic (µg/L)	50[a]	100	190/360[b]	10	10
Nitrate as N (mg/L)	10	–	4	10	4
Selenium (µg/L)	10	50	5/20[b]	50	5
Gross Alpha (pCi/L)	15	15	15	15	15

[a]The strictest Utah surface water standard for arsenic (50 µg/L) is based on domestic use. It is anticipated that Utah will revise this standard to be consistent with the SDWA by December 1, 2003.
[b]Four-day average/1-hour average.

5.3.3 Area of Attainment

The point of compliance for OU III ground water is defined as that portion of the alluvial aquifer within the boundary of the Millsite and downgradient of the Millsite where concentrations of COCs exceed PRGs. This defined area of attainment assumes the boundary of the contaminant plume is determined by the concentration of COCs relative to PRGs, instead of risk and exposure.

5.3.4 Remediation Time Frame

Remediation time frame depends on conditions at the site as well as the remedial actions employed. The acceptability of remediation time frames associated with different ground water restoration actions may depend on existing use or anticipated future use of the affected ground water. EPA emphasizes that longer time frames are generally not acceptable for restoring ground water that is currently used, or expected to be used, as a source of drinking water (EPA 1996b). Similarly, EPA guidance states that longer time frames may be appropriate for restoring ground waters not expected for use as drinking water in the near term and where alternate sources are available (EPA 1996b). In the case of OU III ground water, although it is classified as Class II–Drinking Water Quality Ground Water, the alluvial aquifer is not presently used, or expected to be used, as a source of drinking water because of limited yield and, under current conditions, legal use restrictions. Also, the Burro Canyon aquifer and municipal supply would be available as alternate water sources.

The consensus among DOE, EPA, and UDEQ is that for a remedial alternative to be retained for detailed analysis, the remediation time frame associated with that alternative should be no longer than 50 yr. For this FFS, the time frames for the various alternatives to reduce the concentrations of COCs to the PRGs range from approximately 42 to 37 yr and were estimated from the results of ground water modeling described in Section 3.0 for the no further action and monitored natural attenuation alternatives and in Section G1.0 of Appendix G for active restoration alternatives.

5.4 Identification and Evaluation of Applicable General Response Actions and Remedial Technologies

This section identifies and evaluates the general response actions (GRAs) and associated remedial technologies and process options that are broadly applicable to OU III ground water. GRAs describe categories of different types of actions that will satisfy RAOs when implemented individually or in combination. Each GRA is associated with one or more applicable technology group. A technology group is further divided into specific methods or "process options" of the technology. For example, interception trenches are process options for extraction technology under an active restoration GRA for ground water. The identification and evaluation process in this FFS emphasizes the nature of contamination (dissolved and sorbed metals), the physical and hydrogeologic characteristics of the site, and existing site infrastructure. The GRAs, technology groups, and process options that are retained by this evaluation are the components of the remedial alternatives assembled and evaluated in Section 5.6.

The GRAs considered for the restoration of OU III ground water, and evaluated through the remainder of this section, are

- No further action
- Institutional action
- Monitored natural attenuation
- Containment
- Active restoration

No Further Action

A true no-action GRA or no-action remedial alternative is not applicable to OU III because an interim remedial action was implemented to mitigate potential risk that included (1) a ground water use restriction, (2) active ground water extraction and treatment during Millsite remediation, and (3) installation of a full-scale PRB to treat contaminated ground water after Millsite remediation. Also, remediation of the Millsite represents extensive source control of OU III ground water and surface water COCs. A no-further-action GRA that incorporates the existing site infrastructure but excludes any further remedial measure is instead applicable. The no-further-action GRA is retained to provide a baseline of comparison for other GRAs and remedial alternatives.

Institutional Action

This GRA consists of an administrative action that is intended to limit exposure to contamination. Such administrative measures or "institutional controls" include land use restrictions, ground water use restrictions, provision of an alternate water supply, and water-quality monitoring. Two institutional controls exist which restrict use of OU III alluvial ground water and thereby prevent exposure to contaminants. The ground water management policy, which was implemented in 1999 as a component of the IRA for OU III, also prohibits domestic use of alluvial ground water on and downgradient of the Millsite. Furthermore, the quitclaim deed for the Millsite prohibits use of any ground water within the boundary of the Millsite for human consumption. A copy of the ground water management policy for OU III ground water use is provided in Appendix B. As an example of land use control, restrictive easements were instituted in 2002 under OU II to prohibit the construction of habitable structures and removal of soil from within the identified easement areas (Section 2.4.2). The restrictive easement limits exposure to soil that was remediated to supplemental cleanup standards. Provision of an alternate water supply, as an institutional action, is not applicable to OU III because the alluvial aquifer is not used for any purpose. Water-quality monitoring of the alluvial aquifer and the underlying Burro Canyon aquifer is ongoing.

A summary of the institutional action GRA is shown in Table 5–4. Options that are retained by this initial screening are indicated as "applicable." Rationale for eliminating a process option at this stage is also provided in the table.

Table 5–4. Institutional Action GRA Summary

Technology	Process Option	Description	Screening Result	Screening Comment
Access restrictions	Deed annotation	Notice of ground water contamination placed on deed	Applicable	Ground water use restrictions (which would be retained) have been implemented for OU III through the Utah Division of Water Rights and the quitclaim deed for the Millsite.
	Ground water use restriction	Official denial of applications to appropriate or divert ground water	Applicable	
	Land purchase	Purchase of land restricts access to ground water	Screened out during IRA	
Alternate water supply	Existing municipal supply	Extend existing infrastructure to affected properties	Not applicable to OU III	The alluvial aquifer is not used for any purpose.
	New community supply	Develop new or currently unused source of uncontaminated water		
Monitoring	Ground water and surface water-quality monitoring	Potential drinking water sources are monitored to prevent exposure to contamination	Applicable	Monitoring of surface water and ground water in the alluvial aquifer and Burro Canyon aquifer is ongoing.

Monitored Natural Attenuation (MNA)

This GRA relies on natural dissipation mechanisms such as dispersion, dilution, and adsorption within an aquifer to reduce contaminant concentrations in ground water. There is no intervention to manipulate the physical, geochemical, or hydrological regime. Comprehensive monitoring is a required component of this GRA to evaluate and verify the progress of natural attenuation, as is a contingency plan that defines the appropriate response action(s) should MNA not ultimately perform as expected (EPA 1999).

Dilution of contaminated alluvial ground water is the primary mechanism responsible for natural attenuation at OU III. This occurs from the recharge and mixing of uncontaminated ground water in the western region of the contaminant plume and from the discharge and mixing of uncontaminated ground water from the Burro Canyon Fm. in the eastern region of the plume. Capture and dilution of contaminated ground water by Montezuma Creek, as the aquifer narrows through the canyon, is also a significant process of natural attenuation at OU III.

This GRA is feasible for OU III because (1) extensive source control measures have been completed, (2) comprehensive ground water and surface water monitoring is ongoing, and recent trends indicate decreasing concentrations of COCs, (3) transport behavior of site COCs has been investigated, (4) hydrogeologic conditions favoring natural attenuation have been identified, (5) numerical modeling predicts that natural attenuation processes will lower the uranium concentration in the aquifer to an acceptable level within the established remedial time frame for the area of attainment, (6) institutional controls restrict ground water use within OU III, and (7) in the absence of the institutional controls, the alluvial aquifer is not used for drinking water; future drinking water use is not likely because the aquifer is relatively unproductive, and reliable alternate drinking water sources are available.

Containment

This GRA includes remedial actions intended to minimize the spread of contamination. Ground water containment is achieved using physical vertical barriers, surface caps, or hydraulic controls (e.g., interception trenches and wells). Containment actions are taken to inhibit further migration of contaminated ground water by encompassing the contaminated ground water or altering its direction of flow. These actions often require extraction and injection technologies to maintain containment effectiveness. A slurry wall is currently used at the site as a vertical barrier containment technology that directs alluvial ground water flow to the PRB.

Containment technologies are otherwise not applicable to OU III because plume expansion is not significant, and there are no additional potential receptors that would be imminently threatened by plume expansion. The observed stability of the OU III contaminant plume and decreasing concentration trends result from extensive source control measures and natural attenuation processes. Additional remedial action involving containment is eliminated from further consideration.

A summary of the containment GRA is shown in Table 5–5. Rationale for eliminating a technology or process option at this stage is also provided in the table.

Table 5–5. Containment GRA Summary

Technology	Process Option	Description	Screening Result	Screening Comment
Capping	Multimedia cap	Low-permeability soil/synthetic membrane cap	Not applicable to OU III	Surface recharge is not a significant factor in controlling ground water movement at OU III.
	Asphalt or concrete cap	Low-permeability slab		
Vertical barriers	Slurry walls	Low-permeable slurry material placed in trench	Not applicable to OU III	Plume expansion requiring containment is not significant at OU III.
	Sheet piling	Concrete, wood, or steel sheets placed into aquifer		
	Grout curtain	Closely spaced injection of low-permeability grout		
	Cryogenic wall	Localized freezing of soil water		
Hydraulic control	Extraction and injection wells	Control hydraulic gradient by simultaneous extraction and injection of ground water	Not applicable as a containment action	
	Interceptor and infiltration trenches			

Active Restoration

This GRA involves remedial actions to directly remove contaminants from the ground water or to immobilize or degrade contaminants to less toxic forms within the aquifer. Removal of contaminated ground water from the subsurface (e.g., using extraction wells) requires subsequent treatment and management of treated water and waste residuals. These processes occur above ground and are termed "ex situ" processes. In contrast, "in situ" processes are available to actively treat ground water entirely in the subsurface. The Monticello PRB is an example of active ground water restoration using in situ treatment technology. Active restoration may also involve injecting water to an aquifer, with or without chemical agents, to enhance contaminant

flushing. For example, surfactants can be been used to mobilize nonaqueous phase organic contaminants to increase mass removal at extraction wells.

The following analysis of the active restoration GRA is organized on the basis of four main components: (1) in situ treatment, (2) ex situ water treatment, (3) ground water collection, and (4) ground water discharge. One or more technologies are available under each of these components, and numerous process options within a technology may be applicable to the site. Accompanying tables present the technologies and process options for the given component and summarize results of the screening process for OU III.

In Situ Ground Water Treatment

Permeable reactive barriers are the only applicable in situ treatment process identified for OU III. Other forms of in situ treatment (e.g., bioremediation, chemically enhanced flushing, air sparging) are not applicable to OU III COCs (see Table 5–6). The Monticello PRB, operational since July 1999, consists of two zones of high-permeability ZVI placed in the path of the contaminant plume. The ZVI was selected to specifically treat OU III COCs as ground water flows through the reactive zones. The geochemical and hydraulic performance of the Monticello PRB has been extensively monitored since installation. Because this technology has been demonstrated at the site, it is retained for consideration as a remedial alternative in Section 5.5.

Trenches and wells are potentially applicable for injecting water for enhanced flushing. Treatability studies would be required to evaluate potential mineralogic and microbial interference with injection. However, enhanced flushing is probably not feasible unless ground water extraction and aboveground treatment technologies are also employed, because surplus water is not available at the site for injection.

Table 5–6. In Situ Treatment Summary

Process Option	Description	Screening Result	Screening Comment
Bioremediation	Injection of microbes or microbe nutrients to initiate, sustain, or accelerate contaminant degradation by metabolic processes	Not applicable to OU III	Applicable primarily to organic contaminants
Chemically enhanced flushing	Addition of chemicals to infiltrating water to alter geochemical conditions and mobilize COCs		
Enhanced flushing without chemical agent	Inject uncontaminated water using injection wells or infiltration trenches to augment natural dilution and dispersion		Surplus water is not available at the site
Air sparging	Inject air into aquifer to gasify contaminants and mobilize gas phase from ground water		OU III COCs will not gasify
Permeable reactive barrier	Emplace stationary reactive material into the aquifer to immobilize COCs	Applicable	Full-scale OU III PRB treatability study operational since July 1999

Ex Situ Ground Water Treatment

Ex situ treatment includes technologies that involve thermal, biological, and physical/chemical processes (Table 5–7) to immobilize contaminants, alter contaminants to nontoxic compounds or less toxic forms, or separate the contaminants from the ground water. Thermal treatment processes (e.g., incineration, pyrolysis) are very expensive, energy intensive, and limited in application to large quantities of toxic and persistent organic compounds and, therefore, are excluded from further consideration for OU III. As with in situ biological treatment, ex situ biological remediation is generally not applicable to the COCs at OU III, and the technology group as a whole is eliminated from further consideration.

Physical/chemical ex situ treatment processes represent a broad range of separation techniques to remove contaminants from ground water without degrading or changing the chemical nature of the contaminants. Some options are generally applicable to organic contaminants only (e.g., air stripping and carbon adsorption [Table 5–7]) and are excluded from further consideration. The remaining options under this remedial technology in Table 5–7 (ion exchange, evaporation, flocculation, filtration, adsorption, sedimentation, precipitation, and oxidation/reduction) are potentially applicable to treatment of inorganic contaminants. Reverse osmosis (a filtration process) and activated alumina adsorption were used in the treatment of contaminated ground water that was extracted from March 1998 to May 1999 (Section 2.5) during Millsite remediation. Another example of physical/chemical treatment that has been demonstrated at the site is the removal of COCs from ground water using ZVI, which is the reactive medium in the Monticello PRB. Removal of uranium by ZVI is largely due to reductive precipitation (DOE 2000f). ZVI has potential application for both in situ and ex situ treatment.

Evaporation is retained as a treatment option. An evaporation pond of sufficient capacity (Pond 4) is located about 1 mile south of the PRB (Figure 5–1). Pond 4 is used to contain water and leachate removed from the MMTS tailings-repository leachate-collection system and leak-detection system. It was also used to collect surface runoff during tailings placement and for temporary storage of ground water that was extracted during Millsite remediation. Pond 4 was connected to a temporary pond (Pond 3) and ultimately to the water treatment plant on the Millsite by a temporary pipeline. The temporary pipeline and Pond 3 were removed as part of the remedial action effort.

Pond 4 was designed to function for long-term use as an evaporation pond. It is triple-lined and has a capacity of 11 million gallons above the anticipated volume derived from tailings drainage (7 million gallons). The pond is expected to remain in use for 20 yr, depending on leachate flow from the repository. DOE will continue to monitor Pond 4 performance using on-site staff throughout the operational period of the pond. Pond 4 will be decommissioned when liquid draining from the repository becomes minimal or ceases.

Relative to solar evaporative treatment using Pond 4, the remaining applicable process options have high costs to implement, operate, and maintain. The associated costs, in addition to a potentially longer schedule to implement, would be avoided by using solar evaporation at Pond 4. Furthermore, none of the options offer distinct technical advantage over solar evaporation, which can effectively treat all COCs as a single process. For these reasons, all ex situ treatment processes except solar evaporation at Pond 4 are eliminated from further

consideration. Use of Pond 4 would potentially require installing a pipeline from the pond to the alluvial aquifer.

Table 5–7. Ex Situ Treatment Summary

Technology	Process Option	Description	Screening Result	Screening Comment
Thermal treatment	Incineration, pyrolysis, vitrification	Contaminant destruction by high temperature oxidation or starved-air conditions or immobilization in molten matrix	Not applicable to OU III	Disproportionate and prohibitive cost and energy requirements relative to magnitude of potential risk posed by OU III COCs
Biological treatment	Aerobic	Degradation of contaminants by microbial metabolic processes in the presence of oxygen	Not applicable to OU III	Applicable primarily to organic contaminants
	Anaerobic	Degradation of contaminants by microbial metabolic processes in the absence of oxygen		
Physical/chemical treatment	Solar evaporation	Dissolved and suspended COCs concentrate in liquid phase during evaporation	Applicable	An adequate evaporation pond is available at the site; evaporation can treat all site COCs in a single low-cost/low-maintenance process
	Ion exchange	Chemical exchange of contaminant ion for benign ion on activated resins	Potentially applicable; not cost-effective and no technical advantage relative to solar evaporation	
	Flocculation	Chemical coagulation of dissolved and suspended COCs		
	Filtration (reverse osmosis, microfiltration, media filtration)	Separation processes to remove different particle sizes from solution		
	Distillation	Dissolved and suspended COCs partition to liquid phase during vaporization; vapor is condensed yielding uncontaminated water		
	Sedimentation	Gravity settling of sediments, precipitates, and flocculates		
	Chemical precipitation	Chemical additives induce COCs to precipitate into crystalline form		
	Oxidation/ reduction	Oxidation state of contaminant is altered, reacts to form benign compound		
	Air stripping	Aerate water to induce volatilization of contaminants	Not applicable to OU III	Applicability limited to organic compounds
	Carbon adsorption	Removal of dissolved COCs by adsorption onto granular activated carbon		

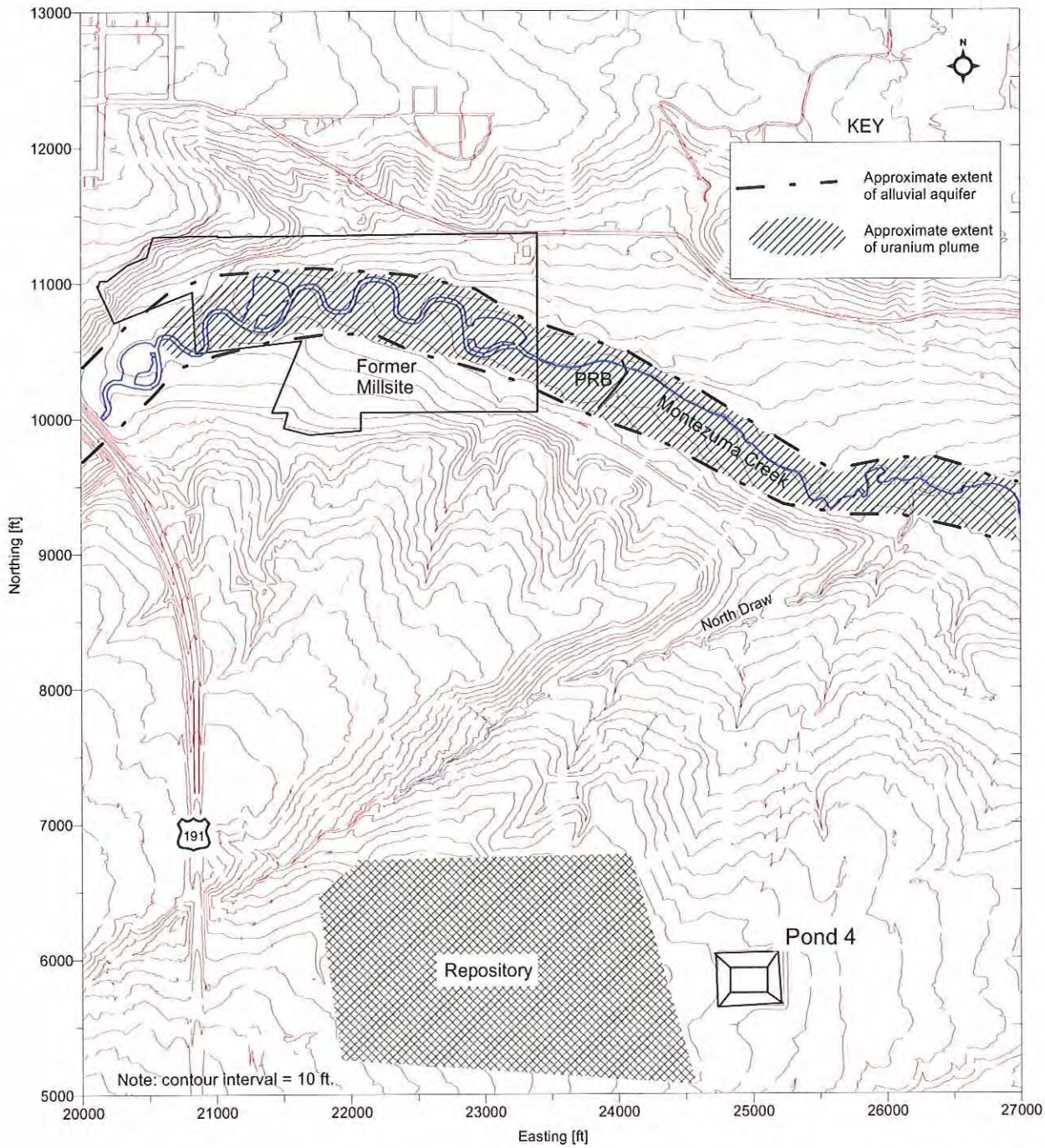

Figure 5–1. Location of Pond 4

Ground Water Collection

Applicable process options under this technology are extraction wells and interceptor trenches (Table 5–8). An extraction well consists of a vertical conduit with a slotted or open interval below the water table; a pump is used to withdraw ground water. Interceptor trenches function by using a pump to withdraw ground water from a trench that has been installed to intersect the water table. Ground water collection is facilitated by optionally installing horizontal perforated

piping into the trench that is backfilled with high-permeability material. OU III site conditions are amenable to extraction wells and interceptor trenches. A properly constructed interceptor trench placed at the base of the aquifer is potentially more effective than ground water extraction using wells because complete capture using wells is less likely. Ground water extraction using wells may require more surface installations that interfere with land use, whereas trenches may create greater initial disturbances. Both options have been employed in prior site activities and are retained for further consideration.

Table 5–8. Ground Water Collection Summary

Technology	Process Option	Description	Screening Result
Ground water collection	Extraction wells	Single or multiple vertical wells to extract ground water using mechanical pumps	Applicable
	Interceptor trenches	Ground water collection in a closed, permeable trench from which ground water is extracted using mechanical pumps	Applicable

Discharge of Treated Water

Ground Water Injection

Trenches and wells are potentially applicable at OU III for injecting ground water following ex situ treatment by all options except solar evaporation. Injection would occur by falling head pressure of the injectate. Injection of treated ground water at strategic locations could enhance contaminant flushing in the aquifer. Subsurface injection requires permits and treatability studies to evaluate potential well fouling by mineral or biological matter. However, ground water injection is eliminated from further consideration because all ex situ treatment options requiring discharge have also been eliminated.

On-Site Discharge

On-site discharge of treated water to Montezuma Creek is feasible. This option was employed by the water treatment operation during Millsite remediation (excavation dewatering and treatment). However, because all ex situ treatment options requiring discharge have been eliminated from further consideration, surface discharge is also eliminated.

5.5 Develop and Screen Potential Remedial Action Alternatives

The GRAs, technologies, and process options retained from the identification and initial screening process documented in Section 5.4 resulted in the assembly of six remedial action alternatives:

- Alternative 1: No Further Action With Institutional Controls
- Alternative 2: MNA With Institutional Controls
- Alternative 3: PRB With Institutional Controls and MNA

- Alternative 4: Enhanced PRB With Institutional Controls and MNA
- Alternative 5: Ground Water Hot-Spot Extraction and Evaporative Treatment With Institutional Controls, PRB, and MNA
- Alternative 6: Ground Water Plume Extraction and Evaporative Treatment With Institutional Controls, PRB, and MNA

Each alternative is intended to represent a valid conceptual approach to remedial action rather than a specific design. The alternatives are described separately in Sections 5.5.1 through 5.5.6 on the basis of

- Conceptual design.
- Remediation time frame.
- Scale of operation.
- Administrative and technical issues.

All alternatives will include eventual decommissioning of the PRB. This will involve excavation and disposal of the ZVI at a suitable repository, and restoration of the disturbed property, each in compliance with ARARs. The time of decommissioning is addressed as a design component for each alternative described below. For the purpose of this FFS, the PRB is assumed to remain effective indefinitely.

Another component common to each alternative is a contingency plan to define appropriate response action(s) and the criteria that would initiate such action(s), should the selected remedy not perform as anticipated. This may be particularly relevant to OU III because all but Alternative 1 incorporate MNA that is supported primarily by predictive analysis, or innovative PRB technology. The contingency plan will be identified in the ROD.

Section 5.5.7 of this report provides a summary of the components of the six potential remedial alternatives in table form. Section 5.5.8 then presents a screening evaluation in which the potential alternatives are compared on the basis of relative overall effectiveness in attaining RAOs, ease of implementation considering technical and administrative requirements, and relative monetary cost. The remedial alternatives with the highest potential for success are analyzed in detail in Section 5.6.

5.5.1 Alternative 1: No Further Action With Institutional Controls

Alternative 1 was developed from the NCP provision that requires consideration of a limited or no action response to serve as a baseline for evaluating other remedial alternatives.

Conceptual Design

The current status of the site includes a ground water use restriction and a functioning PRB that was implemented under the IRA to mitigate potential risk. A comprehensive ground water and surface water monitoring program is also in effect. To best represent a minimum-action alternative, Alternative 1 incorporates the existing institutional controls but excludes additional treatment effects of the PRB. Under this alternative, the ROD for OU III would terminate the PRB treatability study, and the PRB would be decommissioned as soon as possible thereafter. Removal of the PRB would alleviate DOE of all future obligations associated with operating the

PRB. Water-quality monitoring would continue at a much-reduced level of effort, due in part to the elimination of PRB monitoring, relative to the remaining remedial alternatives and current scope. Monitoring conducted under Alternative 1 would (1) determine when PRGs were attained and when the ground water management policy institutional control could be terminated and (2) assess changes in site conditions that could require future remedial actions.

Remediation Time Frame

On the basis of ground water modeling (Section 3.0) and observed trends, the estimated time for the no further action alternative to reduce concentrations of COCs to PRGs is 42 yr (since October 2002). The modeling result assumes that the PRB has no current and future effect in immobilizing site COCs.

Administrative and Technical Requirements

Administrative requirements for a no further action alternative include continued, but reduced-scope, long-term monitoring and continued enforcement of the existing institutional controls. Monitoring would require continued access to the former Millsite (owned by the City of Monticello) and to peripheral properties downgradient of the Millsite. Coordination with property owners would be necessary to establish access rights to conduct monitoring. The operational period for conducting monitoring for this alternative is assumed to be 40 yr, starting October 2004. Administrative requirements of this institutional control would involve coordination and information exchange with regulatory agencies and enforcement authorities until PRGs are attained. Because there is no time allowance for COCs to exceed PRGs, administrative implementation of this alternative may be complex.

Decommissioning the PRB represents added technical and administrative requirements because of a prior commitment to remove the PRB, regardless of the selected remedial alternative, when its operation is no longer necessary. The PRB is located on a 1-acre parcel leased by DOE from the property owner through April 2039. Technical and administrative concerns regarding PRB decommissioning are physical removal methods, compliance with ARARs, and the appropriate method for disposal of PRB materials.

Summary

The primary components of Alternative 1 are

- Institutional controls (enforce existing ground water use restrictions).
- 42-yr predicted remediation time frame.
- Reduced-scope water-quality monitoring; no PRB performance monitoring.
- Near-term decommissioning of the PRB.
- Contingency plan.
- CERCLA 5-year review.

5.5.2 Alternative 2: MNA With Institutional Controls

Conceptual Design

Alternative 2 allows for natural geochemical and hydrological processes to dissipate COC concentrations in ground water to PRGs within the established remediation time frame. Alternative 2 includes ground water and surface water monitoring (water quality analysis, water level monitoring, and stream flow monitoring) and continued enforcement of the existing institutional controls. This remedial strategy differs from Alternative 1 in that, through prior site investigation, natural attenuation processes are documented and can be reasonably expected to attain PRGs within the established remediation time frame. Also, ground water and surface water monitoring is much more comprehensive than in Alternative 1 and is conducted to verify and compare the progress of MNA to predicted restoration rates.

Performance monitoring of the PRB would continue in order to demonstrate no negative effect on ground water quality (effluent COC concentrations exceed influent concentrations) or excessive ground water mounding that could adversely effect land use. The PRB would be decommissioned when either of these indicators of failure occurred or when continued treatment provides only marginal benefit. This approach maximizes the benefit of the PRB without mandating a remedy for the PRB, other than removal, in the event of its failure.

Scale of Operation

This alternative involves continued comprehensive monitoring of the contaminant plume throughout the existing OU III monitoring network until PRGs are attained (the OU III ground water and surface water monitoring network is shown on Figures 2–7and 2–8). The maximum extent of contamination, represented by the present uranium plume, includes most of the Millsite and downgradient of the Millsite for a distance of approximately 4,000 ft (see Figure 1–2). Monitoring results would be evaluated and reported in annual and CERCLA 5-year review documents. As concentrations decrease over time, the extent of monitoring and area where ground water use restrictions apply could be reduced.

Remediation Time Frame

On the basis of ground water modeling (Section 3.0) and observed trends, the estimated remediation time frame for Alternative 2 is 42 yr (since October 2002). The modeling result assumes that the PRB has no current and future effect in immobilizing site COCs.

Administrative and Technical Requirements

The administrative and technical requirements of Alternative 2 are the same as for Alternative 1; however, the more comprehensive monitoring requirements for Alternative 2 may involve more wells and greater monitoring frequency than Alternative 1 and, therefore, more involvement with property owners. Also, the PRB would likely be decommissioned at a later date than in Alternative 1.

Summary

The primary components of Alternative 2 are

- Institutional controls (enforce existing ground water use restrictions).
- 42-yr predicted remediation time frame.
- Comprehensive monitoring to verify MNA and to monitor PRB performance.
- Discretionary operation of the PRB as long as treatment is effective.
- Decommission the PRB upon PRB failure or when continued treatment provides only marginal benefit.
- Contingency plan.
- CERCLA 5-year review.

5.5.3 Alternative 3: PRB With Institutional Controls and MNA

The Monticello PRB is currently effective in immobilizing COCs and is estimated to operate effectively for up to a 15-yr period that began in July 1999. After that time, it is expected that ground water inflow to the PRB will be less contaminated as a result of natural flushing of the plume.

Conceptual Design

This alternative relies on (1) the PRB to effectively treat COCs in upgradient ground water entering the PRB, (2) MNA for ground water downgradient of the PRB (effluent from the PRB will enhance MNA in this region), and (3) enforcement of the existing institutional controls. Comprehensive ground water and surface water monitoring will continue to verify effective treatment of the ground water by the PRB and to verify the progress of MNA. The PRB will be decommissioned when the existing COC plume has passed the PRB and when potential sources of ground water contamination above PRGs on the Millsite are no longer significant.

Scale of Operation

The operational scale of Alternative 3 and Alternative 2 are the same except that the operational period for this alternative is assumed to be 40 yr.

Remediation Time Frame

On the basis of ground water modeling (Section G1.0 of Appendix G) and observed trends, the estimated time for Alternative 3 to reduce the concentrations of COCs in the alluvial ground water to the PRGs is 40 yr (since October 2002). The modeling results assume that the PRB is effective in immobilizing uranium in the ground water.

Administrative and Technical Requirements

The administrative and technical requirements of Alternative 3 are the same as for Alternative 2; however, the PRB may be decommissioned at a different time.

Summary

The primary components of Alternative 3 are

- Institutional controls (enforce existing ground water use restrictions).
- 40-yr predicted remediation time frame.
- Comprehensive monitoring to verify MNA and to monitor PRB performance.
- Effective operation of the PRB until the COC plume has passed the PRB and when potential sources of ground water contamination above PRGs on the Millsite are no longer significant.
- Decommission the PRB when appropriate (no further treatment required or system failure).
- Contingency plan.
- CERCLA 5-year review.

5.5.4 Alternative 4: Enhanced PRB With Institutional Controls and MNA

Conceptual Design

This alternative uses the PRB as described in Alternative 3, with the addition of components to reduce the quantity of contaminated ground water that presently flows around the south slurry wall of the PRB and bypasses treatment. The following two process options (enhancements) are considered: Option 1: extraction of the bypass flow and treatment at the PRB; Option 2: emplacing ZVI to accomplish in situ treatment within the bypass zone.

Alternative 4 relies on (1) the PRB with an enhancement to treat COCs in upgradient ground water entering the PRB, (2) MNA for that portion of the aquifer downgradient of the PRB, and (3) enforcement of the existing institutional controls. Comprehensive ground water and surface water monitoring will continue to verify effective treatment of the ground water by the PRB plus enhancement and to verify the progress of MNA. The PRB and enhancement will be decommissioned when the existing COC plume has passed the PRB and when potential sources of ground water contamination above PRGs on the Millsite are no longer significant.

Scale of Operation

The depth to bedrock in the bypass zone is approximately 35 ft. About 2 ft of saturated alluvium overlies the bedrock, and the width of the bypass zone (between the end of the slurry wall and southern extent of saturated alluvium) is approximately 40 ft. Ground water flow through this zone is estimated to be less than 5 gpm.

Option 1 consists of installing three extraction wells in the bypass zone. Because of the depth to bedrock, extraction wells were considered more practical than a trench for water extraction. Ground water would be extracted and piped to the PRB for distribution along the top surface of the gravel/ZVI zone or the 100-percent ZVI zone for subsequent treatment. The top of the PRB is about 3 ft below ground surface. Option 2 consists of completing an array of 10 to 20 large-diameter boreholes that extend to bedrock in the bypass zone. Each borehole would be backfilled from the bedrock with a 10 ft column of ZVI or ZVI/gravel mix. Option 2 is the potentially advantageous enhancement because its implementation and operation would be independent of the existing ZVI treatment zone. Alternative 4 may require installation of a limited number of small-diameter observation wells to monitor performance of the enhancement.

The operational scale of Alternative 4 is marginally greater than that of Alternative 3 because of additional monitoring requirements and operation and maintenance requirements for Option 1. However, the operational period of Alternative 4 may be slightly shorter (1 to 2 yr, see "Remediation Time Frame") because of the effect of the selected enhancement. Otherwise, the scope of water-quality monitoring and reporting requirements are identical to those of Alternative 3. Figures 5–2 and 5–3 show the general size and configuration of Options 1 and 2, respectively.

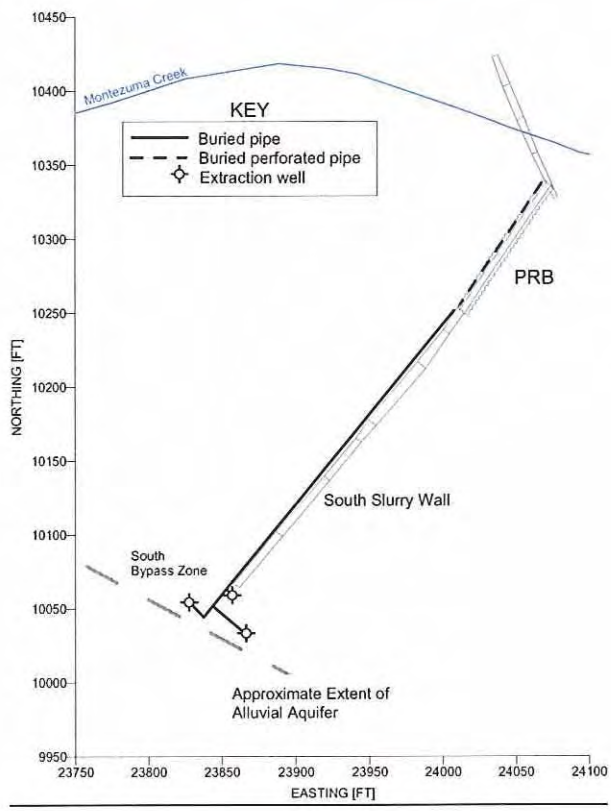

Figure 5–2. Conceptual Design of Alternative 4, Option 1

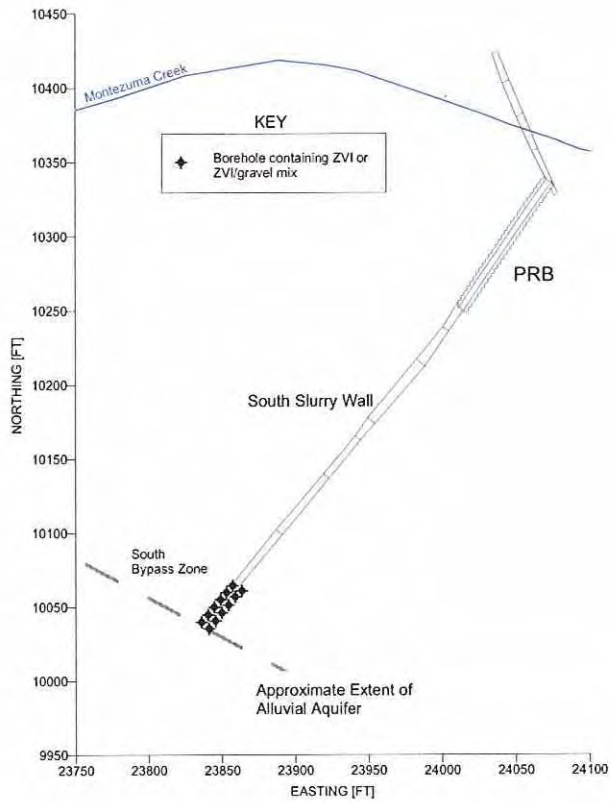

Figure 5–3. Conceptual Design of Alternative 4, Option 2

Remediation Time Frame

On the basis of ground water modeling (Section G1.0 of Appendix G) and observed trends, the estimated time required (since October 2002) for Alternative 4 to reduce COCs to the PRGs is 39 and 38 yr for Options 1 and 2, respectively. The model predictions assume 50-percent capture and treatment efficiency of the enhancements.

Administrative and Technical Requirements

There are no physical limitations to installing the PRB enhancements; however, it is unknown if the lease area is sufficient to install an effective enhancement. Otherwise, the general technical and administrative requirements of Alternative 4, Options 1 and 2, are still slightly greater than for Alternative 3.

Summary

The primary components of Alternative 4 are

- Institutional controls (enforce existing ground water use restrictions).
- 39-yr predicted remediation time frame (Option 1, 50-percent capture of bypass flow).
- 38-yr predicted remediation time frame (Option 2, 50-percent treatment of bypass flow).

- Comprehensive monitoring to verify MNA and to monitor PRB plus enhancement performance.
- Effective operation of the PRB and enhancement until the COC plume has passed the PRB and when potential sources of ground water contamination above PRGs on the Millsite are no longer significant.
- Decommission the PRB and enhancement when appropriate (no further treatment required or system failure).
- Contingency plan.
- CERCLA 5-year review.

5.5.5 Alternative 5: Ground Water Hot Spot Extraction and Evaporative Treatment With Institutional Controls, MNA, and PRB

Conceptual Design

This alternative includes the continued use of the institutional controls, MNA, and the PRB, as described in Alternative 3, plus ground water extraction in a limited area (less than 2 acres) of maximum uranium concentration (hot spot) using extraction wells and treating the water by solar evaporation at Pond 4. Because of the depth to bedrock in the hot-spot area (> 30 ft) and more invasive nature, trenches were considered less practical for ground water extraction than wells. Ground water from the extraction wells would be pumped to a collection tank and conveyed to Pond 4 by truck or pipeline. Hot-spot extraction and treatment would continue for 10 yr, at which time uranium concentrations in the hot-spot area are assumed to become insignificant. The alternative does not rely on the potential capacity of the PRB to treat ground water extracted from the wells.

Scale of Operation

The hot spot identified for this alternative occupies the general area at and immediately downgradient of the south slurry wall bypass zone. At present, the extent of the hot spot is poorly defined, and additional field investigation would be required to characterize uranium distribution in this portion of the plume. Results of the investigation may determine that the magnitude of the hot spot does not justify extraction and treatment. Figure 5–4 presents a schematic of the configuration of Alternative 5. Ten wells are assumed to extract ground water at a sustained total rate of 10 gpm. Extracted water would be pumped in underground piping to an on-site collection tank. Assuming a 20,000-gallon mobile storage tank would be used if ground water were transported to Pond 4 by truck, this option would require daily transport of ground water to Pond 4. During the winter months, a heated tank or tank enclosure would be required. Ground water transport to Pond 4 via pipeline would permit use of a much smaller collection tank (e.g., 5,000 gallons), equipped with high- and low-level pump control sensors, but this option would also require a heated enclosure for the tank and transfer pump and construction of approximately 1-mile of underground pipeline.

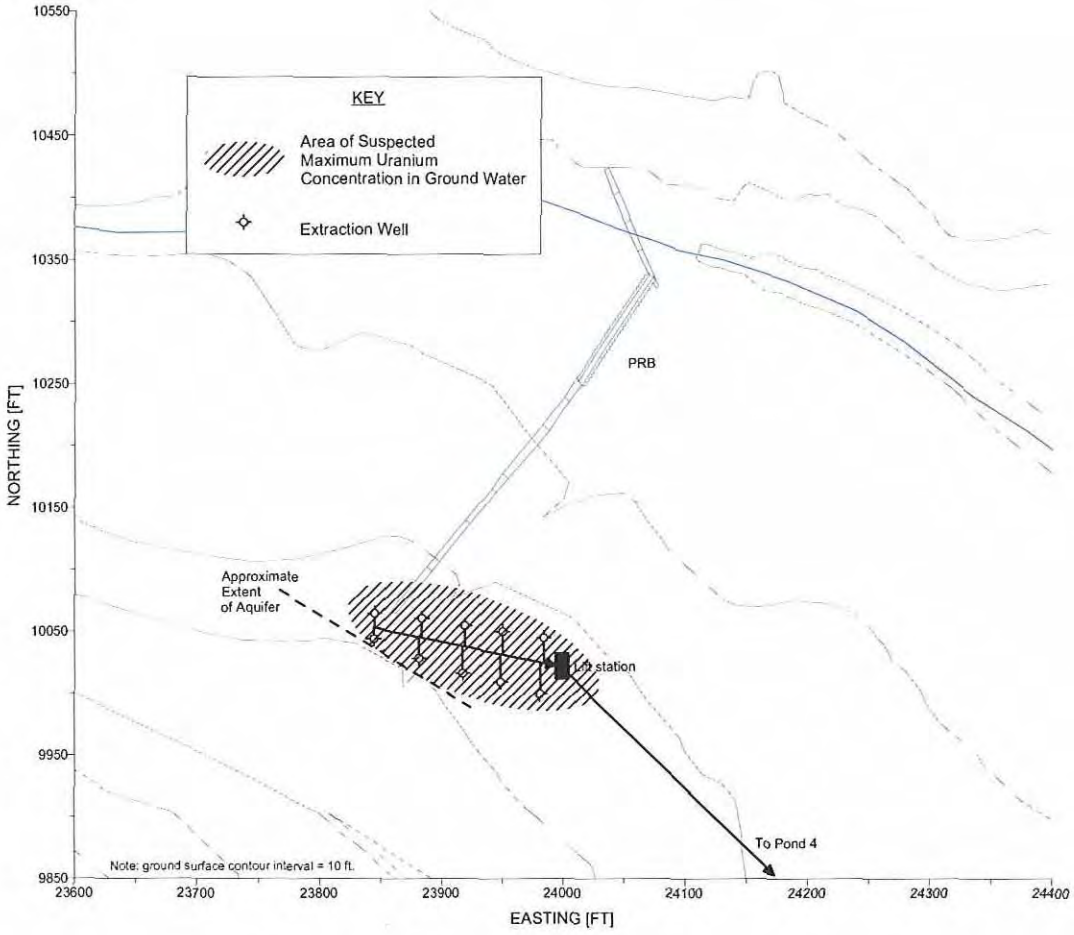

Figure 5–4. Conceptual Design of Alternative 5

The operational scale of Alternative 5 is much greater than for each previous alternative, primarily because of the installation, operation, and maintenance of extraction wells and the transfer system (water truck or pipeline with pump station). Furthermore, the predicted overall time to meet PRGs (37 yr) is not shortened in proportion to the increased level of effort and cost to implement this alternative. Additional monitoring for this alternative would consist of monitoring the individual extraction wells and the combined feed to the collection system.

Remediation Time Frame

The estimated time for Alternative 5 to reduce the COCs to the PRGs is 37 yr (since October 2002) based on the assumption that hot-spot extraction at the location described above has the same effect as Alternative 4 with an in situ treatment enhancement that is 100 percent efficient (see Section G1.0 of Appendix G for ground water modeling summary for Alternatives 3 and 4).

Administrative and Technical Requirements

Administrative requirements for Alternative 5 are

- Procure services to transport contaminated ground water by truck to Pond 4.
- Obtain permission from landowners to install, operate, and maintain the hot-spot system.
- Comply with additional ARARs associated with installing, operating, and decommissioning the hot-spot treatment system.
- Dispose of a small addition to the existing volume of waste solids in Pond 4.

Implementing hot-spot remediation is technically feasible. Additional technical requirements applicable to Alternative 5 are

- Additional field investigation to better define the uranium hot spot.
- Design, construct, and ultimately decommission the extraction system, collection system, and pipeline transfer system.
- Operation and maintenance of extraction wells and pumping systems.

Summary

The primary components of Alternative 5 are

- Institutional controls (enforce existing ground water use restrictions).
- 37-yr predicted remediation time frame.
- Comprehensive monitoring to verify MNA and to monitor PRB and pump-and-treat performance.
- Ground water extraction with 10 wells in the hot-spot area and evaporative treatment at Pond 4 for approximately 10 yr.
- Decommission the hot-spot remediation system.
- Effective operation of the PRB until the COC plume has passed the PRB and when potential sources of ground water contamination above PRGs on the Millsite are no longer significant.
- Decommission the PRB and enhancement when appropriate (no further treatment required or system failure).
- Contingency plan.
- CERCLA 5-year review.

5.5.6 Alternative 6: Ground Water Plume Extraction and Evaporative Treatment With Institutional Controls, PRB, and MNA

Conceptual Design

This alternative includes the continued use of the institutional controls, MNA, the PRB, and ground water extraction and treatment as described in Alternative 5; however, the scale of operation would expand to extract ground water within the general area of the COC plume where uranium concentrations exceed 200 µg/L. Ground water transport to Pond 4 would be by underground pipeline. Plume extraction and treatment by this alternative is assumed to operate for 10 yr.

Scale of Operation

Figure 5–5 presents a schematic of the configuration of Alternative 6. Twenty wells are assumed to extract ground water at a sustained total rate of 10 gpm during the 10-yr period, although the initial bulk rate may be higher (50 to 75 gpm) as ground water is released from storage. The scale of operation would increase compared to Alternative 5 in proportion to the added number of wells requiring operation, maintenance, monitoring, and decommissioning. Additional properties and property owners would be affected.

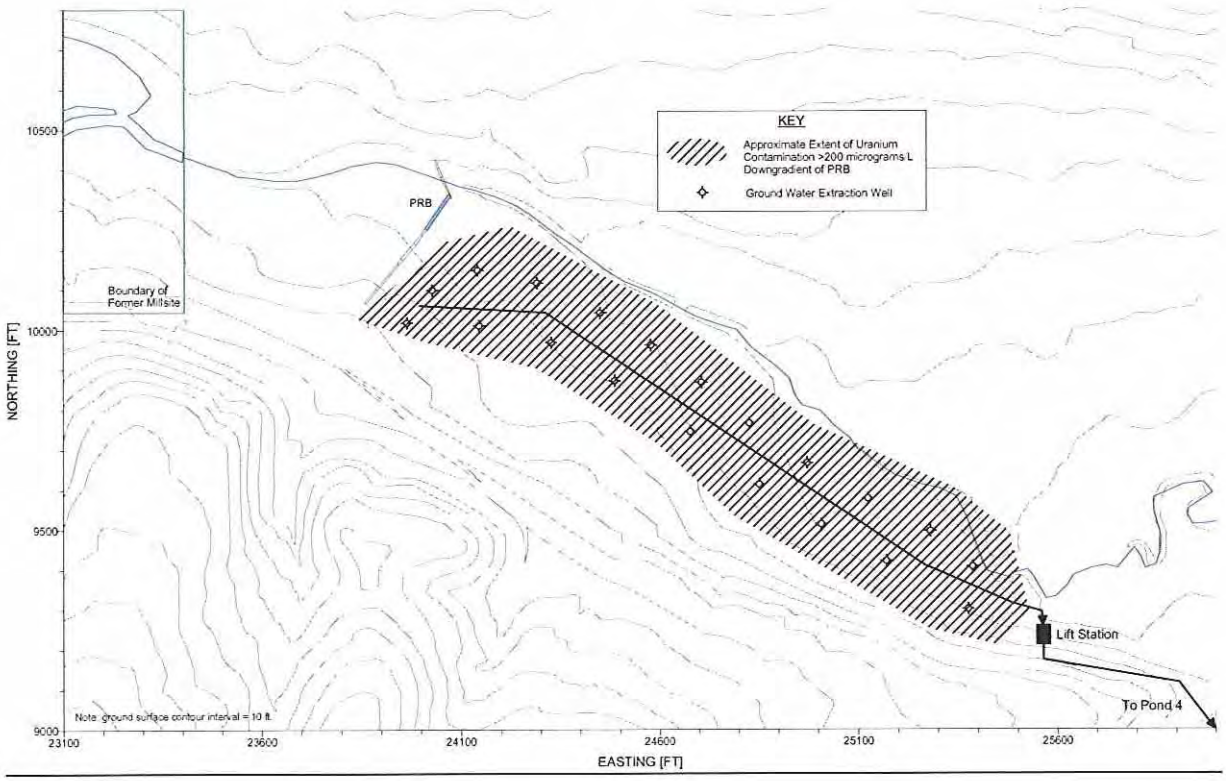

Figure 5–5. Conceptual Design of Alternative 6

Remediation Time Frame

Extensive pumping of the contaminant plume is not likely to reduce the restoration period for OU III ground water significantly because (1) multiple pore volumes are required to flush sorbed COCs from the aquifer and (2) extraction rates necessary to accelerate contaminant flushing may not be sustainable. Initial high pumping rates as ground water is released from storage will stabilize at a lower, total rate equal to the ambient underflow rate (approximately 10 gpm). COC mass removal at this extraction rate can potentially reduce the restoration period, but the effect will be limited by persistent desorption of uranium and the inability to capture all of the contaminated ground water.

Administrative and Technical Requirements

Administrative and technical requirements for Alternative 6 are identical to those for Alternative 5 except that the increased area of the extraction system would affect additional private properties.

Summary

The primary components of Alternative 6 are

- Institutional controls (enforce existing ground water use restrictions).
- Comprehensive monitoring to verify MNA and to monitor PRB and pump-and-treat performance.
- Ground water extraction at 20 wells and evaporative treatment at Pond 4 for 10 yr.
- Decommission the plume remediation system.
- Effective operation of the PRB until the COC plume has passed the PRB and when potential sources of ground water contamination above PRGs on the Millsite are no longer significant.
- Decommission the PRB and enhancement when appropriate (no further treatment required or system failure).
- Contingency plan.
- CERCLA 5-year review.

5.5.7 Summary of Potential Remedial Alternatives

A summary of the main components of the six potential remedial alternatives described in Section 5.5.6 is presented in Table 5–9. The summary table provides a reference for the screening evaluation presented in Section 5.5.8.

5.5.8 Screening Evaluation of Potential Remedial Alternatives

This section presents a screening evaluation in which each of the six potential remedial alternatives is compared against the others on the basis of (1) relative overall effectiveness in attaining RAOs, (2) technical and administrative issues, and (3) cost. Screening results are described below and a summary is presented in Table 5–10. Alternatives retained from this screening are evaluated in detail in Section 5.6.

Effectiveness

On the basis of ground water modeling and observed concentration trends, each alternative is effective in attaining the RAOs within the established remediation time frame for OU III. The estimated time frames do not decrease significantly as the intensity of the response action increases.

Administrative Issues

Continued enforcement of the existing institutional controls restricting ground water use is included in each alternative to prevent exposure to contaminated ground water until PRGs are

attained. In general, administrative complexity increases with the intensity of the response action, mainly because the corresponding level of landowner involvement also increases.

Table 5–9. Summary of the Six Potential Remedial Alternatives

Alternative	Component						
	Water-Quality Monitoring	Institutional Controls	Remediation Time Allowance	PRB Treatment	PRB Decommission	Additional Remedial Technology	Comment
1. No Further Action	yes	yes	no	no	yes	no	Reduced-scope water-quality monitoring to detect gross changes in site conditions. Continued enforcement of existing institutional controls to restrict use of alluvial ground water. Decommission PRB in 2006.
2. MNA with institutional controls	yes	yes	yes	no	yes	no	Comprehensive water-quality monitoring to verify remediation progress (includes PRB monitoring). Continued enforcement of existing institutional controls to restrict use of alluvial ground water. Remediation time allowance does not account for PRB treatment. PRB is decommissioned upon failure or when no longer needed.
3. PRB with MNA and institutional controls	yes	yes	yes	yes	yes	no	Comprehensive water-quality monitoring to verify remediation progress (includes PRB monitoring). Continued enforcement of existing institutional controls to restrict use of alluvial ground water. Remediation time allowance requires PRB treatment. PRB is assumed effective to 2015 then decommissioned.
4. Enhanced PRB, two options with MNA and institutional controls	yes	yes	yes	yes	yes	yes	Implement enhancement to PRB. Comprehensive water-quality monitoring to verify remediation progress (includes expanded PRB monitoring). Continued enforcement of existing institutional controls to restrict use of alluvial ground water. Remediation time allowance requires enhanced PRB treatment. PRB with treatment enhancement is assumed effective to 2015 then decommissioned.
5. Hot-spot ground water extraction with evaporative treatment, MNA, institutional controls, and PRB	yes	yes	yes	yes	yes	yes	Implement pump-and-treat technology for local hot-spot remediation for 10 yr. Comprehensive water-quality monitoring to verify remediation progress (includes PRB and pump-and-treat system monitoring). Continued enforcement of existing institutional controls to restrict use of alluvial ground water. Remediation time allowance requires evaporative and PRB treatment. PRB (without treatment enhancement) is assumed effective to 2015 then decommissioned. Decommission pump-and-treat system after 10 yr.
6. Plume extraction with evaporative treatment, MNA, institutional controls, and PRB	yes	yes	yes	yes	yes	yes	Implement plume-wide pump-and-treat technology for 10 yr. Comprehensive water-quality monitoring to verify remediation progress (includes PRB and pump-and-treat system monitoring). Continued enforcement of existing institutional controls to restrict use of alluvial ground water. Remediation time allowance requires evaporative and PRB treatment. PRB (without treatment enhancement) is assumed effective to 2015 then decommissioned. Decommission pump-and-treat system after 10 yr.

Table 5–10. Summary of Alternatives Screening Evaluation

Potential Alternative	Attain PRGs in Acceptable Time Frame	Relative Complexity of Implementation		Relative Cost	Retain for Detailed Analysis
		Administrative	Technical		
1. No further action with institutional controls	Effective	Moderate	Least	Lowest	Yes
2. MNA with institutional controls	Effective	Least	Least	Low-Moderate	Yes
3. PRB with institutional controls and MNA	Effective	Least	Least	Low-Moderate	Yes
4. Enhanced PRB with institutional controls and MNA	Effective	Low-Moderate	Low-Moderate	Low-Moderate	Yes
5. Hot-spot pump and treat with institutional controls and MNA	Effective	Higher	Higher	High	No; higher cost with little technical advantage
6. Plume pump and treat with institutional controls and MNA	Effective	Highest	Highest	Highest	No; higher cost with little technical advantage

Technical Issues

Each potential alternative is technically feasible for OU III. The ranking for technical complexity in Table 5–10 reflects the increasing relative level of effort to design, construct, and operate and maintain the remedial systems.

Relative Cost Comparison

The remediation time for Alternatives 1 and 2 are identical, however, Alternative 2 is more costly because of the more comprehensive monitoring requirements. The costs of Alternatives 2, 3, and 4 are considered to be approximately equal. This assumes that the cost savings realized as fewer monitoring events within the progressively shorter remediation times for Alternatives 3 and 4 is balanced by the increased scope of the monitoring per event and, for Alternative 4, the added cost of implementing and operating either enhancement.

The costs associated with Alternatives 5 and 6 (capital, operation and maintenance, and monitoring) are much greater than the costs for the other alternatives. These costs are not expected to be offset by a proportional decrease in the remediation time for Alternatives 5 and 6.

5.6 Detailed Analysis of Remedial Action Alternatives

This section documents the detailed analysis of the remedial alternatives retained from the screening evaluation presented in Section 5.5. The final alternatives considered for OU III ground water remediation are

- Alternative 1: No Further Action With Institutional Controls
- Alternative 2: MNA With Institutional Controls
- Alternative 3: PRB With Institutional Controls and MNA
- Alternative 4: Enhanced PRB With Institutional Controls and MNA

For all actions, except Alternative 1, ground water concentration data will be compared to predicted results. If the performance of the remedy deviates from the expected results, an evaluation of the need for contingency actions will be completed. Example contingency measures potentially applicable to OU III are replacement or rejuvenation of the PRB if its operational effectiveness fails and RAOs are compromised.

The detailed analysis is based on evaluating each alternative against the nine evaluation criteria (EPA 1988) listed in Table 5–11. This draft final FFS does not include an evaluation of State Acceptance and Community Acceptance. Evaluation of the State Acceptance will be included in the ROD. Evaluation of Community Acceptance will also be included in the ROD and will be based on comments made at the public meeting when the Proposed Plan is presented and written comments submitted during the public comment period. A Responsiveness Summary addressing all comments will be published with the ROD.

Table 5–11. Detailed Analysis Evaluation Criteria

Threshold Criteria: remedial alternative must meet threshold criteria

1. Overall protection of human health and the environment: *remedy must be protective of human health and the environment as defined by site RAOs.*
2. Compliance with ARARs: *remedy must comply with state and federal regulations or a waiver of noncompliance must be obtained.*

Balancing Criteria: remedial alternative must consider the balancing criteria

1. Long-term effectiveness and permanence: *assesses the magnitude of residual risk and the adequacy of physical and administrative components of the remedy to provide long-term risk reduction after RAOs are met.*
2. Reduction of toxicity, mobility, and volume of contaminants through treatment: *assesses the degree to which the remedy will reduce the toxicity, mobility, and volume of the principal hazards through treatment.*
3. Short-term effectiveness: *assesses the protection of workers, community, and environment while the remedy is implemented.*
4. Implementability: *assesses how technical, administrative, or resource requirements affect implementation of the remedy.*
5. Cost: *assesses the capital, operating, and maintenance costs, and net present value of the remedy throughout its operational period.*

Modifying Criteria: remedial alternative must consider the modifying criteria

1. State acceptance of remedial alternatives (evaluated in the ROD).
2. Community acceptance of remedial alternatives (evaluated in the ROD after public comment on the Proposed Plan).

5.6.1 Alternative 1: No Further Action With Institutional Controls

The primary components of Alternative 1 are

- Institutional actions (enforce existing ground water use restrictions).
- 42-yr predicted remediation time frame.
- Reduced-scope water-quality monitoring, no PRB performance monitoring.
- Near-term decommissioning of the PRB.
- Contingency plan.
- CERCLA 5-year review.

Overall Protection of Human Health

Alternative 1 is protective of human health because institutional controls that prevent exposure to contaminated ground water would be maintained. The alluvial aquifer is classified under Utah statute as a potential drinking water source; however, there is no current domestic use of the ground water. Future use, even in the absence of the institutional controls, is not likely because of low aquifer yield and the availability of water from other sources (Burro Canyon aquifer and municipal supply).

The calculated cancer risk from uranium radioactivity, assuming that the ground water exposure path were complete, is summarized in Table 5–12, at years 0 (October 2002), 20, and 40 for the RME and CT residential exposure scenario. The risk calculation for Alternative 1 is identical to the baseline risk assessment presented in Section 4.1. Additional discussion of the risk calculation for each remedial alternative is presented in Section G2.0 of Appendix G.

Table 5–12. Alternative 1—Added Cancer Risk From Radioactive COCs

Added Cancer Risk Due to Radioactive COCs			
	Year 0	**Year 20**	**Year 40**
RME Exposure	4.7×10^{-4}	4.0×10^{-4}	1.4×10^{-4}
CT Exposure	7.9×10^{-5}	6.4×10^{-5}	1.4×10^{-5}

Compliance With ARARs

Currently, contaminant concentrations exceed surface water and ground water standards specified in Utah's Safe Drinking Water Rules, Groundwater Quality Protection, Standards of Quality for Waters of the State, and UMTRCA. Therefore, compliance with those ARARs will not be met, although institutional controls will limit use of the contaminated ground water until PRGs are met. If alternate concentration limits were developed according to the specifications in each rule, and institutional controls were allowed, then the ARARs would be met. If not, Alternative 1 would require CERCLA waivers to meet the requirements.

Alternative 1 includes monitoring of ground water and surface water. It is assumed that the current monitor well network, or a subset of the current network, is sufficient to assess the progress of alluvial aquifer restoration and that no additional wells are needed. Some existing

wells may be decommissioned. Well decommissioning activities will meet the substantive requirements of Utah Well Drilling Standards.

When the PRB is decommissioned, (1) temporary stream channel modifications may be needed to excavate the PRB, causing temporary habitat loss for wildlife species; (2) storm-water runoff may occur during construction activities; (3) air emissions may occur during excavation; and (4) radionuclides partitioned from ground water to the PRB reactive media may require transportation and disposal. Engineering controls will be used to capture and minimize the discharge of sediment to Montezuma Creek during construction activities to ensure meeting UPDES requirements. Engineering measures will also be used to mitigate air emissions during construction activities to ensure meeting Utah Air Conservation Rules. Handling and disposal of radioactive contamination will conform to requirements of Utah Radioactive Material Management. If stream channel modifications are required, Stream Channel Alteration Permit requirements will be evaluated to ensure compliance with Dredge and Fill Requirements. The U.S. Fish and Wildlife Service will be consulted to ensure that adequate provisions exist for the protection of wildlife resources. All wetland-area disturbances will follow the Monticello Wetlands Master Plan (DOE 1996) that was developed to adhere to Floodplain/Wetlands Environmental Review requirements.

The following regulations are ARARs for this alternative:

- Utah Safe Drinking Water Rules—relevant and appropriate chemical-specific requirement
- Utah Groundwater Quality Protection—applicable chemical-, location-, and action-specific requirement
- Utah Standards of Quality for Waters of the State—applicable chemical-, location-, and action-specific requirement
- Utah Well Drilling Standards—applicable action- and location-specific requirement
- Utah Pollutant Discharge Elimination System—applicable location- and action-specific requirements
- Utah Air Conservation Rules—applicable chemical-, location-, and action-specific requirement
- Utah Radioactive Material Management—chemical- and action-specific requirements
- Uranium Mill Tailings Radiation Control Act—relevant and appropriate chemical-, and action-specific requirement
- Dredge and Fill Requirements—applicable as location- and action-specific requirement
- Fish and Wildlife Coordination Act—relevant and appropriate as a location- and action-specific requirement
- Floodplain/Wetlands Environmental Review—applicable location- and action-specific requirement

Long-Term Effectiveness and Permanence

- Long-term risk (>42 yr) after natural attenuation processes have reduced COC concentrations to PRGs would be negligible. Untreated waste (dissolved COCs in ground water) will disperse to concentrations that do not pose unacceptable risk.
- Natural dispersion of COCs in ground water is considered a permanent remedy. Re-concentration of the dispersed COCs is not feasible by artificial or natural processes.

- Disposal of the reactive media in the PRB at an appropriate facility would ensure long-term protection from COCs contained within the waste PRB media.

Reduction of Toxicity, Mobility, and Volume Through Treatment

This alternative does not achieve a reduction of toxicity, mobility, and volume through treatment.

Short-Term Effectiveness

Workers, the community, and the environment would be protected during the implementation stage (the time until ground water PRGs are attained by natural attenuation).

- Enforcement of the institutional controls until PRGs are met would protect the community from exposure to contaminated ground water.
- Site work that could potentially affect workers includes monitoring, well abandonment, and decommissioning the PRB. Safeguards to protect workers from exposure to site contaminants and other potential hazards are well developed and implementable.
- Adverse effects to the environment from site work would consist of minor disturbance to soil, plants, and possibly riparian habitat at affected wells and the PRB. These effects would be short term, and disturbed areas would be reseeded.

Implementability

Technical aspects of Alternative 1 (monitoring, well abandonment, and PRB decommissioning) are not difficult to implement. Alternative 1 requires alternate concentration limits for OU III ground water and surface water to comply with ARARs or a CERCLA waiver of Utah water quality protection standards. Either of these administrative requirements may be difficult to implement.

Cost

The estimated cost (capital, annual, and net present value [NPV]) of Alternative 1 are presented in Table 5–13. The basis of estimate for the costs is included in Section G3.0 of Appendix G and consists of

- Capital cost, which includes only the direct cost of decommissioning the PRB. There is no capital cost associated with LTS&M because an on-site facility exists.
- Annual costs, which include reduced-scope monitoring (one event per yr), LTS&M technical evaluation and reporting of monitoring results, and monitor well maintenance. Annual costs begin in yr 2004.
- NPV, which assumes a 7-percent discount rate compounded over a continuous 40-yr time series. The NPV has been rounded to the nearest thousand.
- Some costs which are uniform for each alternative, for example access agreement costs, are not included in the cost estimate.

Table 5–13. Alternative 1 Cost Estimate

Capital cost (decommission PRB)	$32,112
Annual monitoring	$25,000
Annual LTS&M	$5,400
Annual monitor well maintenance	$500
Annual indirect cost	$6,180
Total annual cost—Years 1 through 40	$37,080
Net present value	**$526,000**

5.6.2 Alternative 2: MNA With Institutional Controls

The primary components of Alternative 2 are

- Institutional controls (enforce existing ground water use restrictions).
- 42-yr predicted remediation time frame.
- Comprehensive monitoring to verify MNA and to monitor PRB performance.
- Discretionary operation of the PRB.
- Decommission the PRB upon failure of the existing PRB system.
- Contingency plan.
- CERCLA 5-year review.

Overall Protection of Human Health

The level of protection to human health for Alternative 2 is identical to that for Alternative 1 because no further reduction of COC concentrations by the PRB is assumed. Alternatives 1 and 2 differ in that comprehensive monitoring is conducted for Alternative 2 to verify the progress of MNA in attaining RAOs and to determine when PRB failure has occurred.

Compliance With ARARs

Contaminant concentrations currently exceed ground water standards in Utah Safe Drinking Water Rules, Utah Groundwater Quality Protection, and UMTRCA. However, the regulatory provision of MNA allows that compliance with these standards is determined at a future date defined by the remediation time frame for the site. A condition of this FFS is that no remedial alternative be evaluated in the detailed analysis for which the expected remediation time frame exceeds 50 yr. Ground water modeling results and observed trends show that concentrations of the COCs will be below PRGs in 42 yr; during that time, institutional controls will control the use of the contaminated ground water. Selenium concentrations currently exceed Standards of Quality for Water of the State, but it is assumed that concentrations will decrease as the chemistry of surface water and ground water stabilizes following Millsite remediation. If selenium concentrations do not decrease as expected, compliance with that standard will be reevaluated.

ARARS identified for Alternatives 2 and 1 are identical. However, Alternative 2 will comply with ARARS because surface water and ground water concentrations are expected to decrease to levels below PRGs in an acceptable time frame.

Long-Term Effectiveness and Permanence

Alternative 2 is identical to the baseline condition (Alternative 1) with respect to this criterion.

Reduction of Toxicity, Mobility, and Volume Through Treatment

Compared to Alternative 1, operation of the PRB until its failure would achieve a greater reduction in toxicity, mobility, and volume through treatment.

Short-Term Effectiveness

Alternative 2 is identical to the baseline condition (Alternative 1) with respect to this criterion.

Implementability

All components of Alternative 2 represent a minimum level of difficulty in implementing. Administrative implementation requirements of Alternative 2 are less complex than the inherent requirements of Alternative 1 (alternate concentration limits or a waiver of Utah water quality standards). Future remedial action would not be constrained by implementing Alternative 2.

Cost

The estimated cost (capital, annual, and NPV) of Alternative 2 is presented in Table 5–14. The basis of estimate for the costs is included in Section G3.0 of Appendix G, and a summary is provided below. The total cost of Alternative 2 is greater than that of Alternative 1 because of the more comprehensive scope of annual monitoring for Alternative 2.

- Capital cost includes only the direct cost of decommissioning the PRB. There is no capital cost associated with LTS&M because an on-site facility exists.
- Annual costs, beginning in yr 2004, include comprehensive monitoring (two events per yr), LTS&M technical evaluation and reporting of monitoring results, and monitor well maintenance. Monitoring costs assume the PRB is monitored only through year 10. More frequent and comprehensive monitoring of the PRB may be required when symptoms of imminent failure are indicated.
- NPV assumes a 7-percent discount rate compounded over uniform time series of 10 and 30 yr. The discounted cost for the 30-yr period represents the value of annual costs for years 11 through 40, at 11 yr into the future. Discounting that value by a 7-percent compound rate as a single payment after 10 yr determines the present value of those annual costs. This latter value is summed with the discounted value of annual costs for years 1 through 10 to determine NPV in Table 5–14. The NPV has been rounded to the nearest thousand.
- Some costs which are uniform for each alternative, for example access agreement costs, are not included in the cost estimate.

Table 5–14. Alternative 2 Cost Estimate

Capital cost (decommission PRB)	$32,112
Annual monitoring and indirect costs: years 1 through 10	$112,680
Annual monitoring and indirect costs: years 11 through 40	$103,080
Annual LTS&M	$10,400
Annual monitor well maintenance	$500
Net Present Value	**$1,474,000**

5.6.3 Alternative 3: PRB With Institutional Controls and MNA

The primary components of Alternative 3 are

- Institutional controls (enforce existing ground water use restrictions).
- 40-yr predicted remediation time frame.
- Comprehensive monitoring to verify MNA and to monitor PRB performance.
- Effective operation of the PRB until the COC plume has passed the PRB and when potential sources of ground water contamination above PRGs on the Millsite are no longer significant.
- Decommission the PRB when appropriate (no further treatment required or system failure).
- Contingency plan.
- CERCLA 5-year review.

Overall Protection of Human Health

The level of protection for Alternative 3 is similar to that for Alternatives 1 and 2 because institutional controls have been implemented that prevent exposure to contaminated ground water. The alluvial aquifer is classified under Utah statute as a potential drinking water source; however, there is no current domestic use of the ground water. Future use, in the absence of the institutional controls, is not likely because of low aquifer yield and the availability of water from other sources (Burro Canyon aquifer and municipal supply).

The calculated cancer risk from uranium radioactivity, assuming that the ground water exposure path were complete, is presented in Table 5–15, at years 0 (October 2002), 20, and 40 for the RME and CT residential exposure scenario. The risk is slightly less than the baseline condition (Alternative 1) and Alternative 2 as a result of effective treatment by the PRB.

Table 5–15. Alternative 3 Added Cancer Risk Because of Radioactive COCs

Added Cancer Risk Due to Radioactive COCs			
	Year 0	**Year 20**	**Year 40**
RME Exposure	4.7×10^{-4}	3.5×10^{-4}	1.4×10^{-4}
CT Exposure	7.9×10^{-5}	5.5×10^{-5}	1.5×10^{-5}

Compliance With ARARs

Alternative 3 is identical to Alternative 2 with respect to this criterion.

Long-Term Effectiveness and Permanence

Alternative 3 is identical to the baseline condition (Alternative 1) with respect to this criterion.

Reduction of Toxicity, Mobility, and Volume Through Treatment

The PRB reduces the mobility of ground water contaminants through in situ treatment. Mass balance results of the ground water model for Alternative 3 indicate that 62 pounds, or about 15 percent of the original mass of uranium in the model (430 pounds), will be removed by the PRB. The PRB would be excavated and disposed of in a low-level radioactive waste repository after its 15-yr operation. The total mass of ZVI (dry) in the PRB is approximately 550 tons. It is assumed that disposal would occur within a 300-mile radius of the site.

Reduction in toxicity, mobility, or volume for Alternative 3 is equal to that for Alternative 2. This is because the operational periods for both alternatives are expected to be the same. Greater reduction in toxicity, mobility, or volume could be achieved with Alternative 3 if the PRB failed earlier than expected and was then replaced or rejuvenated as a contingency remedy.

Short-Term Effectiveness

Alternative 3 is identical to the baseline condition (Alternative 1) with respect to this criterion. The shorter remediation time for Alternative 3 as compared to Alternatives 1 and 2 has no effect on short-term risk because there is no present risk from ground water and continued enforcement of institutional controls will prevent future risk to human health. Potential future risk to ecological receptors from selenium exposure, as discussed in the update to the OU III ERA, is independent of the remedial alternatives under evaluation.

Implementability

Alternative 3 is identical to Alternative 2 with respect to this criterion.

Cost

The estimated cost (capital, annual, and NPV) of Alternative 3 is presented in Table 5–16. The NPV has been rounded to the nearest thousand. The basis of estimate is identical to Alternative 2 except the operational period is of Alternative 3 is 2 yr less, and, therefore, the total cost is slightly less compared to that of Alternative 2. Annual costs begin in yr 2004.

Table 5–16. Alternative 3 Cost Estimate[a]

Capital cost (decommission PRB)	$32,112
Annual monitoring and indirect costs: years 1 through 10	$112,680
Annual monitoring and indirect costs: years 11 through 38	$103,080
Annual LTS&M	$10,400
Annual monitor well maintenance	$500
Net Present Value	**$1,460,000**

[a]A one-time replacement or rejuvenation of the ZVI in the existing treatment zone is estimated to cost approximately $250,000. This amount is not included in the cost estimate or net present value shown in Table 5–16.

5.6.4 Alternative 4: Enhanced PRB With Institutional Controls and MNA

The primary components of Alternative 4 are

- Institutional controls (enforce existing ground water use restrictions).
- 39-yr predicted remediation time frame (Option 1, 50-percent capture of bypass flow).
- 38-yr predicted remediation time frame (Option 2, 50-percent treatment of bypass flow).
- Comprehensive monitoring to verify MNA and to monitor PRB plus enhancement performance.
- Effective operation of the PRB and enhancement until the COC plume has passed the PRB and when potential sources of ground water contamination above PRGs on the Millsite are no longer significant.
- Decommission the PRB and enhancement when appropriate (no further treatment required or system failure).
- Contingency plan.
- CERCLA 5-year review.

Overall Protection of Human Health and the Environment

The level of protection for Alternative 4 is similar to that for Alternative 3 mainly because institutional controls have been implemented that prevent exposure to contaminated ground water.

The calculated risk, assuming that the ground water exposure path were complete, is slightly less than the baseline condition (Alternative 1) and Alternatives 2 and 3 as a result of effective, enhanced treatment by the PRB (Table 5–17).

Table 5–17. Alternative 4 Added Cancer Risk Because of Radioactive COCs

Option 1 (pump-and-treat enhancement): Added Cancer Risk Because of Radioactive COCs			
	Year 0	**Year 20**	**Year 40**
RME Exposure	4.7×10^{-4}	3.5×10^{-4}	1.4×10^{-4}
CT Exposure	7.9×10^{-5}	5.6×10^{-5}	1.4×10^{-5}
Option 2 (in situ enhancement): Added Cancer Risk Because of Radioactive COCs			
RME Exposure	4.7×10^{-4}	3.4×10^{-4}	1.4×10^{-4}
CT Exposure	7.9×10^{-5}	5.3×10^{-5}	1.4×10^{-5}

Compliance With ARARs

Alternative 4, Options 1 and 2, are identical to Alternative 3 with respect to this criterion. In addition, Option 1 will require compliance with substantive requirements of the Utah Underground Injection Control regulation for water collected at extraction wells and injected into the PRB.

Long-Term Effectiveness and Permanence

Alternative 4, regardless of enhancement option, is identical to the baseline condition (Alternative 1) with respect to this criterion.

Reduction of Toxicity, Mobility, and Volume Through Treatment

Mass balance results of the ground water model for Alternative 4 indicate that 75 pounds, or 18 percent of the original mass of uranium in the model (430 pounds), will be removed by the PRB and Option 1. The enhanced PRB using Option 2 would remove 85 pounds or 20 percent of the initial mass of uranium.

The PRB and enhancement components would be excavated and disposed of in a low-level radioactive waste repository after its 15-yr operation. The total mass of ZVI (dry) in the PRB is approximately 550 tons. It is assumed that disposal would occur within a 300-mile radius of the site.

Failure of the existing ZVI treatment zone with no subsequent separation of that portion of the treatment system, and continued treatment by the independently operating Option 2 enhancement, may provide greater reduction in contaminant mobility than Alternative 3 and Alternative 4, Option 1, using the same failure assumption.

Short-Term Effectiveness

Alternative 4, regardless of enhancement option, is identical to the baseline condition (Alternative 1) with respect to this criterion. The shorter remediation time for Alternative 4 as compared to Alternatives 1, 2, and 3 has no effect on short-term risk because there is no present risk and institutional controls will prevent future risk to human health. Potential future risk to ecological receptors from selenium exposure, as discussed in the update to the OU III ERA, is independent of the remedial alternatives under evaluation.

Implementability

Alternative 4 involves installation of additional components to the existing PRB. Technical implementation of these enhancements is feasible using conventional, readily available methods, equipment, and resources. Alternative 4 is potentially difficult to implement because of landowner concerns.

Cost

The estimated cost (capital, annual, and NPV) of Alternative 4 is presented in Table 5–18. The NPV has been rounded to the nearest thousand. The main assumptions for the basis of estimate are identical to those for Alternative 2 except the operational period of Alternative 4 is 1 to 2 yr less, depending on the enhancement option. Annual costs begin in yr 2004. Costs associated with installing the enhancement, additional monitoring, operation and maintenance of the ground water extraction system (Option 1 only), and decommissioning the enhancement account for the higher cost of Alternative 4 relative to Alternative 3. Option 1 was estimated to be less costly to

install and decommission than Option 2, which assumes that the in situ enhancement will be excavated and disposed of with the remainder of the PRB. A significant expense of Option 2 is in procurement of ZVI. Operating and maintaining the ground water extraction system was assumed to include annual labor costs, cost to replace pumps or repair equipment, and cost of electricity. Additional information on cost estimates is included in Section G3.0 of Appendix G.

Table 5–18. Alternative 4 Cost Estimate[a]

Option 1 (pump-and-treat enhancement)	
Capital cost (install enhancement and decommission PRB)	$60,264
Annual monitoring and indirect costs: years 1 through 10	$117,480
Annual monitoring and indirect costs: years 11 through 37	$107,880
Annual LTS&M	$10,400
Annual monitor well maintenance	$500
Annual extraction system operation and maintenance	$4,000
Net Present Value	**$1,513,000**
Option 2 (in situ enhancement)	
Capital cost (install enhancement and decommission PRB)	$124,988
Annual monitoring and indirect costs: years 1 through 10	$112,680
Annual monitoring and indirect costs: years 11 through 36	$103,080
Annual LTS&M	$10,400
Annual monitor well maintenance	$500
Net Present Value	**$1,536,000**

[a]A one-time replacement or rejuvenation of the ZVI in the existing treatment zone is estimated to cost approximately $250,000. This amount is not included in the cost estimate or net present value shown in Table 5–18.

5.6.5 Summary of Detailed Analysis of Alternatives

This section presents a summary of the detailed analysis presented in Sections 5.6.1 through 5.6.4. Table 5–19 compares the calculated risk for each alternative from radioactive COCs based on RME and CT exposure assumptions. Calculated risk from radioactive COCs at year 0 in the table is based on the exposure assumptions and contaminant concentrations used in the baseline risk assessment presented in Section 4.1. The calculated risks for years 20 and 40 use the same exposure assumptions of the baseline risk assessment. Uranium concentrations used in the risk calculations are from the OU III ground water model described in Section 3.0 and Appendix G, Section G1.0. A summary of the FFS risk calculation method is included in Appendix G, Section G2.0.

Table 5–19. Summary of Estimated Risk from Radioactive COCs

Alternative	RME		
	Risk at Year 0	Risk at Year 20	Risk at Year 40
1	4.7×10^{-4}	4.0×10^{-4}	1.4×10^{-4}
2	4.7×10^{-4}	4.0×10^{-4}	1.4×10^{-4}
3	4.7×10^{-4}	3.5×10^{-4}	1.4×10^{-4}
4 with option 1	4.7×10^{-4}	3.5×10^{-4}	1.4×10^{-4}
4 with option 2	4.7×10^{-4}	3.4×10^{-4}	1.4×10^{-4}
Alternative	**CT**		
	Risk at Year 0	**Risk at Year 20**	**Risk at Year 40**
1	7.9×10^{-5}	6.4×10^{-5}	1.4×10^{-5}
2	7.9×10^{-5}	6.4×10^{-5}	1.4×10^{-5}
3	7.9×10^{-5}	5.5×10^{-5}	1.5×10^{-5}
4 with option 1	7.9×10^{-5}	5.5×10^{-5}	1.4×10^{-5}
4 with option 2	7.9×10^{-5}	5.3×10^{-5}	1.4×10^{-5}

Tables 5–20 and 5–21 present the risk information for the remedial alternatives as the absolute and percent risk reduction for the RME and CT exposure assumptions, respectively, relative to current uranium concentrations, assuming that the currently incomplete ground water ingestion exposure pathway is complete. Risk reduction in Tables 5–20 and 5–21 is calculated as the difference between the risk at years 20 and 40, respectively, from the initial risk (Table 5–19). That difference divided by the initial risk determines the percent risk reduction shown in Tables 5–20 and 5–21.

Table 5–20. Comparison of RME Risk for Radioactive COCs

	Year 20		Year 40	
Alternative	Risk Reduction	Percent Reduction	Risk Reduction	Percent Reduction
1	7.0×10^{-5}	14.9	3.3×10^{-4}	70.2
2	7.0×10^{-5}	14.9	3.3×10^{-4}	70.2
3	1.2×10^{-4}	25.5	3.3×10^{-4}	70.2
4 with option 1	1.2×10^{-4}	25.5	3.3×10^{-4}	70.2
4 with option 2	1.3×10^{-4}	27.7	3.3×10^{-4}	70.2

Table 5–21. Comparison of CT Risk for Radioactive COCs

	Year 20		Year 40	
Alternative	Risk Reduction	Percent Reduction	Risk Reduction	Percent Reduction
1	1.05×10^{-5}	19	6.5×10^{-5}	82.3
2	1.05×10^{-5}	19	6.5×10^{-5}	82.3
3	2.4×10^{-5}	30.4	6.4×10^{-5}	81.0
4 with option 1	2.3×10^{-5}	29.1	6.5×10^{-5}	82.3
4 with option 2	2.6×10^{-5}	32.9	6.5×10^{-5}	82.3

The results indicate that risk is expected to decrease by 15 to 19 percent of the current level in 20 yr by natural attenuation alone (Alternatives 1 and 2). The effect of the PRB with and without enhancement (Option 2) at year 20 is to reduce the potential risk an additional 10 and 13 percent, respectively, relative to Alternatives 1 and 2. Risk reduction is essentially the same for all alternatives at year 40 (i.e., the RME and CT risks are reduced for each alternative by approximately 70 and 80 percent, respectively). Enhancement of the PRB with Option 1 is predicted to provide no additional risk reduction at year 20 or 40.

Table 5–22 provides a final summary of the detailed analysis. As shown in this table and Tables 5–20 and 5–21, remediation time frames and calculated potential risk do not vary appreciably among remedial alternatives. An incomplete ground water ingestion pathway and uniform application of the existing institutional controls ensures that the alternatives are equally protective of human health. Current overall risk to the environment is acceptable, and potential future risk to ecological receptors, as discussed in the updated ERA, is independent of the remedial alternatives evaluated in this detailed analysis.

Compared to Alternatives 3 and 4, Alternative 2 is capable of achieving RAOs without additional technical or administrative requirements, and without reliance on the PRB. Otherwise, Alternatives 2, 3, and 4 are similar in satisfying the criteria evaluated in this detailed analysis (state and community acceptance excluded) with no distinct advantages.

Table 5–22. Comparative Analysis of Alternatives[a]

Screening Criteria	Alternative 1	Alternative 2	Alternative 3	Alternative 4
Overall protection of human health and the environment	Meet RAOs in 42 yr. Institutional controls prevent ground water use.	Meet RAOs in 42 yr. Institutional controls prevent ground water use.	Meet RAOs in 40 yr. Institutional controls prevent ground water use.	Meet RAOs in 38 (Option 2) to 39 yr (Option 1). Institutional controls prevent ground water use.
Compliance with ARARS[b]	May require waivers.	Compliance with ARARs.	Compliance with ARARs.	Compliance with ARARs.
Long-term effectiveness and permanence	Natural attenuation has permanent effect.	Same as Alternative 1 assuming PRB reactive media is removed prior to releasing contaminants to ground water.	Same as Alternative 1 assuming PRB reactive media is removed prior to releasing contaminants to ground water.	Same as Alternative 1 assuming PRB reactive media is removed prior to releasing contaminants to ground water.
Reduction of toxicity, mobility, and volume through treatment	No additional PRB treatment to immobilize COCs.	COCs immobilized in PRB and disposed of at appropriate facility.	COCs immobilized in PRB and disposed of at appropriate facility. Potentially greater effect than Alternative 2.	COCs immobilized in PRB and disposed of at appropriate facility. Potentially greater effect than Alternative 3.
Short-term effectiveness	Effective in protecting workers, community, and environment during implementation.	Same as Alternative 1.	Same as Alternative 1.	Same as Alternative 1.
Implementability	Administrative requirements potentially difficult to implement (non-compliance waiver).	Technical and administrative requirements not difficult to implement.	Technical and administrative requirements not difficult to implement. Longevity of effective PRB operation unknown.	Technical requirements slightly more difficult to implement. Administrative requirements potentially most difficult to implement (landowner concerns).
Net present value	$526,000	$1,474,000	$1,460,000	$1,513,000 (Option 1) $1,536,000 (Option 2)

[a]Excludes evaluation of state and community acceptance which will be included in the ROD following public review of the Proposed Plan.
[b]Alternatives 2, 3, and 4 must meet the state ground water quality standards within the accepted remediation time frame (< 50 years).